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HOW TO DECIDE THE INTERCONNECTION OF ISOLATED TRAFFIC SIGNALS

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ABSTRACT

Increasing traffic congestion along major urban signalized intersections demands the efficient operation and utilization of arterial facilities. Improvement on traffic flow and reduction in vehicular delays may be realized by interconnecting individually isolated intersections into a coordinated signal system, or by adding an adjacent signal into an existing coordinated system. This paper illustrates the development of interconnection warrants for isolated traffic signals by using both simulation study and field data validation.

Simplified procedures were developed to evaluate the need to interconnect signalized intersections based on both simulation and field studies. Field data from several Texas cities were used to compare the results from the TRANSYT-7F and PASSER II computer programs. These programs were applied to address the effects of progression on changes in travel time and travel volume. Detailed field studies were performed at six (6) intersections under isolated-actuated, fixed-time coordination and traffic responsive operations on NASA 1 Road in front of the LBJ NASA Space Center, Houston, Texas.

DISCLAIMER

The contents of this report reflect the views of the author who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas State Department of Highways and Public Transportation, or the Federal Highway Administration, U. S. Department of Transportation. This paper does not constitute a standard, specification, or regulation.

INTRODUCTION

Increasing traffic congestion along major urban signalized intersections makes the efficient traffic management and utilization of arterial facilities an important consideration. Significant improvement on traffic flow and reduction in vehicular delays may be realized by interconnecting individually isolated intersections into a coordinated signal system, or by adding an adjacent signal into an existing coordinated system.

Present analytical methods and computer programs offer capabilities of optimizing the traffic signal coordination for a series of signalized intersections. However, the proper procedures and methods to analyze the effects from coordinating isolated signalized intersections are insufficient. Since the decision of interconnection can be significant within the total signalized operation, guidelines, and simplified procedures are needed to identify where to implement signal interconnection. Recently, transportation researches are moving toward the alternative development of short range, low capital improvement for the safe, efficient and convenient movement of people and goods. The criteria measuring the alternative improvements include travel time, energy consumption, delay and quality of traffic flow.

This paper was summarized from the research sponsored cooperatively by the Texas Department of Highways and Public Transportation (SDHPT) and the Federal Highway Administration (FHWA), U. S. DOT. under HP&R Study Number 2-8-80-293. The study provided the guidelines, and procedures needed to identify when adjacent signalized intersections should be interconnected. This paper illustrates the development material for interconnection warrants of isolated traffic signals using both simulation analysis and field validation. This study is to provide a simple procedure for analyzing whether interconnection of isolated signalized intersection is necessary with respect to the increasing traffic volume. Guidelines and evaluation procedures were developed to identify conditions where interconnection will be beneficial. These methods can provide better signal interconnection, efficient utilization of the street system and smooth traffic operations.

The overall study objective is to develop warrants, guidelines, and procedures to identify where interconnection of signalized intersections should be implemented. An effort was made to evaluate interconnecting isolated traffic signals into a progression system to provide interconnected signal operations. Specific study objectives are to:

1. Identify factors which influence interconnection feasibility of isolated signalized intersections;

2. Evaluate effectiveness of interconnection versus isolated control, and isolated

control versus interconnection with progression phasing;

3. Develop guidelines to identify where interconnection of a series of signalized intersection into a progression system should be implemented;

4. Develop a simple, easy to use evaluation procedure to examine the need for signal interconnection.

STUDY BACKGROUND

Modern traffic signal control strategy to reduce vehicle delay and fuel consumption has been emphasized by readjusting signal timing plans, installing control equipment, and providing interconnection [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 [3] determined that for the arterial street system one half of the vehicular fuel usage was caused by traffic delay at intersections. Since arterial travel occupies a large portion of the areawide travel and arterial traffic control can be effective throughout the day, arterial traffic control improvements can reduce fuel consumption during all time periods.

Even though fewer publications exist addressing when to interconnect a series of isolated signalized intersection, interconnection has been recognized as a viable traffic control improvement alternative. Wagner [4] studied the four possible traffic control system improvements - interconnection of traffic signals, optimization of traffic signal timing, an improved centralized master control of signalized intersections and freeway surveillance and control. He found that the typical improvement in average travel time was as follows:

Traffic Control Improvement	Time Savings
Interconnection of signals	25%
Signal Timing Optimization	17%
Advanced master control system	8-17%
Freeway surveillance and control	20%

The coordination of adjacent signals can reduce the overall travel time, stops and delays, and decrease the fuel consumption and air pollution emissions. 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."

The possible improvement by signal timing optimization depends on the quality of the pre-existing signal timing plan, the geometric constraints of the arterial street and the traffic characteristics. Thus, the level of improvement depends on the quality of the existing system. Wagner also found that signal timing reoptimization was the most cost effective of any enhancement action. In addition, signal interconnection and optimization were found to be most cost effective.

Several attempts were made to relate factors for coordination. In one study, Yagoda and others [5] developed a "Coupling Index", (I), which was the simple ratio of link volume and link length, as shown in Equation (1):

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

Where

I - Coupling Index,
V - Approach Link Volume (VPH),
L - Link Length to Next Signal (Feet).

By computing this index for each link in the potential coordination system, a measure of the need for interconnecting the signal is determined. The NAC [6] felt that "any two or more signals which are less than one-half mile apart or within a cycle length (which may be more than one-half on a high speed approach) should be coordinated."

Pinnell identified various factors that affect arterial street signal control in the Traffic Control Systems Handbook [7]. These are as follows:

1. Distance between intersections,
2. One-way versus two-way street operation,
3. Signal phasing,
4. Arrival characteristics, and
5. Traffic fluctuations with time.

He found that a number of factors are important in determining the need for interconnection [8,9,10,11,12,13,14,15]. They include:

1. **Geographic relationship -**

   Distance between intersections; intersections should be adjacent to each other without being affected by the natural and artificial boundaries, such as rivers and controlled-access facilities.

2. **Volume levels -**

   The larger the link volume usually implies the greater the need for coordination between the signals at the ends of the link.

3. **Traffic flow characteristics** -

If traffic arrivals are uniform throughout the cycle, the red phase of the cycle would produce the same stops and delays as would the green phase. On the other hand, controlled flow in platoons enhances the benefits of coordination with the consideration of platoon dispersion.

This paper presents a model for use in the traffic signal design and provides guidelines and procedures to evaluate the feasibility of interconnecting isolated traffic signals [8,9,10].

MODEL DEVELOPMENT

Intersections should be interconnected only if the arrival flow rates downstream can be guided into compact platoons through effective traffic signal timing plan. Fluctuation in arrival rates is influenced primarily by the following factors to bring flow rates away from uniformity over time.

1. Initial degree of volume variation at the upstream intersection, and
2. Amount of platoon dispersion occurring between intersections.

Volume Considerations

There is no need to interconnect a system of intersections if the volume level is uniform and balanced in most operational periods. Because of the different green time and offsets used in each signal, the amount of stops and delay would not be affected by the coordinated offsets under such uniform arrivals. Several conditions may result in the uniform arrival of vehicles at an intersection:

1. An intersection isolated by distance relative to the other upstream signalized intersection;

2. Consequential traffic volumes entering at mid-block; and

3. Significant truck movement between intersections.

Thus, one indication of the desirability of interconnection is the imbalance in volume at the upstream intersection. In addition, significant traffic entering at mid-block or a large amount of truck traffic travelling between intersections will force arriving flows toward a balance where interconnection can not help to eliminate traffic problems.

Consider the typical link flow pattern between two (2) adjacent intersections as illustrated in Figure 1. The entry volume for the downstream intersection (link 3) consists of the right-turn (Link 2), through (Link 1) and left turn volume (Link 4) from the upstream intersection.

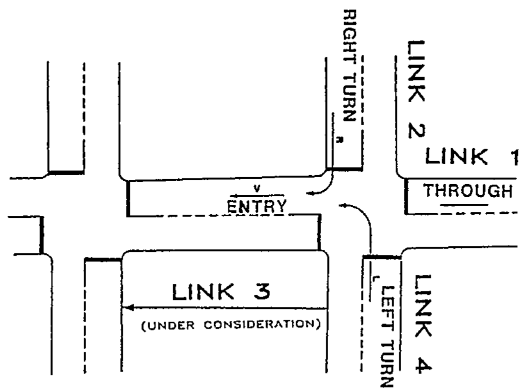

Figure 1 Entry Flow for a Typical Link.

The degree of flow imbalance at upstream intersection is given by the ratio between the maximum link traffic volume feeding from the upstream intersection and the sum of all the link traffic volume coming from the upstream intersection. It can be stated as Equation (2).

$$\text{Imbalance} = \frac{q_{max}}{\bar{q}} \tag{2}$$

Where

q_{max} - usually the through flow rate,
$\bar{q}$ - the average flow rate entering a link from all x number of movements.

The imbalance index, as calculated from the maximum link flow divided by the average upstream entering link flow is an index representing the fluctuations of traffic volume along a downstream link. It varies as in Equation (3):

$$1 \leq \frac{q_{max}}{\bar{q}} \leq x \tag{3}$$

When this factor is 1, uniform flow exists: i.e., cross street, mid-block and turning traffic at upstream intersection are approximately equal to the major entering flow. The effect of the entering flow on the downstream intersection is a state of uniform arrivals over time. Interconnection of signals of upstream and downstream intersection in this case is not desirable. However, when the imbalance factor approaches "x", the effect of flow rate is at its maximum on the downstream intersection, creating the most desirable situation for progression. Imbalance is another way of describing the relationship between flow rates and vehicle platoon formation. However, this equation has not included the effect of platoon dispersion.

Platoon Dispersion

Platoon dispersion results from the drivers adjusting the relative distance between their vehicle and leading and following vehicles. The dispersion of a platoon of vehicles leaving a signalized intersection, as described by Nemeth and Vecellio [7] and the previous North Dallas Corridor study [6], was used to approximate dispersion rate in terms of precent change of platoon length by the following model:

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

Where

- L - Length of the standing platoon (secs),
- ΔL - Change in length over distance and time (secs),
- t - Average travel time (secs).

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

$$D = \frac{1}{1 + t} \qquad (5)$$

Interconnection Model

By combining the previous two concepts, a combined model of Interconnection Desirability (I) representing both the characteristics of platoon dispersion and traffic system characteristics, could be described in Equation (6):

$$I = \left[\frac{X * q_{max}}{q1 + q2 + q3 + \ldots qx}\right] - \left[(x-2)*\frac{1}{1 + t}\right] \qquad (6)$$

As can be readily seen that Equation (6) has a range of from 0 to 2. By normalizing for a range from 0 to 1 and rearranging the above formulation the Equation (7) can be obtained:

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

Where

- t - Link travel time, link length divided by average speed, expressed in minutes;
- x - Number of departure lanes from upstream intersection;
- q_{max} - Straight through flow from upstream intersection;
- $q1,,qx$ - Traffic flow arriving at the downstream approach from the right-turn, left-turn and through movements of upstream traffic signals; and
- N - Number of arrival lanes to the entering link of downstream intersection.

When a value of "1" indicates the most desirable condition for interconnection and "0" indicates the least desirable condition. Basically, this approach [8] measures the coordination requirements of each one-way link by taking into account the platoon dispersion effect in computing the interconnection desirability index (I).

However, this formula does not hold for the case when straight through flow from the upstream intersection (qmax) is zero, yet turning flows are relatively high and the intersections are closely spaced, in which case the interconnection may be desirable. Treating the heavy turning flows as "through" movements in the equation could solve this extreme case. Using this approach, an interconnection desirability index of one (1) would indicate the most desirable condition for interconnection, and zero (0) would be the least desirable. The scale shown in Figure 2 has been suggested as a tool for the delineation of control strategies.

INTERCONNECTION DESIRABILITY INDEX

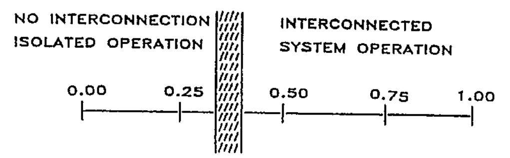

Figure 2 Interconnection Desirability Index.

STUDY PROCEDURE

In this study, experimental design was formulated with simulation and field study to develop numerical guidelines for traffic signal interconnection with variations of different factors, such as, geographic relationship, volume levels, and traffic flow characteristics. A simulation model was used as a theoretical test base to study conditions which cannot easily be reproduced in the field. Then, the field data was collected on selected arterial streets to validate simulation study results.

SIMULATION STUDY

Detailed literature review was performed and selections were made of factors most desirable for interconnection guidelines. Present technology suggests that intersection spacing, percentage 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 traffic signal warrants. However, the simulation of existing isolated traffic control conditions could not be throughly evaluated by the first two models.

The NETSIM model was used to evaluate the coordination of a series of isolated actuated traffic signal operations.

Basically, PASSER II and TRANSYT-7F were used to optimize phase sequence and offsets for pretimed and traffic responsive signals under isolated versus interconnected operations; whereas, NETSIM was used as a study 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, in Figure 3, was used to collect simulation data, establish numerical guidelines under different intersection spacings and left-turn percentages. The TRANSYT-7F runs primarily examined the detailed effects of intersection spacings and the percent of left turning traffic on the arterial.

EXPERIMENTAL SIMULATION DESIGN

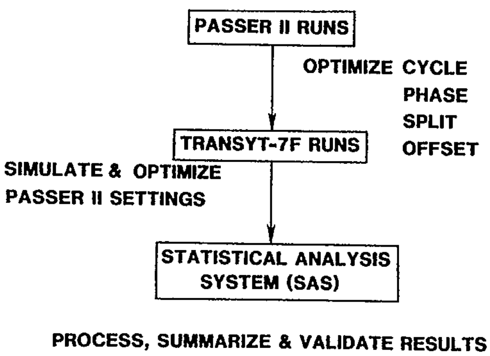

Figure 3 Experimental Simulation Design Plan.

The major variables studied include:

1. Numbers of Signal phases;
2. Phase sequence;
3. Preferred movement;
4. Allowable cycle length;
5. Volume level;
6. Speed variation;
7. Left turn percentage; and
8. Intersection spacing s.

This means a large number of simulation cases must be preformed if all the combinations of variables are used. Computer runs were made for the range of factors identified to determine the sensitivity of model components over the range of factors considered. Operational scenarios were then devised to test the practical accuracy, sensitivity and the applicability of the simulation model.

A synthetic four-node arterial street, as shown on Figure 4, was used to obtain separate but compatible simulation results using both the PASSER II and the TRANSYT-7F models, starting with 10% left-turn movement. In the simulation analysis, 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 respect to different intersection spacings. Then, the TRANSYT-7F was used to simulate and optimize PASSER's **"Best Settings"** to compare the results from PASSER II and TRANSYT-7F studies. Because of the amount of data reduction required, a version of the PASSER II program with simplified output was developed for direct data processing by the **Statistical Analysis System [SAS)** program packages. Performance Measures of Effectiveness (MOE's), 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.

SYNTHETIC FOUR-NODE ARTERIAL

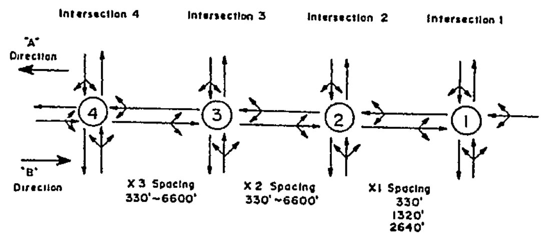

Figure 4 Synthetic Four-Node Arterial Street.

As demonstrated in Figure 5, the performance measurement of average delay on one approach was compared with respect to the spacing variations with letting all other variables remaining constant. Later, the simulation result indicated that the wide variation of operational performance with respect to the geometric spacing of progression systems and the different platoon dispersion model applied. However, they both confirmed the **"Rule-of-Thumb"** ideal cross street spacing for good arterial progression is between 1/4 mile (1440 ft) to 1/3 (1920 ft) mile.

Operational traffic control scenarios under different geometric and traffic levels were devised to test the effectiveness of signal interconnection. The experimental simulation plan was developed to collect simulation data and establish guidelines under different intersection spacings and left-turn percentages. The TRANSYT-7F was primarily used to examine the effects of intersection spacing and the percent of left turning traffic both off and onto the arterial. The overall effectiveness of the computer programs were to examine and evaluate needs for interconnection. An estimation of the reliability for making recommendations on interconnections from the simulation programs under various factor levels were also made.

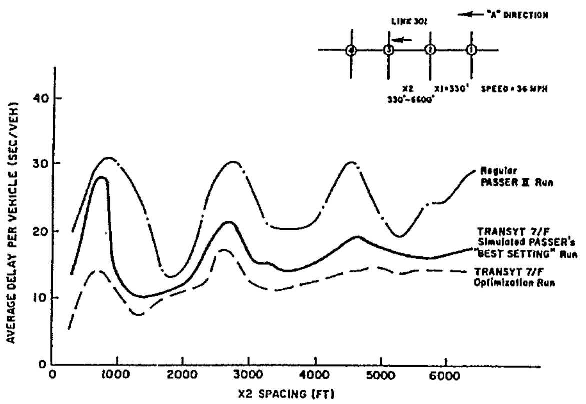

Figure 5 Selected Link Performance MOE versus Intersection Spacing Under PASSER II Run, TRANSYT-7F Simulated PASSER II Run and TRANSYT-7F Optimization Run.

Selected NETSIM runs, similar to the TRANSYT-7F runs were conducted for investigating actuated arterial control on a four intersection arterial signal system. It was performed to determine if intersection spacing and the percentage of turning traffic affect actuated control similar to pre-timed control.

It was assumed in the simulation that:

1. Volumes for each movement are constant over the study time period;
2. Platoon structure remains coherent along the arterial;
3. The link speed remains uniform;
4. There is consistent origin-destination turning traffic volumes;

   a. All side street left turn traffic into through movement,
   b. All main street left turn traffic was originally from the through movement on the main street,
   c. Downstream through traffic on the main street is equal to the sum of side street left turn and right turn, and the through less left turn volume from the main street, and

5. Directional link volumes are balanced.

FIELD STUDY

The first field study was performed by vehicular travel time and delay study on Lamar Boulevard and U.S. 183 in Austin, Texas. They both are high-volume high-type facilities, where the former Lamar Boulevard operated under low to medium speed and the U.S. 183 has medium to high speed operations. Results of this study show good progression exists throughout the two systems regardless of the variance of spacing and the saturated operation along two arterials. However, the field study did not provide enough validation of the simulation analysis because the left turn traffic volume percentage and the corresponding traffic volume were not properly identified.

This travel time and delay study indicated that the positive relationship did exist between the travel time delay and the travel time versus background cycle used. As indicated in Figure 6, the travel time delay was plotted against the distance travelled and the travel time and cycle length ratio for both signal system. These two figures suggest that travel time delay within the interconnected signal system gradually decreases from 0.4 to 0.6 of travel time to cycle length ratio and then increases as travel time increases. It also indicates that the travel time and cycle length ratio can provide a better indicator than the distance alone to represent the proper relationships among distance, travel speed, progression speed and traffic volume levels along the arterial street coordination system.

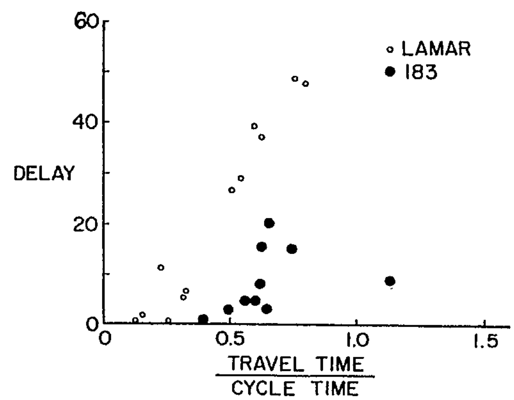

Figure 6 Summary of Field Study Results - Travel Time Delay Versus Travel Time and Cycle Ratio. Austin, Texas.

The second detailed field data collection effort was performed on one six-signalized intersection on Texas SDHPT's NASA 1 FACTS system to collect data on signal timing, travel time, delay and queue data. The NASA 1 computerized traffic signal control system, south of Houston, as illustrated in Figure 7 was selected to test and calibrate the computer models. The cross streets are Kings Row, El Camino, Space Park, Nassua Bay, Point Lookout and Upperbay.

The Specific objectives of the field study were to:

1. Evaluate signal operations under isolated versus interconnected operation by using offsets and delay study;
2. Calibrate platoon dispersion model for Texas driving behavior under both interconnected and isolated traffic operations;
3. Validate simulation study results for offset optimization calculations by the

PASSER II-80, PASSER II-84, and TRANSYT-7F programs;

4. Evaluate the possibility of dropping over-saturated intersections in the progression system to provide critical intersection control strategy; and
5. Evaluate the signal system operation under Isolated Actuated versus Traffic Responsive Mode.

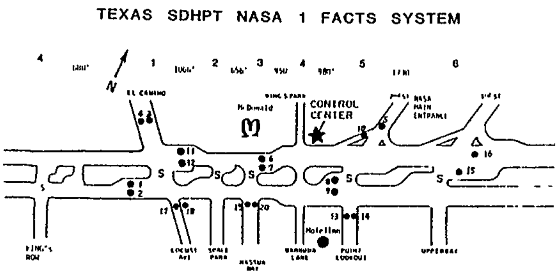

Figure 7 Texas SDHPT NASA 1 FACTS System.

Field data were collected on the NASA 1 System during the noon-rush and off-peak periods for use in the calibration of the combined PASSER II and TRANSYT-7F runs and validation of operational measures. Interconnected intersection studies were conducted on Tuesday, Wednesday and Thursday of one week followed by isolated intersection studies on the following week in May 1984. 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 types include: arterial street, arterial link, cross street, intersection, and arterial MOE validation data.

This field data validation was used to calibrate computer model and provide real world data in evaluating and calibrating the computer models to establish criteria and warrants for interconnecting isolated traffic signals. These methods include the stop delay study, travel time & delay study and platoon dispersion study. The volume count was collected with the assistance from Texas SDHPT's D-19 personnel using NASA 1 FACTS System sampling loop detectors. Selected queue counts and stop delay measurements were made at the same time at each signalized intersection location. The platoon dispersion study was performed by using the video recording equipment from the nearby building.

STUDY RESULTS

Both the simulation analysis and field data collection effort have been summarized to develop the effective interconnection warrants arterial traffic signal control strategies. The major objective is to establish realistic and quantitative relationships among the study factors which has important influences on operational performance measurements and the interconnection decisions. One measure related to the desirability for interconnecting isolated traffic signal is the estimated arterial link delay experienced by the motorists. The other factor used for detecting the potential benefits for interconnection is the interconnection desirability index.

A simulation model was used as a theoretical test bed to enumerate study conditions and scernios which cannot be easily reproduced or easily controlled in the field. More emphasis was made to investigate the generalized relationships among the study factors and their sensitivities with respect to the systemwide performance. This was done especially for the arterial link with delay analysis from the traffic signal interconnection. That is, this simulation study was mainly to establish linkage between the estimated arterial link delay and the proposed interconnection guidelines through the usage of test scenarios for reasonably accurate and reliable representation of the candidate application sites.

Three separate analysis were investigated, i.e., the interconnection index analysis, the combined PASSER II and TRANSYT-7F analysis and the interconnection warrant study. The first analysis studied the basic variation of interconnection desirability index as a function of intersection spacings, progression system design speed, intersection volume levels and the left turn traffic volume percentages. The second analysis collected estimated arterial street performance statistics by applying the combined approach of PASSER II and TRANSYT-7F programs. The last simulation study presents the relationships between the proposed interconnection guidelines developed and the estimated average delay per vehicle measurement using quick-response type analysis upon the operational performance once the potential interconnection became operational.

Due to the inherent complexity of the problem and tremendous variability of the field conditions, the major emphasis was made on the interconnection guidelines for existing traffic signals operated currently under isolated or coordinated modes for two-way progression operation. That is, the major concern was: **Given existing installed traffic signalized intersection, proposed guidelines will recommend whether the interconnection can provide effective operation without adverse effect and undue delay to the arterial system, as well as, the intersection itself.**

In this study, the combined PASSER II and TRANSYT-7F runs were made to evaluate the effectiveness of interconnection versus interconnection with progression phasing under different volume levels. This approach is benefitted by the detailed simulation capability of the TRANSYT-7F to predict platoon travel behavior and to optimize cycle length and phase sequence in the PASSER II program.

It was found in the simulation study that the factors most influencing factors to the arterial link delay are: the traffic volume level (and the resultant Webster's minimum delay cycle length), the intersection spacing, the travel speed and left-turn movement percentages. Most of all, the major impact of the interconnection versus isolated traffic signal operation was found at the uniformity and consistency of arterial travel movements. It was also found that the relationships of the platoon travel over distance and the systemwide background cycle length can influence the total progression system.

The field and simulation data were used along with guideline elements to determine where interconnection of a series of isolated signals is desired. The field and simulation data previously collected were used to verify the guidelines established to evaluate whether signal interconnection is helpful in improving traffic operations through a group of isolated intersections. The guideline and procedure developed in this study can assist in designing beneficial signal interconnection and can provide better utilization of the street system and the fiscal resources.

The results of all the simulation study indicated the lower arterial link delay occurs at a distance of between 1/4 to 1/3 mile or 0.4 to 0.5 cycle length of travel time in two-phase operation, or 0.35 to 0.55 cycle length in four-phase operation. That is, this research finding again confirmed the original **"Rule-of-Thumb"** or **"Ideal Progression Spacing"** of approximately the travel time of one-third to one-half cycle length multiplied by the design speed as the ideal interconnection distance in any generalized arterial.

The results also indicate that highly fluctuated relationships exist between the potential intersection spacing and the probable arterial link delay under good progression phasing condition due to the circular progression platoon propagated along the distance downstream from the upstream traffic signal. As indicated, the effectiveness of the interconnection relies heavily on the location of the "ideal spacing" for the proper combinations of study design variables, such as volume level, left turn percentages, intersection spacing of the neighboring intersections, and the progression speed.

CONCLUSIONS AND RECOMMENDATIONS

The continued demand for urban mobility requires that the highest degree of traffic service be obtained from existing urban arterial streets and intersections. The ability of signalized intersections to move traffic is determined by the physical features of the intersections as well as the type of signalization used. Thus, total system design of a signalized arterial involves concurrently evaluating existing traffic control devices and proper signal timing settings as they function together in the field either as one integrated unit or several isolated subsystems.

The purpose of the study was to find an efficient and usable procedure for practicing traffic engineers in deciding warrants for interconnecting isolated arterial traffic signals to optimize traffic operations. This paper describes the fundamental development of procedures and guidelines for interconnection warrants to minimize the arterial systemwide delay measurement and preserve the convenience of progression movement in multiphase traffic signal timing optimization.

CONCLUSIONS

Traffic signal optimization depends heavily on the relative relationships among the distances between signalized intersections, speed of traffic, cycle length, roadway capacity, and side friction along the arterial. Effective traffic signal operations will not only provide safe crossing gap for the cross street traffic, and accommodate different turning traffic movements but also will guide the randomly arriving traffic through the whole network into compact platoons. Warrants can be used in helping traffic engineers to decide time and locations for proper arterial traffic signal interconnection. The guidelines and procedures developed should be included in the MUTCD in the future.

Because of the highly fluctuated arrival traffic patterns, good sets of preselected cycle length, phase and offset patterns can tailor the arterial traffic signal control to suit particularly sensitive traffic demand patterns. It has also found that a proper compromise between the directional bandwidth could further alleviate total system traffic loading to a certain extent without sacrificing good progression operation. However, care should be taken to monitor traffic speed variations against progression design speeds as well as traffic demand growth along the arterial for successful progression calculations.

It is difficult to compare the impacts of the improvements on the traffic signal timing parameter on the total arterial system operations without the aids from the traffic simulations or a thorough survey of the stops, delay and traffic volumes on the study site. Close monitoring of the traffic flow profile in the field is necessary to further minimize the signed delay from the traffic signal settings calculated from the maximum progression concept.

RECOMMENDATIONS

Further research is recommended on: the calibration of platoon dispersion models used in various traffic signal control strategies, field validation of the interconnection warrants, evaluation of the traffic progression impact, alternative strategies in allocating the directional bandwidths, and the study of local and system optimization tradeoffs in arterial signal optimization. Special attention should be given to a comparison of the progression platoon size and the progression bandwidth in order to use the green time more efficiently without having to sacrifice the progression solution to minimize total arterial system delay. Revision of the internal simulation mechanism inside the NETSIM simulation program is recommended. This would reduce the step size thus reducing the existing cost for simulating combined coordination of fixed-time and actuated signal under isolated or interconnected operations.

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