SOME TRAFFIC SIGNALIZATION DESIGN GUIDES

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This paper presents some guides for use in the design of traffic signal installations that require multiphase signalization. The procedures permit the signal designer to consider all phasing patterns and to select the optimal pattern. Design tables are presented for use at moderately important intersections. Knowing the critical lane volume for each movement through the intersection permits the designer to select from the tables the required g/c ratio for each phasing pattern. The pattern that requires the smallest g/c ratio is the optimal pattern. For more critical intersections, a more sophisticated design guide is presented. It is a computer program that calculates the required g/c ratio for each signalization pattern. It also computes the vehicular delay that would be obtained under different equipment systems (single-dial pretimed, 3-dial pretimed, and several types of traffic-actuated). It then provides a cost-effectiveness comparison of the alternative equipment configurations. Examples of the use of the tables and the computer program are included.

•AT the present time much importance is attached to getting the greatest efficiency from existing traffic networks. This is due largely to the problems related to construction of new facilities in most urban areas.

The arterial street system continues to be a major carrier of vehicular traffic, and the signalized intersections continue to produce many operational problems. Frequently the efficiency of an entire arterial street is determined by a few critical intersections on it. These critical intersections must be subjected to optimal control if the street is to function most efficiently.

Current traffic signalization design procedures do not permit a truly comprehensive design. It is largely a trial-and-error process in which the experience of the designer is heavily weighted in the ultimate design. Frequently also the phasing pattern that is selected must apply over the entire day, even though the volume patterns may change substantially.

Clearly there is a need for a procedure that will allow the traffic signal designer to consider all phasing possibilities and will allow the varying traffic volumes to be considered. The procedure should also provide data that can be used in a cost-effectiveness evaluation of alternative traffic control equipment.

The purpose of this report is to develop traffic signal design tools that will enable the designer to make a more comprehensive analysis of the signalization at critical intersections with regard to signal phasing sequences, signal control equipment, and intersection volume conditions. For major intersections, the designer has two general types of signal control equipment with which he must concern himself. They are

1. Pretimed control with 1 to 3 dials, which displays a single phasing sequence with 1 to 3 cycle lengths, and
2. Traffic-actuated control, which can accommodate numerous phasing sequences and/or cycle lengths.

The design tool should be able to evaluate and compare these two types of control equipment. In either case, the signal designer should be able to use the design tool to

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1. Evaluate the intersection performance using the optimum phasing pattern with 1-dial pretimed control equipment;
2. Evaluate the intersection performance using the optimum phasing pattern with 3-dial pretimed control equipment;
3. Evaluate the pretimed control equipment performance using given cycle lengths;
4. Evaluate the pretimed control equipment performance using optimum cycle lengths;
5. Evaluate the intersection performance using traffic-actuated control and equipment with 3, 4, 5, and 6 phasing modules for displaying the optimum phasing; and
6. Select the optimal signal control equipment by cost-effectiveness considerations.

OBJECTIVE

The development of a traffic signalization design tool is the objective of this report. The design tool is a computer program, the signal operation analysis program (SOAP).

The program has as its primary application the intersections of major importance to the street system where a complete and thorough analysis is needed for signal pattern optimization, cycle length selection, and the decision to select either a pretimed or an actuated controller. With the many variables and options available for this type of intersection, it was necessary and desirable to develop a computer program.

The signal operation analysis program, although intended primarily for the design of signal control systems at individual intersections, is not limited to this application. The logic involved in the selection of a phasing pattern and cycle length for a single intersection can also be used in making the decisions associated with a computerized traffic signal system or other network control system.

In the development of the signalization design guides, a set of design tables was developed, and these tables can be of great assistance in the design of signals at intersections that are not important enough to warrant use of the program. Space limitations do not permit the inclusion of these tables, however.

DEFINITION OF TERMS

The terminology in this discussion conforms to accepted traffic engineering usage, and therefore a complete glossary of terms is not necessary. However, because of the detailed nature of the developments, it is felt that some clarification is desirable to distinguish between the terms "phase", "pattern", and "sequence".

Figure 1 shows the relationship between these three terms. The detailed definitions are as follows:

1. Phase—A phase is a unique combination of nonconflicting movements given right-of-way simultaneously by the traffic signal. This term, therefore, describes the state of the display at a specific point in time.
2. Sequence—The sequence is composed of a set of phases that, when combined in a specific order, make up the complete signal cycle accommodating all of the movements. A sequence is cyclical, with the first phase following the last phase.
3. Pattern—A pattern is a subsequence that accommodates either the northbound and southbound movements or the eastbound and westbound movements. Since these two sets of movements are independent of each other, the pattern concept simplifies the analysis. Two patterns will constitute a sequence when displayed one after the other. The pattern, unlike the sequence, is not in itself cyclical, but the first phase of a given pattern follows the last phase of its counterpart. The definition of a pattern is especially important here since the tables are designed to analyze alternative pattern movements rather than alternative sequences.

CONCEPT OF OPTIMAL DESIGN OF TRAFFIC SIGNALIZATION

The optimal design of traffic signalization consists of the selection of the phasing pattern that will produce the most efficient traffic operation at an intersection under given volume conditions and the selection of the control equipment that provides the most cost-effective means of accomplishing this operation. In the discussion that follows it is

Figure 1. Typical signal cycle showing phases, patterns, and sequence.

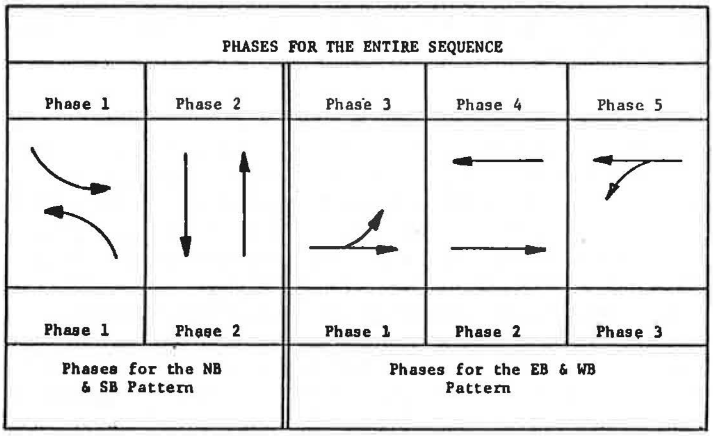
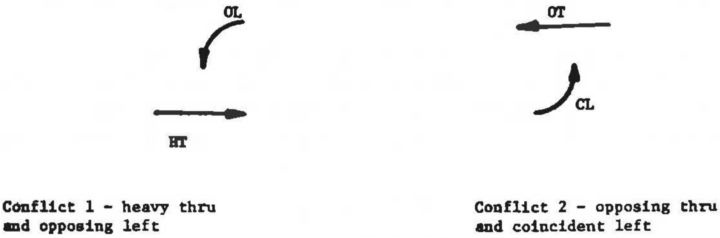


Figure 2. Basic movements and conflicting movements involved in signalization design.

a. Basic Movements Involved in Signalization Design



b. Conflicting Movements Involved in Signalization Design

Table 1. Correspondence of movement designations.

Designated Movement			
HT	CL	OT	OL
Eastbound through	Eastbound left	Westbound through	Westbound left
Westbound through	Westbound left	Eastbound through	Eastbound left
Northbound through	Northbound left	Southbound through	Southbound left
Southbound through	Southbound left	Northbound through	Northbound left

assumed that the intersection has four approach legs. It is also assumed that pedestrians do not have a major influence on the automobile flow and that minimum pedestrian intervals can be provided within the optimum sequence design. In other words, pedestrian considerations are not included in the analyses.

Framework of the Analysis

The analyses are intended to provide a means of comparing alternative traffic signal phasing patterns. In doing so, it is convenient to consider at a given time only the two opposing approaches (for example, either the north and south approaches or the east and west approaches). This is because some of the movements on these opposing approaches can move simultaneously, and it is the selection of the simultaneous movements that is the essence of the analysis. The movements from the side approaches cannot move simultaneously with the movements on the approaches under primary consideration.

Basic Movements—Figure 2a shows the basic movements involved in the signalization design for two opposing approaches. The time required for each phase is determined by the requirements for the critical lane volume in each movement. Thus the volumes of the movements shown in Figure 2a represent critical lane volumes. For the purpose of these analyses the right-turn movement is considered with the through movement, since both have the same conflicting movements. This assumption should lead to conservative values of phase lengths and g/c values.

Figure 2a also shows some of the nomenclature used throughout the analyses. The critical lane volume of one of the through movements will be larger than the other, and this movement is designated the "heavy-through" or HT movement. The left-turning movement from the same approach is called the "coincident-left" or CL movement. The movements from the opposite approach are called opposing movements and the through and left movements are respectively "opposing-through", or OT, and "opposing-left", or OL. The designation of the heavy-through movement fixes the designations of all other movements. Table 1 gives for each possible heavy-through movement the corresponding designations for the other movements.

Figure of Merit—The required g/c ratio (the ratio of the required green time to total cycle length) is used as the figure of merit in comparing phasing patterns. The pattern that accommodates all of the critical lane volumes in the shortest time (smallest g/c ratio) is considered to be the optimal pattern. This figure of merit was selected for the following reasons:

1. The g/c ratio is commonly used for signal phasing analysis;
2. It is applicable to oversaturated and undersaturated intersection approaches;
3. For undersaturated approaches it converts easily into a value for delay; and
4. The conclusions of comparisons of phasing patterns are independent of the cycle length.

The comparisons based on g/c ratios are valid only to the extent that the lost times are the same for all phasing patterns. It can be shown that the lost times of all of the phasing patterns are equal if all amber times are equal. Because of overlap considerations the 3-phase patterns lose only the amount of time lost by the 2-phase patterns. Consequently, the g/c comparisons are valid in cases in which all amber times in a pattern are equal, and these comparisons can be considered guides in cases in which the left-turn ambers are slightly different from the through ambers.

Alternative Phasing Patterns and Their Permutations—The alternative patterns that will be considered are those related to opposing approaches of an intersection with four approaches. Each approach is assumed to have a separate left-turn lane. Most critical intersections would be of this general type. Half-cycle patterns will be considered because the two patterns (east-west and north-south) are independent and can be analyzed separately.

In a given pattern there are four possible combinations of two movements, each of which can be made simultaneously without conflict. These are the four nonconflicting phases from which all phasing patterns must be made; they are shown in Figure 3. All five of the basic signal phasing patterns are also shown in Figure 3. It should be recalled that one of the first steps of the analysis is to rank the critical lane volumes of the

Figure 3. Nonconflicting phases and basic phasing patterns.

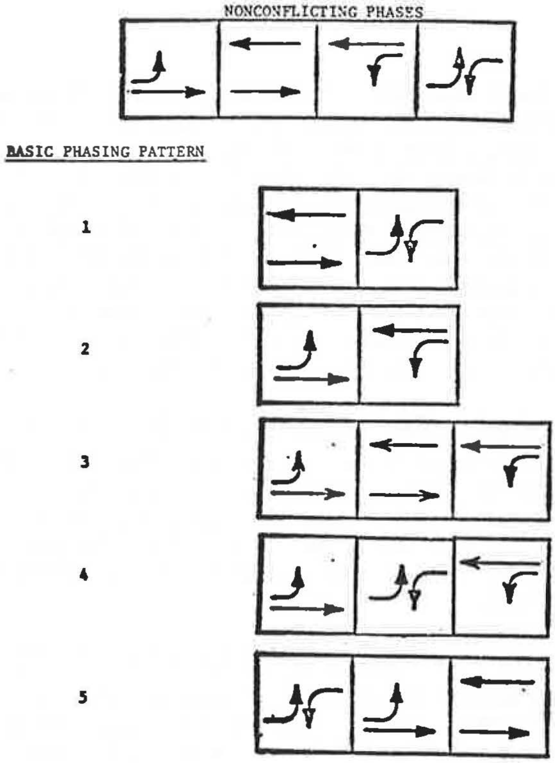
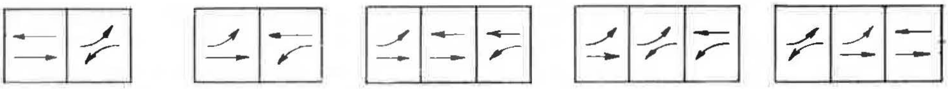


Figure 4. Derivation of g/c requirement for all basic phasing patterns.



Phases	Basic Pattern 1	Basic Pattern 2	Basic Pattern 3	Basic Pattern 4	Basic Pattern 5
1	max (HT,OT)=HT	max (HT,CL)	CL	HT	OL
2	max (CL,OL)	max (OT,OL)	max (HT-CL,OT-OLp)	max (CL-HT,OL-OT,0)	max (HT-OT,CL-OL,0)
3	-	-	OL	OT	OT
TOTAL	HT+max (CL,OL)	max (HT,CL) + max (OT,OL)	max (HT+OL,OT+CL, CL+OL) Note: if CL+OL is the maximum value, ϕ2=0 and Basic Pattern 2 is preferable to Basic Pattern 3.	max (CL+OT,OL+HT, HT+OT) Note: if HT+OT is the maximum value, ϕ2=0 and Basic Pattern 2 is preferable to Basic Pattern 4.	mas (HT+OL,TL+OT, OL+OT) Note: If OL+OT is the maximum value, ϕ2=0 and Basic Pattern 1 is preferable to Basic Pattern 5.

Definitions:
HT = g/c required for heavy through movement
CL = g/c required for coincident left movement
OT = g/c required for opposing through movement
OL = g/c required for opposing left movement

Table 2. Optimal phasing patterns for all volume conditions.

Movement With Highest g/c Requirement	Movement With Second Highest g/c Requirement	Movement With Third Highest g/c Requirement	Movement With Lowest g/c Requirement	Minimum Required g/c	Phasing Patterns With Minimum Required g/c	
					2-Phase	3-Phase
HT	OT	OL	CL	HT + OL	1	3, 5
HT	OT	CL	OL	max (HT + OL, OT + CL)	None	3, 5
HT	OL	OT	CL	HT + OL	1, 2	3, 4, 5
HT	OL	CL	OT	HT + OL	1, 2	3, 4, 5
HT	CL	OT	OL	max (HT + OL, OT + CL)	None	3, 5
HT	CL	OL	OT	HT + OL	2	3, 4, 5
OL	HT	OT	CL	HT + OL	1, 2	3, 4, 5
OL	HT	CL	OT	HT + OL	1, 2	3, 4, 5
OL	CL	HT	OT	HT + OL	1	4, 5
CL	HT	OT	OL	CL + OT	2	3, 4, 5
CL	HT	OL	OT	max (HT + OL, OT + CL)	None	4, 5
CL	OL	HT	OT	max (HT + OL, OT + CL)	None	4, 5

through movements to determine which is the heavy-through movement and which is the opposing-through movement (Figure 2). This allows disregarding a superfluous phasing pattern that would be the same as pattern 5 but with the direction of the second phase reversed. Since the heavy-through is determined, the second phase of basic pattern 5 will always be oriented in the direction of the heavy-through movement.

Examination of all possible permutations of phases in each of the five basic patterns reveals that many of the permutations are not feasible since they would result in the separation of green indications for a movement by a red indication. All of the feasible signal patterns that a designer must consider are those shown in Figure 3 plus the inversion of each (the order reversed). This means that there are exactly 10 phasing patterns that must be considered at each intersection.

Derivation of g/c Requirements for Basic Patterns

This section presents the derivation of the g/c requirements of each of the five basic patterns. The input to the analysis is the g/c required for each of the four movements. The required g/c ratio for a phase must be large enough to satisfy the largest required g/c of either of the two movements of the phase. Figure 4 shows the derivation of the g/c requirements for all five basic phasing patterns and the g/c requirement for each pattern.

Comparison of Patterns for All Volume Combinations

Figure 4 shows the g/c requirement for each basic pattern. The optimal pattern under any given set of volume conditions is the pattern that has the lowest g/c requirement. Thus, a useful tool for the signal designer would be a table that would indicate to him for any volume condition the optimal phasing pattern or patterns to consider.

Table 2 was developed for this purpose. To use this table the designer must rank the critical lane volumes of his four movements. The through movement with the highest g/c requirement is the heavy-through movement, and its designation fixes the designation of the other movements, as summarized in Table 1. With the four movements ranked in order, the designer can look in Table 2 to find the minimum required g/c ratio for his case and can also find the basic phasing patterns that will yield this minimum g/c. He can thus concentrate on these patterns.

Other Considerations of the Basic Patterns

With these values the designer can identify the optimum phasing pattern as the pattern that has the lowest g/c ratio. When more than one pattern gives the minimum g/c value, the choice must be based on other considerations. There are three general rules that may be applied and that will in nearly all cases lead to a unique choice.

Patterns 1 and 2

Because patterns 1 and 2 are simple 2-phase patterns, they are likely to be preferable to the more complicated 3-phase patterns that give the same g/c value. They will probably reduce the safety hazard at a particular intersection, and they will certainly reduce the cost of implementation.

Patterns 3 and 4

If there are no 2-phase patterns with the minimum g/c ratio, the primary basis for choice will be the type of turning interval (restrictive or permissive) that will be used at the intersection. Patterns 3 and 4 are generally preferable under restrictive turning intervals because they do not "split" the red indication as does pattern 5 (for the westbound direction).

The split red can create some confusion for the motorist who expects each movement for the approach (through and left) to be given a continuous green indication.

Pattern 5

Pattern 5 is generally preferable if permissive turns are used since these patterns both end with the phase displaying the two through movements simultaneously, with left turns made on a "yield" basis. Since patterns 3 and 4 both end with a phase displaying the through and left movements in the same direction, the permissive turn from the opposite direction could present some left-turning motorists with unexpected oncoming traffic during this last phase.

Cycle Length Determination

Webster's method (1) is used in the program to calculate the optimal cycle length. As the total traffic volumes approach the capacity of the intersection, an upper limit must be placed on the cycle length to ensure that realistic values are used. The upper limit is set at 120 seconds for pretimed controllers and 150 seconds for actuated controllers to reflect the operation of available equipment.

Comparison of Intersection Control Equipment

The alternative traffic signal control equipment systems are compared in the program through the use of delay. The program calculates the delay each period for each control equipment alternative based on the volumes during the period. Webster's method (1) is used to determine delay for undersaturated conditions. For oversaturated operation, an input-output technique is used to calculate queue lengths on which delay estimates are based.

By comparing the control equipment on a delay basis, an economic analysis can be made that considers the cost and expected advantage (decrease in vehicle hours of delay) incurred with the implementation of one type of control equipment over another. Not only is the operation of the intersection optimized, but a method of justifying the cost for improvements is also provided using the delay comparison.

FUNCTIONAL DESCRIPTION OF THE PROGRAM

The signal operation analysis program performs comparative analyses of various intersection signalization alternatives on a period-by-period basis with 15, 30, or 60 minutes per period. Both the phasing sequence optimization and control equipment selection are considered. The optimum phasing sequence is selected on the basis of g/c ratio. Control equipment is compared on a vehicle-delay basis. This program gives the signalization designer a tool with which to make a complete and comprehensive study of an intersection with a minimum of effort and time.

The program considers the entire portion of the day that is of interest to the signal designer. Many analysis periods during the day are considered, each with its own pattern. Thus the program gives signal design answers that are relevant to the selection of signal control equipment to provide the best operation over an entire day.

Purpose of the Program

The program is structured to answer two major questions:

1. What is the best phasing sequence for an intersection?
2. What is the best way to implement the phasing sequence?

The answer to the first question is determined by summing the g/c requirements (volume-weighted) for each of the five basic patterns for each period of the analysis. The phasing pattern with the lowest average g/c is the optimum pattern. This procedure, except for the volume-weighting, corresponds to applying the phasing pattern tables once for each period of the analysis.

The second question is concerned with different control strategies or equipment, either pretimed or traffic-actuated. The program evaluates the following control equipment:

1. 1-dial, pretimed controller (1 strategy);
2. 3-dial, pretimed controller (1 strategy); and
3. Traffic-actuated controller with 3- to 8-phase capabilities.

Implementation of the phasing sequence necessitates determining certain parameters. Pretimed parameters of cycle length and phase splits are required for all periods (one cycle length and set of splits per dial). Actuated control parameters of cycle length, phase splits, and maximum green time per phase are determined. With actuated control the average cycle length and splits for each period are used. Maximum green times are determined from the total number of analysis periods.

These parameters are used to calculate a value for total vehicle delay for each of the 10 control strategies. The delay value can be used to determine the control equipment to use for optimum efficiency (lowest delay) or to make a cost-effectiveness decision on the control equipment selection. Regardless of the strategy chosen, the parameters of each are available for implementation purposes.

How the Program Works

The program uses the same input data that are collected for use with present design procedures. No special data collection procedures are required. These data include the following:

1. Movement volumes,
2. Effective number of lanes for each movement,
3. Through and turn headways or saturation volumes for each movement, and
4. Lost time per phase.

Additional data for use with the pretimed equipment analysis include

1. Imposed cycle lengths for each dial (for interconnected systems only), and
2. Period to dial associations (required for all systems).

The basic program structure consists of three major analysis routines. The first routine determines the optimum phasing sequence and the best 2-phase and 3-phase patterns for each opposite pair of approaches. Two input variables used in the program are

1. The "more than 1-phase" variable, which allows the insertion of a single phase operation for either pair of opposite approaches (no protected left-turning intervals); and
2. The "2-phase better" variable, which specifies the total g/c percent by which a 3-phase pattern must be less than a 2-phase pattern in order to be chosen as the optimum pattern (default value is 2 percent).

The next routine determines pretimed control parameters and uses them in the delay calculation for both 1-dial and 3-dial equipment. The average optimal cycle length for each pretimed dial is calculated by the program.

The third routine determines average traffic-actuated control parameters such as maximum green time, cycle length, and splits for each period and uses them in the delay calculations for different phasing arrangements used in actuated equipment.

The program uses Webster equations to determine both cycle length and splits for each period of the analysis. The routine for pretimed control uses the period values to establish values for each dial. The routine for actuated control uses the period values directly in the computations. Webster's delay equation is used for undersaturated volume conditions, and an input-output technique determines delay for saturated conditions.

The output of the signal optimization analysis program is of four categories:

1. A visual display of the five basic phasing patterns,
2. A summary of input data,
3. A summary of pretimed control operation, and
4. A summary of actuated control operation.

The visual display is a pictorial representation of the five basic phasing patterns and gives meaning to the pattern numbers printed on the data summary sheet. This is an optional step in the program.

A summary of input data is printed to show the values given to the variables within the program. Its attachment is necessary to clarify the presentation of the results. Also included on the summary sheet is a ranking of the five phasing patterns as to their desirability as the chosen pattern. The volume-weighted g/c for each pattern is the

Figure 5. Signal phasing pattern analysis for sample problem one: input data and value of variables.

```
HEADWAY THRU (SEC) = 2.20            PED SPEED (FT/SEC) =10        LOST TIME PER PHASE (SEC) = 4
HEADWAY TURN (SEC) = 2.20


                            WBT  WBL  EBT  EBL  SBT  SBL  NBT  NBL
                            ***  ***  ***  ***  ***  ***  ***  ***
    NUMBER OF LANES         1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
    SATURATION FLOW         1636 1636 1636 1636 1636 1636 1636 1636


   APPROACH WIDTHS :
      (FEET)                NORTH -     50        EAST -     50
                            SOUTH -     50        WEST -     50
                                          VOLUME                            GIVEN CYCLE LENGTHS
PERIOD       TIME           WBT  WBL  EBT  EBL  SBT  SBL  NBT  NBL          1 DIAL         3 DIAL
****** ************         ***  ***  ***  ***  ***  ***  ***  ***          ************************
   1      800 TO  900       100   50  500  150  200  100  500  150             0              0
   2      900 TO 1000       100   50  600  150  200  100  600  150             0              0
   3     1000 TO 1100       100   50  600  200  200  100  600  200             0              0
   4     1100 TO 1200       100   50  400   50  200  100  400   50             0              0
   5     1200 TO 1300       400  150  200  100  400  150  200  100             0              0
   6     1300 TO 1400       400  150  200  100  400  150  200  100             0              0
   7     1400 TO 1500       400  150  200   50  400  150  200   50             0              0
   8     1500 TO 1600       400  150  200   50  400  150  200   50             0              0
   9     1600 TO 1700       500   50  300  100  500   50  400   50             0              0
  10     1700 TO 1800       500  150  300  100  500  150  400   50             0              0
  11     1800 TO 1900       500  150  300  100  500  150  400   50             0              0
  12     1900 TO 2000       500   50  200  100  400   50  400   50             0              0


                             VOLUME WEIGHTED PATTERNS FOR ALL PERIODS

                            EAST-WEST                                    NORTH-SOUTH
             ****************************************        ***********************************
 PATTERN       3      1      5      6      2      4            3      5      1      6      2      4

 AVG G/C      34     38     36     36     41     41           33     34     37     36     45     45
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Figure 6. Signal phasing pattern analysis for sample one: pretimed control results.

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                                   SINGLE DIAL OPERATION

  CYCLE LENGTH USED =  115      OPTIMUM CYCLE LENGTH =  115   AVG VEH DELAY (SEC) =  78.67  TOTAL DELAY (HRS) = 474.21

                              GREEN TIME PLUS AMBER IN PER CENT OF CYCLE LENGTH

                 0.13          0.22          0.13               0.11          0.26          0.14
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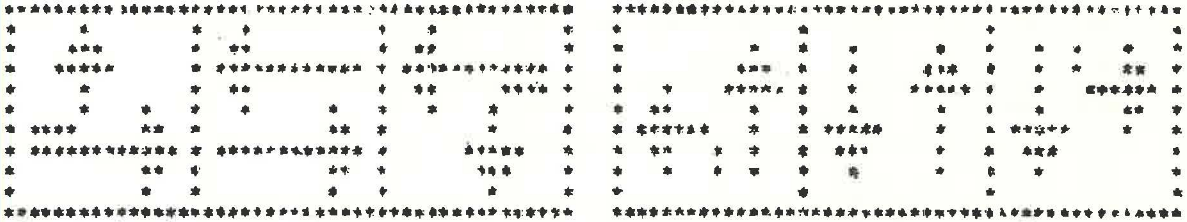

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      USED                                                                                          OPT
DIAL  CYCLE                   GREEN TIME PLUS AMBER IN PER CENT OF CYCLE LENGTH                    CYCLE

  1    120       0.13          0.27          0.07               0.14          0.29          0.11      120

  2     75       0.10          0.23          0.17               0.10          0.23          0.17       75

  3    100       0.10          0.28          0.10               0.08          0.32          0.12      100


                                   THREE DIAL OPERATION

        AVG VEH DELAY (SEC) =  49.74                                 TOTAL DELAY (HRS) = 299.84
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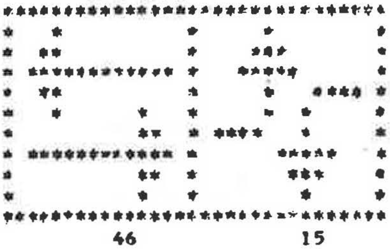
Figure 7. Signal phasing pattern analysis for sample problem one: traffic-actuated results.

TRAFFIC ACTUATED EQUIPMENT

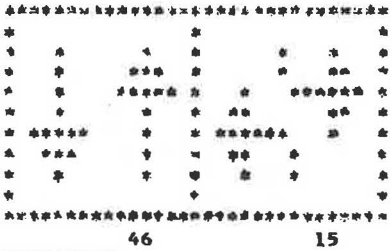
4 PHASE OPERATION

AVG VEH DELAY (SEC) = 57.24   TOTAL DELAY (HRS) = 345.06

EAST-WEST



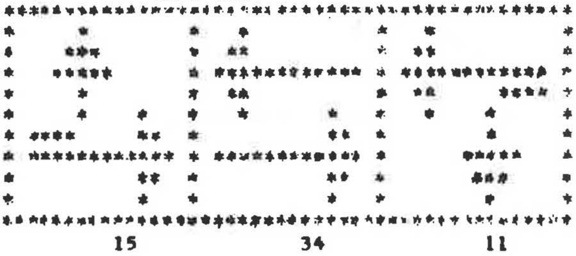
NORTH-SOUTH



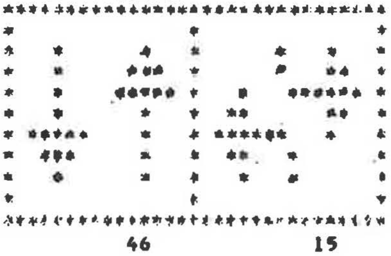
5 PHASE OPERATION

AVG VEH DELAY (SEC) = 42.55   TOTAL DELAY (HRS) = 256.48

EAST-WEST

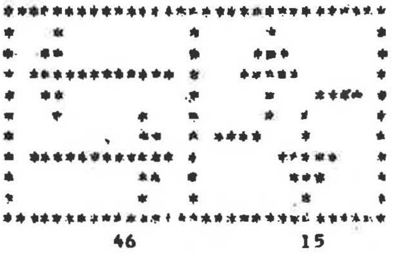


NORTH-SOUTH

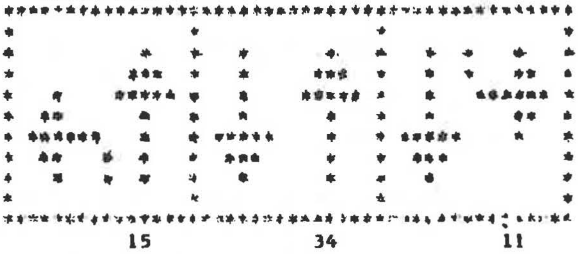


AVG VEH DELAY (SEC) = 44.99   TOTAL DELAY (HRS) = 271.19

EAST-WEST



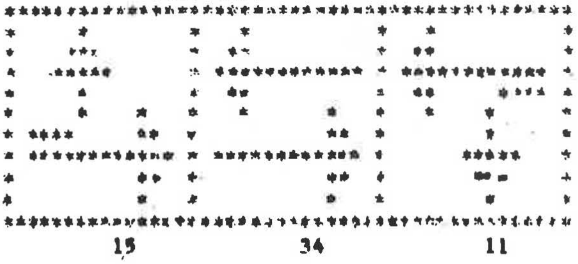
NORTH-SOUTH



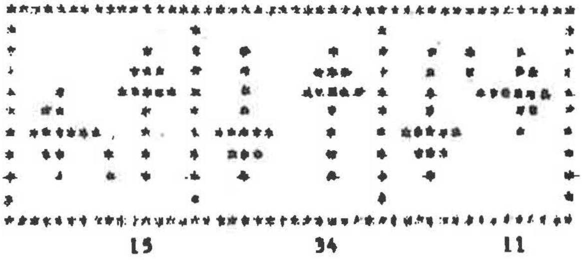
6 PHASE OPERATION

AVG VEH DELAY (SEC) = 33.70   TOTAL DELAY (HRS) = 203.14

EAST-WEST



NORTH-SOUTH



MAXIMUM GREEN TIME IN SECONDS

average value calculated from all periods. This ranking gives an indication of how much better one pattern is than another.

The pretimed control output is for 1-dial and 3-dial equipment. A visual display of the optimum phasing sequence is given and the following values are printed for each control strategy (1-dial or 3-dial):

1. Cycle lengths used,
2. Optimum cycle lengths,
3. Phase splits,
4. Average vehicle delay, and
5. Total vehicle delay for the analysis.

The actuated control output is for various combinations of 1-, 2-, and 3-phase patterns. If an exclusive left-turn interval is required for each opposite pair of approaches, the program calculates (a) average vehicle delay, (b) total delay for the analysis, and (c) maximum green time for each phase module for the following combination of phasing patterns:

East-West	North-South
2-phase	2-phase
2-phase	3-phase
3-phase	2-phase
3-phase	3-phase

If an exclusive left-turn interval is not required (single-phase pattern), the program also outputs data for

East-West	North-South
1-phase	2-phase
1-phase	3-phase
2-phase	1-phase
3-phase	1-phase

The program output can be seen in the example problem to follow.

Sample Problem

Volume data for 12 consecutive 1-hour periods of a typical 4-legged intersection with left-turn intervals required on each approach were input to the program. The results using nonpermissive phasing patterns are presented as "sample problem one." Output for "sample problem one" is shown in Figures 5, 6, and 7.

With this delay information on hand, a cost-effectiveness analysis can be made to indicate the type of equipment that should be installed. With the equipment chosen the program results would then be used to indicate the phasing sequence and set the timing and splits on pretimed equipment. For actuated equipment the program would be used to indicate the phasing sequence and give an insight into what the "max" setting in the controller should be.

REFERENCE

1. Webster, F. V. Traffic Signal Settings. Road Research Technical Paper No. 39, 1958.