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COMPARATIVE ASSESSMENT OF COMPUTER PROGRAMS FOR TRAFFIC SIGNAL PLANNING, DESIGN, AND OPERATIONS

Volume II
Software Description

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16. ABSTRACT

The main goal of this study was to comparatively assess a group of selected computer programs for traffic signal planning, design, and operations. A comprehensive inventory was conducted and a detailed list of the currently available computer software was developed. A short description of individual software was provided, and a comparative processor software, and network software. The final recommendation of software included seven programs for isolated intersections, three preprocessor software, and five network software.

Volume 1 Study Approach, Analysis and Recommendations
Volume 2 Software Descriptions
Volume 3 Recommended Software Output

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CAPCALC (Circular 212)

PROGRAM DESCRIPTION - In 1982, RCAI (Roger Creighton Associates Incorporated) released CAPCALC, a microcomputer software package designed to enable traffic engineers to calculate the capacities and levels of service of at-grade signalized and unsignalized intersections (1).

CAPCALC (intersection CAPacity CALCulation) calculates the capacities and levels of service (LOS) of at-grade signalized and unsignalized intersections using procedure published in Transportation Research Circular 212. The CAPCALC program can be run by anyone with a good technical background who has taken the time to familiarize himself/herself with Circular 212.

CAPCALC is written for a) the Apple II, II+, or IIe computer, b) the IBM Personal Computer, or c) the TRS-80 model 11, 12, or 16.

CAPCALC does not run under DOS, but under a different operating system called the P-system. Before you can use CAPCALC you must set up a separate partition for this operating system on your hard disk.

INPUT - CAPCALC has a screen editing feature. The input data for the signalized intersection are:

1) Intersection general information
2) Intersection geometry for each approach including the number of lanes, width and movement per lane per approach
3) Volume of traffic turning and going straight including the percentage of trucks and buses per approach
4) Critical gap for turning and through traffic, peak hour factor, gradient and right turn factor per approach
5) Cycle length

The input data for the unsignalized intersection uses the physical and traffic data entered as listed above.

In entering data, it is necessary, if unsignalized capacities are to be calculated, to enter the critical gap acceptance data for the minor traffic.

OUTPUT - The SIGNALIZED intersection calculation is made of two modules. The ''PLANNING'' module follows the ''PLANNING'' method of Circular 212. The output for ''PLANNING'' module is as follows:

1) Volume allocation to lanes
2) Left turn check, and
3) Planning results:
   a) number of phases
   b) movements per phase
   c) critical volume per phase
   d) percent capacity used
   e) intersection critical volume
   f) intersection percent capacity used, and
   g) intersection level of service

The ''OPERATIONS AND DESIGN'' module follows the ''OPERATION AND DESIGN'' method of Circular 212. The procedure is the same except that there is an additional output, adjusted per lane volumes. The final results also include, 1) effective green time per phase, 2) average delay per phase, and 3) intersection effective green time.

The output for UNSIGNALIZED intersection is as follows:

a) volume allocation to lanes, and
b) reserve capacity and level of service per lane and per approach

SPECIAL FEATURES AND SHORTCOMINGS - As an aid to CAPCALC users, several additional MOE have been added to Circular 212 procedures, and they are:

1. Percent Capacity Used

   a) CAPCALC automatically calculates the percent of total intersection capacity used by each phase. In both the Planning and Operations and Design Applications, the total intersection capacity is the maximum sum of critical volumes for level of service E corresponding to the number of phases required at the intersection.

   b) The individual percentages for each phase when summed yield the total percent of intersection used. This statistic is an indication of the degree of saturation of the intersection.

2. Effective Green Time

   CAPCALC automatically calculates the effective green time associated with each phase. The intergreen time (amber) for the intersection (in seconds) is calculated as two times the number of phases involved plus two. The effective green time for the intersection is obtained by subtracting the intergreen time from the desired cycle length. The ratio of the critical volume per phase to the sum of the critical volumes for the intersection is the proportion used in calculating the effective green time per phase.

3. Average Delay

   a) Whereas Circular 212 provides the average stopped delay incurred by all vehicles entering the intersection, CAPCALC provides an estimate of the average stopped delay by vehicles likely to be incurred during each phase of controlled movement.

b) The means for estimating delay is Webster and Cobbe's delay function, adapted for use in conjunction with Circular 212 procedures.

c) No delay values or green times are calculated if the level of service is at E or Failure because of the instability of the operating environment under these conditions.

4. It supplies the user with the directory of existing intersection files.

5. Permits rapid entry of required data.

6. It has a very good editing capability, allowing for correction of each screen.

7. It prints input data ''for the record.''

The program has the following shortcomings:

1) The program is limited to four lanes per approach.

2) Question which require single letter responses (such as ''Y'' or ''N'' accept uppercase letters only.

3) It does not run under MS-DOS, but rather under a different operating system called the P-System. this means that if the user wishes to install the program on a hard disk, a special partition is needed.

CAPCALC (1985 HCM)

PROGRAM DESCRIPTION - CAPCALC (intersection CAPacity CALCulation) calculates the capacities and levels of service (LOS) of at-grade signalized and unsignalized intersections (2).

The new HCM 1985 procedures were so markedly different from the Circular 212 procedures that RCAI (Roger Creighton Associates Incorporated) determined to rebuild CAPCALC totally. A supporting reason was to expand the original CAPCALC so that it could deal explicitly with intersections having up to six lanes per approach.

The resulting program was named ''CAPCALC 85''. Its purpose is to increase the productivity of traffic engineering personnel by replacing the manual forms and calculations used in the new HCM with computer procedures capable of being run on a number of widely-available microcomputers.

CAPCALC is written for a) The Apple II/II+/IIe computers, b) The IBM PC/PC XT computers, and TRS-80 II/12/16.

CAPCALC does not run under MS-DOS, but under a different operating system called the P-system. Before CAPCALC can be used, it is necessary to set up a separate partition for this operating system on a hard disc.

INPUT - CAPCALC has a screen editing feature. The input data for the signalized intersection are:

1) Intersection description
2) If the intersection is signalized, the type of signal (Actuated, Semiactuated, or pretimed)
3) Traffic and roadway conditions:
   - percent grade
   - percent heavy vehicles

- presence of adjacent parking lane
- number of parking maneuvers/hour
- number of buses stopping/hour
- peak hour factor for area type
- number of conflicting pedestrians/hour
- presence of a pedestrian button
- number of seconds allowed for pedestrians
- arrival type for approach

4) Geometrics and Volumes per approach

5) Signal phasing

OUTPUT - The SIGNALIZED intersection calculation is composed of two modules, the ''PLANNING'' and ''OPERATIONS AND DESIGN.'' The output for ''PLANNING'' module is as follows:

1) volume for each lane groups per approach
2) E-W and N-S critical volume, and
3) STATUS of the intersection

The output for ''OPERATIONS AND DESIGN'' module is as follows:

1) VOLUME ADJUSTMENT SCREEN which permits the experienced traffic engineer to edit flow rates, lane utilization factors, adjusted flow rates, and proportion of left and right turns in order to fine-tune the calculation to satisfy special circumstances.
2) SATURATIONS AND DESIGN SCREEN which permits the experienced traffic engineer to edit ideal saturated flow, and adjustment factors for: width, heavy vehicle, grade, parking and bus maneuver, area, and right and left turn. This permits fine-tuning the calculations to satisfy special circumstances.

3) CAPACITY ANALYSIS SCREEN which permits the experienced traffic engineer to edit permissive left turn flows, critical lane groups, and lost time per cycle in order to fine-tune the calculations to satisfy special circumstances.

4) LEVEL OF SERVICE SCREEN is an output screen reflecting the input values on the previous three screens. This screen contains the following MOE per lane group per approach:

a) V/C ratio

b) green ratio

c) 1st delay, 2nd delay, lane group delay, and approach delay

d) lane group capacity and level of service

Also, the values for intersection delay and LOS are included within this screen.

5) Intersection diagram

SPECIAL FEATURES AND SHORTCOMINGS - The following qualities and features were built into CAPCAL 85 to increase productivity.

- It can handle up to six lanes per approach.
- It includes three types of signals (pretimed, actuated, and semi-actuated).
- Full ''bullet-proofing'' (''error-trapping'') to prevent data entry errors
- Program ''defaults'' to typical standard values of lane width, peak hour factor, and many other variables to speed up data entry. (The user can enter any other value if so desired.)
- User control over critical variables including signal phasing, signal timing, and vehicle adjustment factors

- Full screen cursor control to allow rapid editing of input values
- It allows the user to move forward or backward from one screen to another screen.
- ''Lane grouping'' for ease of data entry
- Upon revision of the data in any data cell, all results are re-calculated almost instantaneously.
- Printed output in exactly the same form as input and intermediate-calculation screens
- Output suitable for camera-ready reproduction in engineering reports
- Input data printable ''for the record''
- A cycle length of 0 will cause the program to estimate cycle length based on HCM methodology (only if the intersection is not saturated).
- As each green time is entered, it computes and displays the resulting yellow plus red time.
- The program will allow you to enter data in either upper or lower case.
- It is possible to stop the program when it is in the middle of doing something and get back into the program as though it had never been interrupted.
- It can change the number of lines per page in printout.

There are a few shortcoming within this software. These are:

- At least one type of lane group combination is missing in manual
- The user has to be familiar with the 1985 HCM.
- In order to input movements (LTR) the capital letters have to be used.

- It does not run under MS-DOS, but rather under a different operating system called the P-system. This means that if the user wishes to install the program on a hard disk, a special partition is needed.
- If the user chooses a zero cycle length, the program will not calculate the splits and level of service if the intersection is saturated.

CAPSSI

PROGRAM DESCRIPTION - CAPSSI is an acronym for ''Comprehensive Analysis Program for Single Signalized Intersections.'' It entitles a very powerful traffic engineering programming tool (3).

The purpose of the program is to aid the engineer in optimizing traffic signal settings and/or measuring the performance of a single signalized intersection when a specific data set is given. Preliminary considerations of the evaluation of the impacts at a given signalized intersection indicated the need for an advanced algorithm for traffic impact evaluation that would be highly interactive. The BASIC computer language was chosen to develop such a program.

INPUT - The required input is listed below:

1) The intersection identification number.
2) The intersection name or description.
3) The number of critical phases (computed by the user).
4) The flow, saturation capacity flow and lost time for each critical phase (acquired usually from the field).
5) The minimum green times for the required cycle time solution.
6) The actual green times for the predetermined cycle time solution.
7) A range of cycle lengths that are required to be tested.
8) The minimum time for pedestrian crossing is required only if the user is using the Required Cycle Time option.
9) Data for pollution calculations.

OUTPUT - It can be divided into two parts:

1) A record of the time sharing session with the user. This is an echo of what the user inputted. First, a title is printed and then the name of the intersection as inputted by the user. The data for each phase are columnar with the critical phase numbering across the top and the description of each row of data to the left. The first three rows are, respectively: flow, saturation flow and the lost time for each critical movement as inputted by the user. The minimum times are also repeated. Below the table the values for the ''approach and departure speed'' and ''total intersection volume'' are echoed by the computer if the pollution calculations were requested.

2) The second part of the output is the analysis of the input data as performed by CAPSSI. All the information provided by this section is vital to the user in regard to the performance of the intersection on the basis of the inputted data. The output information provided by CAPSSI is listed and defined below:

- RELATIVE SATURATION: The ratio of the flow to the maximum flow which can be passed through the intersection from a particular approach.
- EFFECTIVE GREEN TIME: The chosen green time for that movement minus the lost time.
- MOVEMENT TIME: The effective green time plus the lost time.
- AVERAGE DELAYS: The theoretical time that a vehicle will have to wait in each respective critical movement to pass through the intersection.
- LEVEL OF SERVICE: An objective rating of the performance of the intersection ranging from A+ to F+.

- AVERAGE QUEUE VEHICLES: The theoretical average queue in each respective phase at the beginning of the green period for that phase.
- AVERAGE STOPS AND STARTS: The theoretical average number of times a vehicle must stop or start during a complete cycle for each respective phase.
- DO VEHICLES CLEAR: Tells if, on the average, the vehicles will theoretically clear during any respective green time.
- WEBSTER'S OPTIMUM CYCLE LENGTHS: The cycle time which gives an equal degree of saturation and minimum delay.
- REQUIRED CYCLE LENGTH: The cycle length chosen by CAPSSI that will satisfy all the minimum green times supplied by the user and results in minimum delay for those conditions.
- PREDETERMINED CYCLE LENGTH: The sum of the actual movement times supplied by the user. This will also be the negative cycle time that the user might input to the program to determine the approximate splits for a particular cycle time.
- WEIGHTED AVERAGE DELAY, AND LEVEL OF SERVICE: The average delay for all critical movement weighted with respect to the flow values, in seconds, and an objective level of service rating for this delay.
- EXCESS FUEL USAGE, GALLONS/HOUR: The amount of fuel usage resulting from vehicles stopping at the intersection.
- EXCESS CO, HC AND NOX, GRAM/HOUR: The amount of emissions in grams (hydrocarbons, carbon monoxides and nitrous oxides) in the critical hour for all vehicles stopping at the intersection.

SPECIAL FEATURES AND SHORTCOMINGS: The program has the capability of performing many functions that are of use to the engineer. These functions can be enumerated as follows:

1) CAPSSI will optimize the green time splits at the intersection using the Webster Method. It will then calculate the delays of the critical movements in each phase and objectively evaluate its level of service.

2) CAPSSI can split the cycle time between the critical movements on the basis of equating the degree of saturation for all movements by inputting a negative cycle time into the Actual movement time for one of the critical movements.

3) CAPSSI will evaluate the delays and level of service for existing green splits.

4) CAPSSI will provide the user with (for each critical phase) the average number of stops and starts per vehicle, will calculate the theoretical queue length, and will calculate the fuel consumed and pollution emissions per hour for existing green splits and/or optimized green splits for a given set of data.

5) CAPSSI will consider pedestrian crossing times (or minimum green times) for optimization of splits only. CAPSSI will allow the user to optimize the splits while satisfying all the minimum green times.

6) Because CAPSSI is highly interactive, it allows the user to test a full range of sets of data. These will include saturation flow, a particular movement, test a range of cycle lengths, the approximate split distribution for a particular cycle and test the validity of an existing cycle time and its corresponding split.

7) CAPSSI can be run many times at each intersection to test the impact of different traffic loadings on the intersection. This can be very

useful to the writers of Environmental impacts, as before and after traffic loading conditions may be considered. It can also serve as a useful tool in street design or improvements by evaluating the needed capacity at the intersection.

The major shortcomings of this software are listed below as:

1) CAPSSI requires external hand calculation of Critical Movements.

2) It cannot list the directory of data files.

3) Printer has to be on or the program will automatically terminate the session.

CMA

PROGRAM DESCRIPTION - CMA is a program which uses critical lane movement analysis procedures to examine the capacity and level of service at signalized intersections. The program follows very closely the analysis procedures described in detail in the Transportation Research Board Circular 212. The 212 procedure was developed as the result of research work carried out by JHK Associates and the Traffic Institute of Northwestern University under National Cooperative Highway Research program (NCHRPP) project 3-28 (4).

CMA is a menu driven, interactive program which makes extensive use of prompting to encourage proper operation. The program is designed for simple and effective operation by traffic engineering personnel.

The user should review the TRB 212 procedures to become familiar with its strengths and limitations. It must be noted that some engineering judgement is required to gain the most from the TRB 212 procedure. The procedure is, however, easy to use and will provide insight into the service provided at signalized intersections with a limited amount of effort.

The program is operated from a set of main menu selections. Data entry, data file management and program run operations are each selected from menu choices. Each analysis scenario is managed as an independent disk file. Files can be duplicated and saved under new names and easily modified to test alternative evaluation situations. A concise but complete summary report can be produced as the user wishes.

The program operates on microcomputing systems with the following capacities, features and characteristics:

1. The system must operate under a version of CP/M or MS-DOS.
2. The system must be configured to provide approximately 40K.

3. The system must at least have one disk drive with a minimum of 90K bytes of free space.

4. A printer is not required for analysis but is required to produce summary reports.

INPUT - The required input data are as follow:

1. General Intersection information
2. Intersection volumes
3. Percent Trucks, Percent Buses, Peak Hour Factor, G/C
4. Intersection phasing including phase overlaps
5. Lane Channelization/Widths
6. Intersection Cycle Length
7. Actual Critical Movements

OUTPUT - The first two pages of the output are the user inputted data. The output also includes the following:

1. Left turn capacity check
2. Passenger car equivalent period traffic volumes
3. Calculated critical lane traffic volumes
4. Selected critical volumes (sum of critical volumes)
5. The V/C ratio
6. Indicated intersection Level of Service

SPECIAL FEATURES AND SHORTCOMINGS - CMA has the capability of listing the intersection files. It also has a very good editing feature for both old and new data files.

The user has to choose the critical movements which requires knowledge of Circular 212.

CMA/M

PROGRAM DESCRIPTION

The Critical Movement Analysis of the McTRANS package (CMA/M) is programmed in Applesoft for Apple II computers (5). It carries out a complete analysis for signalized intersections utilizing procedures documented in the TRB Circular 212 publication (Interim Material on Highway Capacity). The program identifies the critical traffic movements at an intersection, performs adjustments for lane width, trucks, pedestrians, left turns, local buses, etc. The program determines degree of saturation and level of service for signalized operation.

INPUT

The input stream to the program includes:

- o Intersection Geometrics: lane configurations and widths
- o Traffic volumes: traffic volumes per movement per direction, truck and local bus volumes, and peak hour factor.
- o Phasing: phasing scheme per direction, cycle length, and pedestrian activities.

OUTPUT

A typical output contains an echo of the input stream and a hard copy of the level of service and critical movements.

SPECIAL FEATURES AND SHORTCOMINGS

The program executes the CMA procedure as described in circular 212 step by step with no special features added to it. It performs analysis of signalized intersections with no capability of performing optimization or design. It runs on Apple II computers only. The screen editing capability is relatively rigid, and some of the editing functions do not perform properly.

EZ-POSIT

PROGRAM DESCRIPTION - EZ-POSIT is an interactive, window-oriented program for traffic engineers (6). With a minimum amount of required input data, the program can produce an optimal signal setting, including cycle time and phasing pattern, that can minimize fuel consumption for a given intersection.

No new techniques were used in developing the technical aspects of the program; however, a great number of concepts and methods described in the Critical Lane Movement Analysis documented in the TRB Interim Materials on Highway Capacity were adopted. This feature makes EZ-POSIT quite applicable to U.S. conditions.

The program is written in UCSD-PASCAL which was developed by the University of California at San Diego. It is the most popular high-level language in microcomputer application today.

INPUT - In the input stage, the program guides the user to specify required data. The user is provided with clear instructions via a menu format, and comprehensive error checks are made. In order to simplify the input procedure, many parameters are defaulted to represent average geometric and traffic conditions. Therefore, volume is the only data the user has to input to the program if the defaulted values can be applicable to his conditions. The input for the optimization process are:

1) Minimum green
2) Lane width
3) Local bus
4) Number of Lanes
5) Pedestrians

6) PHF (%)

7) Trucks (%)

8) Volume (vph)

9) Minimum and Maximum cycle length

The only additional data needed for a design process are:

1) Actual cycle length, and

2) Phasing

The phase setting for isolated intersections is divided into a N-S street pattern and an E-W street pattern, which are independent of each other. The pattern can be grouped into three types:

1) None of the left turn movements are protected

2) One of the left turn movements is protected

   a) North or East bound left turn is protected

   b) South or West bound left turn is protected

3) Both of the left turn movements are protected

   a) Left turn movement first, without overlap

   b) One direction first, without overlap

   c) Left turn movement first, with overlap

   d) One direction first, with overlap

The program can also evaluate the intersection if the user input the Actual green time in addition to above data.

OUTPUT - The optimization process is a procedure to select the optimum signal setting based on the minimum fuel consumption. The Optimization is described by the algorithm in Figure 1.

Three requirements are checked in every iteration before fuel consumption is computed. If any one of the requirements cannot be

```
For each possible N-S phase pattern loop
    For each possible E-W phase pattern loop
        computer PASSENGER_CAR_EQUIVALENT (PCE);
        determine CRITICAL_LANE_VOLUME;
        calculate SUM_OF_CRITICAL_LANE_VOLUME
        set MIN_CYCLE and MAX_CYCLE if necessary;
        from MIN_CYCLE to MAX_CYCLE step 5 sec loop
            calculate SPLIT for each phase;
            check MIN_OVERLAP_TIME (5 sec);
            calculate GREEN_TIME for each movement;
            check MIN_GREEN_TIME;
            check UNPROTECTED_LEFT_TURN;
            compute LEVEL_OF_SERVICE (LOS);
            compute DELAY, NO_OF_STOPS, FUEL_CONSUMPTION;
            record the CYCLE_TIME having MIN_FUEL_CONSUMPTION;
        end_of_cycle_loop;
        record the setting having MIN_FUEL_CONSUMPTION;
    end_of_EW_pattern_loop;
end_of_NS_pattern_loop;
```

Figure 1 EZ.POSIT Optimization Process

fulfilled, computation will not proceed and the program will jump out of the iteration and try the next combination. At the end of each iteration, the computed fuel consumption is compared with the previous optimum setting and the current optimum setting is recorded. The three requirements are as follows:

1) Minimum Overlap Phase - Because the green time defined in this study includes the clearance time, it is not practical to have an overlap phase shorter than the clearance time. Therefore, 5 seconds is used as the minimum overlap phase. This assures that the overlap phase is long enough to release at least two vehicles.

2) Minimum Green Time - It allows pedestrians enough time to cross the street or to avoid an unrealistically short green period.

3) Left Turn Check - This check examines if the exclusive left turn phase should be assigned to accommodate left turn movements. The procedure suggested is as follows:

$$V_L = \frac{7200}{C} + \frac{1200G}{C} - V_o$$

where: V_L = Capacity (vph) for an unprotected left turn

C = Cycle Length (sec)

G = Green time (sec) available for the movement

V_o = Volume (vph) of the opposing through movement

This allows two vehicles per cycle on the clearance and assumes that 1200 vehicles per hour of green (VPHG) will be accommodated as a linear combination of the unprotected left plus the opposing through movements.

If the cycle length is not specified by the user, the program sets a cycle range within the optimum cycle length is determined. The maximum cycle length is defaulted to 120 seconds. As for the minimum cycle length, it is suggested 30 sec. for a 2-phase condition, 45 sec. for a 3-phase condition and 60 sec. for a 4 or more phase condition as the minimum pretimed cycle length.

The OPERATION AND DESIGN APPLICATION of the Critical Movement Analysis is adopted in this program to compute the split and green time. The procedure is as follows:

1) Calculate Passenger Car Equivalence for each lane. The adjustment factors considered by Critical Movement Analysis are as follows:

   a) Lane width

   b) Bus and trucks

   c) Left turns

   d) Right turns and pedestrians activity

   e) Peaking characteristics (Peak Hour Factor)

2) Combining Critical Lane Volume. Critical lane volume for each street is determined.

3) Calculate Splits and Green Time. The allocation of cycle time is based on the proportion of the critical lane volume for each phase to the total critical lane volumes.

The simplified Webster Delay formula is adopted in this program.

$$D = \frac{9}{10}\left[\frac{C(1-L)^2}{2(1-\mu x)} + \frac{X^2}{2Q(1-x)}\right]$$

where: D = average delay (sec/veh.)

C = cycle length (sec)

μ = G/C ratio

X = Degree of Saturation

Q = Volume (pce/sec)

The program uses the following formula to calculate the proportion of vehicles required to stop (stop ratio) at a signal. On an average stop ratio is equal to the vehicles that arrive in red time divided by the vehicles that arrive in whole cycle.

$$S = \frac{R}{C(1-x)} = \frac{(1-L)}{(1-\mu x)}$$

where: R = Red Time (sec)

S = Stop Ratio

This formula assumes that a queue which formed in a red period would release completely during the following green period.

The excess Fuel consumption is calculated using the following formula that is a function of stops and delay.

$$F = Q(AS + BD)$$

where: F = Excess Fuel Consumption (gal/hr)

Q = Volume (pce/hr)

A = Fuel Consumption Rate for Stopped Vehicle (gal/hr/veh)

D = Average Delay per Vehicle (hr/veh)

B = Idle Fuel Consumption Rate (gal/hr/veh)

SOAP suggests 0.6 gal/hr/veh for an idle fuel consumption rate and 0.01 gal/hr/veh for a stopped fuel consumption rate.

As part of the Critical Movement Technique, Table 1 gives the recommended thresholds for the sum of the critical volumes for levels of service A through E.

Table 1 Levels of Service Ranges for CMA

(Source: Critical Movement Analysis)

Level of Service	Two Phases	Three Phases	Four or More Phases
A	1000	950	900
B	1200	1140	1080
C	1400	1340	1270
D	1600	1530	1460
E	1800	1720	1650

SPECIAL FEATURES AND SHORTCOMINGS - EZ-POSIT is an attractive, colorful, and creative window-oriented program. It has a short help file and an easy way of editing the file. It uses every possible combination within the cycle length range (increment of 5 seconds) and every available phase to arrive at the optimum cycle length and phase sequences for an intersection in order to minimize the total delay per intersection.

ICAP

PROGRAM DESCRIPTION - In the late 1960's, the Institute of Transportation and Traffic Engineering of the University of California, with partial support from the Automotive Safety Foundation, developed a series of computer programs for capacity analysis. The ICAP programs are based upon one of these programs. The initial work was carried out by Adolf D. May, Gale Ahlborn and Fredrick L. Colins and is described in articles published in January 1968 Traffic Engineering magazine (7).

ICAP is a set of programs which perform intersection approach capacity analyses in accordance with the definitions and procedures of HRB Special Report No. 87, the 1965 HIGHWAY CAPACITY MANUAL.

The program is configured to operate on a microcomputing system with the following minimum capacities, features and characteristics.

1. Versions of the program are available for CP/M 80 MS-DOS and PC DOS operating systems.
2. CP/M systems require 64K of memory. MS-DOS and PC-DOS systems require a minimum of 128K of memory.
3. The programs are operable on systems with one or more disk drives. One disk drive systems require a minimum of 240K bytes of free space. Two disk drive systems require a minimum of 90K bytes of free space per disk.
4. An 80 column printer is required for the output.

The ICAP programs may be used to calculate combinations of service volume, approach width, load factor, or G/C ratio for signalized intersection approaches. The programs are interactive and menu driven. They are easy to use, require minimum input data, run very quickly and produce essentially identical results to HCM manual capacity analysis efforts.

The ICAP programs consist of two programs, ACAP and TCAP. The ACAP program permits analysis of intersection approaches, the TCAP program permits analysis of intersection turning lanes.

Both ACAP and TCAP include a user accessible '?' Help feature from the main MENU. The '?' Help text files may be customized by the user to include special procedures and instructions.

The ICAP programs operate in two stages, data entry and data processing. The data entry operation is used to prepare, edit and save data. The processing operation analyses prepared input and produces printed reports.

The basic relationship of the intersection capacity program used in ICAP is:

SV = f[(AVw.1f), (G/C), (POP,PHF), (LIM), (RT), (LT), (TF), (BF)]

where:

SV = Service volume in vehicles per hour.

(AVw.1f) = Approach volume in vehicle per hour of green based on approach width and load factor.

(G/C) = Green phase time to cycle time ratio.

(POP,PHF) = Adjustment factor based on metropolitan area size and peak hour factor.

(LIM) = Adjustment factor based on location in metropolitan area.

(RT) = Adjustment factor based on percent right turns.

(LT) = Adjustment factor based on percent left turns.

(TF) = Adjustment factor based on percent trucks through buses.

(BF) = Adjustment factor based on local buses and type bus stop.

After the truck factor is determined, the program proceeds to complete the capacity calculations. Processing is divided into four major parts depending upon the quantity to be determined, service volume, approach width, load factor or G/C ratio.

In calculating an approach width, the Peak Hour Factor, metropolitan area size and location in the metropolitan area are determined. The computer then selects a trial width assuming 10% left turns, 10% right turns and no bus stop. With the initially calculated width, the associated turn factors and bus factors are determined and a revised width is calculated. The iteration continues until:

1. Two consecutive widths are not significantly different;
2. It is established that the calculated width is outside of the Capacity manuals acceptable width range;
3. It is established that an oscillation between two specific width values has occurred; or
4. There are 15 iterations.

In calculating service volume or G/C ratio, direct solutions are possible. The Peak Hour Factor (PHF), metropolitan area size, location in metropolitan area, right turn, left turn, and bus factors are determined. The load factor is then calculated. One of three alternative output may result depending upon the calculated load factor value.

1. If the calculated value is between 0.00 and 1.00, then the load factor value constitutes the output.

2. If the load factor is greater than one there is basically no solution. If this situation occurs, the maximum service volume for a load factor of one is calculated, using the initially given width. The computed maximum values for width and service volume are provided in the output.
3. If the load factor is less than zero, additional calculations are made. If this occurs, the maximum service volume for a load factor of zero is calculated, using the initially given width; and the minimum width for a load factor of zero is calculated, using the initially given service volume. The computed service volume and minimum width are provided in the output.

INPUT - A summary tabulation of input values and range limits are provided in Table.

OUTPUT - The program output includes items describing:

1. Input,
2. Termination or modification statements,
3. Results, and
4. An optional summary tabulation.

All input data are repeated in the output. In the event that the program is terminated and no computations are made, the reasons for program termination are given.

SPECIAL FEATURES AND SHORTCOMINGS - ICAP has the following advantages:

1. It can calculate combinations of service volume, approach width, load factor, or G/C ratio for signalized intersection approaches.

2. The programs are interactive, and has a very good and easy editing capability.

3. ICAP has the capability of showing the directory of files.

ICAP has several shortcomings. These are:

1. It requires the printer to be turned on while it is running, or else the program will automatically terminate the session.

2. It utilizes the 1965 HCM, the 1985 HCM makes this program obsolete.

3. It is supposed to run successfully without inputting G/C. This is not possible within TCAP.

4. The logic of creating two separate files (namely ACAP and TCAP) is considered a poor design because the G/C allocation within ACAP does not capture the turning volume. In other words, the user has to combine the left turning G/C value with the through G/C value.

TABLE 2 DATA INPUT SUMMARY OF ICAP

ITEM	DESCRIPTION	VALUE RANGE
1.	TITLE	------------------
2.	SERVICE VOLUME	0000. TO 9999.
3.	APPROACH WIDTH	10.(1) TO 60.
4.	LOAD FACTOR	0.00 TO 1.00
5.	G/C RATIO	.000 TO .999(2)
6.	PEAK HOUR FACTOR	0.70 TO 1.00
7.	LOCAL ADJUST. FACTOR	0.00 TO 9.99
8.	POPULATION	0001 TO 9999
9.	TYPE OF APPROACH	1 TO 6
10.	TYPE BUS STOP	0 TO 4
11.	LOCATION IN METRO AREA	1 TO 4
12.	NUMBER OF LOCAL BUSES	000. TO 120.
13.	PERCENT RIGHT TURNS	00. TO 99.
14.	PERCENT LEFT TURNS	00. TO 99.
15.	PERCENT TRUCKS	00. TO 50.
16.	CYCLE LENGTH	40. TO 180.
17.	NUMBER OF LANES	0. TO 2.
18.	OPPOSING TRAFFIC	0. TO 999.

(1) Lower boundary depends upon type of approach.
(2) Special Value, can have format of x.xx if coded ''1.00.''

INTERCALC

PROGRAM DESCRIPTIONS - INTERCALC is an interactive program which considers intersection geometry, traffic volumes and traffic signal operation in the determination of isolated intersection performance based upon analytical research performed by Dr. F. V. Webster of the TRRL and upon recent FHWA sponsored research (8).

INTERCALC analyzes the performance at proposed or existing isolated signalized intersections and expresses the results of a given set of traffic and signal conditions in various traffic engineering Measures of Effectiveness terms.

INTERCALC operates on microcomputing systems with the following capacities, features and characteristics:

1. Versions of the program are available for the CP/M 80, MS-DOS and PC-DOS operating systems.
2. CP/M systems require 64K of memory. MS-DOS and PC-DOS systems require a minimum of 128K of memory.
3. The program is operable on systems with one or more disk drives. One disk drive systems require a minimum of 240K bytes of free space. Two disk drive systems require a minimum of 90K bytes of free space per disk.
4. An 80 column printer is required.

INPUT - The following input data are required to run INTERCALC:

1) Intersection name and date.
2) Desired cycle length in seconds.
3) The amount of traffic in vehicles per hour assigned to the particular signal phase movement. Traffic volumes must be adjusted

prior to entry, to reflect conditions such as percent of trucks. Traffic volumes are entered only for traffic movements with separate signal phases.

4) Capacity or Saturation Flow is the number of vehicles which can enter the intersection in one hour under saturated flow conditions for a continuous green display for the sum of all approach lanes.
5) The total minimum time for a phase including Green plus Yellow plus All Red or Walk plus Don't Walk plus all Red as appropriate.
6) The time lost to vehicle movement for each single phase which occurs at the beginning of each green display.
7) The speed at which vehicles approach the intersection under non-congested conditions during periods when the traffic signal is displaying a green indication in the direction of traffic flow.
8) The signal phasing possibilities.

OUTPUT - Intercalc calculates the following items:

1) The interval number in which the signal phase display first occurs.
2) The split time for the intersection is calculated based on the entered traffic parameters and the selected cycle length. The split calculation attempts to balance the degree of saturation on critical approaches to the intersection by adding time to critical movements and subtracting time from non-critical movements, limited by the phase minimum time requirement.
3) The split percent is the split time expressed as a percent of the total cycle.

4) The degree of saturation is a ratio indicating the level of saturation occurring at the approach for the given traffic parameters and cycle length. The ratio is calculated as:

(Volume X Cycle)/(Saturation Flow X (Split time - Lost Time)).

5) The average delay per vehicle in seconds is a calculated measure of intersection performance. The calculation is based upon a modified version for the Webster equation. The delay results are valid for conditions where the degree of saturation is less than 95 percent.

6) The average number of times a vehicle will stop on the intersection approach.

7) The average number of vehicles in a waiting queue for a single lane approach to the intersection when the signal changes from red to green.

8) The probability of clearing the queue of waiting vehicles on each intersection approach. This value is calculated using the Miller equation from the PASSER II-80 program.

9) EX. (EXCESS) FUEL, CO, HC, NOX values in gallons per vehicle and grams per vehicle respectively represent the item quantity in EXCESS of the amount which would be consumed or produced if the control situation did not exist. These values are calculated using the equation and factor values determined by a previous study conducted for the FHWA.

10) The degree of saturation of the most saturated approach at the intersection.

11) The total delay per hour at the intersection, in vehicle hours.

12) The LEVEL OF SERVICE is calculate based on the following Measures of Effectiveness:

a) Total intersection delay,

b) Degree of saturation, and

c) Probability of queue clearance.

The ranges are shown in Table 3.

13) The total stops per hour for all vehicles.

14) TOTAL EXCESS FUEL, CO, HC AND NOX values in gallons and kilograms respectively represent the total item quantity per hour in EXCESS of the amount which would be consumed or produced if the control situation did not exist.

15) Interval diagram illustrating the order of signal displays as they occur in a complete signal cycle. The values are shown in percent of the cycle.

SPECIAL FEATURES AND SHORTCOMINGS - INTERCALC contains the following highlights:

1) It is a menu driven interactive program. It is easy to use, requires minimum input data and produces an effective set of output results. A special feature of the program allows INTERCALC to extract data for an intersection from PASSER II-80 input file.

2) INTERCALC is a computerization of traffic engineering procedures which allows the engineer to perform detailed isolated intersection signal operation analyses considering selection of optimum phasing patterns, geometric changes, left turn phasing, selection of operating strategies and development of detailed traffic signal timing.

Table 3
Delay, Degree of Saturation, and Queue Clearance Logics of INTERCALC

Source (BATHER BELROSE BOJE MICROCOMPUTER PROGRAM USER GUIDE)

DELAY (SEC/VEH)
SOURCE: PASSER II-80

COMMENT: INTERCALC uses the INDIVIDUAL MOVEMENT scale of DELAY values to determine the approach and intersection LOS.

TOTAL INTERSECTION DELAY (Note 1)	INDIVIDUAL MOVEMENT DELAY (Note 2)	LEVEL OF SERVICE
Less than or equal to 16	Less than or equal to 15	A
Less than or equal to 22	Less than or equal to 30	B
Less than or equal to 28	Less than or equal to 45	C
Less than or equal to 35	Less than or equal to 60	D
Less than or equal to 40	Less than or equal to 100	E
Greater than 40	Greater than 100	F

Note 1. From Highway Capacity Manual Interim Guidelines Jan. 1980.
Note 2. From field studies during HPR Study 203 1975.

DEGREE OF SATURATION
SOURCE: PASSER II-80

COMMENT: INTERCALC produces and reports this value and uses the value in the determination of split but does not use the value to report LOS.

DEGREE OF SATURATION	LEVEL OF SERVICE
Less than or equal to 0.60	A
Less than or equal to 0.70	B
Less than or equal to 0.80	C
Less than or equal to 0.85	D
Less than or equal to 1.00	E
Greater than 1.00	

QUEUE CLEARANCE PROBABILITY
SOURCE: PASSER II-80, Miller's Queue Clearance equation.

COMMENT: INTERCALC produces and reports this value as a Measure of Effectiveness but does not use the value to report LOS.

PROBABILITY OF QUEUE CLEARANCE	LEVEL OF SERVICE
Greater than or equal to 0.95	A
Greater than or equal to 0.90	B
Greater than or equal to 0.75	C
Greater than or equal to 0.50	D
Less than 0.49	F

3) Data inputs are similar to PASSER II-80 and it can extract data for an intersection from a PASSER input file.

4) INTERCALC includes a user accessible ''?'' HELP feature from the main MENU. The ''?'' Help text file may be customized by the user to include special procedures and instructions.

5) The phasing possibilities included with INTERCALC are designed to be consistent with PASSER phase designation with several enhancements. Phase references are made using graphical representation rather than either by PASSER phase numbering or NEMA phase numbering. This procedure was selected to minimize the complexity of the phase selection process. Phasing is selected interactively using a set of phase selection screens.

6) It has the capability of showing the list of data files.

The main shortcomings are:

1) INTERCALC requires calculation of saturation flow rate for each approach.

2) It is limited to traffic flow conditions below saturation.

SCA

PROGRAM DESCRIPTION - Signalized Capacity Analysis (SCA) is a spreadsheet program for use with Lotus 123 that incorporates the worksheet calculations contained in Chapter 9 of the 1985 Highway Capacity Manual (9). It is arranged in six sections to look and function much like the worksheets supplied in the capacity manual. To run SCA, the user needs a copy of Lotus 1-2-3 version 1A, an IBM compatible system with at least 256K memory, a double sided disk drive, and an Epson compatible printer to print the output.

INPUT - Once the program is loaded, a help menu is displayed at the top of the screen containing the following functions:

- Input : to input or change data
- GoTo : to move to a specific worksheet
- Header: to input or change header information
- Cycle : to change the signal cycle parameters
- Print : print one or all worksheets
- Save : to save a worksheet
- Recall: to recall a worksheet
- Quit : to Quit SCA

Two tables are provided for ''Input;'' one is related to roadway descriptions and the second is related to traffic.

The input parameters needed for the first table by lane groupings are as follow:

- Grade
- Percentage Heavy vehicles

- Parking data
- PHF
- Pedestrian data

The data inputted to the second table are:

- Movement volumes
- Number of lanes
- Green time
- Proportion of left turn
- Proportion of right turn
- Lane width
- Permitted and protected left turn options

OUTPUT – The program produces six worksheets, and they are:

1) General Information Worksheet
2) Volume Adjustment Worksheet
3) Left Turn Adjustment Worksheet
4) Saturation Flow Adjustment Worksheet
5) Capacity Analysis Worksheet
6) Level of service worksheet

These worksheets are identical to the worksheets listed in the capacity manual.

PROGRAM HIGHLIGHTS AND SHORTCOMINGS – SCA provides a capacity analysis of signalized intersections using the 1985 HCM. It produces worksheets identical to the ones documented in the capacity manual, which makes it easy for the user to cross check the procedure and the results. The use of spreadsheet concept permits observation of calculations update on the screen.

SCA has some shortcomings and they are:

1. The user has to have a Lotus 123 program to run the program.
2. The documentation of the program needs major improvements.
3. Changes to the original program may be made unintentionally by a user who is not experienced with spreadsheet.
4. The program asks for proportion of right turns and left turns in percent, yet it has to be inputted in fractional form.

SIAP & FREESIAP

PROGRAM DESCRIPTION - SIAP, the Signalized Intersection Analysis Program, is functionally similar, but more powerful than FHWA's SOAP84 program. SIAP allows a rapid evaluation of an existing or alternative signal timing control plan for an isolated intersection (10). SIAP can select cycle length, green splits, and dial assignments for up to 48 time periods. There are 196 possible phase sequence combinations that can be evaluated. Both permissive and restrictive left turn treatments can be analyzed. As compared to FHWA's SOAP84, SIAP permits partial control over the green split optimization search to favor a particular street and/or specifying a targeted limit on the maximum degree of saturation allowed. In addition, approach speeds varying from 30 to 50 mph can be entered and affect left turn saturation flow rates and excess fuel consumption.

FREESIAP provides a number of powerful commands to ease the task of SIAP input data preparation. The most important of these is the HELP command. The HELP command gives access to FREESIAP's input prompts for any SIAP card type or FREESIAP's other commands. The commands allow listing of files to screen or printer; modify an individual line; perform a replace, delete or insert edit command; show more detailed information about some of the SIAP cards or terminology; save the free and/or fix format files to disk; and stop or restart FREESIAP. Commands may be executed at any time. Some commands permit exiting the command simply by entering a RETURN.

INPUT - The required order of SIAP input data is relatively simple because input data processing is controlled by the SIAP card type name.

BEGIN. . . . .

```
  *
  *
  SIAP data specifications
  *
  *
RUN
  * ----------------------------------|
  *                                   |
  *                                   |
  alternative data specifications    }  repeatable option
  *                                   |
  *                                   |
RUN ----------------------------------|
COMPARE        (Optional)
END
```

Once a SIAP card has been read, the contents of the card will remain in effect until over-ridden by another SIAP card of the same type, thereby permitting alternative analyses with minimal data input.

When FREESIAP prompts for data or command, simply enter the card type name and data field in free format. The rules for entering SIAP data in free format follow:

1. Enter the SIAP card type name followed by the data field separated by commas.
2. If a data field is skipped, be sure to use a comma in its place.
3. After any given data field, all remaining data fields may be skipped if defaults are acceptable to you.

4. Blanks are not ignored.

5. Do not use commas in comment fields.

FREESIAP detects a wide range of user input errors and responds in a forgiving manner by providing the correct format or specifying what was incorrect and then displays the standard enter data or command prompt. Furthermore, FREESIAP contains an Intraline Editor which is entered with the MODIFY command.

SIAP input data and commands are listed below with a short description of their functions.

- BEGIN - initializes program and global parameters
- CAPACTIY - enters the number of lanes or saturation flow
- CASE - enters title used in conjunction with COMPARE
- CHECK - activates syntex checking only
- COMMENT - documenting or describing input data
- COMPARE - activates comparison for runs with the CASE card
- CONTROL - specify operating parameters for controller
- DENSE - changes internal line counter for 8 lines per inch printers. Affects plots only.
- END - terminate the execution of SIAP
- GROWTH - enters growth factors for traffic volumes
- HEADWAY - specifies saturation headway for each movements
- LEFT - specifies left turns on clearance interval and left turn treatments
- MAXX - targetted maximum degree of saturation used in the green split optimization procedure for pretimed control only
- MIN

  MINNS

MINEW

MINOFF - controls green split optimization in coordination with MAXX for pretimed control only

- MINGREEN - specifies minimum green time by movements
- NOTIMING - cancels preceding TIMING card(s) and allows optimization occur
- NOWARN - suppresses most but not all warning messages
- OPTION - activates or deactivates options. There are currently two options:

  Option1: prints intermediate results of green split optimal search

  Option2: prints intermediate results of cycle length optimization search
- PLOTOFF - requests (or turns off) SIAP printer plots
- RUN - initiates SIAP analysis or optimization for currently defined conditions
- SEQUENCE - specifies phasing sequences
- TABLES - request tables to be printed
- TIMING - specifies timing and phase sequences for an evaluation
- TRUCK - specifies percentage of trucks and or buses
- VOLUME - specifies traffic volumes by movement
- GRNSPLIT - SIAP initially performs a green split based on the critical movement analysis technique. SIAP then begins a green split optimization procedure controlled by user specified options such as MIN, MINNS, and MINEW and the relationship between MAXX and BIGX.

  MAXX = targetted maximum degree of saturation

BIGX = the largest degree of saturation for any movement

- WARN - reverses the effect of NOWARN card

OUTPUT - Included on the floppy diskette are two batch files and their corresponding data files for easily controlling compressed (17 characters per inch) and normal (10 characters per inch) printing.

SIAP output consists of input echoes; various tables if requested; a left turn capacity check; an overall measures of effectiveness (MOE's) summary; time period specific MOE's summary; plots of saturation and delay versus time; and a case comparison if requested. MOE's printed include delay, stops, excess fuel consumption due to stops and accelerations, excess lefts greater than capacity, and maximum queue.

SPECIAL FEATURES AND SHORTCOMINGS - SIAP FREESIAP has the advantage of doing multiple runs. It has the graphic capability of showing the phasing patterns, minimum degree of saturation, average delay, and cycle length. It also is capable of comparing different runs within a simple table form.

SIAP evaluates actuated signal control, however, maximum green time and unit extension are not considered. Cycle lengths and green splits are estimated for average values. By the nature of their design, actuated signals, in general, result in high degree of saturation for the critical movements at both low and high volumes. Most delay equations contain a term for estimating random (and possibly over-saturation) delay. At high degrees of saturation and low volumes, these random delay terms greatly over-estimate delay. A very rough correction for this problem has been added to SIAP for actuated control. This over-estimate may also occur for pretimed control, but only under unusual conditions. Again by their design, actuated signal control results in left turn capacities slightly greater than demand with restrictive left turn treatments unless constrained by maximum green time settings and general intersection over-capacity. For a rough estimate of approach capacity, the user is advised to set minimum cycle time equal to maximum cycle. ''Warning,'' SIAP's and SOAP's signal timing and delay estimation for phasing sequence T (single phase) under actuated control may produce unexpected values due to the complexity of modeling left turn and opposing through traffic conflicts with an actuated signal design. The user is advised to use judgment in evaluating the SIAP output for phase sequence T under actuated signal control.

SICA

PROGRAM DESCRIPTION - SICA is an acronym for Signalized Intersection Capacity Analysis. This computer program was developed for the IBM PC and ''IBM compatible'' microcomputers. The program is written in Microsoft Advanced Basic (11). SICA is intended for use by traffic engineers who are analyzing signalized intersections to determine average stopped delay per vehicle and level of service.

This program is a computerized reproduction of the methodology adopted as Chapter 9 of the 1985 edition of the Highway Capacity Manual (HCM). The program neither changes nor modifies in any way the procedure or parameters used in the HCM methods. While it is expected that an experienced traffic engineer could use this program and interpret the results without knowing the details of the HCM procedure, it is strongly recommended that program users thoroughly familiarize themselves with the HCM.

INPUT -

1) Descriptive Information
2) Turning Movement Volumes per approach
3) Pedestrian Volumes per approach
4) Arrival Type per approach
5) Peak Hour Factor per approach
6) Percent Heavy Vehicles per approach
7) Number of Buses per approach
8) Percent Grade per approach
9) Number of Lanes per approach
10) Lane Group Configuration and Geometrics
11) Parking Information

12) Signal Information including Signal Type and Cycle Length, and

13) Signal Timings for each existent lane group

OUTPUT - The printed output consists of three pages.

The first page provides a copy of all the input data for reference purposes, especially useful for analyzing the same intersection under a variety of conditions.

The second page gives the results of the analysis in terms of the v/c ratio, average stopped delay, and level of service for each lane group; delay and level of service for each approach; and delay and level of service for the intersection as a whole.

The third page provides an additional output information per lane group per approach. These are:

- Adjusted Flow (V)
- Proportion Left Turns (PLT)
- Proportion Right Turns (PRT)
- Adj. Saturation Flow Rate (S)
- Flow Ratio (V/S)
- Green/Cycle Ratio (G/C)
- Lane Group Capacity (C)
- Volume/Capacity Ratio (X)

SPECIAL FEATURES AND SHORTCOMINGS - The following special features are built within this program:

1) The default values provided by the HCM for Pedestrian flow, percent heavy vehicles, peak hour factor, grade, number of buses, number of

parking maneuvers, and arrival type can be used by the program without inputting the data.

2) The program uses the Lane Group Configuration Type shown in Table 4.

3) When the V/C ratio for a given lane group is greater than 1.2, the output form will not show a delay; rather, the lane group, approach, and intersection will be labelled OVERSATURATED. The V/C ratio is printed out so that the analyst can see the degree of oversaturation.

4) It can handle pre-timed, fully actuated, and semi-actuated signals.

SICA has the following shortcomings:

1) It has poor diagnostic messages.

2) It requires the percent trucks in decimal, for example 5 percent trucks should be inputted as 0.05. If the user inputs 5 it will treat it as 500 percent and it will not detect this error.

3) It is not clear whether green time per lane group includes yellow or not.

Table 4 LANE GROUP CONFIGURATION TYPES OF SICA

LEFT TURNS TYPE #	LANE GROUP DESCRIPTION	RIGHT TURNS TYPE #
1	EXCLUSIVE TURN LANE PROTECTED PHASING	9
2	EXCLUSIVE TURN LANE PERMITTED PHASING	10
3	EXCLUSIVE TURN LANE PROTECTED + PERMITTED PHASING	11
4	SHARED TURN + THROUGH LANE PROTECTED PHASING	12
5	SHARED TURN + THROUGH LANE PERMITTED PHASING	13
6	SHARED TURN + THROUGH LANE PROTECTED + PERMITTED PHASING	14
7	SINGLE LANE GROUP APPROACH	7
8	DOUBLE EXCLUSIVE TURN LANE PROTECTED PHASING	16

SIGNAL

PROGRAM DESCRIPTIONS – Barton-Aschman Associates, Inc. has developed a package of traffic engineering and related programs which provide quick, accurate and consistent analysis results of traffic and transportation-related engineering problems. These programs are known collectively as TEAPAC which is an acronym for Traffic Engineering Application PACKage. One of the programs in the package is called SIGNAL (12). SIGNAL analyzes individual intersection control needs based upon approach capacity, lane usage, pedestrian and clearance constraints, and multi-phase signal control. The methodology uses the capacity analysis procedures documented in the 1965 HRB Highway Capacity Manual. The user of the program can analyze existing conditions and timings as well as generate optimum signal timings and phasings. The optimizer in the program seeks to establish the least number of phases of control at the best attainable level of service for a given cycle length.

This interactive analysis tool is particularly useful in developing individual intersection control strategies, controller requirements and required timings since an entire day's variation in volumes can be analyzed quickly and accurately. Two-phase, three-phase, multi-phase, and split-phase control strategies are considered, with the ''best'' phasing being identified for each set of input data and operational constraints, such as the acceptable range of cycles. The user can easily scan the output and quickly determine which phasing will handle an adverse situation most efficiently.

Further, this analysis quickly identifies capacity problems and points directly to the cause of the problem. At this point, solutions can be generated to solve the problem in terms of more sophisticated control strategies, revised lane usage, improved roadway geometrics, or any combination of the above. The results of this analysis will provide valuable timing data related to local control which otherwise would be very time consuming to obtain by conventional hand analysis.

The output is presented to allow the engineer to quickly determine the problem movements at an intersection. Data concerning the level of service of each approach traffic lane are given. The amount of available green time used, and the maximum queue length is also given. Alternative solutions can be quickly and easily tried helping to optimize the solution in a relatively short time.

It is suggested that a companion document, the TEAPAC TUTORIAL, be read first, before reading the user manual. The TEAPAC TUTORIAL introduces the user to the basic commands of the TEAPAC control language and gives instruction on its use. Familiarity with the TEAPAC control language will greatly aid the user in learning the commands unique to SIGNAL, since they are used in the same way and share the same basic format.

INPUT - Almost all of the input parameters have defaults which eliminate the need to enter data for every parameter. These defaults are logical and may be seen for any or all commands with the use of the HELP command. However, there remains two commands for which it is necessary to input data. These are the VOLUMES and WIDTHS commands. The remaining input data commands will be grouped by their subject areas which include movement, approach, intersection and analysis. Through the use of these commands, almost any intersection may be specified quickly in a simple, straightforward manner.

Intersection/Area-wide parameters - There are five commands which refer to factors of the intersection as a whole and the area-characteristics around the intersection. These commands are METROAREA, POPULATION, TYPE, PEDTIME and NETWORK.

Approach-Specific Parameters - The next set of commands refer to the three or four approaches to the intersection. These commands are PEAKHOURFACTORS, PARKINGSIDES, BUSVOLUMES, BUSSTOPS, PEDLEVELS, and PERMISSIVES.

Movement-Specific Parameters - VOLUMES and WIDTHS are two of the movement-specific parameters. Five other commands are also movement specific. These commands are LANES, CHANNELIZATIONS, TRUCKPERCENTS, REQCLEARANCES, and MINIMUMS.

Analysis factors - All the analysis factor commands relate to the timings and phase settings for the intersection. Often these commands are used to override settings of parameters which other operations have set. These commands are GREENTIMES, YELLOWTIMES, CRITICAL, OFFSET, LEADLAGS, and PHASEMOVEMENTS.

OUTPUT - The major output reports provided by the SIGNAL program are listed below along with their calculated Measures Of Effectiveness:

1) Summary of Parameter Values,
2) Capacity Analysis,
   a) Level of Service, and
   b) Maximum Queue.
3) Evaluation of Intersection Performance,

a) Level of Service,

b) Degree of Saturation,

c) Average Delay,

d) Total Delay,

e) Number Stopped,

f) Average Queue, and

g) Maximum Queue.

4) Service volumes,

5) Required G/C's,

6) Successful Sequences,

a) Level of Service.

7) Sorted Sequences,

a) Level of Service.

8) Optimum Timings,

9) Sequence Phase Diagram, and

10) Map of Design Hour Volumes.

SPECIAL FEATURES AND SHORTCOMINGS - The program is able to handle the following:

1) SIGNAL is able to calculate the optimum splits and phasing for a given cycle length.

2) It is capable of drawing Sequence Phase Diagram and Map of Design Hour Volumes.

3) It can generate a clear and useful summary of the data inputted by the user and the default values.

4) It can provide a capacity analysis summary for the intersection and all individual approaches of intersection.

5) It is able to report on a number of performance measures for each traffic stream, as well as the roadway conditions and capacities of each stream.

6) It can calculate the service volumes which are available in each traffic stream at each level of service of operation.

7) It can test every available phasing at a specified cycle length in an attempt to make phasing work at the highest level of service.

8) It enables the user to identify the needed parameters using the ''HELP'' command.

The following shortcomings were observed within this software:

1) In spite of the ability of the software to do so many different types of analysis and evaluation, the program is not very user friendly.

2) The documentation is not clear.

3) It takes time to master the software.

4) It requires capital letters.

5) According to the manual, the program is supposed to be able to choose optimum cycles, however it doesn't have that capability.

6) It utilizes 1965 HCM, the 1985 HCM makes this program obsolete.

SIGNAL85

PROGRAM DESCRIPTION - SIGNAL85, the 1985 Highway Capacity Manual software for signalized intersections is one of the programs available in TEAPAC from Barton-Aschman Associates, Inc. (13).

The purpose of SIGNAL85 is to analyze individual signalized intersections in terms of capacity adequacy for a given set of approach volumes. Factors such as approach width, signal phasing, signal timing, cycle length, pedestrian walk time constraints, controller requirements and many other constraints are all considered in the analysis.

SIGNAL85 can be used to analyze a pre-determined condition or calculate new and optimum timings given a set of constraints. The program can also automatically select an optimum timing and produce an analysis of it.

It is suggested that a companion document, the TEAPAC TUTORIAL, be read first, before reading the signal document. Familiarity with the TEAPAC control language will greatly aid the user in learning the commands unique to SIGNAL85, since they are used in the same way and share the same basic format.

INPUT - The required data to analyze the intersection capacity by approach are divided to the following groups of parameters.

Intersection Parameters

Includes the location within the metropolitan area, population of the metropolitan area in thousands, intersection type, and time allocated to any exclusive pedestrian phases.

Approach Parameters

These parameters include peak-hour factors, parking conditions on each leg of the intersection, pedestrian interference levels for right turns on each approach, and control status of left turns on a green ball following an exclusive phase (permissive left condition). Local bus frequency and stop information is also included.

Movement Parameters

Traffic volumes and truck percentages for the 12 possible movements in the intersection, lane width and usage data for each movement; also, channelizations for turning lanes, minimum timings for green indications and clearance intervals are included within this category.

Analysis Parameters

Timings for each phase (green times and clearance interval times), and critical movements for each phase are inputted within this category.

Design Parameters

Design level of service identifies the desirable operation level, the allowable range of cycle checking, the phasing sequence, and excess data (specifies how any excess green time is assigned to the phasing during the design procedure) are inputted in this section.

OUTPUT - The major output reports provided by the SIGNAL85 program are listed below:

1. **Summary of Parameter Values** - The intersection capacity parameter summary which is a compilation of data pertinent to analyzing intersection capacity by approach are summarized here using the SUMMARISE command.

2. **Capacity Analysis** - The intersection Capacity Analysis report, generated primarily by the ANALYZE command, provides a capacity analysis summary for the intersection and all individual approaches of the intersection.

3. **Evaluation of Intersection Performance** - The evaluation of intersection performance generated by the EVALUATE command is a report designed to summarize a number of performance measures for each traffic stream. The emphasis is more on the estimated level of each stream's performance, rather than on the parameters which were used to calculate the level, as in the case of the capacity analysis worksheet.

4. **Service Volumes** - The Service Volumes report calculates the service volumes which are available in each traffic stream at each level of service of operation. The service volumes are given in vehicles per hour of green, making the assumption that the G/C allocated to the movement is 100 percent. This procedure identifies the maximum service volumes which can be obtained from each traffic stream.

5. **Required G/C's** - The Required G/C's report generated by the GOVERCS command, identifies the green to cycle time ratios which are required by the demand volumes in each traffic stream to maintain each level of service of operation. Thus, if a given movement were to receive exactly the G/C shown for a level of service, that movement would operate at exactly that level of service.

6. **Successful Sequences** - While the program is proceeding with the operational design of each of the specified phasings, the Successful Sequences report is produced by the DESIGN command to inform the user of the progress of the design. Each phasing is tested at all specified cycle lengths in an attempt to make the phasing work at the highest level of service. The first time a phasing is successfully designed at a given level of service, the phasing code is printed along with the level of service, the G/C + Y/C represents the proportion of the cycle which is required to make the critical movements operate at exactly the specified level of service; therefore, the lower the G/C + Y/C required, the more probable is a successful operation of the sequence.

7. **Sorted Sequences** - The Sorted Sequences report generated by the SORT command, provides a valuable tool which can be used in making phasing selections and cycle selection. This report is also an optional output of the DESIGN command. The sorted order reflects a very basic way of identifying which phasings have the highest probability of being successful--those with the lowest overall requirement of cycle time at the best level of service. This is the order in which the sequences are sorted.

8. **Optimum Timings** - The Optimum Timings report generated by the TIMINGS command provides a list of the G/C + Y/C phase times which are required by the critical movements to maintain operation at the designed level of service. These phase times are shown in seconds per second for the cycle length shown and are totalled in the last line. The required phase times are then adjusted so that the total G/C + Y/C equals 1.000 by allocating excess time to the defined priority movements.

9. Sequence Phase Diagram - This diagram, generated by the DIAGRAM command, provides a graphical interpretation of a specified phase sequence code number. This diagram is also an integral part of the output for the ANALYZE and EVALUATE commands, and is an optional output of the TIMINGS commands. Each phase is designated by a square box with arrows inside indicating the movements which are allowed during that phase.

10. Map of Design Hour Volumes - The Map of Design Hour Volumes generated by the MAP command, provides a worksheet document which shows the relative positions of the 12 turning movement volumes on a schematic diagram of the intersection. In addition to the 12 turning movement volumes, the diagram displays the total volumes of traffic entering and exiting the intersection on each leg.

SPECIAL FEATURES AND SHORTCOMINGS - The output is presented in a way that allows the engineer to quickly determine the problem movements at an intersection. Data concerning the level of service of each approach lane is given. The amount of available green time used, and the maximum queue length is also given. Alternative solutions can be quickly and easily tried, helping to optimize the solution in a short time.

SIGNAL85 has adapted the new Highway Capacity Manual 1985 methodology and is able to do different types of analyses.

According to the user manual the next version of the program will be able to calculate the Optimum Cycle length from a given range using the Webster Delay Model.

One of the few shortcomings with this software is the documentation. It is the old SIGNAL documentation, and it takes a long time to master the software. Furthermore, the program is so structured that a new user would feel that the program is unfriendly, and that a relatively long training period is needed to utilize its fullest potential.

SOAP 84

The Florida Department of Transportation and Federal Highway Administration have recently developed a computer model that provides a valuable tool for examining a wide range of intersection signal design alternatives and selecting the best alternative.

SOAP, which is an acronym for Signal Operations Analysis Package, is a traffic signal controller optimizing tool which enables the user to design the signal timing for any three or four legged intersection. SOAP will determine the optimal cycle length, phasing pattern and left-turn configuration for isolated intersections. The user may preselect any of the design parameters if he chooses, or allow SOAP to determine them by an optimization algorithm. SOAP can analyze present timing as well. Since the model has this dual capability--design and analysis--it can be used as an evaluation tool to compare the relative effectiveness of alternative control strategies (14).

MODEL DESCRIPTION

The Signal Operations Analysis Package (SOAP) was designed and written by the University of Florida Transportation Research center. The program was written in Fortran IV on an IBM 370/165 computer system. The program consists of over 11,000 card images. Almost one half of these are actual Fortran code with the remaining lines used for Program documentation.

This program requires 202K bytes of computer memory. During the development phase the program has been run using IBM FORTRAN G, H-extended and WATFIV compilers. A version is also available for Burroughs computers. The current program is a stable and reliable version and should be free of errors. The program should be ready to run on most IBM systems with some changes required for other systems.

Execution time will vary considerably depending upon the time periods, type of control and use of progression analysis features. Typically, on the IBM 370/165, an execution time of two or three seconds may be required. More detailed information of the model program is found in the Programmer's Manual.

INPUT REQUIREMENTS

The developers of the model have provided a program which can be run with only the normal information gathered by typical traffic engineering agencies. Provisions have been made for the user to modify the default values built into the program to reflect local conditions.

A standardized format for all input data is used to simplify the coding as much as possible.

There are three types of inputs which are required. These are:

Type 1 - Instruction cards which tell SOAP what to do,

Type 2 - Parameter cards which tell SOAP how to do it; and

Type 3 - Data cards which supply the input variables for the intersection under study.

Data may be coded and submitted to the computer as a single run or for multiple runs.

SOAP input data may consist of an original data deck for a given intersection with multiple runs for evaluating alternatives. In addition, multiple intersections, or problems, may be included at the user's discretion.

Instruction Cards

It was noted earlier that multiple runs can be accommodated by SOAP. This does not mean that data requirements become overly burdensome. There are three levels of a complete execution:

1. A ''job'' which is the complete execution
2. Problems, which are completely separate and independent analyses, but stacked for convenience to avoid multiple job executions; separated by BEGIN cards; and
3. Runs within a problem separated by RUN cards

The key instruction cards are thus the BEGIN, RUN and END cards. The BEGIN card clears all data arrays and commences a completely new problem. When a RUN card is encountered, SOAP begins execution and outputs all reports requested prior to the RUN card. It then looks for either another BEGIN card (to start a new problem), a COMPARE card (to insure that the previous run is included in the comparison) or an END card to terminate execution. If none of these is encountered (including the card following a COMPARE card) SOAP will begin to accept changes to the current data in preparation for the next run.

Parameter Cards

The parameter cards follow a BEGIN card. These four cards (PATTERN, LEFTURN, CONTROL, and LINK) establish the signal patterns, left turn sequence, the controller dial settings, cycle lengths and coordination data. All are optional and SOAP either has default values or will produce the parameters internally. Additionally, the EXISTING data card has parameters similar to the PATTERN card.

With multiple phasing and sequencing, there can be up to eight phases and these may be sequenced in many combinations, or patterns. To understand how to use the PATTERN, LEFTURN and EXISTING cards, it is necessary to know precisely how SOAP interprets several traffic engineering terms, specifically ''phase,'' ''pattern,'' and ''sequence.''

1. Phase is a unique green display which authorizes only certain movements to occur. Typical phases are shown in Figure 2.
2. Pattern is the combination of phases for the north-south (N-S) and east-west (E-W) directions. For example, in Figure 2, the N-S pattern consists of phases 1, 2, and 3, as indicated at the top of the figure.
3. Sequence is the complete phasing for the cycle, or phases 1-5 as shown at the top of Figure 2.

To simplify coding of the input cards, a standard terminology for describing phases was developed. The permitted movements are simply named according to their direction, as illustrated in Figure 2.

Data Cards

Eight data cards exist, but only two (VOLUME and CAPACITY) are required.

The VOLUME card is necessary to establish the traffic volumes for each of the eight movements. A separate card is necessary for each time interval where a volume change occurs. If data are missing for some intervals, the user has the option to allow the program to estimate the volumes by interpolation of values on each side of the vacant interval(s) or to omit the interval(s).

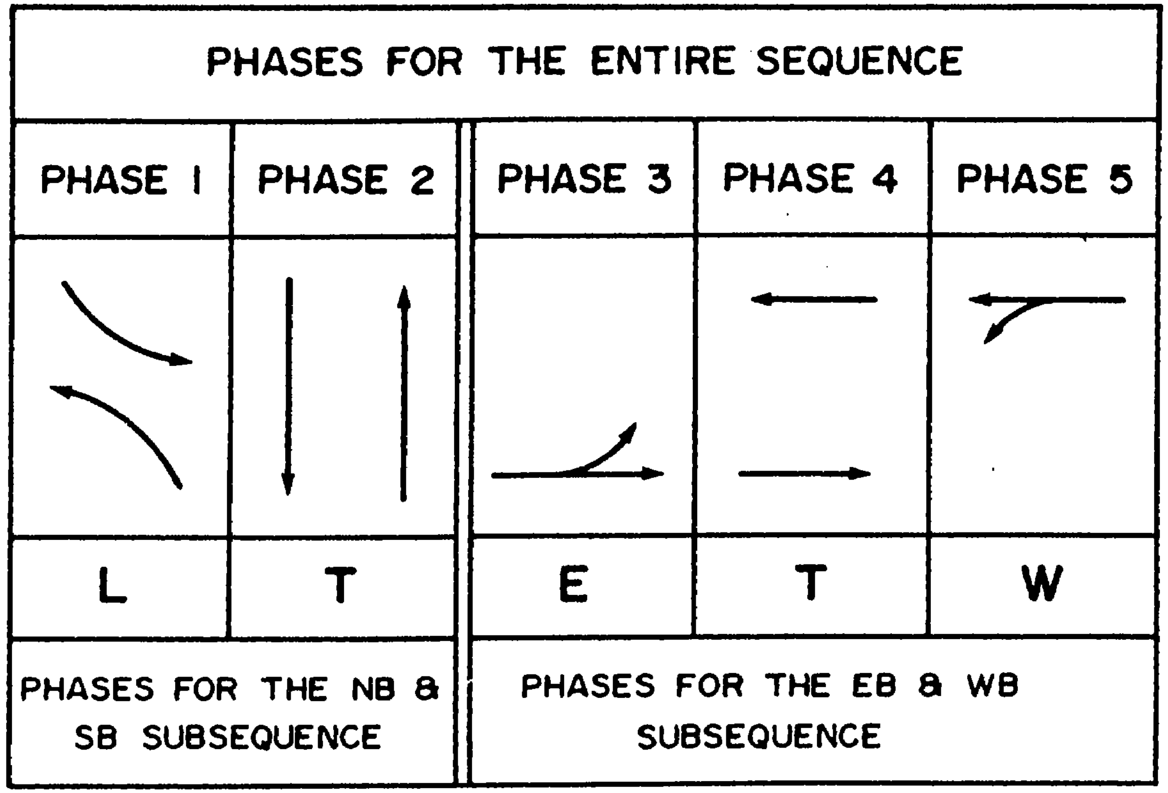

Figure 2 SOAP Phasing Code.

The CAPACITY Card establishes the (maximum) capacity, or saturation flow per hour of green time, given to each movement. However, the user has the option of coding the number of lanes and the saturation flows will be estimated using the departure headways provided in the HEADWAY Card. The number of lanes should be coded as a decimal number (e.g. 2.1) to permit the user to adjust saturation flows for narrow pavements and other restrictions.

Although the HEADWAY Card is optional, frequent users of SOAP will find it desirable to conduct headway studies for their area.

The EXISTING Card is optional but can be used to input existing signal timing.

The MINGREEN Card is also optional but should be used when minimum green times for pedestrian crossing are different than the default values. The default values are 10 seconds for protected left turns and 15 seconds for through movement for pretimed signals and zero seconds for actuated signals.

The traffic volumes can be adjusted to reflect trucks and buses by use of the TRUCKS Card. The program converts the percent of trucks and buses to equivalent passenger vehicles by multiplying by a factor 1.6.

The GROWTH Card can be used to update old data or to reflect projected changes in traffic volumes. The user can apply factors to each movement to reflect these changes.

OPERATIONAL SUMMARY

SOAP has three inherent functions, namely, design, analysis, and operations. To design signal timing it is necessary to configure the intersection and input the appropriate data. SOAP then produces all legitimate phasing patterns. It internally analyzes each pattern and selects the ones which can be executed using the minimum amount of green time.

The next step is dial assignment and timing. A typical controller provides three dials which allow up to three timing patterns to be implemented. SOAP can handle up to six such patterns. The user must decide how many patterns are to be used at a given intersection and assign them to the appropriate dial (control period). If any pattern is unassigned, SOAP will do so, based on the traffic demands. If actuated control is desired, no pattern assignments are made and SOAP makes its computations accordingly.

Cycle length is the most difficult design element to determine. This is a particularly complex problem when several control periods are to be designed. However, SOAP produces these quickly, based on the volumes, capacities and several other parameters. A trial and error optimization procedure is used to find the cycle length which produces the minimum total delay, subject to constraints which govern the amount of queueing which can be tolerated.

Analysis is accomplished by computing the various measures of effectiveness, MOE, which are:

- delay,
- stops,
- excess fuel consumption,
- degree of saturation, and
- left-turn conflicts.

This allows the user to quantify the effects of either the designed control strategy, or if desired, any explicit scheme he wishes to analyze.

Evaluation comes in the comparison of several alternative schemes. Comparisons can be produced by SOAP automatically or the user may make them off-line, manually.

COMPUTATIONAL ALGORITHMS

The MOE's produced by SOAP were identified above. The computational algorithms to compute these measures are discussed in the following paragraphs.

Delay is calculated using the well accepted Webster's method for unsaturated flow under fixed-timed operations. The Webster model has three components. The delay due to uniform arrivals is expressed as:

$$D_1 = \frac{C(1-\lambda)^2}{2(1-\lambda X)}$$

D_1 = delay due to uniform arrivals (sec/veh),

C = cycle length (sec),

λ = the proportion of green time given to the movement (effective green time / C), and

X = the degree of saturation of the movement (V/C).

The delay due to random arrivals, D_2, is,

$$D_2 = \frac{X^2}{2v(1-X)}$$

where v = volume (veh/sec) and the rest as shown above.

An adjustment factor, D_3, is,

$$D_3 = -0.65 \frac{C}{V^2}^{1/3}[X(2+5\lambda)]$$

which was developed empirically to provide a better mathematical fit to field studies. Webster's delay increases infinitely as the v/c ratio approaches 1.0; therefore Webster's formula is only practical to use up to v/c = 0.975. For high degrees of saturation, the modified Webster's delay model, used in the TRANSYT signal network design and analysis program, is also used in SOAP. In this delay model, the first term of Webster's model was retained, and the second and third terms were replaced by a single term of the form:

$$D_2 + D_3 = \left[\left(\frac{B_n}{B_d}\right)^2 + \frac{X^2}{B_d} \right]^{1/2} - \frac{B_n}{B_d}$$

where: $B_n = 2(1-X) + XZ$

$B_d = 4Z - Z^2$

$Z = (2X/v)*(60/T)$

v = approach volume in vehicle per hour

T = period length in minutes (usually 60 minutes)

For actuated control, no reliable delay model existed and this problem is extremely complex. The approach used in SOAP was to modify Webster's model. The actuated control strategy is assumed to:

a) Distribute the available green time in proportion to the demand on the critical approaches, and

b) To minimize ''wasted'' time by terminating each green interval as soon as the queue has been served.

This approximation simulates a ''well timed'' actuated controller. To achieve the results calculated by SOAP, it is therefore necessary to avoid excessively long initial and extension intervals.

The cycle length calculated by SOAP uses the Webster's method also. For fixed time operation the optimal cycle length, C_o, is,

$$C_o = \frac{1.5L + 5}{1-Y}$$

where: L = sum of all lost time due to starting and stopping critical movements, and

Y = overall degree of saturation (i.e. the proportion of green time required for the movement of traffic)

For actuated control the ''cycle length'' is the average cycle length which ensures all excess time is dissipated in the starting and stopping process, or 1 - Y. Therefore, the average cycle length, C_a, is simply 1.1L/(1-Y). In the low to moderate demand range, will always be lower than C_o and the difference is slack time necessary to provide for the stochastic variation in demand.

The proportion of vehicles required to stop, P_s, is equal to the number of vehicles joining the queue while it is still discharging, all divided by the number of arrivals per cycle, or:

$$P_s = \frac{rs}{c(s-v)}$$

where: r = length of red (sec.)

s = saturation flow during green (veh/sec) and the rest as before

Excess fuel consumption is computed from the percentage of stops as follows:

$$E_s = \alpha v P_s$$

where: E_s = gallons of fuel consumed due to stops (gal/hr)

α = fuel consumption rate (gal/stop)

v = volume (veh/hr), and

P_s = percent of stops

The excess fuel consumption due to delay, E_d, is:

$$E_d = \beta v d/3600$$

where: β = fuel consumption rate per veh-hr of idling

d = average vehicle delay (sec/veh)

and of course total consumption, E, is the sum of E_s and E_d. The Claffey data indicate that a reasonable value for idling fuel consumption is approximately 0.6 gallons per hour.

The v/c ratio is a reflection of the degree of saturation of the intersection. For an individual approach the degree of saturation, X, is found by:

$$X = \frac{V}{\lambda S} = \frac{V}{s}$$

as previously defined.

Left-turn conflicts occur when left turns are permissive, or not exclusively protected. The measure of effectiveness is the number of left turns which cannot be accommodated safely. Since protected left turns have no conflicts, none are computed. When the turning vehicles may cross traffic there must be sufficient gaps in the oncoming traffic. Based on data derived from simulation using the NETSIM model, curves that relate opposing volume to left turn saturation rate were developed and they are used by SOAP 84. The left turn saturation flow rate is described by the following two conditions:

1. Single lane opposing flow:

$$S_L = 1404 - 1.632\ V_o + 0.0008347\ V_o^2 - 0.0000002138\ V_o^3$$

2. Multiple lane opposing flow:

$$S_L = 1393 - 1.734\ V_o + 0.0009173\ V_o^2 - 0.0000001955\ V_o^3$$

where: S_L = saturation flow for unprotected left turns (vph)

V_o = opposing through volume (vph)

Given the opposing flow, the left turn saturation flow is taken from the curve and compared to the left turn demand. Any ''excess'' demand is the number of left turn conflicts. It is recognized that many left turns are made at the beginning or end of the red; thus the left turn conflicts are not necessarily denied their turn, but it is felt that this MOE would indicate when (and where) enough excess left-turn maneuvers may occur that remedial action might be warranted.

OUTPUT REPORTS

There are six types of outputs available from SOAP. Each of these provide useful information to the user.

Input Summary

The input data is echoed prior to execution. Where appropriate, messages are included so the user can verify that the action taken by SOAP was as intended. The liberal use of the comment card will assist the user in recalling the basis for the input data.

MOE Report

For each run a table of the numerical results of the current run is output. General and control strategy information is found above the table. Within the table are the current values of the MOE, namely:

1. Delay in vehicle-hours
2. Percent saturation (v/c)
3. Maximum queue length in vehicles
4. Percentage of stops
5. Excess fuel consumed (due to stops and delays) in gallons, and
6. Left-turn conflicts

All but the last are given separately for the through and left-turn movements for the four directions.

Below this table is a summary of items 1 (also in average seconds/vehicle), 2, 5 and 6 for the entire intersection. To the right of the summary is the phasing diagram.

Design Recommendations

SOAP develops recommended designs based on optimal flow as constrained by input parameters. There are two types of output for recommended designs.

1. Phasing Patterns. When protected left turns are specified for one or more approaches, it is necessary to choose the optimal phase patterns from several alternatives. SOAP determines the best two and three phase patterns for both the N-S and E-W directions. Each of the four possible phase combinations which may result from these choices is analyzed as a separate design configuration so the user may compare the MOE. The phase sequence in each pattern is indicated as either:

a. User specified

b. Determined by analysis of progression characteristics, or

c. Unimportant (i.e., opposite phase sequence equally acceptable)

2. Timing Design. Each design configuration must be optimized in terms of cycle length, splits and patterns before the MOE can be calculated. For each analysis period, the table includes dial number, cycle length and splits. Above the table is general information and control strategy specifications. The ''PATTERN'' entries indicate the possible sequences resulting from the choices available and are interpreted exactly as discussed in the previous section.

When the control is actuated, an asterisk (*) will appear in the DIAL column and the cycle length and splits are average for each period.

Intermediate Calculations Reports

The TABLE and PLOT commands are instruction cards which enable the user to call for output of many tables (or plots) which are maintained by SOAP.

Table options include printouts of 42 different types of tables which indicate either basic parameters (trucks and bus factors, minimum green time, capacities, etc.) or operational measures (v/c ratios, degree of saturation, average delay by period, etc.)

Plot options graphically portray a comparison of two different statistics. Presently, eight plots are available and show such comparisons as cycle length versus period, delay or volumes per period and excess fuel consumption by period.

Comparison Summaries

SOAP may be used to examine several different control strategies at an intersection. Each alternative may generate up to four MOE tables depending on the choice of phasing patterns to handle left turns. To facilitate the comparison of these alternatives, the user may request a separate summary of MOE's following a series of runs.

A second table gives the comparison of the ''best'' case designs. The output is obtained by including a COMPARE card in the input deck (after the last RUN card which is to be included). Cases can be labeled by including CASE card(s) in the deck.

Diagnostic Messages

SOAP contains an extensive library of messages to inform the user of fatal errors in the inputs; to alert the user to potential, but non-fatal, errors; and to advise the user of actions taken by SOAP, such as the use of default values in lieu of data which were not input. There are (4) levels of messages, as follow:

1. 100 level - fatal messages which must be corrected before SOAP can execute. There are a total of 34 errors at this level.

2. 200 level - warning that the user may wish to reconsider some aspect of his inputs. There are 17 of these messages.
3. 300 level - simply informing the user that SOAP took some action as a result, usually, of omitted data cards. There are 19 of these messages.
4. 400 level - these are high level messages that will not generally occur except when the user is highly proficient with SOAP and is getting into the program itself.

The placement of messages generally occurs in the input report at the location where SOAP had to make a decision.

ADDITIONAL FEATURES

The SOAP options are extensive in terms of the design, configuration and control strategies which can be analyzed or optimized. To summarize, the following options are available in SOAP:

1. Analysis vs. design
2. Existing preset timing vs. optimization
3. Pretimed vs. actuated
4. Protected vs. unprotected left-turn
5. Isolated run vs. multiple runs with comparison
6. Preset vs. optimal phase sequencing
7. Preset vs. optimal dial assignments
8. Numerous input data vs. default options
9. Isolated vs. coordinated control
10. Data check without execution

APPLICATIONS AND LIMITATIONS

As stated earlier, SOAP can be used to design and/or analyze any standard traffic control strategy for either pretimed or actuated operations. As such, it is limited primarily in the same areas which the controller itself is limited. The analysis and optimization is clearly based on mathematical approximations of the real world and therefore necessarily cannot take into account any extraordinary or erratic human behavior.

SOAP cannot duplicate fully the logic of intelligent controllers with microprocessor ''brains'' which can be programmed to be extremely responsive to traffic in real time. For instance, the combining of right turns with through traffic in SOAP presents some problems with accurate estimation of capacity. This is not a severe limitation, however, since the very function of these sophisticated controllers is to optimize on a real time basis, but SOAP is a very powerful and realistic off-line design tool for the practicing signal design engineer.

SOAP 84 (MICROCOMPUTER VERSION)

The Signal Operation Analysis Package (SOAP) was developed as a tool for design and evaluation of the operation of a signalized intersection.

The data input scheme is based on 80 column records which are read from a text file. The scheme was originally designed to accommodate standard punched card data entry. The purpose of the data input manager (DIM) is to produce the text file in the required format from data entered interactively using a microcomputer with screen displays for input and editing. This allows one to concentrate on the problem one is trying to solve, instead of worrying about getting the right numbers in the right columns.

In this sense, the DIM is an excellent aid to productivity and creativity. It is important to note, however, that it does not eliminate the need for a thorough knowledge of SOAP's data coding requirements. If one is not familiar with the use of SOAP as a traffic engineering tool, it will be necessary to review the SOAP84 Users Manual (14).

SOAP/M

PROGRAM DESCRIPTION - SOAP/M is a microcomputer version of the Signal Operation Analysis Package. It is part of the McTRAN system developed by the University of Florida (15). SOAP/M carries out a complete design for signalized intersection timing, including calculation of cycle length and splits. The computational methodology is similar, but not identical, to the methodology used in the original mainframe version of SOAP. SOAP/M permits inputting only one set of design volumes, capacities, etc., whereas the original mainframe version can run up to 48 contiguous time periods, each with its own characteristics.

The approach used in timing signals is based on an iterative process to minimize a weighted sum of delay and stops. Computation of delay and stops is based on the same model using in the TRANSYT program.

INPUT

The program requires the basic parameters, such as:

- Volume
- Capacity
- Percent Trucks
- Peak Hour Factor
- Lost Time per phase
- Phasings
- Minimum green times

OUTPUT

The output of the program includes:

- Optimal cycle length and splits

- Estimates of delay, stops, fuel consumption and annual operating cost.
- Two-page summary report showing the input stream.

SPECIAL FEATURES AND SHORTCOMINGS

SOAP/M has the following special features:

- Phasing optimization is attained by a trial and error procedure.
- Graphical display of the degree of saturation on all movements is provided.
- Annual operating costs can be estimated.
- Multiple runs can be carried out by the user.

The shortcomings of the program are:

- Peak hour factor is given for the intersection and not by the approach.
- The last three features of the traffic data input (Growth Factor, Approach Distances, and Speed) are not operational.
- It does not provide a comparison of results for multiple runs.
- The program is only available for Apple Computers.

TEXAS

The TEXAS (Traffic EXperimental and Analytical Simulation) model was developed for Texas State Highways and Public Transportation (SDHPT) by the University of Texas' Center for Highway Research (16). It is a microscopic model which simulates isolated intersections from two uncontrolled one-way streets to complex intersections with multiphase control, and/or multiple lane movements.

MODEL DESCRIPTION

The model was originally developed using FORTRAN IV. With close to 15,000 lines of executable statements, and it was developed for both IBM and CDC computers. It requires a maximum of 110K octal words on the CDC computer and 210K bytes on the IBM computer.

The model is composed of three major subprograms:

1. The Geometry Processor: it reads geometric data, ''constructs'' the physical intersection, and plots the intersection and prints detailed output.
2. The Driver-Vehicle Processor: it reads input data and ''creates'' the driver-vehicle traffic stream to be used in the traffic simulation.
3. The Simulation Processor: it is a microscopic stochastic simulation model with time scan updating.

INPUT REQUIREMENTS

There are two basic formats for the three processors in the model. The Geometry Processor and Driver-Vehicle processor have the same input format while the simulation processor has its own separate input format.

Four basic types of data must be inputted for the simulation processor:

1. Geometric information related to the intersection including number of approaches, number of lanes, lane width, number of sight distance restrictions, etc.
2. Traffic data such as volumes, speeds, types of headway distributions, etc.
3. Types of vehicles to be included in the simulation, vehicle length, deceleration and acceleration rate, maximum velocity for each vehicle class, minimum turning radius, etc.
4. Lane control parameter such as type of traffic control, number of intervals in signal cycle, interval length, initial interval, vehicle interval, detector locations, etc.
5. Types of drivers, and perception-reaction time for each type.

OPERATIONAL SUMMARY

As defined earlier, TEXAS is a microscopic, deterministic and stochastic time scan simulation model. The detailed descriptions of the three major subprograms are provided individually below.

Geometry Processor (GEOPRO)

The purpose of the GEOPRO is to describe the physical system to be simulated. The attributes of the system remain constant for any simulation of the physical configuration input. The geometric configuration of the intersection is usually based on the engineering data available from a scaled engineering drawing of the intersection. The only significant restrictions on the geometric layout is that all approaches must be linear, but may approach at any reasonable angle and may have no vertical curves.

Curb radii, vehicle paths and lanes are all realistically flexible and bays (or parking in portions of lanes) can be described as lanes which are available only for specified sections.

After ''constructing'' the geometric layout, GEOPRO determines all allowable vehicle paths through the intersection and identifies all points of conflict. Lane changing within the intersection may be permitted as an option. Maximum speeds, sight distance restrictions and conflicts (including non-crossing conflicts, such as merges or close passing of opposing left-turns) are generated by GEOLPRO. Plots of the intersection and vehicle paths are output by GEOPRO as are printed details and coded data output to tape to be used by the Simulation Processor.

Driver-Vehicle Processor (DVPRO)

The DVPRO reads the same data as GEOPRO, this subprogram is concerned with the preprocessing of driver-vehicle units. The data are generally available from routine traffic studies, and were described earlier. It is primarily in DVPRO where the random, or stochastic variation in the traffic stream is applied. The user may specify the number of driver and vehicle classes (defaults are three and ten, respectively). Driver classes are nonaggressive, normal or aggressive. Vehicle characteristics are length, vehicle operational factor (e.g., sluggish, normal or responsive), maximum acceleration and deceleration rates, maximum speed, and turning radius. Based on the percentage of drivers and vehicles assigned to each of the several classes a driver-vehicle class matrix is generated. The traffic streams (per approach) are generated by randomly assigning the above classes to each individual vehicle to be simulated. Thus, an input ''queue'' is built into arrays and each driver-vehicle unit is fully described in terms of the (mostly) randomly assigned attributes which are:

- o queue-in time (sum of previous headways, or arrival time)
- o driver class number
- o vehicle class number
- o desired speed
- o desired outbound approach number
- o inbound lane number (inbound approach numbers are not randomly assigned)

Table 5 shows the default values used for the various characteristics. A variety of probability distributions are used to assign the above attributes. Output are printed summaries of the input streams and coded data written to tape for use in the simulation model.

Traffic Simulation Processor (SIMPRO)

This subprogram (SIMPRO) is the actual simulation model. Using previously generated data stored on magnetic tape and further card inputs to establish parameters to be used, SIMPRO performs the dynamic activity computations required for the simulation.

SIMPRO handles the physical case of any single, multi-leg, multi-lane, mixed traffic intersection (including split intersections) either without control or with any conventional type of traffic sign or signal control. The model attempts to minimize preparatory calculations and is thus highly user oriented.

The model operates on a time scan basis, where at every time increment (1/2 to one second) the simulated position and operational status of every driver-vehicle unit and (any existing) control status are updated, as

Table 5 - TEXAS Default Driver and Vehicle Characteristics

	1	2	3	4	5	6	7	8	9	10
	Small Car	Medium Car	Large Car	Vans, Mini-bus	Single unit	Semi-trailer	Full trailer	Recrea-tional	Bus	Sports Car
Length	15	17	19	25	30	50	55	25	35	14
Operating Characteristics Factor	100	110	110	100	85	80	75	90	85	115
Maximum Deceleration	8	11	11	8	11	11	11	8	11	12
Maximum Acceleration	8	9	11	8	8	7	6	6	5	14
Maximum Velocity	150	192	200	150	160	160	150	150	125	205
Minimum Turning Radius	20	22	24	28	42	40	45	28	28	20
Percentage Aggressive Drivers	30	35	20	25	40	50	50	20	25	50
Percentage Average Drivers	40	35	40	50	30	40	40	30	50	40
Percentage Slow Drivers	30	30	40	25	30	10	10	50	25	10
Percentage in Traffic Stream	20	32	30	15	.5	.2	.1	.2	.5	1.5

	1	2	3
Driver Class and Type	Aggressive	Average	Slow
Driver Characteristics Factor	110	100	85
Perception-Reaction Time	0.5	1.0	1.5

needed. The degree of updating depends on the likelihood of change. For example, the relative actions of driver-vehicle units are interdependent, thus must be updated at every time increment.

Some events (e.g., interval changes of traffic signal displays) are predictable and times are flagged for updating at the appropriate time increment. With regard to the simulation time increment, the shorter the time, the more accurate the results.

There are two control times of importance to the simulation process. The first is startup time, where the system is started empty and the simulation model proceeds to load the system. No statistics are recorded during this step. The user must input this time since no algorithm has yet been offered to reliably determine when equilibrium has been achieved. The developers have suggested using at least two minutes (simulated real time) for this step.

The second step is the actual simulation time, which is also user specified. Due to the high cost of simulation (despite significant compression from real time), simulation times will normally be short, compared to say field or macroscopic studies. The developers recommend at least 10 minutes to obtain sufficient results for analysis.

The simulation process operates within the above time constraints in a manner very closely approximating the real world. Arrivals are random (due to the stochastically derived headways), decisions are dynamic (e.g., gap acceptance and lane changes are responsive to the immediate traffic environment) and the car following submodel is among the most complex, and realistic, of any existing model. At each instant, the model makes available to the simulated driver his desired speed, destination, present position, speed, acceleration, deceleration (as well as the rate of change