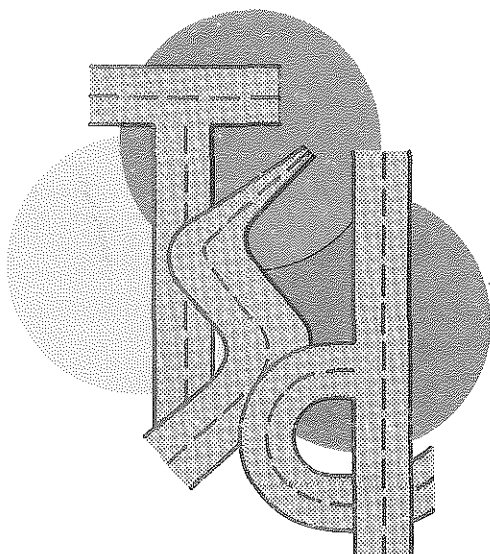


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1974

**OPERATING MANUAL
FOR
INTERSECTION CAPACITY ANALYSIS
COMPUTER PROGRAM
(Q16288)**

TSD-254-74



**TRAFFIC and
SAFETY
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COMPUTER PROGRAM
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TSD-254-74

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INFORMATION RETRIEVAL DATA

KEY WORDS: Computer Programs, Intersection Capacity, Signalized Intersections

ABSTRACT: The manual explains the use of the computer program for determining the capacity of a signalized intersection. That program used equations developed by the Michigan Department of State Highways and Transportation, which are based on the theory that headway decreases for each successive vehicle in a cycle. Input data needed are Lane Type, Lane Width, Cycle Length, Split, Percent Amber, Approach Volumes, and Percent Trucks. The solution of a multi-phase signal is shown by example. The development of the equations used is discussed. The use of a remote terminal to the Department's Burroughs B5500 computer is also explained.

REFERENCE: Mercer, Donald J., and Maleck, Thomas L., Operating Manual for Intersection Capacity Analysis Computer Program (Q16288), Report TSD-254-74, Michigan Department of State Highways and Transportation, Lansing, October 1974.

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CHAPTER 1

INTRODUCTION

This manual explains the use of a remote terminal to the Michigan Department of State Highways and Transportation's Burroughs B5500 computer. In particular the manual is concerned with the computer program for Intersection Capacity Analysis (Q16288).

That program will compute the capacity of each lane of each approach of an intersection, given the lane type, cycle-length, signal split, percent amber and lane width. It will also determine the volume/capacity ratio of each lane, based on the flows and percents of trucks, and will distribute the flows to balance the V/C ratios. The program will handle a two-phase signal; multi-phase signals can be solved by setting up successive runs of the programs, as the example in Chapter 3 shows.

The equations used to compute capacity were developed by the Traffic and Safety Division. The headway approach is used, with the theory that headway decreases with each successive vehicle in a cycle, up to a point. The program was written in COBOL by the Computer Services Division.

The Department's computer system is capable of providing a great deal of assistance. There are numerous pre-written programs available to solve many problems, such as traverses, statistical analyses, and horizontal and vertical alignments. In addition, individual programs can be written to solve particular problems. Some jobs can be run on the

terminal, some must be run by batch (punching the proper control and data cards and delivering them to the Machine Operations Room). The options available to users are numerous. Anyone with a massive amount of data to analyze should look to the possibility of the computer doing the work more quickly, easily, accurately.

This manual is expected to have a short useful life. Many changes are contemplated for the program to make it more powerful and versatile, but requiring more input and decision-making from the user. In addition, the Department will replace its computer system with another, larger system in the summer of 1975. That change will undoubtedly bring about changes in the procedures for using the remote terminals and the programs.

Comments or suggestions on the use of the manual or on the Intersection Capacity Programs will be welcomed by the authors.

HOW TO USE THE
COMPUTER REMOTE TERMINAL

This chapter gives a brief discussion of the procedures used to log-in (enter) or log-out on the terminal and of some of the command verbs. Not all commands are described nor are all possible uses of them given. The complete information is available in the 90-page booklet Burrough B5500 Time Sharing System Terminal Users Guide. The Terminal's Special Characters

The terminal is similar to a conventional typewriter except that it has several special function keys:

← (Left Arrow; Upper Case of the Letter O). Each line of input must end with this key. When it is typed the information is transmitted to the computer and the machine responds with a carriage return and a line feed. On some terminals, a different symbol appears when that key is typed.

␣ (Backspace; Upper Case of "7"). This character erases the last character typed and will replace it with whatever character is typed next. This key can be used repeatedly to erase more than one character. Example: 1234'AB is entered in the computer as 12AB.

! (Delete; Upper Case of "1"). This character erases the entire line being typed. When it is typed the computer responds with DEL, and a carriage return and a line feed. If the computer is under a SEQ command (discussed later) the sequence number will be retyped by the computer.

WRU (Upper Case of "E") or BREAK (2nd row, far right). These two keys allow the user to stop the computer and regain control. Use WRU if the teletype is not typing and BREAK if it is.

?← This combination results in a preprogrammed message being typed; the message depending on the situation. If it is typed immediately after the computer has printed ERR: *message* a further explanation of the error encountered is typed by the computer.

An example* of the use of ', !, and ?← follows:

	<u>Explanation</u>
<u>SEP +10←</u>	Automatic sequencing command
<u>10 TEN←</u>	
<u>20 TWENTY←</u>	Spelling corrected by backspace
<u>30 FORTY!DEL</u>	Line 30 deleted
<u>30 THIRTY←</u>	Correct line 30 entered
<u>40←</u>	Automatic sequencing ending
<u>#</u>	Computer ready for new command
<u>P 10,30,20←</u>	Print command
<u>ERR: 20</u>	Error message from computer
<u>?←</u>	Request for explanation of error
<u>ONE OF YOUR PARAMETERS IS ILLEGAL</u>	Preprogrammed explanation
<u>P 10,20,30←</u>	Correct print command
<u>10 TEN</u>	} File printed
<u>20 TWENTY</u>	
<u>30 THIRTY</u>	

Log-in and Log-out

To gain access to the computer it is first necessary to establish a telephone connection; from the Lansing office the extension is 32900. A busy signal indicates that all lines are busy; a continuous ringing indicates that the computer is not available, a high pitch steady tone indicates a successful connection. When that is heard, the user places the handset into the proper receptacle and turns the terminal to LINE.

The computer first asks for a user code, for the Traffic and Safety Division that is QTRAF.

The computer next asks for a password. The password,

* In this manual, examples of data entered by the user are boxed in

which is changed frequently, prevents unauthorized use of the computer and the user's files. It is available from other users. The computer blacks out eight spaces for both the user code and the password so that they cannot be read by others. If either is not entered correctly, such as misspelling or using an old password, the user must relog.

Finally the computer asks for a charge code, which consists of the three digits of the user's organization code, the two digits of the terminal number and (if he wishes) the user's initials.

When the log-in is completed, the computer will type out any messages it has for users; when it types a pound symbol (#) the user can proceed.

To log-out, the user types either BYE or HELLO; the difference being that with BYE the computer breaks the telephone connection and with HELLO it retains the connection and prepares to log-in a new user. Thus, HELLO should be used as a courtesy if another person is waiting to use the terminal. In either case the computer lists the total time the user was on and the times used for various functions, and the user's session is ended.

An example of logging in and out follows:

Log-in

```
RS500 TIME SHARING - 01/04, STATION 12
ENTER USER CODE, PLEASE-
[REDACTED]
AND YOUR PASSWORD
[REDACTED]
ENTER CHARGE CODE-490140JM-
10/04/74 9:12 AM.
GOOD MORNING, USER          YOU HAVE STATION 12
```

Log-out

```
BYE-
ON FOR 7 MIN, 24.3 SEC.
C&E USE 6.9 SEC.
EXECUTE 13.5 SEC.
IO TIME 33.3 SEC.
OFF AT 9:20 AM.
GOODBYE QTRAF
10/04/74
```

Files

A file is a collection of information, such as a computer program or the data needed to run a program, that the user can save from one session to another. Each file must have a name, which is any combination of letters and numbers up to six characters long, the first being a letter. The computer adds on the user code to form the complete identification. Other users must include the user code when they specify the file. For example, to run the Intersection Capacity Analysis program a user with the user code QTRAF can specify "E Q16288," but a user working under a different user code must specify "E Q16288/QTRAF".

The file that a user is currently building or changing is called his "work file", it is stored on the disk when he enters SAVE (p. 16). Note that two versions of the same file can exist simultaneously, one on disk and the other as a work file. The user must distinguish between the two. Example: Suppose a user writes a program and names it QA3. He saves it and attempts to run it, but the computer sends back an error message. He then locates and corrects the error. If he next types RUN, the computer will run the work file version, containing the correction. But if he types RUN QA3, it will run the incorrect version stored on disk and will find the same error.

Files are also designated by type. The type will be SEQ (sequenced) unless the user specifies another type. The other types available to the user are those of the different programming languages: ALGOL, COBOL, BASIC, and FORTRAN. Output from the execution of a program are of the type INFO.

Sequence Numbers

Each line of a user's files must contain its own unique sequence number, which is a positive integer up to eight digits that identifies the line. The computer arranges these in numerical order, so they do not need to be entered in order. Sequence numbers can be either typed in by the user or generated by the computer (using the SEQ command). When typed in, the computer considers everything up to the first non-numerical character (blank, letter, comma, etc.) as the sequence number (up to eight digits). Note that if the first column of data in a line contains a number and if the sequence number is typed in by the user, the full eight digits (including leading zeros) must be typed to distinguish between sequence numbers and data. Example: Suppose line number 250 containing the information "24,15" is to be typed in. If the user types in 25024,15 the computer will interpret it as being sequence number 25024 containing the information ",15". To enter it correctly the user must type 0000025024,15. To allow flexibility for making changes in a file, gaps should be left between sequence numbers.

Halt/Load

A halt/load occurs when the time-sharing system breaks down and must be restarted. When this happens, some or all of the data in the work file is usually lost and any jobs that were running at the time, either on line or by scheduling, are terminated and must be re-run. The user's first indication of a half/load is a lack of response from the computer.

After a time the computer will print:

```
H  
A  
L  
T  
RESTARTING . . . PLEASE WAIT
```

When restarting, the computer asks all users to log-in again. Generally, it will also disconnect the phone line and the user must re-establish the connection.

When to Enter Data

Once the computer has been given a command nothing should be entered until it announces that it has completed processing the command, except when it is executing a program or working on a SEQ command.

For some commands the computer types END command; for others it types a pound symbol (#). If there is an error in the command, such as specifying a non-existent file, or a sequence number of more than 8 digits, the computer will respond with a one-word error message preceded by ERR:. In any of these cases the computer waits for another command.

When the computer is running a program and needs a line of input data from the user it types a question mark. The data is typed on the same line, beginning in the first space after the question mark.

When the computer is generating sequence numbers, the data is typed on the same line as the number typed by the computer, beginning in the first space after the number.

DUMP Cards

To save a file overnight, it must be transferred to magnetic tape at the end of the day and reloaded onto the disk the next morning. To request this, the user punches a dump card and delivers it to the Machine Operations Room.

A dump card is a pink punched card that contains the file name, including user code, beginning in the first column. The name and user code are separated by a slash (/) and the user code is followed by a comma and a dash (Figure 1).

The file will then be saved for 15 days after it is last used. After that if the user does not request that it be retained, the file may be removed by Computer Services Division.

This method should be used only to store active files. If the user doesn't expect to use the file again for a while, but wants to avoid having to type it again, he should use paper tape (PUNCH command, p 15) or punch cards (COPY TO PUNCH, p 11) to store it, then re-enter it onto the disk when he once more needs it.

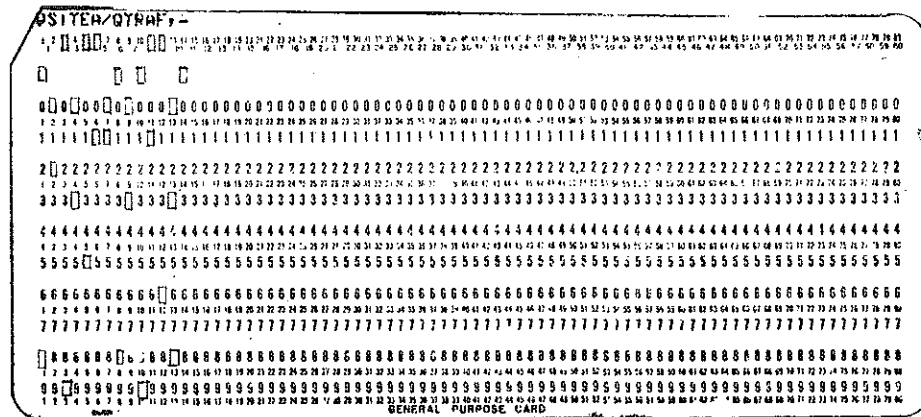


Figure 1. Example of a Dump Card, for a file named QSITEA

Commands

The following is a brief description of 27 command verbs. These verbs are part of the Command and Edit (CANDE) language that is used on time sharing. Examples of the commands are often given in the form `COMMAND file sequence`. *File* refers to any file in the user's library; the command will cause that file to be used. If the file to be used is the work file, its name is omitted. *Sequence* refers to a list of sequence numbers of that file that will be used. If the list is omitted the entire file is used. Up to nine sequence numbers can be listed, but always in ascending order. They can be individual numbers, separated by a comma, or a series, separated by a dash. The word END can be used instead of the last number in a series. Example: Suppose a file has 10 records in sequence numbers from 100 to 1000, in increments of 100. If the list of sequence numbers given for a particular command is "100, 250, 300-400, 600, 790-END" the command would act on sequence numbers 100, 300, 400, 600, 800, 900, and 1000. Note that sequence number 250 was ignored as there is no such number in the file.

APPEND This command causes records from one file to be copied onto the end of the work file. Its format is:

`APPEND file sequence`

The sequence numbers of the appended portion are equal to the highest sequence number of the original work file plus the sequence numbers in the appended file. Example: Suppose a part of file QA1 is to be appended to the work file, QA2, by the command `APPEND QA1 30+` :

FILE:QA2

5 FIVE
10 TWO TIMES FIVE
15 THREE TIMES FIVE
20 FOUR TIMES FIVE
25 FIVE SQUARED

FILE:QA1

10 TEN
20 TWENTY
30 THIRTY

After the file is appended, the work file would be

5 FIVE
10 TWO TIMES FIVE
15 THREE TIMES FIVE
20 FOUR TIMES FIVE
25 FIVE SQUARED
55 THIRTY

CHANGE This command causes the name of a file to be changed. Its format is:

CHANGE *file1* TO *file2*

or CHANGE TO *file3*

In the second case, the work file is changed. The old name is removed and may be used again.

COMPILE This command causes a source computer program to be converted into an object file. Its format is:

COMPILE *file type*

The command "COMPILE" can be abbreviated "C". The type may be omitted if the file type matches the computer language used.

COPY This command causes a file to be copied either onto the work file or into a hard-copy version (printout or punch cards). Its format is:

COPY *file sequence*

or COPY *file1 sequence* TO *file2*

or COPY *file sequence* TO PRINTER

or COPY *file sequence* TO PUNCH

In the first case, a file containing no information must first be established as the work file. In the second case

file 2 will be created, filled with the information from *file 1*, and saved. In the last two cases the output will be available in the Machine Operation Room about 30 minutes later. The printer will produce a printed copy of a file much faster than will typing it out on the terminal. The output would be on full sized computer sheets (11 X 14) double-spaced. Note that if the word PRINTER (case 3) were misspelled (such as PRIMTER) the result would be the creation of a file named PRIMTER, and the specified file would not be printed. The fourth case will transfer a file onto a deck of punch cards. Appendix 1 shows the procedure for re-entering a file from punch card onto the disk storage.

DELETE This command causes the records specified to be removed from the work file. Its format is:

DELETE *sequence*

If the sequence is omitted the entire file is deleted, only the work file's name is retained.

EXECUTE This command causes the object file of a computer program to be run. Its format is:

EXECUTE *file*

The command "EXECUTE" can be abbreviated "E".

FILES This command causes the names of all the files in the user's library to be printed. Its format is:

FILES

FIX This command causes one specified record to be changed by removing a portion and replacing it with another. Its format is:

FIX *sequence number* *old string* *new string*

The computer searches the record until it finds a string of characters exactly identical to the old string, removes that string, and replaces it with the new string. If the two strings are not of the same length, the part of the record right of the old string is either shifted right to make room for the new string or shifted left to fill in the gaps as necessary. Any non-blank character that does not appear in the old string can be used as the delimiter, such as "#" shown above.

The old string shown in the FIX command must be an exact copy of the portion to be removed, including any blanks; and must be the first time that particular string appears in the record. Example: Suppose the following record appears in the work file 1800 EB INDINA TRAIL; the user wants to correct the spelling of Indiana. The command FIX 1800 #IN#IAN would result in 1800 EB IANDINA TRAIL. A correct command would be FIX 1800 #INA#IANA, which would result in: 1800 EB INDIANA TRAIL.

The FIX command is not acted upon when entered; when some other command, such as SAVE is entered, all FIX commands are applied. The word FIX can be substituted by "*".

LIST This command causes the specified file to be printed with a heading showing file name, type, and the data. Its format is:

LIST *file sequence*
or LIST FILES

The command LIST can be abbreviated "L".

In the second case the computer will list all files in the user's library, showing the number of records, the type, and the dates created and last used.

LOAD This command causes a file from the user's library to become the work file. Its format is:

LOAD file

MAKE This command causes a file of the name specified to be created as the work file. Its format is:

MAKE file type

If the file type is not specified the type SEQ is assumed.

MERGE This command causes the specified file to be merged into the work file, according to the sequence numbers of both files. Its format is:

MERGE file sequence

If the same sequence number appears in both files, the work file version is used. Example: Suppose a part of file QA1 is to be merged with the work file, QA2, by the command

```
MERGE QA1 20-END-:
```

```
FILE:QA2
```

```
5 FIVE
10 TWO TIMES FIVE
15 THREE TIMES FIVE
20 FOUR TIMES FIVE
25 FIVE SQUARED
```

```
FILE:QA1
```

```
10 TEN
20 TWENTY
30 THIRTY
```

After the merge, the work file would be:

```
5 FIVE
10 TWO TIMES FIVE
15 THREE TIMES FIVE
20 FOUR TIMES FIVE
25 FIVE SQUARED
30 THIRTY
```

PRINT This command causes the specified file to be typed on the terminal. Its format is:

PRINT file sequence

The command PRINT can be abbreviated "P".

PUNCH This command causes the specified file to be punched on paper tape at the terminal. Its format is:

PUNCH *file*

After entering the PUNCH command the user must turn on the paper tape punch. The computer will punch 10 rubouts, the file name, 40 rubouts, the contents of the file, including sequence numbers, and 40 more rubouts. The rubouts, which consist of punching out all holes, are to aid the user in handling the paper tape; they are ignored by the computer.

The user can make his own paper tape without obtaining access to the computer. He turns the terminal to LOCAL, turns the punch on, types the rubouts, then enters the information just as if he were working with the computer, with one exception: At the end of each line, after the left arrow, he must type RETURN and FEED keys. He can type deletes (!) and backspaces ('), but the paper tape cannot include commands other than FIX statements. The user can either enter sequence numbers on the paper tape or have the computer set them when it reads the tape, via a TAPE command.

REMOVE This command causes the specified file to be erased from the user's library. Its format is:

REMOVE *file*

Up to nine files can be specified, separated by commas. The user should remove all of his files that he no longer needs.

RENAME This command causes the name of the work file to be changed to the specified name. Its format is:

RENAME *file2*

RESEQ This command causes the sequence numbers of the

specified file to be changed. Its format is:

RESEQ *file sequence*

or RESEQ *file base + increment*

Base is the sequence number to be used for the first record; *increment* is the amount each subsequent sequence number is increased. If either base or increment, or both, is omitted the value of 100 is used.

RUN This command causes a computer program to be compiled, if necessary, then executed. Its format is:

RUN *file type*

The command RUN can be abbreviated "R". The type may be omitted if the file type matches the computer language used. If the program has already been compiled, RUN is equivalent to EXECUTE.

SAVE This command causes the work file to be stored on disk in the user's library. Its format is:

SAVE

If there is a previous version of the file stored on disk, that version is erased and replaced with the new version. If the work file and the previous version are identical, the SAVE command is ignored. The work file is retained. To prevent losing data by a halt/load, the user should make frequent use of SAVE. If he attempts a command that will destroy a work file before it is saved, such as logging out or using a LOAD command, the computer will respond with ERR: NO SAVE. That error message can be overridden by re-typing the command.

SCHEDULE This command causes the information in the

specified file to be processed off-line at a later time, with the output being stored in another specified file.

Its format is:

SCHEDULE *file1* TO *file2*

SEQ This command causes the computer to generate and type sequence numbers for the work file. Its format is:

SEQ *base + increment*

Base is the sequence number to be used for the first record; *increment* is the amount each subsequent sequence number is increased. If the increment is omitted, the value of 100 is used. If the base is omitted, it is set equal to the sum of the highest sequence number currently in the file plus the increment (if there are no records in the file, the base is equal to the increment). The automatic sequencing is terminated by the user typing a left arrow in the first column after the sequence number.

STATUS This command causes the computer to report on the progress of a scheduled job. Its format is:

STATUS *file2*

File 2 is the output file specified in the SCHEDULE command. The machine will respond with SCHEDULED, RUNNING (*number of input records read*), or DONE. When DONE, the user can print the output file. Note: DONE does not imply successful completion; if the job was running at the time of a halt/load it will be reported as done, although it must be re-run. So the user should be sure he has a successful run before he removes his input file.

STOP This command causes a scheduled job to be removed

from scheduling if its execution has not yet begun or to be aborted if it is running. Its format is:

STOP SCHEDULE *file2*

TAPE This command causes the computer to accept input data for the work file from a paper tape. Its format is:

TAPE

TAPE SEQ *base + increment*

In the second case, the computer will generate sequence numbers as discussed in SEQ above.

After this command the computer types OK. The user must then turn the tape reader to ON, unless it is already set to AUTOSTART. To avoid delay, the user should have the tape loaded onto the reader before this command is typed. A work file must be established, by a LOAD or MAKE command, before this command.

When the tape has been read, the user types ?END to terminate the tape mode.

TO This command causes a message to be typed on other designated terminals. Its format is:

TO *user code: message*

or TO *line number: message*

or TO *SP0: message*

In the first case the message is sent to all users operating under that user code; in the second case it is sent to the terminal connected to that line; in the third case it is sent to the supervisory printer at the time sharing system's master control panel. The terminals receiving the message will receive:

FROM *sender's user code (sender's line number) message*

If the intended receiver is not connected or is busy the computer will so inform the user and the message is not delivered.

Messages from the supervisory printer are received as:

ATTN:; *message*

TYPE This command causes the type of the work file to be changed to that specified. Its format is:

TYPE *type*

Any one of the five types (p 6) other than INFO can be specified.

WHATS This command causes the computer to provide certain information about the file in question. Its format is:

WHATS *file*

The computer will report on the number of records, type, and date created of the file specified. If the file is omitted the computer will report on the name and type of the work file.

CHAPTER 3

USING COMPUTER PROGRAM Q16288

General

For any undivided intersection up to four legs operating under a two-phase signal, this program will determine the capacity for each lane, distribute the flow onto the lanes, determine the volume/capacity (V/C) ratio and print the results.

The information required is:

1. Number of Approaches (up to 4)
2. Coded lane type for each approach (up to 6 lanes per approach)
3. Approach volumes, percent truck, lane width, and cycle split for each approach
4. Cycle length
5. Percent Amber
6. Names of Approaches

Form 1569, "Intersection Capacity Analysis," (Appendix 2) shows the format needed to enter the data into the computer. This form should be filled out in advance, to reduce the time at the computer terminal and to reduce errors.

After accepting the input data the program gives the user an opportunity to have the data printed out in a table and to correct any lines, as necessary, in the input. When the user is satisfied with the data, he instructs the computer to execute the computations.

Given the input data, the program first checks for certain "design errors". These are errors that cause the computer to

either calculate values that are incorrect or waste time calculating values that have no meaning. The errors that are checked for are:

1. Either providing laneage for non-existent flows or failing to provide laneage for existent flows.
2. Attempting to provide a dual turn through opposing traffic.
3. Providing two or more optional lanes for the same turn so that, in reality, turn vehicles would cross the path of thru vehicles.
4. Specifying left turn lanes for both with and without opposing traffic.
5. Specifying either left turn lanes with opposing when there is no opposing flow, or left turn lanes without opposing when there is opposing flow.
6. Assigning total green time of more than 100 percent for Approaches that cross.

Any design error found must be corrected before the program will proceed, so the user is given another opportunity to change the data.

The program next adjusts the approach volumes by multiplying them by the truck factors; separate factors are used for each flow (left, thru, and right) for each approach. The factor increases the volumes by 0.5 percent for each 1 percent trucks. Then the lane width factors are calculated, to be applied to reduce the capacities after the capacities are computed. One factor is used for all lanes of each approach; the factors reduce the capacity by 6 percent for each 1 ft reduction in lane width below 12 ft. The minimum width is 8 ft and there is no increase in capacity if the width is more than 12 ft.

The capacities of Type 5 (Thru Only) and Type 7 (Right

Turn Only) lanes are calculated next, based on the theory that headways decrease for each successive vehicle up to a limit, as described in Chapter 4.

The equations used for Type 5 lanes are cubic for the first 5 vehicles (11.81 sec of green time), quadratic for the fifth to seventeenth vehicle (33.78 sec) and linear thereafter. The equations used for Type 7 are cubic for the first 5 vehicles (14.80 sec) and linear thereafter. If the green time available falls in the ranges of the cubic or quadratic equations, the number of vehicles (to the nearest 0.1 vehicle) that can be accommodated within the green time is solved by successive trials. If the green time falls in the range of the linear equation, the equations are solved directly. The Type 5 Lane Capacity is assigned to Type 3 and 6 Lanes (option lanes), to be adjusted later if the lanes also accommodate turns; and the Type 7 Lane Capacity is assigned to Type 1 and 8 Lanes (turn-only lanes).

The penalty factor, to convert turn vehicles into equivalent thru vehicles, is computed as the ratio of Type 5 Lane Capacity to Type 7 Lane Capacity. It increases slightly as green time increases: 1.27 for 10 sec and 1.40 for 35 sec.

The capacities of Type 2 and 4 Lanes (left turns through opposing traffic) are computed as follows: 1) They are assigned a minimum capacity of 2 turns per cycle. 2) Additional turn capacity is determined by subtracting the opposing thru flow from 1200, and multiplying the difference by the percent green time for that approach. If the opposing flow is 1200 vph or more, it is assumed that there are no gaps to allow

additional turns. 3) The thru capacity for a Type 4 Lane is determined by computing the fraction of the time that the lane is not blocked by a vehicle waiting to turn left, assuming that turn vehicle arrives randomly. If there are 2 or more turns per cycle, it is assumed that the lane is continually blocked and there is no thru capacity. By this method each turn vehicle is penalized heavily, reducing the thru capacity by 4 to 6 vph. The penalty is based on the number of turns and the cycle length.

After all capacities are computed, the flow is distributed for each approach by balancing V/C ratios. The program first determines if there are option lanes for either or both turning movements. If there are no option lanes, the flows for each move are distributed evenly among all lanes that will accommodate the move. If there are option lanes the computer next determines if the option lanes carry turns only, thru vehicles only, or a mixture of the two.

After the flows are distributed, the truck factors are removed from the approach volumes, the capacities are similarly reduced, V/C ratios are computed, and the results are printed.

How to Use Program Q16288

This program is designed to be used through a remote terminal. It uses a conversation mode for inputting the data; that is, it asks the user for each line of data, usually giving him an example of the form of the input.

Use of the program is best explained by discussing a sample problem: A three-lane, one-way arterial that inter-

sects a four-lane, two-way street, with the following data:

1. Flows (vph) & (%Trucks)	M93 (Wisconsin Av)		Ontario Drive	
	Eastbound		Northbd	Southbd
Left turns	375	(5.0)	None	85(15.0)
Thru vehicles	1445	(15.0)	760(10.0)	630(8.0)
Right Turns	1050	(7.5)	185(15.0)	None
TOTAL	2870		945	715

2. Cycle split: 61% Wisconsin Ave, 39% Ontario Drive
3. Use 60 sec cycle, 2-phase, 6% (3.6 sec) amber
4. Lane widths: Wisconsin Ave 11 ft, Ontario Drive 12 ft
5. Right turn lane may be added to Wisconsin Ave

The user fills out Form 1569 (Fig. 2), gains access to the computer and prepares to run the job. In this example, the user will enter 23 lines of information, beginning with a request to run the program.

```

E Q16288*
RUNNING
  
```

```

INTERSECTION CAPACITY ANALYSIS.
ENTER NUMBER OF APPROACHES 1,2,3,4.
  
```

The machine responds, types out the title, and requests the number of approaches. The program requests data for, and analyzes, each approach in sequence, up to the number typed (maximum of 4).

```

E Q16289*
ENTER LANE TYPE CODES FOR APPROACH 1 ;
ONE CODE FOR EACH LANE UP TO SIX LANES
  
```

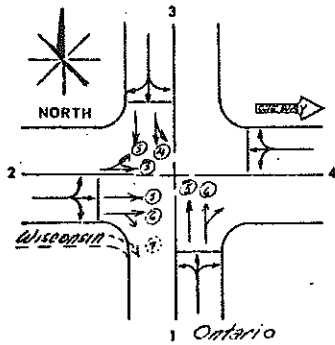
The program requests the codes for the types of lanes for each approach; the codes are shown on Form 1569. Although the program does not now consider the order of the lane types, in future revisions the order may be important, so the user is asked to number them from outside to inside. With the code used, the lane types would always be entered in

decreasing numerical value (except for a dual right turn with a Type 8 lane). The computer will accept any number of Lane Types 1, 5 and 7. However, a design error will appear at the time of execution if certain combinations appear:



INTERSECTION CAPACITY ANALYSIS

LOCATION <i>M 93 (Wisconsin) @ Ontario</i>	COUNTY	CONTROL SECTION	JOB NUMBER
BY			DATE



- INSTRUCTION:**
1. Number Approaches Consecutively
 2. Number Lanes from Outside to Inside
 3. Set Approach 1 Opposite 3 and 2 Opposite 4
 4. To gain access to the computer, follow this log-in sequence.

USER CODE: QTRAF

PASSWORD:

CHARGE CODE: _____
└─ Your initials (Optional)
└─ Station Number
└─ Organization Code

E Q16288

STEP 1 ENTER NUMBER OF APPROACHES: 4 (10)

STEP 2 ENTER LANE TYPE CODES:

APPR NO	LANE NUMBER						
	1	2	3	4	5	6	
1	6	5					← (21)
2	6	5	3				← (22)
3	5	4					← (23)
4							← (24)

LANE TYPE	
1 - Left Only W/out Opposing	
2 - Left Only W Opposing	
3 - Left/Thru Option W/out Opposing	
4 - Left/Thru Option W Opposing	
5 - Thru Only	
6 - Right/Thru Option	
7 - Right Only	
8 - Left/Right Option	

STEP 3 ENTER APPROACH VOLUMES, PERCENT OF TRUCKS, LANE WIDTH, CYCLE SPLIT:

APPR NO	APPROACH VOLUMES - VPH			PERCENT TRUCKS - %			LANE WIDTH / FT.	CYCLE SPLIT C + A / %
	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT		
1	0000	0760	0135	0000	6100	0150	0120	0390
2	0375	1445	1050	0050	0150	0075	0110	0010
3	0085	0670	0000	0150	0080	0000	0120	0390
4								

STEP 4 ENTER CYCLE LENGTH (SEC): 060 (40)

STEP 5 ENTER PERCENT OF AMBER (%): 060 (50)

STEP 6 ENTER NAME OF APPROACHES:

APPR NO	NAME OF APPROACHES
1	N.B. ONTARIO DRIVE
2	E.B. WISCONSIN DRIVE (M 93)
3	S.B. ONTARIO DRIVE
4	

STEP 7 IF DATA IS BEING PUT IN A FILE, FOR SCHEDULING, ALSO TYPE:

NO (OR YES, IF TABLE IS TO BE PRINTED)
 NO
 EXC
 NO

Figure 2. Form 1569 for Wisconsin/Ontario Sample Problem

Only one each of Lane Types 2, 3, 4, 6 and 8 are accepted; if Lane Type 2 is used, Types 1, 3 and 4 are not allowed; if Type 4 is used, Types 1, 2 and 3 are not allowed; and if Type 8 is used, only Types 1 and 7 may also be used. The lane codes for each approach (maximum of 6 lanes per approach) are entered as a continuous number, with no spaces between.

```
765+
ENTER LANE TYPE CODES FOR APPROACH 2 ;
ONE CODE FOR EACH LANE UP TO SIX LANES
7653+
ENTER LANE TYPE CODES FOR APPROACH 3 ;
ONE CODE FOR EACH LANE UP TO SIX LANES
754+
ENTER APPROACH VOLUMES, PERCENT OF TRUCKS, LANE WIDTH, CYCLE SPLIT
FOR APPROACH 1 USING 4 DIGIT FIELDS
SEPARATING BY COMMAS.
SAMPLE:
LEFT TURNS : 0000 (NONE)
THRUS      : 2000
RIGHT TURNS: 3000
PERCENT TRUCKS
LEFT       7.5
THRU      12.0
RIGHT     10.5
LANE WIDTH 11.5
CYCLE SPLIT: 55%
WOULD BE ENTERED
0000,2000,3000,0075,0120,0105,0115,0550
```

The program next asks for 8 bits of information for each approach: the flows and percent trucks for each move, the lane width, and the cycle split. Each is entered as a four-digit number. The location of the decimal point, shown on Form 1569, is important, as the decimal point is not entered. A few rules should be followed: for the percent truck values, the maximum value should be 1000 (equivalent to 100 percent). There is no check in the program for this; if, for example, 1500 is entered the capacity will be calculated for 150 percent trucks. The smallest and largest values of lane width that will affect the programs are 0080 and 0120 (8 ft and 12 ft) respectively. Any value lower than 0080 will produce a lane width factor of 0.76, any value higher than 0120 will produce a lane width factor of 1. The cycle splits

are read to the nearest 0.1 percent. Since signals can be set only to the nearest whole percent, the last digit should be zero. The computer adds the cycle splits for Approaches 1 and 2 and those for Approaches 3 and 4. If either sums to more than 1000 (100 percent) a design error will be printed.

The eight four-digit numbers are separated by a space between each pair of numbers. Anything can be entered in those columns. However, a non-numeric figure (such as a comma) is recommended. Then, if the user makes a mistake in spacing (such as entering a three-digit number) the computer will not accept the data and the user is given a chance to correct. The data is entered on one line for each approach.

```
0000,0760,0185,0000,0100,0150,0120,0390
ENTER APPROACH VOLUMES, PERCENT OF TRUCKS, LANE WIDTH, CYCLE SPLIT
FOR APPROACH 2 USING 4 DIGIT FIELDS
SEPARATING BY COMMAS.
375,1445,1050,0050,0150,0075,0110,0610
ENTER APPROACH VOLUMES, PERCENT OF TRUCKS, LANE WIDTH, CYCLE SPLIT
FOR APPROACH 3 USING 4 DIGIT FIELDS
SEPARATING BY COMMAS.
0085,0630,0000,0150,0080,0000,0120,0390
ENTER CYCLE LENGTH (3 DIGITS) EXAMPLE 60 SECS IS 060
```

The computer next requests cycle length, given as a three-digit number and read to the whole second, and the percent amber, also a three-digit number but read to 0.1 percent. Again, the last digit should be zero. The computer will accept any numerical values entered.

```
060
ENTER % OF AMBER (3 DIGITS)
EXAMPLE: 7 % WOULD BE 070
060
ENTER NAME FOR APPROACH 1, 1 TO 30 CHARACTERS
```

The last bit of input is the name for each approach. The names should be descriptive enough (direction, street name, route number) to allow anyone to identify the location. The name can be up to 30 spaces long, if a longer

name is entered, the portion after the thirty-space limit is ignored by the computer. If no name is to be used, a single blank space is entered.

```

1NS ONTARIO DRIVE-
ENTER NAME FOR APPROACH 2, 1 TO 30 CHARACTERS
2EB WISCONSIN AVENUE (M93)-
ENTER NAME FOR APPROACH 3, 1 TO 30 CHARACTERS
3SB ONTARIO DRIVE-
DO YOU WISH TO PRINT TABLE SET (YES OR NO)
  
```

Normally the user should have the table set printed. That results in the input data being printed out again with proper headings and proper placement of the decimal points. That will not only aid anyone who uses the analysis in the future, but more importantly it also allows the user to check his input (such as making sure that 5 percent trucks and 11 ft lane widths didn't come out ^{as} 50 percent and 1.1 ft).

4YES-

NUMBER OF APPROACHES: 3 CODE 10

LANE TYPE	APP LANE NUMBER						CODE
NO	1	2	3	4	5	6	DE
1	6	5					21
2	6	5	3				22
3	5	4					23
4							24

APP NO.	APP LEFT	APP VOLUMES THRU	VPH RIGHT	PERCENT OF LEFT	PERCENT OF THRU	PERCENT OF RIGHT	LANE WIDTH	CYCLE SPLIT	CODE DE
1		760	185	10.0	15.0	12.0	.390	31	
2	375	1445	1050	5.0	15.0	7.5	11.0	.610	32
3	85	630		15.0	8.0		12.0	.390	33
4							.000	34	

CYCLE LENGTH 060 SECONDS CODE 40

% OF AMBER .060 DECIMAL CODE 50

1 NS ONTARIO DRIVE	CODE 61
2 EB WISCONSIN AVENUE (M93)	CODE 62
3 SB ONTARIO DRIVE	CODE 63
4	CODE 64

IF YOU WISH TO CHANGE INPUT DATA PREVIOUSLY ENTERED:

1. LOCATE DESIRED DATA LISTED ABOVE.

2. TYPE IN 2 DIGIT CODE THAT APPEARS TO THE RIGHT OF THAT DATA

IF NO CHANGE, TYPE NO

The user is next given a chance to correct his input by re-entering any line(s) that need changing. He enters first the line code numbers; the computer responds by repeating the appropriate question for that line of input. Once a line code number is typed in, the entire line, corrected, must be re-entered. After each change, the computer prints the last two lines again, giving the user the opportunity to make as many changes as necessary. When all changes are made, the user types NO.

~~NO~~
 ENTER: CHG FOR MORE CHANGES
 EXC TO EXECUTE PROGRAM AND LIST RESULTS
 STP TO STOP THE RUN
 PRT TO PRINT TABLE SET AGAIN

The user next selects one of four steps for the computer to follow. If he enters CHG the program will return to the change routine. If he enters EXC the computer first checks for design errors (returning to the change routine if it finds any) then performs the calculation and prints out the results. If he enters STP the job is ended, all input is lost, and the computer awaits further instructions. If he enters PRT the table set is printed again. Unless the user is positive that all corrections were entered properly, he should request the table set again.

~~EXC~~
 DESIGN ERRORS FOLLOW:
 NO ERRORS TO REPORT

LANE	LANE TYPE	LEFT THRU	RIGHT	CAP.	V/C
APPROACH 1 NB ONTARIO DRIVE					
1	(6) RIGHT/THRU OPTION	254	184	457	.96
2	(5) THRU ONLY	505		526	.96
APPROACH 2 EB WISCONSIN AVENUE (M93)					
1	(6) RIGHT/THRU OPTION		1050	646	1.62
2	(5) THRU ONLY	970		866	1.12
3	(3) LEFT/THRU OPTION W/OUT OPP	374	474	757	1.12
APPROACH 3 SB ONTARIO DRIVE					
1	(5) THRU ONLY		519	532	.97
2	(4) LEFT/THRU OPTION W/OPPOSIN	84	110	198	.98

SIGNAL SPLIT (60 SECOND CYCLE)

APPROACH		CYCLE SPLIT	TIME (SEC)
1	NB ONTARIO DRIVE	GREEN 33 % AMBER 6 %	19.80 3.60
2	EB WISCONSIN AVENUE (M93)	GREEN 55 % AMBER 6 %	33.00 3.60
3	SB ONTARIO DRIVE	GREEN 33 % AMBER 6 %	19.80 3.60

DO YOU WISH TO RUN ANOTHER ANALYSIS, YES OR NO

The user is next given a chance to run another analysis, either with all new data or with changes in the current data. In this sample problem, at Approach 2 the right/turn option lane cannot accommodate the right-turn demand; consequently thru vehicles are not using that lane and overloading the other two lanes. The user knows he has right-of-way available for a right-turn lane, so he adds one Type 7 lane to Approach 2 laneage.

YES

DO YOU HAVE ALL NEW DATA, OR ONLY CHANGES TO THE OLD.
ENTER NEW OR CHG

CHG

2. TYPE IN 2 DIGIT CODE THAT APPEARS TO THE RIGHT OF THAT DATA
IF NO CHANGE, TYPE NO

22

ENTER LANE TYPE CODES FOR APPROACH 2 ;
ONE CODE FOR EACH LANE UP TO SIX LANES

653

2. TYPE IN 2 DIGIT CODE THAT APPEARS TO THE RIGHT OF THAT DATA
IF NO CHANGE, TYPE NO

Since only one short line was changed, the user decides against reprinting the table set and executes the computation again.

NO

ENTER: CHG FOR MORE CHANGES
EXC TO EXECUTE PROGRAM AND LIST RESULTS
STP TO STOP THE RUN
PRT TO PRINT TABLE SET AGAIN

EXC

DESIGN ERRORS FOLLOW:
NO ERRORS TO REPORT

LANE	LANE TYPE	LEFT	THRU	RIGHT	CAP.	V/C
APPROACH 1 NB ONTARIO DRIVE						
1	(6) RIGHT/THRU OPTION	254	184	457		.96
2	(5) THRU ONLY	505		526		.96
APPROACH 2 EB WISCONSIN AVENUE (M93)						
1	(7) RIGHT ONLY		624	645		.96
2	(6) RIGHT/THRU OPTION	267	425	715		.96
3	(5) THRU ONLY		837	865		.96
4	(3) LEFT/THRU OPTION W/OUT OPP	374	340			.96

```

APPROACH 3 SB ONTARIO DRIVE
1 (5) THRU ONLY          519      532 .97
2 (4) LEFT/THRU OPTION W/OPPOSIN 84 110      198 .98

```

SIGNAL SPLIT (60 SECOND CYCLE)

APPROACH		CYCLE SPLIT	TIME (SEC)
1	NB ONTARIO DRIVE	GREEN 33 %	19.80
		AMBER 6 %	3.60
2	EB WISCONSIN AVENUE (M93)	GREEN 55 %	33.00
		AMBER 6 %	3.60
3	SB ONTARIO DRIVE	GREEN 33 %	19.80
		AMBER 6 %	3.60

DO YOU WISH TO RUN ANOTHER ANALYSIS, YES OR NO

Now the user has an operational intersection and has no more changes to make, so he stops the run. The computer responds with "EOJ" (end of job), prints out the computed time used for execution of the program, and awaits further instruction.

```

NO
STP TEST EOJ

```

END Q16288 10.8 SEC.

Note the following on these two sample runs:

1. Due to round-off errors, the sum of the vehicles for each move after the flows are distributed is slightly less than the approach volumes. For the same reason, balanced V/C ratio may vary slightly.
2. For Approach 2, the capacity of the option lane carrying only right turns (run 1: 646 vph) matches the capacity of a right-turn only lane (run 2: 645 vph). The capacity of an option lane (except Type 4) is based on the proportion of thru and turn vehicles carried; and unused capacity is based on the same proportion. For Approach 2, run 2, the Right/Thru Option Lane would carry 276 thrus and 439 right turns if the V/C ratio were 1.00. If there were no turning vehicles in the option lane the capacity of that lane would be that of a thru-only lane (865 vph).
3. The unused capacity of a Type 4 lane (Left/Thru Option W/Opposing, Approach 3) consists entirely of thru vehicles. The flow assigned to this lane consists of 100 percent of the left turn capacity (84 vehicles) plus 96 percent (110 vehicles) of its

thru capacity (114 vehicles). The V/C ratio calculated for this lane is the weighted average of the two flows; for that reason the final V/C ratio of a Type 4 lane will always be closer to 1.00 than will the V/C ratio of any lane it is balanced with.

Scheduling

To schedule a computer job means to store the input on the disk file so that the computer can execute the program sometime later in the day and store the results in another file. The user then returns to the terminal and has the answer printed out. Almost any job run on the terminal can be scheduled, if the user can foresee what information the computer will need and the exact order and format necessary. By edict some jobs, such as BASIS statistical analyses, must be scheduled because of the long computer time required.

Scheduling has these advantages for the Intersection Capacity Analysis program:

1. Input time is reduced. The user doesn't have to wait for the computer to type out its part of the input dialogue.
2. Output time can be reduced. The user can request only the portion of the output he needs. The input file appears in tabular form, although without headings or decimal points, so the user may decide he doesn't need the table set.
3. The input file can be retained, revised, and re-entered later. Thus, if the user is unsure what changes he has the option of making, he can sign off the terminal, analyze the intersection layout, then return later in the day, change only the lines that need changing, and re-schedule the job. By doing this, he avoids the need to re-enter all the data. In addition, by using FIX, he can make changes within a line (such as signal split) without needing to re-enter the entire line.

Scheduling, however, has some disadvantages:

1. The user loses his opportunity to change the input and run the program a second time, based on the results of the first run. That must now be done by

a second scheduling of the job.

2. The user loses his opportunity to correct the input. The computer will carry the program as far as it can with the input given. If, for example, percent amber is entered as 500 instead of 050, the computer will perform the calculation using 50 percent amber, even though that results in zero or negative green time. Or in another example, if a design error is found, the input file won't have the data the computer needs to correct it, so the job will be ended with an error message.
3. At least two trips to the terminal are needed. Often the user, on his second trip, finds that he can't get a line to the computer, or that the computer hasn't completed the job, or that the job couldn't be successfully finished because of a halt/load or an error in the input. As a result, scheduling will generally require more of the user's time than will the conventional method unless he has many intersec-tions to analyze. There is also danger, as this process takes place after several hours, that the working day may end before it is completed. Then the user must begin anew the next day; if he failed to make provision to save his input files overnight, all may be lost.

How to Schedule

The first step in scheduling a job is to build the input file:

1. A file is created by a MAKE command. The user selects the name of the file; if he has several files to make he should devise a code to avoid confusion, such as Q16M1, Q16M2, etc.
2. Each line of a file, called a "record," must have a sequence number. They may be entered by the user, or they may be generated by the computer, using the SEQ command.
3. The data is next entered in the exact order and format shown on Form 1569.
4. After the approach names are entered, the user must add four more lines to answer the computer's questions:
 - (a) NO or YES to answer the question: DO YOU WISH TO PRINT TABLE SET?

- (b) NO to answer the question: IF YOU WISH TO CHANGE INPUT DATA PREVIOUSLY ENTERED . . . ?
 - (c) EXC to select between choices of CHG, EXC, STP or PRT.
 - (d) NO to answer the question: DO YOU WISH TO RUN ANOTHER ANALYSIS? The user can enter YES here if he knows in advance what changes he wishes to make and the information the computer will need. He will then enter either NEW or CHG. If NEW, he must enter all new data, beginning with the number of approaches. If CHG, he must enter for each line to be changed, first the line code number, second the complete data for the line. After all changes are entered he must finish with three lines: NO/EXC/NO.
5. To stop the computer from continuing to type sequence numbers, the user next types a single left arrow in the first space.
 6. The user next types SAVE.
 7. The user next types PRINT. After the computer prints out the file the user checks it for errors. If he finds any, he can correct them by using FIX or by re-typing the sequence number and the data.
 8. After all changes are made the user must type SAVE again and should follow that with another PRINT command.

The user then schedules the job and names the output file, with a SCHEDULE command. The user checks on his job by a STATUS command. The computer will respond with SCHEDULED, RUNNING, or DONE.

When the job is DONE, the user requests to have the output file printed, with a PRINT command. The output file contains all of the questions, examples, and input lines just as though it had been run live. As such, a typical problem will produce an output file of about 150 lines, with 34 more lines if the table set is printed. Since the user is interested in only part of the output file, he can ask for printing of only the sequence numbers containing that part; those

a second scheduling of the job.

2. The user loses his opportunity to correct the input. The computer will carry the program as far as it can with the input given. If, for example, percent amber is entered as 500 instead of 050, the computer will perform the calculation using 50 percent amber, even though that results in zero or negative green time. Or in another example, if a design error is found, the input file won't have the data the computer needs to correct it, so the job will be ended with an error message.
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How to Schedule

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4. After the approach names are entered, the user must add four more lines to answer the computer's questions:
 - (a) NO or YES to answer the question: DO YOU WISH TO PRINT TABLE SET?

- (b) NO to answer the question: IF YOU WISH TO CHANGE INPUT DATA PREVIOUSLY ENTERED . . . ?
 - (c) EXC to select between choices of CHG, EXC, STP or PRT.
 - (d) NO to answer the question: DO YOU WISH TO RUN ANOTHER ANALYSIS? The user can enter YES here if he knows in advance what changes he wishes to make and the information the computer will need. He will then enter either NEW or CHG. If NEW, he must enter all new data, beginning with the number of approaches. If CHG, he must enter for each line to be changed, first the line code number, second the complete data for the line. After all changes are entered he must finish with three lines: NO/EXC/NO.
5. To stop the computer from continuing to type sequence numbers, the user next types a single left arrow in the first space.
 6. The user next types SAVE.
 7. The user next types PRINT. After the computer prints out the file the user checks it for errors. If he finds any, he can correct them by using FIX or by re-typing the sequence number and the data.
 8. After all changes are made the user must type SAVE again and should follow that with another PRINT command.

The user then schedules the job and names the output file, with a SCHEDULE command. The user checks on his job by a STATUS command. The computer will respond with SCHEDULED, RUNNING, or DONE.

When the job is DONE, the user requests to have the output file printed, with a PRINT command. The output file contains all of the questions, examples, and input lines just as though it had been run live. As such, a typical problem will produce an output file of about 150 lines, with 34 more lines if the table set is printed. Since the user is interested in only part of the output file, he can ask for printing of only the sequence numbers containing that part; those

sequence numbers can be calculated from Table 1. Example:
 If there are a total of ten lanes on four approaches and if the table set is to be printed, the user would enter PRINT Q16M1A 64-97, 108-146. The user can also have all or part of the file printed on the printer with a COPY TO PRINTER command. This method of printing the output takes considerably less machine time than does printing the information on the terminal.

The user, after reviewing the output, can change his input file and re-schedule the job if he wishes. If he wants to retain the input file, he can do so by either filing a dump card (p. 9) which will result in the file being stored magnetically for 15 days, and loaded onto the disk each day, or having the file punched on paper tape. The user will notice that the full 8 digit sequence number is punched when the first column in the output is a digit.

Number Of Approaches	Table Set Not Printed	Table Set Printed	
	Location Of OUTPUT TABLE	Location Of TABLE SET	Location Of OUTPUT TABLE
1	47 to (60 + N)*	37 to 70	81 to (96 + N)
2	56 to (74 + N)	46 to 79	90 to (108 + N)
3	65 to (88 + N)	55 to 88	99 to (122 + N)
4	74 to (102 + N)	64 to 97	108 to (136 + N)

* N = Total number of lanes, all approaches. This will print output through signal phasing.

In all cases the execution time required is shown in the seventh line following the end of the output table.

Table 1. Sequence Numbers for critical data in output file.

When the user is finished with a file he should clean up the machine storage by erasing it with a REMOVE command.

Example Problem

This example is designed to show:

1. How the program can be used to solve a three phase signal
2. How the program is run by scheduling

In this example, a five-lane north-south trunkline is intersected by a four-lane city street. The investigator is to develop a signal system for the intersection, based on the following information:

	M63 (Ohio Ave.)		Indiana St.	
1. Flow (vph)	Northbd	Southbd	Eastbd	Westbd
Left Turns	238	88	55	92
Thru Vehicles	1,213	1,057	474	387
Right Turns	122	39	61	206
TOTAL	<u>1,573</u>	<u>1,184</u>	<u>590</u>	<u>685</u>

2. Assume 5 percent trucks on all legs
3. All lane widths are 12 ft
4. Right turn lanes can be added to all approaches
5. Cycle-length is 75 sec.
6. Use 4 sec \pm amber
7. Cycle can be 2-, 3-, or 4-phase
8. Maximum V/C ratios for both routes should be balanced

The problem is approached by first attempting the simplest solution: A two-phase signal with existing laneage. If that doesn't produce an operational intersection it will at least provide a base for adjustments.

The percent amber is calculated: $4/75 = 0.0533$, say 0.05.

The approximate signal split is determined. In this case it is calculated by the ratios of highest flows per lane

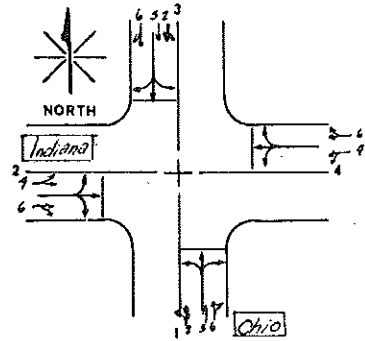
for each route

Route	High Flow Per Lane	Proportion
Ohio	NB 524	0.604
Indiana	WB 343	0.396
TOTAL	867	



INTERSECTION CAPACITY ANALYSIS

LOCATION <i>M63 Ohio @ Indiana / Prairie</i>	COUNTY <i>Wood</i>	CONTROL SECTION <i>84042</i>	JOB NUMBER
BY	DATE		

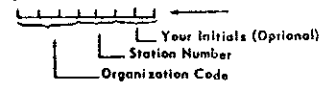


- INSTRUCTION:**
1. Number Approaches Consecutively
 2. Number Lanes from Outside to Inside
 3. Set Approach 1 Opposite 3 and 2 Opposite 4
 4. To gain access to the computer, follow this log-in sequence.

USER CODE: QTRAF

PASSWORD:

CHARGE CODE:



E Q16288

STEP 1 ENTER NUMBER OF APPROACHES: 4 (10)

STEP 2 ENTER LANE TYPE CODES:

APPR NO	LANE NUMBER	
	1 2 3 4 5 6	
1	6 5 2	(21)
2	6 4	(22)
3	6 5 2	(23)
4	6 4	(24)

LANE TYPE	
1 - Left Only W/out Opposing	
2 - Left Only W Opposing	
3 - Left/Thru Option W/out Opposing	
4 - Left/Thru Option W Opposing	
5 - Thru Only	
6 - Right/Thru Option	
7 - Right Only	
8 - Left/Right Option	

STEP 3 ENTER APPROACH VOLUMES, PERCENT OF TRUCKS, LANE WIDTH, CYCLE SPLIT:

APPR NO	APPROACH VOLUMES - VPH			PERCENT TRUCKS - %			LANE WIDTH - FT.	CYCLE SPLIT - G.A. (S)
	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT		
1	0238	1213	0122	0030	0050	0050	0120	0600
2	0055	0474	0001					0400
3	0088	1037	0039					0600
4	0092	0387	0206					0400

STEP 4 ENTER CYCLE LENGTH (SEC): 075 (40)

STEP 5 ENTER PERCENT OF AMBER (%): 050 (50)

STEP 6 ENTER NAME OF APPROACHES:

APPR NO	NAME OF APPROACHES
1	NB, OHIO, AV, (M63)
2	EB, INDIANA
3	SB, OHIO, AV, (M63)
4	WB, INDIANA

STEP 7 IF DATA IS BEING PUT IN A FILE, FOR SCHEDULING, ALSO TYPE:

NO (OR YES, IF TABLE IS TO BE PRINTED)
 NO
 EXC
 NO

Figure 3. Form 1569 for Ohio/Indiana Sample Problem

With this information the user can prepare Form 1569
 (Fig. 3), make the input file, and schedule the initial run:

```
#
MAKE Q16MI-
FILE:Q16MI - TYPE:SEQ -- CREATED
#
SEQ 110+10-
110E Q16288-
120A-
130652-
14064-
150652-
16064-
1700238,1213,0122,0050,0050,0050,0120,0600-
180055,0474,0061,0050,0050,0050,0120,0400-
190088,1057,0038,0050,0050,0050,0120,0600-
200092,0387,029'06,0050,0050,0050,0120,0400-
2100'5 DEL
210075-
220050-
230NB OHIO AV (M 63)-
240EB INDIANA+
250SB OHIO AV (M 63)-
260WB INDIANA-
270N0-
280N0-
290EXC-
300N0-
310-
#
SAVE+
WAIT-
```

FILE:Q16MI - TYPE:SEQ -- SAVED.

```
PRINT-
110 E Q16288
120 4
130 652
140 64
150 652
160 64
170 0238,1213,0122,0050,0050,0050,0120,0600
180 0055,0474,0061,0050,0050,0050,0120,0400
190 0088,1057,0038,0050,0050,0050,0120,0600
200 0092,0387,0206,0050,0050,0050,0120,0400
210 075
220 050
230 NB OHIO AV (M 63)
240 EB INDIANA
250 SB OHIO AV (M 63)
260 WB INDIANA
270 N0
280 N0
290 EXC
300 N0
```

```
#
SCHEDULE Q16MI TO Q16MIA-
WAIT-
```

END SCHEDULE 1.3 SEC.

```
STATUS Q16MIA-
RUNNING(17)
```

Later:

```
STATUS Q16MIA-
DONE.
P Q16MIA 74-112-
DESIGN ERRORS FOLLOW:
NO ERRORS TO REPORT
```

LANE	LANE TYPE	LEFT	THRU	RIGHT	CAP.	V/C
APPROACH 1 NB OHIO AV (M 63)						
1	(6) RIGHT/THRU OPTION	520	121	923		.69
2	(5) THRU ONLY	692		997		.69
3	(2) LEFT ONLY, W/OPPOSING	238		157		1.51
APPROACH 2 EB INDIANA						
1	(6) RIGHT/THRU OPTION	326	60	563		.68
2	(4) LEFT/THRU OPTION W/OPPOSIN	54	147	271		.74
APPROACH 3 SB OHIO AV (M 63)						
1	(6) RIGHT/THRU OPTION	501	38	969		.55
2	(5) THRU ONLY	555		995		.55
3	(2) LEFT ONLY, W/OPPOSING	88		94		.93
APPROACH 4 WB INDIANA						
1	(6) RIGHT/THRU OPTION	377	206	527		1.10
2	(4) LEFT/THRU OPTION W/OPPOSIN	91	9	101		1.01

SIGNAL SPLIT (75 SECOND CYCLE)

APPROACH		CYCLE SPLIT	TIME (SEC)
1	NB OHIO AV (M 63)	GREEN 55 %	41.25
		AMBER 5 %	3.75
2	EB INDIANA	GREEN 35 %	26.25
		AMBER 5 %	3.75
3	SB OHIO AV (M 63)	GREEN 55 %	41.25
		AMBER 5 %	3.75
4	WB INDIANA	GREEN 35 %	26.25
		AMBER 5 %	3.75

 REMOVE 016M1A-
 #

The capacity of a Type 2 or 4 lane is dependent more on the opposing thru flow than on cycle split, so the investigator knows that he probably cannot obtain sufficient left turn capacity for Approach 1 by increasing the green time (in fact, even at 100 percent green, the maximum capacity for Approach 1 is 207 left turns per hour). The left turn capacity for Approach 3 is two turns per cycle reduced by the truck factor. So the investigator decides that he needs a third phase. The third phase can either:

1. Stop Thru and Right-turn Flows and allow simultaneous left turns from Approaches 1 and 3, or
2. Stop Approach 3 and allow all movements from Approach 1

In either case, the left-turn flow from Approach 1

determines the cycle split required for the third phase. That flow equals 238 vph/48 cycles per hour = 5 vpc. From Table 2 (p.49) that flow requires about 15 sec of green time, or 19 sec (25 percent) of the cycle split, leaving 75 percent of the split available for Phases 1 and 2. The cycle splits required for the approaches can be estimated from the V/C ratios:

	App 1	App 2	App 3	App 4
(G + A) Split Provided	.600	.400	.600	.400
-Amber	<u>-.050</u>	<u>-.050</u>	<u>-.050</u>	<u>-.050</u>
=Green Provided	.550	.350	.550	.350
xV/C ratio	<u>x.69</u>	<u>x.68</u>	<u>x.55</u>	<u>x1.10</u>
=Green Required	.380	.238	.302	.385
+Amber	<u>+.050</u>	<u>+.050</u>	<u>+.050</u>	<u>+.050</u>
=Split Required	.430	.288	.352	.435

Summing all possible combinations:

Ohio	Indiana	App 2	App 4
App 1		0.718	0.865
App 3		0.640	0.787
(0.75 Available)			

It is evident that Approach 4 cannot be accommodated with either Ohio Avenue split. Thus added laneage, a right turn lane, will be needed for Approach 4, making Approach 2 the critical Indiana St. Approach.

It appears that the combination of Approaches 1 and 2 could be accommodated with a small amount of green time to spare (0.032 or 2.4 sec). But because the capacity equations are not linear, the cycle splits calculated above are too short if the V/C ratio is less than 1.00 and too long if the V/C ratio is more than 1.00. For example, to accommodate 69 percent of the capacity of Approach 1 requires about 72 percent of the green time provided. So the investigator could expect the Approach 1 and 2 combination to be over-capacity

and decides to use the second option for his third phase:
to stop Approaches 2, 3 and 4 and allow all moves for
Approach 1. He sets up his phasing:

Phase	App 1	App 2	App 3	App 4	Split Req'd	Split Provided
1	Red	Green	Red	Green	0.288	0.32
2	G(Th&Rt)	Red	Green	Red	0.352	0.40
3	Green	Red	Red	Red	0.250	0.28
TOTAL					0.890	1.00

The investigator corrects his input file by 1) adding a right-turn only (Type 7) lane to Approach 4; 2) removing the Type 2 lane and the left-turn flow from Approach 1; 3) changing the cycle splits to: Approach 1, 0.68 (sum of phases 2 and 3), Approach 2, 0.32, Approach 3, 0.40, Approach 4, 0.32.

The data for the solution of the third phase can be added to the input file by changing the last line from NO to YES (answer the question DO YOU WISH TO RUN ANOTHER ANALYSIS), following that with NEW (answer the question DO YOU HAVE ALL NEW DATA OR ONLY CHANGES TO THE OLD), and entering the data beginning with the number of approaches. Note that the Type 2 lane for Approach 1 becomes a Type 1 lane because there is no opposing traffic during Phase 3.

The investigator updates his file and schedules the second run:

```
LOAD 016M1+
FILE:016M1 - TYPE:SEQ -- LOADING
20 RECORDS LOADED, LAST RECORD LOADED=300
```

```
END LOAD 1.0 SEC.
```

```
FIX 130 #652#65+
FIX 160 #64#764+
FIX 170 #0238#0000+
FIX 170 #0050#0000+
FIX 170 #0600#0680+
FIX 180 #0400#0320+
FIX 190 #0600#0400+
FIX 200 #0400#0320+
```

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MICHIGAN DEPT. STATE HIGHWAYS &
TRANSPORTATION LANSING, MICH.**


```

SEQ 300+10+
300 YES+
310 NEW+
320 I+
330 I+
340 0238,0000,0000,0500,***050,0000,0000,0120,0280+
350 075+
360 050+
370 NB ØHIØ AV (M 63) *LT PHASE*+
380 NØ+
390 NØ+
400 EXC+
410 NØ+
420 C+
#
SAVE+
WAIT-

```

FILE:Q16M1 - TYPE:SEQ -- SAVED.

```

P 130, 160-200,300-END+
130 65
160 764
170 000,1213,0122,0000,0050,0050,0120,0680
180 0055,0474,0061,0050,0050,0050,0120,0320
190 0088,1057,0038,0050,0050,0050,0120,0400
200 0092,0387,0206,0050,0050,0050,0120,0320
300 YES
310 NEW
320 I
330 I
340 0238,0000,0000,0050,0000,0000,0120,0280
350 075
360 050
370 NB ØHIØ AV (M 63) *LT PHASE*
380 NØ
390 NØ
400 EXC
410 NØ

```

```

#
SCHEDULE Q16M1 TO Q16M1B+
WAIT.

```

END SCHEDULE 1.4 SEC.

The investigator can estimate the sequence numbers in the output table for the second problem by adding the sequence numbers calculated from Table 1 to the last sequence number for the output table for the first problem (112). For the second problem (1 approach, 1 lane) the output should be about (112 + 47) to (112 + 61). To be certain of including the entire output table, two or three lines on each side of these limits should also be printed, yielding the limits of 157-175.

```

STATUS Q16M1B+
DONE.
PRINT Q16M1B 74-112, 157-175+
DESIGN ERRORS FOLLOW:
NO ERRORS TO REPORT

```

LANE	LANE TYPE	LEFT	THRU	RIGHT	CAP.	V/C
APPROACH 1 NB OHIO AV (M 63)						
1	(6) RIGHT/THRU OPTION	519	121	1068		.60
2	(5) THRU ONLY	693		1157		.60
APPROACH 2 EB INDIANA						
1	(6) RIGHT/THRU OPTION	331	60	419		.93
2	(4) LEFT/THRU OPTION W/OPPOSIN	54	142	207		.95
APPROACH 3 SB OHIO AV (M 63)						
1	(6) RIGHT/THRU OPTION	502	38	580		.93
2	(5) THRU ONLY	554		594		.93
3	(2) LEFT ONLY, W/OPPOSING	88		94		.93
APPROACH 4 WB INDIANA						
1	(7) RIGHT ONLY		206	330		.62
2	(6) RIGHT/THRU OPTION	381		441		.86
3	(4) LEFT/THRU OPTION W/OPPOSIN	91	5	98		.99

SIGNAL SPLIT (75 SECOND CYCLE)

APPROACH		CYCLE SPLIT	TIME (SEC)
1	NB OHIO AV (M 63)	GREEN 63 %	47.25
		AMBER 5 %	3.75
2	EB INDIANA	GREEN 27 %	20.25
		AMBER 5 %	3.75
3	SB OHIO AV (M 63)	GREEN 35 %	26.25
		AMBER 5 %	3.75
4	WB INDIANA	GREEN 27 %	20.25
		AMBER 5 %	3.75

STP TO STOP THE RUN
PRT TO PRINT TABLE SET AGAIN

??EXC
DESIGN ERRORS FOLLOW:
NO ERRORS TO REPORT

LANE	LANE TYPE	LEFT	THRU	RIGHT	CAP.	V/C
APPROACH 1 NB OHIO AV (M 63) *LT PHASE*						
1	(1) LEFT ONLY, W/OUT OPPOSING	238		278		.85

SIGNAL SPLIT (75 SECOND CYCLE)

APPROACH		CYCLE SPLIT	TIME (SEC)
1	NB OHIO AV (M 63) *LT PHASE*	GREEN 23 %	17.25
		AMBER 5 %	3.75

REMOVE Q16M1B-
#

The investigator now has an operational design, he needs to make only minor adjustments. The right-turn lane he added to Approach 4 has considerable surplus capacity, so he removes the dual turn by changing the Type 6 lane to a Type 5. This will not effect the computed capacity. The V/C ratio for the third phase is slightly lower than those for the other two phases. The investigator attempts to balance

these by taking two percent from Phase 3's split and adding one percent to each of the others. To prepare a work file for the intersection, he also has the table sets printed for both problems (sequence numbers 270 and 380). With these changes the investigator schedules the third run:

```
LOAD Q16M1-
FILE:Q16M1 - TYPE:SEQ -- LOADING
31 RECORDS LOADED, LAST RECORD LOADED=410
```

```
END LOAD .9 SEC.
```

```
FIX 160 #764#754-
FIX 270 #NO#YES-
FIX 380 #NO#YES-
FIX 170 #680#670-
FIX 180 #320#330-
FIX 190 #400#410-
FIX 200 #320#330-
FIX 340 #280#260-
SAVE-
WAIT-
```

```
FILE:Q16M1 - TYPE:SEQ -- SAVED.
```

```
P 160-200,270,340,380-
160 754
170 0000,1213,0122,0000,0050,0050,0120,0670
180 0055,0474,0061,0050,0050,0050,0120,0330
190 0088,1057,0038,0050,0050,0050,0120,0410
200 0092,0387,0206,0050,0050,0050,0120,0330
270 YES
340 0238,0000,0000,0050,0000,0000,0120,0260
380 YES
```

```
#
SCHEDULE Q16M1 TO Q16MIC-
WAIT.
```

```
END SCHEDULE 1.3 SEC.
```

```
STATUS Q16MIC-
RUNNING(12)
```

Later he prints out his output and he is finished with the computer.

```
STATUS Q16MIC-
DONE.
P Q16MIC 64-97, 108-146, 184-217, 228-242, 249-
```

```
NUMBER OF APPROACHES: 4 CODE 10
```

LANE TYPE	CODE						CODE
APP LANE NUMBER	DE						DE
NO	1	2	3	4	5	6	
1	6	5					21
2	6	4					22
3	6	5	2				23
4	7	5	4				24

APP NO.	APP LEFT	VOLUMES THRU	VPH RIGHT	PERCENT LEFT	PERCENT THRU	OF TRUCKS RIGHT	LANE WIDTH	CYCLE SPLIT	CØ DE
1		1213	122		5.0	5.0	12.0	.670	31
2	55	474	61	5.0	5.0	5.0	12.0	.330	32
3	88	1057	38	5.0	5.0	5.0	12.0	.410	33
4	92	387	206	5.0	5.0	5.0	12.0	.330	34

CYCLE LENGTH 075 SECONDS CØDE 40

% OF AMBER .050 DECIMAL CØDE 50

1 NB OHIO AV (M 63) CØDE 61
 2 EB INDIANA CØDE 62
 3 SB OHIO AV (M 63) CØDE 63
 4 WB INDIANA CØDE 64

DESIGN ERRORS FOLLOW:
 NO ERRORS TO REPORT

LANE LANE TYPE LEFT THRU RIGHT CAP. V/C

APPROACH 1 NB OHIO AV (M 63)
 1 (6) RIGHT/THRU OPTION 519 121 1052 .61
 2 (5) THRU ONLY 693 1136 .61

APPROACH 2 EB INDIANA
 1 (6) RIGHT/THRU OPTION 331 60 437 .89
 2 (4) LEFT/THRU OPTION W/OPPØSIN 54 142 214 .92

APPROACH 3 SB OHIO AV (M 63)
 1 (6) RIGHT/THRU OPTION 502 38 599 .90
 2 (5) THRU ONLY 554 613 .90
 3 (2) LEFT ONLY, W/OPPØSING 88 94 .93

APPROACH 4 WB INDIANA
 1 (7) RIGHT ONLY 206 344 .59
 2 (5) THRU ONLY 381 459 .83
 3 (4) LEFT/THRU OPTION W/OPPØSIN 91 5 98 .99

SIGNAL SPLIT (75 SECONØ CYCLE)

APPROACH	LANE	LANE TYPE	GREEN	AMBER	CYCLE SPLIT	TIME (SEC)
1	NB OHIO AV (M 63)		GREEN	62 %	46.50	
			AMBER	5 %		3.75
2	EB INDIANA		GREEN	28 %	21.00	
			AMBER	5 %		3.75
3	SB OHIO AV (M 63)		GREEN	36 %	27.00	
			AMBER	5 %		3.75
4	WB INDIANA		GREEN	28 %	21.00	
			AMBER	5 %		3.75

NUMBER OF APPROACHES: 1 CØDE 10

LANE TYPE	CØ DE
APP LANE NUMBER	DE
NØ 1 2 3 4 5 6	
1 1	21
2	22
3	23
4	24

APP NO.	APP LEFT	VOLUMES THRU	VPH RIGHT	PERCENT LEFT	PERCENT THRU	OF TRUCKS RIGHT	LANE WIDTH	CYCLE SPLIT	CØ DE
1	238			5.0			12.0	.260	31
2								.000	32
3								.000	33
4								.000	34

CYCLE LENGTH 075 SECONDS CØDE 40

% OF AMBER .050 DECIMAL CODE 50

1 NB OHIO AV (M 63) *LT PHASE* CODE 61
2 CODE 62
3 CODE 63
4 CODE 64

DESIGN ERRORS FOLLOW:
NO ERRORS TO REPORT

LANE LANE TYPE LEFT THRU RIGHT CAP. V/C

APPROACH 1 NB OHIO AV (M 63) *LT PHASE*
1 (1) LEFT ONLY, W/O OUT OPPOSING 238 252 .94

SIGNAL SPLIT (75 SECOND CYCLE)

APPROACH CYCLE SPLIT TIME (SEC)
1 NB OHIO AV (M 63) *LT PHASE* GREEN 21 % 15.75
AMBER 5 % 3.75

END Q16288 7.9 SEC.

REMOVE Q16M1, Q16M1*IC-
#

Had the investigator selected the first option for the third phase (p. 41) and allowed simultaneous left turns from Approaches 1 and 3, he would have obtained a design that is on the margin of being operational:

Phase	Approach	Second Run		Third Run	
		Split	V/C	Split	V/C
1	App 2	0.30	1.03	0.31	0.98
	App 4	0.30	0.95	0.31	0.90
2	App 1	0.44	1.02	0.45	0.99
	App 3	0.44	0.82	0.45	0.80
3	App 1	0.26	0.94	0.24	1.05
	App 3	0.26	0.35	0.24	0.39

CHAPTER 4

THE THEORY USED IN INTERSECTION CAPACITY ANALYSIS

The equations used in the program for estimating lane capacity are the product of in-the-field research that culminated in the summer of 1972. Four locations were studied with the total survey data amounting to slightly less than 30,000 vehicles. Each site was to represent lane headway characteristics for population areas over 10,000, 100,000, and 1 million. Consequently, one intersection was selected in Charlotte, one near Lansing and two in the greater Detroit area.

All intersections intersect at or near 90 degrees with flat grades, have good alignment, curb and gutter, and generally are void of deficiencies that would significantly affect the results of the study. During the survey period all vehicles of the approaching traffic were recorded.

The equations selected for the intersection capacity analysis program were developed from the data obtained at the Study Site Number 3: Southfield Road at 10 Mile Road, City of Southfield, Oakland County.

Being the first major intersection north of the northern terminus of M-39, a north-south freeway, it is one of the most heavily used intersections in Michigan. Excessive backups are experienced on all legs for several hours during the day.

Traffic control was provided by a two-phase, 80-sec

cycle, stop-and-go traffic signal with 39 sec of green time for Southfield Road.

The southbound approach of Southfield Road consists of two 12 ft lanes with right turns occurring from Lane 1. A center left-turn lane provides storage for vehicles desiring to turn left.

The northbound approach consists of two thru lanes, a center left-turn lane and a right-turn lane. Both approaches have 12 ft lanes.

A real-time recorder was used in registering the individual headways of successive vehicles per lane. The recorder registered sixty bits of information every one-quarter of a second. The controls were divided into ten panels with six buttons per control panel. Each lane of the approach was assigned one control panel. The first four buttons (bits) were coded with respect to the vehicular characteristics as follows:

- #1 Passenger vehicle thru
- #2 Passenger vehicle turn*
- #3 Truck thru
- #4 Truck turn*

For this study trucks were defined as vehicles having more than one rear axle or one rear axle with dual tires. In general, single unit vehicles were considered trucks and vehicles such as pickups and panel trucks were recorded as passenger vehicles. A datum line was determined for each approach being surveyed. Normally, the stop bar, a standard

* The turn was either right or left depending upon the lane position

VEH	THRU LANE		TURN LANE	
	HEADWAY	TOTAL TIME	HEADWAY	TOTAL TIME
1	3.02	3.02	3.52	3.52
2	2.57	5.59	3.11	6.63
3	2.24	7.82	2.83	9.46
4	2.03	9.86	2.68	12.14
5	1.95	11.81	2.65	14.80
6	1.91	13.72	2.65	17.45
7	1.90	15.62	2.65	20.09
8	1.88	17.50	2.65	22.75
9	1.87	19.37	2.65	25.40
10	1.85	21.23	2.65	28.05
11	1.84	23.07	2.65	30.69
12	1.82	24.89	2.65	33.34
13	1.81	26.70	2.65	36.00
14	1.79	28.49	2.65	38.65
15	1.78	30.27	2.65	41.29
16	1.76	32.03	2.65	43.94
17	1.75	33.78	2.65	46.59
18	1.75	35.53	2.65	49.24
19	1.75	37.28	2.65	51.89
20	1.75	39.03	2.65	54.54
21	1.75	40.78	2.65	57.19
22	1.75	42.53	2.65	59.84
23	1.75	44.28	2.65	62.49
24	1.75	46.03	2.65	65.14
25	1.75	47.78	2.65	67.79
26	1.75	49.53	2.65	70.44
27	1.75	51.28	2.65	73.09
28	1.75	53.03	2.65	75.75
29	1.75	54.78	2.65	78.39
30	1.75	56.53	2.65	81.04
31	1.75	58.28	2.65	83.69
32	1.75	60.03	2.65	86.34
33	1.75	61.78	2.65	89.00
34	1.75	63.53	2.65	91.64
35	1.75	65.28	2.65	94.29
36	1.75	67.03	2.65	96.94
37	1.75	68.78	2.65	99.59
38	1.75	70.53	2.65	102.25
39	1.75	72.28	2.65	104.89
40	1.75	74.03	2.65	107.54

Table 2. Headways and Total Green Time required for Thru and Turn Passenger Cars

pavement marking at signalized intersections, served as the datum line. If not available, a painted yellow line was applied prior to the survey and located at the springpoint of the curbed turning radius.

An individual from the survey crew was assigned to a particular lane. As the rear tire of successive vehicles touched the datum line, an impulse was recorded via the appropriate bit with respect to vehicle type and movement. Impulses were recorded for every vehicle until the queue had cleared the intersection. An additional crew member was assigned a control panel to record the signal phases. Survey crews varied in size depending on the number of lanes being surveyed. Twenty-four hour machine counts supplemented the survey by providing approach volumes and turning movements.

A simple computer program was developed to read the magnetic tape from the recorder and reconstruct the lane-flow characteristics.

In assembling the data in a usable form, individual headways were determined by hand from the computer printouts. Average headways for each variable were computed from the first to the n^{th} vehicle of the queue. The average headways were classified with respect to study site, peak period, lane position, vehicle type and vehicle movement. The average headways for passenger vehicles making a thru movement were plotted with respect to time and vehicle position in the queue.

In developing a relationship for the various conditions previously mentioned, a mathematical curve fitting was

applied by using the basic quadratic equation $Y = aX^2 + bX + c$ and linear equation $Y = mX + b$. The coefficients were computed from the empirical data. Often both equations were needed for a good fit. To ensure the proper tangency between the two equations the slope of the linear equation was equated to the first derivative of the quadratic equation.

$$m = \frac{dy}{dx} = 2aX + b$$

Knowing the relationship of individual starting headways as a function of time and vehicle queue position, lane-cycle capacity (total time required) was easily determined by integrating the previously mentioned equations. Due to the fact that the variable does not vary uniformly with time, a simple adjustment was introduced. Consequently, the basic equation is as follows:

$$\begin{aligned}
 t &= \int_{x=0}^{x=i} (aX^2 + bX + c) dx \\
 &+ \frac{1}{2} \int_{x=0}^{x=i} [2aX + (a + b)] dx \\
 &+ \int_{x=i}^{x=n} [mX + (\frac{1}{2}m + b)] dx
 \end{aligned}$$

Therefore:

$$\begin{aligned}
 T &= \left| \frac{a}{3}X^3 + \frac{(a + b)}{2}X^2 + (\frac{1}{2}a + \frac{1}{2}b + c) X \right|_{x=0}^{x=i} \\
 &+ \left| \frac{m}{2}X^2 + (\frac{1}{2}m + b) X \right|_{x=i}^{x=n}
 \end{aligned}$$

T = the total amount of green time/cycle needed to clear a queue of n vehicles.

For program Q16288, those equations are:

Thru Lane:

$$T = \left| 0.0210 X^3 - 0.291 X^2 + 3.292 X \right|_{\substack{x=5 \\ x=0}} \\ + \left| - 0.00765 X^2 + 1.999 X \right|_{\substack{x=n \\ x=5}}$$

Turn Lane:

$$T = \left| 0.0214 X^3 - 0.269 X^2 + 3.769 X \right|_{\substack{x=5 \\ x=0}} \\ + \left| - 0.0194 X^2 + 2.417 X \right|_{\substack{x=n \\ x=5}}$$

When these equations were expanded for long cycle length it was found that the computed capacities were abnormally high for thru lanes and low for turn lanes. To compensate, these equations are discontinued and replaced with constant headways at the arbitrary values of 1.75 sec headway for thru lanes after the 17th vehicle (33.78 sec of green time) and 2.65 sec for turn lanes after the 5th vehicle (14.80 sec of green time). The individual headways and total green times used in the program are shown in Table 2.

The backbone of the research is the hypothesis that the capacity of an intersection is highly correlated to the type of lane operation and variability of individual vehicular headways with length of green time. The common denominator for analysis is the headway of a passenger thru vehicle. Compensation factors are used for converting turning vehicles and trucks to equivalent passenger thru vehicles.

There are many factors that affect capacity; most are difficult to quantitate. The study sites were selected to minimize the effects of these factors. Therefore, in using

the capacity equations of this study the following should be assumed: signalization, good pavement; relatively flat approaches, moderate or no pedestrians traffic and in general a good geometric design.

Preliminary use of these capacity equations indicates that the resultant values represent the upper limits of true capacity. Thus actual volumes will seldom if ever exceed calculated volumes. For design purposes v/c ratios of less than 1.0 should be used.

APPENDIX 1

PROCEDURE FOR RUNNING COMPUTER JOBS BY BATCH MODE

This appendix shows by example how to set up a deck of punch cards so that a job can be run by batch mode. The example used is Program Q17150, for loading a deck of cards onto the disk. This description is very brief. The complete procedure for all types of programs is given in the Department's 198-page Data Processing Guide.

① STATE OF MICHIGAN
DEPARTMENT OF STATE HIGHWAYS
COMPUTER SERVICE DIVISION

COMPUTER SERVICE REQUEST

Form 2350 F (Rev. 10/72)
Destroy all previous editions.

Please run for production program(s) **Q17150** Date Submitted _____ Org. Code **490**

Distribution Normal Other **TRAFFIC & SAFETY** Don. Marcer

Special Instructions (Use when deviating from abstract)
TSS

Output Needed: (Check one) 24 Hrs. 3 Days 1 Week Other

Oper. Inits. _____ Run Date _____

① All jobs begin with Form 2350F, "Computer Services Request," showing the program number. To aid in returning the cards and output to the user, he should include the division name and his name on the card. For program Q17150 only, the letters TSS (for Time Sharing System) tell the Machine Operation Section that the user is waiting to use

the program results on the terminal; so, if possible, they will run the job immediately instead of running it overnight.

② The next card (pink-colored) lists the program to be run. The first column is punched so as to be unrecognizable to the computer; in this case the numbers 1, 2, and 3 were all punched in that column. This card punch applies to all the pink-colored control cards. The command (COMPILE or EXECUTE) to the computer begins in the third column. The user's organization code is punched in columns 60 to 62, the letters HY in columns 67 and 68, and the user's initials in columns 70 to 72.

③ The next card (pink-colored) tells the computer the name of the file being loaded. Different programs require different cards here. In some cases hundreds of cards may be required at this point.

④ The next card (pink-colored) informs the computer that the data for the run will follow. The "C" after the "Q" in the file name signifies that the data is on cards.

⑤ The next cards (salmon-colored) are the data cards; the data must be in proper order and in the form required by the program. For program Q17150, the sequence numbers of the data cards are punched in columns 72 to 80. The data will be listed in the time-sharing file as type UNKNOWN; the user must correct the type. In this example, the first 3 cards of the file given on page 38 are shown.

⑥ The last card (pink) is the END statement.

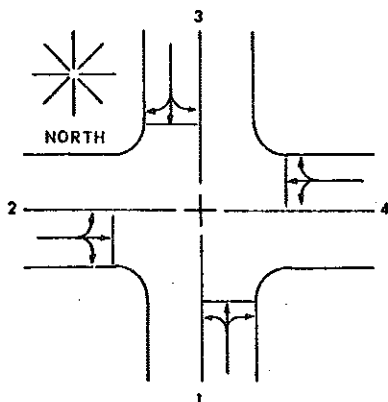
APPENDIX 2

INPUT FORM FOR INTERSECTION CAPACITY ANALYSIS



INTERSECTION CAPACITY ANALYSIS

LOCATION	COUNTY	CONTROL SECTION	JOB NUMBER
BY		DATE	



INSTRUCTION:
 1. Number Approaches Consecutively
 2. Number Lanes from Outside to Inside
 3. Set Approach 1 Opposite 3 and 2 Opposite 4
 4. To gain access to the computer, follow this log-in sequence.

USER CODE: QTRAF

PASSWORD:

CHARGE CODE: _____
 Your Initials (Optional)
 Station Number
 Organization Code

E Q16288

STEP 1 ENTER NUMBER OF APPROACHES: _____ (10)

STEP 2 ENTER LANE TYPE CODES:

APPR NO	LANE NUMBER					
	1	2	3	4	5	6
1						
2						
3						
4						

(21) (22) (23) (24)

LANE TYPE	
1 - Left Only W/out Opposing	
2 - Left Only W Opposing	
3 - Left/Thru Option W/out Opposing	
4 - Left/Thru Option W Opposing	
5 - Thru Only	
6 - Right/Thru Option	
7 - Right Only	
8 - Left/Right Option	

STEP 3 ENTER APPROACH VOLUMES, PERCENT OF TRUCKS, LANE WIDTH, CYCLE SPLIT:

APPR NO	APPROACH VOLUMES - VPH						PERCENT TRUCKS - %						LANE WIDTH (FT)	CYCLE SPLIT G + A (%)
	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT								
1														
2														
3														
4														

(31) (32) (33) (34)

STEP 4 ENTER CYCLE LENGTH (SEC): _____ (40)

STEP 5 ENTER PERCENT OF AMBER (%): _____ (50)

STEP 6 ENTER NAME OF APPROACHES:

APPR NO	NAME OF APPROACHES
1	
2	
3	
4	

(61) (62) (63) (64)

STEP 7 IF DATA IS BEING PUT IN A FILE, FOR SCHEDULING, ALSO TYPE:

NO (OR YES; IF TABLE IS TO BE PRINTED)
 NO
 EXC
 NO

REFERENCES

1. Burroughs Advanced Statistical Inquiry System Reference Manual, Burroughs Corporation, Detroit Michigan (1969).
2. Burroughs B5500 Time Sharing System Terminal User's Guide, Burroughs Corporation, Detroit Michigan (1969).
3. Maleck, Thomas L., Vehicular Starting Headways as a Function of Lane Operation and Green Time, Master's Degree Thesis, Michigan State University, East Lansing, Michigan (1972).
4. Peckham, Donald J., Data Processing Guide, Michigan Department of State Highways, Lansing (1970).