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USER'S MANUAL for Interactive MAXBAND

(Arterial Case)

by

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WP#1178-80 December 1980

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Abstract

MAXBAND is a computer program that finds traffic signal settings to maximize bandwidths on arteries.

This manual describes an interactive version of MAXBAND that runs on a PR1ME 400 computer at the Sloan School of Management, M.I.T. Inputs are arterial geometry, signal splits, range of acceptable cycle lengths, ranges of acceptable speeds and left turn phasing patterns permitted. The outputs produced are bandwidths, cycle length, beginning and ending times of splits and greenband at each signal, link speeds and space-time diagrams. The manual describes how the user gets onto the computer and uses the program. Traces are presented for two sample sessions; one using a printing terminal to solve a short artery (5-signals), and another using a graphics terminal to solve a longer artery (11-signals).

This version of MAXBAND lacks two features found in a batch program developed for the FHWA: the calculation of green splits from link flows and the ability to handle triangular networks.

CHAPTER 1

Introduction

The manner in which traffic signals are set affects large numbers of people every day. It is therefore desirable to be able to set signals well and to be able to do so quickly and easily.

MAXBAND is a computer program that finds traffic signal settings on arteries so as to achieve maximal bandwidth. Problems are formulated as mixed integer programs based on a theory developed by Little [1966;1977].

This user's manual describes a particularly convenient interactive version of MAXBAND written in EXPRESS, a high level computer language. The mixed integer program is solved using a mathematical programming package written in FORTRAN by Land and Powell [1973]. A previous interactive version written in EXPRESS was implemented by Rizzi [1977], and a batch program version written in FORTRAN has been prepared for the Federal Highway Administration by Little and Kelson [1980]. The latter contains two features not present in the on-line version; namely, the ability to calculate splits from link flows and the ability to handle simple triangular networks.

The program is currently available on the PR1ME 400 minicomputer located at the Sloan School of Management, M.I.T. The program could be implemented on any facility which supports EXPRESS, for example, the TYMSHARE IBM/370 network which currently offers EXPRESS on a national basis.

System inputs include:

1. Arterial geometry
2. Signal splits
3. Range of acceptable cycle lengths
4. Ranges of acceptable speeds
5. Left turn phasing patterns permitted

Outputs include:

1. Bandwidth in each direction
2. Cycle length
3. Beginning and ending times of splits and greenband at each signal
4. Speeds on links
5. Space-time diagrams

It is recommended that problems with 10 or less signals be run on-line, while larger problems (up to 15 signals) should be run under batch operations since it takes several hours to solve such problems on the PR1ME. Batch operations require documentation not provided in this manual. To obtain such documentation, contact the East Campus Computing Facilty at the Sloan School of Management.

Anyone who would like to solve a problem on an experimental basis should contact John D. C. Little at the Sloan School of Management, M.I.T., Cambridge, MA 02139, (617) 253-3738.

CHAPTER 2

Inputs

Most users will not require the full generality of the program. Therefore, a standard problem will be defined as one that (1) has a single outbound design speed and associated tolerance and a single inbound design speed and tolerance, (2) has the limit on speed change from one link to the next fixed at 10 per cent of the design speed, and (3) has no band advances for queue clearance in either direction at any signal.

A symmetric problem will be defined as one in which all the inbound data is exactly the same as the outbound data; hence, the program only asks for the outbound data.

A general problem has no limitations on any of the inputs.

The following few pages contain filled out input forms for a symmetric case, a standard case and a general case. Chapter 4 gives complete traces for running the first two of these problems. Blank input forms for all cases appear in Appendix A.

The computer starts by asking for the following information which the user provides as applicable:

Artery name
System of units - Metric or English
Number of signals
Signal names
Type of system - asymmetric or symmetric
Outbound distance between signals
Cycle time range
Outbound design speed
Outbound tolerance on design speed
Outbound limit on speed change from previous link
Outbound red/green splits
Outbound band advance (for queue clearing, if applicable)

If the user has indicated a symmetric case, the input is finished. Otherwise (standard or general case) he provides the following additional data as applicable:

Inbound distance between signals
Inbound design speed
Inbound tolerance on design speed
Inbound limit on speed change from previous link
Outbound left turn splits
Inbound red/green splits
Inbound left turn splits
Inbound band advance
Desired ratio of inbound to outbound greenbands
Left turn pattern selection

It should be pointed out that left turn green times are only used in the asymmetric (standard or general) case.

Standard Artery

(1) Name of artery: Main St. Waltham Ma Number of signals 11

(2) Cycle time: Lower limit 60 (seconds). Upper limit 100 (seconds).

(3) Outbound speed: Design center 30 kph ~~mph~~. Tolerance ± 3 kph ~~mph~~.

(4) Inbound speed: Design center 30 kph ~~mph~~. Tolerance ± 3 kph ~~mph~~.

(5) Target ratio of inbound to outbound band width: 1.0

(6) Signal name (down = outbound)	(7) Distance from previous signal (meters ~~feet~~)	(8) Thru green outbound (fraction of cycle)	(9) Thru green inbound (fraction of cycle)	(10) Left turn green outbound (fraction of cycle)	(11) Left turn green inbound (fraction of cycle)	(12) Acceptability of Left Turn Patterns (1 = acceptable, 0 = not): Outbound LT before green and inbound LT before green (a)	Outbound LT before green and inbound LT after green (b)	Outbound LT after green and inbound LT before green (c)	Outbound LT after green and inbound LT after green (d)
1 Banks	xxxxxxx	.6875	.5375	.15	0	1		1	
2 Prospect	247	.4375	.4375	0	0	0		0	
3 Bacon	337	.7125	.575	.1375	0	1		1	
4 Exchange	220	.75	.75	0	0	0		0	
5 Moody	244	.325	.325	0	0	0		0	
6 Lexington	110	.6625	.3875	.275	0	1		1	
7 Elm	70	.6625	.3875	.275	0	1		1	
8 Appleton	253	.75	.75	0	0	0		0	
9 Lyman	125	.5875	.5875	0	0	0		0	
10 Newton	104	.4625	.4625	0	0	0		0	
11 Linden	320	.65	.45	.2	0	1		1	
12									
13									
14									
15									

Notes by item number: (3) (4) If no tolerance specified, ±10% is assumed as a default. A limit on change in speed between signals equal to the tolerance is assumed. (5) Actual ratio will be target ratio unless larger band width is at its limit and smaller can be further increased, in which case it will be. (12) If only outbound has left turn phases, fill in (a) and (c); if only inbound, (a) and (b). Other columns are 0.

MAXBAND

Symmetric Artery

(1) Name of artery: Broadway, Cambridge, Ma. Number of signals 5

(2) Cycle time: Lower limit 80 (seconds). Upper limit 100 (seconds).

(3) Speed: Design center 45 (kph ~~mph~~). Tolerance ± 5 (kph ~~mph~~)

(4) Signal name (down = outbound)	(5) Distance from previous signal (meters ~~feet~~)	(6) Green time (fraction of cycle)
1 Portland	xxxxxxxx	.525
2 Windsor	305	.6
3 Columbia	168	.6375
4 Prospect	335	.4
5 Inman	183	.6
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

Notes by item number: (3) If no tolerance is specified ± 10% of design speed is assumed. A limit on change of speed between signals equal to the tolerance is assumed.

MAXBAND

General Artery

(1) Name of artery: Wisconsin Ave., Washington, D.C. Number of signals 15

(2) Cycle time: Lower limit 60 (seconds). Upper limit 100 (seconds).

(3) Target ratio of inbound to outbound band width: 1.0

(4) Maximum number of iterations 100,000

OUTBOUND DATA

(5) Signal name (down = outbound)	(6) Outbound distance from previous signal (meters ~~feet~~)	(7) Outbound design speed from previous signal (kph ~~mph~~)	(8) Outbound speed tolerance in (7) ± (kph ~~mph~~)	(9) Limit on outbound speed change from previous link ± (kph ~~mph~~)	(10) Thru green outbound (fraction of cycle)	(11) Left turn green for outbound (fraction of cycle)	(12) Outbound band advance for queue clearance (fraction of cycle)
1 Wiscon1	xxxxxx	xxxxx	xxxxx	xxxxx	.5	0	0
2 Wiscon2	326	24.14	3.22	xxxxx	.6753	0	0
3 Wiscon3	132	24.14	3.22	3.22	.5429	0	0
4 Wiscon4	183	24.14	3.22	3.22	.6571	0	0
5 Wiscon5	348	24.14	3.22	3.22	.4	0	0
6 Wiscon6	101	24.14	3.22	3.22	.6571	.2571	0
7 Wiscon7	311	24.14	3.22	3.22	.5429	0	0
8 Wiscon8	242	24.14	3.22	3.22	.4143	0	0
9 Wiscon9	290	24.14	3.22	3.22	.7857	0	.05
10 Wiscon10	126	24.14	3.22	3.22	.6429	0	0
11 Wiscon11	352	24.14	3.22	3.22	.4857	0	0
12 Wiscon12	99	24.14	3.22	3.22	.6714	0	0
13 Wiscon13	230	24.14	3.22	3.22	.5857	0	0
14 Wiscon14	345	24.14	3.22	3.22	.55	.075	0
15 Wiscon15	189	24.14	3.22	3.22	.675	0	0

Notes by item number: (3) Actual ratio will be target ratio unless smaller band can be further increased after larger has reached its limit. (4) Default = 10,000. (7) Default is all speeds equal. (8) Default is ± 10% of design speed. (9) Default is speed tolerance of (8).

General Artery (cont.)

(13) Name of Artery: Wisconsin Ave., Washington, D.C.

INBOUND DATA

(14) Signal name (down = outbound) (same as page 1)	(15) Inbound Distance from previous signal (meters ~~feet~~)	(16) Inbound design speed (kph ~~mph~~)	(17) Inbound speed tolerance in (16) ± (kph ~~mph~~)	(18) Limit on inbound speed change from previous link ± (kph ~~mph~~)	(19) Thru green inbound (fraction of cycle)	(20) Left turn green for inbound (fraction of cycle)	(21) Inbound band advance for queue clearance (fraction of cycle)
1 Wiscon1	xxxx	xxxx	xxxx	xxxx	.5	0	0
2 Wiscon2	326	24.14	3.22	xxxx	.6753	0	.05
3 Wiscon3	132	24.14	3.22	3.22	.5429	0	0
4 Wiscon4	183	24.14	3.22	3.22	.6571	0	0
5 Wiscon5	348	24.14	3.22	3.22	.4	0	0
6 Wiscon6	101	24.14	3.22	3.22	.4	0	0
7 Wiscon7	311	24.14	3.22	3.22	.5429	0	0
8 Wiscon8	242	24.14	3.22	3.22	.5714	.1571	0
9 Wiscon9	290	24.14	3.22	3.22	.7857	0	0
10 Wiscon10	126	24.14	3.22	3.22	.6429	0	0
11 Wiscon11	352	24.14	3.22	3.22	.4857	0	0
12 Wiscon12	99	24.14	3.22	3.22	.6714	0	.05
13 Wiscon13	230	24.14	3.22	3.22	.5857	0	0
14 Wiscon14	345	24.14	3.22	3.22	.475	0	0
15 Wiscon15	189	24.14	3.22	3.22	.675	0	0

Notes: (15) Default is outbound distance. (16) Default is outbound speed. (17) Default is ± 10% of design speed of (16). (18) Default is speed tolerance of (17).

General Artery (cont)

(22) Name of Artery: Wisconsin Ave., Washington, D.C.

LEFT TURN PATTERN CONSTRAINTS

(23)	(24)			
	Acceptability of Left Turn Patterns (1 = acceptable, 0 = not)			
	Outbound LT before green and		Outbound LT after green and	
Signal name (down = outbound) (same as page 1)	inbound LT before green (a)	inbound LT after green (b)	inbound LT before green (c)	inbound LT after green (d)
1 Wiscon1	0	0	0	0
2 Wiscon2	0	0	0	0
3 Wiscon3	0	0	0	0
4 Wiscon4	0	0	0	0
5 Wiscon5	0	0	0	0
6 Wiscon6	1	0	1	0
7 Wiscon7	0	0	0	0
8 Wiscon8	1	1	0	0
9 Wiscon9	0	0	0	0
10 Wiscon10	0	0	0	0
11 Wiscon11	0	0	0	0
12 Wiscon12	0	0	0	0
13 Wiscon13	0	0	0	0
14 Wiscon14	1	0	1	0
15 Wiscon15	0	0	0	0

Notes: (24) Default condition is that all left turn patterns are acceptable. If only outbound has left turn phases, fill in (a) and (c); if only inbound, (a) and (b). Other columns are 0.

CHAPTER 3

Using the Computer

SECTION 3.1

Logging into the PR1ME

Interactive MAXBAND exists on a PR1ME 400 minicomputer located at the Sloan School of Management and can be reached by dialing:

617-258-6008

One must obtain a login username and password. After calling and getting connected to the computer, hit the carriage return (for the rest of this user's manual, <cr> means hit the carriage return). The computer will then print

login please

Hit return again, and the computer will print a password mask. Then type (in capital letters)

LOGIN username password <cr>

If you get double images, type

TERM -HALF <cr>

If you get no images, type

TERM -FULL <cr>

Note: @ is the character delete and [is the line delete.

Now type

A L7LITTLE password <cr>

(Consult Professor Little for the current password.)

Next type

A L.AND.P 0 2 <cr>

SECTION 3.2

Entering EXPRESS

Now we want to get into EXPRESS, so type

DSS MAXBAND <cr>

The computer will print four lines each saying LOAD COMPLETE, then a warning message that may be disregarded. Finally the following appears

WELCOME TO MAXBAND (THE MESSAGES ABOVE ARE ALL IRRELEVANT)

If you are using a graphics terminal, you will find it helpful to read the EXPRESS plotter booklet. This will tell you how to identify the plotter you are using to the computer. For example, if you are using a Tektronix terminal, you type

TERMINAL TEKxxxx <cr>

where xxxx is replaced by the number of the terminal. In our example, we will be using a Tektronix 4013, so we type

TERMINAL TEK4013 <cr>

For most printing terminals, no terminal identification is necessary.

SECTION 3.3

Entering Street Data

The user simply types

MB.INPUT <cr>

and answers the questions asked. The number of signals must be between 3 and 20. You have the choice of metric or English units. For metric units distance is in meters, speed in kilometers per hour; for English, feet and miles per hour. Time is in seconds for cycle time and in cycles for everything else.

One note on the left turn times (both outbound and inbound): The splits that are given by the user might allow more left turn green time than the user has requested. In this case the program will automatically increase the left turn time to the maximum permitted by the splits. An example is given in Chapter 4.

SECTION 3.4

Printing Out the Inputs

If the user types

MB.PRINT <cr>

all of the input variables are printed out.

SECTION 3.5

Solving Problem and Output

To solve a problem, type

MB.SOLVE <cr>

The program will run and tell the user how many CPU seconds each stage takes. The stages are (1) matrix generation (2) optimization by mixed integer linear program and (3) output. Chapter 4 gives examples.

If the problem has previously been solved, and only the output is desired, the user types

MB.OUTPUT <cr>

The output has two options, table and plot:

(i) Table

This produces times for the start of red, end of red, start and end of greenband, start and end of band advance. In addition the inbound and outbound speeds on links are printed. See examples for more details.

(ii) Plot

A space-time diagram for the artery showing the greenband is produced for each direction.

First the computer will print a "File created" comment and then, on a graphics terminal only, an arrow (>) will appear; the user simply hits the carriage return to produce the plot. On a printing terminal the operation is continuous.

A graphics terminal produces a better looking plot. Outputs from both types of terminal are demonstrated in the examples chapter. On a graphics terminal, the computer pauses after a plot is produced, to permit the user to make a hard copy, if desired. Hitting the return continues the program.

The user may choose either, both or neither of the two options. The program, no matter which option is used, automatically displays the cycle time and the inbound and outbound bandwidths.

SECTION 3.6

File Data / Use Data

To file the data for possible reuse at a later date, type

FILE filename DATABASE <cr>

where filename is replaced by whatever name you select for the file. After hitting the <cr>, the computer will prompt

COMMENT

Now you can type any message, e.g. a phrase identifying the problem. If more than one line is desired, a hyphen (-) followed by a <cr> at the end of a line will result in a prompt

CONTINUE

and the message can be continued.

When the data is desired once again, simply type

USE filename <cr>

SECTION 3.7

Modify Street Data

To change the current data, either just entered or brought back via a USE command, simply type

MB.INPUT <cr>

and type

NC <cr>

for any item that the user does not want to change. To terminate a data question series in the middle, type DONE. Everything will be left as before. The modified problem can be rerun via a MB.SOLVE command. Users having experience with EXPRESS can change data variables directly, but the MB.INPUT sequence should be gone through with NC's and DONE's to be sure all flags and derived variables are correctly set.

SECTION 3.8

Restarting a Problem

If the maximum number of iterations specified by the user is not large enough to solve the entire problem, the program will terminate at the iteration limit and print out a message saying that a node (data file) has been punched (stored on disk) so that the program can be restarted at the exact point where it stopped. To do this type MB.SOLVE, enter a new (larger) maximum number of iterations and type "yes" when asked if this is a restart of a previous run.

One warning: the restart must be the next problem solved, even if it is in another computer session. If another problem is run before the problem is restarted, the node will be erased, and the original problem will have to be resolved from the beginning.

Another warning: if the user enters a maximum number of iterations that is so small that the original linear program of the mathematical program cannot be solved (iterations are simplex iterations), the program will instruct the user to resolve the problem from the beginning using a larger maximum (Note: this is not a restart). This problem can be avoided if the maximum number of iterations always exceeds 1000.

SECTION 3.9

Running Times

The following are representative running times

5-signal symmetric	5 minutes
11-signal standard	1 hour
17-signal standard	5 hours

These times were when the system was fairly empty. With more users, the running times can be much greater.

SECTION 3.10

Leaving EXPRESS

An important thing to know about EXPRESS is that the user is dealing with a database. When the user enters EXPRESS, the variables all have values. No matter whether the user enters new data or uses a USE command, if one leaves EXPRESS, the variables will be reset to their original values and the new values will be lost unless they are "updated" or else filed via a FILE command.

The user can make the current values permanent by typing

UPDATE <cr>

If one then types

EXIT <cr>

the values of the variables will be left at what they were at the last UPDATE. An UPDATE can be typed at any time in an EXPRESS session. If there are no UPDATE's, the variables are left at their original values, i.e. those at the beginning of the EXPRESS session, when the EXIT is typed. EXIT gets the user out of EXPRESS.

A third command

QUIT <cr>

executes first an UPDATE and then an EXIT, and so it also takes the user out of EXPRESS.

SECTION 3.11

ESCAPE and BREAK Keys

If you want to stop a program in EXPRESS while it is running, press the ESCAPE key. This will stop the program and keep you within EXPRESS.

The BREAK key will throw you out of EXPRESS. The variables will be left at what their values were at the last UPDATE.

However, if the user hits the BREAK key by accident, one can recover by typing

START <cr> <cr>

as the first command after the BREAK. The program will be restored in EXPRESS at the exact place it was before the BREAK key was hit.

SECTION 3.12

Leaving the PR1ME

Once one leaves EXPRESS via an EXIT, QUIT or BREAK key, one simply types

LO <cr>

to log off the machine. Then disconnect the telephone and turn off the terminal. If using a plotter, be sure to turn off the hard copy unit, too.

CHAPTER 4

Examples

This chapter contains two examples. The first is a 5-signal symmetric problem for Broadway in Cambridge, Massachusetts done using a printing terminal. The second is an 11-signal standard problem for Main Street in Waltham, Massachusetts done using a Tektronix 4013 graphics terminal along with its accompanying hard copy unit. The two examples are fully annotated and show how to get into and out of EXPRESS.

EXAMPLE #1

USER TYPING IS UNDERLINED

```
login please
C>                                          C> means you are at PRIME operating
C>LOGIN [redacted]                             system level

PRIMOS Version MDS.18.0.2
L7LITTLE (5) LOGGED IN AT  15:58 80/12/01
PROJECT CODE:MATT
 *  * YOU CAN NOW PRINT FILES USING EITHER THE PRINT OR THE SPOOL COMMAND

C>CO TTY
C>A L.AND.P 0 2
C>DSS MAXBAND              Entering EXPRESS and bringing in MAXBAND
LOAD COMPLETE
LOAD COMPLETE
LOAD COMPLETE
Already exists.  load over existing entry ignored (F$ERX )
LOAD COMPLETE


   WELCOME TO MAXBAND (THE MESSAGES ABOVE ARE ALL IRRELEVANT)

TYPE MB.INPUT TO INPUT TRAFFIC DATA
TYPE MB.PRINT TO PRINT OUT INPUT TRAFFIC DATA
TYPE MB.SOLVE TO SOLVE PROBLEM AND PRINT OUT RESULTS
TYPE MB.OUTPUT TO SIMPLY PRINT OUT RESULTS OF PREVIOUSLY SOLVED PROBLEM
NOTE: MB.SOLVE AUTOMATICALLY EXECUTES MB.OUTPUT
```

```
->MB.INPUT                    → means you are at EXPRESS level.
TRAFFIC DATA INPUT
ARTERY NAME >BROADWAY
1 METRIC SYSTEM  2 ENGLISH SYSTEM >1
NUMBER OF SIGNALS >5
SIGNAL NAMES
SIG 1: >PORTLAND
SIG 2: >WINDSOR
SIG 3: >COLUMBIA
SIG 4: >PROSPECT
SIG 5: >INMAN
1 ASYMMETRIC   2 SYMMETRIC >2
OUTBOUND DISTANCE FROM PREVIOUS SIGNAL TO SIGNAL (METERS)
SIG WINDSOR: >305
SIG COLUMBIA: >168
SIG PROSPECT: >335
SIG INMAN: >183
LOWER LIMIT ON CYCLE TIME (SEC) >80
UPPER LIMIT ON CYCLE TIME (SEC) >100
DO YOU WANT DIFFERENT DESIGN SPEEDS FOR EACH OUTBOUND SIGNAL ? >NO
OUTBOUND DESIGN SPEED (KM/HR)>45
DESIGN SPEED TOLERANCE
1 DEFAULT (=10% OF DESIGN SPEED))  2 NEW VALUES >2
DO YOU WANT DIFFERENT TOLERANCES FOR EACH SIGNAL ? >NO
OUTBOUND DESIGN SPEED TOLERNCE (KM/HR)>5
LIMIT ON SPEED CHANGE FROM PREVIOUS LINK
1 DEFAULT  (=10% OF DESIGN SPEED)  2 NEW VALUES >2
DO YOU WANT DIFFERENT LIMITS ON SPEED CHANGE FROM PREVIOUS LINK FOR EACH
 SIGNAL
>NO
LIMIT ON CHANGE IN OUTBOUND SPEED FROM PREVIOUS LINK (KM/HR)>2
OUTBOUND GREEN TIME (FRACTION OF CYCLE)
SIG PORTLAND: >.525
SIG WINDSOR: >.6
SIG COLUMBIA: >.6375
SIG PROSPECT: >.4
SIG INMAN: >.6
BANDWIDTH ADVANCE
1  DEFAULT (=0)  2  NEW VALUES >1
```

```
->MB.PRINT

(STNAME)    ARTERY NAME

STNAME     BROADWAY


(NSIG)      NUMBER OF SIGNALS

NSIG              5


(T1)        LOWER LIMIT ON CYCLE TIME (SEC)
(T2)        UPPER LIMIT ON CYCLE TIME (SEC)

T1               80
T2              100


(D)         OUTBOUND DISTANCE FROM PREVIOUS SIGNAL TO SIGNAL (METERS)
(DESSPEED)  OUTBOUND DESIGN SPEEDS (KM/HR)
(TLP)       OUTBOUND DESIGN SPEED TOLERANCES (KM/HR)
(CS)        LIMITS ON CHANGE IN OUTBOUND SPEED FROM PREVIOUS LINK (KM/HR)
(GREEN)     OUTBOUND GREEN TIME (FRACTION OF CYCLE)
(EL)        OUTBOUND LEFT TURN GREEN TIME (FRACTION OF CYCLE)
(TAU)       OUTBOUND BANDWIDTH ADVANCE (FRACTION OF CYCLE)

SIG               D DESSPEED      TLP      CS   GREEN     EL     TAU
PORTLAND         NA       NA       NA      NA    .525      0       0
WINDSOR         305       45        5      NA      .6      0       0
COLUMBIA        168       45        5       2   .6375      0       0
PROSPECT        335       45        5       2      .4      0       0
INMAN           183       45        5       2      .6      0       0
```

```
->MB.SOLVE
MAXIMUM NUMBER OF ITERATIONS
(TYPE NC TO USE THE DEFAULT SETTING OF 100000 ITERATIONS) >25
IS THIS A RESTART OF A PREVIOUS RUN? >NO

(DIFF1)     CPU SECONDS USED DURING THE MATRIX GENERATOR

DIFF1           26.71

OPTIMIZATION FINISHED

(DIFF2)     CPU SECONDS USED DURING THE OPTIMIZATION

DIFF2           29.28

THE MAXIMUM NUMBER OF ITERATIONS HAS BEEN REACHED IN THE BRANCH-AND-BOUN
D ALGORITHM.
A NODE HAS BEEN PUNCHED SO THAT YOU MAY RESTART THE PROGRAM.
->MB.SOLVE
MAXIMUM NUMBER OF ITERATIONS
(TYPE NC TO USE THE DEFAULT SETTING OF 100000 ITERATIONS) >NC
IS THIS A RESTART OF A PREVIOUS RUN? >YES
OPTIMIZATION FINISHED

(DIFF2)     CPU SECONDS USED DURING THE OPTIMIZATION

DIFF2           63.22

OUTPUT VALUES IN METRIC UNITS

(ZOUT)      CYCLE TIME (SEC)

ZOUT            80.00

OUTBOUND SOLUTION

(B)         OUTBOUND BANDWIDTH (CYCLES)

B                 .32
```

Node is actually written to disk.

OUTPUT: 1 TABLE ONLY 2 PLOT ONLY 3 BOTH 4 NEITHER >3

(ST.RED) START OF RED CYCLE

SIG CYCLE	PORTLAND	WINDSOR	COLUMBIA	PROSPECT	INMAN
1	0.00	.54	.56	.94	.04
2	1.00	1.54	1.56	1.94	1.04
3	2.00	2.54	2.56	2.94	2.04

(END.RED) END OF RED CYCLE

SIG CYCLE	PORTLAND	WINDSOR	COLUMBIA	PROSPECT	INMAN
1	.48	.94	.92	1.54	.44
2	1.48	1.94	1.92	2.54	1.44
3	2.48	2.94	2.92	3.54	2.44

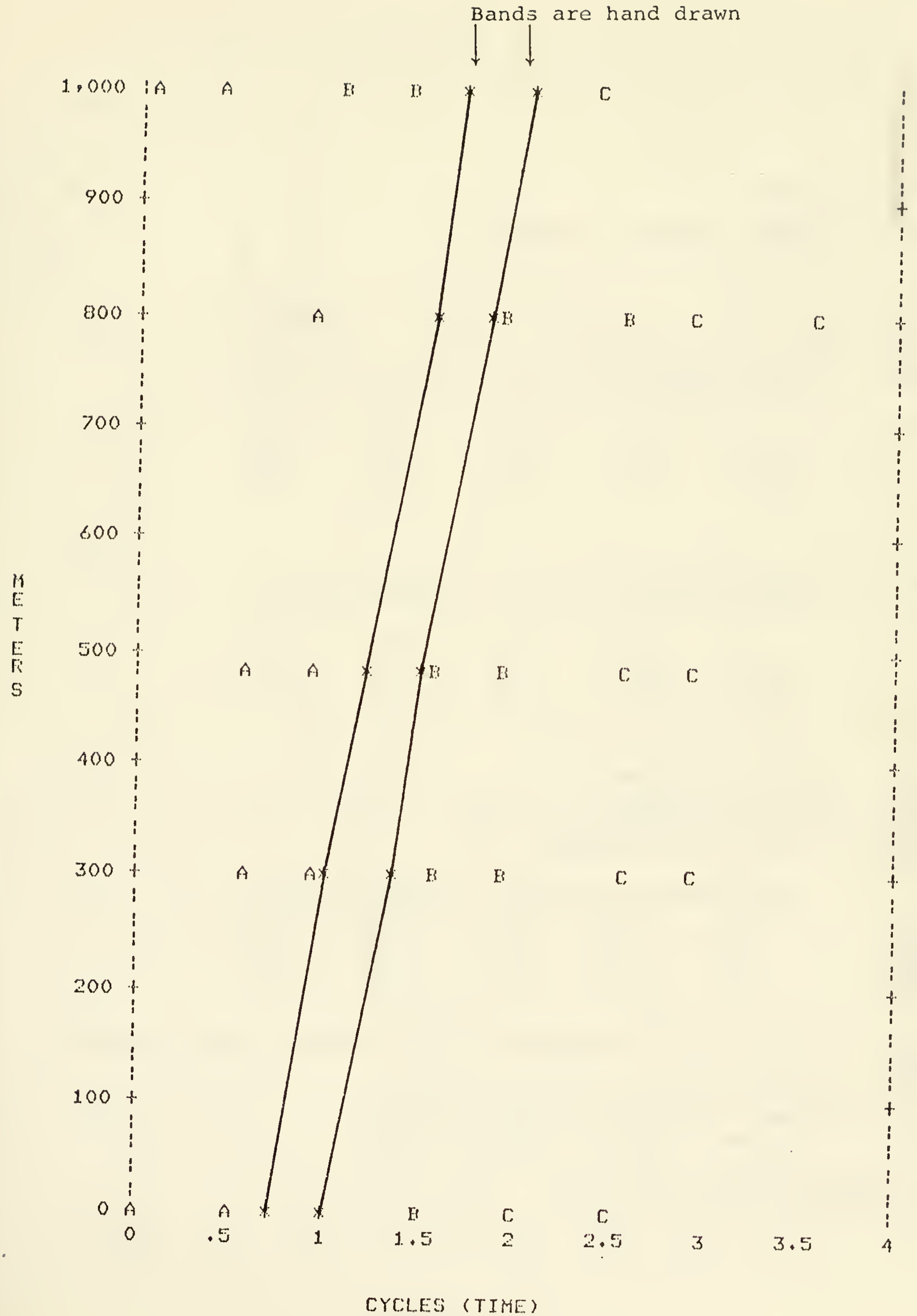
(ST.GB) START OF GREENBAND
(END.GB) END OF GREENBAND
(ST.ADV) ST.GB PLUS BANDWIDTH ADVANCE
(END.ADV) ST.ADV PLUS GREENBAND

SIG	PORTLAND	WINDSOR	COLUMBIA	PROSPECT	INMAN
ST.GB	.68	1.02	1.19	1.54	1.72
END.GB	1.00	1.33	1.51	1.86	2.04
ST.ADV	.68	1.02	1.19	1.54	1.72
END.ADV	1.00	1.33	1.51	1.86	2.04

(AVGSP) AVERAGE SPEED IN GREENBAND FROM PREVIOUS SIGNAL TO SIGNAL
(KM/HR)

SIG	WINDSOR	COLUMBIA	PROSPECT	INMAN
AVGSP	41.01	42.40	43.89	45.49

FILE CREATED: 10/11/79 19:15:24
COMMENT: PLOT FOR 3 CYCLES


Bands are hand drawn
1,000
900
800
700
600
500
400
300
200
100
0
METERS
0
.5
1
1.5
2
2.5
3
3.5
4
CYCLES (TIME)

INBOUND SOLUTION

(BBAR) INBOUND BANDWIDTH (CYCLES)

BBAR .32

OUTPUT: 1 TABLE ONLY 2 PLOT ONLY 3 BOTH 4 NEITHER >3

(ST.RED) START OF RED CYCLE

SIG CYCLE	INMAN	PROSPECT	COLUMBIA	WINDSOR	PORTLAND
1	.04	.94	.56	.54	0.00
2	1.04	1.94	1.56	1.54	1.00
3	2.04	2.94	2.56	2.54	2.00

(END.RED) END OF RED CYCLE

SIG CYCLE	INMAN	PROSPECT	COLUMBIA	WINDSOR	PORTLAND
1	.44	1.54	.92	.94	.48
2	1.44	2.54	1.92	1.94	1.48
3	2.44	3.54	2.92	2.94	2.48

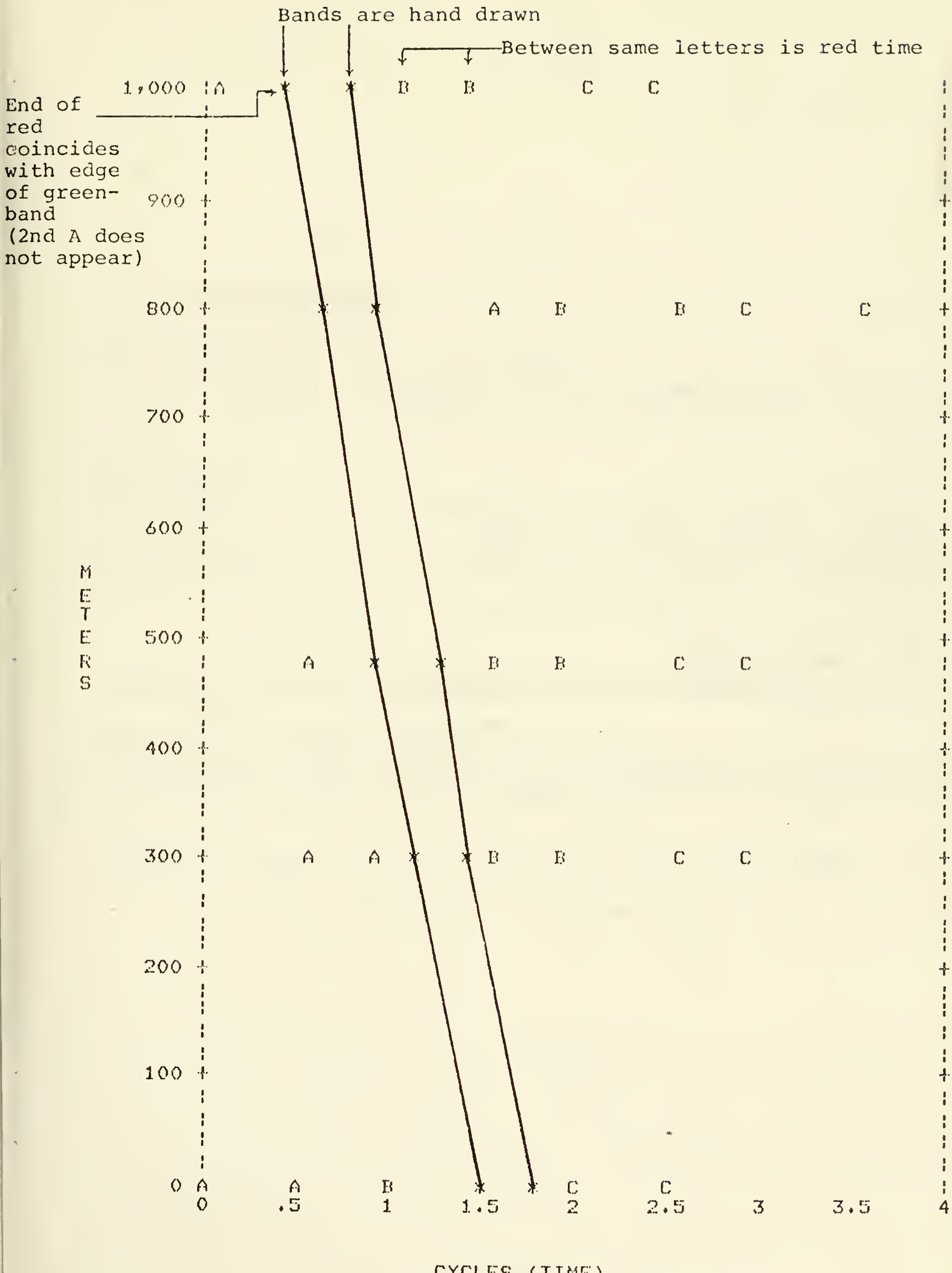
(ST.GB) START OF GREENBAND
(END.GB) END OF GREENBAND
(ST.ADV) ST.GB PLUS BANDWIDTH ADVANCE
(END.ADV) ST.ADV PLUS GREENBAND

SIG	INMAN	PROSPECT	COLUMBIA	WINDSOR	PORTLAND
ST.GB	.44	.62	.96	1.14	1.48
END.GB	.76	.94	1.28	1.46	1.79
ST.ADV	.44	.62	.96	1.14	1.48
END.ADV	.76	.94	1.28	1.46	1.79

(AVGSP) AVERAGE SPEED IN GREENBAND FROM PREVIOUS SIGNAL TO SIGNAL
(KM/HR)

SIG	PROSPECT	COLUMBIA	WINDSOR	PORTLAND
AVGSP	45.49	43.89	42.40	41.01

FILE CREATED: 10/11/79 19:15:24
COMMENT: PLOT FOR 3 CYCLES


Bands are hand drawn
Between same letters is red time
End of red coincides with edge of green-band (2nd A does not appear)
1,000
900
800
700
600
500
400
300
200
100
0
METERS
A
B
C
0
.5
1
1.5
2
2.5
3
3.5
4
CYCLES (TIME)

```
(DIFF3)    CPU SECONDS USED DURING THE OUTPUT ROUTINE

DIFF3        73.64

->FILE BROADWAY DATABASE        Save data on disk file
COMMENT: >BROADWAY, CAMBRIDGE EXAMPLE
->UPDATE          save data in database
->USE BROADWAY  restore data from file (Still in file!)
FILE CREATED: 12/01/80 16:28:09
COMMENT: BROADWAY, CAMBRIDGE EXAMPLE
->EXIT    Leave EXPRESS
C>LO      Leave PRIME
L7LITTLE (5) LOGGED OUT AT  16:33 80/12/01
320.7 MRUS, 0.58 HOURS (LOCAL), PROJECT=MATT
C>
```

EXAMPLE #2

USER TYPING IS UNDERLINED

```
C>LOGIN [redacted]

PRIMOS Version MDS.18.0.2
L7LITTLE (2) LOGGED IN AT  11'59 80/12/02
PROJECT CODE MATT
 *  * YOU CAN NOW PRINT FILES USING EITHER THE PRINT OR THE SPOOL COMMAN

C>CO TTY
C>A L.AND.P 0 2
C>DSS MAXBAND
LOAD COMPLETE
LOAD COMPLETE
LOAD COMPLETE
Already exists.  load over existing entry ignored (F$ERX )
LOAD COMPLETE



   WELCOME TO MAXBAND (THE MESSAGES ABOVE ARE ALL IRRELEVANT)

TYPE MB.INPUT TO INPUT TRAFFIC DATA
TYPE MB.PRINT TO PRINT OUT INPUT TRAFFIC DATA
TYPE MB.SOLVE TO SOLVE PROBLEM AND PRINT OUT RESULTS
TYPE MB.OUTPUT TO SIMPLY PRINT OUT RESULTS OF PREVIOUSLY SOLVED PROBLEM
NOTE: MB.SOLVE AUTOMATICALLY EXECUTES MB.OUTPUT

->TERMINAL TEK4013
->
```

Identify terminal (Necessary for graphics but not most printing terminals)

```
->MB INPUT
TRAFFIC DATA INPUT
ARTERY NAME >MAIN STREET, WALTHAM
1 METRIC SYSTEM  2 ENGLISH SYSTEM >1
NUMBER OF SIGNALS >11
SIGNAL NAMES
SIG 1: >BANKS
SIG 2: >PROSPECT
SIG 3: >BACON
SIG 4: >EXCHANGE
SIG 5: >MOODY
SIG 6: >LEXINGTON
SIG 7: >ELM
SIG 8: >APPLETON
SIG 9: >LYMAN
SIG 10: >NEWTON
SIG 11: >LINDEN
1 ASYMMETRIC   2 SYMMETRIC >1
OUTBOUND DISTANCE FROM PREVIOUS SIGNAL TO SIGNAL (METERS)
SIG PROSPECT: >247
SIG BACON: >337
SIG EXCHANGE: >230
SIG MOODY: >244
SIG LEXINGTO: >110
SIG ELM: >70
SIG APPLETON: >253
SIG LYMAN: >125
SIG NEWTON: >104
SIG LINDEN: >330
ARE INBOUND DISTANCES THE SAME AS OUTBOUND DISTANCES? >YES
LOWER LIMIT ON CYCLE TIME (SEC) >60
UPPER LIMIT ON CYCLE TIME (SEC) >100
DO YOU WANT DIFFERENT DESIGN SPEEDS FOR EACH OUTBOUND SIGNAL ? >
```

```
DO YOU WANT DIFFERENT DESIGN SPEEDS FOR EACH OUTBOUND SIGNAL ? >NO
OUTBOUND DESIGN SPEED (KM/HR)>30
DESIGN SPEED TOLERANCE
1 DEFAULT (=10% OF DESIGN SPEED))  2 NEW VALUES >1
LIMIT ON SPEED CHANGE FROM PREVIOUS LINK
1 DEFAULT  (=10% OF DESIGN SPEED)  2 NEW VALUES >1
ARE INBOUND DESIGN SPEEDS AND TOLERANCES THE SAME AS
OUTBOUND DESIGN SPEEDS AND TOLERANCES? >YES
ARE INBOUND LIMITS ON SPEED CHANGE FROM PREVIOUS LINK THE SAME AS
OUTBOUND LIMITS ON SPEED CHANGE FROM PREVIOUS LINK? >YES
OUTBOUND GREEN TIME (FRACTION OF CYCLE)
SIG BANKS: > 6375 .4375 .7125 .75 .325 .6625 .6625 .75 .5875 .4625 .65
DO YOU WANT ANY OUTBOUND LEFT TURN GREEN TIME ? >YES
OUTBOUND LEFT TURN GREEN TIME (FRACTION OF CYCLE)
SIG BANKS: > 10 0 .1375 0 0 .275 .275 0 0 0 .2
INBOUND GREEN TIME (FRACTION OF CYCLE)
SIG BANKS: > 5375 .4375 .575 .75 .325 .3875 .3875 .75 .5875 .4625 .45
DO YOU WANT ANY INBOUND LEFT TURN GREEN TIME ? >NO
BANDWIDTH ADVANCE
1  DEFAULT (=0)  2  NEW VALUES >1
DESIRED RATIO OF INBOUND TO OUTBOUND GREENBANDS >1

LEFT TURN PATTERN SELECTION FOR EACH SIGNAL

PATTERNS

(1) OUTBOUND LEFT TURN BEFORE GREEN AND INBOUND LEFT TURN BEFORE GREEN
(2) OUTBOUND LEFT TURN BEFORE GREEN AND INBOUND LEFT TURN AFTER GREEN
(3) OUTBOUND LEFT TURN AFTER GREEN AND INBOUND LEFT TURN BEFORE GREEN
(4) OUTBOUND LEFT TURN AFTER GREEN AND INBOUND LEFT TURN AFTER GREEN

FOR EACH SIGNAL BELOW, TYPE ONE (1) IF YOU WANT THE PATTERN IN QUESTION
TO BE CONSIDERED AND TYPE ZERO (0) IF YOU DO NOT WANT THE PATTERN
IN QUESTION TO BE CONSIDERED

LEFT TURN PATTERN FORMING MATRIX
SIG BANKS
PAT 1: >1
PAT 2: >0
PAT 3: >1
PAT 4: >0
LEFT TURN PATTERN FORMING MATRIX
SIG BACON
PAT 1: >1 0 1 0
LEFT TURN PATTERN FORMING MATRIX
SIG LEXINGTO
PAT 1: >1 0 1 0
LEFT TURN PATTERN FORMING MATRIX
SIG ELM
PAT 1: >1 0 1 0
LEFT TURN PATTERN FORMING MATRIX
SIG LINDEN
PAT 1: >1 0 1 0
->
```

Short cut on input. Just leave a space between each signal in the list. (For negative numbers, comma required.)

->MB PRINT

(STNAME)   ARTERY NAME

STNAME   MAIN STREET, WALTHAM

(NSIG)   NUMBER OF SIGNALS

NSIG   11

(T1)   LOWER LIMIT ON CYCLE TIME (SEC)
(T2)   UPPER LIMIT ON CYCLE TIME (SEC)

T1   60
T2   100

MAKE HARD COPY (IF DESIRED), THEN HIT 'RETURN' TO CONTINUE. SCREEN WILL THEN BE ERASED. > <CR>

(D)   OUTBOUND DISTANCE FROM PREVIOUS SIGNAL TO SIGNAL (METERS)
(DESSPEED) OUTBOUND DESIGN SPEEDS (KM/HR)
(TLP)   OUTBOUND DESIGN SPEED TOLERANCES (KM/HR)
(CS)   LIMITS ON CHANGE IN OUTBOUND SPEED FROM PREVIOUS LINK (KM/HR)
(GREEN)   OUTBOUND GREEN TIME (FRACTION OF CYCLE)
(EL)   OUTBOUND LEFT TURN GREEN TIME (FRACTION OF CYCLE)
(TAU)   OUTBOUND BANDWIDTH ADVANCE (FRACTION OF CYCLE)

Note that machine increase this from 10 to 15 due to left turn time availability

SIG	D	DESSPEED	TLP	CS	GREEN	EL	TAU
BANKS	NA	NA	NA	NA	.6875	.15	0
PROSPECT	247	30	3	NA	.4375	0	0
BACON	337	30	3	3	.7125	.1375	0
EXCHANGE	230	30	3	3	.75	0	0
MOODY	244	30	3	3	.325	0	0
LEXINGTO	110	30	3	3	.6625	.275	0
ELM	70	30	3	3	.6625	.275	0
APPLETON	253	30	3	3	.75	0	0
LYMAN	125	30	3	3	.5875	0	0
NEWTON	104	30	3	3	.4625	0	0
LINDEN	320	30	3	3	.65	.2	0

MAKE HARD COPY (IF DESIRED), THEN HIT 'RETURN' TO CONTINUE. SCREEN WILL THEN BE ERASED. > <CR>

(DBAR)   INBOUND DISTANCE FROM PREVIOUS SIGNAL TO SIGNAL (METERS)
(DESPDB)   INBOUND DESIGN SPEEDS (KM/HR)
(TLPB)   INBOUND DESIGN SPEED TOLERANCES (KM/HR)
(CSB)   LIMITS ON CHANGE IN INBOUND SPEED FROM PREVIOUS LINK (KM/HR)
(GREENBAR) INBOUND GREEN TIME (FRACTION OF CYCLE)
(ELBAR)   INBOUND LEFT TURN GREEN TIME (FRACTION OF CYCLE)
(TAUBAR)   INBOUND BANDWIDTH ADVANCE (FRACTION OF CYCLE)

SIG	DBAR	DESPDB	TLPB	CSB	GREENBAR	ELBAR	TAUBAR
BANKS	NA	NA	NA	NA	.5375	0	0
PROSPECT	247	30	3	NA	.4375	0	0
BACON	337	30	3	3	.575	0	0
EXCHANGE	230	30	3	3	.75	0	0
MOODY	244	30	3	3	.325	0	0
LEXINGTO	110	30	3	3	.3875	0	0
ELM	70	30	3	3	.3875	0	0
APPLETON	253	30	3	3	.75	0	0
LYMAN	125	30	3	3	.5875	0	0
NEWTON	104	30	3	3	.4625	0	0
LINDEN	320	30	3	3	.45	0	0

MAKE HARD COPY (IF DESIRED), THEN HIT 'RETURN' TO CONTINUE. SCREEN WILL THEN BE ERASED. > <CR>

(PATCHOIC) LEFT TURN PATTERN FORMING MATRIX

PAT	1	2	3	4
SIG				
BANKS	1	0	1	0
PROSPECT	0	0	0	0
BACON	1	0	1	0
EXCHANGE	0	0	0	0
MOODY	0	0	0	0
LEXINGTO	1	0	1	0
ELM	1	0	1	0
APPLETON	0	0	0	0
LYMAN	0	0	0	0
NEWTON	0	0	0	0
LINDEN	1	0	1	0

(KK) DESIRED RATIO OF INBOUND TO OUTBOUND GREENBANDS

KK 1

```
->MB.SOLVE
MAXIMUM NUMBER OF ITERATIONS
(TYPE NC TO USE THE DEFAULT SETTING OF 100000 ITERATIONS) >NC
IS THIS A RESTART OF A PREVIOUS RUN? >NO

(DIFF1)    CPU SECONDS USED DURING THE MATRIX GENERATOR

DIFF1        54.89

OPTIMIZATION FINISHED

(DIFF2)    CPU SECONDS USED DURING THE OPTIMIZATION

DIFF2     1,677.79

OUTPUT VALUES IN METRIC UNITS

(ZOUT)     CYCLE TIME (SEC)

ZOUT         60.00

OUTBOUND SOLUTION

(B)        OUTBOUND BANDWIDTH (CYCLES)

B               .24

OUTPUT: 1 TABLE ONLY  2 PLOT ONLY  3 BOTH  4 NEITHER >3
MAKE HARD COPY (IF DESIRED), THEN HIT 'RETURN' TO CONTINUE.  SCREEN WILL
 THEN BE ERASED. > <CR>
```

(ST RED)	START OF RED CYCLE				
CYCLE	1	2	3	4	5
SIG					
BANKS	0.00	1.00	2.00	3.00	4.00
PROSPECT	.55	1.55	2.55	3.55	4.55
BACON	.96	1.96	2.96	3.96	4.96
EXCHANGE	.91	1.91	2.91	3.91	4.91
MOODY	.94	1.94	2.94	3.94	4.94
LEXINGTO	.61	1.61	2.61	3.61	4.61
ELM	.62	1.62	2.62	3.62	4.62
APPLETON	.96	1.96	2.96	3.96	4.96
LYMAN	.04	1.04	2.04	3.04	4.04
NEWTON	.47	1.47	2.47	3.47	4.47
LINDEN	.01	1.01	2.01	3.01	4.01

MAKE HARD COPY (IF DESIRED), THEN HIT 'RETURN' TO CONTINUE. SCREEN WILL THEN BE ERASED. > <CR>

(END RED)	END OF RED CYCLE				
CYCLE	1	2	3	4	5
SIG					
BANKS	.31	1.31	2.31	3.31	4.31
PROSPECT	1.11	2.11	3.11	4.11	5.11
BACON	1.25	2.25	3.25	4.25	5.25
EXCHANGE	1.16	2.16	3.16	4.16	5.16
MOODY	1.62	2.62	3.62	4.62	5.62
LEXINGTO	.95	1.95	2.95	3.95	4.95
ELM	.96	1.96	2.96	3.96	4.96
APPLETON	1.21	2.21	3.21	4.21	5.21
LYMAN	.45	1.45	2.45	3.45	4.45
NEWTON	1.01	2.01	3.01	4.01	5.01
LINDEN	.36	1.36	2.36	3.36	4.36

MAKE HARD COPY (IF DESIRED), THEN HIT 'RETURN' TO CONTINUE. SCREEN WILL THEN BE ERASED. > <CR >

(ST.GB)	START OF GREENBAND
(END.GB)	END OF GREENBAND
(ST ADV)	ST GB PLUS BANDWIDTH ADVANCE
(END.ADV)	ST.ADV PLUS GREENBAND

SIG	ST GB	END.GB	ST.ADV	END.ADV
BANKS	.62	.86	.62	.86
PROSPECT	1.11	1.35	1.11	1.35
BACON	1.73	1.96	1.73	1.96
EXCHANGE	2.18	2.42	2.18	2.42
MOODY	2.71	2.94	2.71	2.94
LEXINGTO	2.95	3.19	2.95	3.19
ELM	3.10	3.33	3.10	3.33
APPLETON	3.57	3.81	3.57	3.81
LYMAN	3.80	4.04	3.80	4.04
NEWTON	4.01	4.25	4.01	4.25
LINDEN	4.59	4.83	4.59	4.83

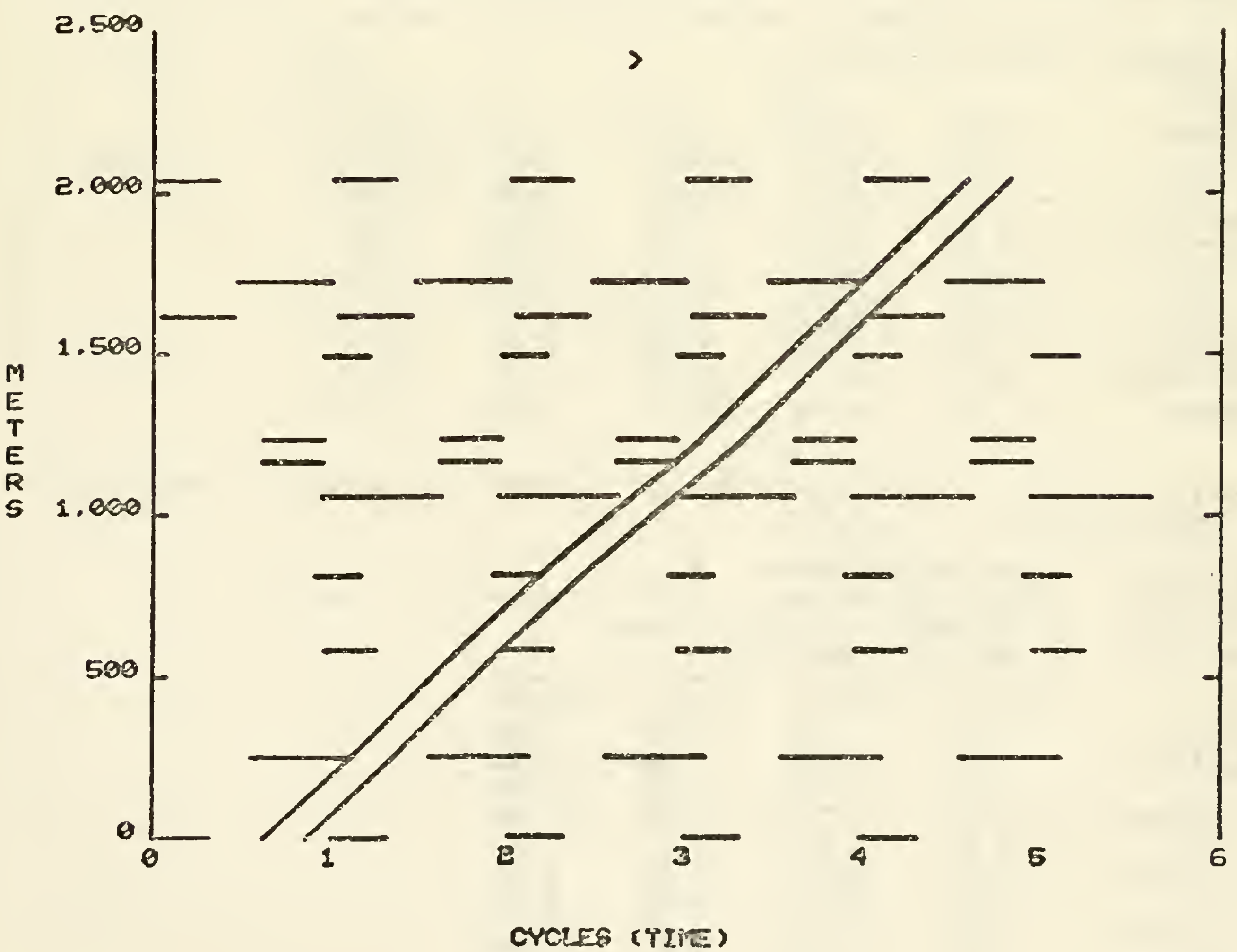
MAKE HARD COPY (IF DESIRED), THEN HIT 'RETURN' TO CONTINUE. SCREEN WILL THEN BE ERASED. > < CR>

(AVGSP) (KM/HR) AVERAGE SPEED IN GREENBAND FROM PREVIOUS SIGNAL TO SIGNAL

SIG	AVGSP
PROSPECT	30.25
BACON	33.00
EXCHANGE	30.25
MOODY	27.92
LEXINGTO	27.00
ELM	29.17
APPLETON	31.72
LYMAN	33.00
NEWTON	30.25
LINDEN	33.00

FILE CREATED: 10/11/79 19:10:13
COMMENT: PLOT FOR 5 CYCLES
> <CR>

First take Hard Copy, then Hit Carriage Return
to continue program



<CR>

INBOUND SOLUTION

(BBAR) INBOUND BANDWIDTH (CYCLES)

BBAR .24

OUTPUT: 1 TABLE ONLY 2 PLOT ONLY 3 BOTH 4 NEITHER >3
MAKE HARD COPY (IF DESIRED), THEN HIT 'RETURN' TO CONTINUE. SCREEN WILL
THEN BE ERASED. > <CR>

(ST.RED) START OF RED CYCLE

CYCLE SIG	1	2	3	4	5
LINDEN	.01	1.01	2.01	3.01	4.01
NEWTON	.47	1.47	2.47	3.47	4.47
LYMAN	.04	1.04	2.04	3.04	4.04
APPLETON	.96	1.96	2.96	3.96	4.96
ELM	.62	1.62	2.62	3.62	4.62
LEXINGTO	.61	1.61	2.61	3.61	4.61
MOODY	.94	1.94	2.94	3.94	4.94
EXCHANGE	.91	1.91	2.91	3.91	4.91
BACON	.96	1.96	2.96	3.96	4.96
PROSPECT	.55	1.55	2.55	3.55	4.55
BANKS	0.00	1.00	2.00	3.00	4.00

MAKE HARD COPY (IF DESIRED), THEN HIT 'RETURN' TO CONTINUE. SCREEN WILL
THEN BE ERASED. > <CR>

(END RED) END OF RED CYCLE

CYCLE SIG	1	2	3	4	5
LINDEN	.56	1.56	2.56	3.56	4.56
NEWTON	1.01	2.01	3.01	4.01	5.01
LYMAN	.45	1.45	2.45	3.45	4.45
APPLETON	1.21	2.21	3.21	4.21	5.21
ELM	1.23	2.23	3.23	4.23	5.23
LEXINGTO	1.23	2.23	3.23	4.23	5.23
MOODY	1.62	2.62	3.62	4.62	5.62
EXCHANGE	1.16	2.16	3.16	4.16	5.16
BACON	1.39	2.39	3.39	4.39	5.39
PROSPECT	1.11	2.11	3.11	4.11	5.11
BANKS	.46	1.46	2.46	3.46	4.46

MAKE HARD COPY (IF DESIRED), THEN HIT 'RETURN' TO CONTINUE. SCREEN WILL
THEN BE ERASED. > <CR>

(ST.GB) START OF GREENBAND
(END.GB) END OF GREENBAND
(ST.ADV) ST.GB PLUS BANDWIDTH ADVANCE
(END.ADV) ST.ADV PLUS GREENBAND

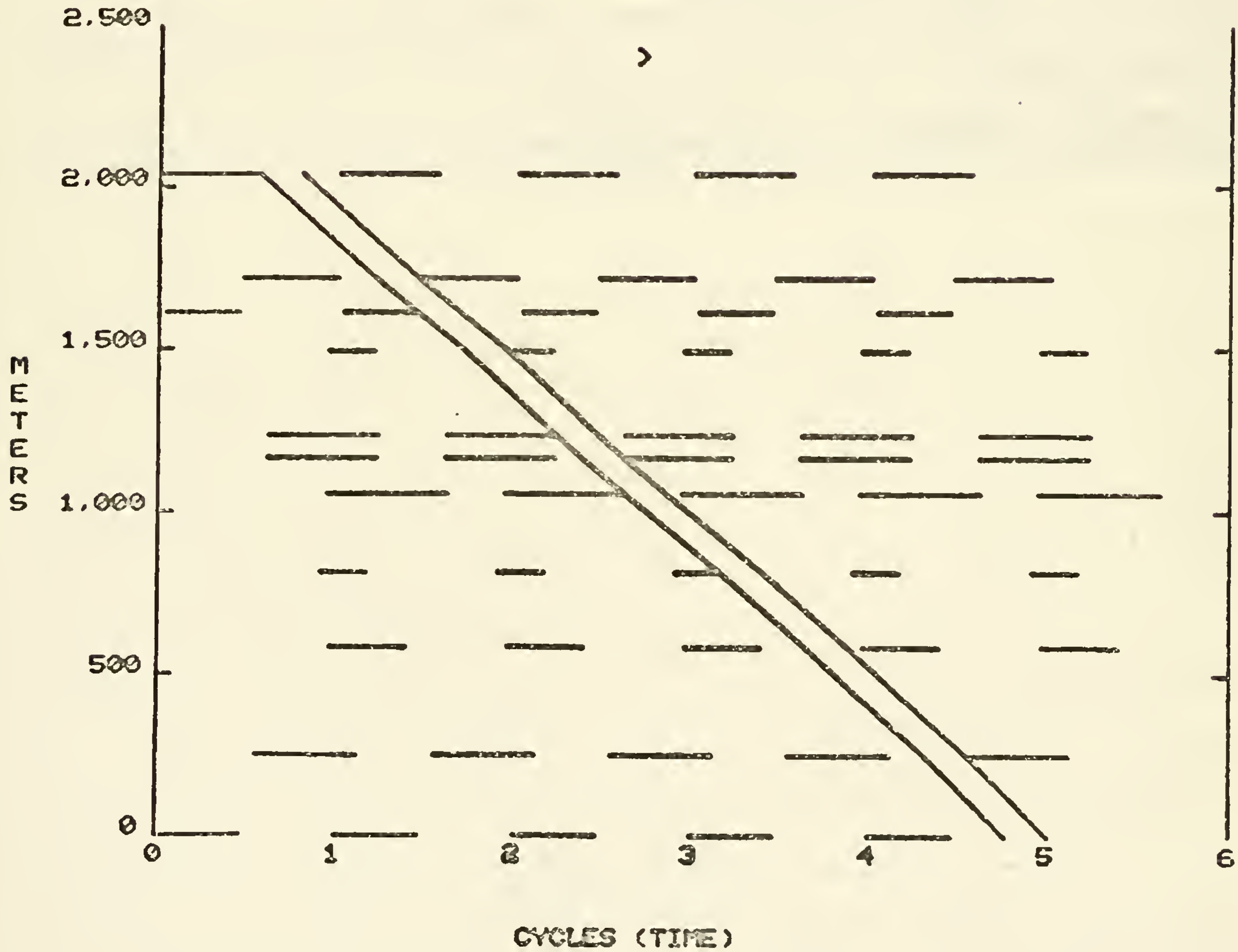
SIG	ST.GB	END.GB	ST.ADV	END.ADV
LINDEN	.56	.80	.56	.80
NEWTON	1.22	1.46	1.22	1.46
LYMAN	1.45	1.69	1.45	1.69
APPLETON	1.72	1.96	1.72	1.96
ELM	2.23	2.47	2.23	2.47
LEXINGTO	2.38	2.61	2.38	2.61
MOODY	2.62	2.86	2.62	2.86
EXCHANGE	3.16	3.40	3.16	3.40
BACON	3.64	3.88	3.64	3.88
PROSPECT	4.31	4.55	4.31	4.55
BANKS	4.76	5.00	4.76	5.00

MAKE HARD COPY (IF DESIRED), THEN HIT 'RETURN' TO CONTINUE. SCREEN WILL
THEN BE ERASED. > <CR>

(AVGSP) AVERAGE SPEED IN GREENBAND FROM PREVIOUS SIGNAL TO SIGNAL
(KM/HR)

SIG	AVGSP
NEWTON	29.17
LYMAN	27.00
APPLETON	27.60
ELM	29.88
LEXINGTO	29.17
MOODY	27.00
EXCHANGE	27.00
BACON	28.62
PROSPECT	30.25
BANKS	33.00

FILE CREATED: 10/11/79 19:10:13
COMMENT: PLOT FOR 5 CYCLES
> <CR>



<CR>

```
(DIFF3)     CPU SECONDS USED DURING THE OUTPUT ROUTINE

DIFF3        114.82
```

```
->FILE WALTHAM DATABASE
COMMENT: >MAIN STREET, WALTHAM EXAMPLE    Save data on disk file
->USE WALTHAM
FILE CREATED: 12/02/80 13:53:20
COMMENT: MAIN STREET, WALTHAM EXAMPLE    Restore data
->QUIT          Automatic update

DATA BASE UPDATED
C>LO   Leave PRIME
LTLITTLE (2) LOGGED OUT AT  13:55 80/12/02
2053 6 MRUS, 1.93 HOURS (LOCAL), PROJECT=MATT
C>
```

REFERENCES

Land, A. and Powell, S., Fortran Codes for Mathematical Programming, London: John Wiley and Sons, 1973.

Little, John D. C., "The Synchronization of Traffic Signals by Mixed-Integer Linear Programming," Operations Research, Vol. 14, No. 4, July-August, 1966, pp. 568-594.

Little, John D. C., Maximal Bandwidth for Arterial Traffic Signals: Theory and Interactive Computation, Massachusetts Institute of Technology, Alfred P. Sloan School of Management, Working Paper WP 970-78, September 1977.

Little, John D. C. and Kelson, Mark D., "Optimal Signal Timing for Arterial Signal Systems," Report for Federal Highway Administration Under Contract DOT-FH-11-9562, April 1980.

Rizzi, W. D., "An Interactive Program for Setting Traffic Signals on an Artery," S.B. thesis, M.I.T., May 1977.

APPENDIX

MAXBAND

Standard Artery

(1) Name of artery: ______________________ Number of signals ______________________

(2) Cycle time: Lower limit ______________(seconds). Upper limit ______________(seconds).

(3) Outbound speed: Design center ______________ kph/mph. Tolerance ± ______________ kph/mph.

(4) Inbound speed: Design center ______________ kph/mph. Tolerance ± ______________ kph/mph.

(5) Target ratio of inbound to outbound band width: ______________________

(6) Signal name (down = outbound)	(7) Distance from previous signal (meters/feet)	(8) Thru green outbound (fraction of cycle)	(9) Thru green inbound (fraction of cycle)	(10) Left turn green outbound (fraction of cycle)	(11) Left turn green inbound (fraction of cycle)	(12) Acceptability of Left Turn Patterns (1 = acceptable, 0 = not): Outbound LT before green and inbound LT before green (a)	Outbound LT before green and inbound LT after green (b)	Outbound LT after green and inbound LT before green (c)	Outbound LT after green and inbound LT after green (d)
1	xxxxxxx								
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									

Notes by item number: (3) (4) If no tolerance specified, ±10% is assumed as a default. A limit on change in speed between signals equal to the tolerance is assumed. (5) Actual ratio will be target ratio unless larger band width is at its limit and smaller can be further increased, in which case it will be. (12) If only outbound has left turn phases, fill in (a) and (c); if only inbound, (a) and (b). Other columns are 0.

Symmetric Artery

(1) Name of artery:____________________ Number of signals________

(2) Cycle time: Lower limit__________(seconds). Upper limit__________(seconds).

(3) Speed: Design center________(kph/mph). Tolerance ± __________(kph/mph)

(4) Signal name (down = outbound)	(5) Distance from previous signal (meters/feet)	(6) Green time (fraction of cycle)
1	xxxxxxxx	
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

Notes by item number: (3) If no tolerance is specified ± 10% of design speed is assumed. A limit on change of speed between signals equal to the tolerance is assumed.

MAXBAND

General Artery

(1) Name of artery: ______________________ Number of signals ______________

(2) Cycle time: Lower limit ______________ (seconds). Upper limit ______________ (seconds).

(3) Target ratio of inbound to outbound band width: ______________

(4) Maximum number of iterations ______________

OUTBOUND DATA

(5) Signal name (down = outbound)	(6) Outbound distance from previous signal (meters / feet)	(7) Outbound design speed from previous signal (kph / mph)	(8) Outbound speed tolerance in (7) ± (kph / mph)	(9) Limit on outbound speed change from previous link ± (kph / mph)	(10) Thru green outbound (fraction of cycle)	(11) Left turn green for outbound (fraction of cycle)	(12) Outbound band advance for queue clearance (fraction of cycle)
1	xxxxxx	xxxxx	xxxxx	xxxxx			
2				xxxxx			
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

Notes by item number: (3) Actual ratio will be target ratio unless smaller band can be further increased after larger has reached its limit. (4) Default = 10,000. (7) Default is all speeds equal. (8) Default is ± 10% of design speed. (9) Default is speed tolerance of (8).

General Artery (cont.)

(13) Name of Artery:______________________________

INBOUND DATA

(14) Signal name (down = outbound) (same as page 1)	(15) Inbound Distance from previous signal (meters / feet)	(16) Inbound design speed (kph / mph)	(17) Inbound speed tolerance in (16) ± (kph / mph)	(18) Limit on inbound speed change from previous link ± (kph / mph)	(19) Thru green inbound (fraction of cycle)	(20) Left turn green for inbound (fraction of cycle)	(21) Inbound band advance for queue clearance (fraction of cycle)
1	xxxx	xxxx	xxxx	xxxx			
2				xxxx			
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

Notes: (15) Default is outbound distance. (16) Default is outbound speed. (17) Default is ± 10% of design speed of (16). (18) Default is speed tolerance of (17).

(22) Name of Artery: ______________________________

LEFT TURN PATTERN CONSTRAINTS

(23)	(24) Acceptability of Left Turn Patterns (1 = acceptable, 0 = not)			
	Outbound LT before green and		Outbound LT after green and	
Signal name (down = outbound) (same as page 1)	inbound LT before green (a)	inbound LT after green (b)	inbound LT before green (c)	inbound LT after green (d)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Notes: (24) Default condition is that all left turn patterns are acceptable. If only outbound has left turn phases, fill in (a) and (c); if only inbound, (a) and (b). Other columns are 0.