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STEP-THROUGH SIMULATION IS FASTER THAN DRIVING

by

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The Center for Highway Research, in cooperation with the Texas Highway Department and the Federal Highway Administration, has been developing a stochastic input, micro-level, deterministic, step-through traffic simulation package under the Cooperative Highway Research Program.

BACKGROUND

Traffic engineers and transportation planners presently do not have adequate techniques for solving two practical engineering problems: (1) computing the capacity of uncontrolled and sign-controlled intersections, and (2) timing traffic signals on street networks. Computer simulation can be used to develop a methodology for solving these and other frequently occurring traffic flow problems. Better evaluation of proposed highway facilities and optimum utilization of existing street networks will thus be possible, and savings of time and money to all road users can be realized.

PROBLEM DEFINITION

Traffic movement on a road network is a complex, time-varying phenomenon which depends largely on the desires and capabilities of individual drivers operating various types of vehicles over the real estate designed for that purpose. Engineers charged with the responsibility of optimizing traffic flow at specific locations, such as intersections, have historically observed traffic movements, hopefully under conditions nearly like those in question, and prescribed geometric configurations and regulatory controls similar to the ones known to have performed satisfactorily in the past. From this approach, no general technique of interpolating or extrapolating the many complicated interactions of various physical features with driver and vehicle performance characteristics to assure optimum efficiency and safety of traffic flow has been developed. And, except for a few staged experiments such as those conducted by the Road Research Laboratory or by General Motors Corporation, studies have generally been limited to observing whatever traffic occurred during the field studies at the selected sites.

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Computer simulation of the three major elements involved (driver, vehicle, and road) can be used to develop a methodology for evaluating the complex interaction that occurs in real-world traffic flow, but in a much compressed time frame.

By simulation, various combinations of physical features including lane arrangements and different traffic control schemes can be studied under a wide range of chosen traffic conditions. Then, optimization techniques can be used to determine the most practicable method for effecting traffic movements at intersections and on street networks.

Most of the simulation attempted to date has utilized probability and queueing theory and has been formulated on a macroscopic scale, i.e., the movements of groups of vehicles have been modeled, or traffic has been considered as a flowing fluid. The UTCS1 program developed by Peat, Marwick, Mitchell and Co. has been successful in realistically modeling traffic movement on multiple-lane, multiple-intersection networks while the SIGNET program developed at Purdue University is the first realistic attempt at modeling isolated intersections on a somewhat microscopic level.

CENTER FOR HIGHWAY RESEARCH TRAFFIC SIMULATION PACKAGE

The simulation package being developed by the Center for Highway Research consists of two pre-simulation processors and a traffic simulator. One pre-simulation processor (Fig 1) takes the geometry of the area being simulated and creates inputs to the traffic simulator. Input to the geometry processor includes data normally available on a traffic inventory of the intersection. Input may include:

(1) number of approaches,
(2) approach length,
(3) approach direction,
(4) type of approach (inbound or outbound),
(5) coordinate information,
(6) speed limit of approach,
(7) number of lanes,
(8) lane widths,
(9) turning movements from each lane, and
(10) other geometric information.

The geometry processor takes this information and creates input to the traffic simulator describing the different paths which may be used by vehicles and all points of conflict that occur within the intersection.

The other pre-simulation processor (Fig 2) takes data about drivers and vehicles and creates input to the traffic simulator. Input to the driver-vehicle processor includes data that describes:

(1) a frequency distribution of driver characteristics,

(2) individual driver characteristics not commonly found in the traffic stream,

(3) a frequency distribution of vehicle characteristics,

(4) individual vehicle characteristics not commonly found in the traffic stream,

(5) traffic flow conditions at the intersection, and

(6) other data used by the driver-vehicle processor.

The driver-vehicle processor takes this information and generates random deviates for the traffic simulator in accordance with the pre-specified frequency distributions, thus describing each driver-vehicle unit in the traffic stream.

The final link in the simulation package is the traffic simulator (Fig 3). The traffic simulator is a FORTRAN IV program created by COLEASE, a simulation language processor recently developed at the Center for Highway Research under the direction of Dr. Roger S. Walker. COLEASE is designed to minimize computer core storage requirements and execution time. COLEASE takes input describing the driver response functions and the type of traffic control and creates the traffic simulator. The traffic simulator uses the step-through method of simulation whereby each vehicle in the system is examined at selected time increments (usually 1/2 to 1 real-time second). For each time increment, a driver's logical (or illogical) response such as speed up, slow down, keep same speed, or change lanes is computed after reviewing various input stimuli that would be available to the driver. The inputs might include such information as "is the vehicle ahead slowing down?" "is the vehicle ahead stopped?" "what is the distance to the crosswalk?" "will I be at a point of conflict in the intersection when another vehicle will be there?" "what is the minimum turning radius of the path which I have chosen?" etc. After computing the driver's priority response, a new vehicle position and velocity is calculated and stored; then, another driver-vehicle unit is examined in sequence.

Output data from the traffic simulator can vary depending upon the desire of the user. Normally, the output includes such parameters as total stopped time delay, average stopped time delay per vehicle, total time under a specified speed, average time under a specified speed per vehicle, average approach speeds, and approach volumes.

To aid in the development of the traffic simulation package, interactive graphics routines have been written to display the results of the simulation on a computer-controlled display terminal. This aid allows the user to see the vehicles step through the intersection and change parameters of the simulation as the simulation is in progress. It also permits a visual check on the realism of the simulation model.

APPLICATIONS

In using the simulation model, the traffic engineer takes a layout of an intersection (Fig 4) and from the geometrics of the intersection, enters data (Fig 5) into the geometry processor. The geometry processor arranges these data, calculates all the vehicle and pedestrian paths within the intersection and on the approaches, calculates the points of conflict, and plots the results if the plot option is set (Fig 6).

The engineer then enters data about the drivers, vehicles, and traffic streams under consideration into the driver-vehicle processor. The driver-vehicle processor uses this information to create a traffic stream for the traffic simulator.

The output from the geometry and driver-vehicle processor also serves as input to the traffic simulator. After running the simulation and reviewing the output, the traffic engineer may change the conditions and run the simulation as many times as necessary to evaluate alternative intersection control schemes. A ratio of simulation time to real time of 1 to 100 is expected for all but the most complex intersections.

POTENTIAL USES

Examples of alternatives that may be studied by the practicing traffic engineer include

(1) adding a lane,
(2) adding a left-turn lane,
(3) adding a free right-turn lane,
(4) using two-way yield sign control,
(5) using two-way stop sign control,
(6) using four-way stop sign control,
(7) using a pretimed controller,
(8) using an actuated controller,
(9) adding phases to a controller such as a protected left-turn phase,
(10) leading or lagging green phases,

(11) restricting parking, or

(12) handling emergency vehicles.

SUMMARY

This simulation package will allow the practicing traffic engineer or transportation planner to test different types of intersection geometry and traffic control schemes so that he may optimize traffic flow through intersections.

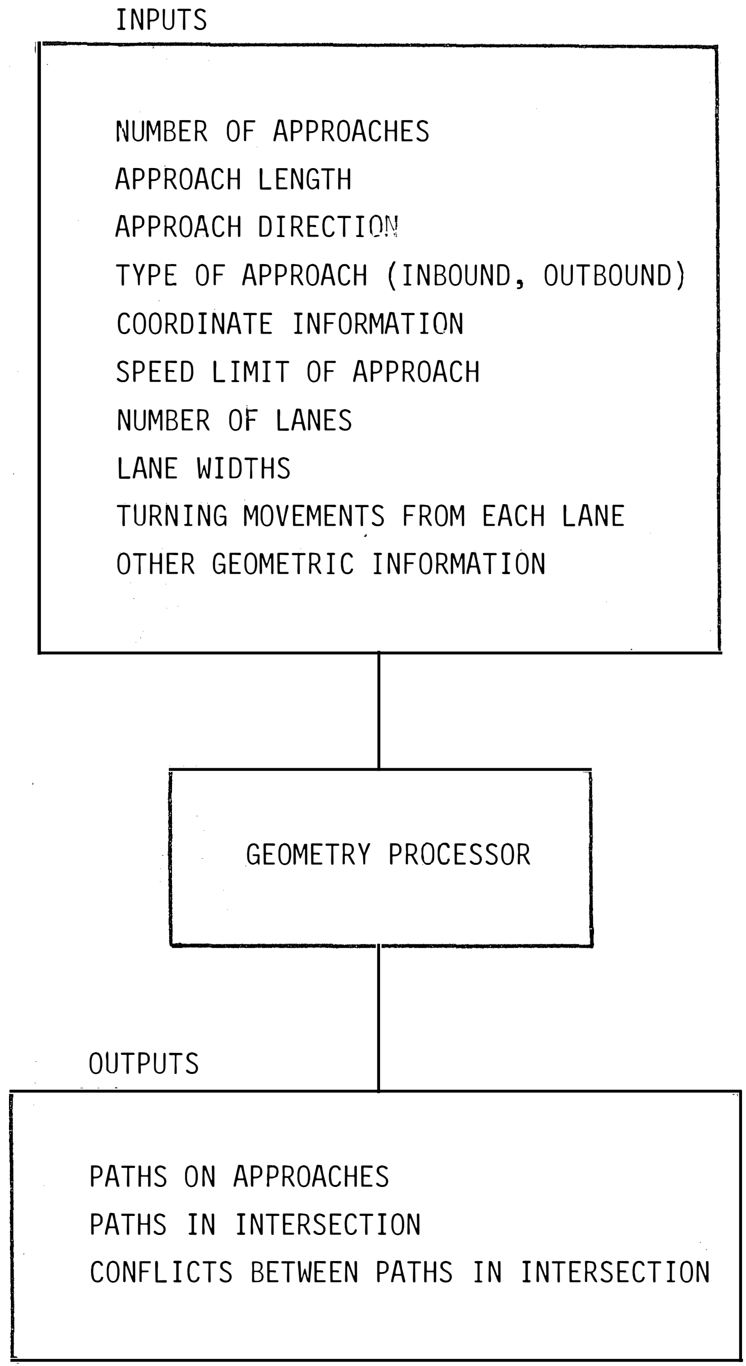

FIG 1. GEOMETRY PROCESSOR

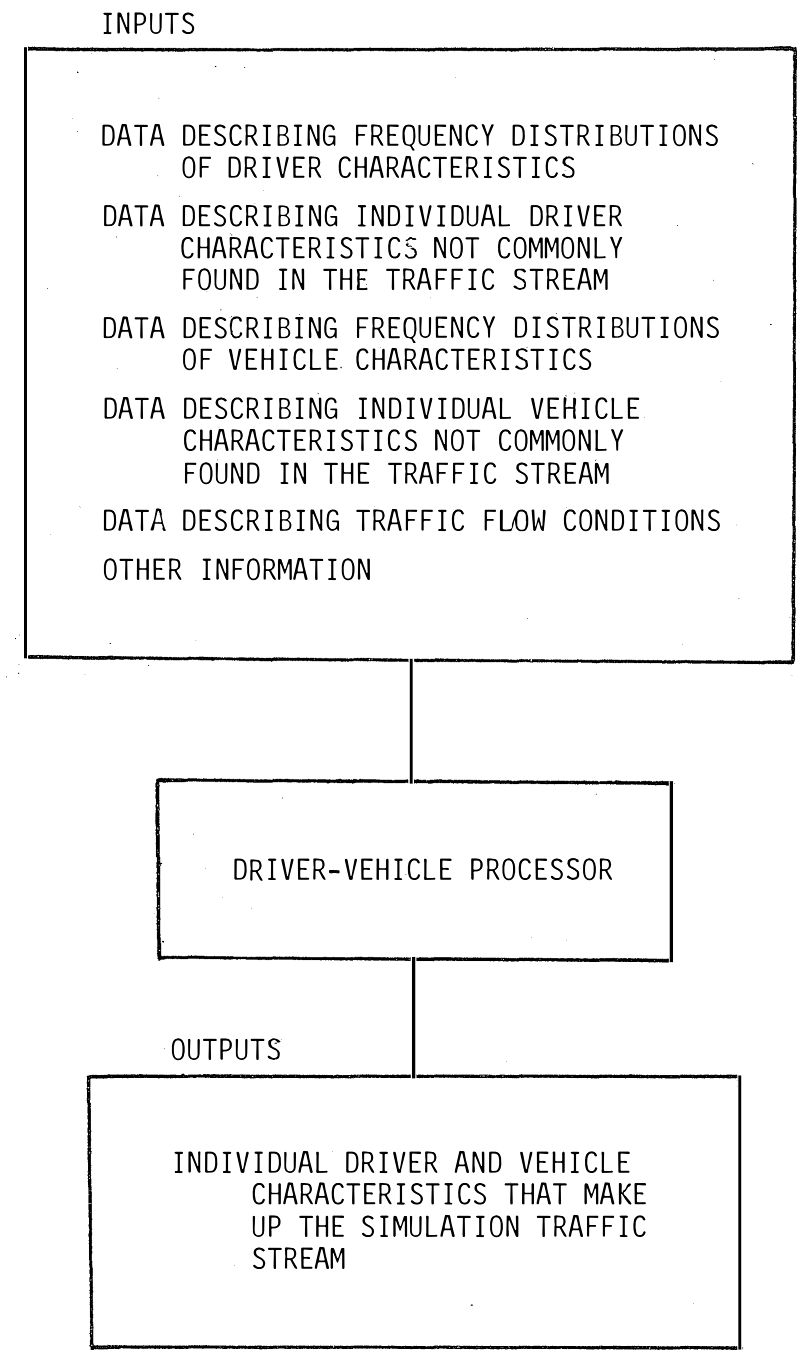

FIG 2. DRIVER-VEHICLE PROCESSOR

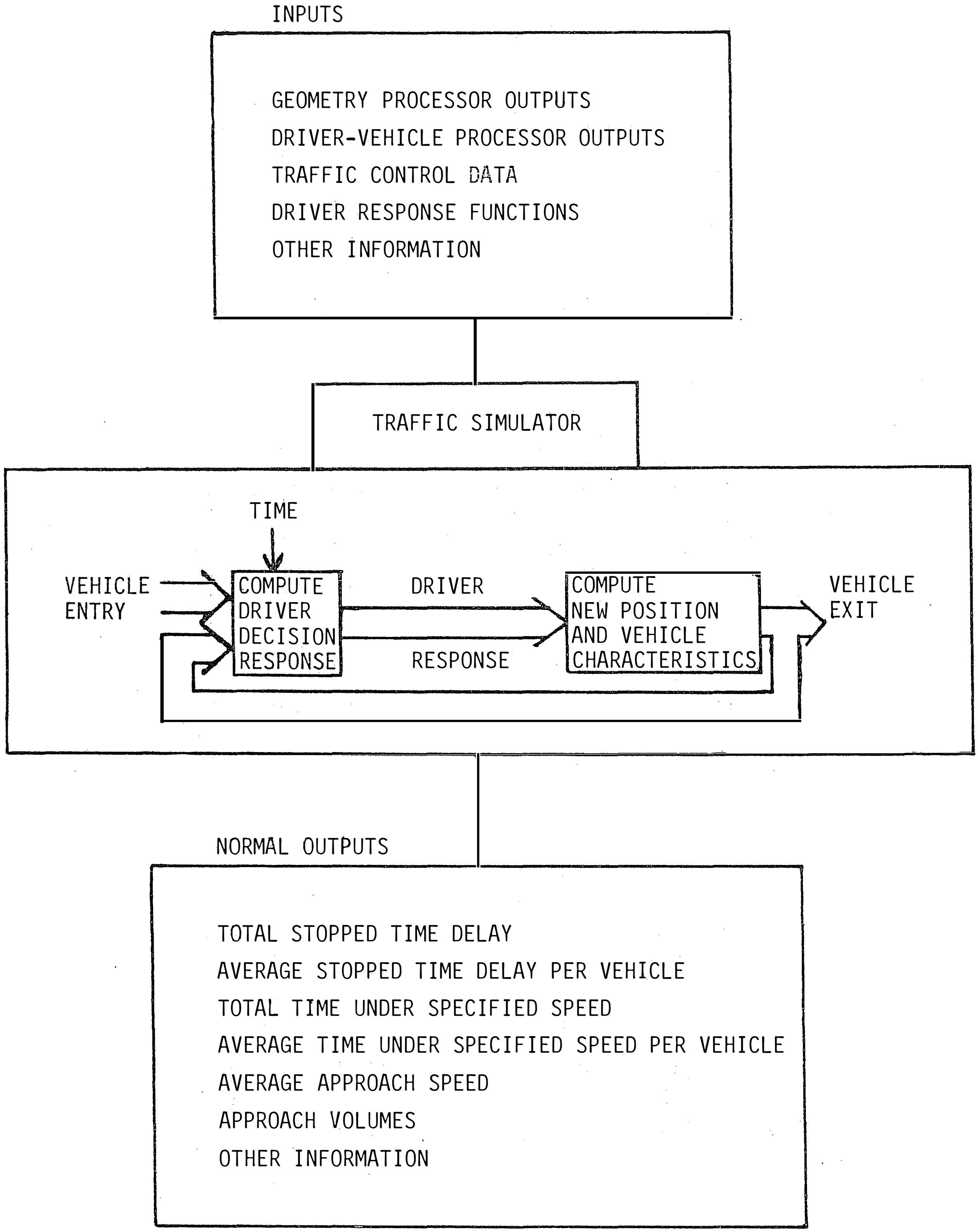

FIG 3. TRAFFIC SIMULATOR

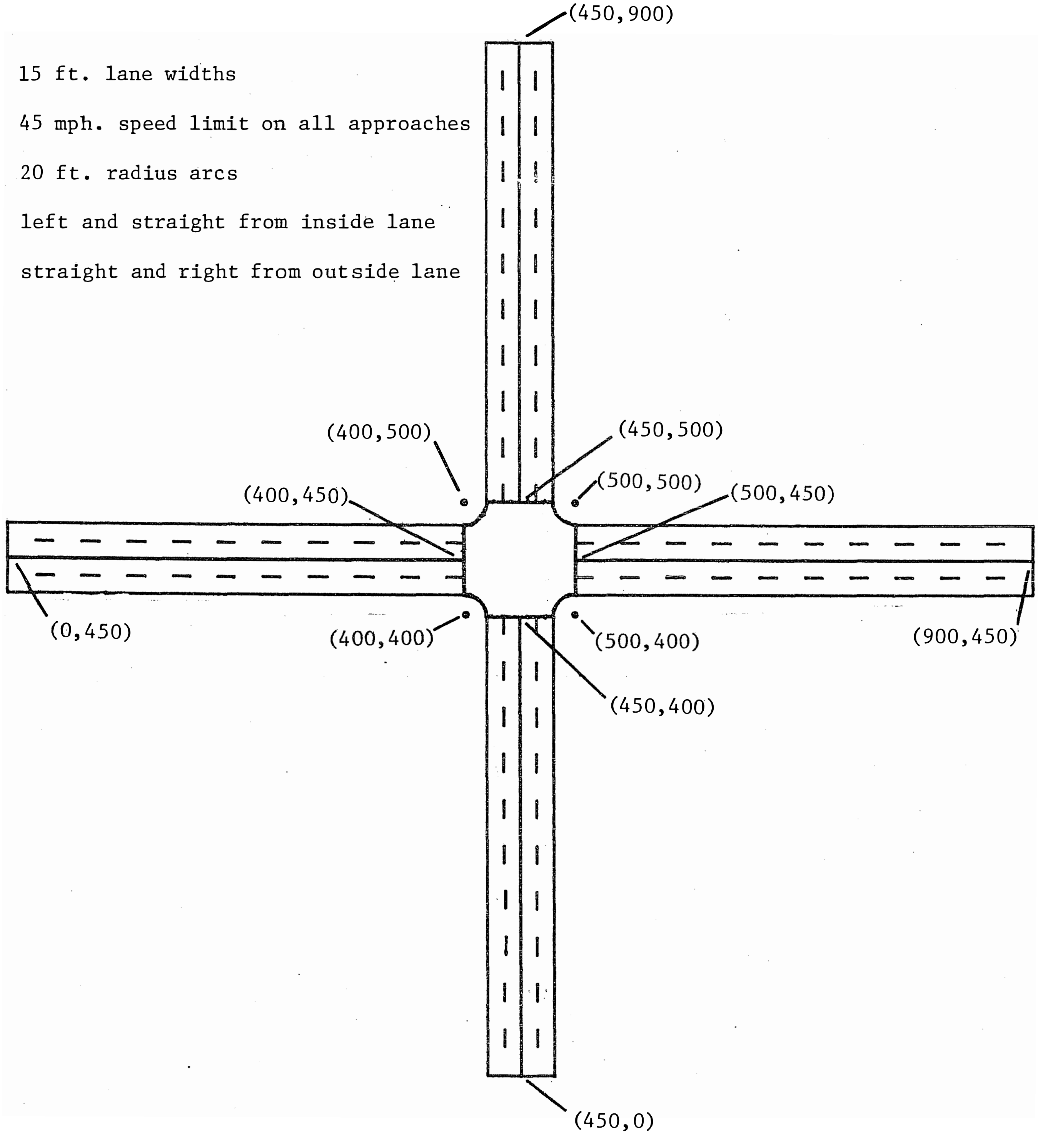

FIG 4. 4 LEG INTERSECTION EXAMPLE LAYOUT

```
*****                                   4 LEG INTERSECTION EXAMPLE
    4
    1
    3
    5
    7
    4
    2
    4
    6
    8
    8
    1 180 400 450 900   45    2   15    6   15    3
    2   0 400 450 500   45    2   15    0   15    0
    3 270 400 900 450   45    2   15    6   15    3
    4  90 400 500 450   45    2   15    0   15    0
    5   0 400 450   0   45    2   15    6   15    3
    6 180 400 450 400   45    2   15    0   15    0
    7  90 400   0 450   45    2   15    6   15    3
    8 270 400 400 450   45    2   15    0   15    0
    4
    1 500 500 180  90   20    0
    2 500 400 270  90   20    0
    3 400 400   0  90   20    0
    4 400 500  90  90   20    0
    0
OPTION1
PLOT1
1.0
SAME
20
10
500.0
```

FIG 5. GEOMETRY PROCESSOR INPUT

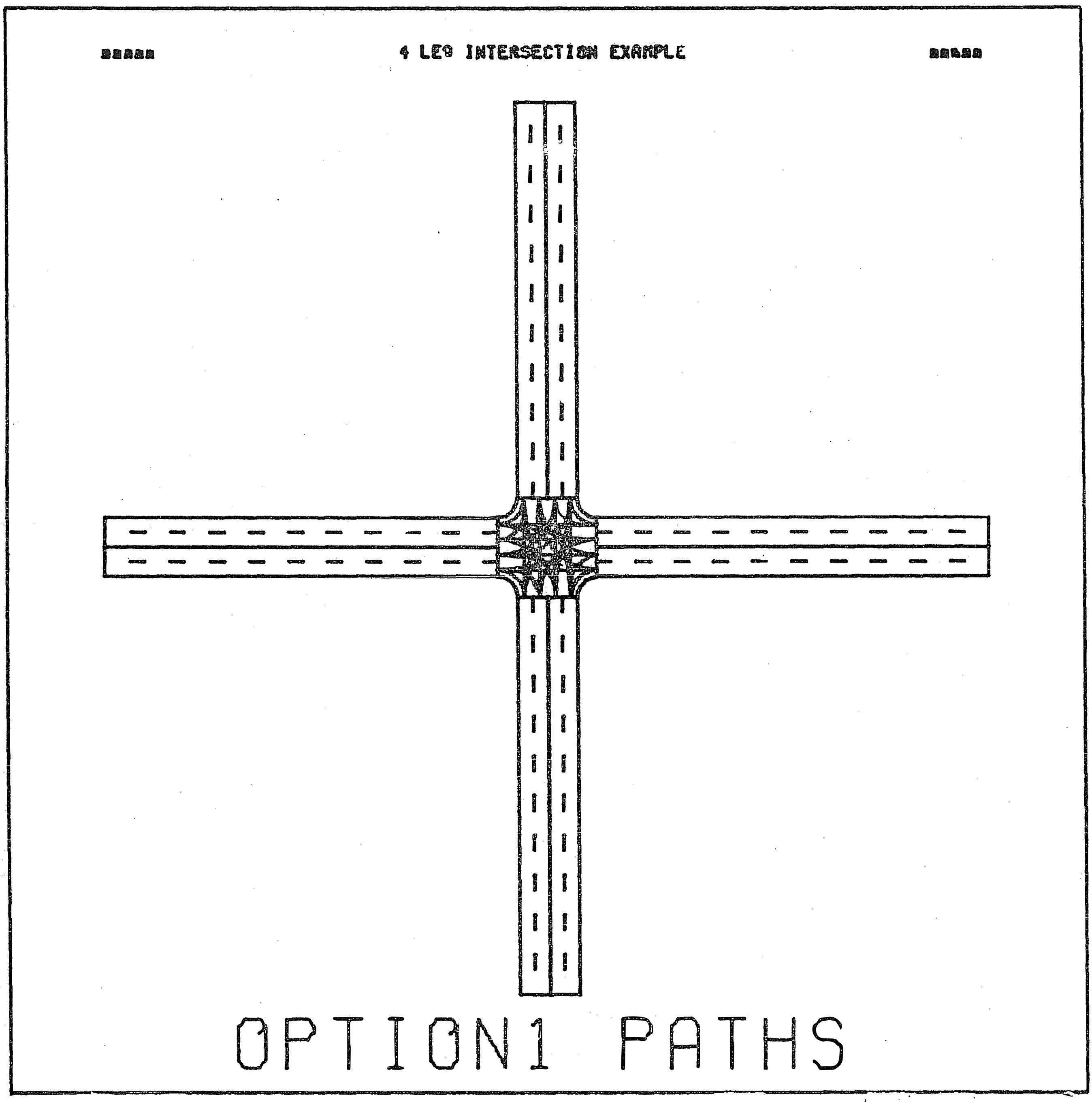

FIG 6a. GEOMETRY PROCESSOR OUTPUT - PLOT

PROGRAM FOR THE CALCULATION OF VEHICLE PATHS IN AN INTERSECTION

PROGRAMMED BY THOMAS W. RIOUX

***** 4 LEG INTERSECTION EXAMPLE *****

TABLE 1 - LISTING OF INBOUND APPROACH NUMBERS

1
3
5
7

TOTAL NUMBER OF INBOUND APPROACHES = 4

TABLE 2 - LISTING OF OUTBOUND APPROACH NUMBERS

2
4
6
8

TOTAL NUMBER OF OUTBOUND APPROACHES = 4

TABLE 3 - LISTING OF APPROACHES

APPROACH NUMBER	=	1
APPROACH AZIMUTH	=	180
APPROACH LENGTH	=	400
INBOUND CENTERLINE X COORDINATE	=	450
INBOUND CENTERLINE Y COORDINATE	=	900
SPEED LIMIT (MPH)	=	45
NUMBER OF LANES	=	2

LANE NUMBER	LANE WIDTH	LEGAL TURNING MOVEMENTS
1	15	6 = LS
2	15	3 = SR

FIG 6b. GEOMETRY PROCESSOR OUTPUT - PRINTED OUTPUT

PROGRAM FOR THE CALCULATION OF VEHICLE PATHS IN AN INTERSECTION

PROGRAMMED BY THOMAS W. RIOUX

***** 4 LEG INTERSECTION EXAMPLE *****

APPROACH NUMBER	=	2
APPROACH AZIMUTH	=	0
APPROACH LENGTH	=	400
INBOUND CENTERLINE X COORDINATE	=	450
INBOUND CENTERLINE Y COORDINATE	=	500
SPEED LIMIT (MPH)	=	45
NUMBER OF LANES	=	2

LANE NUMBER	LANE WIDTH	LEGAL TURNING MOVEMENTS
1	15	0 = OUTB
2	15	0 = OUTB

APPROACH NUMBER	=	3
APPROACH AZIMUTH	=	270
APPROACH LENGTH	=	400
INBOUND CENTERLINE X COORDINATE	=	900
INBOUND CENTERLINE Y COORDINATE	=	450
SPEED LIMIT (MPH)	=	45
NUMBER OF LANES	=	2

LANE NUMBER	LANE WIDTH	LEGAL TURNING MOVEMENTS
1	15	6 = LS
2	15	3 = SR

APPROACH NUMBER	=	4
APPROACH AZIMUTH	=	90
APPROACH LENGTH	=	400
INBOUND CENTERLINE X COORDINATE	=	500
INBOUND CENTERLINE Y COORDINATE	=	450
SPEED LIMIT (MPH)	=	45
NUMBER OF LANES	=	2

LANE NUMBER	LANE WIDTH	LEGAL TURNING MOVEMENTS
1	15	0 = OUTB
2	15	0 = OUTB

FIG 6b. GEOMETRY PROCESSOR OUTPUT - PRINTED OUTPUT continued

PROGRAM FOR THE CALCULATION OF VEHICLE PATHS IN AN INTERSECTION

PROGRAMMED BY THOMAS W. RIOUX

***** 4 LEG INTERSECTION EXAMPLE *****

APPROACH NUMBER	=	5
APPROACH AZIMUTH	=	0
APPROACH LENGTH	=	400
INBOUND CENTERLINE X COORDINATE	=	450
INBOUND CENTERLINE Y COORDINATE	=	0
SPEED LIMIT (MPH)	=	45
NUMBER OF LANES	=	2

LANE NUMBER	LANE WIDTH	LEGAL TURNING MOVEMENTS
1	15	6 = LS
2	15	3 = SR

APPROACH NUMBER	=	6
APPROACH AZIMUTH	=	180
APPROACH LENGTH	=	400
INBOUND CENTERLINE X COORDINATE	=	450
INBOUND CENTERLINE Y COORDINATE	=	400
SPEED LIMIT (MPH)	=	45
NUMBER OF LANES	=	2

LANE NUMBER	LANE WIDTH	LEGAL TURNING MOVEMENTS
1	15	0 = OUTB
2	15	0 = OUTB

APPROACH NUMBER	=	7
APPROACH AZIMUTH	=	90
APPROACH LENGTH	=	400
INBOUND CENTERLINE X COORDINATE	=	0
INBOUND CENTERLINE Y COORDINATE	=	450
SPEED LIMIT (MPH)	=	45
NUMBER OF LANES	=	2

LANE NUMBER	LANE WIDTH	LEGAL TURNING MOVEMENTS
1	15	6 = LS
2	15	3 = SR

FIG 6b. GEOMETRY PROCESSOR OUTPUT - PRINTED OUTPUT continued

PROGRAM FOR THE CALCULATION OF VEHICLE PATHS IN AN INTERSECTION

PROGRAMMED BY THOMAS W. RIOUX

***** 4 LEG INTERSECTION EXAMPLE *****

```
APPROACH NUMBER                        =    8
APPROACH AZIMUTH                       =  270
APPROACH LENGTH                        =  400
INBOUND CENTERLINE X COORDINATE        =  400
INBOUND CENTERLINE Y COORDINATE        =  450
SPEED LIMIT (MPH)                      =   45
NUMBER OF LANES                        =    2

          LANE NUMBER   LANE WIDTH   LEGAL TURNING MOVEMENTS

               1            15               0 = OUTB
               2            15               0 = OUTB

TOTAL NUMBER OF APPROACHES =  8
```

TABLE 4 - LISTING OF ARCS

```
ARC NUMBER                             =    1
CENTER X COORDINATE                    =  500
CENTER Y COORDINATE                    =  500
BEGINNING AZIMUTH                      =  180
NUMBER OF DEGREES                      =   90
RADIUS OF ARC                          =   20
ROTATION FROM BEGINNING AZIMUTH        =    0 =      CLOCKWISE

ARC NUMBER                             =    2
CENTER X COORDINATE                    =  500
CENTER Y COORDINATE                    =  400
BEGINNING AZIMUTH                      =  270
NUMBER OF DEGREES                      =   90
RADIUS OF ARC                          =   20
ROTATION FROM BEGINNING AZIMUTH        =    0 =      CLOCKWISE

ARC NUMBER                             =    3
CENTER X COORDINATE                    =  400
CENTER Y COORDINATE                    =  400
BEGINNING AZIMUTH                      =    0
NUMBER OF DEGREES                      =   90
RADIUS OF ARC                          =   20
ROTATION FROM BEGINNING AZIMUTH        =    0 =      CLOCKWISE
```

FIG 6b. GEOMETRY PROCESSOR OUTPUT - PRINTED OUTPUT continued

PROGRAM FOR THE CALCULATION OF VEHICLE PATHS IN AN INTERSECTION

PROGRAMMED BY THOMAS W. RIOUX

***** 4 LEG INTERSECTION EXAMPLE *****

ARC NUMBER	=	4		
CENTER X COORDINATE	=	400		
CENTER Y COORDINATE	=	500		
BEGINNING AZIMUTH	=	90		
NUMBER OF DEGREES	=	90		
RADIUS OF ARC	=	20		
ROTATION FROM BEGINNING AZIMUTH	=	0	=	CLOCKWISE

TOTAL NUMBER OF ARCS = 4

TABLE 5 - LISTING OF OPTIONS

OPTION1 PATHS SELECTED

NO PLOT SELECTED

20 DEGREES LEFT OR RIGHT OF STRAIGHT WILL BE CONSIDERED STRAIGHT

10 DEGREES LESS THAN 180 UTURN WILL BE CONSIDERED A UTURN

A STRAIGHT LINE WILL BE USED FOR A PATH WITH A RADIUS GT 500.00

FIG 6b. GEOMETRY PROCESSOR OUTPUT - PRINTED OUTPUT continued

PROGRAM FOR THE CALCULATION OF VEHICLE PATHS IN AN INTERSECTION

PROGRAMMED BY THOMAS W. RIOUX

***** 4 LEG INTERSECTION EXAMPLE *****

TABLE 6 - LISTING OF LANE COORDINATES (LANE,APPROACH)

IXAPP(1, 1) =	442	IYAPP(1, 1) =	500
IXAPP(2, 1) =	427	IYAPP(2, 1) =	500
IXAPP(1, 2) =	458	IYAPP(1, 2) =	500
IXAPP(2, 2) =	473	IYAPP(2, 2) =	500
IXAPP(1, 3) =	500	IYAPP(1, 3) =	458
IXAPP(2, 3) =	500	IYAPP(2, 3) =	473
IXAPP(1, 4) =	500	IYAPP(1, 4) =	442
IXAPP(2, 4) =	500	IYAPP(2, 4) =	427
IXAPP(1, 5) =	458	IYAPP(1, 5) =	400
IXAPP(2, 5) =	473	IYAPP(2, 5) =	400
IXAPP(1, 6) =	442	IYAPP(1, 6) =	400
IXAPP(2, 6) =	427	IYAPP(2, 6) =	400
IXAPP(1, 7) =	400	IYAPP(1, 7) =	442
IXAPP(2, 7) =	400	IYAPP(2, 7) =	427
IXAPP(1, 8) =	400	IYAPP(1, 8) =	458
IXAPP(2, 8) =	400	IYAPP(2, 8) =	473

FIG 6b. GEOMETRY PROCESSOR OUTPUT - PRINTED OUTPUT continued

```
*****                    4 LEG INTERSECTION EXAMPLE                    *****
   4
   1
   3
   5
   7
   4
   2
   4
   6
   8
   8
 180 400 450 900  66   2  15   6   8  15   3  23
   0 400 450 500  66   2  15   0   8  15   0  23
 270 400 900 450  66   2  15   6   8  15   3  23
  90 400 500 450  66   2  15   0   8  15   0  23
   0 400 450   0  66   2  15   6   8  15   3  23
 180 400 450 400  66   2  15   0   8  15   0  23
  90 400   0 450  66   2  15   6   8  15   3  23
 270 400 400 450  66   2  15   0   8  15   0  23
   4
 500 500 180  90  20   0
 500 400 270  90  20   0
 400 400   0  90  20   0
 400 500  90  90  20   0
   0
  32
   1   1   4   1   0   0   0   0   0 500 500  91  58 270  90   0   0   0   0   0
   0   0   0   0   0   0  91   4  18   1
   1   1   4   2 442 500  15 442 485 500 485  91  58 270  90   0   0   0   0   0
   0   0   0   0   0   0 106   4  18   1
   1   1   6   1 442 500 100 442 400   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0 100   2  66   0
   1   1   6   2   0   0   0   0   0 272 500  51 170  90  17 597 400  51 170 287
  17   0   0   0   0   0 102   2  31   0
   1   2   6   1   0   0   0   0   0 597 500  51 170 270  17 272 400  51 170  73
  17   0   0   0   0   0 102   2  31   1
   1   2   6   2 427 500 100 427 400   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0 100   2  66   0
   1   2   8   1 427 500  15 427 485 400 485  42  27  90  90   0   0   0   0   0
   0   0   0   0   0   0  57   1  13   0
   1   2   8   2   0   0   0   0   0 400 500  42  27  90  90   0   0   0   0   0
   0   0   0   0   0   0  42   1  13   0
   3   1   6   1   0   0   0   0   0 500 400  91  58   0  90   0   0   0   0   0
   0   0   0   0   0   0  91   4  18   1
   3   1   6   2 500 458  15 485 458 485 400  91  58   0  90   0   0   0   0   0
   0   0   0   0   0   0 106   4  18   1
   3   1   8   1 500 458 100 400 458   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0 100   2  66   0
   3   1   8   2   0   0   0   0   0 500 628  51 170 180  17 400 303  51 170  17
```

FIG 6c. GEOMETRY PROCESSOR OUTPUT - TRAFFIC SIMULATOR INPUT

17	0	0	0	0	0	102	2	31	0										
3	2	2	1	500	473	15	485	473	485	500	42	27	180	90	0	0	0	0	0
0	0	0	0	0	0	57	1	13	0										
3	2	2	2	0	0	0	0	0	500	500	42	27	180	90	0	0	0	0	0
0	0	0	0	0	0	42	1	13	0										
3	2	8	1	0	0	0	0	0	500	303	51	170	0	17	400	628	51	170	163
17	0	0	0	0	0	102	2	31	1										
3	2	8	2	500	473	100	400	473	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	100	2	66	0										
5	1	2	1	458	400	100	458	500	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	100	2	66	0										
5	1	2	2	0	0	0	0	0	628	400	51	170	270	17	303	500	51	170	107
17	0	0	0	0	0	102	2	31	0										
5	1	8	1	0	0	0	0	0	400	400	91	58	90	90	0	0	0	0	0
0	0	0	0	0	0	91	4	18	1										
5	1	8	2	458	400	15	458	415	400	415	91	58	90	90	0	0	0	0	0
0	0	0	0	0	0	106	4	18	1										
5	2	2	1	0	0	0	0	0	303	400	51	170	90	17	628	500	51	170	253
17	0	0	0	0	0	102	2	31	1										
5	2	2	2	473	400	100	473	500	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	100	2	66	0										
5	2	4	1	473	400	15	473	415	500	415	42	27	270	90	0	0	0	0	0
0	0	0	0	0	0	57	1	13	0										
5	2	4	2	0	0	0	0	0	500	400	42	27	270	90	0	0	0	0	0
0	0	0	0	0	0	42	1	13	0										
7	1	2	1	0	0	0	0	0	400	500	91	58	180	90	0	0	0	0	0
0	0	0	0	0	0	91	4	18	1										
7	1	2	2	400	442	15	415	442	415	500	91	58	180	90	0	0	0	0	0
0	0	0	0	0	0	106	4	18	1										
7	1	4	1	400	442	100	500	442	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	100	2	66	0										
7	1	4	2	0	0	0	0	0	400	272	51	170	0	17	500	597	51	170	197
17	0	0	0	0	0	102	2	31	0										
7	2	4	1	0	0	0	0	0	400	597	51	170	180	17	500	272	51	170	343
17	0	0	0	0	0	102	2	31	1										
7	2	4	2	400	427	100	500	427	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	100	2	66	0										
7	2	6	1	400	427	15	415	427	415	400	42	27	0	90	0	0	0	0	0
0	0	0	0	0	0	57	1	13	0										
7	2	6	2	0	0	0	0	0	400	400	42	27	0	90	0	0	0	0	0
0	0	0	0	0	0	42	1	13	0										

FIG 6c. GEOMETRY PROCESSOR OUTPUT - TRAFFIC SIMULATOR INPUT continued