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DIAMOND INTERCHANGE TRAFFIC CONTROL

Vol. 3. Program Manual for Microscopic Simulation Model of Diamond Interchange Traffic Operations

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B. D. Widdice

May 1972
Final Report

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16. Abstract

Results of a research contract to improve the operational efficiency of high demand signalized diamond interchanges are presented in a six (6) volume report. In this volume, a manual has been developed to assist users of a digital computer simulation model of detailed traffic operations in a diamond interchange, including the two nearby signalized intersections. The model employs microscopic modeling techniques. It has been programmed in JOVIAL, a high-level computer language for IBM 360 (or 370) digital computers under the OS/360 operating system. The model can accommodate parameter value changes in geometrics, signal control, and demand distributions. Traffic operations such as average travel time, speed, and queue length are provided. This information can be provided on a section or an overall system basis.

Other volumes in this report include:

Vol. No.	FHWA NO.	Short Title	NTIS(PB)No.	Cost
1	73-34	Geometric Design & Signal Char.	217527	$ 3.00
2	73-35	Design Manual	217518	3.00
4	73-37	Macroscopic Simulation Model	216990	3.00
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PREFACE

This is one of a series of reports being issued under the Research Programs on Control and Geometric Design of Diamond Interchanges. It describes the use of a microscopic digital computer simulation model of traffic operations in a diamond interchange complex, programmed for an IBM 370. The work is being performed under Contract No. FH-11-7568 for the Federal Highway Administration, in collaboration with the State of California Division of Highways and the City of Los Angeles Department of Traffic. Jaime F. Torres is the Program Manager of this research program.

B. D. Widdice was principally responsible for the development of this model. Substantial contributions were made by J. Nemeczky, D. Levine, H. Manelowitz, and J. Norum. J. F. Torres and J. Nemeczky made significant contributions in the preparation of this report.

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1. INTRODUCTION

The need for a tool or technique for determining the preferred design and operational configurations for diamond interchanges is well recognized by practitioners in the traffic engineering field. Traffic operations are so complex in a signalized diamond interchange, further complicated in urbanized areas by its closeness to other signalized surface street intersections, that the problem defies analytical solution. The application of field experimental techniques to the investigation of operational problems, furthermore, is an expensive and time-consuming process. The only feasible way to investigate these difficult operational problems in an effective way is through the application of simulation.

A digital computer simulation model of detailed traffic operations in a diamond interchange complex has been developed by SDC. A diamond interchange complex is defined to include the two nearby signalized surface street intersections, as well as the two ramp intersections. This configuration thus encompasses a wide number and variety of traffic movements. Microscopic simulation modeling techniques have been applied in the development of a digital computer simulation model of the diamond interchange complex. The microscopic simulation of traffic was believed to be necessary in order to reasonably guarantee reliable model outputs and also to be able to provide users of the model with detailed operational information. Traffic and highway engineers often would like to know the detailed behavior of traffic, such as the location and speeds of vehicles in specific lanes. The use of microscopic techniques permits the detailed examination of intricate traffic movements on the diamond interchange and also is able to provide precise estimates of average travel time, speed, queue lengths, and lane-changing information. This information can be provided on a lane or section basis, as well on an overall, system basis. The output statistics provided include averages and standard deviations.

The simulation model has been tested and validated, using aerial photographic data. Before-and-after studies have also been conducted with this model and the performance results have been compared against the measured performance of the corresponding operational situations - these have shown good agreement.

This program manual describes the use and application of this simulation model, with the principal discussion on the model application presented in Section 5. A general description of the model logic is given in Section 3, in order to assist the user in the application of the model. Examples have been used wherever it was felt it would be helpful to the model user. The model is capable of accommodating parametric changes in: (1) geometrics, (2) demands, and (3) signalization. It is further flexible enough to be able to simulate computerized traffic control operations, as well as pretimed traffic control systems operations.

The remainder of the manual discusses the program constraints and limitations (in Section 4), job control (in Section 6), and some of the program printouts (in Section 7).

2. GENERAL MODEL DESCRIPTION

The simulation model uses a periodic scanning method to update and move vehicles. This method advances the arterial clock one review period (0.50 seconds), upon which the entire system is reviewed and updated to the conditions corresponding to the current time. To increase model stability, all arterial drivers are assumed to have a uniform response time - a delay of one second between the time a driver perceives an event, decides to respond, and initiates the response.

The simulation model has been programmed in JOVIAL, an SDC-developed high-level language. The model can be run on the IBM-360 type of computers, under the OS/360 operating system. The operation of the computer program requires about 344,000 bytes of core, which includes the IBM computer operating system requirements. The program, itself, is estimated to require about 311,000 bytes of core. The ratio of simulated time to computer running time is approximately three-to-one, for medium to heavy traffic conditions, and for a facility including the two signalized nearby arterial intersections. As the number of vehicles being processed is reduced, the ratio increases.

2.1 VEHICLE MOVEMENT LOGIC

By the very nature of the microscopic model, the precise location, velocity, and acceleration characteristics of each vehicle are known with a precision of 0.1 foot, 0.1 foot/sec, and 0.01 ft/sec/sec, respectively. Movement of the arterial vehicles is governed by four basic models: free behavior, car-following, stopping, and turning. When the spacing between the leader and follower is more than a user-designated distance, a following vehicle is defined as being in a free-behavior mode and is independent of the preceding vehicle. The free-behavior mode determines the constant rate of acceleration (plus or minus) required to allow a vehicle to achieve or maintain its desired free-flow velocity.

The specific form of the stimulus-response car-following model is the reciprocal spacing model. This model is responsible for all leader-follower behavior when the two vehicles are closer than the user-designated distance and thus involved in the car-following process. The mathematical form of this model is:

$$\ddot{x}_n = \alpha \frac{[\dot{x}_{n-1} - \dot{x}_n]}{[x_{n-1} - x_n]}$$

where

n = follower

$n-1$ = leader

x = position of the vehicle

$\dot{x}$ = velocity of the vehicle

$\ddot{x}$ = acceleration of the vehicle

α = characteristic lane velocity .

If a vehicle must stop, because of a red traffic signal or because its leader is stopped or stopping, the stopping model determines the constant deceleration rate required to bring the vehicle to its desired stopped location. Upon this determination, the required rate is compared to the vehicle's desired deceleration rate. No vehicle will begin to decelerate until the required rate exceeds the desired rate. If the desired rate is not exceeded, the vehicle will continue to operate under the other three models until the desired rate is exceeded.

All turn-designated vehicles determine if their current velocity is greater than the maximum permissible turning velocity for the particular turning maneuver they are to begin. If the current velocity exceeds the maximum turning velocity, the deceleration rate required to reach maximum turning velocity at the beginning of the turn is computed. This computed deceleration rate is used to slow the vehicle if the rate is more restrictive than the rate computed from the free-behavior or car-following model.

The vehicle behavior equation yields an acceleration (positive or negative) which begins after one driver-vehicle reaction time (one second) and continues for one review period (0.50 seconds). The vehicle movement between reviews is determined by the equations of motion.

2.2 VEHICLE PERFORMANCE STATISTICS

The Model 3-A statistics are categorized into system and regional groupings. System statistics are provided by origin-destination and include the number of vehicles traversing the facility, average travel time, and average velocity. Regional statistics are also provided by origin-destination and include the number of entering and exiting vehicles, average velocity, input and output boundary velocities, delay, and average travel time. Additional origin-destination regional statistics include total amount of stopped time, sectional average run time, and velocity.

Operational performance is also described on a lane basis. Statistics include number of entering and exiting vehicles and average travel time, delay, and input and output boundary velocity.

Lane-change plan formation information is tabulated according to the lane in which the plan was formed. Statistics include number of changes, left and right, and the average amount of time required to complete the planned lane-change.

Vehicle queueing information is derived by grouping all vehicles using a common lane. Information is given on average number of vehicles queued and the maximum number of vehicles queued in that lane.

3. GENERAL LOGIC DESCRIPTION

The following section discusses the parametric modifications which can be made to the simulation model. These modifications may be made both statically and/or dynamically. Static modification includes initialization of all program parametric values before the simulation problem has begun execution. Dynamic modifications are restricted to changes in arterial traffic signal timing and vehicle generation flow rates. These dynamic changes may be made during the execution of the simulation problem.

The time duration for each simulation problem may be divided into two time periods. During both periods vehicles enter and traverse the arterial street network. However, summary vehicle performance statistics for the arterial street network are tabulated only during the second time period. During the first time period, which is used for system warmup, these statistics are not tabulated.

The number of integer seconds allocated to system warmup is entered into the model through the simple item AWARMUP. This is a signed 32-bit item. The number of integer seconds allocated to system statistical tabulation, exclusive of warmup period, is entered into the model through the simple item ENDCLT. This is a signed integer 32-bit item. The sum of the times allocated to AWARMUP and ENDCLT equals the total time duration of the simulation problem. This total time duration is computed by program logic and is not entered into the model.

The time period defined by ENDCLT may be divided into contiguous statistical tabulation periods. At the end of each tabulation period, the vehicle performance statistics can be summarized and produced as output on magnetic tape. The cumulative time duration of each summary period is entered into the model through the table item IOEPILOG. This is a signed 32-bit integer item.

At the completion of each summary output, the statistical tabulation tables are cleared, thus subsequent output will only reflect traffic performance for the current period.

Dynamic changes to the values of selected parametric items, during execution of the program, are made through the reading of computer cards and may be at any time during the simulation problem. The data entered are substituted for existing values of the parametric item(s) by procedure NUDATA, (cf. Section 5.1.) which involves the reading of computer cards with the prescribed changes. The cumulative time after which additional data cards will be read is entered into the model through the table item TMELIN. This is a signed 32-bit item.

3.1 REGION IDENTIFICATION

The diamond interchange complex simulation model consists of the arterial street serving a diamond interchange, the two exit ramps, and the links and approaches to the two nearby intersections. A nearby signalized intersection is considered to be located at each arterial street approach to the diamond interchange.

The arterial street-diamond interchange geometric configuration has been subdivided into twenty-two regions, composed of lane groupings having unidirectional traffic flow and characterized by uniform operating conditions. These regions are defined as "active" regions. There are also eight regions which are used by the arterial model, but only as a means to constrain the simulation to the output operational characteristics in a controlled manner. These exit regions are defined as "downstream" regions. These two sets of regions comprise a total of 30 regions.

Figure 3.1 is a diagrammatical representation of the thirty permissible regions which may be used to simulate the arterial street system. Referring to Figure 3.1, regions 0 through 21 are designated as the "active" regions, while regions 22 through

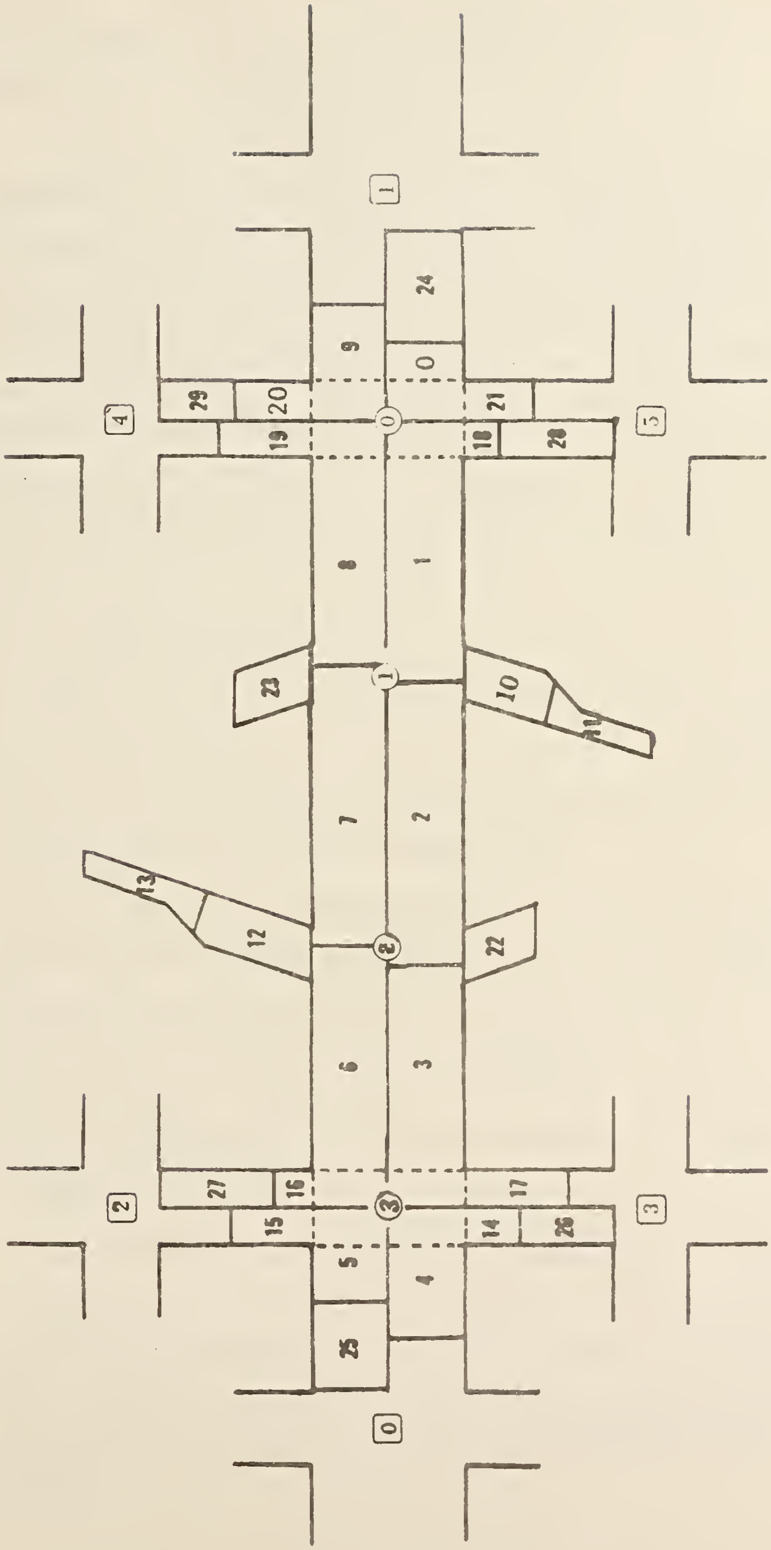


Figure 3.1. Diamond Interchange Complex Geometry Showing All Possible Regions

29 are the "downstream" regions. During each simulation problem, regions 0 through 21 are designated as being "active" or "inactive" in order to simulate a particular geometric site.

The entire 22 "active" regions are not required to be used during a simulation problem. The only restriction on permissible geometrics configurations is that the "active" regions being simulated must be a contiguous set or subset of the 22 "active" regions. For example, an isolated diamond interchange with one exit ramp and one entrance ramp may be represented by designating regions 1, 2, 3, 6, 7, 8, 12, and 13 as "active" regions. Regions 23, 24, and 25 would be designated as "downstream" regions, while all remaining regions are considered to be "inactive". Vehicles would be prohibited from entering region 23 from region 2, thereby forming the single entrance ramp. See Section 3.3 for turn designations from a section, which explains how certain turn maneuvers may be prohibited.

A four-way intersection may be represented by designating regions 3, 4, 5, 6, 14, 15, 16, and 17 as "active" regions and regions 2, 25, 26, and 27 would be designated "downstream" regions by the model, while all remaining regions are considered to be "inactive". Vehicles would only be permitted to enter region 2 from region 3, thereby eliminating the entrance ramp (region 22). Thus, by designating a contiguous subset of the twenty-two "active" regions as being "active or "inactive" during a simulation problem, various geometric configurations of an arterial street or a diamond interchange may be simulated.

Each of the first 22 bits (left-justified) of the 32-bit computer word ARTERIAL identifies the correspondingly numbered region in Figure 3.1. By designating a "0" or "1" in the appropriate bit of ARTERIAL, the desired contiguous subset of the 30 possible regions are identified for the geometric configuration to be simulated.

Program logic requires each "active" model region to be designated if it is a system entrance region or a system exit region. An entrance region is one through which vehicles enter the simulated roadway. An exit region is one through which vehicles exit the simulated roadway and is not controlled by a traffic signal, cf. Section 3.8. Items ENTRAN and XIT are used to denote a region as an entrance or exit region, respectively. Both are signed integer 16-bit items. A "0" denotes the region is not an entrance or exit region, while a "1" denotes the region is an entrance or exit region.

3.2 LANE IDENTIFICATION

Each of the thirty arterial street active or downstream regions may have from one to four lanes with the exception of the entrance and exit ramp regions. These six regions (10, 11, 12, 13, 22, and 23) may have from one to three lanes.

A maximum lane configuration has been established and a unique numerical designation has been given to each lane, see Figure 3.1A. This numerical designation has been assigned so that, generally, lane number increases when moving across lanes from the curb lane to the median lane. For example, Table 3-1 has the program default values identifying the first lane number in each model and downstream region.

Certain lane information is identified or classified as entrance or exit lane information. An entrance lane is considered to be a lane at the entrance boundary of a region through which vehicles may enter the region. An exit lane is considered to be a lane at the exit boundary of a region through which vehicles may exit the region.

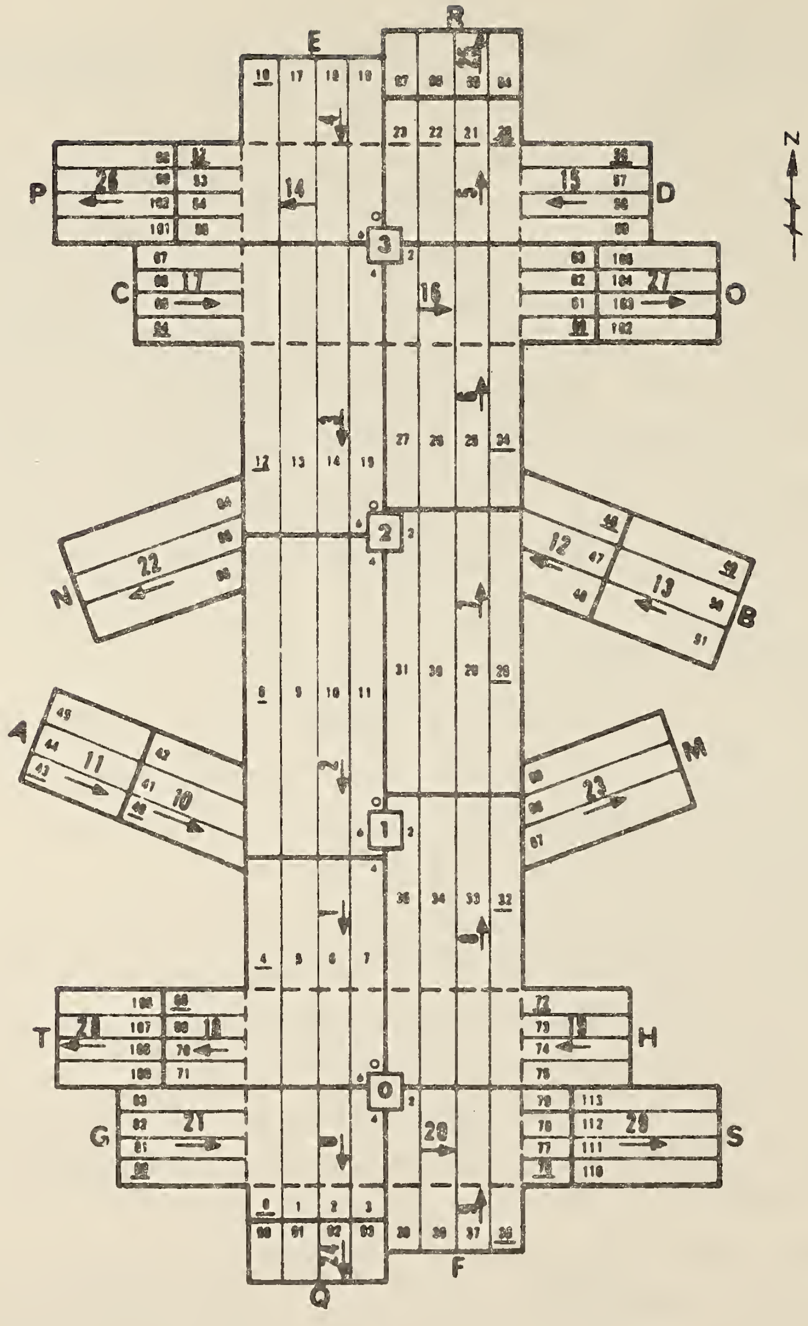


Figure 3.1A. Lane Assignments of Simulation Model.

TABLE 3-1

REGIONAL DEFAULT VALUES

Region	First Lane in Region	Region							
		Ahead	Behind	BSIDE	Out on Right (RTOUT)	Out on Left (LTOUT)	In on Right (RTIN)	In on Left (LTIN)	Opposing (POSE)
0	0	24	1	9	*	*	*	*	*
1	4	0	2	8	18	20	21	19	9
2	8	1	3	7	*	23	10	*	8
3	12	2	4	6	22	*	*	12	7
4	16	3	*	5	14	16	17	15	6
5	20	25	6	4	*	*	*	*	*
6	24	5	7	3	16	14	15	17	4
7	28	6	8	2	*	22	12	*	3
8	32	7	9	1	23	*	*	10	2
9	26	8	*	0	20	18	19	21	1
10	40	30	11	30	1	7	8	2	*
11	43	10	*	30	*	*	*	*	*
12	46	30	13	30	6	2	3	7	*
13	49	12	*	30	*	*	*	*	*
14	52	26	15	17	*	*	*	*	*
15	56	14	*	16	5	3	4	6	17
16	60	27	17	15	*	*	*	*	*
17	64	16	*	14	3	5	6	4	15
18	68	28	19	21	*	*	*	*	*
19	72	18	20	20	8	0	1	9	21
20	76	29	21	19	*	*	*	*	*
21	80	20	*	18	0	8	9	1	19
22	84	*	*	*	*	*	*	*	*
23	87	*	*	*	*	*	*	*	*
24	90	*	*	*	*	*	*	*	*
25	94	*	*	*	*	*	*	*	*
26	98	*	*	*	*	*	*	*	*
27	102	*	*	*	*	*	*	*	*
28	106	*	*	*	*	*	*	*	*
29	110	*	*	*	*	*	*	*	*

The integer number of lanes at the entrance boundary of each model and downstream region used in the simulation problem is entered into the model through the table item NOLAN. This is a signed 16-bit item. The program logic uses this entrance lane information in conjunction with other lane and regional information to establish the number of exit lanes.

During program initialization, program logic assigns lane numbers corresponding to the lane numerical designations in Figure 3.1A. In regions having fewer than the maximum lane configuration, the program logic assumes the lanes being simulated start at the curb lane and indexes the required number of adjacent lanes. For example, if model region 2 is designated as having two entrance and two exit lanes, then lanes 8 and 9 will be included in the simulation problem and no consideration will be given to lanes 10 and 11.

3.3 STRAIGHT-THROUGH AND TURN MOVEMENTS

Each model region has designated to it whether left-turn, right-turn, and straight-through movements are permitted from the region. Consequently, by designating which movements are permitted to enter an intersection the desired intersectional operational control may be introduced into the simulation problem.

The following table items are used to indicate if the associated movement is permitted to emanate from the model region:

TRNST - Straight Movement

TRNLT - Left-turn Movement

TRNRT - Right-turn Movement.

By definition "0" indicates the movement is not permitted, while "1" indicates the movement is permitted to emanate from the model region. By designating the above three items to be "0" or "1", the permitted movements are entered into the model. These three items are unsigned integer 1-bit items.

3.3.1 Turn-Movement Options. All right-turn movements must be made single-file from the curb lane, with the exception of the two exit ramp regions 10 and 12 where dual right-turn movements are permitted.

In region 10 and 12, one of six combinations of left- and right-turn movements is permitted during a segment of the simulation problem. Table item RAMP is used to designate which configuration of lanes and turn combinations have been selected to be simulated. This is a signed integer 16-bit item. By setting the table item RAMP to one of the following numerical values, the turn options permitted from the exit ramp regions 10 and 12 are established for the model. The numerical designations are given in Table 3-1A and are shown in Figure 3.2.

TABLE 3-1A TURN OPTION DESIGNATIONS

1 - Two-lane ramp with dual left turns and single right turns.
2 - Three-lane ramp with dual left turns and single right turns.
3 - Two lane ramp with both single left and right turns.
4 - Two-lane ramp with single left and dual right turns.
5 - Three-lane ramp with single left and dual right turns.
6 - Three-lane ramp with both dual left and right turns.

These six left- and right-turn movement options from regions 10 and 12 are depicted in Figure 3.2. The model's logic also considers regions 11 and 13 as exit-ramp regions. However, no left or right-turn movements are permitted from these two regions. For all regions, except regions 10 and 12, RAMP should be set to 0.

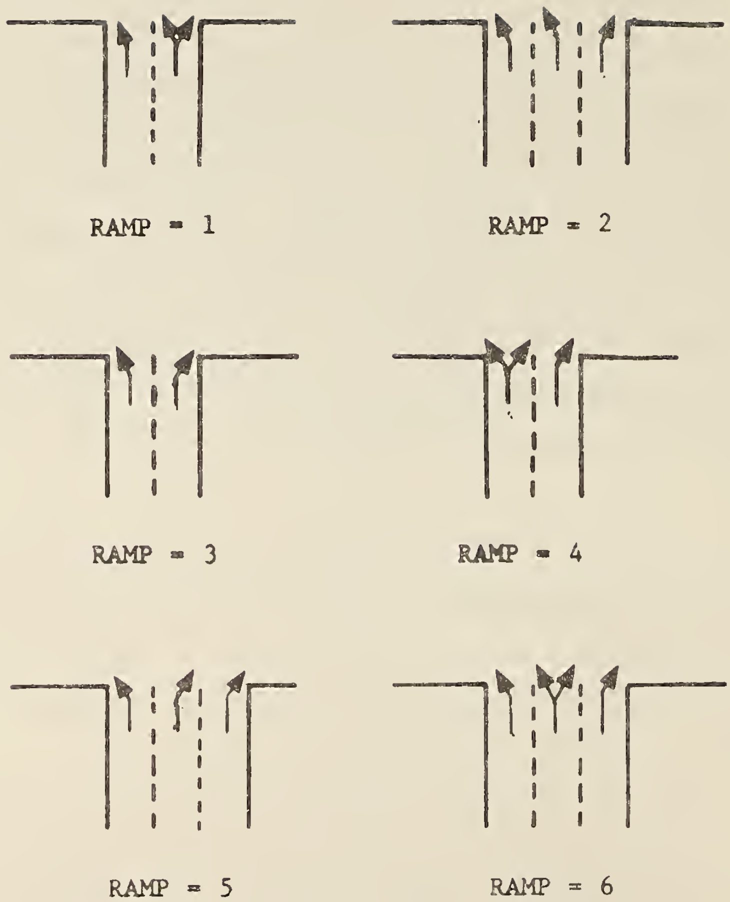


Figure 3.2. Turning Movements Permitted from Off-Ramp (Regions 10 and 12)

All left-turn movements are made from the lane(s) closest to the median side of the region. Single and dual left-turn movements are permitted to be made from all model regions, with the exception of regions 3 and 8. All left-turn movements are prohibited in these two model regions for there are no regions into which left-turning vehicles may enter. If dual left-turns are permitted to emanate from a region, table item DBL is set equal to "1". If only single left-turns are permitted, item DBL is set equal to "0". This is an unsigned integer 8-bit item.

The unit integer percent of the total left-turn movement which may elect to use a dual left-turn lane is entered into the model through the table item DLT. This is a signed integer 8-bit item. Furthermore, the integer percent of the total right-turn movement which may elect to use a dual right-turn lane in region 10 or 12 is entered into the model through the table item DRT. This is a signed integer 8-bit item. It is not implied that this percentage of vehicles will actually make a dual turn. This percentage represents only the portion of the total turn movement that may use the dual turn lane. The remaining percentage of vehicles will automatically select a single turn trajectory.

The selection of a dual turn movement is based upon the shortest queue length in the dual turn lane. The selection is weighted toward the single turn and not the dual turn. The number of queued vehicles in the single turn lane must exceed the number of queued vehicles in the dual lane plus a specified number of additional queued vehicles in the dual turn lane. These additional queued vehicles are used to bias the selection of a dual turn. The number of additional queued vehicles are entered into the model through the table items

XTRCAR for a left-turn, and XTRVEH for a right-turn movement. Both table items are signed integer 16-bit items.

Exclusive left-turn lanes may be declared in all model regions. Only left-turn movements are permitted to exit these lanes. In the regions 10 and 12--the two exit ramp regions--two exclusive dual left-turn lanes may be declared using table item RAMP. For all remaining regions, the exclusive left-turn lane designation is entered into the model through the table item EXLT. This is an unsigned integer 1-bit item. If an exclusive left-turn storage lane is required, table item EXLT is set equal to "1", and if the lane is not required, the table item is set equal to "0".

In the case where a dual left-turn movement is permitted, the median lane is automatically designated as an exclusive left-turn lane. The lane adjacent to the median lane, from which the second left-turn movement is made, may not be designated as an exclusive left-turn lane. Straight-through or right-turn movements may share this second lane.

The various left turn movements which may be simulated are given in Figures 3.2 and 3.3.

3.3.2 <u>Left- and Right-Turn Classification</u>. Vehicles that desire to turn left or right at an intersection select a turn trajectory to follow throughout their turn. Left-turning vehicles decide if gaps and lags in opposing approach traffic are sufficiently large to be accepted. If a gap or lag is found to be acceptable, a turn trajectory is selected to allow the vehicle to make the turn with the largest permissible turning radius. This turn is referred to as a "free" turn. If the gap or lag is found to be unacceptable, then the vehicle selects a shorter turn radius and then proceeds to a designated location in the intersection and waits until an acceptable gap or lag is

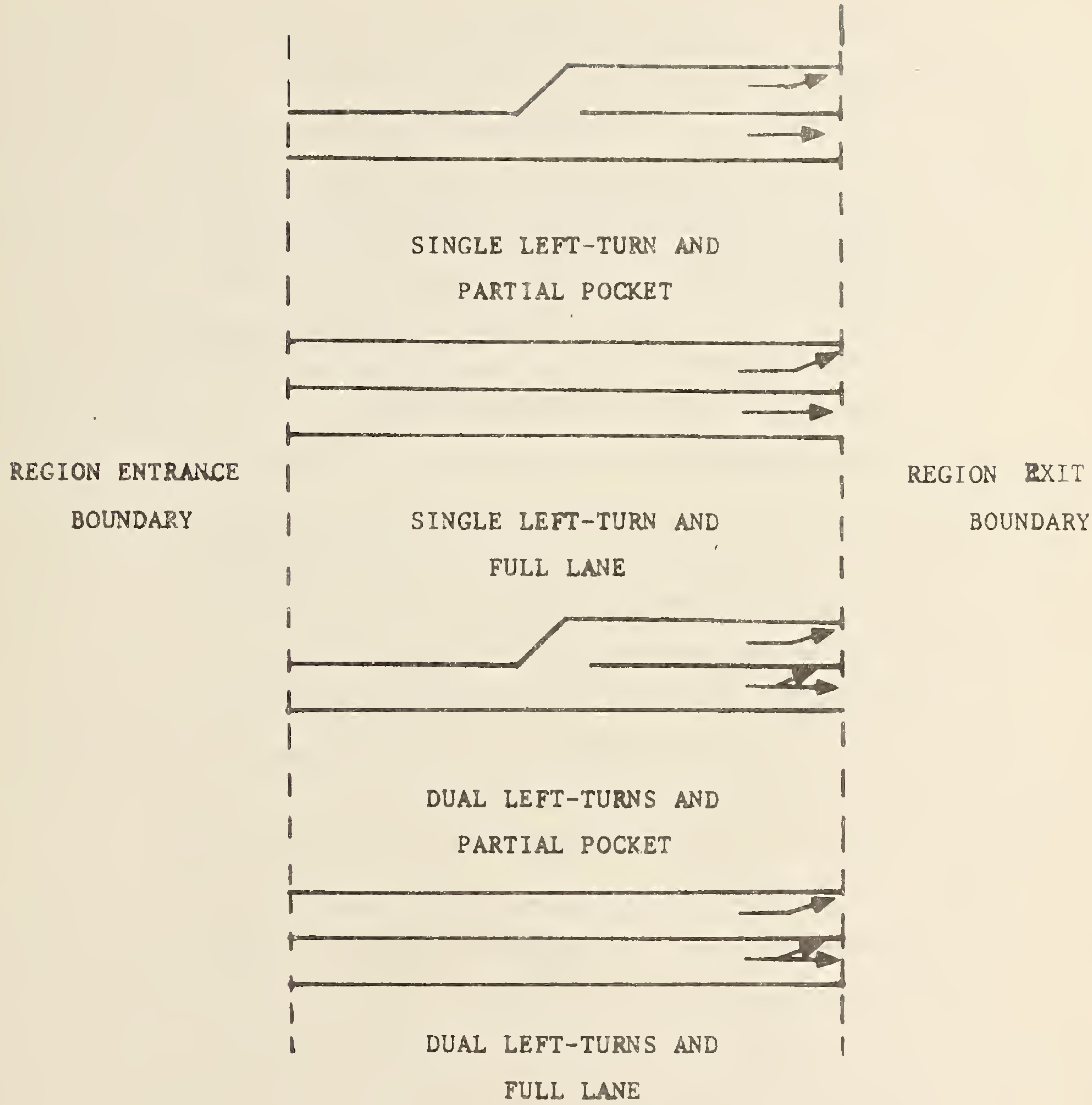


Figure 3.3. Allowable Arterial On-Ramp Left-Turn Geometric and Operational Combinations

found. This turn trajectory is referred to as a "delayed" turn. There is no differentiation made for right-turn trajectories as made between a "free" or "delayed" left-turn.

Data required for the left-or right-turn movements is classified into 238 unique turn trajectories. This total includes both "free" and "delayed" left-turns as well as right-turns. The turns are classified according to the lane from which the turn begins and the lane in which the turn terminates. Information contained in each classification pertains to:

- Lane number from which the turn begins
- Lane number in which the turn terminates
- Radius of the turn
- Maximum allowable turning velocity
- Wait position if the vehicle must stop
- Location at which the vehicle enters another section
- Coordinate translation value
- Percentage of vehicles accepting the turn.

All turn classification data with the exception of the turn radius and turning percentage are either default values or are computed by the model during program initialization. The radius of turn must be provided for each turn classification permitted by the constraints of lane configuration and permitted turns, see Section 3.3.1. The turning radius, expressed in tenths of feet, is entered into the model through the table item RAD. This is a signed integer 13-bit item.

The maximum allowable turning velocity for all turns is computed using the equation

$$\text{Maximum Velocity} = \sqrt{f*g*RAD}$$

Where f = coefficient of friction

g = acceleration of gravity, 32.2 ft/sec/sec

RAD = turning radius

The AASHO Policy on Geometric Design (Rural) indicates that the 95-percentile turning speed is associated with a coefficient of friction, f, equal to 0.3 for medium low-speed turns. Therefore,

$$\text{Maximum Velocity} = \sqrt{9.66*RAD}$$

Table 3-2 lists each turn classification giving originating section and lane, terminating section and lane, direction of turn (left or right), and if the left-turn is "free" or "delayed". The appropriate subset of these 238 turn trajectories must be selected to facilitate the required turn maneuvers using the prescribed lane configuration.

The probability of a vehicle accepting a certain turn classification depends upon the direction of the turn movement (left or right) and if the turn is a dual or single turn. A left-turn movement is classified as either a "free" or "delayed" left-turn. However, a left-turn vehicle may not select a "delayed" left-turn since this turn is imposed upon the turning vehicle if it is unable to complete the previously selected "free" turn. Thus, for each direction of turn there are two groupings of turns which may be selected to complete the required turn movement. For

Left-turn: 1. single "free" turn

2. dual "free turn

Right-turn: 1. single turn

2. dual turn.

TABLE 3-2

LEFT AND RIGHT TURN CLASSIFICATION

Turn Classification	Originating Section	Originating Lane	Terminating Section	Terminating Lane	Direction Turn	Free or Delayed
1	1	Median	20	76	Left	Free
2	1	Median	20	76	Left	Delay
3	1	Median	20	77	Left	Free
4	1	Median	20	77	Left	Delay
5	1	Median	20	78	Left	Free
6	1	Median	20	78	Left	Delay
7	1	Median	20	79	Left	Free
8	1	Median	20	79	Left	Delay
9	1	Adjacent*	20	76	Left	Free
10	1	Adjacent	20	76	Left	Delay
11	1	Adjacent	20	77	Left	Free
12	1	Adjacent	20	77	Left	Delay
13	1	Adjacent	20	78	Left	Free
14	1	Adjacent	20	78	Left	Delay
15	1	Adjacent	20	79	Left	Free
16	1	Adjacent	20	79	Left	Delay
17	1	Curb	18	68	Right	-
18	1	Curb	18	69	Right	-
19	1	Curb	18	70	Right	-
20	1	Curb	18	71	Right	-
21	2	Median	23	87	Left	Free
22	2	Median	23	87	Left	Delay
23	2	Median	23	88	Left	Free
24	2	Median	23	88	Left	Delay
25	2	Median	23	89	Left	Free

*Lane adjacent to median lane to account for possibility of dual left-turns.

TABLE 3-2 (CONTINUED)

Turn Classification	Originating Section	Originating Lane	Terminating Section	Terminating Lane	Direction Turn	Free or Delayed
26	2	Median	23	89	Left	Delay
29	2	Adjacent	23	87	Left	Free
30	2	Adjacent	23	87	Left	Delay
31	2	Adjacent	23	88	Left	Free
32	2	Adjacent	23	88	Left	Delay
33	2	Adjacent	23	89	Left	Free
34	2	Adjacent	23	89	Left	Delay
37	3	Curb	22	84	Right	-
38	3	Curb	22	85	Right	-
39	3	Curb	22	86	Right	-
41	4	Median	16	60	Left	Free
42	4	Median	16	60	Left	Delay
43	4	Median	16	61	Left	Free
44	4	Median	16	61	Left	Delay
45	4	Median	16	62	Left	Free
46	4	Median	16	62	Left	Delay
47	4	Median	16	63	Left	Free
48	4	Median	16	63	Left	Delay
49	4	Adjacent	16	60	Left	Free
50	4	Adjacent	16	60	Left	Delay
51	4	Adjacent	16	61	Left	Free
52	4	Adjacent	16	61	Left	Delay
53	4	Adjacent	16	62	Left	Free
54	4	Adjacent	16	62	Left	Delay
55	4	Adjacent	16	63	Left	Free

TABLE 3-2 (CONTINUED)

Turn Classi-fication	Originating Section	Originating Lane	Terminating Section	Terminating Lane	Direction Turn	Free or Delayed
56	4	Adjacent	16	63	Left	Delay
57	4	Curb	14	52	Right	-
58	4	Curb	14	53	Right	-
59	4	Curb	14	54	Right	-
60	4	Curb	14	55	Right	-
61	6	Median	14	52	Left	Free
62	6	Median	14	52	Left	Delay
63	6	Median	14	53	Left	Free
64	6	Median	14	53	Left	Delay
65	6	Median	14	54	Left	Free
66	6	Median	14	54	Left	Delay
67	6	MMedian	14	55	Left	Free
68	6	Median	14	55	Left	Delay
69	6	Adjacent	14	52	Left	Free
70	6	Adjacent	14	52	Left	Delay
71	6	Adjacent	14	53	Left	Free
72	6	Adjacent	14	53	Left	Delay
73	6	Adjacent	14	54	Left	Free
74	6	Adjacent	14	54	Left	Delay
75	6	Adjacent	14	55	Left	Free
76	6	Adjacent	14	55	Left	Delay
77	6	Curb	16	60	Right	-
78	6	Curb	16	61	Right	-
79	6	Curb	16	62	Right	-
80	6	Curb	16	63	Right	-

TABLE 3-2 (CONTINUED)

Turn Classi- ficiation	Originating Section	Originating Lane	Terminating Section	Terminating Lane	Direction Turn	Free or Delayed
81	7	Median	22	84	Left	Free
82	7	Median	22	84	Left	Delay
83	7	Median	22	85	Left	Free
84	7	Median	22	85	Left	Delay
85	7	Median	22	86	Left	Free
86	7	Median	22	86	Left	Delay
89	7	Adjacent	22	84	Left	Free
90	7	Adjacent	22	84	Left	Delay
91	7	Adjacent	22	85	Left	Free
92	7	Adjacent	22	85	Left	Delay
93	7	Adjacent	22	86	Left	Free
94	7	Adjacent	22	86	Left	Delay
97	8	Curb	23	87	Right	-
98	8	Curb	23	88	Right	-
99	8	Curb	23	89	Right	-
101	9	Median	18	68	Left	Free
102	9	Median	18	68	Left	Delay
103	9	Median	18	69	Left	Free
104	9	Median	18	69	Left	Delay
105	9	Median	18	70	Left	Free
106	9	Median	18	70	Left	Delay
107	9	Median	18	71	Left	Free
108	9	Median	18	71	Left	Delay

TABLE 3-2 (CONTINUED)

Turn Classification	Originating Section	Originating Lane	Terminating Section	Terminating Lane	Direction Turn	Free or Delayed
109	9	Adjacent	18	68	Left	Free
110	9	Adjacent	18	68	Left	Delay
111	9	Adjacent	18	69	Left	Free
112	9	Adjacent	18	69	Left	Delay
113	9	Adjacent	18	70	Left	Free
114	9	Adjacent	18	70	Left	Delay
115	9	Adjacent	18	71	Left	Free
116	9	Adjacent	18	71	Left	Delay
1179	9	Curb	20	76	Right	-
118	9	Curb	20	77	Right	-
119	9	Curb	20	78	Right	-
120	9	Curb	20	79	Right	-
121	10	Median	7	28	Left	Free
122	10	Median	7	28	Left	Delay
123	10	Median	7	29	Left	Free
124	10	Median	7	29	Left	Delay
125	10	Median	7	30	Left	Free
126	10	Median	7	30	Left	Delay
127	10	Median	7	31	Left	Free
128	10	Median	7	31	Left	Delay
129	10	Adjacent	7	28	Left	Free
130	10	Adjacent	7	28	Left	Delay
131	10	Adjacent	7	29	Left	Free
132	10	Adjacent	7	29	Left	Delay
133	10	Adjacent	7	30	Left	Free

TABLE 3-2 (CONTINUED)

Turn Classi-fication	Originating Section	Originating Lane	Terminating Section	Terminating Lane	Direction Turn	Free or Delayed
134	10	Adjacent	7	30	Left	Delay
135	10	Adjacent	7	31	Left	Free
136	10	Adjacent	7	31	Left	Delay
137	10	Curb	7	4	Right	-
138	10	Curb	7	5	Right	-
139	10	Curb	7	66	Right	-
140	10	Curb	7	7	Right	-
141	10	Curb	7	4	Right	-
142	10	Curb	7	5	Right	-
143	10	Curb	7	6	Right	-
144	10	Curb	7	7	Right	-
145	12	Median	2	8	Left	Free
146	12	Median	2	8	Left	Delay
147	12	Median	2	9	Left	Free
148	12	Median	2	9	Left	Delay
149	12	Median	2	10	Left	Free
150	12	Median	2	10	Left	Delay
151	12	Median	2	11	Left	Free
152	12	Median	2	11	Left	Delay
153	12	Adjacent	2	8	Left	Free
154	12	Adjacent	2	8	Left	Delay
155	12	Adjacent	2	9	Left	Free
156	12	Adjacent	2	9	Left	Delay
157	12	Adjacent	2	10	Left	Free
158	12	Adjacent	2	10	Left	Delay

TABLE 3-2 (CONTINUED)

Turn Classification	Originating Section	Originating Lane	Terminating Section	Terminating Lane	Direction Turn	Free or Delayed
159	12	Adjacent	2	11	Left	Free
160	12	Adjacent	2	11	Left	Delay
161	12	Curb	6	24	Right	-
162	12	Curb	6	25	Right	-
163	12	Curb	6	26	Right	-
164	12	Curb	6	27	Right	-
165	12	Curb	6	24	Right	-
166	12	Curb	6	25	Right	-
167	12	Curb	6	26	Right	-
168	12	Curb	6	27	Right	-
169	15	Median	3	12	Left	Free
170	15	Median	3	12	Left	Delay
171	15	Median	3	13	Left	Free
172	15	Median	3	13	Left	Delay
173	15	Median	3	14	Left	Free
174	15	Median	3	14	Left	Delay
175	15	Median	3	15	Left	Free
176	15	Median	3	15	Left	Delay
177	15	Adjacent	3	12	Left	Free
178	15	Adjacent	3	12	Left	Delay
179	15	Adjacent	3	13	Left	Free
180	15	Adjacent	3	13	Left	Delay
181	15	Adjacent	3	14	Left	Free
182	15	Adjacent	3	14	Left	Delay
183	15	Adjacent	3	15	Left	Free

TABLE 3-2 (CONTINUED)

Turn Classi-fication	Originating Section	Originating Lane	Terminating Section	Terminating Lane	Direction Turn	Free or Delayed
184	15	Adjacent	3	15	Left	Delay
185	15	Curb	5	20	Right	-
186	15	Curb	5	21	Right	-
187	15	Curb	5	22	Right	-
188	15	Curb	5	23	Right	-
189	17	Median	5	20	Left	Free
190	17	Median	5	20	Left	Delay
191	17	Median	5	21	Left	Free
192	17	Median	5	21	Left	Delay
193	17	Median	5	22	Left	Free
194	17	Median	5	22	Left	Delay
195	17	Median	5	23	Left	Free
196	17	Median	5	23	Left	Delay
197	17	Adjacent	5	20	Left	Free
198	17	Adjacent	5	20	Left	Delay
199	17	Adjacent	5	21	Left	Free
200	17	Adjacent	5	21	Left	Delay
201	17	Adjacent	5	22	Left	Free
202	17	Adjacent	5	22	Left	Delay
203	17	Adjacent	5	23	Left	Free
204	17	Adjacent	5	23	Left	Delay
205	17	Curb	3	12	Right	-
206	17	Curb	3	13	Right	-
207	17	Curb	3	14	Right	-
208	17	Curb	3	15	Right	-

TABLE 3-2 (CONTINUED)

Turn Classi-fication	Originating Section	Originating Lane	Terminating Section	Terminating Lane	Direction Turn	Free or Delayed
209	19	Median	0	0	Left	Free
210	19	Median	0	0	Left	Delay
211	19	Median	0	1	Left	Free
212	19	Median	0	1	Left	Delay
213	19	Median	0	2	Left	Free
214	19	Median	0	2	Left	Delay
215	19	Median	0	3	Left	Free
216	19	Median	0	3	Left	Delay
217	19	Adjacent	0	0	Left	Free
218	19	Adjacent	0	0	Left	Delay
219	19	Adjacent	0	1	Left	Free
220	19	Adjacent	0	1	Left	Delay
221	19	Adjacent	0	2	Left	Free
222	19	Adjacent	0	2	Left	Delay
223	19	Adjacent	0	3	Left	Free
224	19	Adjacent	0	3	Left	Delay
225	19	Curb	8	32	Right	-
226	19	Curb	8	33	Right	-
227	19	Curb	8	34	Right	-
228	19	Curb	8	35	Right	-
229	21	Median	8	32	Left	Free
230	21	Median	8	32	Left	Delay
231	21	Median	8	33	Left	Free
232	21	Median	8	33	Left	Delay
233	21	Median	8	34	Left	Free

TABLE 3-2 (CONTINUED)

Turn Classi-fication	Originating Section	Originating Lane	Terminating Section	Terminating Lane	Direction Turn	Free or Delayed
234	21	Median	8	34	Left	Delay
235	21	Median	8	35	Left	Free
236	21	Median	8	35	Left	Delay
237	21	Adjacent	8	32	Left	Free
238	21	Adjacent	8	32	Left	Delay
239	21	Adjacent	8	33	Left	Free
240	21	Adjacent	8	33	Left	Delay
241	21	Adjacent	8	34	Left	Free
242	21	Adjacent	8	34	Left	Delay
243	21	Adjacent	8	35	Left	Free
244	21	Adjacent	8	35	Left	Delay
245	21	Curb	0	0	Right	-
246	21	Curb	0	1	Right	-
247	21	Curb	0	2	Right	-
248	21	Curb	0	3	Right	-

The random selection of the turn classification within a grouping begins with the turn trajectory entering the curb lane and continues toward the median lane of the region being entered until a turn trajectory has been selected.

The integer percent of acceptance of each turn classification is entered into the model through the table item PTNTY. This is an unsigned integer 8-bit item.

3.4 VELOCITY PROFILE

Each model region is prescribed a free flow velocity, which vehicle driver types either try to attain, or maintain while operating in a free behavior mode. Maximum free flow velocity is not required to be a single value for the entire region, but may be a profile of a linearly increasing or decreasing free flow velocity. The free flow velocity at the entrance to the region is entered into the model through the table item SITVEL, and the free flow velocity at the exit of the region is entered into the model through the table item STTVEL. Both free flow velocities are expressed in tenths of feet per second. Both table items are signed integer 16-bit items.

The free flow velocity profile in a region is created by these entrance and exit velocities and is used to modify free behavior vehicular performance as vehicles proceed through the region. A linear interpolation is made between the entrance and exit values to determine the free flow velocity permitted at any location within the region. All lanes within a region have the same velocity profile. The relationship of this free flow velocity at a given location in a region to a vehicle-driver type operating at that location is explained in Section 3.6.3.

In the example shown in Figure 3.4,the assumed entrance free-flow velocity of model region 10 is 88.0 feet per second, while the exit

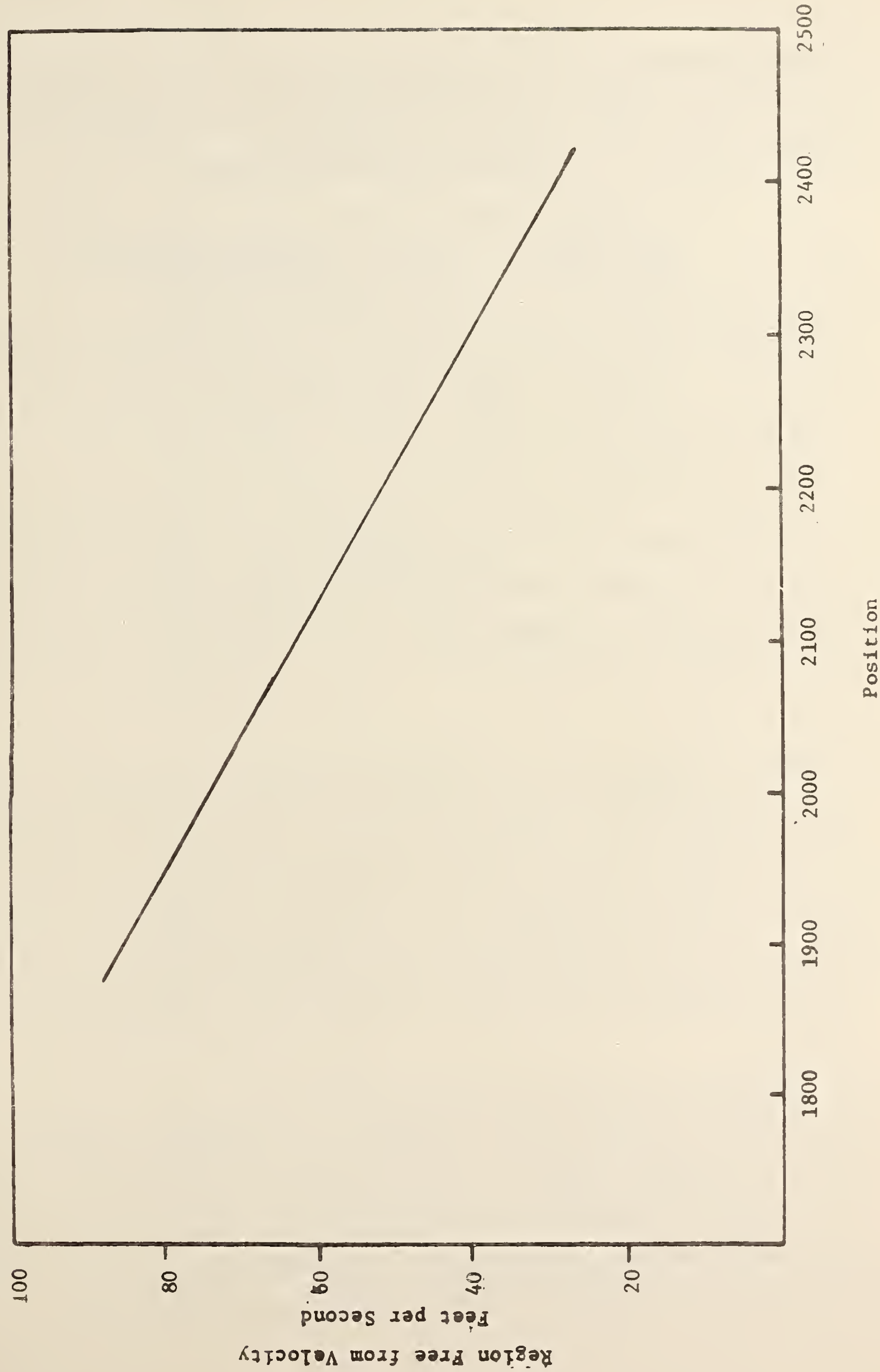


Figure 3.4. Region Velocity Profile.

free-flow velocity is 26.4 feet per second, or 60 and 18 miles per hour, respectively. Linear interpolation between these two velocities yields that the free-flow velocity changes by:

$$\frac{26.4-88.0}{2420.5-1877.8} = -0.1135 \frac{\text{feet per second}}{\text{feet from region origin}}$$

The region origin has a benchmark of 1877.8, the region exit has a benchmark of 2420.5. Thus, if a vehicle is at the 2300.0 feet location in region 10, the regional free-flow velocity for that location would be decreased by:

$$(0.1135)\ (2300.0-1877.8) = -47.9 \text{ feet per second}$$

to 88.0 - 47.9 = 40.1 feet per second. Thus, at the 2300 foot location in region 10, free-behavior mode vehicles would have an average value of 40.1 feet per second. The velocity of the vehicles varies around this value.

3.5 SITE GEOMETRICS

Vehicular and intersection operational performance may be affected by site geometrics. Several of the major geometric considerations have been identified and are used in the simulation model to evaluate their influence upon operational performance. The geometric features which have been included are: (1) angle of intersection of the cross street with the through street, (2) exclusive storage lane, (3) lane width, (4) median width, and (5) overlap of lanes in opposing sections.

The diamond interchange may be divided into 22 model regions having unidirectional flow of traffic and uniform operating conditions. A uniform operating condition requirement is that all vehicles within the region must be controlled by a common traffic signal. Therefore, a model region generally comprises the segment of roadway between traffic signals, or approximately mid-intersection to mid-intersection. The exact locations of the end points of a model region will be discussed in more detail in Section 5.2. The locations of the entrance and exit to a model region, in tenths of feet, are entered into the model through the table items NTRY and EXIT, respectively. Both are unsigned integer 16-bit items.

3.5.1 Model Coordinate Systems. The ten separate and distinct coordinate systems used in the simulation model are shown in Figure 3.5. There is a coordinate system for each of the ten unidirectional traffic movements. The coordinate values always increase positively with the direction of traffic flow. All data representing locations within a region is with respect to the coordinate system for that region. All coordinate lines run through the right-hand curbline boundary of the region. When several regions are linked together to form a continuous segment of roadway, the curblines of the linked regions are assumed to form a continuous line.

Turning vehicles going from one coordinate system into another coordinate system, eg., from model region 10 into model region 7, are translated into the new coordinate system when they have reached the end of their turn. This translation point and the translation value applied to all vehicular position values when moving from one coordinate system into another is defined by the turning radius, cf. Section 3.3.3.

The relationship of the intersecting coordinate systems is entered into the model through the table items SETRAN and SETRAND. The former is an unsigned integer 16-bit item, while the latter is a signed integer 16-bit item.

Five coordinate relationship values are entered for both SETRAN and SETRAND. The values give the relationship of a

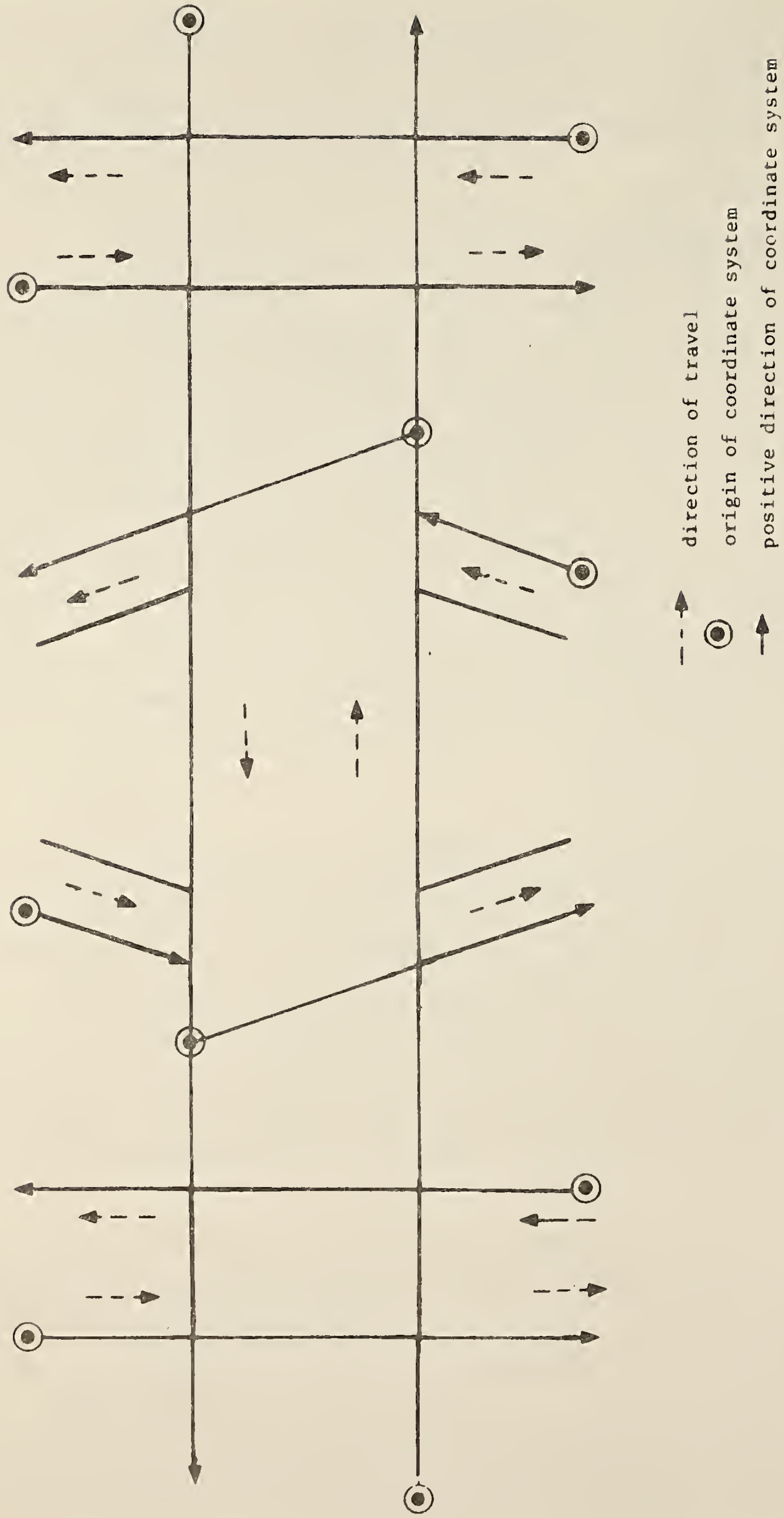


Figure 3.5. Ten Coordinate Systems.

model region to the five adjoining regions into which the turning vehicle may enter or from which a vehicle may exit and conflict with the desired movement of the turning vehicle. These five adjoining regions are identified as follows:

- region out on the right
- region in on the right
- region opposing
- region out on the left
- region in on the left.

Section 5.6.3 will illustrate these considerations.

3.5.2 Angle of Intersection. The angle of intersection of the cross-street is defined to be the angle formed by the curb-line projection of the region the vehicle is exiting and the region that the vehicle is entering. Generally, the cross-street may have two intersection angles with the through-street. Figure 3.6 is a schematic representation of the two angles. Angle "A" is formed by the cross-street serving right-turn vehicles leaving the through-street, while angle "B" is formed by the cross-street serving left-turn vehicles leaving the through-street. Angle "A" is measured in a clockwise direction from the projection of the curb-line in the exiting region, while angle "B" is measured in a counter-clockwise direction from the same reference. These angles are expressed in ten-thousandths of a radian and are entered into the model through the table item DFLECT. This is a signed integer 32-bit word.

3.5.3 Exclusive Storage Lane. Each of the 22 model regions may have a lane which begins beyond the entrance of the region. To utilize an exclusive storage lane, a vehicle would normally be required to change lanes to enter the lane after it has entered the region. If such a lane is designated

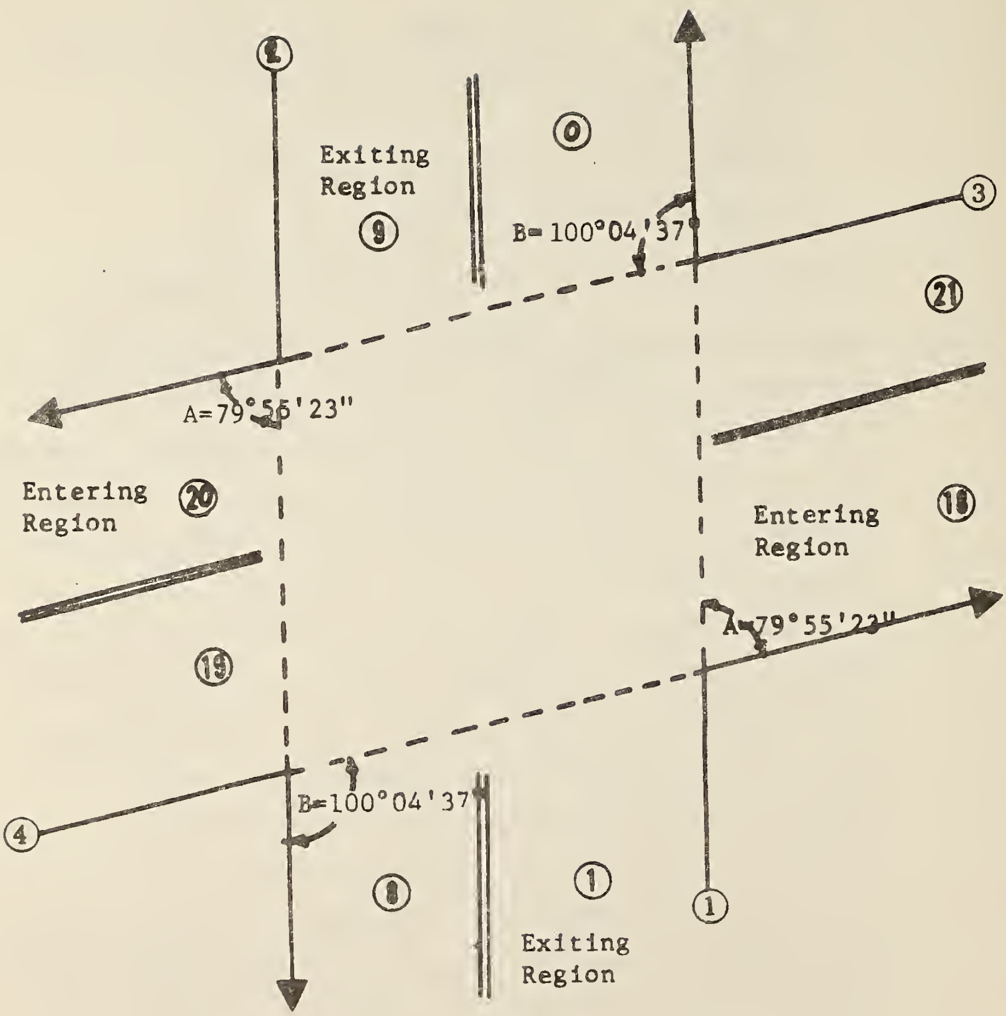


Figure 3.6. Angle of Intersection.

in a region, it is assumed it will become the median lane for the region. Although the lane begins beyond the entrance to the region, it mav not terminate before the exit of the region. This additional lane may be considered to be the exclusive left-turn-storage lane by designating it, using item EXLT. Otherwise, it is considered to be an additional lane which begins within a region to be used by all vehicles. If the lane is designated as an exclusive left-turn-storage lane, its geometric configuration and the turn options which are permitted are shown in Figure 3.2. If the lane is the beginning of a new lane in the region, its geometric configuration and the permitted turn options are shown in Figure 3.7. The left-turn movements are considered optional.

If a storage lane is required in the simulation problem, the request is entered into the model through the table item POCKET. This is an unsigned integer 1-bit item. The item is set equal to "0" if no storage lane is required and it is set equal to "1" if it is required.

The location of the beginning of an exclusive storage lane within a model region must be specified. The location, expressed in tenths of feet,is entered into the model through the table item BGNPOC. This is an unsigned 16-bit item.

3.5.4 Uniform Lane Width. A uniform lane width is used for all simulation problems. This lane width is used by the model when determining region and intersection widths and in the initialization of turn classification data. The uniform lane width,expressed in tenths of feet,is entered into the model through the simple (as compared to table) item ILWF. This is a signed integer 32-bit item.

3.5.5 Median Width. Traffic traveling in opposite directions may be separated bv a median or divisional island. The width of

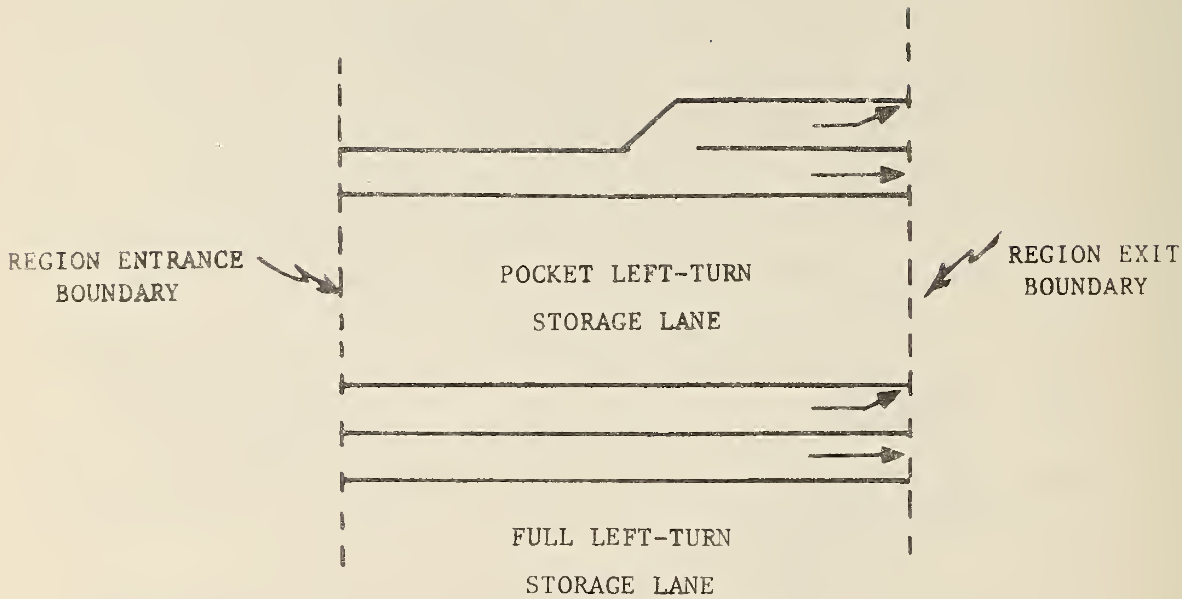


Figure 3.7. Non-Exclusive Left-Turn Movement Storage Lane With Optional Straight-Through Movement.

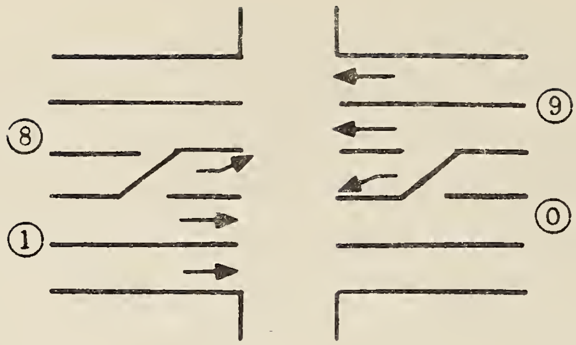
the separation is represented as an integer multiple of the lane width. Those regions considered by the program logic to carry traffic in opposite directions are listed in Table 3-1 under the heading BSIDE. These regions are considered to be adjacent to each other and have their median lane side sharing a common boundary, median, or divisional island. The number of integer multiples for the separation width is entered into the model through the table item OLAP1. This is a signed integer 8-bit item.

3.5.6 Lane Overlap. The alignment of the median lanes of opposing model regions may result in the downstream end of a lane in one region actually overlapping a lane in the opposing region. This overlapping of opposing regions usually occurs at the two nearby intersections, when exclusive left-turn storage lanes are required.

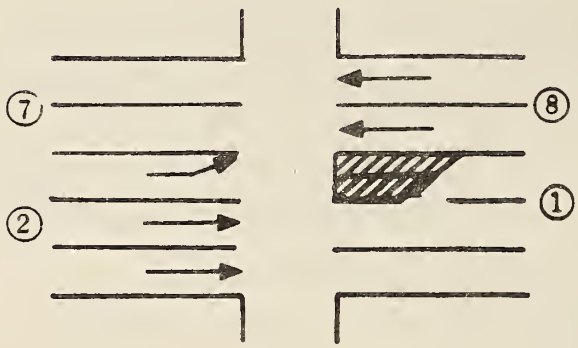
Table 3-1 has listed under the heading POSE those regions considered by the program logic which may possibly have lanes which are carrying traffic in the opposite direction. Two examples of lane overlap are shown in Figure 3.8. Case 1 has lane overlap, while case 2 does not since the traffic in the median lanes of regions 2 and 8 do not directly oppose each other. Case 3 has median or divisional island separation.

The amount of lane overlap is expressed in integer multiples of the average lane width and is entered into the model through the table item OLAP. This is a signed integer 8-bit item.

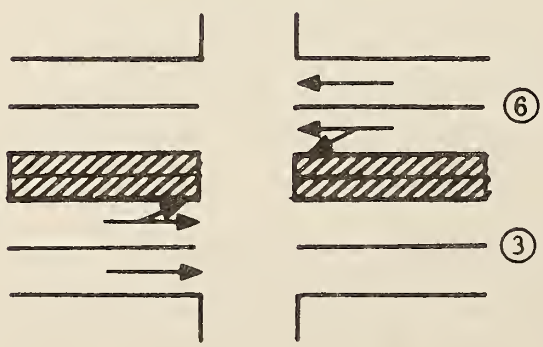
3.5.7 Stopline Location. During the red phase of the timing sequence, vehicles will modify their performance in order to stop at or behind the designated stopline position. Each lane has a unique stopline location, thus the stoplines may



CASE 1 - OVERLAP



CASE 2 - NO OVERLAP



CASE 3 - MEDIAN SEPARATION

Figure 3.8. Median Width and Lane Separation

be staggered across a region. The exact location is measured relative to the origin of the appropriate coordinate system for the stopline. This information is entered into the model through the table item STP. This is an unsigned 16-bit integer item.

3.6 VEHICLE GENERATION

Geometric considerations related to each study site restrict the maximum number of vehicles that may occupy a lane at a given time. The permitted lane occupancy is entered into the model through the table item TENT. This is a signed integer 16-bit item. If the occupancy entered into TENT is less than the number of vehicles which may actually be in the lane at a given time, the simulation will be unable to provide for the storage of the vehicle data, and the simulation problem will be terminated (cf. Section 7.6.2).

Certain lanes are considered as system entrance lanes. Program logic using the table item ENTRAN identifies the model regions considered to be system entrance regions, and those lanes at the entrance boundary of these entrance regions are designated as entrance lanes. Program logic uses the data described in this section to generate vehicular arrival headways for vehicles entering the system through that entrance lane.

Vehicles are generated into each entrance lane and a computer procedure using prescribed traffic characteristics determines the following for each entering vehicle:

- Vehicular arrival time
- Vehicle-driver type
- Origin-destination.

3.6.1 Entrance Lane Flow. The number of vehicles generated into each entrance region is broken down to a per-lane basis, and generation flow rates are specified according to entrance lane. There is a maximum of 30 entrance lanes--4 lanes each for 6 arterial street regions, and 3 lanes each for 2 exit ramp regions.

Flow rate is expressed as the number of vehicles arriving in an entrance lane during a specified period of time and is entered into the model through the table item SFLOW. This is a signed integer 16-bit item. The time period over which the flow rate is specified is expressed in hundredths of an hour and is entered into the model through the table item CNTME. This item is an unsigned integer 9-bit item.

3.6.2 Vehicular Arrival Time. The generation of intervehicular gaps for each entrance lane is accomplished through the use of: (1) a truncated exponential density function or (2) an Erlang density function. The summation of these intervehicular gaps produces the arrival times of vehicles in an entrance lane. The generation of traffic is on a per-lane basis and is independent of the generation rate of other lanes. However, the type of generator used must be the same for all lanes. The generator requires that an initial random number be prescribed. This seed number, called RN, must be an odd number. RN may be modified only at the beginning of a simulation exercise.

When using either of the two vehicle generation methods, the largest acceptable headway may be regulated. Since the headway between consecutive vehicles is related to the entering flow rate, the largest acceptable headway is expressed as the number of standard deviations from the average intervehicular headway for the specified flow rate. The number of standard deviations specified applies to all entrance flow rates. It is expressed as a unit integer value, and is entered into the model through the simple-item computer word KAY. This is a signed integer 32-bit word.

If an excessive headway is generated, it is ignored; the generation procedure is continued in that lane until a headway less than or equal to the maximum is generated.

The minimum acceptable headway may also be specified. No vehicle will be entered into an entrance lane until the specified minimum period has elapsed since the last entry of a vehicle into the same lane. This minimum value, applicable to all entrance lanes, is expressed in tenths of a second and is entered into the model through the simple item HDWY. This is a signed integer 32-bit item.

In addition to specifying the type of generator to produce inter-arrival gaps, there is also the choice of cyclical or non-cyclical input. Cyclical inputs are permitted at all input regions with the exception of exit-ramp regions 10, 11, 12, and 13.

Cyclical generation of vehicles is the generation of traffic at two flow rates corresponding to the major and minor movements of vehicles released from the traffic signal upstream from the entrance of the network being modeled. This method of vehicle generation may be required in the simulation problem when intervehicular arrival times at the arterial street entrance boundary are signal dependent.

The major movement of traffic is considered to be the through-street movement coming from the dummy upstream intersection feeding the entrance lane. The traffic generated into entrance lane 64, for example, may be composed of traffic coming from the upstream region controlled by dummy signal [3]. The total traffic entering an arterial street entrance lane from dummy signals [0], [1], [2], [3], [4], and [5] is therefore composed of the through street movement, M_T, the right-turn movement, M_R, and the left-turn movement, M_L.

The traffic is generated cyclically by specifying the percent composition of the major traffic movement to the total traffic arriving at each entrance lane boundary. Using this percentage breakdown, the program determines two-generation flow rates during initialization; one each for the major and minor movements. These rates are expressed in terms of vehicles-per-hour of green for the respective traffic movements. The unit percentage of the major movement vehicles entering each entrance lane is entered into the model by the table item MAJOR. This is an unsigned integer 7-bit item.

Only while headways are being generated cyclically is there considered to be major and minor movements. Under non-cyclical generation, a single generation flow rate is used for the entire study period.

The selection of cyclical or non-cyclical generation of intervehicular gaps is denoted by a "0" or "1" in table item INFLOW. A value of "0" denotes non-cyclical, while "1" denotes cyclical generation. This item is an unsigned integer 4-bit item.

3.6.3 Origin-Destinations. A vehicle using the arterial street system may be required to travel through several regions and make various combinations of turning movements along its trajectory. There are 56 possible system origin-destination combinations that vehicle trajectories may employ through the system. Thus, operational control and system performance may be evaluated by examining statistical output for all vehicles having similar O-D system trajectories in an individual region, and comparing their performance to other vehicles in similar regions.

Table 3-3 in conjunction with Figure 3.1A identifies the paths of the 56 system origin destinations. Origin-destinations 1 and 13, describing off-ramp vehicles driving through to the on-ramp, are not permitted in the model.

When using the maximum configuration shown in Figure 3.1A, the system entrance locations are designated by letters A through H, while the system exit locations are designated by letters M through T.

TABLE 3-3 THE 56-SYSTEM-ORIGIN-DESTINATION TRAJECTORIES

	SYSTEM EXIT REGIONS							
SYSTEM ENTRY REGIONS	M	N	O	P	Q	R	S	T
A	13*		23	24	19	22	21	20
B		*1	8	9	10	7	12	11
C	32	33	27		29	28	30	31
D	39	40		34	36	35	37	38
E	6	5	25	26	2		4	3
F	17	18	15	16		14	42	41
G	56	55	54	53	51	52	50	
H	49	48	47	46	44	45		43

* Off-ramp vehicles cannot take on-ramps.

An origin-destination "0" is assigned to vehicles unable to continue along their predetermined trajectory. This may occur if they are unable to change lanes in order to complete a required turn. The modification to the vehicle's origin-destination is made by the program's logic.

Each "model" region 0 through 21 may be a system entrance region, depending upon the geometric configuration being simulated. Table 3-4 lists the origin-destinations which

TABLE 3-4

ALLOWABLE ORIGIN-DESTINATIONS IN EACH REGION

Region	Allowable Origin-Destinations														
0	2	10	19	29	36	44	51								
1	2	3	4	10	11	12	19	20	21	29	30	31	36	37	38
2	2	3	4	6	10	11	12	29	30	31	32	36	37	38	39
3	2	3	4	5	6	29	30	31	32	33	36	37	38	39	40
4	2	3	4	5	6	25	26								
5	7	14	22	28	35	45	52								
6	7	8	9	14	15	16	22	23	24	45	46	47	52	53	54
7	14	15	16	18	22	23	24	45	46	47	48	52	53	54	55
8	14	15	16	17	18	46	47	48	49	52	53	54	55	56	
9	14	15	16	17	18	41	42								
10	19	20	21	22	23	24									
11	19	20	21	22	23	24									
12	7	8	9	10	11	12									
13	7	8	9	10	11	12									
14	9	16	24	26	34	46	53								
15	34	35	36	37	38	39	40								
16	8	15	23	25	27	47	54								
17	27	28	29	30	31	32	33								
18	3	11	20	31	38	41	43								
19	43	44	45	46	47	48	49								
20	4	12	21	30	37	42	50								
21	50	51	52	53	54	55	56								

are permitted to enter and operate within a region. If an origin-destination, other than those listed, is assigned as entering an entrance region, the simulation problem will be terminated. If an origin-destination, other than those listed, is made to enter a non-entrance region, the origin-destination of the vehicle is changed to "0". After this change, all statistical tabulations for the vehicle are assigned to origin-destination "0", however, the vehicle performance characteristics will remain unchanged.

Each system entrance lane is assigned a distribution of system destinations used to randomly assign origin-destinations to vehicles entering that lane. Although the assignment of origin-destination is made on a per lane basis, the origin-destinations are only related to the entrance region and the regions through which the vehicles must pass to reach their assigned destination regions.

The unit percentage of each origin-destination to the total population of origin-destinations for a particular entrance lane is entered into the model through the table item ODDIST. This is a signed integer 32-bit item.

The assignment of the subset of region origin-destinations which may be assigned to an entrance lane is controlled by the table item REGNOD. Item REGNOD contains the sequential ordering of the appropriate subset of regional origin-destinations permitted to enter a particular entrance lane during the simulation problem. This is an unsigned integer 8-bit item.

Table items P2LOD and P2FOD contain the first and last table index values of table item REGNOD which corresponds to the first and last origin-destination of the subset entering a particular lane. Both are signed integer 16-bit items.

3.6.4 Vehicle-Driver Types. Each vehicle entering an entrance lane is assigned a vehicle-driver type which is retained as it passes through the system. Five vehicle-driver types have been provided to represent the mixture of vehicle-drivers having different performance characteristics. These range from type 0, which possesses the most conservative performance characteristics, through type 5, which possesses the most radical performance characteristics. These five types characterize the entire population of vehicles and are not directly related to a particular entrance lane.

The proportion of each vehicle-driver type, in terms of percent, is entered into the model by the table item DTPROB. This is a signed integer 32-bit item.

The maximum acceleration capability of the vehicle-driver type, expressed in hundredths of a foot per second, is entered into the model by the table item AAMAX. This is a signed integer 16-bit item.

The maximum deceleration capability of the vehicle-driver type, expressed in hundredths of a foot per second, is entered into the model by the table item AADES. This is a signed integer 16-bit item.

Each region has a maximum free flow velocity profile which free behavior mode vehicles either maintain or try to attain, cf. Section 3.4. Table item ATVEL describes, for each vehicle-driver type, the percent above or below the regional velocity profile that it uses for its maximum free flow velocity. This table item is a signed integer 16-bit item.

At each position within a region, a maximum free flow velocity is computed based upon the velocity profile. This value is then modified to reflect the percent deviation which is permitted by the vehicle's vehicle-driver type.

When a vehicle is performing a lane-change maneuver, the maximum permitted free flow velocity may be exceeded, determined by the combination of the regional velocity profile and vehicle-driver type. The percent by which a vehicle of a particular vehicle-driver type may deviate from its permissible free flow velocity is entered into the model by table item MXVEL. This is a signed integer 16-bit item.

Turning maneuvers require that cross-street traffic or opposing traffic movement be examined to determine if there exists a gap or lag into which the vehicle may enter, and thereby complete its turn maneuver. The acceptance of gaps or lags by left- or right-turning vehicles is based upon the turning vehicle's vehicle-driver type. The criterion for the acceptance or rejection of a gap or lag is the time-headway formed by the gap or lag. The minimum time-headway in tenths of a second, which a vehicle-driver type will accept, is entered into the model through the table item RTCRTL for right-turn vehicles and table item LTCRTL for left-turn vehicles. Both items are signed integer 8-bit items.

3.7 LANE CHANGING

Lane changing is required in many instances to enable the vehicle to complete the trajectory as prescribed by the vehicle's origin-destination. The lane-changing specification for a simulation problem is entered into the model through the simple item DOLCIN. When lane changing is required, this item is set to "1", and when lane changing is not permitted , it is set to "0". This is a signed integer 32-bit item.

The program subroutines required to facilitate vehicles changing lanes duplicate the important characteristics of actual traffic.

It is recommended that the parametric inputs and internal coefficients in the lane-change routines not be modified unless extenuating circumstances require program logic modifications.

3.8 TRAFFIC SIGNAL TIMING

The traffic movement being simulated in the non-exit model regions must be controlled by a traffic signal. Exit model regions need not be controlled by a traffic signal. The four traffic signals--two at the ramp intersections and two at the two four-way intersections--are denoted by a ○ in Figure 3.1. The parametric input data requirements for the traffic signals are discussed in this section.

Figure 3.1 also shows six dummy traffic signals denoted by a □. The parametric input data requirements for these six traffic signals will be discussed in Section 3.9. Table 3-5 contains the default values of the arterial signal indices which define the table entry where the appropriate control information is found.

The traffic signal operational control parameters listed below are given on an individual traffic signal basis, and the parameters for one signal are not required to have any relationship with the other signals in the system. For instance, one signal may have a 60-second time cycle, while the remaining signals have an 85-second time cycle. Also, one signal may have a two-phase control sequence, while another may have a three-phase control sequence. The offset relationship for each signal with respect to its time reference base is used to establish the required relationship between individual traffic signals operating in the simulation problem.

Operational control parameters required for each traffic signal used in the simulation problem include:

TABLE 3-5

REGION AND SIGNAL FACES ASSOCIATED WITH ARTERIAL SIGNALS

Arterial Signal	Model Signal Face Indications Controlling Region*	Region Controlled By Signal
0	0, 1 2, 3 4, 5 6, 7	1 19 9 21
1	0, 1 2, 3 4, 5 6, 7	2 - 8 10, 11
2	0, 1 2, 3 4, 5 6, 7	3 12, 13 7 -
3	0, 1 2, 3 4, 5 6, 7	4 15 6 17

*cf. Figure 3.9

- time cycle
- number of intervals
- interval signal indications
- interval timings
- master reference time cycle
- offset
- interrupt time
- method of control.

3.8.1 Time Cycle. The time cycle for each traffic signal is defined as the time period required for one complete sequence of signal indications. The length of each traffic signal's time cycle is expressed in integer seconds and is entered into the model through the table item SYCL. This is a signed integer 16-bit item.

3.8.2 Interval Signal Indications. An interval for a time cycle is defined as any one of the several divisions of the time cycle during which signal indications do not change. The signal indications composing each interval are the illuminated traffic control signal lenses that control specific traffic movements.

The four traffic signals have four signal faces on each signal head. Two traffic movement indications are provided on each signal face: the straight-through and right-turn movements and the left-turn movement.

A numerical value of 0, 2, 4 or 6 is assigned to each of the four combinations of straight-through and right-turn movements, while the value of 1, 3, 5 or 7 is assigned to each of the four left-turn movements which mav occur at an intersection, cf. Figure 3.9. Consequently, each of the eight numerically coded traffic movements controlled by a traffic signal is thereby identifiable with a particular

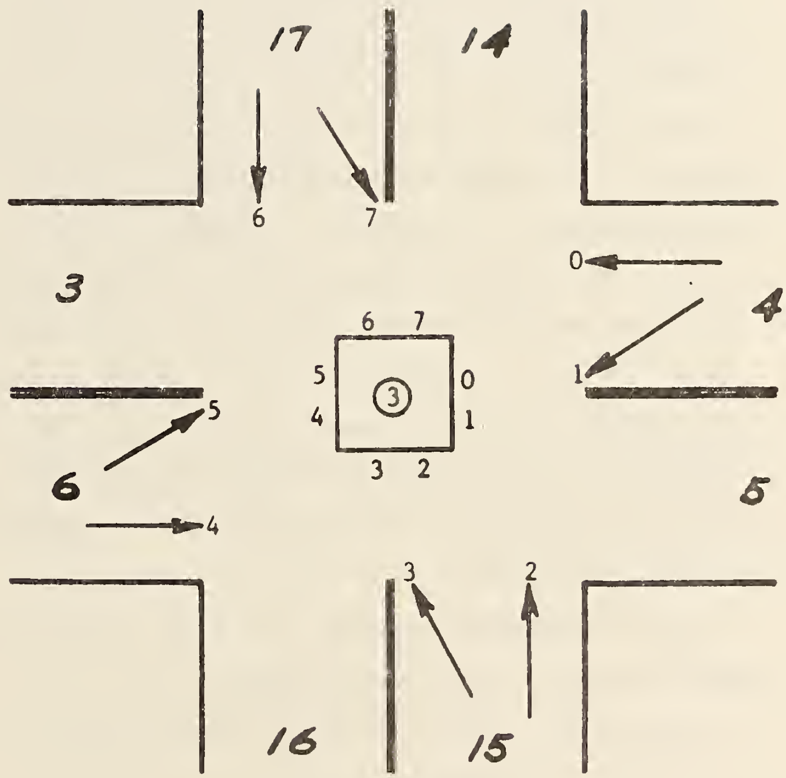


Figure 3.9. Signal ③ Face - Traffic Movement Definition.

signal face of the traffic signal. Table 3-5 contains the numerical value assigned to each of the traffic movements which may emanate from each region. The left-turn associated with each signal face may be either an exclusive or gap-lag acceptance movement.

The numerical designation corresponding to the controlled traffic movement identifies each signal face of a particular traffic signal. For example, using Table 3-5 and Figure 3.1, signal face indications 0 and 1 of traffic signal ③ is the signal face controlling the traffic movements 0 and 1 which emanate from model region 4. Signal face indications 2 and 3 of the same signal controls the traffic movements 2 and 3 which emanate from model region 15. This relationship extends to the two remaining faces of traffic signal ③, and also applies to the 3 remaining arterial traffic signals. Through the use of this traffic movement-signal face combination scheme, the signal indications composing each interval are identified.

The following convention has been adopted to describe the color of a signal indication:

0 = green - traffic movement may proceed into the intersection

1 = amber - intersection clearance

2 = red - traffic movement may not proceed into the intersection.

By indicating the appropriate combination of 0's, 1's, and 2's for the eight traffic movements, the signal indications for each interval are entered into the model through the table item SIGCON. This is an unsigned integer 32-bit item. Consecutive entries of item SIGCON represent the exact order in which the intervals are to be displayed during the time cycle of the traffic signal.

Therefore, for each traffic signal there is an associated set of table items, SIGCON, containing the consecutive sequence of signal indications to be displayed. The first entry of each set must contain the first interval of the sequence to be displayed during the respective timing cycle.

3.8.3 Number of Intervals. The total number of intervals comprising the complete sequence of signal indications for each traffic signal is entered into the model through the table item NOSI. This is a signed integer 8-bit item. If there is no traffic signal in an intersection, then item NOSI is set equal to "0".

3.8.4 Interval Timing. Interval timing is defined as the percentage of the time cycle allocated to each interval of a particular phasing plan. The integer percent allocated to each interval is entered into the model through the table item SPCNT. This is a signed integer 16-bit item.

3.8.5 Master Reference Time Cycle. A master reference time cycle is provided for each arterial traffic signal to be used as a time reference base. The integer seconds in each master reference time cycle is entered into the model through the table item SMSTCYL. This is a signed integer 16-bit item. The use of the master reference time cycle is described in the following section.

3.8.6 Offset. Offset is defined as the number of seconds, or percent of the time cycle, that the green indications appear at a given traffic signal after a certain time instant, which is the reference base. The program logic uses the master reference time cycle associated with each traffic signal as the time reference base.

At the beginning of the simulation problem, all master reference time cycles are assumed to be at time zero in their respective time cycle. This assumption permits the offset relationship to be established between traffic signals and the master reference cycle. This initialization determines the interval signal indications to be displayed at the beginning of the simulation problem and the amount of time remaining until termination of the interval. The integer value of the offset relationship between the traffic signal and its master reference time cycle is entered into the model through the table item SOFFSET. This is a signed integer 16-bit item.

The value of the offset may be expressed as (1) the amount of time in integer-seconds, or (2) the amount of time expressed as a percent. In both cases, the offset represents the elapsed time between the beginning of the master reference time cycle and the beginning of the green on the reference face (see Section 3.8.7) of the arterial traffic signal. Table item TYPOFF is set equal to "0" when the offset is expressed in integer-seconds, or it is set equal to "1" when the offset is expressed in integer-percent. This is an unsigned integer 4-bit item.

3.8.7 Signal Reference Face Program logic assumes that the beginning green indication used to establish the offset relationship between the traffic signal and its master reference time cycle is contained in the initial entrv of the set of table items SIGCON associated with each traffic signal, cf. Section 3.8.2.

The signal face (0 through 7) on which the beginning green indication is displayed is entered into the model through the table item P2FACE. This would be the reference face. This is an unsigned integer 4-bit item.

The program logic uses this designation of a signal reference face in a validity check of the signal indication data, cf. Section 3.8.2, to assure that proper offset relationships are established between a traffic signal and its master reference time cycle.

3.8.8 Method of Signal Control. During a simulation problem, traffic signal operational parameters may be modified. These modifications may not be made dynamically by program logic, but must be introduced into the program at times selected prior to the beginning of the simulation problem. When parametric modifications are made, the modified values are entered into the model through their respective table item entry. In addition, table item DIALCHN is set equal to a "1" to indicate the associated signal. When the modifications have been initiated, table item DIALCHN is reset to its initial default value of "0". DIALCHN is an unsigned integer 1-bit item.

Operational parameter modifications at an individual traffic signal are initiated at the beginning of the first time cycle after the request has been made for operational modifications.

Certain operational parametric modifications to a traffic signal may affect the synchronized operation of a traffic signal's time cycle with its master reference time cycle, e.g. change to length of time cycle, modification of offset requirements, etc. Two algorithms have been incorporated into the program logic to determine if the desired offset relationship has been established or is being maintained with each traffic signal. The two methods are referred to as "pretimed control" and "computer control". The selection of which offset correction method to use is entered into the model through the table item PEWTER. When the table item PEWTER is set equal to "0", the offset correction will be made using the "pretimed control" logic. If the table item is set equal to "1", the "computer control" logic will be used. PEWTER is an unsigned integer 1-bit item.

1. Pretimed Control. The "pretimed control" offset correction method algorithm emulates the logic incorporated in a pretimed traffic signal controller. Once each time cycle, the algorithm checks the offset relationship between the traffic signal and its master reference time cycle to determine if the desired offset is being maintained. The exact time within the time cycle that this check is made is established by the table item SOFFSET, see Section 3.8.6.

   When the offset relationship is found to be in error, the time cycle is lengthened, as in the pretimed controller, to reestablish the desired offset relationship.

   After the determination that an error exists, the time cycle continues to operate in its predetermined manner until a designated time location within the time cycle is reached. This time location, expressed as the elapsed time since the beginning of the time cycle, is entered into the model through the table item NTRUPKEY. This is a signed integer 16-bit item.

Upon reaching this time location, and the offset relationship must be corrected, the time cycle is interrupted and lengthened, similarly to the way it is accomplished in a pretimed controller. During the interruption, the currently displayed interval indications are continued until the shorter of the two time periods elapse. These two time periods are: (1) the exact time required to lengthen the time cycle, or (2) the maximum period of time the time cycle may be interrupted. This latter period of time is entered into the model through the table item SNTRUP. This is a signed integer 16-bit item.

The maximum period of time a single time cycle may be interrupted is entered into the model as an integer percent of the time cycle, if table item TYPNTRU is set equal to "0". If this table item is set equal to "1", the maximum interruption time is entered in integer seconds. TYPNTRU is an unsigned integer 1-bit item.

2. Computer Control. The two primary differences between the "computer" and "pretimed" control algorithms are: number of times within the time cycle the offset relationship is checked and the methods used to establish the desired offset relationship. While the traffic signal is under "pretimed control", the offset relationship is checked once per time cycle vs. each timing interval in the time cycle for "computer control". When an offset relationship is being reestablished under "pretimed control", the time cycle may only be lengthened while under

"computer control", each timing interval period may be lengthened or shortened.

When a traffic signal is operating under "computer control" and the offset relationship is found to be in error, two calculations are made to determine if the time cycle should be lengthened or shortened. First, the maximum and minimum times permitted in each timing interval are used to determine the minimum total elapsed time required to reestablish the offset relationship. Accordingly, each timing interval will be lengthened or shortened until the desired relationship has been established.

The total number of integer seconds each timing interval may be lengthened or shortened are, respectively, entered into the model through the table items SMAXRUP and SMINRUP. These are signed integer 16-bit items. Additionally, a maximum and minimum time cycle for each traffic signal are, respectively, entered into the model through the table items SMAXCYL and SMINCYL. These are signed integer 16-bit items.

3.9 DUMMY TRAFFIC SIGNAL TIMING

Cyclical generation of vehicular arrival times in an entrance lane (see Section 3.6.2) requires the use of traffic signals upstream from the system entrance region. Six upstream traffic signals have been provided for this cyclical generation. Non-cyclical generation of vehicular arrival times does not require the use of dummy traffic signals. These six signals used in cyclical generation are denoted by a □ in Figure 3.1 and are referred to as dummy traffic signals. This section discusses the parametric data input requirements of these six upstream dummy traffic signals.

Each dummy traffic signal has associated with it the following information which is required for the cyclical generation of vehicular arrival times:

- Model entrance region it controls
- Time cycle
- Offset relationship
- Travel time to entrance region
- Timing intervals.

Certain items, i.e. time cycle, signal indications, timing interval, etc., have the same definition for both the arterial and dummy traffic signals.

3.9.1 Signal Assignment. Figure 3.1 shows the location of the six dummy traffic signals if the maximum regional configuration is being simulated, using all 22 model regions. When the maximum regional configuration is not being used, and cyclical generation of vehicular arrival times is required, the upstream dummy traffic signal controlling the entrance region must be specified. Table 3-6 contains the program default values for the six dummy traffic signals, when the maximum regional configuration is used.

The location of each dummy traffic signal is not predefined, as with the arterial traffic signals, for the entrance region may vary from one simulation problem to another. Consequently, the entrance region controlled by the dummy traffic signal must be identified, if it has other than a default value. The entrance region which the upstream dummy traffic signal "controls" is entered into the model through the table item P2RLSECT. This is an unsigned integer 8-bit item. For example, if the intersection controlled by arterial traffic signal (3) were not included in the simulation problem, then model region 3 would be declared as a system

TABLE 3-6

PRESET VALUES FOR DUMMY TRAFFIC SIGNAL

Dummy Traffic Signal	Entrance Region (P2RLSECT)	Cyclical or Non-cyclical (INFLOW)	Downstream Arterial Signal (DP2SIG)	Downstream Signal Face (DP2FACE)
0	4	1	3	0
1	9	1	0	4
2	15	1	3	2
3	17	1	3	6
4	19	1	0	2
5	21	1	0	6

entrance region. Traffic signal (3) would become dummy traffic signal [0] and would be designated as "controlling" the cyclical generation of vehicular arrival times into model region 3.

If the downstream reference arterial traffic signal has other than a default value, the number of the arterial traffic signal is entered into the model through the table item DP2SIG. This downstream arterial traffic signal controls the vehicular traffic emanating from the entrance region controlled by the dummy traffic signal. This table item is an unsigned 4-bit item.

The signal reference face, which contains the beginning green indication used to establish the offset relationship with the arterial traffic signal, is entered into the model through table item DP2FACE. This is an unsigned 8-bit item. The signal reference face for use by the dummy traffic signal is not required to be the same as that designated for establishing the offset relationship between the arterial traffic signals and its master reference cycle.

3.9.2 Generation Designation. Each dummy traffic signal has a designation if it is used for the cyclical generation of vehicular arrival times into an entrance region, cf. Section 3.6.2. This designation is entered into the model through the table item INFLOW. This is an unsigned integer 4-bit item.

If the dummy traffic signal is to be used for the cyclical generation of vehicular arrival times, the table item is set equal to "1". However, if vehicular arrival times are generated non-cyclically, the table item is set equal to "0".

3.9.3 Time Cycle. The integer seconds in the time cycle for the dummy traffic signal is entered into the model through table item DCYCLE. This is an unsigned integer 8-bit item.

3.9.4 Offset. The offset relationship for a dummy traffic signal does not use a master reference time cycle. The offset is established by relating the beginning green signal indication for the upstream dummy traffic signal and the beginning green indication on a reference signal face of the downstream arterial traffic signal. This offset relationship is established at the beginning of the simulation problem and is used for the entire simulation problem, regardless of changes which may be made to the operation of the arterial traffic signal. The offset, expressed in integer seconds, is entered into the model through the table item DOFFSET. This is a signed integer 8-bit item.

3.9.5 Travel Time to Entrance Region Boundary. The entire length of roadway from the upstream dummy traffic signal to the downstream arterial traffic signal is not required to be included in the entrance region to the system being simulated. However, when using the cyclical generator, the excluded portion of this roadway must be included when computing vehicular arrival times. An average travel time is computed for vehicles to travel from the upstream dummy traffic signal to the entrance boundary of the entrance region. The integer seconds for this travel time is entered into the model through the table item DTRT. This is an unsigned integer 8-bit item.

3.9.6 Timing Intervals. Unlike the arterial traffic signal, the timing interval information for the dummy traffic signal reflects only the times allocated to the green, amber, and red timing intervals for the major movement, MT. The integer percentages of the time cycle allocated to the three interval indications of the major movement are entered into the model through the table item MT. This is a signed integer 32-bit item.

4. PROGRAM CONSTRAINTS AND LIMITATIONS

This section discusses general Program constraints related to the structuring of tables and item size. Table structure limitations include both maximum table entries and table partitioning. The maximum numerical value for table and simple items is discussed.

4.1 TABLE LIMITATIONS

Data related to vehicle representation are stored in several tables in the model. This data for vehicles being simulated represents their performance and operation as they move along the roadway. The characteristics used to represent each vehicle are:

position

velocity

acceleration

origin - destination

system entrance time

actual length

effective length

maximum desired acceleration

maximum desired deceleration

direction of turn

The number of entries in the vehicle representation tables are defined by the simple item EPC. EPC is preset to a value of 800; Therefore 800 vehicle entries may be represented in the simulation problem at any one time. These vehicle tables are partitioned into three parts, with the maximum number of entries in each partition defined by the simple items CHNCAR, LPTR, and EPC.

Where,

CHNCAR=100

LPTR=200

EPC=800

The vehicles may be required to change lanes or make left-and right-turn maneuvers as they traverse the system. In these two cases, the vehicle making the maneuver may encounter a vehicle which it must follow, but is located in another coordinate system. In this case, all data representing the lead vehicle is duplicated and entered into another entry of the vehicle data table. All locational positions of the lead vehicle are translated into the coordinate system of the following vehicle. All subsequent inquiries by the following vehicle regarding the lead vehicle will be obtained by this duplicated data. Data related to vehicles changing lanes are contained in entries 1 through CHNCAR-1, and for turning vehicles from entry CHNCAR through LPTR-1. The remaining entries LPTR through EPC-1 are used for representation of vehicles operating within the system. These latter vehicles are actually those vehicles which are being moved through the simulated roadway and are referred to as "actual" vehicles, whereas the first two groups of vehicles (entries 1 through LPTR-1) are referred to as "dummy" vehicles.

Using present program constraints, there may be at any given time in the simulation problem, 600 "actual" vehicles operating within

99 "dummy" vehicles changing lanes requiring translated data from its new leader.

100 "dummy" vehicles making a left-or right-turn requiring translated data from its new leader.

The current and two past performance histories are retained in the present table structure, with the table divided into three equal segments.

The maximum number of entries in this table is computed by the equation

(number of histories) (EPC)

The number of histories presently equals 3, and EPC is defined as 800.

Therefore,

$$(3)\ (800)=2400$$

entries have been provided to retain data related to past vehicular performance. This computation is entered into the model through the simple item RTXEPC.

The number of past histories which are to be retained are computed by

$$N = \frac{RT}{CYL} + 1$$

where

N = number of histories to be retained

RT = reaction time of the driver in seconds

CYL = number of seconds per incremental advancement of the simulated clock to review all vehicles

The values that have been assigned to these items are:

RT = 1.00 seconds

CYL = 0.50 seconds

Therefore,

$$N = \frac{1.00}{0.50} + 1 = 3$$

The quotient of $\frac{RT}{CYL}$ must in an integer number.

There may only be 100 lane change plans formed and being executed at any given time in the simulation problem.

There are a maximum of 22 model regions (numbered 0 through 21) and eight constraint regions (numbered 22 through 29). The maximum number of lanes in the model is 84 (numbered 0 through 83).

There may only be twelve timing interval periods per arterial traffic signal and three per dummy traffic signal.

There may only be five vehicle-driver types, defined by simple item NDT.

The maximum time period which may be simulated is in excess of 2000 hours of simulated time.

To modify any of the above-mentioned table sizes and structuring, the program must be recompiled after the modifications have been made.

4.2 ITEM SIZE LIMITATIONS

Parametric data is entered into the model as either a decimal or hexadecimal integer number. The maximum numerical value of a parametric data item is constrained by the number of bits allocated to the item. If the item is a signed integer, one bit of the allocation is reserved for the sign of the value. Therefore, the maximum value of a simple or table item is computed by the following equation:

$$\text{MAXIMUM VALUE} = 2^{X} - 1,$$

where

X = number of bits allocated - 1 (signed item)

or

X = number of bits allocated (unsigned item)

The following two examples are used to illustrate the calculation required to determine the maximum assignable value to an item.

(1) The maximum value for a region exit boundary coordinate, EXIT:

- Number of bits in table item EXIT = 16
- Item is unsigned, therefore X = 16 bits
- Maximum value = $2^{16} - 1 = 65535$

The units for table item EXIT are expressed in tenths of feet; therefore, the largest value of any exit coordinate may be 6553.5 feet. The item is unsigned; therefore the value is always positive.

(2) The maximum value for the offset for a dummy signal, DOFFSET;

- . Number of bits in table item = 8
- . Item is signed, therefore X = 8 - 1 = 7
- . Maximum value = $2^7 - 1 = 127$.

The units for the table item DOFFSET are expressed in seconds; therefore, the largest value of an offset for a dummy signal is plus or minus 127 seconds. The item is signed, therefore it may be negative.

5. SET-UP OF THE MODEL FOR A SIMULATION PROBLEM

This section discusses the parametric data requirements, how data is derived, and subsequently how it is entered into the model through the procedure NUDATA.

The time duration of the simulation problem is the sum of simple items AWARMUP and ENDCLT. Item AWARMUP is the amount of simulated time to be expended before the beginning of the tabulations of vehicle performance statistics. This period should encompass a time period sufficient for vehicle occupancy in the simulated regions to reach a desired stable level. This time period, in seconds, is entered into the model through the simple item AWARMUP. If 15 minutes (900 seconds) are required for system warmup, then

AWARMUP=900

If no warmup period is specified, the program assigns a value of "0" to AWARMUP.

The amount of time in the second time period of the simulation problem is defined by simple item ENDCLT. After system warmup, this is the total time period during which vehicle performance statistics will be tabulated. If a simulation problem is to study vehicle performance for a time period of one hour and twenty-five minutes (5100 seconds), then

ENDCLT=5100

Therefore, with a 15-minute warmup period and an 85-minute statistical tabulation period, there will be a total duration of simulation time of 100 minutes (15 + 85 = 100).

Table item IOEPIOLOG is used to indicate when vehicle performance statistics will be summarized and output by the computer on magnetic tape. The table index used for each entry is the increment value (0 through LINTME - 1) associated with each entry. Item LINTME is defined as 20. If summary statistics are required at time periods of 10, 15, 18, 9, and 12 minute intervals after a 15-minute warmup period, the following data will be entered.

IOEPILOG(0)=1500	15+10=25 minutes=1500 seconds
IOEPILOG(1)=2400	25+15=40 minutes=2400 seconds
IOEPILOG(2)=3480	40+18=58 minutes=3480 seconds
IOEPILOG(3)=4020	58+9=67 minutes=4020 seconds

Thus, in the simulation problem there will first be a 15-minute period (AWARMUP=900) during which no vehicle performance statistics will be tabulated. Following this period, statistics will be accumulated for 10 minutes. Twenty-five minutes (15-minute warmup plus 10 minutes) of simulated time will have elapsed before the first summary statistics will be output on magnetic computer tape. Fifteen minutes later, at time 40 minutes, the summary statistics for the period from time 25 through time 40 will be output on magnetic computer tape. This process continues until 79 minutes (67 + 12 = 79) of simulated time has elapsed, at which time the summary statistics from time 67 through time 79 will be output on magnetic tape. The job will then be terminated, ENDCLT-4740 (79*60=4740).

No intermediate summary statistics will be output between the end of the warmup period and the end of simulation problem unless specified through table item IOEPILOG. This table is automatically reset at the beginning of each simulation problem with default values which assure no intermediate summary outputs.

Dynamic changes may be made at any time after the beginning of the simulation problem by following a call to procedure NUDATA. This procedure will continue to read computer cards and modify the indicated parametric data items until an ENDDATA card is read. This process of consecutive calls to NUDATA will continue until an ENDFILE card is read.

The cumulative time between consecutive NUDATA calls is entered into the model through table item TMELIN. The table index for each entry is the incremental value (0 through LINTIME - 1) associated with each entry. Simple item LINTME is defined as 20.

If a 30-minute simulation problem is to be conducted with traffic signalization parameters changed every 5 minutes and generation flow rates changed every 7 minutes, the following data would be entered.

TMELIN(0)=300	5 minute signal change
TMELIN(1)=420	7 minute flow rate change
TMELIN(2)=600	10 minute signal change
TMELIN(3)=840	14 minute flow change
TMELIN(4)=900	15 minute signal change
TMELIN(5)=1200	20 minute signal change
TMELIN(6)=1260	21 minute flow rate change
TMELIN(7)=1500	25 minute signal change
TMELIN(8)=1680	28 minute flow rate change.

When the cumulative elapsed seconds given in consecutive entries of TMELIN has elapsed, procedure NUDATA will begin to read computer cards until an ENDDATA card is read. Consecutive sets of data cards must be ordered to reflect the desired changes to be made at that time since no check is made to determine if these parametric data items should be modified at this time.

5.1 NUDATA - A COMPUTER ROUTINE WITH A CAPABILITY FOR DYNAMICALLY CHANGING SYSTEM PARAMETERS

When modeling a particular system configuration, all characteristics of interest pertaining to the particular system are determined for the model of that system. Some are variables that describe the state of the model as a function of time, such as regional vehicle counts, generation flow rates, and intersection signalization-these values may change with the time period being simulated. Others are fixed-constants that may describe the limitations of the model, such as origin-destination values, maximum number of regions, maximum number of input regions, maximum number of output regions, and vehicle-driver classifications--these do not change over the time periods being simulated. Of primary interest to NUDATA, however, are those constants that influence or control model behavior, such as the definition of the active regions of a particular model configuration, the regions that serve as model inputs, and the regions that serve as model outputs--these constants are modified whenever a change in model conditions and/or behavior is required.

These model characteristics that influence or change model behavior are termed parameters. Parameter-modification is NUDATA's purpose and task.

The simulation is constructed so that it can operate in an iterative mode, each iteration representing a unique exercise. If parameter-modification is needed, it can be accomplished between iterations, but also at arbitrary decision points during any chosen exercise.

Parameter-modification is best accomplished by NUDATA through a method that incorporates some of the most desirable properties and capabilities of a full-scale compiler.

Briefly, a compiler accepts as input, source statements expressed in a high-level language such as FORTRAN, JOVIAL, etc. JOVIAL is System Development Corporation's developed high-level command and control language. The compiler then interprets this input and generates computer instructions that, when executed at some later time, will perform the actions specified by the source statements.

Parameter-modification for the diamond interchange model can be accomplished by a single instance of a high-level language, the assignment statement. Furthermore, when parameter modification is necessary, it is needed at time of call, i.e., dynamically; therefore, no computer instructions for later execution need be generated.

NUDATA accepts as input, assignment statements written in FORTRAN, JOVIAL, or a FORTRAN-JOVIAL mixture. It then interprets each statement and directly performs the action(s) specified by that statement. Thus, via NUDATA, none, one, or any number of parameters, in any arbitrary order, may be set/reset.

Parameters are defined in the diamond interchange model and have their own unique characteristics. Some are subscripted, others are not. All are integers, signed or unsigned. Some are full computer words in size (32 bits), others occupy "n" binary digits ("n" less than a computer word), and various positions within the computer word.

In the assignment statement, the constants that set/reset parameters may be expressed by the user as integer values or hexadecimal values. Their representation must conform to the specifications of the high-level language in which they are expressed.

Input statements may be keypunched either 026 or 029--NUDATA recognizes both character sets; thus, an 026/029 mixture causes no problems.

Card columns 73 through 80 are reserved for sequence numbers; input statements are punched free-form in columns 2 through 72. More than one input statement may be punched on one card.

Although flexibility is offered when punching input statements, errors sometimes occur. In these cases, NUDATA prints the type of error and the card image in which it occurred.

Procedure NUDATA continues to read computer cards until either of two cards are read: ENDDATA or ENDFILE. The ENDFILE card denotes there are no remaining data cards to be read by procedure NUDATA, and therefore signifies the end of the program execution. After the ENDFILE card is read, statistics are summarized and output to reflect vehicle performance since the last statistical summary.

If multiple simulation problems are to be evaluated during one execution, the set of NUDATA cards should be set in the proper call sequence. After the termination of each simulation problem, procedure

NUDATA is called to determine if more data cards are to be read. If the card ENDFILE is not encountered, the data cards which are read are considered to establish a simulation problem. The simulated system is established using the values in all tables at the end of the preceding simulation problem and those modifications made by NUDATA. If, for instance, a replication of the run is to be made with no changes made to the system, the seed value for the random number, RN, must be changed. This is a simple 32-bit item. This number must be an odd-integer.

The time duration of the simulation must be established, as well as when statistical information is to be output and when procedure NUDATA will be called to enter additional data.

The digital computer simulation model has 87 parameters that may be modified. These parameters represent:

(1) Model operation characteristics, such as elapsed simulation time, I/O requests, etc.

(2) Model-characteristics for a particular geometry, such as active regions, input and output regions, regional length, number of lanes in a region, etc.

(3) Traffic demand and vehicle generation, such as flow rate, major-minor distribution, etc.

(4) Intersection signalization, such as time cycle, timing interval, signal indications, etc.

(5) Vehicle-driver classifications, such as maximum acceleration and deceleration rates, free-flow velocity requirements, etc.

(6) Lane change characteristics such as maximum and minimum times for changes, etc.

The 87 parameters have been grouped into these six classifications, according to the relationship to the operation of the model. A dictionary of these parameters is given in Tables 5-1, 5-2, 5-3, 5-4, 5-5, and 5-6. Included in the description of each item are the following:

(1) Identification of the time as a table item (requiring a subscript) or a simple item.

(2) Identification of the item as signed or unsigned.

(3) Item size given in bits.

(4) Identification of the data entered, in terms of decimal or hexadecimal digits.

(5) Determine whether a subscript is required--if so, the identity of the subscript.

(6) The scale factor and the units of expression.

(7) The function or description of the item.

Several of the NUDATA items enter data into the model as hexadecimal numbers. The conversion of binary numbers to hexadecimal number equivalents is as follows:

- Group the binary bits into groupings of four.
- Then, using Table 5-7, determine the equivalent hexadecimal.

For example, a binary <u>0101</u> is equal to a hexadecimal 5, while a binary <u>1101</u>, <u>0101</u> is equal to a hexadecimal D5.

The conversion of decimal numbers (base 10) to a hexadecimal number equivalent is as follows:

TABLE 5-1

MODEL OPERATIONS

Item	Table or Simple Item	Signed or Unsigned Item	Number of Bits of Item	Item Number Format	Index	Units	Item Description
AWARMUP	S	S	32	Decimal	None	XXX Seconds	Elapsed seconds of no-performance statistics accumulation
CKEIO	S	S	32	Decimal	None	XXX Cycles	Beginning cycle for lane printouts
CKEIO1	S	S	32	Decimal	None	XXX Cycles	Ending cycle for lane printouts
ENDCLT	S	S	32	Decimal	None	XXX Seconds	Elapsed seconds for performance statistics accumulation
IOEPILOG	T	S	32	Decimal	Incremental Entry	XXX Seconds	Time when procedure EPILOG is called
IOQ	S	S	32	Decimal	None	XXX Cycles	Number of cycles between printout of vehicle queue statistics
LAMBDA	S	S	32	"0" or "1"	None	X	0 = Null 1 = Print vehicle collision data
NTART	S	S	32	Decimal	None	XXX Cycles	Number of cycles to print vehicle entrance data
PVD	S	S	32	Decimal	None	XXX Cycles	Time between periodic lane printouts of all vehicles operating in the lane for perscribed intervals
QRPT	S	S	32	Decimal	None	XXX Cycles	Elapsed cycles for queue tabulation for a prescribed interval
RTOR	S	S	32	"0" or "1"	None	None	0 = Null 1 = Right-turn-on-red permitted
RN	S	S	32	Decimal	None	XXX Odd Number	Seed number for the random number generator
TMLIN							

TABLE 5-2

MODEL CHARACTERISTICS

Item	Table or Simple Item	Signed or Unsigned Item	Number of Bits of Item	Item Number Format	Index	Units	Item Description
ARTERIAL	S	S	32	Hexadecimal	None	None	Simulated region indicator
BGNPOC	T	U	16	Decimal	Region Number	X.X Feet	Beginning location of exclusive left turn lane
DBL	T	U	8	"0" or "1"	Region Number	None	0 = Null 1 = Dual left turn permitted
DFLECT	T	S	32	Decimal	22 + Region Number	X.XXXX Radians	Coordinate system angle of intersection
ENTRAN	T	S	16	"0" or "1"	Region Number	None	0 = Null 1 = System entrance region
EXIT	T	U	16	Decimal	Region Number	X.X Feet	Region exit location
EXLT	T	U	1	"0" or "1"	Region Number	None	0 = Null 1 = Exclusive left turn lane in region
ILWF	S	S	32	Decimal	None	X.X Feet	Average lane width
NOLAN	T	S	16	Decimal	Region Number	XX	Number of entrance lanes into region
NTRY	T	U	16	Decimal	Region Number	X.X Feet	Region entrance location
OLAP	T	S	8	Decimal	Region Number	X	Region overlap in number of average lane widths
OLAP1	T	S	8	Decimal	Region Number	X	Median width in number of average lane widths
POCKET	T	U	1	"0" or "1"	Region Number	None	Exclusive left turn lane in region
RAD	T	S	13	Decimal	Turn Classification	X.X Feet	Radius of turn trajectory

TABLE 5-2 (CONTINUED)

Item	Table or Simple Item	Signed or Unsigned Item	Number of Bits in Item	Item Number Format	Index	Units	Item Description
SETRAN	T	U	16	Decimal	Constant + Region Number	X.X Feet	Equivalent coordinate in region
RAMP	T	S	16	Decimal	Region Number	None	Ramp region indentification that designates turn-movement configuration
SALO	T	S	16	Decimal	Region Number	X.X Ft/Sec	Car following proportionately constant
SETRAND	T	S	16	Decimal	Constant + Region Number	X.X Feet	Distance from exit to intersection of two coordinate systems
SITVEL	T	S	16	Decimal	Region Number	X.X Ft/Sec	Region free flow entrance velocity
STP	T	U	16	Decimal	Lane Number	X.X Feet	Stop line location
STTVEL	T	S	16	Decimal	Region Number	X.X Ft/Sec	Region free flow exit velocity
TENT	T	S	16	Decimal	Lane Number	XX Vehicles	Maximum total vehicles permitted in lane
TRNLT	T	U	1	"0" or "1"	Region Number	None	0 = Null 1 = Left turns permitted
TRNRT	T	U	1	"0" or "1"	Region Number	None	0 = Null 1 = Right turns permitted
TRNST	T	U	1	"0" or "1"	Region Number	None	0 = Null 1 = Straight thru permitted
XIT	T	S	16	"0" or "1"	Region Number	None	Exit Section Identification

TABLE 5-3

TRAFFIC DEMAND AND VEHICLE GENERATION

Item	Table or Simple Item	Signed or Unsigned Item	Number of Bits of Item	Item Number Format	Index	Units	Item Description
CHNFLOW	S	S	32	"0" or "1"	None	None	0 = Null 1 = Requested flow rate change
CNTME	T	U	9	Decimal	32 + Arterial Entrance Lane	X.XX Hours	Counting period for number of vehicles
GNTYP	S	S	32	"0" or "1"	None	None	0 = Exponential generation 1 = ERLANG generation
HDWY	S	S	32	Decimal	None	X.X Seconds	Minimum allowable entrance headway
DKAY	S	S	32	Decimal	None	None	Number of standard deviations for largest headway
MAJOR	T	U	7	Decimal	32 + Arterial Entrance Lane	XXX Percent	Percent traffic assigned to major movement
ODDIST	T	S	32	Hexadecimal	28 + Arterial Entrance Lane	XXX Percent	Percent of the total vehicles in a lane with this origin-destination
PTNTY	T	U	8	Decimal	Turn Number Classification	XXX Percent	Percent of acceptance of this turn classification
P2FOD	T	S	16	Decimal	32 + Arterial Entrance Lane	None	Pointer to first region origin-destination
P2FOD	T	S	16	Decimal	32 + Arterial Entrance Lane	None	Pointer to last region origin destination
REGNOD	T	U	8	Decimal	28 + Cummulative Sum of Entries	None	Identification of the origin-destination in a region
SFLOW	T	S	16	Decimal	32 + Arterial Entrance Lane	XXX Vehicles Per Unit Time	Total number of vehicles per unit of time

TABLE 5--

INTERSECTION SIGNALIZATION

Item	Table or Simple Item	Signed or Unsigned Item	Number of Bits of Item	Item Number Format	Index	Units	Item Description
DCYCLE	T	U	8	Decimal	Dummy Signal Number	XX Seconds	Dummy signal time cycle
DIALCHN	T	U	1	"0" or "1"	Arterial Signal Number	None	0 = Null 1 = Dial change requested
DOFFSET	T	S	8	Decimal	Dummy Signal Number	XX Seconds	Dummy signal offset
DP2FACE	T	U	8	Decimal	Dummy Signal Number	None	Reference signal face for dummy signal
DP2SIG	T	U	4	Decimal	Dummy Signal Number	None	Reference signal
DSIG	T	S	32		Dummy Signal Number	XXX Percent	Dummy signal timing interval percentage
DTRT	T	U	8	Decimal	Dummy Signal Number	XX Seconds	Travel time to system entrance
INFLOW	T	U	4	"0" or "1"	Dummy Signal Number	None	0 = Non-cyclical generation 1 = Cyclical generation
NOSI	T	S	8	Decimal	Arterial Signal Number	None	Number of timing intervals
NTRUPKEY	T	S	16	Decimal	Arterial Signal Number	XXX Seconds or Percent	Position of interruption in time cycle
PEWTER	T	U	1	"0" or "1"	Arterial Signal Number	None	0 = Pretimed control 1 = Computer control
P2FACE	T	U	4	Decimal	Arterial Signal Number	None	Reference arterial signal face for beginning of timing interval
P2RLSECT	T	U	8	Decimal	Dummy Signal Number	None	Entrance region for a signal

TABLE 5-4 (CONTINUED)

Item	Table or Simple Item	Signed or Unsigned Item	Number of Bits of Item	Item Number Format	Index	Units	Item Description
SIGCON	T	U	32	Hexadecimal	Constant + Time Interval	None	Identification of signal indications in a timing interval
SMINCYL	T	S	16	Decimal	Arterial Signal Number	XX Seconds	Minimum allowable time cycle
SMINRUP	T	S	16	Decimal	Arterial Signal Number	XX Seconds	Maximum timing interval shortening
SMAXCYL	T	S	16	Decimal	Arterial Signal Number	XX Seconds	Maximum allowable time cycle
SMAXRUP	T	S	16	Decimal	Arterial Signal Number	XX Seconds	Maximum timing interval extension
SMSTCYL	T	S	16	Decimal	Arterial Signal Number	XX Seconds	Master reference time cycle
SNTRUP	T	S	16	Decimal	Arterial Signal Number	XXX Seconds or Percent	Maximum time cycle extension
SOFFSET	T	S	16	Decimal	Arterial Signal Number	XXX Seconds or Percent	Arterial signal offset
SPCENT	T	S	16	Decimal	Arterial Signal Number	XXX Percent	Percentage timing interval is of time cycle
SYCL	T	S	16	Decimal	Arterial Signal Number	XX Seconds	Time cycle

TABLE 5-4 (CONTINUED)

Item	Table or Simple Item	Signed or Unsigned Item	Number of Bits of Item	Item Number Format	Index	Units	Item Description
TYPKEY	T	U	1	"0" or "1"	Arterial Signal Number	None	0 = Percent for NTRUPKEY 1 = Second NTRUPKEY
TYPNTRU	T	U	1	"0" or "1"	Arterial Signal Number	None	0 = Percent SNTRUP 1 = Second SNTRUP
TYPOFF	T	U	1	"0" or "1"	Arterial Signal Number	None	0 = Percent SOFFSET 1 = Second SOFFSET

TABLE 5-5

VEHICLE-DRIVER CLASSIFICATION

Item	Table or Simple Item	Signed or Unsigned Item	Number of Bits of Item	Item Number Format	Index	Units	Item Description
AADES	T	S	16	Decimal	Vehicle-Driver Classification	-X.XX Ft/sec/sec	Desired deceleration
AAMAX	T	S	16	Decimal	Vehicle-Driver Classification	X.XX Ft/sec/sec	Maximum allowable acceleration
ATVEL	T	S	16	Decimal	Vehicle-Driver Classification	XXX Percent	Percent above or below region free flow velocity
DTPROB	T	S	32	Hexadecimal	Vehicle-Driver Classification	XXX Percent	Percent of total drivers in a classification
LTCRTL	T	S	8	Decimal	Vehicle-Driver Classification	XX.X Seconds	Critical left-turn gap/lag acceptance time
MXVEL	T	S	16	Decimal	Vehicle-Driver Classification	XXX Percent	Percent increase in region flow velocity used for lane change
RTCRTL	T	S	8	Decimal	Vehicle-Driver Classification	X.X Seconds	Arterial right-turn gap/lag acceptance time

TABLE 5-6

LANE CHANGE CHARACTERISTICS

Item	Table of Simple Item	Signed or Unsigned Item	Number of Bits of Item	Item Number Format	Index	Units	Item Description
DOLCHN	S	S	32	"0" or "1"	None	None	0 = Null 1 = Lane changing permitted
IMPAX	S	S	32	Decimal	None	XXX Seconds	Number of seconds until maximum impatience
MAXTM	S	S	32	Decimal	None	XXX Seconds	Maximum allowable time for a lane change
MINTM	S	S	32	Decimal	None	XXX Seconds	Minimum time for a lane change
TMACO	S	S	32	Decimal	None	XXX Seconds	Number of seconds for lane change accommodation

TABLE 5-7

NUMBER CONVERSION TABLE

Decimal	Hexadecimal	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
10	A	1010
11	B	1011
12	C	1100
13	D	1101
14	E	1110
15	F	1111

(1) Divide the decimal number by a decimal 16.

(2) Convert the decimal number remainder to a hexadecimal equivalent using Table 5-7.

(3) Repeat steps 1 and 2 using the decimal quotient resulting from step 1 until the quotient is less than decimal 16.

(4) Convert the last decimal quotient to a hexadecimal equivalent.

(5) The resulting hexadecimal digits taken in reverse order are the hexadecimal equivalent of the decimal number.

For example, a decimal 3978 is converted to a hexadecimal equivalent as follows:

<u>Step 1</u>. $\frac{3978}{16}$ = 248 remainder 10,

<u>Step 2</u>. decimal 10 = hexadecimal <u>A</u>,

<u>Step 3</u>. quotient 248 not less than 16, repeat steps 1 and 2.

<u>Step 1</u>. $\frac{248}{16}$ = 15 remainder 8,

<u>Step 2</u>. decimal 8 = hexadecimal <u>8</u>,

<u>Step 3</u>. quotient 15 is less than 16,

<u>Step 4</u>. decimal 15 = hexadecimal <u>F</u>,

<u>Step 5</u>. the hexadecimal quivalent of decimal 3978 is hexadecimal F8A.

The hexadecimal number is entered into the model using the program language required format X(--------). The X denotes the 8 characters contained within the parentheses is a hexadecimal number. Zeros are used to complete the required eight characters if the hexadecimal number does not contain 8 characters. The letter "O" may not be used within the parentheses of a hexadecimal number.

5.2 REGION IDENTIFICATION

The roadway carrying unidirectional flow of traffic is segmented into regions having uniform operating conditions, e.g., having uniform geometrics and controlled by a single traffic signal. These ten unidirectional flows are represented in Figure 3.5. The traffic in each model region shown in Figure 3.1 is controlled by one of four arterial traffic signals, denoted by a ◯.

The convenient location for placing regional boundaries is in the middle of the intersection. However, the exact location is dependent upon two items: site geometrics and the way in which the model will be used. However, in general, the boundary should not be placed such that vehicles will come under the influence of the downstream signal until they have partially cleared the intersection.

Using the nearby four-way intersection shown in Figure 5.3, the boundaries between the various regions have been located so all intersection traffic is included in the region approaching traffic signal ③.

Site geometrics may require the segmentation of the roadway at points other than mid-intersection. An example of such a situation is illustrated in Figure 5.1. In this situation, the entrance and exit ramps do not form a common intersection. In this hypothetical example, the regional boundaries can therefore be placed to coincide with the geometric boundaries, as indicated.

Each of the first 22 bits (left-justified) of the 32-bit computer word ARTERIAL has an order position corresponding to the numbered active region in Figure 3.1. By designating a "0" or "1" in the appropriate bit of ARTERIAL, the desired continguous subset of the 22 possible active regions may be identified for the geometric configuration to be simulated and evaluated. When the appropriate bit

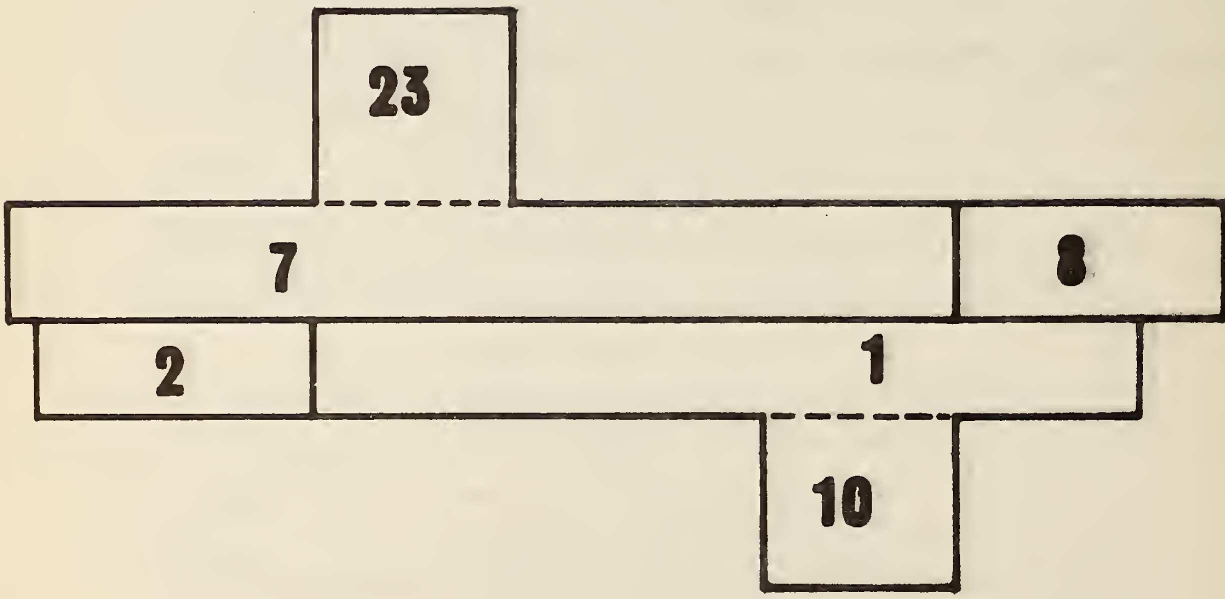


Figure 5.1. Regicn Boundaries

configuration has been established, the eight-byte hexadecimal representation is then entered into the model through ARTERIAL. The downstream regions do not have to be designated.

The following are examples representative of the various geometric configurations which may be simulated using those regions depicted in Figure 3.1, the method used in identifying the desired regions, and the procedure which must be followed to have the model simulate those regions.

(1) All "active" regions are used as shown in Figure 3.1. The bit configuration for this geometry is shown below.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0

The hexadecimal equivalent of this bit configuration is FFFFFC00, therefore,

ARTERIAL=X(FFFFFC00)

(2) A partial diamond interchange, as shown in Figure 5.2. The bit configuration for this geometry is shown below.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	1	1	1	0	0	1	1	1	0	1	0	1	1	0	0	0

17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

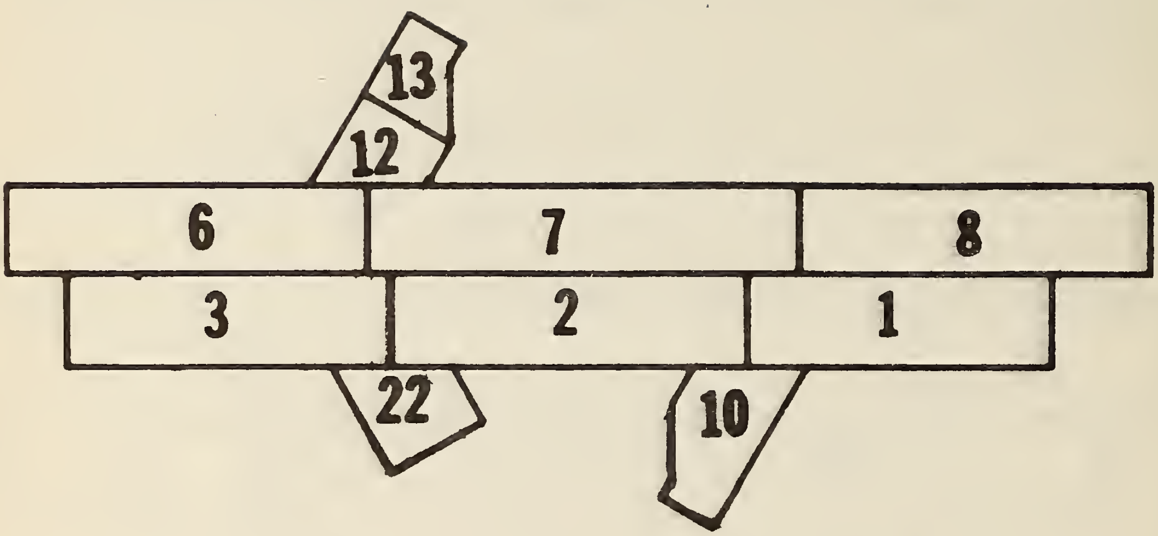


Figure 5.2. Partial Diamond Interchange

The hexadecimal equivalent of this bit configuration is 73AC000, therefore,

ARTERIAL=X(73AC0000)

(3) A nearby four-way intersection, as shown in Figure 5.3. The binary digit configuration is shown below for this geometry.

0	0	0	1	1	1	1	0	0	0	0	0	0	0	1	1	1
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

The hexadecimal equivalent is 1E03C000, therefore,

ARTERIAL=X(1E03000)

(4) Combined cases (2) and (3). The binary digit configuration for the combined case is shown below.

0	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

The hexadecimal number equivalent is 7FAF000, therefore,

ARTERIAL=X(7FAFC000)

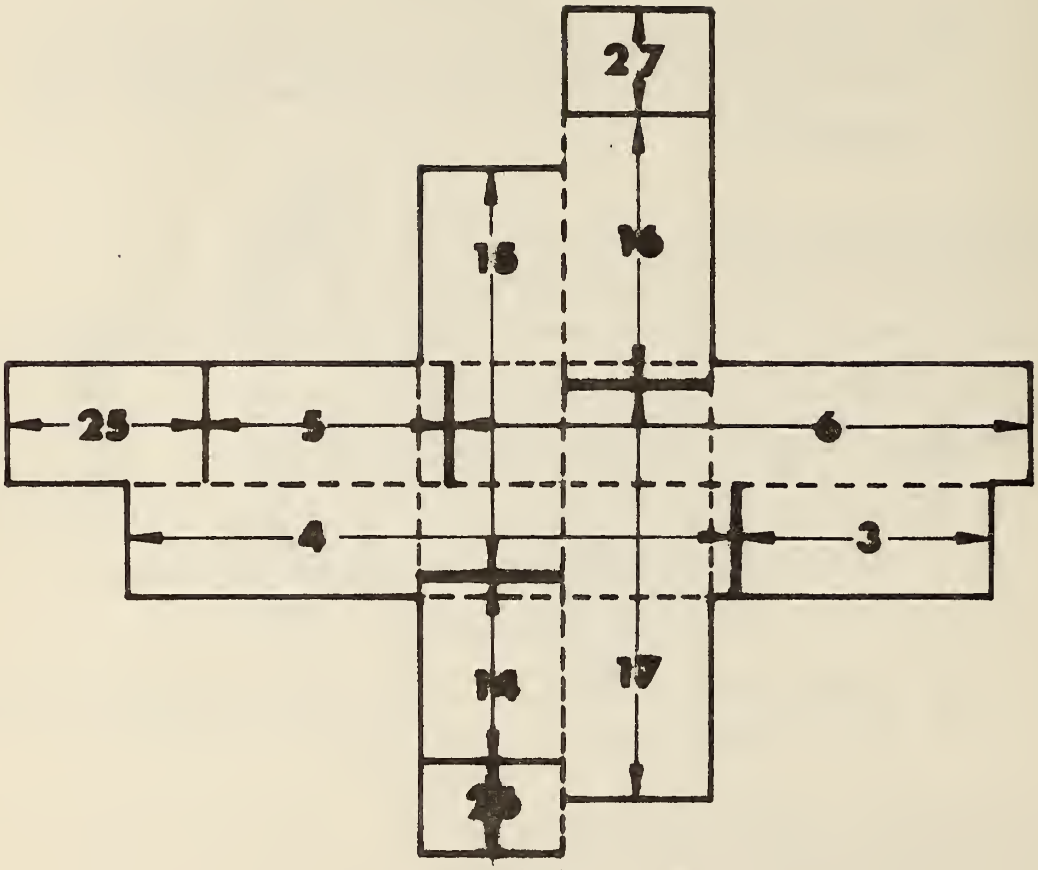


Figure 5.3. Arterial Intersection

The active model regions must be designated if they are to be used as either entrance or exit regions. This information is entered into the model through the table items ENTRAN and XIT. The table index used for each entry of these table items is the model region number (0 through 21) associated with each entry. The corresponding item is set equal to a "0" if the region is not an entrance region, or an exit region and "1" if it is. Using Figure 5.2, regions 3, 8, 10, and 13 are entrance regions, while regions 1 and 6 are exit regions. Vehicles may exit model regions 3 and 7; however, these regions are under the control of arterial traffic signal number (2), cf. Figure 3.1.

Therefore, using Figure 5.2,

ENTRAN(1)=0	XIT(1)=1
ENTRAN(2)=0	XIT(2)=0
ENTRAN(3)=1	XIT(3)=0
ENTRAN(6)=0	XIT(6)=1
ENTRAN(7)=0	XIT(7)=0
ENTRAN(8)=1	XIT(8)=0
ENTRAN(10)=1	XIT(10)=0
ENTRAN(12)=0	XIT(12)=0
ENTRAN(13)=1	XIT(13)=0

5.3 LANE IDENTIFICATION

The number of entrance lanes into each region (active and downstream), is entered into the model through the table item NOLAN. The table index used for each entry of NOLAN is the region number (0 through 29) associated with each entry. The program logic determines the number of exit lanes from the region based upon the designation of the table item POCKET. This item designates if there is an exclusive left-turning lane which begins beyond the entrance to the region. The table index used for each entry POCKET is the model region number (0 through 21) associated with each entry.

Using the diamond interchange geometry shown in Figure 5.4, the lane data for this geometry is as follows:

NOLAN(1)=2	POCKET(1)=1
NOLAN(2)=2	POCKET(2)=1
NOLAN(3)=2	POCKET(3)=0
NOLAN(6)=3	POCKET(6)=0
NOLAN(7)=3	POCKET(7)=1
NOLAN(8)=2	POCKET(8)=1
NOLAN(10)=2	POCKET(10)=0
NOLAN(12)=3	POCKET(10)=0
NOLAN(13)=2	POCKET(13)=0
NOLAN(22)=3	
NOLAN(23)=2	

The program logic using the POCKET value of "1" for regions 1, 2, 7 and 8 will include an additional lane on the median side of the respective region. The underlined numbers in Figure 3.1A, e.g. 8, are the default lane number assigned by program logic to the lanes which are included in the simulation problem. All subsequent lane-related information will use the assigned lane numbers as shown in Figure 3.1A.

Table item POCKET should only be set equal to "1" when the number of lanes at the exit of a region is one greater than the number of lanes at the entrance of the region.

A uniform lane width is required. This value is used as the lane width for all lanes included in the simulation problem. This value is expressed in tenths of feet, and is entered into the model through the simple item ILWF. Thus, if the average width is established as 11.5 feet,

ILWF=115

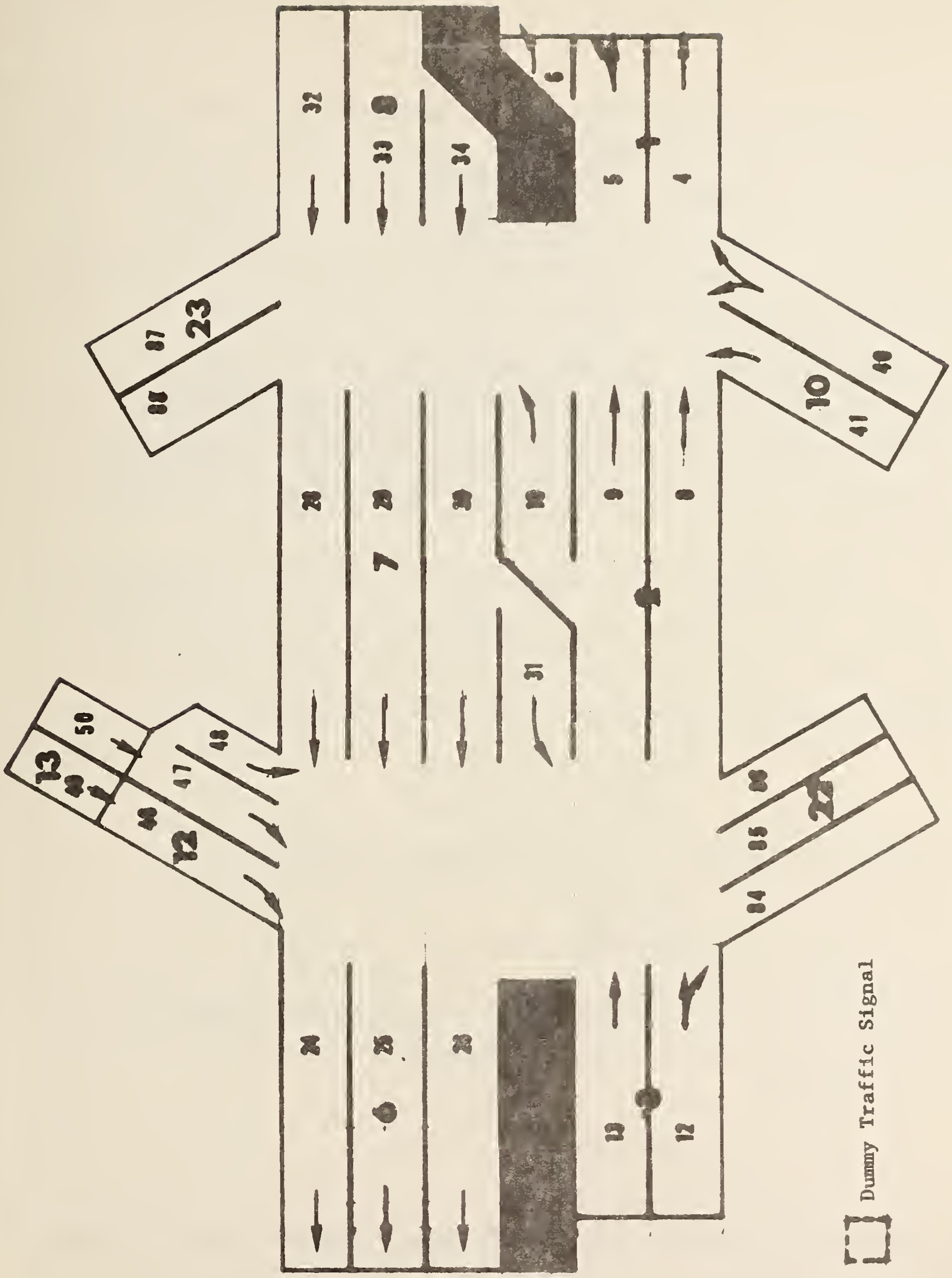


Figure 5.4. Diamond Interchange With Lane Configuration

The average lane-width is also used to determine the width of the separation between adjacent regions, cf. Section 3.5.5. The amount of separation is expressed as integer multiples of the average lane-width and is entered into the model through the table item OLAP1. The table index for each entry of the table item is the model region number (0 through 21) associated with each entry.

The diamond interchange geometry shown in Figure 5.6 (page 44) has adjacent regions which share common (striped) boundaries while others have a median or divisional island between them. The region which is adjacent to another region is listed in Table 3.1 under the heading BSIDE.

The following examples using Figure 5.6 are given as representative data entries. Model regions 1 and 8 are separated by a median which is 15 feet wide. The average lane width is 11.5 feet. Thus, the approximate separation is one lane-width. Therefore,

OLAP1(1)=1

OLAP1(8)=1

Model regions 2 and 7 share a common boundary. Therefore,

OLAP1(2)=0

OLAP1(7)=0

Model regions 3 and 6 are separated by a median 19 feet wide. With the average lane width equal to 11.5, the approximate separation is 2 lane widths. Therefore,

OLAP1(3)=2

OLAP1(6)=2

Model regions 10, 11, and 12 are not adjacent to another region. Therefore, OLAP1(10)=0

OLAP1(11)=0

OLAP1(12)=0

The uniform lane-width is also used to determine lane overlap, cf. Section 3.5.6. Lane overlap is entered into the model through the table item OLAP. The table index for each entry of the table item is the model region number (0 through 21) associated with each entry. Cases 1, 2, and 3 of Figure 3.8 are used in the following example for data determination and as representative data entries. In Case 1, there are overlaps of one lane-width for regions 1 and 9. Therefore,

OLAP(1)=1

OLAP(9)=1

In Case 2, there is no overlap for regions 2 and 8. Therefore,

OLAP(2)=0

OLAP(8)=0

As in the case of OLAP1, the width of a median or divisional island is expressed in multiples of the lane-width. This value for the separation of a region and the region opposing it is expressed as a negative number, and is set equal to OLAP. In Case 3, there is an average median width of two lane-widths. Thus,

OLAP(4)=-2

OLAP(6)=-2

5.4 STRAIGHT-THROUGH AND TURN MOVEMENTS

Table items: TRNST - Straight-through movement
TRNLT - Left-turn movement
TRNRT - Right-turn movement

are set equal to a "0" or "1" to denote if the associated turning movement is permitted to emanate from the model region. The table index used for each entry of the three table items is the model region number (0 through 21) associated with each entry. A "0" denotes that the movement is not permitted while a "1" denotes that the movement is permitted.

Using the diamond interchange geometry shown in Figure 5.4, the data to reflect the indicated turning movements is as follows:

TRNST(1)=1	TRNLT(1)=1	TRNRT(1)=0
TRNST(2)=1	TRNLT(2)=1	TRNRT(2)=0
TRNST(3)=1	TRNLT(3)=0	TRNRT(3)=1
TRNST(6)=1	TRNLT(6)=0	TRNRT(6)=0
TRNST(7)=1	TRNLT(7)=1	TRNRT(7)=0
TRNST(8)=1	TRNLT(8)=0	TRNRT(8)=1
TRNST(10)=0	TRNLT(10)=1	TRNRT(10)=1
TRNST(12)=0	TRNLT(12)=1	TRNRT(12)=1
TRNST(13)=1	TRNLT(13)=0	TRNRT(13)=0

Median lanes permitting a left-turn movement may have the additional designation of being an exclusive left-turn lane. This information is entered on a model region basis. The assumption is made that the left-most lane from the curb is reserved as the exclusive turning lane. The table index used for each entry of EXLT is the model region number (0 through 21) associated with each entry. For all regions which do not have exclusive left-turn lanes, the item is set equal to "0".

However, for the remaining regions item EXLT is set equal to "1" as follows:

EXLT(1)=1
EXLT(2)=1
EXLT(7)=1
EXLT(10)=1
EXLT(12)=1

Thus, lanes 6, 10, 31, 41, and 48 will be exclusive left-turn lanes.

The "0" and "1" designations for the above items will provide the turning movements as indicated in each lane of Figure 5.4. This is with the exception of the three exit ramp regions 10, 12, and 13.

5.4.1 Ramp Turn Movements. Each model has associated with it a table item, RAMP, which denotes: (1) whether the region is a ramp region and (2) if the region is a ramp region, the turn options which are permitted to use the lanes in the region. The table index used for each entry of item RAMP is the model region number (0 through 21) associated with each entry. All the entries with the exception of regions 10, 12, and 13 are set equal to "0" to designate the region as a non-ramp region. Using Figure 3.2, items RAMP for ramp regions 10, 12, and 13 are set equal to an index (defined in Table 3.1a), which denotes the desired turn movements using the lane configuration for that region. Therefore,

RAMP(10)=1
RAMP(12)=6
RAMP(13)=0

5.4.2 Left- and Right-Dual-Turn Movements. If dual left-turns are permitted to emanate from a region, table item DBL which is associated with that model region is set equal to "1". In regions not permitting a dual left-turn movement, the item is set equal to "0". The table index used for each entry of DBL is the model region number (0 through 21). Again using Figure 5.4, all entries for item DBL are set equal to "0" with the exception of regions 1, 10, and 12. These regions which permit dual left-turns are set equal to "1" as follows:

DBL(1)=1

DBL(10)=1

DBL(12)=1

The percent (0 through 100) of the total left-turn movement emanating from the region which may elect to use the dual turn lane is indicated in table item DLT. This percent does not indicate the percent of the total left-turn movement that will actually make dual left-turns. Instead, only that percent of the total left-turn movement will consider the dual left-turn lane to determine if it has fewer queued vehicles than does the exclusive left-turn storage lane. The table index used for each entry of DLT is the model region (0 through 21) associated with each entry. The table item DLT is set equal to "0" for all regions not having or only having a single left-turn movement. Regions 1, 10, and 12 do permit dual left-turns. Therefore, item DLT is set equal to the required percentage as follows:

DLT(1)=10

DLT(10)=47

DLT(12)=31

The percentages used are only representative values. Any integer value between 0 and 100 may be used.

Using region 10 as an example, 47 percent of the vehicles in lane 40 which must turn left from region 10 will first determine if the queue in lane 40 plus a specified number of additional queued vehicles in lane 40 are less than the total number of queued vehicles in lane 41. If this is found to be true, the left-turn vehicle will remain in lane 41 and enter region 7 using a dual left-turn. If the converse is true, i.e., lane 41 has the shorter queue, the vehicle will attempt to change lanes into lane 41 to complete the required left-turn. However, if the vehicle does not succeed in its lane-change attempt, it then remains in lane 40 and makes a dual left-turn. This specified number of additional queued vehicles in the dual turn lane is entered into the model through the table item XTRCAR. The table index used for each entry of XTRCAR is the model region number (0 through 21) associated with each entry. For example, if the specified number of additional queued vehicles in the dual left-turn lane of regions 1 and 10 is 5 and 7, respectively, then items

XTRCAR(1)=5 , and
XTRCAR(10)=7 .

The percentage of total right-turn movements emanating from a region which may elect to use the dual right-turn lane in regions 10 and 12 is indicated in item DRT. Only regions 10 and 12 may have a dual right-turn movement which is indicated by the appropriate numerical value of item RAMP. The table index for region 10 is "0" while the index for region 12 is "2". Therefore, if ramp region 12 is assumed to permit an 80 percent dual right-turn movement, the percentage is entered as follows,

DRT(2)=80

Region 10 does not permit such a movement, hence,

DRT(0)=0

As in the case of the dual left-turn movement, the determination of whether or not a right-turn vehicle will use a dual right-turn lane is based upon the shortest queue in the two right-turn lanes. The specified number of additional vehicles in the dual turn lane is entered into the model through the table item XTRVEH.

As in the case of table item DRT, the index for region 10 is "0", while the index for region 12 is "2". Thus, if four additional vehicles are added into the dual right-turn lane 47, then

XTRVEH(2)=4

while

XTRVEH(0)=0

Region 10 has no dual right-turn lane.

In this case, a dual right-turn will be made by the vehicle each time the queue in lane 46 is greater than

N + 4

where

N = number of queued vehicles in lane 47.

5.5 TURN CLASSIFICATION

The turning radius must be established for all "free" and "delayed" left-turns--both single and dual-- and single and dual right-turns. The turn radius is entered into the model through the table item RAD. Using Table 3-2, the turning direction and the lane from, and into, which the turn will be made determines the turn classification number. This classification number is then used as the table index for each entry of RAD. The range of classification numbers is from 0 through 249.

Turns from regions 2 and 10 will be used to illustrate the determination of the classification number, the determination of the turning radius, and the entering of data into the model. Figure 5.5 will be used which is an enlargement of the diamond interchange geometry shown in Figure 5.4. It will only include regions 1, 2, 7, 8, 10, and 23.

The two right-turns from region 10 have turn classifications of 137 and 138. Classification 137 originates in lane 40 of region 10 and terminates in lane 4 of region 1. Classification 138 also originates in lane 40 of region 10 but terminates in lane 5 of region 1. The turning radii for classifications 137 and 138 are 40.0 feet and 60.0 feet, respectively. Thus,

RAD(137)=400 , and
RAD(138)=600 .

The four left-turns shown which originate in region 2 and terminate in region 23 have the classifications 21, 22, 23, and 24. Classifications 21 and 22 originate in lane 10 and terminate in lane 87, while classifications 23 and 24 also originate in lane 10 but terminate in lane 88. Classifications 21 and 23 are the "free" turns, while classifications 22 and 24 are the "delayed" turns. Classifications 21 and 22 form one turn trajectory alternative, while classifications 23 and 24 form another turn trajectory

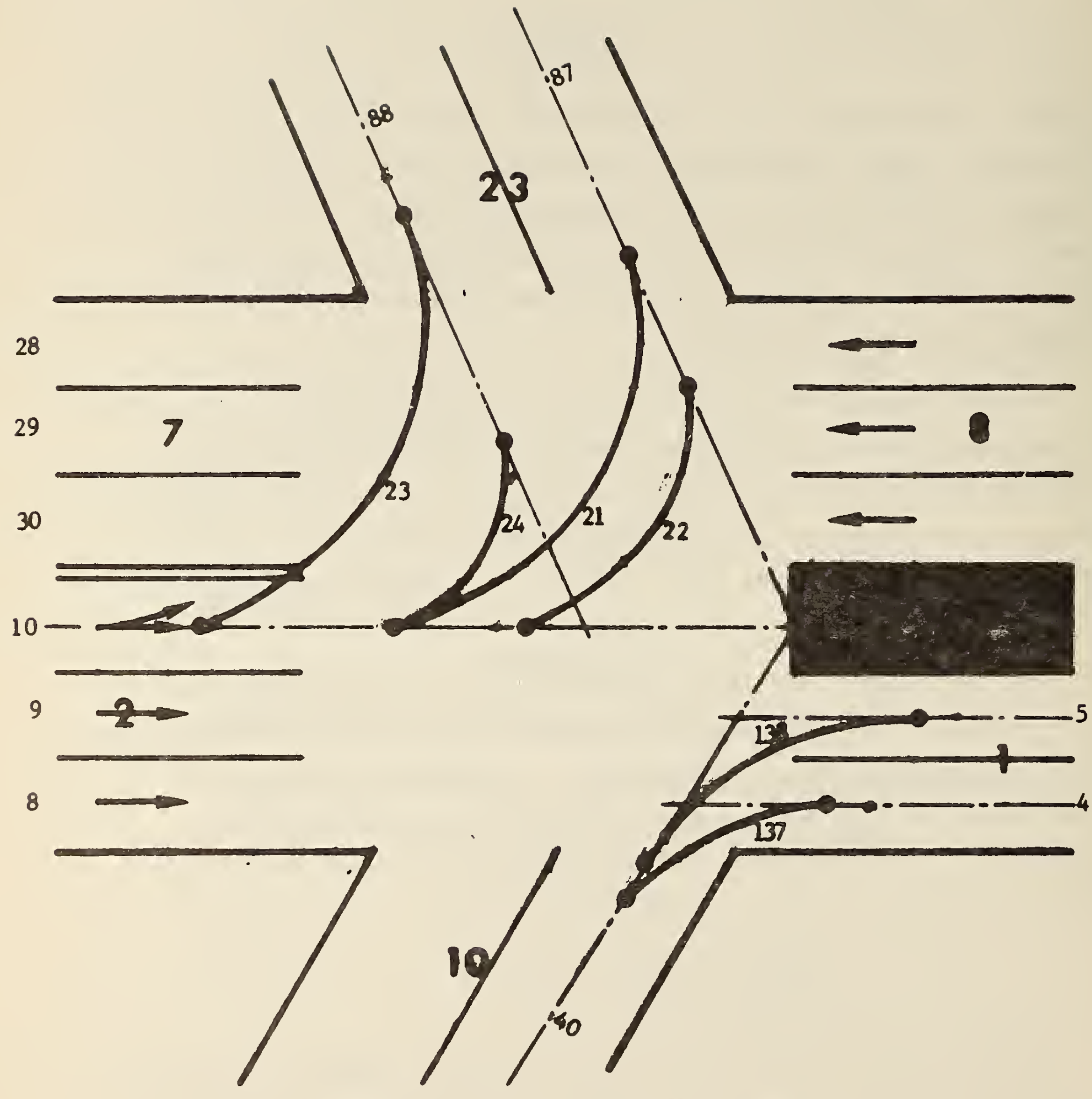


Figure 5.5. Enlargement of One Intersection

alternative. The respective radii are entered as

RAD(21)=600

RAD(22)=400

RAD(23)=500

RAD(24)=400 .

Program logic determines all required beginning and end locations of the circular curve segments as well as the maximum turning velocity. The required coordinate translation value is computed to enable the vehicle to modify all its locational values when it terminates its turn so it may enter the new coordinate system.

The program-computed values for classifications 137 and 138 are listed in Table 5-8.

TABLE 5-8 TURN CLASSIFICATION DATA

Classification	137	138
Radius (ft)	40.0	60.0
Beginning Location (ft)*	2401.0	2391.0
End Location (ft) *	2463.8	2485.2
Maximum Velocity (ft/sec)*	9.8	12.0
Region Exit Location (ft)	2436.0	2436.0
Wait Location (ft)	2421.2	2415.6
Coordinate Translation (ft)	6.2	4.8
Terminating Lane	4	5
* Program Computations		

Each turn classification is assigned a value representing the probability of that turn classification being selected to complete a given turn movement. When the percentages of acceptance are assigned for a particular turn movement, single "free" left-, dual "free" left-, single right-, and dual right-turns are considered as separate groups, even though they may enter the same region. The cumulative percentage within each grouping must equal 100 percent. "Delayed" left-turns are not considered when a turn classification is being selected. Therefore, no percentage of acceptance should be assigned to the "delayed" left-turn classifications.

The cumulative probability of a vehicle accepting a certain turn classification is entered into the model through the table item PTNTY. The table index for each entry of the table is the turn classification number (0 through 248) associated with each entry.

When a vehicle is selecting a turn classification, it will first determine if the turn should be a single or dual turn. After making this determination, the turn classification is selected from that particular group. The groupings are therefore treated separately when assigning a probability of acceptance of a turn classification.

Figure 5.4 is used as an example to establish the probability of a turn vehicle accepting a given turn classification. Consider the left- and right-turn movement from region 10 entering regions 1 and 7. Turn classifications which may be considered by the turning vehicles are: free left-turns from lanes 40 and 41 entering lanes 28, 29, and 30, and the right-turn from lane 40 entering lanes 4 and 5. The turn classifications which may be selected are:

FREE LEFT-TURN	RIGHT-TURN	
Single	Single	Dual
145	161	165
147	162	166
	163	167

The three groups listed are treated separately when assigning the probability of a vehicle accepting a particular turn classification. A crossing of vehicle trajectories should be avoided since program logic does not check for crossing trajectories. For example, vehicles from both lanes 46 and 47 may not turn right into lane 24. If vehicles are permitted to enter lane 25 from lane 46, then all vehicles turning from lane 47 must enter lane 26 to avoid the crossing of vehicle turning trajectories. In the case where vehicles from lane 47 are permitted to enter lanes 25 and 26, then all vehicles turning from lane 46 must enter lane 24. The right-turns from lane 46 are reduced from three (161, 162, and 163) to one (161). Hence,

PTNTY(161)=100

Thus, 100 percent of all vehicles turning right from lane 46 will enter lane 24. Because vehicles enter lane 24 from lane 46, no vehicles from lane 47 may enter lane 24. Therefore,

PTNTY(165)=0

Thus, no vehicles are permitted to accept turn classification 129. If 60 percent of the right-turn vehicles from lane 47 enter lane 25, then 40 percent enter lane 26 from lane 47. Therefore,

PTNTY(166)=60

PTNTY(167)=40

The left-turn vehicles from lane 48 entering region 2 may enter lanes 8 and 9 if the distribution is 30:70 respectively, then,

PTNTY(145)=30

PTNTY(147)=70

The sum of the percentages of acceptance in each grouping of turn classifications must equal 100 percent. This is illustrated in the table following.

TABLE 5-9 TURN CLASSIFICATION PERCENTAGES

FREE LEFT-TURN		SINGLE RIGHT-TURN		DUAL RIGHT-TURN	
Turn Class.	Percent	Turn Class.	Percent	Turn Class.	Percent
147	30	161	100	165	0
147	70	162	0	166	60
		163	0	167	40
TOTAL	100		100		100

5.6 REGIONAL VELOCITY PROFILE

The free flow velocity profile of a region is established by designating a free flow velocity at both the entrance and exit of the model region. This data is entered into the model through the table item SITVEL (entrance free flow velocity) and STTVEL (exit free flow velocity). The table index for both these table items is the model region number (0 through 21) associated with each entry. A linear interpolation is made between SITVEL and STTVEL for each region to determine the free flow velocity at any given location within the region.

Again referring to Figure 5.6, the regional free flow velocity profile for the model regions shown are listed below:

SITVEL(1)=510	STTVEL(1)=600
SITVEL(2)=510	STTVEL(2)=420
SITVEL(3)=510	STTVEL(3)=510
SITVEL(6)=450	STTVEL(6)=510
SITVEL(7)=580	STTVEL(7)=400
SITVEL(8)=510	STTVEL(8)=600
SITVEL(10)=700	STTVEL(10)=240
SITVEL(11)=880	STTVEL(11)=700
SITVEL(12)=700	STTVEL(12)=280

It should be noted the profile velocity is not required to be continuous across contiguous regions. Such a case is the non-continuous profile from region 2 to region 1. The exit free flow velocity from region 2 is 42.0 feet per second, while the entrance free flow velocity into region 1 is 51.0 feet per second. This, therefore, produces a velocity reduction as vehicles approach the intersection, but may increase their velocity after they have cleared the intersection.

5.7 MODEL COORDINATE SYSTEMS

Each unidirectional flow of traffic must have its own coordinate system. The system entrance boundaries mark the beginning of each coordinate system, and all coordinate systems must have coordinates greater than zero. This latter restriction complies with specifications which declare several locational table items as <u>unsigned</u> integers.

The coordinate at the system entrance boundaries must be greater than an amount which depends upon the maximum system entrance velocity. When a vehicle is entered into the model, it is assumed that it previously had a constant velocity and acceleration equal to zero. Each vehicle retains past performance histories which include position locations within an entrance lane. Since the vehicle is entered at a boundary with a velocity greater than zero, the previously inferred position locations will be less than the entrance boundary. Thus, the maximum distance traveled by a vehicle entering a particular lane must be computed. The beginning coordinate for that region must therefore be greater than this maximum travel distance.

The maximum travel distance is determined by the following equation:

Maximum travel distance = (x + 1) (y)

$$\text{where } x = \frac{\text{driver reaction time}}{\text{time per review}}, \text{ an integer value}$$

and y = (maximum entrance velocity) (time per review)

A sample computation, using the following values, is prescribed below:

driver reaction time = 1.0 second
time per review = 0.5 second
maximum entrance velocity = 55.0 feet per second

Maximum travel distance is then given by:

$$(x + 1)\ (y) = \left(\frac{1.0}{0.5} + 1\right)(55.0 * 0.5)$$

$$= (3)\ (27.5) = 82.5 \text{ feet}$$

In this example, the beginning coordinate must be greater than 82.5 feet to assure that the extrapolated vehicle position locations are greater than zero.

The maximum travel distance is, therefore, the minimum coordinate value of the coordinate system. The coordinate value at the origin may, however, exceed this value.

The maximum coordinate value is also set by the declared specifications for locational table items. As illustrated in Section 5.1, table item EXIT may have a maximum value of 65535. Since positions are generally retained in tenths of feet, the maximum abscissa for a coordinate system is 6553.5 feet.

5.7.1 Region Coordinates. The coordinates for the entrance and exit boundaries for each model region are entered into the model through the table items NTRY and EXIT, respectively. The table index used for each entry of the table items is the model region number (0 through 21) associated with each entry. The coordinate value which is entered is expressed in tenths of feet.

Figure 5.6, a schematic representation of a diamond interchange, has six coordinate systems--one for each of the four entrance and exit ramps, and one for each of the two directions of traffic flow along the arterial street. The beginning location of each of the six coordinate systems is denoted by a ◯. Also shown in Figure 5.6 are the entrance and exit locations for each model region.

In the example shown in Figure 5.6, the coordinates were derived by establishing values at the beginning of each coordinate system. The system entrance location for model region 3 was set equal to 1192.0 feet. The region is 821.0 feet in length. Therefore, the exit of the region has a coordinate of 2013.0 feet, (1192.0 + 821.0). Since model regions 2 and 3 are contiguous regions, therefore region exit coordinate for region 3 is the region entrance coordinate of region 2. Region 2 is 377.0 feet in length. Thus, the exit coordinate of region 2 is 2390.0 feet, (2013.0 + 377.0). Region 1 is 1481.0 feet in length. Therefore, the exit coordinate of region 1 is 3871.0 feet, (2390.0 + 1481.0). Model regions 1, 2, and 3 form a contiguous segment of unidirectional roadway which is 2679.0 feet in length. This represents the exit coordinate of region 1 minus the entrance coordinate of region 3,

$$(3871.0 - 1192.0 = 2679.0).$$

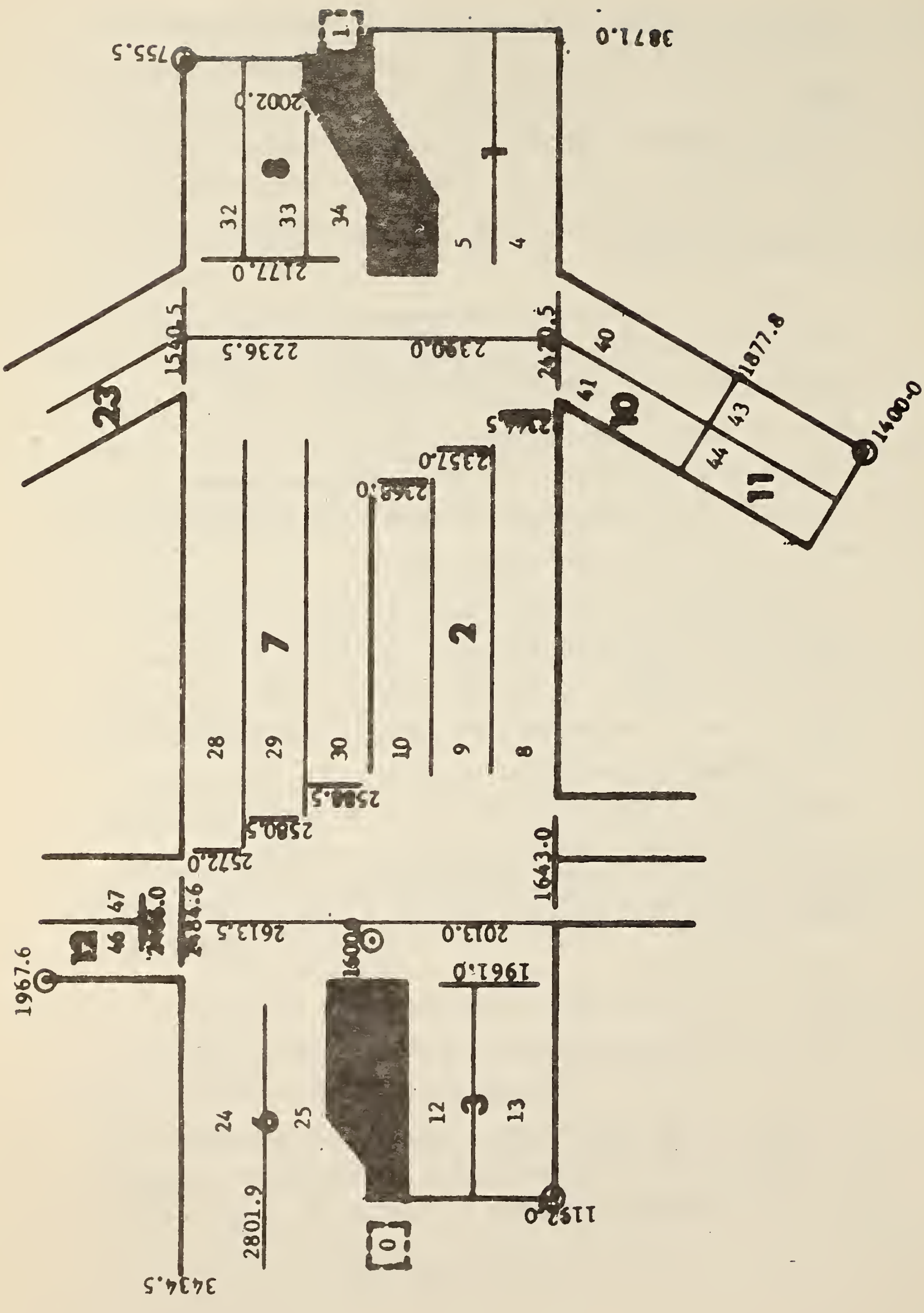


Figure 5.6. Sample Coordinate System.

Using Figure 5.6, the following list describes the data required to define the length of regions which are to be included in the model.

NTRY(1)=23900	EXIT(1)=38710
NTRY(2)=20130	EXIT(2)=23900
NTRY(3)=11920	EXIT(3)=20130
NTRY(6)=26135	EXIT(6)=34345
NTRY(7)=22365	EXIT(7)=26135
NTRY(8)=7555	EXIT(8)=22365
NTRY(10)=18778	EXIT(10)=24205
NTRY(11)=14000	EXIT(11)=18778
NTRY(12)=19676	EXIT(12)=24846

5.7.2 Lane Coordinates. The beginning and end boundary locations for lanes within a region are assumed to be equal to the corresponding boundary locations for the region. This is true for all lanes with the exception of an exclusive storage lane which begins at or beyond the entrance to a region. The coordinate corresponding to the beginning of the exclusive storage lane is entered into the model through the table item BGNPOC. The table index used for each entry of this table item is the model region number (0 through 21) associated with each entry. In the example shown in Figure 5.6, there is an exclusive storage lane in model region 8. The left-turn storage lane in region 2 begins at the entrance boundary of region 2. It is, therefore, not considered an exclusive storage lane even though there is no lane in region 3 from which vehicles may leave and enter directly into lane 10. Traffic in lane 13 enters lane 9 and then must change lanes into lane 10. The same is true for lane 41; traffic in lane 43 must first enter lane 40, then change lanes if they desire to enter lane 41.

The general practice should be followed to set all entries of BGNPOC equal to the corresponding entry of NTRY. Therefore,

BGNPOC(1)=23900
BGNPOC(2)=20130
BGNPOC(3)=11920
BGNPOC(6)=26135
BGNPOC(7)=22365
BGNPOC(10)=18778
BGNPOC(11)=14000
BGNPOC(12)=19676

The beginning of the storage lanes in regions 6 and 8 are beyond the entrance to the region. Therefore, the data for the beginning of these exclusive storage lanes are entered as follows:

BGNPOC(6)=28019
BGNPOC(8)=20020 .

The stopline location in each lane is entered into the model through the table item STP. The table index used for each entry is the lane number (0 through 83) associated with each entry. The location of a stopline must be contained within the model region with the exception of region 11 and 13. The location of a stopline in one lane is not dependent upon the location of stoplines in other lanes. The location of each stopline is with respect to traffic control requirements and site geometrics.

The locations of the stoplines in lanes 8, 9, and 10 are staggered to permit a larger turn radius for the left-turn movement from region 10. However, in lanes 32, 33, and 34, there is a common stopline across all lanes. A sample representation of the data entries are:

STP(8)=23680

STP(9)=23570

STP(10)=23445

STP(32)=21770

STP(33)=21770

STP(34)=21770

Each lane must have a stopline coordinate value. However, in exit ramp regions 11 and 13, no stopline is required within the region. The two model regions 10 and 11 are controlled by arterial traffic signal ①, while model regions 12 and 13 are controlled by arterial traffic signal ②. Vehicles in region 11 approaching arterial traffic signal ① during the red signal indication begin to slow in order to stop at the stopline locations for lanes 40, 41, or 42. The exact lane stopline location is dependent upon which lane the vehicle currently occupies in region 11. The same is true for vehicles operating in region 13. Consequently, stopline location for lanes 43, 44, and 45 are set equal the stopline location for lanes 40, 41, and 42, respectively, and likewise for lanes 49, 50, 51. Thus,

STP(43)=24205

STP(44)=24205 .

5.7.3 Coordinate Translation. The internal processing and vehicle bookkeeping operations require vehicle positions to be modified upon entering a region. This position value modification does not affect straight-movement vehicles when they move from one region to another. Turn vehicles, however, leave one coordinate system and enter another coordinate system when they exit one region and enter another region. Consequently, the position location of their past performance histories in the exited region must be translated into the coordinate system they have just entered.

The relationship of the intersecting coordinate system with each region is entered into the model through table items SETRAN and SETRAND. There are five regions whose coordinate systems may intersect any one other coordinate system. They are identified as follows:

TABLE 5-10 SETRAN-SETRAND CONSTANTS

RTOUT=0	region out on the right
RTIN=1	region in on the right
POSE=2	region opposing
LTOUT=3	region out on the left
LTIN=4	region in on the left

The numerical value to which each of the five above items are set equal to indicates the block of the table containing the data for the indicated regions. For example, all data pertaining to the regions out on the left are contained in the fourth block (block number 3).

The table index for the table items SETRAN and SETRAND is a constant plus the model region number (0 through 21) associated with each entry. The constant equals the simple item NAS times the required numerical constant corresponding to the intersecting coordinate system as given in Table 5-10. Item NAS is defined as 22. Thus, translation data for region 2 would be contained in the entries listed in the fourth column of Table 5-11. Index values for other regions are computed in like manner.

TABLE 5-11

SETRAN- SETRAND TABLE INDEXES

NAS (1)	Intersecting Coordinate System (2)	Model Region (3)	Table Index (4)
22	RTOUT=0	2	2
22	RTIN=1	2	24
22	POSE=2	2	46
22	LTOUT=3	2	68
22	LTIN=4	2	90

The table index listed in column 4 is the sum of the entries in column 3 with the product of the entries in columns 1 and 2.

It is assumed all coordinate systems have their zero "ordinate" value on the curbline of the region, and the curbline forms a common curbline boundary between regions. The projections of these curbline boundaries are used to establish the locations of the intersections of two coordinate systems.

The data entered for each entry of table item SETRAN is the coordinate value at this intersection of two coordinate systems. The numerical value entered is with relationship to the coordinate system intersecting the region for which data is being entered.

Figure 5.3 shows a schematic representation of a nearby four-way intersection. For that geometry the region out on the right is region 14; the region in on the right is region 17; the region opposing is region 6; the region out on the left is region 16; and the region in on the left is region 15. Figure 5.7 represents the diamond interchange ramp intersection controlled by arterial traffic signal (1). There is no region out on the right or in on the left. Thus the entries for that data are set equal to zero.

Figure 5.7 will be used to demonstrate the data requirements needed to establish the relationship of one coordinate system with another. Data will be established for region 2 with the required table index given in Table 5-12. The data is as follows:

(1) RTOUT=0 ; Region out on the right does not exist for region 2. Therefore:

SETRAN(2)=00

(2) RTIN=1 ; Region in on the right, region 10. The projection of the curblines of regions 2 and 10 intersect at point A with the intersection in the coordinate system of region 10. Therefore:

SETRAN(24)=4385

(3) POSE=2 ; Region opposing, region 8. The projection of the curblines of regions 2 and 8 do not intersect. The data entered is the intersection of the projection of the exit boundary of region 2 and the curbline projection of region 8. The intersection at point B is in the coordinate system of region 8. Therefore:

SETRAN(46)=21479

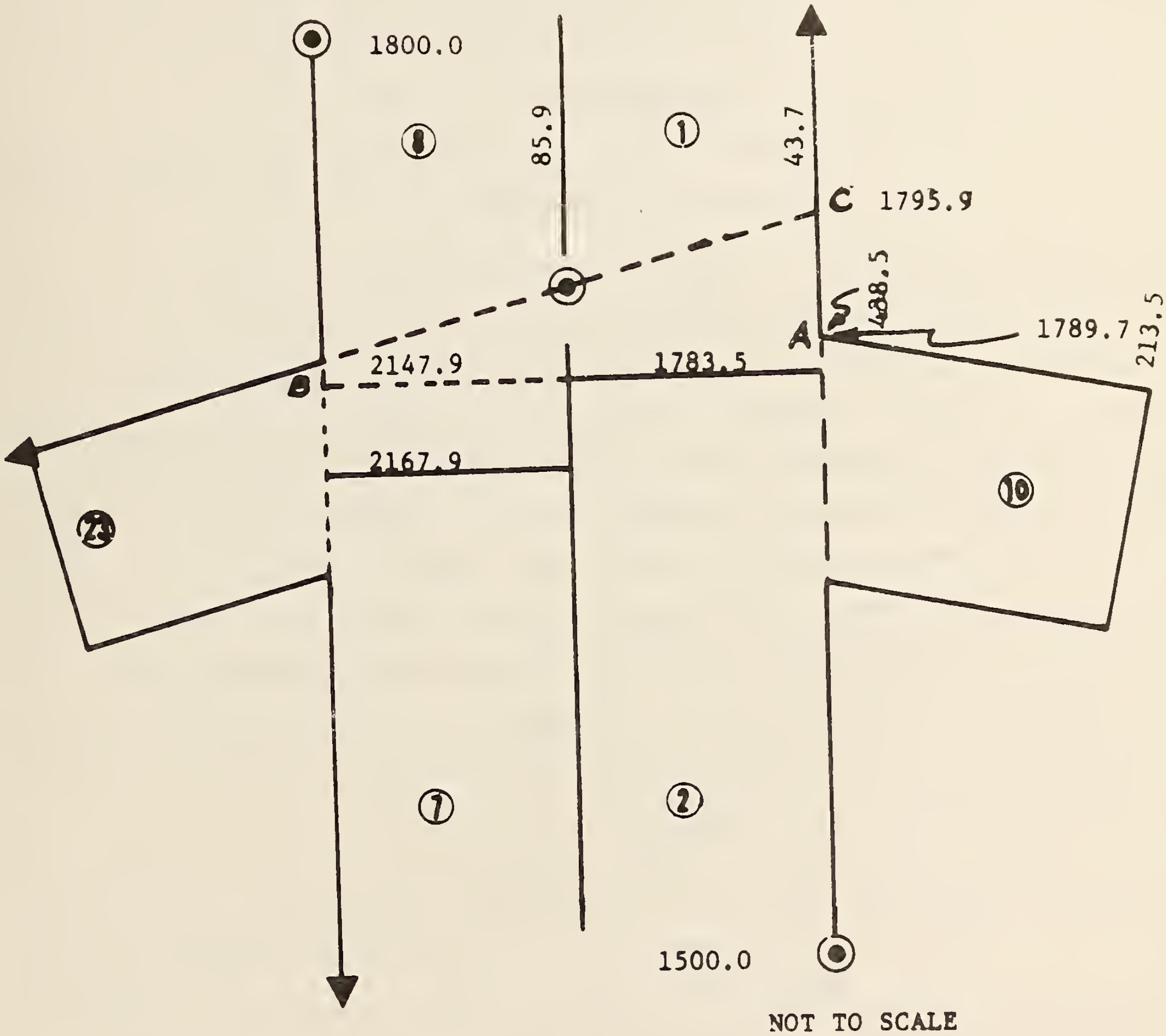


Figure 5.7 Coordinate Intersection in a Ramp Intersection

(4) LTOUT=3 ; Region out on the left, region 23. The projection of the curbline of regions 2 and 23 intersect point C with the intersection in the coordinate system of region 23. Therefore:

SETRAN(68)=437

(5) LTIN=4 ; Region in on the left does not exist for region 2. Therefore:

SETRAN(90)=00

Table item SETRAND contains the distance of the curbline projection intersection from the regional exit boundary, as given in EXIT. The distance is computed by subtracting the exit boundary location from the intersection location of the two coordinate systems. The coordinates used are all within the coordinate system of the region for which data is being entered. Table index values for region 2 are listed in Table 5-11 and will be used for the following data entries.

(1) RTOUT=0 ; Region out on the right does not exist for region 2. Therefore:

SETRAND(2)=00

(2) RTIN=1 ; Region in on the right, region 10. The distance from the exit boundary of region 2 to point "A" is 1789.7 - 1783.5 = 6.2 feet. Therefore:

SETRAND(24)=62

(3) POSE=2 ; Region opposing, region 8, does not apply for SETRAND computation for the coordinate systems do not intersect. Therefore:

SETRAND(46)=00

(4) LTOUT=3 ; Region out on the left, region 23. The distance from the exit boundary of region 2 to point "C" is 1795.9 - 1783.5 = 12.4 feet. Therefore:

SETRAND(68)=124

(5) LTIN=4 ; Region in on the left does not exit for region 2. Therefore:

SETRAND(90)=00 .

5.7.4 Angle of Intersection. The angle of intersection of the cross-streets is entered into the model through the table item DFLECT. The table index for this table item is a constant plus the model region number (0 through 21) associated with each entry. The constant for the clockwise angle is "0" while the constant for the counterclockwise angle is NAS. This item is defined as 22. The angle is measured in radians.

The clockwise angle measures the angle of intersection of the zero ordinates for the coordinate systems of a region and its region out on the right. The counterclockwise angle measures the angle of intersection of the zero ordinate for the coordinate system of a region and its region out on the left. The two angles are shown in Figure 3.6. Angle "A" is the clockwise angle, while angle "B" is the counterclockwise angle.

Figure 3.6 will be used as a representation of the angles to be measured and the data conversion requirements. Angle "A" for regions 1 and 9 79°55'23", or 79.9230 degrees. Noting that,

1 radian = 57.29578 degrees

Therefore,

$$\text{Angle "A"} = \frac{79.9230}{57.29578} = 1.3949 \text{ radians}$$

The table index for angle "A" is "0" plus the model region number. Thus for region 1

DFLECT(1)=13949

DFLECT(9)=13949 .

Angle "B" for region 1 is 100°04'37" or 100.0769 degrees. Therefore,

$$\text{Angle "B"} = \frac{100.0769}{57.29578} = 1.7467 \text{ radians}$$

The table index for angle "B" is NAS, defined as 22, plus the model region number. Thus, for regions 1 and 9,

DFLECT(23)=17467

DFLECT(31)=17467

If the angle out on the right, or in on the left, does not exist for a region, the angle "A" or angle "B" is set equal "0". There is no region out on the right for region 2 of Figure 5.4. Therefore the angle "A" of region 2 is

DFLECT(2)=0

There is no region in on the left for region 3 of Figure 3.1. Therefore the angle "B" of region 3 is

DFLECT(25)=0 .

5.8 VEHICLE GENERATION

Lane occupancy is entered into the model through the table item TENT. The table index for each entry of this table item is the lane number (0 through 84) associated with each entry. Maximum lane occupancy is given by

$$\text{Occupancy} = \frac{L}{d}$$

where

L = lane length from entry to exit boundary

d = average length of a vehicle.

Thus, for an average vehicle length of 20 feet, the permitted occupancy in the lanes in regions 7 and 10 of Figure 5.6 will be, respectively,

$$\frac{2613.5-2236.5}{20.0} = 18.85 \text{ vehicles}$$

and

$$\frac{2420.5-1877.8}{20.0} = 27.14 \text{ vehicles}$$

Therefore,

TENT(28)=18

TENT(29)=18

TENT(30)=18

TENT(40)=27

TENT(41)=27

Each entry of TENT represents the number of storage locations which are allocated for that lane. These table entries will contain vehicle-representative data. The summation of the TENT values must not exceed the storage locations allocated for "actual" vehicles, cf. Section 2. The actual vehicle storage is established by the simple items EPC and LPTR and equals

$$EPC - LPTR$$

Using the present values,

$$EPC = 800$$

and

$$LPTR = 200$$

Therefore,

$$\sum_{n=0}^{83} TENT(N) \leq 600$$

The vehicle generation flow rate is established for each system entrance lane. The program logic uses these generation rates to produce intervehicular arrival times for each lane. After the generation of a vehicle into a lane, the destination of that vehicle is established using parametric input data.

5.8.1 Entrance Lane Flow Rate. Flow rates are specified as the number of vehicles that enter a lane in a prescribed period of time. After the regional geometry and lane configuration is established, the table index associated with each table entry is assigned. This index value is then referred to as the entrance lane number.

All flow rate data are entered according to this assigned entrance lane number. The convention for assignment of entrance lane numbers is as follows: beginning with the smallest numerical region lane number, assign each entrance lane a table index value. The first entrance lane is assigned a table index value of 32 (the first 31 values are assigned to the freeway model) and the assignment is in ascending order until a possible 30 entrance lanes have been assigned. An example of this assignment process is shown below using the model region and lane configuration shown in Figure 5.4.

Number of a Lane Which is a System Entrance Lane	Corresponding Entrance Lane Number and Table Index
12	32
13	33
32	34
33	35
40	36
41	37
49	38
50	39

In this example, all flow rate data pertaining to lane number 41 will have a table index value of 37. However, if the number of lanes entering a system entrance region is changed, the subsequent entrance lane numbers must be modified. This modification will reflect the addition or subtraction of lanes entering a system entrance region. For example, if a lane were added to regions 3, 8, and 13, of Figure 5.4, the table index for the new lanes must be included. The modified indexes are shown below.

Number of Lane Which is a System Entrance Lane	Corresponding Entrance Lane Number and Table Index
12	32
13	33
14	34
32	35
33	36
34	37
40	38
41	39
49	40
50	41
51	42

In this example, flow rate data pertaining to lane number 41 will have a table index value of 39 instead of the previous 37.

The lane flow rate is entered into the model through the table item SFLOW. The time period used in this flow rate is the specified period during which vehicles will be generated into the entrance lane. Model logic converts the vehicle count per period of time to a flow rate in vehicles per hour using the following equation:

$$\text{Vehicles per hour} = \frac{\text{Flow rate per time period}}{\text{Hours per time period}}$$

For example, if 75 vehicles will be required to be generated into a lane in a 30-minute period; the flow rate would be 75 vehicles per 30 minutes, or 150 vehicles per hour. The time period is expressed in 100th's of an hour.

The flow rate and its associated period of time are entered into the model through the table items SFLOW and CNTME, respectively. The table index for each entry of these table items is the entrance lane number (32 through 61) associated with each entry. Representative flow rate data for the diamond interchange configuration shown in Figure 5.4 are given in the following table.

TABLE 5-12

FLOW RATE DATA

Model Lane Number (1)	Entrance Lane Number (2)	Flow Rate (3)	Time Period (Hour X100) (4)	Equivalent Hourly Rate (5)
12	32	SFLOW(32)=173	CNTME(32)=50	346
13	33	SFLOW(33)=164	CNTME(33)=50	328
32	34	SFLOW(34)=132	CNTME(34)=25	528
33	35	SFLOW(35)=124	CNTME(35)=25	496
40	36	SFLOW(36)=52	CNTME(36)=33	157
41	37	SFLOW(37)=0	CNTME(37)=33	0
49	38	SFLOW(38)=60	CNTME(38)=83	72
50	39	SFLOW(39)=28	CNTME(39)=83	33

In the above table, the time period for entrance lanes 32 and 33 is 30 minutes, for entrance lanes 34 and 35 it is 15 minutes, for entrance lanes 36 and 37 it is 20 minutes, and for entrance lanes 38 and 39 it is 50 minutes. The number of vehicles to be generated during the corresponding time periods are listed in column 3. Column 5 contains the program-converted flow rate expressed as number of vehicles per hour. It should be noted in the example model, that lane 44 will have no vehicles enter since the entrance flow rate is zero.

5.8.2 Vehicular Arrival Time. The generation of intervehicular arrival times for each entrance lane is accomplished through the use of: (1) a truncated exponential density function, or (2) an Erlang density function. The method of generation may not be mixed. Either one or the other must be used for generation of intervehicular arrival times in all lanes. The simple item GNTYPE designates which density function should be used. The designation values are:

GNTYP=0 -- use truncated exponential density function

GNTYP=1 -- use Erlang density function.

When using either of the two generation methods, the largest acceptable headway may be regulated. The acceptable headway is expressed as the number of standard deviations from the average intervehicular headway for a specified flow rate. The simple item KAY is set equal to the number of standard deviations from the average intervehicular headway for a specified flow rate that yields the largest acceptable headway.

For example, if

KAY=2

and a flow rate of 500 vehicles per hour are to enter lane 43, the largest acceptable headway is computed, using:

$$\frac{3600}{\left(\frac{1.0 - (1.0 + KAY)}{1.0 - e^{-KAY}}\right) SFLOW}$$

This gives the average number of seconds between vehicles for a given flow rate SFLOW. The largest acceptable headway is therefore equal to

(average intervehicular headway)KAY

For example, if

KAY=2

and the flow rate for model lane 43 is 500 vehicles per hour, a headway will not be accepted if it is greater than 20.9 seconds. If an excessive headway is generated, it is ignored; the generation procedure is continued in that lane until a headway less than or equal to 20.9 seconds is computed.

The minimum acceptable intervehicular headway is designated by the simple item HDWY. If a value other than the default value of 2.0 seconds is required, for instance 2.5 seconds,

HDWY=25

If multiple runs are made with a value other than the default value, the simple item HDWY must be reset to the desired value.

Table item INFLOW designates if the vehicle generated into an entrance lane is done so in a cyclical or non-cyclical manner. The method chosen for generation of vehicles into a region applies to each lane in that region. The table index for each entry of the table item is the dummy traffic signal number (0 through 5) associated with each entrance region. Since no dummy traffic signal is associated with an exit ramp region, all generation of traffic into these regions must be made using the non-cyclical method. No table item INFLOW is associated with the exit ramp regions.

Representative data and the following discussion will be related to the diamond interchange configuration shown in Figure 5.4.

TABLE 5-13

CYCLICAL AND NON-CYCLICAL GENERATION

Entrance Region	Dummy Signal	Method of Generation
3	0	Cyclical
8	1	Non-Cyclical
10	---	Non-Cyclical
13	---	Non-Cyclical

Cyclical generation will be used to enter traffic into region 3, while non-cyclical generation will be used for region 8. Therefore,

INFLOW(0)=1

INFLOW(1)=0

The percentage of vehicles entering a region from movement M_T, cf. Section 3.6.2, is entered into the model through the table item MAJOR. The table index for each entry of the table item is the entrance lane number (32 through 61) associated with each entry.

Exit ramp regions may not have traffic generated cyclically, therefore the percentage of vehicles entering ramp-model lanes 40, 41, 49, and 50 must always be comprised entirely of the M_T movement, therefore,

MAJOR(36)=100

MAJOR(37)=100

MAJOR(38)=100

MAJOR(39)=100

Model region 8 uses non-cyclical generation of traffic entering lanes 32 and 33, thus the entering traffic will be comprised entirely of the M_T movement. Therefore,

MAJOR(34)=100

MAJOR(35)=100

Model region 3 uses cyclical generation of traffic into model lanes 12 and 13. Traffic entering these lanes must therefore be proportioned as entering on movement M_T or movements M_R and M_L. These movements are considered to be originating from dummy signal "0". Using the flow rates given in Table 5-12, there will be 346 vehicles generated into model lane 12 during one hour, and 328 vehicles into model lane 13 during a similar period. Suppose 69 vehicles entered lane 12 during the minor movements M_R and M_L from dummy signal 0. Thus, the percent of vehicles entering during movement M_T is

$$\left(\frac{346 - 69}{346}\right)100 = 80 \text{ percent}$$

Therefore,

MAJOR(32)=80

If 220 vehicles enter lane 12 during the major movement M_T from dummy signal 0, the percentage of vehicles entering during movement M_T is

$$\left(\frac{220}{328}\right)100 = 67$$

Therefore,

MAJOR(33)=67

The flow rate inputs through SFLOW are given in vehicles per period of time, and not vehicles per hour of green.

5.8.3 Origin-Destinations. Fifty-six system origin-destinations (OD's) are defined to simulate vehicle trajectories through the system, and to produce the predetermined flows within the system. Table 3-3, in conjunction with Figure 3.1A, permit the tracing of the trajectories. Table 3-4 lists the origin-destinations wich are permitted to enter and operate in each model region.

After selecting the model regions to be included in the simulation problem, the entrance regions are identified. If the Figure 5.4 diamond interchange configuration is being simulated, with the indicated turning movements, the entrance regions are model regions 3, 8, 10, and 13. Table 3-4 lists those OD's which are permitted to enter the system through these four regions. If only straight-through movements are permitted to exit region 6, and only the straight-through and left-turn movements are permitted to exit region 1, then the list of permitted OD's as given in Table 3-4, is reduced to that given in Table 5-14.

TABLE 5-14

ORIGIN-DESTINATIONS

Entrance Region	Entrance Origin-Destinations
3	2, 4, 5, 6
8	14, 17, 18
10	19, 21, 22
13	7, 10, 12

This set of origin-destinations which are permitted to operate within the system is only used as an example. If it is required, all OD's which are permitted to operate in regions 3, 8, 10, and 13, cf. Table 3-4, may be included.

The subset of origin-destinations entering a region has now been established. The assignment of origin-destination is on a per entrance lane basis, therefore a subset of the region subset may be assigned to each entrance lane in the region. The assignment per entrance lane allows different origin-destination descriptors to be assigned to each lane, as well as different distributions assigned to the origin-destinations entering each entrance lane.

For purposes of illustration, the origin-destinations shown on Table 5-15 will be assigned to each entrance lane.

TABLE 5-15

ORIGIN-DESTINATION LANE ASSIGNMENT

Entrance Region	Model Entrance Lane	Program Index Number	Origin-Destination
3	12	32	2, 4, 5
3	13	33	2, 4, 6
8	32	34	14, 17, 18
8	33	35	14, 17
10	40	36	19, 21, 22
10	41	37	22
13	49	38	7, 10
13	50	39	7, 10, 12

The complete subset of origin-destinations on a per entrance lane basis is entered into the model through the table item REGNOD. The table item used for each entry of REGNOD is

28 plus the sequential increment of each entry. The origin-destinations are ordered sequentially beginning with entrance lane 32. This ordering is given in Table 5-16.

In Table 5-16, the sequential ordering of the origin-destinations is listed in column 3. The corresponding value listed in column 2 is the table index value for table item REGNOD. For example, OD's 19, 21, and 22 enter entrance lane 36 (model lane 40). This information is entered into the model through

REGNOD(39)=19
REGNOD(40)=21
REGNOD(41)=22

Data relating to the beginning and ending of each origin-destination grouping associated with each entrance lane is entered into the model through the table items P2FOD and P2LOD. The table index used for each entry of these two items is the entrance lane number (32 through 61) associated with each entry. P2FOD corresponds to the first location, while P2LOD corresponds to the last location of table item REGNOD, containing the origin-destinations for an entrance lane. Using Table 5-16,

P2FOD(32)=28	P2LOD(32)=30
P2FOD(33)=31	P2LOD(33)=33
P2FOD(34)=34	P2LOD(34)=36
P2FOD(35)=37	P2LOD(35)=38
P2FOD(36)=39	P2LOD(36)=41
P2FOD(37)=42	P2LOD(37)=42
P2FOD(38)=43	P2LOD(38)=44
P2FOD(39)=45	P2LOD(39)=47

TABLE 5-16

REGNOD-ODDIST ASSIGNMENT

Entrance Lane (1)	REGNOD ODDIST Index (2)	Origin-Destination (3)	Percent of Lane Total (4)	Cumulative Total (5)	Hexadecimal Equivalent (6)
32	28	2	30	30	1E
32	29	4	25	55	37
32	30	5	45	100	64
33	31	2	40	40	28
33	32	4	15	55	37
33	33	6	45	100	64
34	34	14	37	37	25
34	35	17	8	45	2D
34	36	18	55	100	64
35	37	14	38	38	26
35	38	17	62	100	64
36	39	19	30	30	1E
36	40	21	12	42	2A
36	41	22	58	100	64
37	42	22	100	100	64
38	43	7	98	98	62
38	44	10	2	100	64
39	45	7	10	10	0A
39	46	10	85	95	5F
39	47	12	5	100	64

This data indicates, for instance, that for entrance lane 36 the origin-destinations which may enter that lane are contained in REGNOD table entries 39, 40, and 41. The first entry, P2FOD is 39, and the last entry, P2LOD is 41. The data contained in entries 39, 40, and 41 of REGNOD are 19, 21, and 22, cf. Table 5-16.

The unit percentage of each origin-destination to the total population of origin-destination for a particular lane is entered into the model through the table item ODDIST. The table index used for each entry is the corresponding index value of table item REGNOD, column 2, Table 5-16. These percentages, as shown in column 4 and summed to produce a cummulative total for the lane, column 5, cf. Table 5-16. A hexadecimal format is used for entry of this distribution data into the model. The hexadecimal equivalent (0 to 64) of the cumulative percentage (0 to 100) is contained in the first two bytes (left-justified) followed by six zeros. Again, using entrance lane 36, the percentage of OD's 19, 21, and 22 are 30, 42, and 100 percent. The hexadecimal equivalents are 1E, 2A, and 64. Therefore,

```
ODDIST(39)=X(1E000000)
ODDIST(40)=X(2A000000)
ODDIST(41)=X(64000000)
```

Origin-destination 7 in entrance lane 39 constitutes 10 percent of origin-destinations entering that lane. Therefore,

```
ODDIST(45)=X(0A000000)
```

Using the flow rate in column 5 of Table 5-12, and the origin-destinations given in column 4 of Table 5-16, the number of vehicles generated for each origin-destination in exit-ramp lane 40 is shown below.

Origin-Destination	Percent per Origin-Destination	Number of Vehicles per Origin-Destination
19	30	47
21	12	19
22	58	91

5.7.4 Vehicle-Driver Types. Five vehicle-driver types have been provided to classify the mixture of vehicle-drivers having different performance characteristics. One of five vehicle-driver types is assigned to each vehicle entering an entrance lane. The table index for each entry of a vehicle-driver type table item is the vehicle-driver type class (0 through 4) associated with each entry.

The cumulative distribution of each vehicle-driver type for the total population of vehicle-driver types is entered into the model using a hexadecimal format. The hexadecimal equivalent (0 through 64) of this percentage is contained in the first two bytes (left-justified) followed by six zeros of the table item DTPROB. The default values for this item are:

DTPROB(0)=X(07000000)
DTPROB(1)=X(1F000000)
DTPROB(2)=X(45000000)
DTPROB(3)=X(5D000000)
DTPROB(4)=X(64000000)

Thus, the percentage associated with each vehicle-driver type probability are:

TYPE0=7

TYPE1=24

TYPE2=45

TYPE3=24

TYPE4=7

The maximum acceleration capability default values for each vehicle-driver type are:

AAMAX(0)=400	,	4.00 feet per second per second
AAMAX(1)=450	,	4.50 feet per second per second
AAMAX(2)=500	,	5.00 feet per second per second
AAMAX(3)=550	,	5.50 feet per second per second
AAMAX(4)=600	,	6.00 feet per second per second

The maximum deceleration capability default values for each vehicle-driver type are:

AADES(0)=-400	,	-4.00 feet per second per second
AADES(1)=-400	,	-4.00 feet per second per second
AADES(2)=-400	,	-4.00 feet per second per second
AADES(3)=-400	,	-4.00 feet per second per second
AADES(4)=-400	,	-4.00 feet per second per second

The minimum time-headway acceptable for each vehicle-driver type is entered into the model through the table item RTCRTL. The default values are:

RTCRTL(0)=20	,	2.0 seconds
RTCRTL(1)=20	,	2.0 seconds
RTCRTL(2)=20	,	2.0 seconds
RTCRTL(3)=20	,	2.0 seconds
RTCRTL(4)=20	,	2.0 seconds

The minimum time-headway acceptable for each vehicle-type accepting a gap when left-turning is entered into the model through the table item LTCRTL. The default values are:

LTCRTL(0)=30 , 3.0 seconds
LTCRTL(1)=30 , 3.0 seconds
LTCRTL(2)=30 , 3.0 seconds
LTCRTL(3)=30 , 3.0 seconds
LTCRTL(4)=30 , 3.0 seconds

Each vehicle-driver type may deviate from the regional velocity profile by a percentage which is input through the table item ATVEL. The default values are:

ATVEL(0)=100
ATVEL(1)=100
ATVEL(2)=100
ATVEL(3)=100
ATVEL(4)=100

Using the example previously given in Section 3.4 and shown in Figure 3.4, the regional velocity profile is shown as line 1 in Figure 5.8. This figure graphically displays the vehicle-driver type velocity profile for cases other than ATVEL(_)=100. In Figure 5.8, the example vehicle-driver type may use only 89 percent of the permissible regional free flow velocity, ATVEL(_)=89. Using this example, 89 percent of the regional free flow velocity for a location may be used by the particular vehicle-driver type.

With the default values of 100 percent, the permitted free flow velocity for a vehicle-driver type will equal the regional velocity profile. If the value were changed to 110 percent, the permitted free flow velocity would exceed the regional

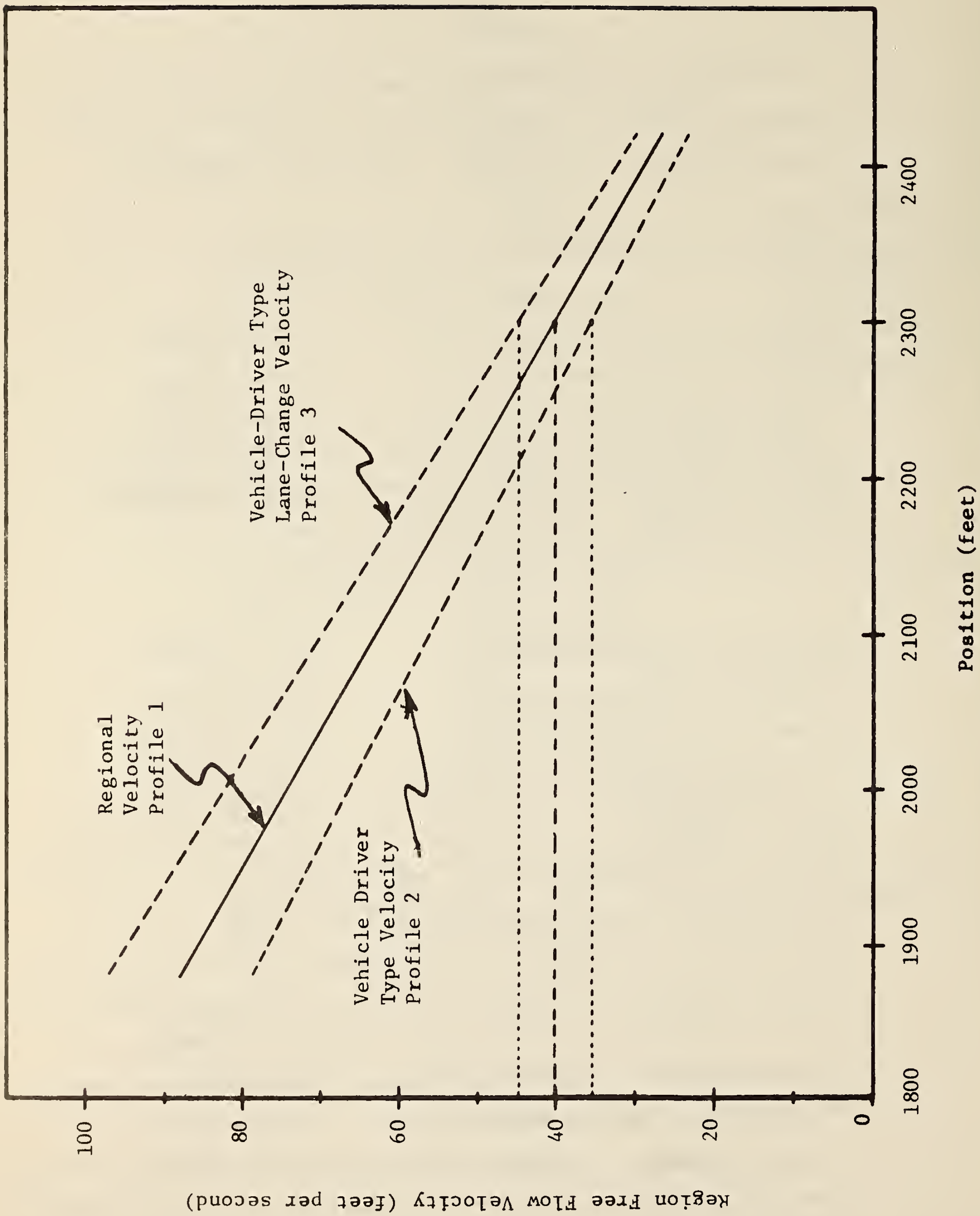


Figure 5.8 Region Velocity Profile

velocity profile by 10 percent. This case is shown in Figure 5.8. The regional velocity profile was established in Section 3.4 and represented in Figure 3.4. In the example given in Section 3.4, the regional free flow velocity for location 2300.0 feet in model region 10 would be reduced to

(40.1)(0.89) = 35.6 feet per second

The profile of this decreased free flow velocity is shown as line 2 of Figure 5.8.

Each vehicle-driver type, when changing lanes, may also deviate from the regional velocity profile by a percentage which is input through the table item MXVEL. The default values are

MXVEL(0)=110
MXVEL(1)=110
MXVEL(2)=110
MXVEL(3)=110
MXVEL(4)=110

With the default values of 110 percent, the permitted maximum lane change velocity for a vehicle-driver type will exceed the regional profile by 10 percent. This 10 percent increase is shown as line 3 in Figure 5.8. In the previous example, the maximum lane change velocity for the location 2300 feet in model region 10 would be:

(40.1)(1.10)=44.1 feet per second

For both table item ATVEL and MXVEL, the percent deviation from the regional free flow velocity profile is added to 100 before it is entered into the model, e.g., if the increase were 12 percent, the value entered into the model would equal

100 + 12 = 112, while if it were a decrease of 12 percent the value would be 100 - 12 = 88.

5.9 TRAFFIC SIGNAL TIMING

Traffic in the non-exit model regions is controlled by one of four traffic signals. The traffic signal operation control parameters for these four signals are not required to have any relationship with the other (dummy) signals in the system. Representative data will be used in the following examples to demonstrate the signal control data requirements and methods of entering the data into the model.

Signalization information is shown in Table 5-17 and phasing patterns are shown in Figure 5.9 for the geometric configuration shown in Figure 3.1.

TABLE 5-17

ARTERIAL TRAFFIC SIGNALIZATION

Arterial Signal	Time Cycle	Number of Intervals	Offset	
			Percent	Seconds
0	75	8	--	9
1	80	6	30	--
2	80	6	--	49
3	60	4	76	--

5.9.1 Time Cycle. The integer seconds for the time cycle is entered into the model through the table item SYCL. The table index for each entry is the traffic signal number (0 through 3) associated with each signal. The table entry values for the time cycles given in Table 5-17 are:

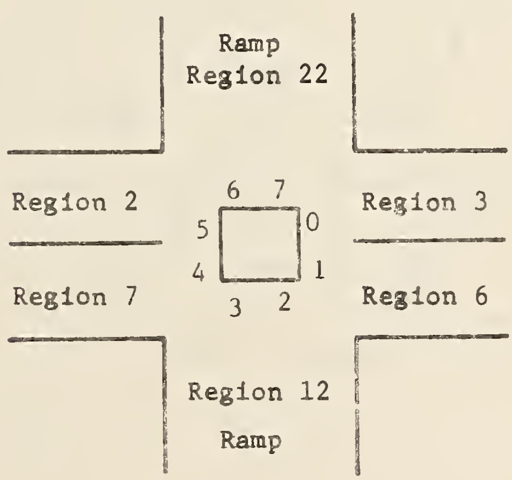
SYCL(0)=75

SYCL(1)=80

SYCL(2)=80

SYCL(3)=60

5.9.2 Interval Signal Indications. The divisions of the time cycle during which the signal indications do not change are defined as a signal interval. The intervals for each of the traffic signals for an example are shown in Figure 5.9. The horizontal roadway shown in the array is the major arterial street, while the vertical roadway is the cross-street, or an entrance or exit ramp. For example, the intersection controlled by traffic signal (1) is shown in more detail below.



The traffic signal shown in the intersection shows the traffic movements (0 through 7, cf. Section 3.8.2) controlled by a particular face of traffic signal (1) . The traffic movements emanating from each region are listed in Table 3-5. They do, however, have the same orientation to the major and minor streets as those shown in the above figure.

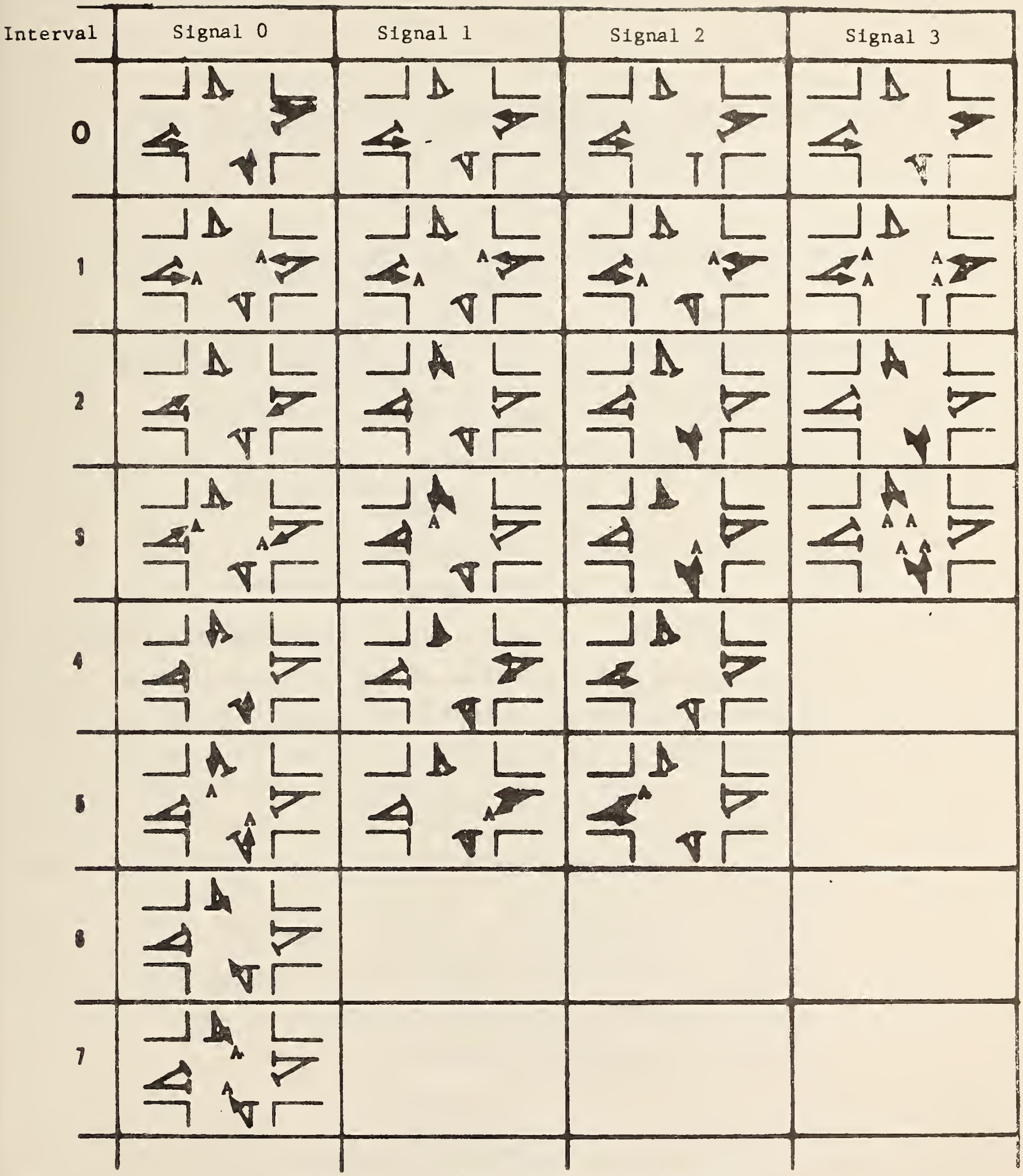


Figure 5.9. Phasing Pattern Information.

The permitted movements and the corresponding signal indications are represented by arrows in Figure 5.9. The definition of each arrow is as follows:

 green movement, straight-through

 green movement, left-turn

A  amber indication for the movement

 red indication, no movement

The following signal convention:

0 = green movement,
1 = amber movement,
2 = red movement,

is used to index the signal indications for each of the eight permitted movements for each interval of the time cycle. The eight indications are entered into the model through the table item SIGCON. A hexadecimal format is used for data entry with each of the eight bytes in the computer word corresponding to the equivalently numbered traffic movement. Byte zero is the leftmost byte and byte seven is the rightmost byte. The table index used for each entry is a constant plus the interval number (0 through MNOFI-1) associated with each interval. The constant is the traffic signal number (0 through 3) times the simple item MNOFI. The value of MNOFI is 12. Thus, the constant, for each signal is given by:

signal ⓪ = 0
signal ① = 12
signal ② = 24
signal ③ = 36.

Therefore, the signal indication for the fourth interval, beginning with zero, of signal (3) is

36+4=40

and all signal indication data for this interval would be contained in entry 40 of SIGCON.

Interval number zero in each phasing plan must contain the beginning of the green movement which is used to establish the desired offset relationship between the traffic signal and its master reference time cycle. See Sections 3.8.6 and 3.8.7, and Sections 5.9.6 and 5.9.7.

Representative data using Figure 5.9 for the traffic signals is as follows:

SIGNAL (0) :

SIGCON(0)=X(02220222)

SIGCON(1)=X(12221222)

SIGCON(2)=X(20222022)

SIGCON(3)=X(21222122)

SIGCON(4)=X(22022202)

SIGCON(5)=X(22122212)

SIGCON(6)=X(22202220)

SIGCON(7)=X(22212221)

SIGNAL ② :

SIGCON(24)=X(02220222)

SIGCON(25)=X(12221222)

SIGCON(26)=X(22002222)

SIGCON(27)=X(22112222)

SIGCON(28)=X(22220022)

SIGCON(29)=X(22220122)

Note for this signal, traffic movements 6 and 7 remain in a constant red state, 2, for that face of the traffic signal is facing exit-ramp 22. Traffic movements 2 and 3 are also a constant red state for traffic signal ① , for that face is facing exit-ramp 23.

5.9.3 Number of Intervals. The total number of intervals comprising the complete sequence of signal indications for each traffic signal is entered into the model through the table item NOSI. The table index for each entry is the traffic signal number (0 through 3) associated with each entry. For the phasing pattern shown in Figure 5.9, the number of intervals for each signal are:

NOSI(0)=8
NOSI(1)=6
NOSI(2)=6
NOSI(3)=4

5.9.4 Interval Timing. The unit percentage (0 through 100) of the time cycle allocated to each interval of a phasing plan is entered into the model through the table item SPCNT. This percentage is computed by

$$\left(\frac{\text{number of seconds in interval}}{\text{number of seconds in time cycle}}\right) * 100$$

The sum of the integer percentages for the intervals in the time cycle must equal 100 percent.

Representative interval times for signals ⓪ and ② are given in Table 5-18 and are entered as follows:

SIGNAL ⓪

SPCNT(0)=30

SPCNT(1)=4

SPCNT(2)=15

SPCNT(3)=4

SPCNT(4)=25

SPCNT(5)=4

SPCNT(6)=14

SPCNT(7)=4

SIGNAL ②

SPCNT(24)=46

SPCNT(25)=4

SPCNT(26)=24

SPCNT(27)=4

SPCNT(28)=18

SPCNT(29)=4

TABLE 5-18

INTERVAL TIMING

Interval	SIGNAL							
	0		1		2		3	
	Seconds	Percent of Cycle	Seconds	Percent of Cycle	Seconds	Percent of Cycle	Seconds	Percent of Cycle
0	22.5	30	33.6	42	36.8	46	33.6	56
1	3.0	4	3.2	4	3.2	4	3.0	5
2	11.25	15	21.6	27	19.2	24	20.4	34
3	3.0	4	3.2	4	3.2	4	3.0	5
4	18.75	25	15.2	19	14.4	18	-	-
5	3.0	4	3.2	4	3.2	4	-	-
6	10.5	14	-	-	-	-	-	-
7	3.0	4	-	-	-	-	-	-
Total	75.0	100	80.0	100	80.0	100	60.0	100

5.9.5 Master Reference Time Cycle. The integer seconds in the master reference time cycle for each traffic signal is entered into the model through the table item SMSTCYL. It is this master reference which is used to determine and establish the offset relationship between traffic signals. The table index used for each entry of SMSTCYL is the traffic signal number (0 through 3) associated with each entry. The master reference time cycles for this example are equal to the time cycle for the corresponding traffic signal. Therefore:

SMSTCYL(0)=75

SMSTCYL(1)=80

SMSTCYL(2)=80

SMSTCYL(3)=60

5.9.6 Offset. The master reference time cycle is used as a time reference base when offset relationships are determined. There is one master per signal cycle determined by master. The offset is defined as the number of seconds or percent of the time cycle that the green indications appear at a given traffic signal after a certain instance.

The integer value of the offset expressed in seconds or percent is entered into the model through the table item SOFFSET. The table index used for each entry of this item is the traffic signal (0 through 3) associated with each entry. The offsets listed in Table 5-17 are entered as follows:

(continued)

SOFFSET(0)=9

SOFFSET(1)=30

SOFFSET(2)=43

SOFFSET(3)=76

All offset values are converted to seconds if the value is expressed in percent.

Table item TYPOFF is used to indicate if offset is expressed in seconds or percent

0 = integer seconds

1 = integer percent

The table index for each entry of this table item is the traffic signal (0 through 3) associated with each entry.

Table 5-17 lists signals ⓪ and ② as having their offset established in percent of the time cycle while the offset for signals ① and ③ are expressed as seconds. Therefore,

TYPOFF(0)=0

TYPOFF(1)=1

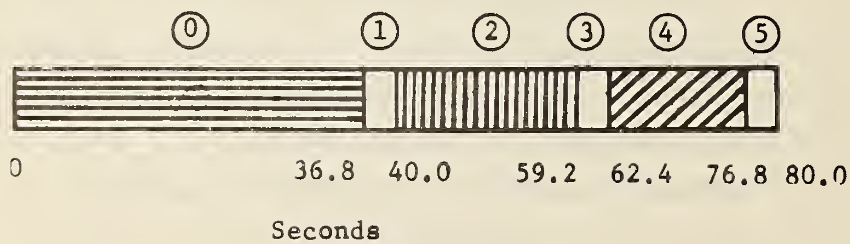
TYPOFF(2)=0

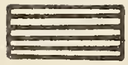
TYPOFF(3)=1

At the beginning of the simulation problem the desired offsets are established between the traffic signal and its master reference time cycle. After this, offset relationships are maintained as part of the signal control function by lengthening or shortening the time cycle.

During program initialization, the beginning green indication contained in interval zero on the reference face of the traffic signal (cf. Section 5.9.7) is adjusted in time to establish the desired offset relationship. The master reference is assumed to be at time zero at the beginning of the simulation problem. The following is an example of the method used to establish the signal indications which are to be displayed at time zero in the simulation problem and the time remaining for that signal indication.

The interval timings and sequencing of signal indications may be described by the following timing bar chart for arterial traffic signal (2) .



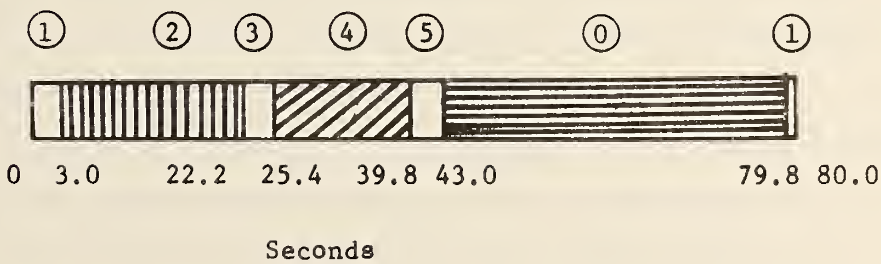
 indicates green through-movement on the major arterial street

 indicates green movement from the minor arterial street or exit ramp

 indicates green through-and left-turn movement on the major arterial street

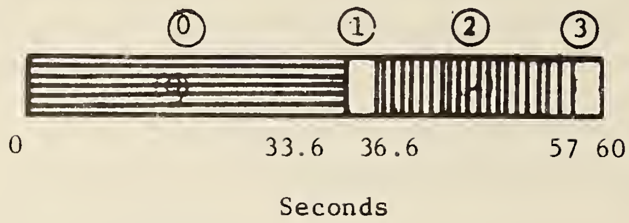
number in circle is the interval number (ordered from beginning of green)

This timing bar chart represents the initial sequencing for a zero offset. Table 5-17 lists an offset of 43 seconds. The master reference time cycle during initialization is assumed to be at time zero in its own time cycle. With the master reference at zero, the traffic signal phasing pattern is displaced 43 seconds as shown below.



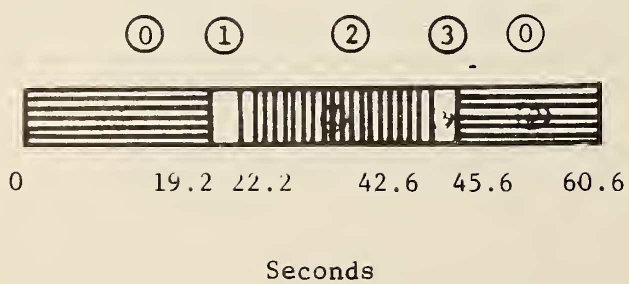
The above timing bar chart shows that the interval used for traffic signal ② at the beginning of the simulation is interval 1, which remains on for 3.0 seconds. The interval is assumed to have begun 0.2 seconds (3.2-3.0) prior to the beginning of the simulation and will remain "on" for 3.0 seconds. After this abbreviated initial interval, all subsequent interval times are as shown in Table 5-18 for traffic signal ②.

For traffic signal ③ , the offset is 76 percent of the 60-second time cycle, or 45.6 seconds. The timing bar chart shown below for this signal is for zero offset.



The beginning is again displaced 45.6 seconds with respect to the beginning of the 60-second master reference time cycle shown below.

Arterial
traffic
signal



Interval ⓪ will be the interval displayed at the beginning of the simulation problem, and will remain "on" for 19.2 seconds. It is assumed the interval had begun 14.4 seconds (33.6-19.2) prior to the beginning of the simulation problem.

5.9.7 Signal Reference Face. The reference face is defined as that signal face index (0 through 7) which displays the beginning green indication used to establish the desired offset relationship between the traffic signal and its master reference time cycle (cf. Section 3.8.7 and Figure 3.9). The reference face (with associated traffic movements 0 through 7) is entered into the model through the table item P2FACE. The table index for each entry is the traffic signal number (⓪ through ③) associated with each entry.

Refering to Table 5-10, the reference face for each traffic signal is as follows:

P2FACE(0)=0

P2FACE(1)=4

P2FACE(2)=0

P2FACE(3)=0

5.9.8 Method of Signal Control. During a simulation problem, traffic signal operational parameters may be modified on a predetermined basis. When a change is to be made in the operation of traffic signals, table item DIALCHN designates which traffic signal is to be modified. If a change is to be made, table item DIALCHN associated with that traffic signal is set equal to "1". A "0" indicates no changes have been requested. The table index for each entry is the traffic signal number (0 through 3) associated with each entry.

If at some predetermined time in the simulation problem, changes are to be made to traffic signal ③ , then

DIALCHN(3)=1

When NUDATA reads data cards at this time, this "1" will indicate to the signal control procedure that operational control changes are to be made to traffic signal ③ . The changes to be made to a traffic signal must also be included in the data cards read by NUDATA. Changes to traffic signal operations at these predetermined times within the simulation problem may include any or all signalization parameters.

Certain operational changes may affect the synchronized operation of a traffic signal's time cycle with its master reference time cycle. Two methods -- pretimed control and computer control -- may be used to re-establish or maintain the desired synchronized operation. Table item PEWTER is used to designate which of the two control methods will be used to establish the desired offset relationship. The table index for each entry of this table item is the traffic signal index (0 through 3) associated with each signal. Table item PEWTER is set equal to

0 for pretimed control
1 for computer control

As an illustration, traffic signals ① and ② will have their offset maintained by the pretimed control algorithm while traffic signal ⓪ and ③ will have their offset maintained by the computer control algorithm. Therefore,

(continued)

PEWTER(0)=1

PEWTER(1)=0

PEWTER(2)=0

PEWTER(3)=1

1. Pretimed Control. The pretimed signal control algorithm emulates a pretimed traffic controller. Once each cycle, the offset relationship is checked to determine if the desired offset is being maintained. This check is made at the beginning of interval zero which designates the beginning of the time cycle. This interval has been displayed from the beginning of the master reference time cycle by an amount equal to the offset (cf. Section 5.9.6).

   If the desired offset has not been established after a change has been made to the operational control of the traffic signal, the number of seconds in the time cycle is increased to permit the desired offset to be re-established. For example, if the offset assigned for traffic signal ② were increased from 43 seconds to 55 seconds, as shown in Figure 5.10, the offset relationship would be required to be modified by 12 seconds (55-43). Thus, the time cycle would be required to be increased by 12 seconds. As in a pretimed controller, the time cycle will be stopped in a timing interval for the required or permitted amount of time. During this time, the time cycle is stopped and the signal indications will not change.

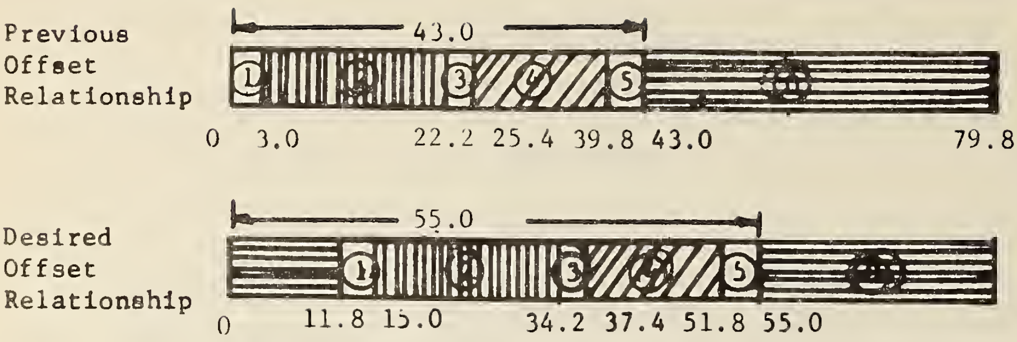


Figure 5.10. Offset Correction.

Before the time cycle may be increased by the required 12 seconds, two factors must be considered: (1) Do the 12 seconds exceed the maximum permissible time a time cycle may be interrupted? and (2) Is the selected signal indication timing interval presently being displayed?

The number of seconds or the percent of the time cycle that the time cycle may be extended is entered into the model through the table item SNTRUP. The table index for each entry of this item is the traffic signal index (0 through 3) associated with each signal of Table 5-19.

This table item contains the maximum interrupt time in seconds or percent of the time cycle. Table item TYPNTRU designates if the value contained in SNTRUP is expressed in seconds or percent of the time cycle. The table index for each entry of the table item is the traffic signal index (0 through 3) associated with each signal. As an example, if the maximum interrupt times for traffic signals ⓪ and ② are expressed in seconds, while the interrupt times for traffic signals ① and ③ are expressed in percent of the time cycle, then,

TYPNTRU(0)=1

TYPNTRU(1)=0

TYPNTRU(2)=1

TYPNTRU(3)=0

and, the maximum interrupt times are given by:

SNTRUP(0)=18	or	18.0 seconds	
SNTRUP(1)=17	or	13.6 seconds	(.17x80 seconds)
SNTRUP(2)=10	or	10.0 seconds	
SNTRUP(3)=15	or	9.0 seconds	(.15x60 seconds)

Table 5-19. Maximum Interrupt Time

After the determination of an incorrect offset relationship, the time cycle continues to operate in its predetermined manner until a designated time location within the time cycle is reached. When this time location is reached, the timing will remain in that signal interval until the offset correction has been made, or until the maximum interrupt time has elapsed. The time location where the correction will be made is described in per cent of the time cycle or seconds since the beginning of interval zero. This time period is entered into the model through the table item NTRUPKEY. Table item TYPKEY designates whether the value for NTRUPKEY is expressed in seconds or percent of the time cycle. The table index for each entry of both table items is the traffic signal index (0 through 3) associated with each signal.

If the time locations for traffic signals (0) and (2) are expressed as a percent of the time cycle and for traffic signals (1) and (3) are expressed in seconds, then,

TYPKEY(0)=0

TYPKEY(1)=1

TYPKEY(2)=0

TYPKEY(3)=1

and the time locations are given by:

Time Location of Time Cycle Interruption

NTRUPKEY(0)=12 or 9.0 seconds (.12x75 seconds)

NTRUPKEY(1)=18 or 18.0 seconds

NTRUPKEY(2)=30 or 24.0 seconds (.30x80 seconds)

NTRUPKEY(3)=41 or 41.0 seconds

For example, for traffic signal (2) the time cycle may only be interrupted 24.0 seconds after the beginning of interval zero, and only for 10.0 seconds per time cycle.

In the example of the 12.0 second offset correction for traffic signal (2) (discussed at the beginning of this section) the time cycle may only be interrupted for 10.0 seconds, Table 5-18, and the time cycle is interrupted 24.0 seconds after the beginning of interval zero. The required offset correction, 12.0 seconds, exceeds the maximum permissible time cycle interruption time of 10.0 seconds. Consequently, 24.0 seconds after the beginning of interval zero, the time cycle is increased by 10.0 seconds to 90.0 seconds. This produces an offset of 53.0 seconds. At the beginning of interval zero, the desired offset is incorrect by 2.0

seconds (55.0-53.0). The above process is repeated and the time cycle is now increased from 80 to 82.0 seconds, producing an offset relationship of 55.0 seconds. This procedure is shown in the timing bar charts below for signal (2) . The heavily-shaded areas are the 10.0 second and 2.0 second time periods added in the two consecutive time cycles required to establish the desired offset. The interval timings are given at the bottom of the bar chart. The desired timing intervals are shown in Figure 5.11.

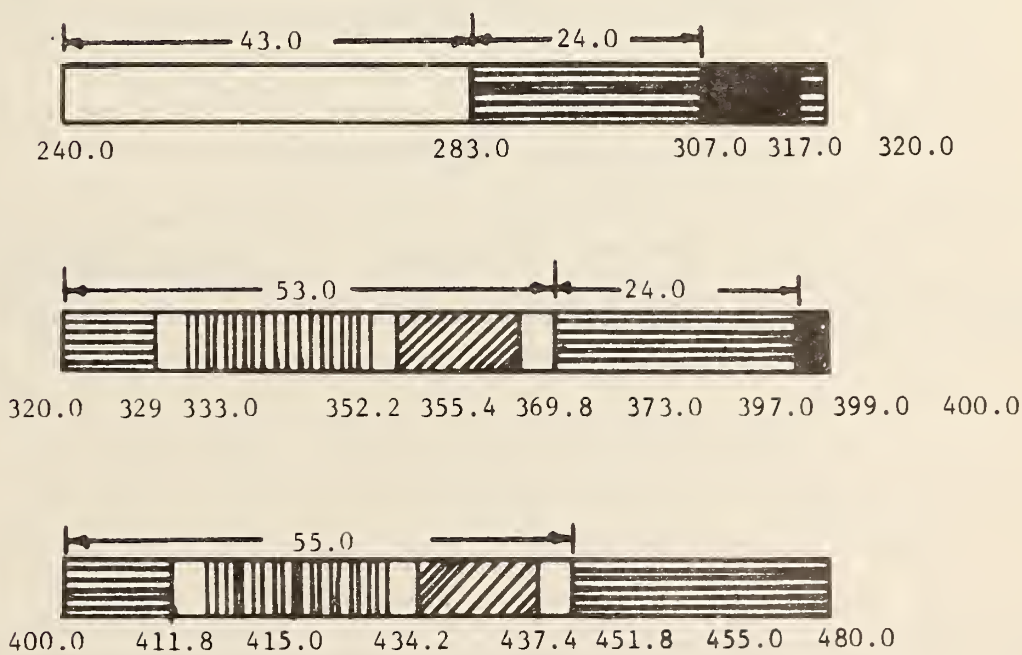


Figure 5.11. Offset Correction.

2. Computer Control. While a traffic signal is under pretimed control, the time cycle may only be increased and only at certain time locations within the time cycle. When under computer control, the offset relationship is checked at the beginning of each timing interval. If an incorrect offset relationship is detected, the timing interval may be lengthened or shortened to re-establish the desired offset relationship in the minimum total elapsed time.

In the pretimed control case, the maximum extension of the time cycle was required; whereas under computer control, the amount of time each timing interval may be lengthened or shortened is required. These values are entered into the model through the table items SMAXRUP. The maximum amounts that a timing interval may be lengthened or shortened, with the resulting timing intervals, are illustrated below for an 80-second cycle (desired).

TABLE 5-19

MAXIMUM AND MINIMUM TIMING INTERVALS

Interval Number	Interval Timing (Seconds)	Maximum Extension (Seconds)	Maximum Shortening (Seconds)	Interval Timing	
				Maximum (Seconds)	Minimum (Seconds)
0	36.8	10	15	46.8	21.8
1	3.2	2	0	5.2	3.2
2	19.2	8	8	27.2	11.2
3	3.2	2	0	5.2	3.2
4	14.4	6	5	20.4	9.4
5	3.2	2	0	5.2	3.2
Total	80.0	30	28	110.0	52.0

As in the previous example, traffic signal ② will be used to illustrate the re-establishment of the desired offset relationship. Under computer control, the following computations are made to determine if the desired offset relationship could be re-established in the minimum total elapsed time by lengthening or shortening the time cycle.

An offset may be established by adding or subtracting the required time to the existing time cycle of a traffic signal. Using traffic signal ② of Table 5-17, suppose the offset is changed from 49.0 seconds to 20.0 seconds. This desired offset of 20.0 seconds may be established by one of two methods:

(1) Lengthening the time cycle

Let $T_1 = S_2 - S_1$,

where

S_2 = desired offset

S_1 = existing offset

If value T_1 is negative, the signed value T_1 is added to the time cycle.

$T_1' =$ time cycle $+ T_1$

Thus, substituting the above-given values,

$T_1 = 20.0 - 49.0 = -29.0$ seconds

Since T_1 is negative, then,

$T_1' = 80.0 + (-29.0) = 51.0$ seconds.

Thus, 51.0 seconds must be added to the time cycle to change the offset relationship from 49.0 seconds to 20.0 seconds.

(2) Shortening the time cycle

$$\text{Let } T_2 = S_2 - S_1,$$

If value T_2 is positive, the value T_2 is subtracted from the time cycle.

$$T_2' = \text{time cycle} - T_2$$

Thus,

$$T_2' = 49.0 - 20.0 = 29.0 \text{ seconds}$$

Thus 29.0 seconds must be subtracted from the time cycle to change the offset relationship from 49.0 seconds to 20.0 seconds.

After establishing the total amount of time to add or subtract to a time cycle in order to re-establish the desired offset, the minimum total elapsed time to make the transition from one offset to another is established as follows:

(1) Using the maximum time cycle - add to each timing interval an amount equal to the maximum amount which may be added, SMAXRUP, or the amount required to establish the desired offset.

(2) Using the minimum time cycle - subtract from each timing interval an amount equal to the maximum amount which may be subtracted, SMINRUP, or the amount required to establish the desired offset.

To transition from the 49.0 second to the 20.0 second offset, the following computations are made.

At time 289.0 seconds, time at bottom of timing bar chart signal (2) had a 49.0 second offset with its master reference time cycle (cf. Figure 5.12). However, the desired offset was 20 seconds. In this example, 59.0 seconds (T_1=51.0) may be added to the time cycle to achieve the required 20.0 second offset. Using Table 5-19 for the maximum timing interval extension yields the timing bar chart in Figure 5.17. From time 289.0 until time 478.2, the timing interval plus the maximum permitted extension for that interval was used (cf. Table 5-19). One second was then added to timing interval 3, after which the desired offset relationship was established. Thus, from time 289.0 through time 479.2, the 80.0 second time cycle was being lengthened, producing time cycles equal to 110.0 and 101.0 seconds. The desired seconds in each timing interval are listed in Table 5-19. The number of seconds in each timing interval, from time 289.0 through time 500.0, are shown at the top of the timing bar chart, shown in Figure 5.12.

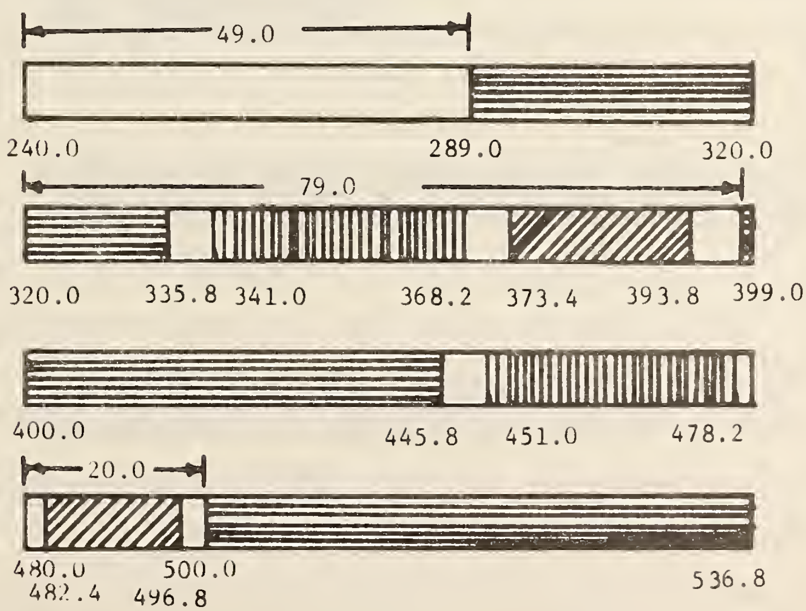


Figure 5.12. Signal (2) Maximum Cycle Length Under Computer Control.

Under computer control, the time cycle may be shortened. In this example, 29.0 seconds (T_2=29.0) may be subtracted from the time cycle to achieve the required 20.0 second offset. Using Table 5-19 for the maximum timing interval shortening yields the timing bar chart in Figure 5.13. From time 289.0 until time 341.0, the timing interval minus the maximum permitted shortening for that interval was used (cf. Table 5-19). One second was then subtracted from timing interval "0", after which the desired offset relationship was established. Thus, from time 289.0 through time 342.0, the 80.0 second cycle was being shortened, producing time cycles equal to 52.0 and 79.0 seconds. The desired seconds in each timing interval are listed in Table 5-19. The number of seconds in each timing interval from time 289.0 through time 420.0 are shown at the top of the timing bar chart, Figure 5.13

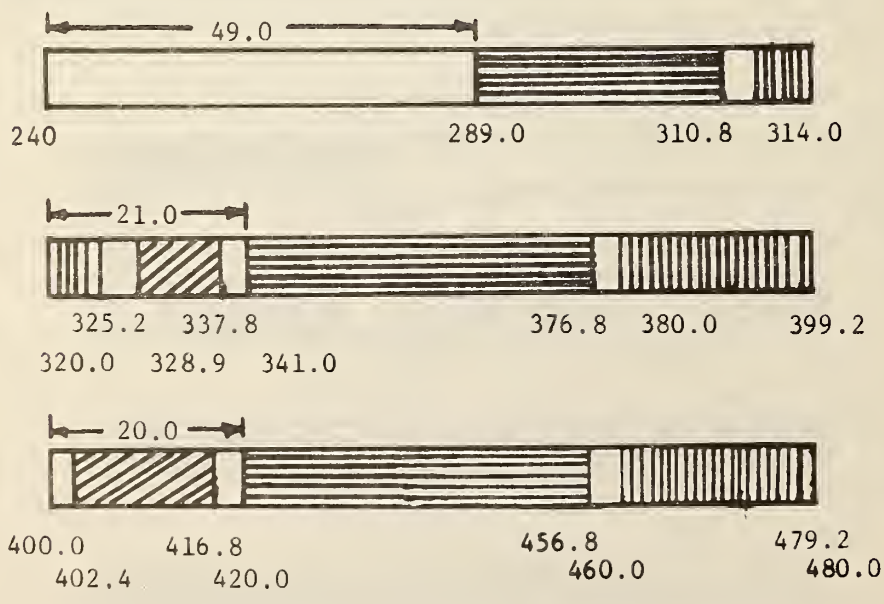


Figure 5.13. Signal (2) Minimum Cycle Length Under Computer Control.

In these two examples, the computer control algorithm would have elected to shorten the time cycle, since the desired 20.0 second offset was achieved in

$$479.2 - 289.0 = 190.2 \text{ seconds}$$

when the time cycle was extended, and only

$$342.0 - 289.0 = 53.0 \text{ seconds}$$

when the time cycle was shortened.

The criteria for selection of which method to use is based upon the minimum total elapsed time to achieve the desired offset relationship.

5.10 Dummy Traffic Signal Timing. To facilitate cyclical generation of vehicular arrival times in an entrance lane, six dummy traffic signals (three per arterial input) -- upstream from the entrance regions -- have been provided. The data requirements for these signals are used only in the cyclical generation of traffic. If non-cyclical generation is used, no data for the dummy traffic signal is required.

In the following examples, non-cyclical generation will be prescribed at one dummy signal. Three dummy traffic signals, see Figure 5.14, are assumed to be used to control the entry of traffic into the system entrance, regions. The phasing pattern for each of the three is shown in Figure 5.15 and interval timing information is given in Table 5-20.

The table index for all table entries, unless noted, is the dummy traffic signal number (0 through 5) associated with each entry.

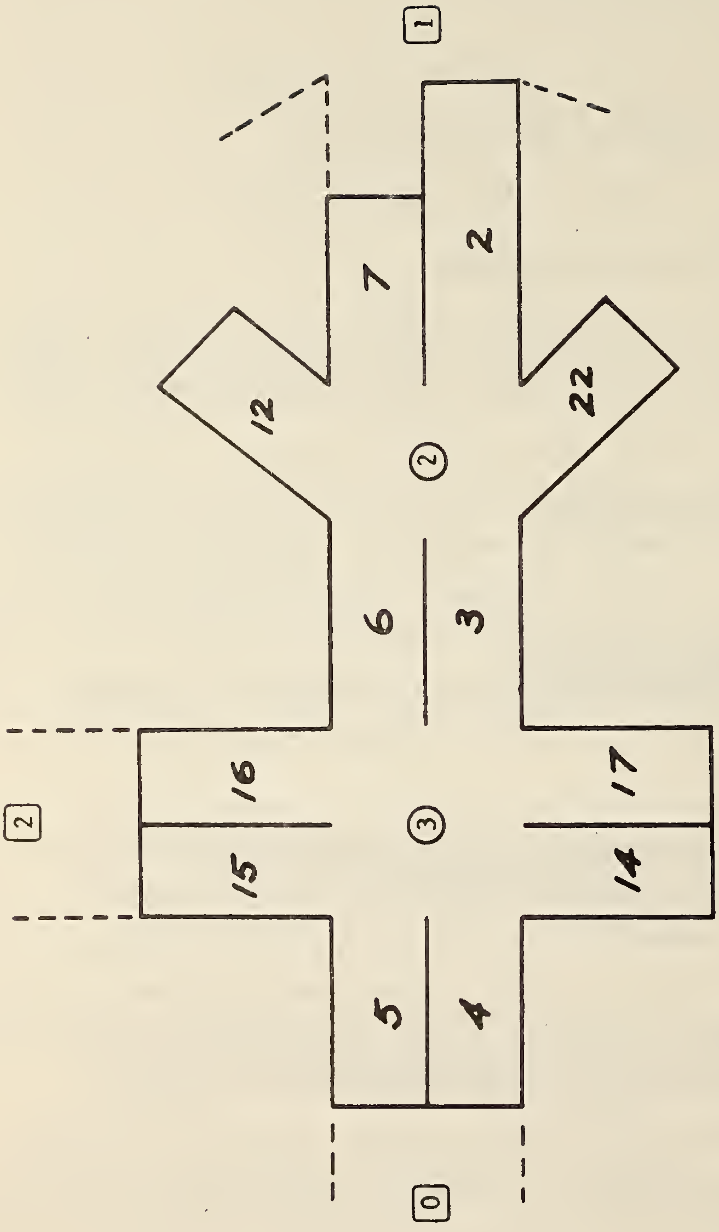


Figure 5.14. Dummy Traffic Signal Configuration.

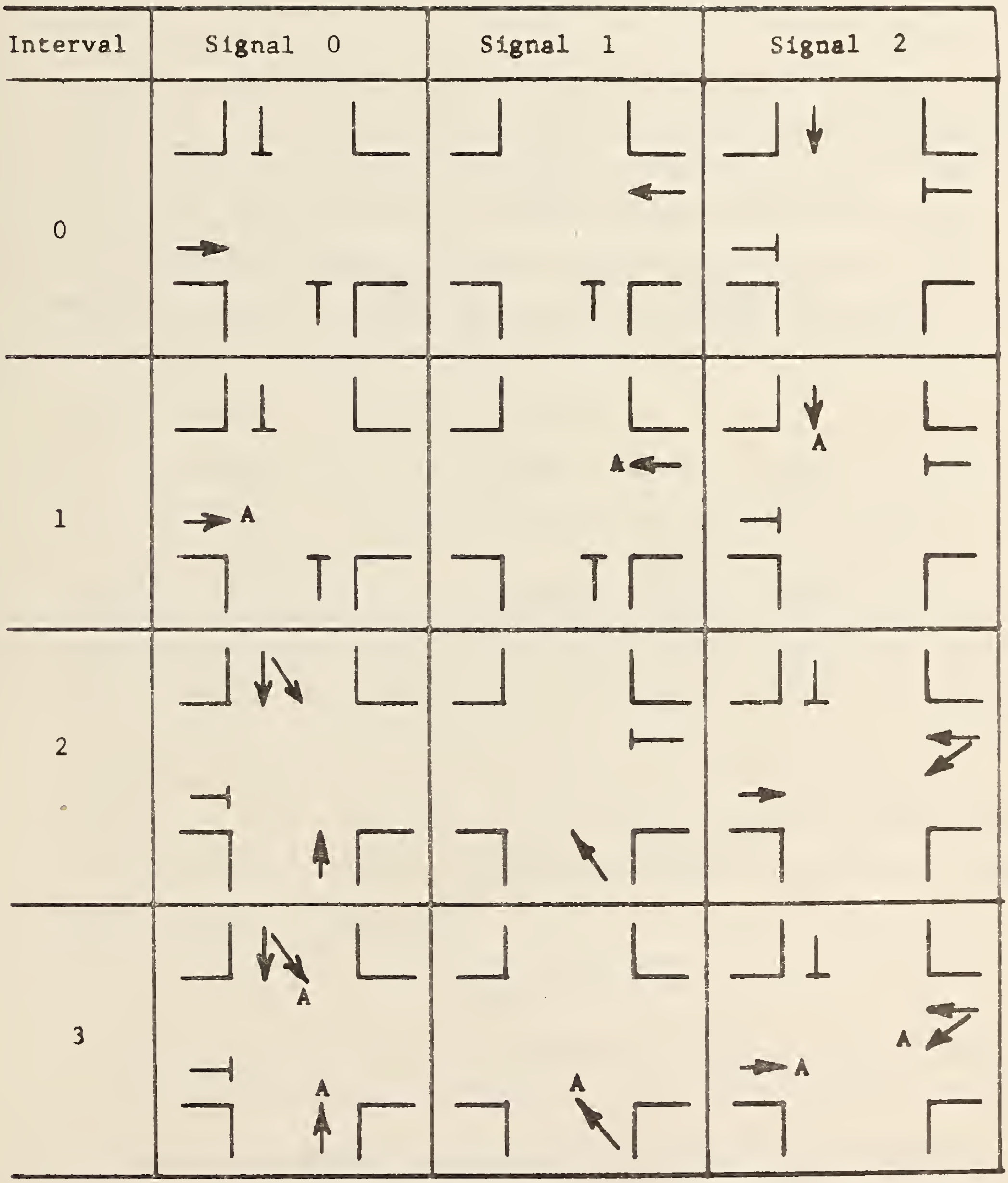


Figure 5.15. Dummy Traffic Signal Phasing Pattern Combination

TABLE 5-20

DUMMY TRAFFIC SIGNAL INTERVAL TIMING

	Signal					
	0		1		2	
Interval	Seconds	Percent Of Cycle	Seconds	Percent Of Cycle	Seconds	Percent Of Cycle
0	43.4	58	34.2	57	49.6	62
1	3.75	5	3.0	5	3.2	4
2	24.0	32	19.8	33	24.0	30
3	3.75	5	3.0	5	3.2	4
Total	75.0	100	60.0	100	80.0	100

5.10.1 Signal Assignment. The six dummy traffic signals are located as shown in Figure 3.1 when the maximum regional configuration is used. When this maximum regional configuration is not used and cyclical generation of vehicular arrival times is required, the upstream dummy traffic signal controlling the entrance region must be redefined. The default entrance region is changed by entering into table item P2RLSECT the new entrance region controlled by the dummy traffic signal.

An example of this reassignment of dummy signals is shown in Figure 5.14. This configuration requires cyclical generation of traffic into regions 4, 7, and 15. Vehicles exiting from region 2 are controlled by arterial traffic signal (1), while vehicles entering region 7 are controlled by dummy traffic signal [1]. The default values for item P2RLSECT, listed in Table 3-6 indicate dummy traffic signal [0] and [2] control the cyclically generated vehicles entering regions 4 and 15, respectively. However, using this subset of the maximum regional configuration required dummy traffic signal [1] to control the entry of vehicles into region 7. Therefore,

P2RLSECT(1)=7

The table index of each entry of this table item is the dummy traffic signal number (0 through 5) associated with each entry.

Table item DP2SIG designates the arterial traffic signal controlling the traffic emanating from the entrance region controlled by a dummy traffic signal. The arterial traffic signal downstream from dummy traffic signals [0] and [2] is arterial traffic signal (3).

However, arterial traffic signal (2) is downstream from dummy traffic signal [1] , Figure 5.14. Therefore,

DP2SIG(1)=2

5.10.2 Generation Designation. If a dummy traffic signal is used for the cyclical generation of vehicular arrival times, table item INFLOW is set equal to "1". If non-cyclical generation is used, the table item is set equal to "0". Cyclical generation is required to enter regions 4, 7 and 15. These regions are controlled by dummy signal [0], [1] , and [2] . Therefore,

INFLOW(0)=1

INFLOW(1)=1

INFLOW(2)=1

These are default values, as listed in Table 3-6. All remaining dummy traffic signals are set to generate traffic non-cyclically. Therefore,

INFLOW(3)=0

INFLOW(4)=0

INFLOW(5)=0

5.10.3 Time Cycle. The integer seconds in the time cycle for the dummy traffic signal is entered into the model through table item DCYCLE.

DCYCLE(0)=75

DCYCLE(1)=60

DCYCLE(2)=80

5.10.4 Offset. The offset relationship is established at the beginning of the simulation problem between the dummy traffic signal and its downstream arterial traffic signal. This offset relationship is entered into the model through the table item DOFFSET. If offsets of 25, 40, and 18 seconds are assumed to be required for dummy traffic signals [0], [1], and [2], then the following assignments are made:

DOFFSET(0)=25

DOFFSET(1)=40

DOFFSET(2)=18

5.10.5 Travel Time to Entrance Region. The average travel time, in seconds, from the dummy traffic signal to the boundary of the entrance region is entered into the model through table item DTRT. This travel time is computed by the relationship:

$$\frac{d}{v}$$

where: d = distance from the dummy traffic signal to the boundary of the entrance region.

v = average velocity for the corresponding roadway.

If the distances from dummy traffic signals [0], [1], and [2] to their respective entrance regions are 750, 390 and 1255 feet, and the corresponding average velocities are 43.5, 28.9, and 59.8 feet per second, then,

DTRT(0)=17, since $\frac{750}{43.5} = 17.24$ seconds

DTRT(1)=13, since $\frac{390}{28.9} = 13.49$ seconds

(continued)

$$DTRT(2)=21, \quad \text{since} \quad \frac{1255}{59.8} = 20.99 \text{ seconds}$$

5.10.6 Timing Interval. The percentages of the time cycle allocated to the major movement green, the amber, and the red interval indications are entered into the model through table item DSIG. The table index for this table item is a constant plus:

0 , for the green timing interval

1 , for the amber timing interval

2 , for the red timing interval.

The constant is equal to:

0 , for dummy traffic signal [0]

3 , for dummy traffic signal [1]

6 , for dummy traffic signal [2]

9 , for dummy traffic signal [3]

12 , for dummy traffic signal [4]

15 , for dummy traffic signal [5]

Thus, the red timing interval value, for dummy traffic signal [1], entered into DSIG, is:

3+2=5

while for the green timing interval for dummy traffic signal [4] , the value entered is:

12+0=12

The phasing patterns for the three dummy traffic signals are shown in Figure 5.15. The orientation of each intersection is given by the entrance region number given in each block of the figure. The direction of the major movement and the minor movements are also shown.

The major movement green signal indication is contained in timing interval 0, the amber signal indication in timing interval 1, and the red signal indication for the major movement is contained in intervals 2 and 3.

Using Figure 5.15 and Table 5-20, the interval timing information, in percent, for the three dummy traffic signals [0] , [1] , and [2] , are respectively,

DSIG(0)=58	;	green
DSIG(1)=5	:	amber
DSIG(2)=37	;	red
DSIG(3)=57	;	green
DSIG(4)=5	;	amber
DSIG(5)=38	;	red
DSIG(6)=62	;	green
DSIG(7)=4	;	amber
DSIG(8)=34	;	red

6. JOB CONTROL

Figure 6.1 is a sample of the Job Control Language needed to execute the simulation model.

The STEPLIB card identifies the partitioned data set containing the load module. In the sample, both the partitioned data set and its member load module are named SIGNAL. The user should code the UNIT and VOLUME parameters on his STEPLIB card to correspond to the unit and volume onto which he has moved the program.

The data set with DDNAME of LOG6 is used for List, Queue, Collision and Epilogue printouts.

The data set with DDNAME of LOG4 is currently not written into.

The data set with DDNAME of LOG7 is used for PROLOGUE and traffic signal data printouts.

The data set with DDNAME of SYSPRINT is used for error message printouts.

The data set with DDNAME of DUMP is used for dumps made by the program.

```
//GO EXEC PGM=SIGNAL, REGION=346K
//STEBLIB DD DSN=SIGNAL,DISP=(OLD,KEEP),UNIT=2314,VOL=SER=SDC374
//LOG6 DD SYSOUT=A,DCB=(LRECL=132,RECFM=FBA,BLKSIZE=2640)
//LOG4 DD SYSOUT=A,DCB=(LRECL=132,RECFM=FBA,BLKSIZE=2640)
//LOG7 DD SYSOUT=A,DCB=(LRECL=132,RECFM=FBA,BLKSIZE=2640)
//SYSPRINT DD SYSOUT=A,DCB=(LRECL=128,RECFM=FBA,BLKSIZE=1920)
//SYSUDUMP DD SYSOUT=A
//DUMP DD SYSOUT=A
//SYSIN DD *
      NUDATA  INPUT  CARDS
                |
                |
                v
//
```

Figure 6.1. Sample Deck Required to Operate Simulation Model

7. PROGRAM PRINTOUTS

7.1 DATA CARDS READ INTO MODEL

The following is a sample list of data entered into the simulation model through procedure NUDATA, as discussed in Section 5.1. As the procedure reads the computer card, the information contained on the card is also output, and then the indicated parametric value is modified to reflect the new desired value.

```
RAD( 61)=400    RAD( 62)=200    RAD( 63)=500    RAD( 64)=200
RAD(65 )=600    RAD( 66)=200    RAD( 77)=200    RAD( 78)=300
RAD( 79)=400    RAD( 81)=600    RAD( 82)=400    RAD( 83)=500
RAD( 84)=400    RAD( 97)=400    RAD( 98)=600    RAD(101)=500
RAD(102)=300    RAD(103)=500    RAD(104)=300    RAD(105)=500
RAD(106)=300    RAD(117)=200    RAD(118)=400    RAD(119)=500
RAD(121)=600    RAD(122)=600    RAD(123)=600    RAD(124)=400
RAD(125)=600    RAD(126)=400    RAD(137)=400    RAD(138)=600
RAD(145)=700    RAD(146)=600    RAD(147)=600    RAD(148)=400
RAD(149)=600    RAD(150)=400    RAD(161)=400    RAD(162)=600
RAD(163)=600    RAD(169)=600    RAD(170)=300    RAD(171)=500
RAD(172)=200    RAD(173)=400    RAD(174)=200    RAD(185)=250
RAD(186)=350    RAD(187)=450    RAD(189)=600    RAD(190)=300
RAD(191)=500    RAD(192)=200    RAD(193)=400    RAD(194)=200
RAD(205)=170    RAD(206)=270    RAD(207)=370    RAD(226)=200
RAD(227)=400    RAD(245)=200    RAD(246)=400
       ''80 SEC CYCLE''
       '' INTERSECTION=0''
SPCNT(0)=54 SPCNT(1)=4 SPCNT(2)=38 SPCNT(3)=4
NOSI(0)=4  SYCL(0)=80 SMSTCYL(0)=80
SIGCON( 0)=X(00220022) SIGCON( 1)=X(11221122)
SIGCON( 2)=X(22022202) SIGCON( 3)=X(22122212)
SOFFSET(0)=0   TYPOFF(0)=0  NTRUPKEY(0)=20 TYPNTRU(0)=0
NTRUPKEY(0)=5  TYPKEY(0)=0
       ''INTERSECTION=1''
SPCNT(12)=42 SPCNT(13)=4 SPCNT(14)=20 SPCNT(15)=4 SPCNT(16)=26
SPCNT(17)=4    NOSI(1)=6  SYCL(1)=80   SMSTCYL(1)=80
SIGCON(12)=X(02220222) SIGCON(13)=X(12221222)
SIGCON(14)=X(22222200) SIGCON(15)=X(22222211)
SIGCON(16)=X(00222222) SIGCON(17)=X(01222222)
SOFFSET(1)=93  TYPOFF(1)=0  NTRUPKEY(1)=20 TYPNTRU(1)=0
NTRUPKEY(1)=5  TYPKEY(1)=0
       ''INTERSECTION=2''
SPCNT(24)=50 SPCNT(25)=4 SPCNT(26)=20 SPCNT(27)=4 SPCNT(28)=18
SPCNT(29)=4    NOSI(2)=6    SYCL(2)=80    SMSTCYL(2)=80
SIGCON(24)=X(02220222) SIGCON(25)=X(12221222)
SIGCON(26)=X(22002222) SIGCON(27)=X(22112222)
SIGCON(28)=X(22220022) SIGCON(29)=X(22220122)
SOFFSET(2)=44  TYPOFF(2)=0  NTRUPKEY(2)=20 TYPNTRU(2)=0
NTRUPKEY(2)=5  TYPKEY(2)=0
```

```
''INTERSECTION=3''
SPCNT(36)=53 SPCNT(37)=4 SPCNT(38)=39 SIGCON(39)=4
NOSI(3)=4   SYCL(3)=78   SMSTCYL(3)=78
SIGCON(36)=X(02220222)  SIGCON(37)=X(12221222)
SIGCON(38)=X(22C02200)  SIGCON(39)=X(22112211)
SOFFSET(3)=10   TYPOFF(3)=0   NTRUPKEY(3)=20 TYPNTRU(3)=0
NTRUPKEY(3)=5   TYPKEY(3)=0


SETRAN( 66)=CC000     SETRAN( 67)=15750     SETRAN( 68)=14555
SETRAN( 69)=00000     SETRAN( 70)=14750     SETRAN( 71)=00000
SETRAN( 72)=16750     SETRAN( 73)=15580     SETRAN( 74)=00000
SETRAN( 75)=17750     SETRAN( 76)=22035     SETRAN( 77)=00000
SETRAN( 78)=19850     SETRAN( 79)=00000     SETRAN( 80)=00000
SETRAN( 81)=11560     SETRAN( 82)=00000     SETRAN( 83)=33965
SETRAN( 84)=00000     SETRAN( 85)=38400     SETRAN( 86)=00000
SETRAN( 87)= 7250     SETRAN( 88)=00000     SETRAN( 89)=18315
SETRAN( 90)=00000     SETRAN( 91)=25666     SETRAN( 92)=17335
SETRAN( 93)=00000     SETRAN( 94)=15335     SETRAN( 95)=00000
SETRAN( 96)=25210     SETRAN( 97)=16063     SETRAN( 98)=24250
SETRAN( 99)=00000     SETRAN(100)=26345     SETRAN(101)=00000
SETRAN(102)=00000     SETRAN(103)=34705     SETRAN(104)=0
SETRAN(104)=12300     SETRAN(106)=0         SETRAN(107)= 7065
SETRAN(105)=0         SETRAN(109)=39015
SETRAND(  0)=0         SETRAND(  1)= -615     SETRAND(  2)=0
SETRAND(  3)=-240      SETRAND(  4)= -740     SETRAND(  5)=0
SETRAND(  6)= -740     SETRAND(  7)=0         SETRAND(  8)= -310
SETRAND(  9)= -615     SETRAND( 10)=0         SETRAND( 11)=0
SETRAND( 12)= 0        SETRAND( 13)=0         SETRAND( 14)=0
SETRAND( 15)= -585     SETRAND( 16)=0         SETRAND( 17)= -585
SETRAND( 18)=0         SETRAND( 19)= -565     SETRAND( 20)=0
SETRAND( 21)= -565     SETRAND( 22)=0         SETRAND( 23)=0
SETRAND( 24)=  350     SETRAND( 25)=0         SETRAND(26 )=0
SETRAND( 27)=0         SETRAND( 28)=0         SETRAND( 29)=  220
SETRAND( 30)=0         SETRAND( 31)=0         SETRAND( 32)=  850
SETRAND( 33)=0         SETRAND( 34)=  850     SETRAND( 35)=0
SETRAND( 36)=0         SETRAND( 37)=0         SETRAND( 38)=00000
SETRAND( 38)=0         SETRAND( 40)=0         SETRAND( 41)=0
SETRAND( 42)=0         SETRAND( 43)=0         SETRAND( 44)=0
SETRAND( 45)= -615     SETRAND( 46)=0         SETRAND( 47)=00000
SETRAND( 48)= -740     SETRAND( 49)=0         SETRAND( 50)= -740
```

```
STP(64)=14545     STP(65)=14545     STP(66)=14545     STP(67)=14545
STP(68)=22315     STP(69)=22315     STP(70)=22315     STP(71)=0
STP(72)=17550     STP(73)=17550     STP(74)=17550     STP(75)=0
STP(76)=20315     STP(77)=20315     STP(78)=20315     STP(79)=0
STP(80)=15550     STP(81)=15550     STP(82)=15550     STP(83)=0
P2PLSECT(1) = 0     DP2SIG(1) = 0
DCYCLE(0) = 80     DOFFSET(0) = 3      DTRT(0) = 11
DCYCLE(1) = 80     DOFFSET(1) = 28     DTRT(1) = 46
DCYCLE(2) = 60     DOFFSET(2) = 22     DTRT(2) = 18
DCYCLE(3) = 60     DOFFSET(3) = 40     DTRT(3) = 16
DCYCLE(4) = 80     DOFFSET(4) = 68     DTRT(4) = 11
DCYCLE(5) = 80     DOFFSET(5) = 17     DTRT(5) = 18
DOFFSET(0)=46   DOFFSET(1)=51
DTRT(2)=12
  DSIG(0) = 50       DSIG(1) = 4      DSIG(2) = 46
  DSIG(3) = 61       DSIG(4) = 4      DSIG(5) = 35
  DSIG(6) = 57       DSIG(7) = 5      DSIG(8) = 38
  DSIG(9) = 55       DSIG(10) = 5     DSIG(11) = 41
  DSIG(12) = 61      DSIG(13) = 4     DSIG(14) = 35
  DSIG(15) = 82      DSIG(16) = 4     DSIG(17) = 14

 SITVEL(9)=510   STTVEL(9)=510
 SITVEL(10)=700
 SITVEL(11)=880   STTVEL(11)=700
 SITVEL(12)=700
 SITVEL(0)=510 SITVEL(1)=550 SITVEL(11)=720 SITVEL(13)=760
 SITVEL(14)=470 SITVEL(17)=510 SITVEL(18)=510 SITVEL(19)=550
 SITVEL(20)=400 SITVEL(21)=370
STTVEL(1)=510 STTVEL(13)=650 STTVEL(14)=510 STTVEL(18)=400
 STTVEL(19)=510 STTVEL(20)=480 STTVEL(21)=400
 STTVEL(1)=550  SITVEL(2)=420  SITVEL(8)=600

 P2FOD(43)=63     P2LOD(43)=63
 P2FOD(44)=64     P2LOD(44)=67
 P2FOD(45)=63     P2LOD(45)=69
 P2FOD(46)=70     P2LOD(46)=72
 P2FOD(47)=73     P2LOD(47)=73
 P2FOD(48)=74     P2LOD(48)=74
 P2FOD(49)=75     P2LOD(49)=75
 P2FOD(50)=76     P2LOD(50)=77
 P2FOD(51)=78     P2LOD(51)=78
REGNOD(28)=2   REGNOD(29)=3
REGNOD(30)=4   REGNOD(31)=5
REGNOD(32)=6   REGNOD(33)=26
REGNOD(34)=2   REGNOD(35)=4
REGNOD(36)=5   REGNOD(37)=6
REGNOD(38)=26  REGNOD(39)=26
```

REGNOD(40)=14	REGNOD(41)=15	REGNOD(42)=17	REGNOD(43)=18
REGNOD(44)=42	REGNOD(45)=14	REGNOD(46)=15	REGNOD(47)=17
REGNOD(48)=18	REGNOD(49)=42	REGNOD(50)=41	REGNOD(51)=19
REGNOD(52)=20	REGNOD(53)=22	REGNOD(54)=23	REGNOD(55)=7
REGNOD(56)=10	REGNOD(57)=12	REGNOD(58)=34	REGNOD(59)=34
REGNOD(60)=35	REGNOD(61)=34	REGNOD(62)=36	REGNOD(63)=27
REGNOD(64)=27	REGNOD(65)=29	REGNOD(66)=32	REGNOD(67)=33
REGNOD(68)=27	REGNOD(69)=28	REGNOD(70)=43	REGNOD(71)=45
REGNOD(72)=48	REGNOD(73)=43	REGNOD(74)=43	REGNOD(75)=50
REGNOD(76)=50	REGNOD(77)=51	REGNOD(78)=50	

POCKET(3)=1 POCKET(8)=1

BGNPOC(3)=18610 BGNPOC(8)=20020

BGNPOC(3)=17610

SFLOW(32)=603	MAJOR(32)=90	CNTME(32)=100
SFLOW(33)=396	MAJOR(33)=90	CNTME(33)=100
SFLOW(34)=0	MAJOR(34)=100	CNTME(34)=100
SFLOW(35)=575	MAJOR(35)=80	CNTME(35)=100
SFLOW(36)=610	MAJOR(36)=77	CNTME(36)=100
SFLOW(37)=83	MAJOR(37)=90	CNTME(37)=100
SFLOW(38)=350	MAJOR(38)=100	CNTME(38)=100
SFLOW(39)=387	MAJOR(39)=100	CNTME(39)=100
SFLOW(40)=0	MAJOR(40)=100	CNTME(40)=100
SFLOW(41)=264	MAJOR(41)=90	CNTME(41)=100
SFLOW(42)=235	MAJOR(42)=90	CNTME(42)=100
SFLOW(43)=0	MAJOR(43)=100	CNTME(43)=100
SFLOW(44)=416	MAJOR(44)=90	CNTME(44)=100
SFLOW(45)=406	MAJOR(45)=90	CNTME(45)=100
SFLOW(46)=171	MAJOR(46)=90	CNTME(46)=100
SFLOW(47)=56	MAJOR(47)=90	CNTME(47)=100
SFLOW(48)=0	MAJOR(48)=100	CNTME(48)=100
SFLOW(49)=0	MAJOR(49)=100	CNTME(49)=100
SFLOW(50)=434	MAJOR(50)=100	CNTME(50)=100
SFLOW(51)=311	MAJOR(51)=97	CNTME(51)=100

AWARMUP=400 ENDCLT=381

ARTERIAL=X(FFFFFC00)

REGNOD(28)=26	REGNOD(29)= 2
REGNOD(30)= 3	REGNOD(31)= 4
REGNOD(32)= 5	REGNOD(33)= 6
REGNOD(34)=26	REGNOD(35)= 2
REGNOD(36)= 3	REGNOD(37)= 4
REGNOD(38)= 5	REGNOD(39)= 6
REGNOD(40)=14	REGNOD(41)=15
REGNOD(42)=17	REGNOD(43)=18
REGNOD(44)=42	REGNOD(45)=14
REGNOD(46)=15	REGNOD(47)=17
REGNOD(48)=18	REGNOD(49)=41
REGNOD(50)=19	REGNOD(51)=21
REGNOD(52)=22	REGNOD(53)=23
REGNOD(54)= 7	REGNOD(55)= 8
REGNOD(56)=10	REGNOD(57)=12
REGNOD(58)=34	REGNOD(59)=35

7.2 PARAMETRIC INITIALIZATION

7.2.1 Turn Trajectory Data. The sample printout below illustrates the trajectory data for some of the turns which are default values, input, or computed during program initialization.

TURN	RADIUS	PC	PT	VMAXT	XEXIT	WAIT	TRAN	ELANE	ACCEPT
1	50.0	3846.5	3925.0	11.0	3898.8	3869.0	-2275.0	76	20
2	50.0	3846.5	3925.0	11.0	3898.8	3869.0	-2275.0	76	0
3	50.0	3836.5	3915.0	11.0	3888.8	3859.0	-2265.0	77	100
4	50.0	3836.5	3915.0	11.0	3888.8	3859.0	-2265.0	77	0
5	50.0	0.0	0.0	11.0	0.0	0.0	0.0	78	0
6	50.0	0.0	0.0	11.0	0.0	0.0	0.0	78	0
17	20.0	3825.0	3856.4	7.0	3839.4	3839.4	-1999.9	68	80
18	40.0	3815.0	3877.8	9.8	3835.2	3835.2	-2001.3	69	100
19	50.0	0.0	0.0	11.0	0.0	0.0	0.0	70	0
21	60.0	2356.5	2455.9	12.0	2424.9	2381.1	-909.6	87	60
22	40.0	2378.3	2444.6	9.8	2436.1	2398.5	-920.1	87	0
23	50.0	2357.4	2440.3	11.0	2420.7	2379.9	-904.0	88	100
24	40.0	2368.3	2434.6	9.8	2426.1	2388.5	-909.2	88	0
37	40.0	1955.6	2016.6	9.8	1975.8	1975.8	-330.6	84	60
38	50.0	1956.0	2032.3	11.0	1978.5	1978.5	-337.1	85	100

The column headings for the turn trajectory data are described below:

TURN	Turn classification number, default value.
RADIUS	Turn radius (feet) input.
PC	Beginning location of turn (feet), computed.
VMAXT	Maximum turn velocity (feet per review period), computed.
XEXIT	Location where turn vehicle is considered to have left the region (feet), computed. Used to compute regional performance statistics.
WAIT	Location where stopping vehicle waits for a gap or lag which it may accept (feet), computed.
TRAN	Translation constant from the coordinate system the vehicle is leaving to the coordinate system it is entering (feet), computed.
ELANE	Lane that turn vehicle will enter, default.
ACCEPT	Cumulative percent of vehicles accepting this turn classification.

7.2.2 Arterial Traffic Signal Data. Sample printouts of data for the traffic signals are presented in this section. In the first printout, arterial traffic signal data while operating under "computer" control are presented.

Line 1 contains the simulation time, in review periods (cycles) over which the data were computed and became the desired operational parametric data for the arterial traffic signal. The 15 cycles would be 7.5 seconds from the beginning of the simulation problem, since a review period is equal to 0.50 seconds.

Line 2 indicates the arterial traffic signal number associated with the signalization data.

The values listed in line 4 under the headings in line 3 indicate the following:

CYCLE LENGTH	Number of review periods in the time cycle (review period equals 0.50 seconds).
NUMBER OF INTERVAL	Total number of timing intervals in time cycle.
BEGINNING INTERVAL	The number of the timing interval presently displayed.
BEGINNING CYCLE*	The number of review periods remaining in the timing interval.
OFFSET	The desired offset, in review periods, between the arterial traffic signal and the master reference time cycle.
INTERRUPT KEY	The time location in the time cycle at which "pretime" control logic may interrupt the time cycle.

*At time zero of the simulation a 1 has been added to the number of reviews remaining.

ARTERIAL SIGNAL INFORMATION AT 15 CYCLES

PHASING PATTERN FOR SIGNAL NUMBER... 3

CYCLE LENGTH CYCLES	NUMBER OF INTERVAL	...BEGINNING... INTERVAL	CYCLE
82	4	0	81

DIRECTION OF APPROACH OF THE SIGNAL

INTERVAL	.....NORTH.... STR/RGHT	LEFT	....EAST ..... STR/RGHT	LEFT	.....SOUTH.... STR/RGHT	LEFT
0	GREEN	GREEN	RED	RED	GREEN	GREEN
1	AMBER	AMBER	RED	RED	AMBER	AMBER
2	RED	RED	GREEN	GREEN	RED	RED
3	RED	RED	AMBER	AMBER	RED	RED

OFFSET CYCLES	INTERRUPT(CYCLE) KEY MAX TIME	TYPE CONTROL
80	4	COMPUTER

.....WEST...... STR/RGHT	LEFT	PERCENT	INTERVAL	MAX	MIN
RED	RED	54	44	88	42
RED	RED	8	7	11	7
GREEN	GREEN	30	24	50	24
AMBER	AMBER	8	7	11	7

TYPE CONTROL — Indicates whether the traffic signal is operating under pretimed or computer control.

Line 6, and those lines following, list the signalization parameters indicated in line 5. The parameters are as follows:

INTERVAL	The interval number associated with the timing interval.
DIRECTION OF APPROACH	The eight columns listed under this heading correspond to the eight traffic movements controlled by the arterial traffic signal. NORTH is movements 0 and 1; EAST is 2 and 3; SOUTH is 4 and 5; and WEST is 6 and 7.
PERCENT	The percent of the time cycle allocated to a particular timing interval.
INTERVAL	The desired number of review periods in the timing interval.
MAX	The maximum time, in review periods, for the timing interval when the time cycle is being extended by pretimed and computer control, to establish the desired offset.
MIN	The minimum time, in review periods, for the timing interval when the time cycle is being shortened by computer control to establish the desired offset.

A sample of a dummy traffic signal data printout is shown below.

DUMMY SIGNAL	..INPUT SECTION	SIGNAL TO.... SIGNAL	FACE	CYCLICAL INFLOW	CYCLE (SEC)	OFFSET (SEC)	TRV TME (SEC)	...PERCENT OF CYCLE... GREEN	AMBER	RED
0	4	3	0	YES	78	46	20	50.0	4.0	46.0
1	9	0	4	YES	80	51	40	61.0	4.0	35.0
2	15	3	2	YES	60	22	5	57.0	5.0	38.0
3	17	3	6	YES	60	40	25	55.0	5.0	40.0
4	19	0	2	YES	80	58	11	61.0	4.0	35.0
5	21	0	6	YES	80	17	18	82.0	4.0	14.0

The data indicates:

DUMMY SIGNAL	Dummy traffic signal number.
INPUT SECTION	Model region number which the dummy traffic signal controls.
INPUT SIGNAL	The downstream arterial traffic signal.
INPUT FACE	The signal face of the downstream arterial traffic signal which is used to establish the offset relationship between the two traffic signals.
CYCLICAL FLOW	Is cyclical or non-cyclical flow required? If non-cyclical flow is required (NO), the signalization data for this signal will not be used by the simulation problem.

OFFSET	The offset relationship in seconds between the dummy and arterial traffic signal.
TRV TME	The average travel time, seconds, from the dummy traffic signal to the entrance boundary of the entrance region.
PERCENT GREEN	The percent of the time cycle allocated to the green phase of the major movement.
PERCENT AMBER	The percent of the time cycle allocated to the amber phase of the major movement.
PERCENT RED	The percent of the time cycle allocated to the red phase of the major movement.

1. Regional Data

The data listed below reflect the regional geometrical and operational data established at the beginning of the simulation problem.

The parameters listed under each heading are described below:

SECTION ACTIVE	The model region number used in the simulation problem.
TYPE	Describes the region as an arterial region (ART) or an exit-ramp region (RAMP).
NTRY SECTION	Is this a system entrance region?
XIT SECTION	Is this a system exit region?
PERMITTED TURNS	Describes if LEFT, STRAIGHT, or RIGHT turns are permitted to emanate from the model region.

GEOMETRICAL AND OPERATIONAL DATA FOR ALL ACTIVE ARTERIAL SECTIONS

SECTION ACTIVE	TYPE	ENTRY SECTION	EXIT SECTION	--PERMITTED TURNS------ LEFT	STRAIGHT	RIGHT	LANES ENTRY	LANES EXIT	---POSITION--- ENTRY	EXIT
0	ART	NO	YES	NO	YES	NO	2	2	3901.5	4035.5
1	ART	NO	NO	YES	YES	YES	2	3	2390.0	3901.5
2	ART	NO	NO	YES	YES	NO	3	3	2013.0	2390.0
3	ART	NO	NO	NO	YES	YES	2	3	1230.0	2013.0
4	ART	YES	NO	NO	YES	YES	2	2	578.0	1230.0
5	ART	NO	YES	NO	YES	NO	3	3	3470.5	4048.5
6	ART	NO	NO	NO	YES	YES	3	3	2613.5	3470.5
7	ART	NO	NO	YES	YES	NO	3	3	2236.5	2613.5
8	ART	NO	NO	NO	YES	YES	2	3	786.5	2236.5
9	ART	YES	NO	YES	YES	YES	3	3	591.0	786.5
10	RAMP	YES	NO	YES	NO	YES	2	2	1877.8	2436.0
12	RAMP	YES	NO	YES	NO	YES	2	2	1967.6	2431.6
14	ART	NO	YES	NO	YES	NO	3	3	1733.5	2133.5
15	ART	YES	NO	YES	YES	YES	3	4	1275.0	1733.5
16	ART	NO	YES	NO	YES	NO	3	3	1533.5	1933.5
17	ART	YES	NO	YES	YES	YES	3	4	1075.0	1533.5
18	ART	NO	YES	NO	YES	NO	2	2	1831.5	1964.5
19	ART	YES	NO	NO	YES	YES	2	2	1375.0	1831.5
20	ART	NO	YES	NO	YES	NO	2	2	1631.5	2031.5
21	ART	YES	NO	NO	YES	YES	2	2	1417.3	1631.5

----OVERLAP--- OPPOSE	BESIDE	LEFT POCKET	PERMIT DUAL	POCKET ENTRANCE	PERCENT DUAL	CHANGE POINT
0.0	0.0	NO	NO	3871.0	0.0	3985.5
1.0	0.0	YES	NO	3623.0	0.0	3770.0
0.0	0.0	NO	NO	1975.0	0.0	2318.0
0.0	1.0	YES	NO	1761.0	0.0	1911.0
0.0	0.0	NO	NO	578.0	0.0	1085.0
0.0	0.0	NO	NO	3434.5	0.0	3998.5
0.0	0.0	NO	NO	2613.5	0.0	3326.5
0.0	0.0	NO	NO	2191.5	0.0	2538.5
0.0	1.0	YES	NO	2002.0	0.0	2127.0
1.0	0.0	NO	NO	591.0	0.0	655.0
0.0	0.0	NO	NO	1877.8	0.0	2370.5
0.0	0.0	NO	NO	1967.6	0.0	2416.1
0.0	0.0	NO	NO	1705.5	0.0	1470.0
1.0	0.0	YES	NO	1519.0	0.0	1605.0
0.0	0.0	NO	NO	1503.0	0.0	1883.5
1.0	0.0	YES	NO	1262.0	0.0	1404.5
0.0	0.0	NO	NO	1803.0	0.0	2181.5
0.0	0.0	NO	NO	1375.0	0.0	1705.0
0.0	0.0	NO	NO	1603.5	0.0	1981.5
0.0	0.0	NO	NO	1175.0	0.0	1505.0

LANES NTRY	The number of lanes at the entrance boundary of a model region.
LANES XIT	The number of lanes at the exit boundary of a model region.
POSITION NTRY	The coordinate value at the entrance boundary to a model region.
POSITION XIT	The coordinate value at the exit boundary of a model region.
OVERLAP OPPOSE	The number of average lane widths which the model region overlaps the opposing region.
OVERLAP BESIDE	The number of average lane widths separating the model region and the region beside it.
LEFT-POCKET	Does a lane beging within the model region?
PERMIT DUAL	Are dual left-turns permitted?
POCKET ENTRANCE	The coordinate location of the beginning the pocket lane.
PERCENT DUAL	The percent of the left-turn traffic which considers a dual left-turn.
CHANGE POINT	Coordinate location established by model logic to be used by the lane change logic.

2. Lane Data

The data listed below list the lane geometrical and operational data established at the beginning of the simulation problem.

GEOMETRICAL AND OPERATIONAL DATA FOR EACH ACTIVE ARTERIAL LANE

LANE	SECTION	ALPHA FT/CYL	MAXIMUM VEHICLES	--PERMITTED TURNS---- LEFT	STRAIGHT	RIGHT	STOP POSITION	--VEL (FT/CYL)- ENTRY	EXIT
0	0	15.00	6	NO	YES	NO	4035.5	51.0	51.0
1	0	15.00	6	NO	YES	NO	4035.5	51.0	51.0
4	1	15.00	67	NO	YES	YES	3820.0	55.0	55.0
5	1	15.00	67	NO	YES	NO	3820.0	55.0	55.0
6	1	15.00	12	YES	NO	NO	3820.0	55.0	55.0
8	2	15.00	17	NO	YES	NO	2368.0	42.0	42.0
9	2	15.00	17	NO	YES	NO	2368.0	42.0	42.0
10	2	15.00	17	YES	NO	NO	2357.0	42.0	42.0
12	3	15.00	35	NO	YES	YES	1961.0	51.0	51.0
13	3	15.00	35	NO	YES	NO	1961.0	51.0	51.0
14	3	15.00	35	NO	YES	NO	1961.0	51.0	51.0
16	4	15.00	29	NO	YES	YES	1135.0	51.0	51.0
17	4	14.50	29	NO	NO	NO	1135.0	51.0	51.0
20	5	15.00	26	NO	YES	NO	4048.5	51.0	51.0
21	5	15.00	26	NO	YES	NO	4048.5	51.0	51.0
22	5	15.00	26	NO	YES	NO	4048.5	51.0	51.0
24	6	15.00	38	NO	YES	YES	3376.5	45.0	51.0
25	6	15.00	38	NO	YES	NO	3376.5	45.0	51.0
26	6	15.00	38	NO	YES	NO	3376.5	45.0	51.0
28	7	15.00	17	NO	YES	NO	2588.5	58.0	40.0
29	7	15.00	17	NO	YES	NO	2588.5	58.0	40.0
30	7	15.00	17	YES	NO	NO	2580.5	58.0	40.0
32	8	16.00	65	NO	YES	YES	2177.0	60.0	60.0
33	8	15.00	65	NO	YES	NO	2177.0	60.0	60.0
34	8	15.00	65	NO	YES	NO	2177.0	60.0	60.0
36	9	15.00	8	NO	YES	YES	705.0	51.0	51.0
37	9	15.00	8	NO	YES	NO	705.0	51.0	51.0
38	9	15.00	8	YES	NO	NO	705.0	51.0	51.0
40	10	15.00	25	YES	NO	YES	2420.5	70.0	51.0

LANE	SECTION	ALPHA FT/CYL	MAXIMUM VEHICLES	--PERMITTED TURNS--- LEFT	STRAIGHT	RIGHT	STOP POSITION	--VEL (FT/CYL)- ENTRY	EXIT
41	10	15.00	25	YES	NO	NO	2420.5	70.0	51.0
46	12	15.00	23	YES	NO	YES	2466.1	70.0	51.0
47	12	15.00	23	YES	NO	NO	2466.1	70.0	51.0
52	14	15.00	18	NO	YES	NO	1520.0	47.0	51.0
53	14	15.00	18	NO	YES	NO	2133.5	47.0	51.0
54	14	15.00	18	NO	YES	NO	2133.5	47.0	51.0
56	15	16.75	20	NO	YES	YES	1655.0	44.0	51.0
57	15	16.75	20	NO	YES	NO	1655.0	44.0	51.0
58	15	15.00	20	NO	YES	NO	1655.0	44.0	51.0
59	15	15.00	9	YES	NO	NO	1655.0	44.0	51.0
60	15	15.00	18	NO	YES	NO	1933.5	51.0	44.0
61	16	15.00	18	NO	YES	NO	1933.5	51.0	44.0
62	16	15.00	18	NO	YES	NO	1933.5	51.0	44.0
64	17	15.00	20	NO	YES	YES	1454.5	51.0	51.0
65	17	14.00	20	NO	YES	NO	1454.5	51.0	51.0
66	17	15.00	20	NO	YES	NO	1454.5	51.0	51.0
67	17	15.00	11	NO	NO	NO	1454.5	51.0	51.0
68	18	15.00	18	NO	YES	NO	2231.5	51.0	40.0
69	18	15.00	18	NO	YES	NO	2231.5	51.0	40.0
72	19	15.00	20	NO	YES	YES	1755.0	55.0	51.0
73	19	15.00	20	NO	YES	NO	1755.0	55.0	51.0
76	20	15.00	19	NO	YES	NO	2031.5	40.0	48.0
77	20	15.00	19	NO	YES	NO	2031.5	40.0	48.0
80	21	15.00	19	NO	YES	YES	1555.0	37.0	40.0
81	21	15.00	19	NO	YES	NO	1555.0	37.0	40.0

The parameters listed under each heading are:

LANE	The lane number used in the region being simulated.
SECTION	The region number containing this lane.
ALPHA	The proportionality constant used in the car-following equation, feet per review period.
MAXIMUM VEHICLES	The maximum number of vehicles permitted to operate in the lane at a given time.
PERMITTED TURNS	Describes if LEFT, STRAIGHT, or RIGHT turns are permitted to emanate from the lane.
STOP POSITION	The stop line location within the lane.
VEL	Entrance and exit profile velocity.

7.2.3 Vehicle Generation Data. The data required to generate inter-vehicular arrival times in an entrance lane is shown in the sample listing in this section. Line 1 indicates the time, in seconds, that program logic will begin to use the data which follows. The data following line 2 are:

ENTRY LANE	The table index corresponding to the entrance lane number.
ARTERIAL LANE	The arterial lane corresponding to the entrance lane number.
ARTERIAL SECTION	The number of the region containing the entrance lane.
MAJOR VEHICLES	The number of vehicles for a given time period.

VEHICLE GENERATION FOR ARTERIAL ENTRANCE LANES
BEGINNING AT TIME 0.0 SEC.

ENTRY LANE	..ARTERIAL.. LANE	SECTION	..........MAJOR.......... VEHICLES / HOUR		PCENT	VEH/HR GREEN
32	16	4	347	1.00	90	624
33	17	4	325	1.00	90	585
34	36	9	526	1.00	90	776
35	37	9	494	1.00	90	728
36	38	9	60	1.00	90	88
37	40	10	76	1.00	100	76
38	41	10	160	1.00	100	160
39	46	12	356	1.00	100	356
40	47	12	72	1.00	100	72
41	56	15	34	1.00	90	53
42	57	15	116	1.00	90	183
43	58	15	191	1.00	90	301
44	64	17	78	1.00	90	127
45	65	17	277	1.00	90	453
46	66	17	321	1.00	90	525
47	72	19	87	1.00	90	128
48	73	19	61	1.00	90	90
49	80	21	173	1.00	90	189
50	81	21	151	1.00	90	165

......MINOR..... LANE	VEH/HR GREEN
62	75
63	70
64	150
65	141
66	17
67	0
68	0
69	0
70	0
71	8
72	30
73	50
74	19
75	69
76	80
77	24
78	17
79	123
80	107

LANE/ ....ORIGIN AND DESTINATIONS..............
OD OD NUMBER (PERCENTAGE)

16	28	2	26	3	27	4	38	5	79	6	93	26	100
17	36	2	15	3	16	4	29	5	39	6	100		
36	43	14	60	15	62	17	88	18	95	42	100		
37	50	14	60	15	63	17	70	18	100				
38	56	41	100										
40	59	19	52	20	56	21	100						
41	65	22	88	23	100								
46	71	7	92	8	100								
47	77	10	89	11	90	12	100						
56	83	34	14	35	100								
57	88	34	100										
58	94	34	52	36	77	37	78	38	79	39	89	40	100
64	103	27	3	29	14	30	16	31	18	32	60	33	100
65	112	27	100										
66	116	27	86	28	100								
72	121	43	36	45	49	47	83	48	60	49	100		
73	128	43	100										

MAJOR HOUR	The time period in hours during which the vehicles were counted.
MAJOR PCENT	The percent of total traffic entering the entrance lane coming from movement M_T.
MAJOR VEH/HR GREEN	The converted vehicular generation rates required to generate the desired vehicular flow rate. The rate is expressed in vehicles per hour of green of the upstream dummy signal.

The following relates to the generation of the minor movement generated rates.

MINOR LANE	The table index where minor flow rate are stored. Index is entrance lane plus 30.
MINOR VEH/HR GREEN	Same as MAJOR VEH/HR GREEN. If flow rate is "0", then non-cyclical generation is indicated.

The data following line 3 describes the origin-destinations which are permitted to enter the indicated entrance lane. The data following line 3 are:

LANE	The arterial lane number of the entrance lane.
OD	The value contained in table P2FOD for that entrance lane. This value is the beginning storage location for the remainder of the data on that line.
ORIGIN-DESTINATION OD NUMBER	The data listed under this heading is the pairing of the origin-destination number and the cumulative percent this origin-destination constitutes of the total traffic entering the entrance lane.

An example of this last data printout is given using lane 47. Origin-destinations 10, 11, and 12 enter the lane. OD 10 constitutes 89 percent of the traffic, OD 11 constitutes 1 percent, OD 12 the remaining 10 percent; the cumulative percent is therefore:

OD	Percent of Total	Cumulative
10	89	89
11	1	90
12	10	100

7.2.4 Vehicle-Driver Classification. Listed below are the data related to the five arterial vehicle-driver types. The data is as follows:

ARTERIAL DRIVER TYPE CHARACTERISTICS.....

DRIVER TYPE	PERCENT OF DRIVERS	MAX ACCELERATION (FT/SEC SQ)	DESIRED DECELERATION (FT/SEC SQ)
1	7.0	4.00	-4.00
2	24.0	4.50	-4.00
3	38.0	5.00	-4.00
4	24.0	5.50	-4.00
5	7.0	6.00	-4.00

DESIRED VEL (FT/SEC)	CRITICAL GAP LT	CRITICAL GAP RT (CYL)
100.00	6	4
100.00	6	4
100.00	6	4
100.00	6	4
100.00	6	4

DRIVER TYPE — The vehicle-driver classification number.

PERCENT OF DRIVERS — The percent this classification constitutes of the total population.

MAX ACCELERATION — The maximum permissible acceleration (in feet per second per second for this classification).

DESIRED DECELERATION — The desired deceleration rate in feet per second per second for this classification.

DESIRED VEL — The percentage of the locational free-flow velocity profile used by this classification.

CRITICAL GAP LT — The left-turn critical gap-lag acceptance headway.

CRITICAL GAP RT — The right-turn critical gap-lag acceptance headway.

7.3 VEHICLES ENTERING THE SYSTEM

By setting simple item NTART equal to 1, the following vehicle information is output on magnetic computer tape at the time the vehicle enters the system. If NTART is equal to "0", this data is not output. The entrance data output is as follows:

LANE/SEC	Lane and section number the vehicle has entered.
OD	Origin-destination assigned to the vehicle.
DT	The vehicle-driver type classification assigned to the vehicle.
AEQTP	The current mode of operation of the vehicle. The possible values are as follows: 0 = stopped 1 = car-following 2 = free behavior 3 = stopping 4 = slowing for left- or right-turn 5 = stopping for left-turn 6 = stopped for left-turn 7 = going in free left-turn 8 = going in delayed left-turn 9 = going in right-turn
SEQUENCE NO. — SIMUL	The sequential order of entry of all vehicles entering all entrance lanes.
SEQUENCE NO. — REAL	The value listed under this heading is the current acceleration of the vehicle as it entered the lane.

TIME	SIMUL	The time in seconds the vehicle entered the lane.
	DELTA	The time in seconds the vehicle was generated into the storage table. The difference between the previous time TIME, SIMUL) and this time equals the delay accumulated while waiting to enter the system.
VELOC.	SIMUL	The vehicle's entrance velocity into the lane.
	DELTA	The system identification number of the vehicle. This also represents the storage location for all data pertaining to this vehicle.

The remaining data reflects the operation of the lane, and may be used to give a comparison of this vehicle's entrance requirements with regard to previous vehicles entering the lane as well as vehicles of the same origin-destination. The origin-destination data is listed under OD-SEC. A sample listing of this data is shown below.

VEHICLES INPUT TO ARTERY SYSTEM...

LANE/SEC NO.'S		OD	DT	REQ TP	SEQUENCE NO. SIMUL	SEQUENCE NO. REAL	TIME (SEC) SIMUL	TIME (SEC) DELTA	VELOC. SIMUL
30	21	50	2	2	1	0.0	0.4	0.4	37.0
36	9	17	3	2	2	0.0	7.3	7.3	50.4

(FPS) DELTA	NO. VEH. IN LANE	NO. VEH. IN SEC	AVG. VELOCITY (FPS) IN-BOUNDARY LANE	AVG. VELOCITY (FPS) IN-BOUNDARY OD-SEC	AVG. VELOCITY (FPS) ENTIRE OD-SEC	AVERAGE TRAVEL TIME (SEC) LANE	AVERAGE TRAVEL TIME (SEC) OD-SEC
799	1	1	37.0	37.0	0.0	0.0	0.0
798	1	1	50.3	50.0	0.0	0.0	0.0

7.4 CURRENT VEHICLES OPERATING IN THE SYSTEM

A sample of the periodic vehicle performance printout is presented in this section for each review period between times CKE10 and CKE101, or at the periodic time defined by PVD. Line 1 indicates the number of the review period minus 1 that the data was printed. This is the current vehicle representation statistic for the vehicles currently operating in the simulated roadway. Also listed on this line is the number of this simulation problem, since several simulation problems may be studied during a single execution.

Line 2 indicates the section (or model region) and the lane number that the vehicles are presently occupying. The data listed under line 3 is the vehicle representation data.

CAR	The vehicle order in the lane as ordered from the entrance to the exit of the lane.
POS	The coordinate location of the front of the vehicle in the lane.

VEL	The current velocity of the vehicle in feet per review period.
ACC	The current acceleration of the vehicle in feet per review period squared.
DIST	The separation distance between the vehicle and its leader in feet.
DM	Indicates the turn vehicle by SJI number following this vehicle.
EQTP	The present mode of operation of the vehicle, cf. Section 7.3.
PLN	The lane this vehicle desires to use when exiting this region.
CLN	The present lane in which this venicle is operating.
D4S	This vehicle is following a vehicle in another coordinate system. The lead vehicle has its translated coordinates stored in this table location.
JP	The storage location of the vehicle data for the previous review period.
SJI	The vehicle identification number.
OD	The origin-destination of this vehicle.
SP	The stop position of the vehicle.
GO	The amber decision 0 = No decision 1 = Stop for amber signal 2 = Do not stop for amber signal

CYCLE = 0999 1

SECTION 3,	LANE	12

CAR	POS	VEL	ACC	DIST	DM	EQTP	PLN	CLN	D4S	JP	SJI	OD
0	1725.5	25.5	0.05	--	-	2	12	12	--	--	796	2
1	1572.1	24.9	0.04	136.4	-	1	12	12	--	1596	799	2
2	1475.1	25.0	0.12	80.0	-	2	12	12	--	1599	772	2
3	1353.5	21.1	1.37	104.6	-	2	12	12	--	1572	794	2

,	LANE	13

CAR	POS	VEL	ACC	DIST	DM	EQTP	PLN	CLN	D4S	JP	SJI	OD
0	1725.5	25.5	0.05	--	-	2	13	13	--	--	786	2
1	1572.4	25.4	0.02	136.1	-	2	13	13	--	1586	781	2
2	1472.4	25.3	0.01	83.0	-	1	13	13	--	1581	782	2
3	1367.3	24.3	1.09	88.1	-	2	13	13	--	1582	798	2
4	1275.6	18.7	1.59	74.7	-	2	13	13	--	1598	788	2

SECTION 4,	LANE	16

CAR	POS	VEL	ACC	DIST	DM	EQTP	PLN	CLN	D4S	JP	SJI	OD
0	1010.4	24.8	0.59	326.1	-	2	16	16	--	1594	791	2
1	882.8	24.0	-1.01	110.6	-	4	16	16	--	1591	773	26

SP	GO	TURN	EL	SIG	TYP	DBG	TAG	QSR	TVL	FRT	ADT	PAN
1137.4	0	0	8	4	0	DBG	0	1	255	-	2	0
1114.7	0	0	8	4	0	DBG	0	1	255	-	0	0
1092.3	0	0	8	4	0	DBG	0	1	255	-	2	0
1068.7	0	0	8	4	0	DBG	0	1	255	-	3	0

SP	GO	TURN	EL	SIG	TYP	DBG	TAG	QSR	TVL	FRT	ADT	PAN
1137.4	0	0	9	4	0	DBG	0	3	255	-	2	0
1114.6	0	0	9	4	0	DBG	0	3	255	-	0	0
1092.0	0	0	9	4	0	DBG	0	3	255	-	2	0
1068.6	0	0	9	4	0	DBG	0	3	255	-	3	0
1045.8	0	0	9	4	0	DBG	0	3	255	-	4	0

SP	GO	TURN	EL	SIG	TYP	DBG	TAG	QSR	TVL	FRT	ADT	PAN
0.0	0	0	12	0	0	DBG	0	1	255	-	2	0
0.0	0	2	52	0	57	DBG	-1	0	255	-	2	0

, LANE 17

CAR	POS	VEL	ACC	DIST	DM	EQTP	PLN	CLN	D4S	JP	SJI	OD
0	1021.7	25.5	0.00	236.9	-	2	17	17	--	1588	771	2
1	884.0	25.5	0.00	120.7	-	2	17	17	--	1571	797	2

, LANE 18

CAR	POS	VEL	ACC	DIST	DM	EQTP	PLN	CLN	D4S	JP	SJI	OD
0	1222.2	9.8	0.00	--	-	7	18	18	--	--	787	34
1	1125.5	9.7	0.01	79.7	-	1	18	18	--	1587	777	34
2	1067.4	9.7	0.00	41.1	-	1	18	18	--	1577	793	34

SECTION 14, LANE 52

CAR	POS	VEL	ACC	DIST	DM	EQTP	PLN	CLN	D4S	JP	SJI	OD
0	1815.7	14.5	1.50	--	-	2	52	52	--	--	774	26

SECTION 15, LANE 56

CAR	POS	VEL	ACC.	DIST	DM	EQTP	PLN	CLN	D4S	JP	SJI	OD
0	1654.9	0.0	0.00	--	-	0	56	56	--	--	769	18
1	1636.9	0.0	0.00	1.0	-	0	56	56	--	1569	785	14
2	1618.9	0.0	0.00	1.0	-	0	56	56	--	1585	778	14
3	1600.9	0.0	0.00	1.0	-	0	56	56	--	1578	780	14

SP	GO	TURN	EL	SIG	TYP	DBG	TAG	QSR	TVL	FRT	ADT	PAN
0.0	0	0	13	0	0	DBG	0	0	255	-	2	0
0.0	0	0	13	0	0	DBG	0	0	255	-	2	0

SP	GO	TURN	EL	SIG	TYP	DBG	TAG	QSR	TVL	FRT	ADT	PAN
1247.0	0	1	60	0	41	DBG	-1	0	255	-	1	0
0.0	0	1	60	0	41	DBG	-1	0	255	-	2	0
0.0	0	1	60	0	41	DBG	-1	0	255	-	3	0

SP	GO	TURN	EL	SIG	TYP	DBG	TAG	QSR	TVL	FRT	ADT	PAN
1045.9	0	0	98	4	0	DBG	0	0	243	-	4	0

SP	GO	TURN	EL	SIG	TYP	DBG	TAG	QSR	TVL	FRT	ADT	PAN
1654.9	1	0	52	2	0	DBG	-1	0	244	-	1	0
1632.9	1	0	52	2	0	DBG	-1	0	241	-	0	0
1610.9	1	0	52	2	0	DBG	-1	0	239	-	2	0
1588.9	1	0	52	2	0	DBG	-1	0	235	-	2	0

TURN	Direction of turn for this vehicle. 0 = Straight 1 = Left turn 2 = Right turn
EL	The lane the vehicle desires to enter in the next region it will enter.
SIG	The condition of the current signal display for the signal face (0, 2, 4, or 6) which controls this region. 0 = green 1 = amber 2 = red The left-turn indication is not indicated.
TYP	Turn classification number.
TAG	Lane change modification. -1 = no desire to change lane 0 = will change lanes if delay is encountered 1 = change to avoid accident 2 = change right this region 3 = change left this region 4 = change right this or the next region 5 = change left in this or the next region 6 = change to avoid delay

QSR	The quadrant around the lane changing vehicle to be searched for a suitable gap. 1 = front and to the left of the changer 2 = rear and to the left of the changer 3 = front and to the right of the changer 4 = rear and to the right of the changer
TVL	The free flow velocity this vehicle will try to achieve or maintain at this location.
FRT	The lead vehicle forming the gap into which the lane change vehicle will enter.
ADT	The vehicle-driver classification.
PAN	The storage location for the lane-change plan information.

7.5 PERIODIC QUEUE INFORMATION

Periodic queue information may be obtained by setting simple item IOQ to the elapsed time between the queue information printout. The heading indicates the period in review periods between printouts.

QUEUE REPORT OF CYCLE 7200

SECTION	LANE	QUEUE	CSIL	NONQUE	SIGNAL
3	12	0	0	0	NONE
3	13	0	0	0	NONE
4	16	4	6	2	GREN
4	17	1	5	4	GREN
4	18	2	2	0	GREN
14	52	0	1	1	NONE
14	53	0	1	1	NONE
15	56	0	0	0	RED
15	57	0	0	0	RED

The data listed under the headings are as follow:

SECTION	The model region number which is active during the simulation problem.
LANE	The lane number which is used in the region.
QUEUE	The present number of vehicles which are queued in the lane.
CSIL	The total number of vehicles in the lane.
NONQUE	The number of non-queued vehicles in the lane.
SIGNAL	The current signal display on signal face 0, 2, 4, or 6 controlling this region.

7.6 ERROR AND JOB TERMINATION MESSAGES

The following are messages which indicate a completion of the simulation either by a recognizable error condition or a normal simulation problem completion.

7.6.1 Error Messages.

While procedure NUDATA is reading cards, these data cards are checked for validity. If a recognizable error is detected, an error message is output indicating the error and the run is terminated. The following are the errors which may be recognized and the messages output.

1. Read error during data input.
2. End-of-file data input.
3. Illegal symbol-pair.
4. Illegal character.
5. Multiple assignment - operator.
6. Missing statement - part.
7. Improper (constant) specification.

8. Item - name not in NUDATA dictionary.
9. Improper subscript.
10. Superfluous subscript.
11. Missing subscript.
12. Constant not compatible with item.
13. Illegal constant.

7.6.2 Operations Error Messages. Procedure WRAPUP is called by other procedures to terminate a simulation problem. This termination may be the normal completion of the simulation problem or due to error conditions encountered during the execution of the simulation problem. The following are the error identifiers which are output and the corresponding explanation of each error.

CHNDIAL	Arterial traffic signal data is incorrect. Either timing intervals do not sum to 100 percent or beginning green of phasing pattern is not in interval zero.
FINISH	Simulation problem completed.
FLOWOD 1	Table item P2RLSECT for dummy traffic signal is incorrectly set.
GETMY	Table entries exhausted. Entries used to establish dummy vehicles for use by vehicles changing lanes.
GETDUM	Table entries exhausted. Entries used to establish dummy vehicles for use by vehicles which are following vehicles in other coordinate systems.
GETPLN	Table entries exhausted. Entries used to lane-change plane information.

GETPTR 1	Table entries exhausted. To many actual vehicles attempting to operate in the system.
SESUP E1	Undelayed travel time through region less than or equal to 0.0.
SESUP E5	Insufficient entries allocated to a lane. More vehicles may operate in a lane than indicated.
XITVEL 1	Insufficient entries allocated to a lane. More vehicles may operate in a lane than indicated.

7.7 PERFORMANCE STATISTICS

At the termination of the vehicle performance statistical tabulation period -- defined by default values or table item IOEPILOG -- the statistics related to vehicle performance during that period are output according to:

- System performance by origin-destination
- Regional performance by origin-destination
- Queue formation
- Lane performance
- Lane change plan formations

7.7.1 Vehicle Performance Statistics by Origin-Destination. At the termination of the vehicle performance statistical tabulation period -- defined by default values or table item IOEPILOG -- the statistics related to vehicles exiting the arterial street system, and each arterial model region are output.

1. System Performance by Origin-Destination

The statistics relating to vehicles exiting the arterial street system are otuput in the format shown in the listing in this section. The items in this list are described below.

OD NO.	The origin-destination of the exiting vehicle.
VEHICLE TRAVERSING SYSTEM	The total number of vehicles of this origin-destination which exit the system during the tabulation period.
SYSTEM AVERAGE VELOCITY	The average velocity in feet per second and miles per hour. THis is the average of the average velocity for all vehicles of this origin-destination.
SYSTEM AVERAGE TRT	The average of the average travel time in seconds for all vehicles of this origin-destination.
STD. DEVIATE AVEL	The standard deviation of the average-average velocity.
STD. DEVIATE TRT	The standard deviation of the average travel time.

7.7.2 Section and Lane Queue Information. The summary queue information is printed at the end of each tabulation period. This information is approximate since it was not maintained to account for queued vehicles which lane-change to another lane. Because of this, the queue information may only be used as a general guideline of queued veicles in a lane or a section.

SYSTEM SIMULATED THRU-VEHICLE STATISTICS, ART.

G.D. NO.	VEHICLES TRAVERSING SYSTEM
0	0
1	0
2	18
3	3
4	1
5	28
6	18
7	20
8	0
9	0
10	3
11	0
12	0
13	0
14	39
15	4
16	0
17	17
18	15
19	3
20	1
21	0

---SYSTEM AVERAGE---			STD. DEVIATE	
OF AVG. VELOC. (FPS)	(MPH)	TRT (SEC)	AVEL (FPS)	TRT (SEC)
26	18.2	132.1	3.93	18.14
23	16.0	143.2	0.51	3.09
20	14.0	183.1	0.00	0.00
24	16.8	58.1	4.25	9.28
23	16.3	79.2	3.65	15.92
33	22.9	75.8	8.41	19.38
29	20.3	104.5	4.75	18.20
25	17.1	140.5	3.52	21.23
25	17.2	131.7	5.88	26.04
20	14.2	79.7	5.23	14.74
25	17.6	85.7	7.31	27.07
32	22.3	83.2	5.91	14.86
32	22.0	78.1	0.00	0.00

22	14
23	0
24	0
25	0
26	4
27	62
28	5
29	3
30	0
31	0
32	4
33	0
34	34
35	2
36	2
37	0
38	0
39	0
40	0
41	9
42	13
43	11
44	0
45	3
46	0
47	0
48	0
49	0
50	45
51	5
52	0

24	16.5	123.1	3.97	19.45
25	17.2	38.7	1.62	2.59
30	20.9	37.1	31.51	15.22
19	13.4	60.2	6.48	23.29
24	17.0	131.5	4.41	23.93
13	9.5	117.8	2.64	25.62
29	20.0	37.5	14.34	18.07
19	13.0	50.3	0.73	2.00
24	17.0	132.0	3.59	18.70
4	3.0	93.6	2.90	43.16
28	19.7	19.8	4.86	4.31
18	12.9	41.4	13.40	16.66
22	15.6	163.1	2.97	22.59
23	15.8	37.7	13.66	19.76
27	18.8	12.9	14.59	5.52

SECTION AND LANE QUEUE INFORMATION TABULATED EVERY 0.50 SECONDS

NUMBER	SECTION TOTAL VEH QUEUE	AVG. QUEUE	STD.DEV. QUEUE	MAX. QUEUE
0	0			
1	2466	2.04	103.3	2466
2	1885	1.47	6552.7	1886
3	2433	1.93	6552.7	2434
4	1955	1.52	6552.3	1955
5	0			

NUMBER	LANE TOTAL VEH QUEUE	AVG. QUEUE	STD.DEV. QUEUE	MAX. QUEUE
0	0			
1	0			
4	1016	2.13	1.0	6
5	1194	2.05	1.1	5
6	298	1.00	0.0	1
8	0			
9	0			
10	1925	2.04	1.3	8
12	1522	3.45	2.1	9
13	1461	2.20	1.3	6
14	551	1.94	1.1	6
16	1406	2.94	2.0	9
17	616	2.31	1.4	6
18	0			
20	0			
21	0			
22	0			

6	7005	5.35	103.9	7005
7	2084	1.61	97.0	2084
8	5863	4.29	49.3	5863
9	5733	4.04	70.5	5734
10	3471	2.64	93.0	3471
11	0			
12	2619	1.94	6553.3	2619
13	0			
14	0			

24	3068	4.36	2.3	11
25	2907	3.83	1.7	7
26	1153	2.79	1.6	6
28	54	1.28	0.4	2
29	318	2.13	1.2	5
30	1762	1.89	1.1	5
32	3261	4.32	1.8	7
33	2274	2.90	1.6	8
34	421	1.60	0.5	2
36	2047	2.71	1.8	6
37	1984	2.96	1.6	6
38	1806	2.39	1.2	5
40	69	1.00	0.0	1
41	3448	3.19	1.6	8
43	0			
46	2143	2.47	1.3	6
47	533	1.22	0.5	3
49	0			
52	0			
53	0			
54	0			

7.7.3 Vehicle Performance Statistics Per Lane. Vehicle performance statistics similar to those for regional vehicle performance are given on a per-lane basis.

7.7.4 Lane Change Plans. The number and type of lane changes are classified according to the lane in which the plan was formed.

ALL SIMULATED VEHICLE STATISTICS PER LANE IN A SECTION

	--VEHICLES---		-----LANE AVERAGE----			-STD. DEV.-	
	ENTER	EXIT	AVG. VEL (FPS)	(MPH)	TRT (SEC)	AVG.VEL (FPS)	TRT (SEC)
[illegible]	20	19	35	23.70	4.20	13.77	1.17
[illegible]	15	15	35	24.19	3.82	3.95	0.44
[illegible]	20	19	32	21.98	51.06	10.67	15.43
[illegible]	[illegible]	15	31	21.18	56.40	12.81	19.06
[illegible]	[illegible]	1	14	9.61	105.56	0.00	0.00
[illegible]	15	17	32	21.59	12.17	[illegible]	1.73
[illegible]	22	19	3[illegible]	2[illegible].31	13.07	[illegible].77	1.27
[illegible]	21	[illegible]	18	12.41	29.31	6.27	20.91

---IN BOUNDARY-------			--OUT BOUNDARY--------			----DELAY----	
AVG. VEL (FPS)	(MPH)	STD.DEV (FPS)	AVG. VEL (FPS)	(MPH)	STD.DEV (FPS)	AVG. (SEC)	STD.DEV (SEC)
26	17.72	1.46	44	30.14	9.36	-0.10	0.79
28	19.23	0.86	45	30.84	3.08	0.04	0.10
2[illegible]	19.62	0.89	24	16.32	5.68	21.83	15.16
32	21.75	0.83	28	19.22	8.60	27.89	19.05
			17	11.69	0.00	73.50	0.00
30	20.[illegible]3	0.87	32	21.54	6.38	2.71	1.49
26	17.40	0.83	33	22.47	7.04	2.93	1.69
30	20.70	0.77	22	15.00	0.00	16.60	21.17

12	52	43	23	15.45	34.47	4.27	5.82
13	37	19	25	17.04	32.32	5.42	4.81
14	0	21	27	18.32	30.90	6.77	7.78
16	66	51	27	18.21	25.46	7.05	5.47
17	32	32	28	19.04	24.79	6.93	6.38
18	0	0					
[illegible]	22	21	48	32.54	12.11	0.95	0.24
[illegible]	36	32	48	32.83	12.05	2.79	0.80
[illegible]	32	30	48	32.56	12.15	2.74	0.79
[illegible]	[illegible]	[illegible]	17	11.59	50.68	3.24	7.52
[illegible]	55	32	23	15.83	42.14	[illegible]	13.55
[illegible]	7	29	26	17.59	37.91	10.11	13.68

36	24.51	0.91	23	15.70	7.34	16.88	6.08
34	23.00	0.89	28	18.79	7.07	16.46	4.93
			30	20.70	7.68	14.58	8.04
[illegible]	3.47	0.00	37	24.92	8.24	12.51	5.43
5	3.47	0.00	36	24.78	6.46	12.00	6.38
32	21.85	0.30	51	34.78	0.23	0.05	0.07
35	23.82	0.88	51	34.73	0.23	0.05	0.10
35	23.93	0.95	51	34.80	0.16	0.07	0.07
31	21.08	0.90	28	18.98	8.01	32.21	8.20
26	17.59	1.14	37	25.17	7.20	24.11	14.04
20	13.65	0.48	37	25.20	7.84	19.45	14.19

28	32	37	26	18.00	15.73	6.98	3.26
29	44	37	25	16.72	16.77	6.41	3.43
30	21	15	17	11.61	34.70	8.79	26.04
32	59	41	28	19.23	58.21	9.91	21.49
33	58	35	35	23.65	46.82	9.81	18.40
34	0	21	38	26.17	41.65	10.02	15.79
36	64	69	23	15.38	11.80	11.40	9.39
37	63	58	26	17.74	11.88	16.37	8.39
38	9	9	3	1.86	89.48	1.94	43.21
40	27	5	24	16.24	23.74	2.68	2.82
41	0	17	14	9.22	48.73	6.30	17.76

31	20.82	0.89	31	21.08	8.98	5.22	4.18
34	23.10	1.19	32	21.53	9.22	6.30	4.43
42	28.88	1.00	26	17.67	2.89	24.14	26.08
32	21.49	0.85	27	18.48	10.18	31.02	20.72
36	24.37	1.03	37	25.43	10.79	21.21	18.62
			42	28.88	9.94	16.43	15.99
3	2.00	0.16	30	20.44	8.68	6.56	9.39
3	2.12	0.18	36	24.37	10.30	6.65	8.25
4	2.54	0.09	19	12.85	2.34	83.17	43.02
67	45.98	0.19	12	8.40	0.72	10.15	2.82
			20	13.72	4.05	37.17	17.84

LANE CHANGE PLANS FORMED AND COMPLETED PER LANE.

LANE NUM	NUMBER OF CHANGES TOTAL	LEFT	RIGHT	...LANE CHANGE PLANS FORMED IN A LANE....... 1.00 SECONDS OR LESS. TOTAL	AVG.TIME (SEC)	STD.DEV. (SEC)	....MORE THAN 1.00 TOTAL	AVG.TIME (SEC)	STD.DEV. (SEC)
0	0	0	0				0		
1	0	0	0				0		
4	8	8	0	6	1.00	0.00	2	3.25	0.75
5	14	3	11	6	1.00	0.00	8	4.06	1.24
6	0	0	0				0		
8	12	12	0	8	1.00	0.00	4	4.37	1.63
9	29	3	26	18	1.00	0.00	11	3.86	1.75
10	0	0	0				0		
12	40	40	0	24	1.00	0.00	16	4.68	1.98
13	79	65	14	17	1.00	0.00	62	6.11	0.95
14	0	0	0				0		
16	33	33	0	26	1.00	0.00	7	4.07	2.08
17	24	0	24	17	1.00	0.00	7	3.35	1.57
18	0	0	0				0		
20	0	0	0				0		
21	0	0	0				0		
22	0	0	0				0		

24	33	33	0	26	1.00	0.00	7	3.57	1.55
25	99	83	16	95	1.00	0.00	4	3.62	1.95
26	14	0	14	0	1.00	0.00	5	2.80	1.60
28	17	17	0	16	1.00	0.00	1	4.00	0.00
29	43	2	41	37	1.00	0.00	6	4.00	1.22
30	0	0	0				0		
32	88	88	0	67	1.00	0.00	21	3.59	1.84
33	109	47	62	40	1.00	0.00	69	5.47	1.70
34	0	0	0				0		
36	26	26	0	18	1.00	0.00	8	3.00	0.90
37	90	0	90	36	1.00	0.00	54	4.56	1.85
38	0	0	0				0		
40	52	52	0	50	1.00	0.00	2	3.25	0.75
41	0	0	0				0		

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