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16. Abstract

A new microscopic traffic simulation package, called the TEXAS Model, which can be used as a tool by transportation engineers to evaluate traffic performance at isolated intersections operating under various types of intersection control has been developed. The package consists of a geometry processor, a driver-vehicle processor, and a traffic simulation processor.

Input to the TEXAS Model has been designed to be user oriented and minimal while output is concise and functional. Documentation has been developed for both users and programmers.

The TEXAS Model may be applied in evaluating existing or proposed intersection designs and for assessing the effects of changes in roadway geometry, driver and vehicle characteristics, flow conditions, intersection control, lane control, and signal timing plans upon traffic operations.

The TEXAS Model is a useful and effective method for predicting traffic performance at existing and proposed intersections. The summary statistics that are reported can be obtained for a fraction of the cost of conventional field study techniques. The detail that has been incorporated into the model gives the user confidence that the behavior of the simulated driver-vehicle units is similar to that which is observed in the real world.

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THE TEXAS MODEL FOR INTERSECTION TRAFFIC - DEVELOPMENT

by

Clyde E. Lee
Thomas W. Rioux
Charlie R. Copeland

Research Report Number 184-1

Simulation of Traffic by a
Step-Through Technique (Applications)

Research Project 3-18-72-184

conducted for

Texas
State Department of Highways and Public Transportation

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR HIGHWAY RESEARCH

THE UNIVERSITY OF TEXAS AT AUSTIN

December 1977

PREFACE

Computer simulation is a valuable tool which can provide insight into the operation of engineering processes. Simulation of traffic flow and intersection control allows engineers to study the performance of proposed highway intersections under various conditions, even before construction begins, so that capacity, safety, efficiency, cost, and enviromental impact can be evaluated. Better utilization of existing streets and highways can also be realized through application of simulation results.

This report discusses the development of a new traffic and intersection simulation package that was developed at the Center for Highway Research, The University of Texas at Austin, as part of the Cooperative Highway Research Program sponsored by the Texas State Department of Highways and Public Transportation and the Federal Highway Administration under the supervision of Dr. Clyde E. Lee, Director of the Center for Highway Research.

This is the first in a series of four reports on Research Study Number 3-18-72-184, "Simulation of Traffic by a Step-Through Technique." This report describes the development of the TEXAS Model for Intersection Traffic and the algorithms that are used in the computations. Appendices B through F, which are referenced in this report, are bound in a separate volume and constitute the second in this series of reports. The four reports which deal with the development, use, and application of the TEXAS Model are

> Research Report No. 184-1, "The TEXAS Model for Intersection Traffic - Development," Clyde E. Lee, Thomas W. Rioux, and Charlie R. Copeland.
>
> Research Report No. 184-2, "The TEXAS Model for Intersection Traffic - Programmer's Guide," Clyde E. Lee, Thomas W. Rioux, Vivek S. Savur, and Charlie R. Copeland.

Research Report No. 184-3, "The TEXAS Model for Intersection Traffic - User's Guide," Clyde E. Lee, Glenn E. Grayson, Charlie R. Copeland, Jeff W. Miller, Thomas W. Rioux, and Vivek S. Savur.

Research Report No. 184-4, "The TEXAS Model for Intersection Traffic - Analysis of Signal Warrants and Intersection Capacity," Clyde E. Lee, Vivek S. Savur, and Glenn E. Grayson.

The authors of this report wish to express their appreciation and extend thanks to the many individuals associated with several agencies who have contributed generously of their talents and time during the conduct of this research program. Special thanks go to the personnel with the Center for Highway Research, Divisions 18T and 19 of the Texas State Department of Highways and Public Transportation, and the Federal Highway Administration.

ABSTRACT

A new microscopic traffic simulation package, called the TEXAS Model, which can be used as a tool by transportation engineers to evaluate traffic performance at isolated intersections operating under various types of intersection control has been developed. The package consists of a geometry processor, called GEOPRO, a driver-vehicle processor, called DVPRO, and a traffic simulation processor, called SIMPRO.

GEOPRO calculates the geometric paths of vehicles on the approaches and in the intersection, identifies points of conflict between intersection paths, and determines the minimum available sight distance along each inbound approach. This information is written onto a magnetic tape for subsequent use by SIMPRO.

DVPRO characterizes the traffic stream to be simulated by generating queue-in time and other random descriptors for individually characterized driver-vehicle units, describes pertinent characteristics of up to 5 classes of drivers and up to 15 classes of vehicles, and writes this information on a tape for later use by SIMPRO. An auxiliary headway-distribution-fitting processor aids the user in selecting appropriate headway distributions that describe observed or predicted traffic patterns.

SIMPRO processes each driver-vehicle unit through the intersection system and gathers and reports a large selection of performance statistics. Linear acceleration and deceleration models are incorporated within the TEXAS Model, and a non-integer, microscopic, generalized car-following equation is used. Traffic signal simulators are included for pretimed, semi-actuated, and full-actuated controllers. Other intersection control options include uncontrolled, yield sign controlled, less-than-all-way stop sign controlled, and all-way stop sign controlled. Several new techniques of traffic simulation are implemented, including a geometrically accurate lane-change maneuver; sight distance restriction checking; intersection conflict checking; and efficient storage and logic processing methods. New field data recording devices which aid in collecting data for validation of the traffic

simulation package and in determining suitable input for the model are described.

Input to the TEXAS Model has been designed to be user oriented and minimal while output is concise and functional. Documentation has been developed for both users and programmers.

The TEXAS Model may be applied in evaluating existing or proposed intersection designs and for assessing the effects of changes in roadway geometry, driver and vehicle characteristics, flow conditions, intersection control, lane control, and signal timing plans upon traffic operations.

The TEXAS Model is a useful and effective method for predicting traffic performance at existing and proposed intersections. The summary statistics that are reported can be obtained for a fraction of the cost of conventional field study techniques. The detail that has been incorporated into the model gives the user confidence that the behavior of the simulated driver-vehicle units is similar to that which is observed in the real world.

SUMMARY

A practical tool for evaluating existing or proposed intersection designs and for assessing the effects of changes in roadway geometry, driver and vehicle characteristics, flow conditions, intersection control, lane control, and signal timing schemes upon traffic operations has been developed by the Center for Highway Research. It is called the TEXAS Model for Intersection Traffic.

The TEXAS Model is a new microscopic traffic simulation package consisting of a geometry processor, GEOPRO, a driver-vehicle processor, DVPRO, and a traffic simulation processor, SIMPRO. Two sets of input designed to be user oriented and minimal must be coded: 1) a set for GEOPRO and DVPRO and 2) a set for SIMPRO. Both GEOPRO and DVPRO write data that will remain constant for each simulation run onto a magnetic tape for later use by SIMPRO.

GEOPRO calculates the paths that vehicles will follow through the intersection, intersection conflict points, and available sight distance. DVPRO generates the random descriptors of the driver-vehicle units that are used in the simulation. SIMPRO processes each driver-vehicle unit through the intersection system while gathering a large selection of performance statistics which are reported at the end of the simulation.

Several new features of traffic simulation are incorporated in the model. Unique field data recording devices were developed to aid in the data collection that was necessary for validating the traffic simulation package. Sufficient detail is incorporated into the model to give the user confidence that the behavior of the simulated driver-vehicle is similar to that which would be observed in the field under the same conditions.

Examples of input and output for three intersections, which include a wide variety of geometrics, traffic patterns, and signal control schemes are provided. These example runs show the versatility of the TEXAS Model. The relative ease of making changes in geometrics, traffic conditions, and control strategies encourages the user to investigate several feasible schemes before deciding on the most viable alternative to be implemented.

IMPLEMENTATION STATEMENT

The design of intersections and the associated optimization of traffic control require analysis of the effects of several interacting variables, such as traffic patterns, geometric configurations, and traffic control schemes. In the past, experience with similar situations and rationalization have served as the primary means for evaluating anticipated results of unknown combinations of these variables.

Now, as a result of this research, engineers can study the expected performance of intersections under various conditions and decide on an optimum design or strategy before actual implementation in the field. The summary statistics of the performance values that are reported by the TEXAS Model for Intersection Traffic are obtained for a fraction of the cost of conventional field study techniques. Detail has been incorporated into the model to give the user confidence that the behavior of the simulated driver-vehicle units is similar to that which would be observed in the real world.

Since the improvement of intersection performance has long been of concern to traffic engineers, this new and valuable tool will be of interest and potential usefulness to engineers concerned with planning, geometric design, and traffic operations in municipal transportation departments, state highway departments, and the Federal Highway Administration.

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1.0 INTRODUCTION

Satisfactory solutions to traffic control problems at street and highway intersections involve the evaluation of capacity, efficiency, safety, environmental impact, and cost. This evaluation requires, among other things, a detailed analysis of the expected responses of individual driver-vehicle units to the unique conditions which may exist momentarily in the intersection area. Traffic movement on a road network is a complex, time-varying phenomenon which depends largely on the desires and capabilities of the individual drivers, the capabilities of the vehicles, the physical geometry of the road network and the type of traffic control.

Engineers charged with the responsibility of optimizing traffic flow at intersections have historically observed traffic behavior at intersections and designed geometric configurations and regulatory traffic controls to improve existing conditions. In the past, their recommendations were derived mainly from the experience gained when such changes were made to other intersections with similar problems. Inadequacies in this approach led engineers to predict and use macroscopic estimations of traffic stream flow characteristics. As traffic demands grew, more sophisticated analysis techniques were needed. The lack of adequate means for predicting and tracing the response of individual driver-vehicle units has concerned transportation engineers through the years. Adequate tools have not been available for evaluating the performance of isolated intersections, actuated signal controllers, or uncontrolled intersections. Traffic simulation models for evaluating changes in roadway geometry; drivers and vehicles; flow conditions; type of intersection and lane control; and signal controller options have not been available nor adequate.

Advances in digital computer technology during the past decade or so have made it feasible to simulate complex physical phenomena with considerable sophistication in a much compressed time frame. Several traffic simulation programs have been developed (Refs 1-10), but none of these has been designed specifically to handle the general case of a single, multi-leg, mixed-traffic intersection operating either without control or with any conventional form of traffic control. Detailed computer simulation of the four major elements involved in the traffic flow (the driver, the vehicle, the roadway geometry, and the traffic control) can be used to evaluate the complex interactions that occur in actual traffic flow. By simulating various combinations of roadway geometry and traffic control under a wide range of chosen traffic conditions, the user can determine the optimum traffic flow conditions which can be practically attained at an intersection.

In 1971, development of a traffic simulation package was undertaken as part of the Cooperative Research Program between the Center for Highway Research at The University of Texas at Austin, the Texas State Department of Highways and Public Transportation, and the United States Department of Transportation Federal Highway Administration. The objective of the research effort was to develop, verify, calibrate, and validate a microscopic traffic simulation package to evaluate traffic performance at isolated intersections operating under various types of intersection control. The scope included the development of all necessary computer programs in a form in which the general user could input and run the simulation package; the design and testing of a new generation of field data collection and storage devices; the collection of appropriate field data to calibrate the resulting model; and the development of project documentation. The scope of the study was restricted to the simulation of traffic at a single intersection since other models (Refs 11-12) were at that time being configured primarily to handle multi-intersection, signalized networks. Emphasis was placed on making the traffic simulation package user-oriented and on minimizing computer storage. The philosophy of initially incorporating as much detail as possible into the model and then subsequently eliminating any nonessential components was adopted.

In the model which was developed, each individually characterized driver-vehicle unit is examined separately. At selectable time intervals (from one-half to one second), the computer program makes available to the simulated driver information suck as desired speed; destination; current position, velocity, acceleration, and acceleration slope (jerk); relative position and velocity of adjacent vehicles in the system; critical distances which must be maintained; sight restrictions; and the location and status of traffic control devices. The simulated driver can (1) maintain speed, (2) accelerate, (3) decelerate, or (4) change lanes. Driver response is a function of driver and vehicle characteristics; roadway geometry; intersection and lane control; and the actions of the other driver-vehicle units in the system. The highest priority logical response of the driver-vehicle unit is determined on the premise that the driver wants to maintain a desired speed but, will obey traffic laws and will maintain safety and comfort. To implement the chosen action, a future position, velocity, acceleration, and acceleration slope (jerk) are calculated, appropriate descriptors of the driver's actions are stored, and logic values are updated.

Structured programming techniques were used in developing the necessary computer programs. Each distinct function in the computer program is isolated into a separate subprogram such that the higher-level subprograms contain mainly FORTRAN CALL statements to the lower-level subprograms. The average length of a subprogram is one to two pages of executable code. A special storage management technique is used as necessary to minimize computer storage requirements. FORTRAN IV language is used to implement the package on both Control Data Corporation (CDC6600) and International Business Machines (IBM370-155) computers. To achieve overall efficiency, computational functions which may not change during the analysis of a given intersection were isolated into a separate processor.

In this document, equations are written using standard FORTRAN IV conventions (Ref 13). Specifically, the symbol "*" denotes multiplication, the symbol "/" indicates division, and the symbol "**" represents the raising of a quantity to a power. As an example of multiplication, the equation

$$A = B*C \tag{1.1}$$

is interpreted as "A is equal to B times C". As an example of division, the equation

$$A = B/C \tag{1.2}$$

is interpreted as "A is equal to B divided by C". As an example of the raising of a quantity to power, the equation

$$A = B**C \tag{1.3}$$

is interpreted as "A is equal to B taken to the C power". In addition, standard FORTRAN IV function names are used, such as ABS, ATAN, COS, and EXP.

In this document, verification is defined as the process of ensuring that a particular algorithm for computation has been properly implemented in computer language. Calibration is defined as the process of modifying the verified computer model such that statistics gathered and reported by the model reasonably agree with the statistics gathered from field studies under similar conditions. Validation is defined as the process of ensuring that the calibrated model is valid over a wide range of conditions.

2.0 ORGANIZATION OF THE TRAFFIC SIMULATION PACKAGE

The traffic simulation package which was developed consists of two distinct components: (1) the traffic simulation portion and (2) the field data collection and analysis portion. The traffic simulation portion performs the calculations necessary to step each driver-vehicle unit through the intersection system and to gather simulated performance statistics, while the field data collection and analysis portion performs the calculations necessary for reducing observed real-world performance information to a form comparable with the simulation results.

The traffic simulation portion consists of two pre-simulation processors and the traffic simulation processor. An essential function in the pre-simulation process is defining the geometry of the intersection. A geometry processor, GEOPRO, was developed to calculate and store all geometric details that are held constant for each traffic simulation run. GEOPRO (1) takes engineering data which describe the geometry of the intersection (normally available from a plan-view diagram of the intersection), (2) calculates the vehicle paths on the approaches, the vehicle paths within the intersection, the points of conflict between intersection paths, and the minimum available sight distance between vehicles on inbound approaches, and (3) writes the geometry data onto a magnetic tape for subsequent use by the traffic simulation processor.

Another essential function in the pre-simulation process is defining the traffic stream. A driver-vehicle processor, DVPRO, was developed to characterize each driver-vehicle unit in the simulated traffic stream. DVPRO (1) takes engineering data which describe the traffic flow (normally available from routine traffic studies), (2) describes the characteristics of several driver and vehicle classes, generates individually characterized driver-vehicle units, and orders these units sequentially by queue-in time, and (3) writes the driver-vehicle data onto a magnetic tape for subsequent use by the traffic simulation processor.

Repetitious computations that are required for simulating the movement of each driver-vehicle unit through the intersection in response to the defined conditions are incorporated into a traffic simulation processor called SIMPRO. This processor (1) takes the output tapes produced by GEOPRO and DVPRO plus additional card input which describes traffic control and other parameters for the particular simulation run, (2) processes each driver-vehicle unit through the simulation system, and (3) gathers and prints performance statistics about the simulation. The interrelation among these three processors is shown in Fig 2.1.

For the field data collection and analysis portion, a new generation of field data collection and recording devices was developed to aid in collecting real-world performance statistics to be used for calibrating the simulation model and to serve as input to the simulation pre-processors. A delay recording device was developed to record observed stopped delay, queue delay, volumes, headways, and signal indications on voice-grade cassette tapes. A special time recording device was also developed to record observed headways and to time critical traffic maneuvers.

In addition, several processors were developed to process and analyze the data. To retrieve the data stored by the delay recording device, an analog-to-digital processor, ADPRO, was developed. This processor (1) takes the cassette tapes produced by the delay recording device and (2) produces a digital tape containing the collected data. A delay, volume, and headway processor, DVHPRO, (1) accepts the digital tapes produced by ADPRO and (2) calculates and prints the observed performance statistics for selected time intervals. These performance statistics can be used as input to the traffic simulation processors or to calibrate the model. A headway distribution fitting processor, DISFIT, was developed to aid in selecting appropriate mathematical descriptors of observed headway distributions. DISFIT (1) takes headways recorded by the delay recording devices or by the time recording device, (2) computes location and dispersion parameters for the data, fits selected mathematical distributions to the empirical headway data, calculates Chi-square for the Chi-squared goodness-of-fit test, and determines the maximum cumulative difference for the Kolmogorov-Smirnov one-sample test, and (3) plots a histogram of the input headway data and of each distribution fitted. The interrelation among these processors is shown in Fig 2.2.

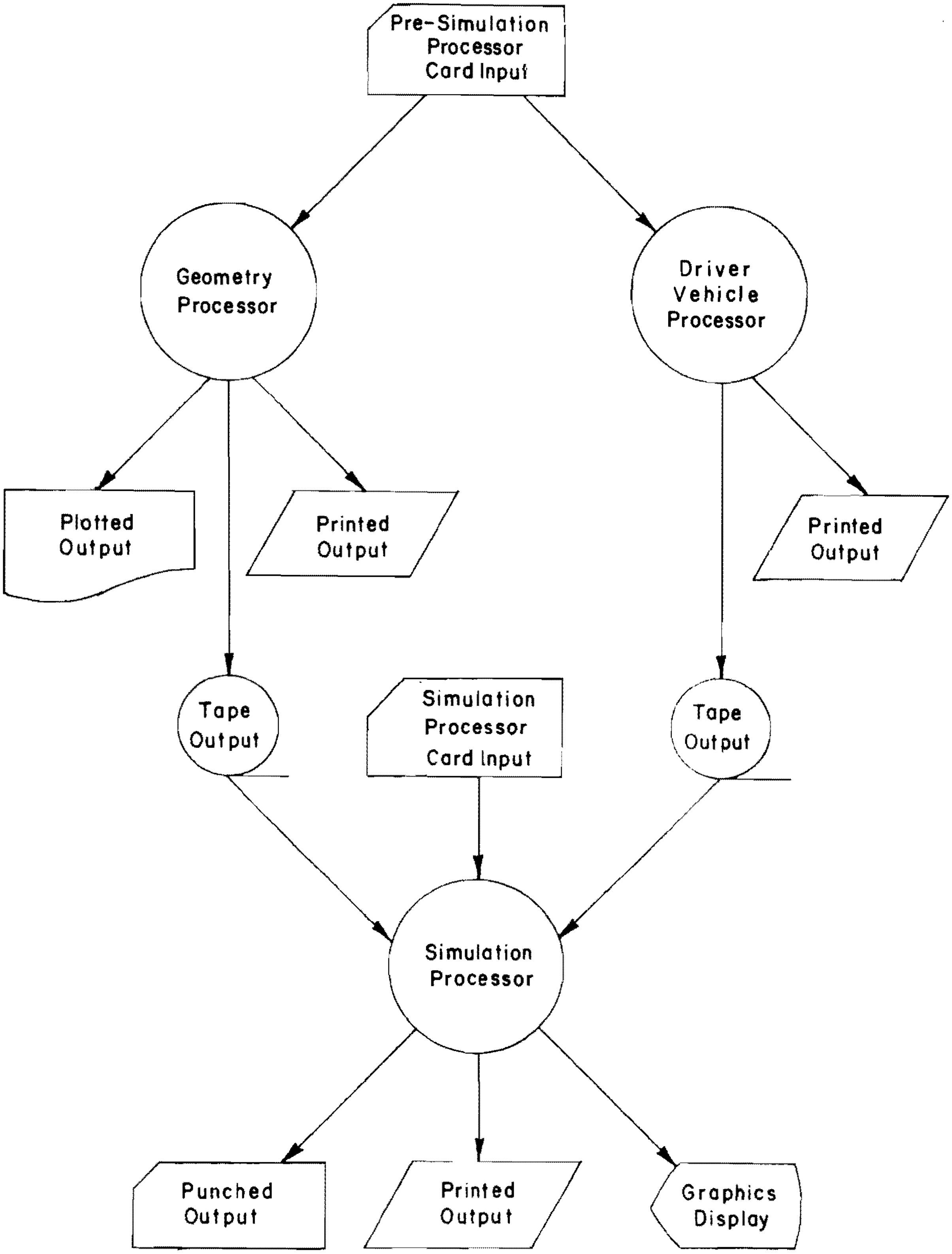


Fig 2.1. Components of the traffic simulation package.

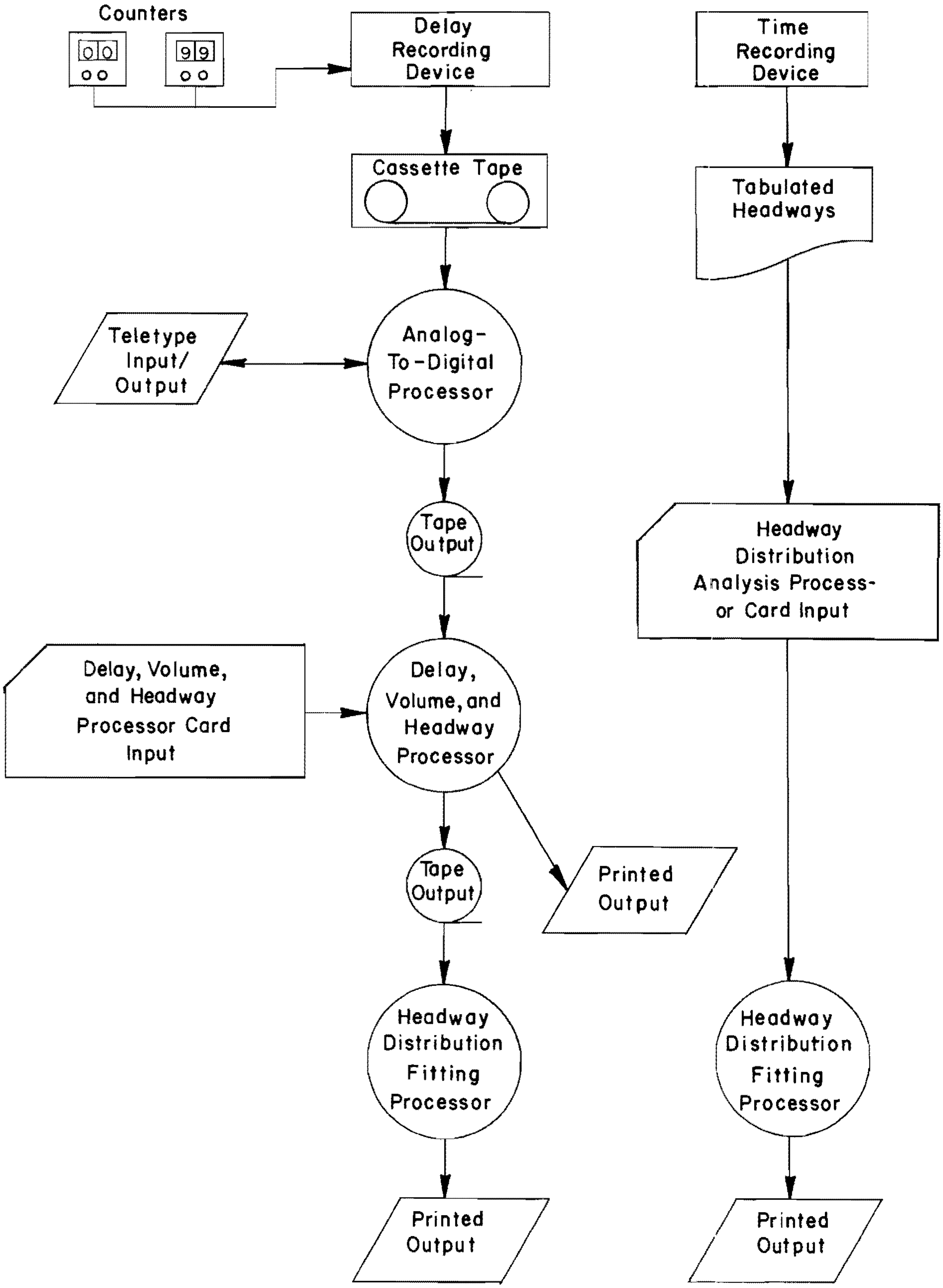


Fig 2.2. Components of the field data collection and analysis package.

3.0 THE GEOMETRY PROCESSOR

3.1 Introduction And Purpose

The geometry processor, GEOPRO, is one of the two pre-simulation processors. The purpose of GEOPRO is to calculate the vehicle paths on the approaches, the vehicle paths within the intersection, the points of conflict between intersection paths, and the minimum available sight distance between vehicles on inbound approaches. This information is processed in such a manner as to eliminate all need for Cartesian coordinate information within the traffic simulation model, but data are available which can define the coordinates for any vehicle along any path, if desired. GEOPRO writes the geometry data onto a magnetic tape for subsequent use by the traffic simulation processor. All calculations and indexing of geometry information for the traffic simulation process are included in GEOPRO. Initial development of the geometry processor has been described by Rioux (Ref 14).

3.2 Input Requirements

The geometry processor accepts as input the engineering data describing the physical layout of the intersection. This data is normally available from a plan-view diagram of the intersection. The generalized input to GEOPRO is shown in Table 3.1. The geometry processor options allow the user to define the type of intersection paths to be generated, to request the type of plot output desired, and to set the values of some parameters used in the calculations. A detailed explanation of the input and its format is contained in "The TEXAS Model for Intersection Traffic - User's Guide" (Ref 15). Extensive input error checking is performed by GEOPRO to ensure that certain data are within defined bounds, that all necessary information is provided, and that certain information is not duplicated. The geometry processor will print a message which describes the input error and then stop. There are 59

Table 3.1 Generalized Input to the Geometry Processor

1. Title for the geometry processor run
2. Approach information
   a. Number and list of inbound and outbound approaches
   b. Azimuth for each approach
   c. Coordinates for start of each approach
   d. Speed limit for each approach (mi/hr)
   e. Number of lanes for each approach
   f. Maximum angular deviation of straight-through movement for each approach
   g. Maximum angular deviation of u-turn movement for each approach
3. Lane information
   a. Width of each lane (ft)
   b. Geometry of each lane
      1. Full length of lane available
      2. First of lane available only
      3. Last of lane available only
      4. Lane blocked in middle only
   c. Turning movements which can be generated from each inbound lane
   d. Turning movements which can be accepted by each outbound lane
4. Arc information (for plotting)
   a. Number of arcs
   b. Coordinates for center of each arc
   c. Beginning azimuth of each arc
   d. Sweep angle of each arc
      1. Positive for clockwise
      2. Negative for counter-clockwise
   e. Radius of each arc (ft)
5. Line information (for plotting)
   a. Number of lines
   b. Coordinates for beginning point of each line
   c. Coordinates for end point of each line

(continued)

Table 3.1 (continued)

6. Sight distance restriction information
    a. Number of sight distance restriction points
    b. Coordinates of each sight distance restriction point
7. Geometry processor options
    a. Path type option (PRIMARY/OPTION1)
    b. Plot option (PLOT/PLOTI/NOPLOT)
    c. Plot framing option (SAME/SEPARATE) (if plot requested)
    d. Plot scale factor (ft/in) (if plot requested)
    e. Maximum radius of arc portion of intersection paths (ft)
    f. Maximum distance between two intersection paths for an intersection conflict to be detected (ft)
    g. Plot paper width (12/30 inches)

input errors detected by GEOPRO.

3.2.1 Input For Approaches

In developing the input for GEOPRO, the user refers to a plan-view diagram of the intersection under study and determines which direction shall be referenced as zero degrees azimuth. The user then numbers each inbound approach (one which feeds traffic into the intersection) and each outbound approach (one which carries traffic away from the intersection). The approach numbers may be arbitrarily assigned but must be in the range from 1 to 12 and must not be duplicated. The recommended procedure is to start numbering the inbound approaches from the top of the diagram (zero degrees azimuth) and proceed sequentially in a counter-clockwise direction until all inbound approaches are numbered, and then to sequentially number the outbound approaches in the same manner. A normal four-leg intersection will have four inbound and four outbound approaches. For the inbound approaches, the southbound approach will be number 1, the eastbound approach will be number 2, the northbound approach will be number 3, and the westbound approach will be number 4. For the outbound approaches, the northbound approach will be number 5, the westbound approach will be number 6, the southbound approach will be number 7, and the eastbound approach will be number 8. The user then determines the direction of traffic flow (azimuth) and the Cartesian coordinates (between 0 feet and 2250 feet [686 meters]) of the median edge (left edge) of the approach in the direction of traffic flow. Also noted are the speed limit and the number of lanes. In order to define the type of movement for each generated intersection path for each inbound approach, the user must supply the number of degrees left or right of approach azimuth that is to be considered a straight-through movement and the number of degrees left or right of a full 180 degree turn that is considered a U-turn (see Fig 3.1). It is necessary to designate the turn type in this manner so that paths can be defined properly for certain skewed intersections and for intersections with more than four legs.

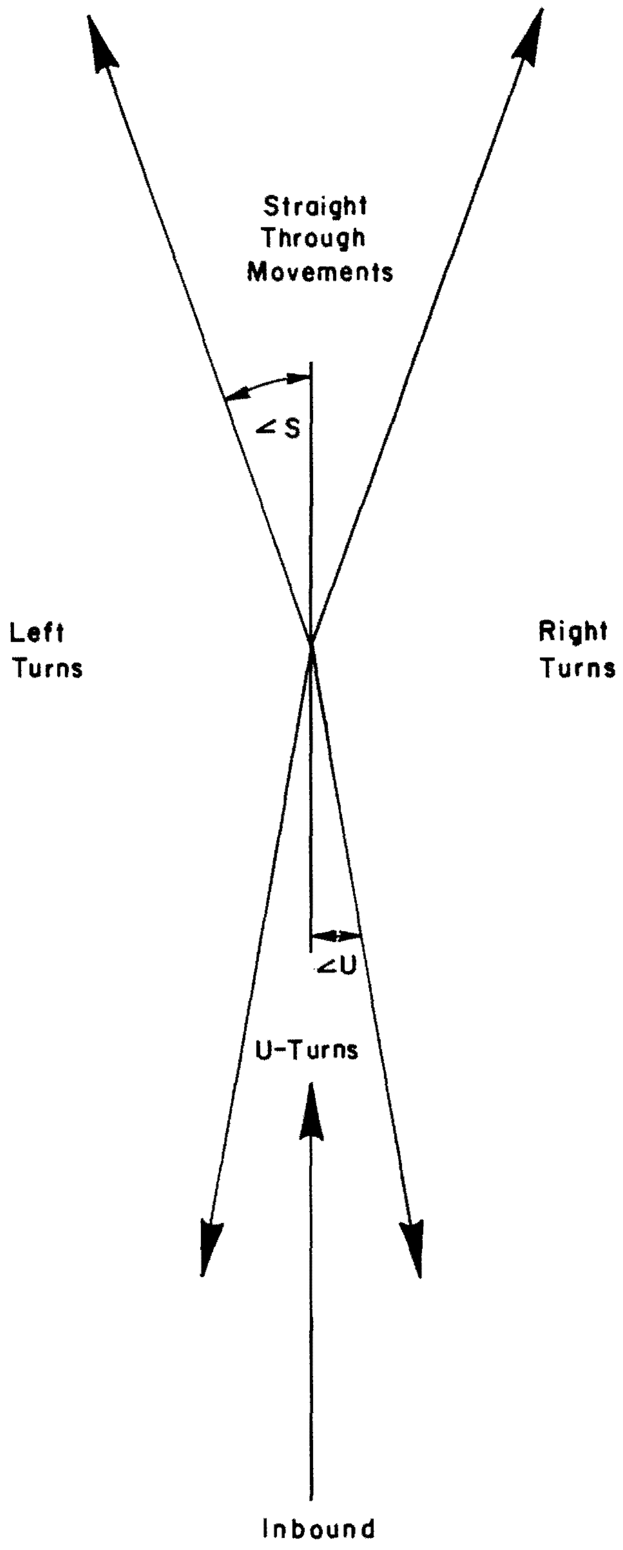


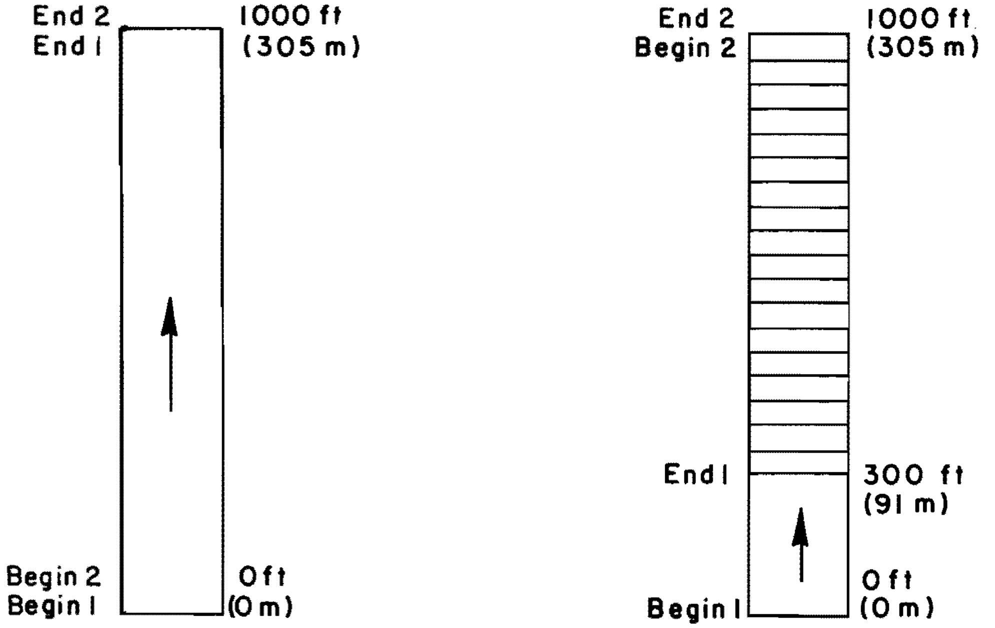
Fig 3.1. Definition of type of movement.

3.2.2 Input For Lanes

For each lane, the user must specify the width, where the lane is available and not available for traffic, and the turning movements which can be generated from the lane (if an inbound lane) or the turning movements which can be accepted by the lane (if an outbound lane). GEOPRO accommodates four types of lanes (see Fig 3.2): (1) the full length of the lane is available, (2) only the first part of the lane is available, (3) only the last part of the lane is available, and (4) the middle part of the lane is not available. When describing the turning movements that the lane can accommodate, the user can specify U-turn, left turn, straight-through movement, and/or right turn. If a plot is requested, these specifications are plotted as arrows at the end of each inbound lane and at the start of each outbound lane to provide the user with a visual check. These specifications are illustrated in Fig 3.3. In the top half of this figure, a normal intersection is shown, and in the bottom half, an example of an intersection with channelized right-turn bays is presented. Note that if outbound lane B is also designated for accepting straight-through movements, an intersection path connecting inbound lane A and outbound lane B will be generated by GEOPRO. After all the intersection paths are generated, a check is performed to ensure that an intersection path is available for each turning movement that is specified for each inbound lane. If not, an execution error message is printed and GEOPRO stops.

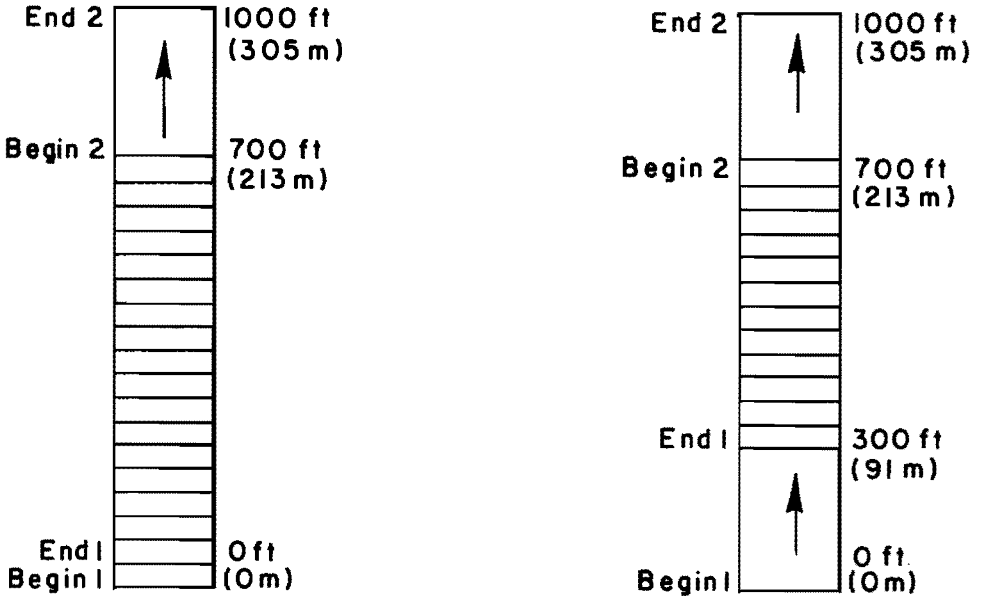
3.2.3 Input For Arcs And Lines

To improve the quality of plot output, the user may specify arc segments of simple circles and straight line segments that are to be drawn by GEOPRO. These are used to delineate curb returns, houses, buildings, detectors, and other objects GEOPRO would not normally plot.



Full Length of the Lane is Available

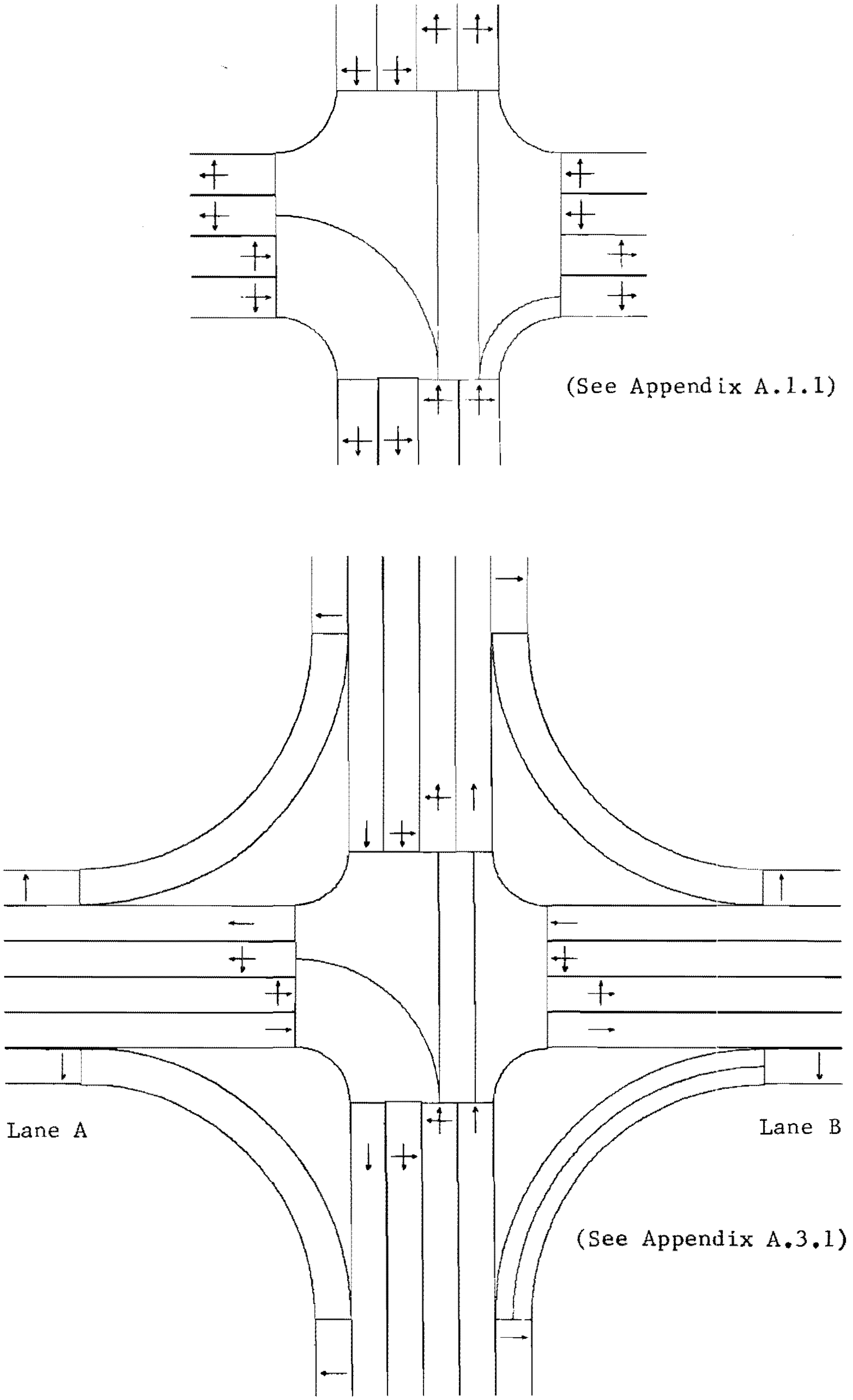
Only the First Part of the Lane is Available



Only the Last Part of the Lane is Available

The Middle Part of the Lane is not Available

Fig 3.2. Definition of lane geometry.



(See Appendix A.1.1)

(See Appendix A.3.1)

Fig 3.3. Turning movement specification.

3.2.4 Input For Sight Distance Restrictions

If there are sight distance restrictions, the user provides coordinates of critical points along the obstruction. The geometry processor considers only horizontal alignment sight distance restrictions and does not accommodate vertical alignment sight obstructions. When checking for restrictions, it is assumed that a vertical wall extends in a straight line from the start of the other approach to the specified coordinates. Thus, a continuous obstruction may normally be represented by specifying a single coordinate.

3.2.5 Input For Geometry Processor Options

The geometry processor path type option allows the generation of PRIMARY intersection paths, where no lane changing within the intersection is allowed, or OPTION1 intersection paths, where the intersection paths may change not more than one lane. Examples of PRIMARY intersection paths are illustrated in Fig 3.4 and examples of OPTION1 intersection paths are shown in Fig 3.5.

The plot option allows the user to specify NOPLOT; PLOT, for ball point pen plots; and PLOTI, for ink pen plots. The plot framing option controls the plotting of the generated intersection paths: SAME, for intersection paths for all inbound approaches drawn on the same plot frame; or SEPARATE, for the intersection paths for each inbound approach drawn on separate plot frames. Figures 3.3, 3.4, and 3.5 are examples of the use of the SEPARATE plot frame option. The user may also specify (1) the plot scale factor, in ft/in, for the plot of the entire intersection and approach area and (2) the plot scale factor, in ft/in, for the enlargement of the intersection area only. If the user does not specify these plot scale factors (or if a plot scale factor is too small for the plot paper width) and a plot has been requested, GEOPRO will select the appropriate scale factor, from a list of normal scale factors, which will maximize the size of the plot within the available plot paper width. The plot paper width can be specified by the user as 12 inches (0.3048 meters) or 30 inches (0.762 meters). The user can also specify the maximum radius for the arc portion of an intersection path. If a generated intersection path has a radius which is larger than the maximum

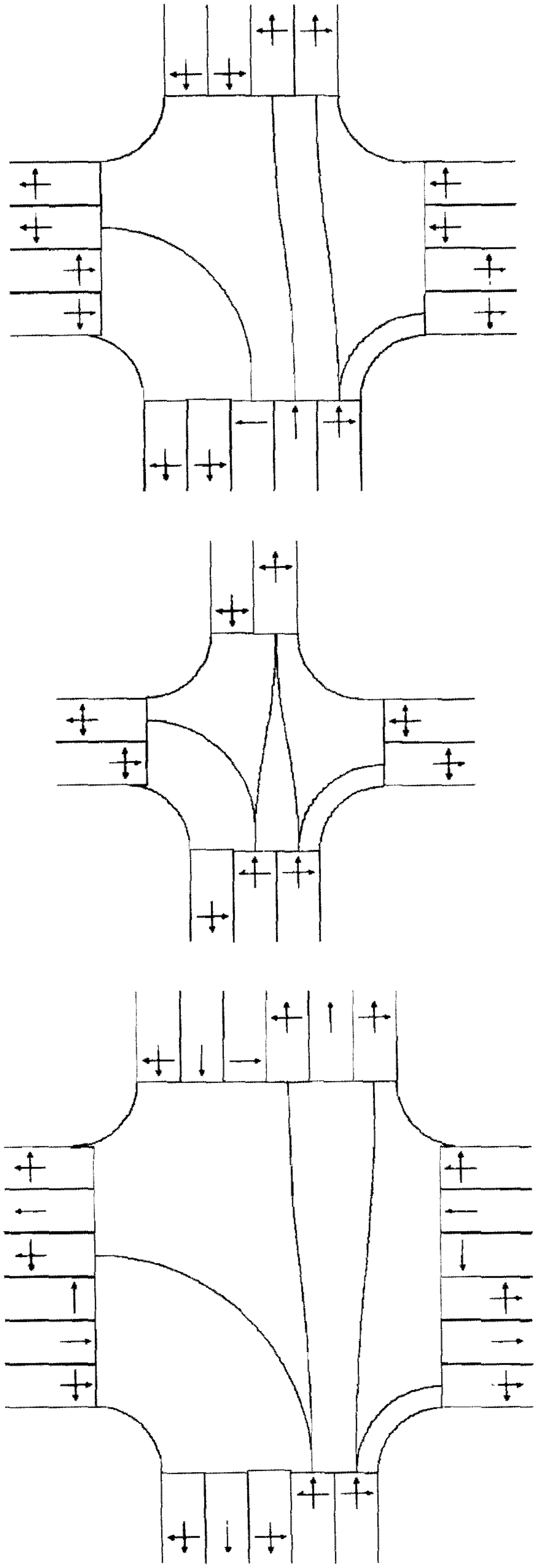


Fig 3.4. PRIMARY intersection paths.

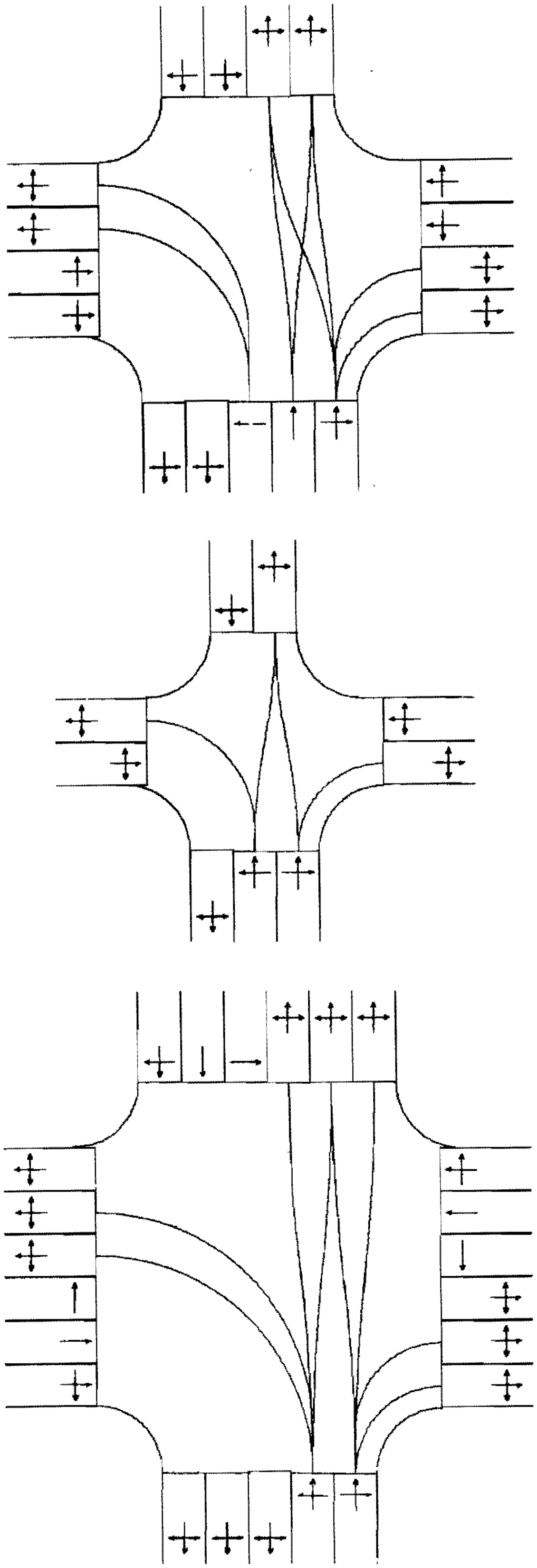


Fig 3.5. OPTION1 intersection paths.

specified, then GEOPRO will replace the path with a straight line segment path. Also specified is the maximum distance between two intersection paths for which an intersection conflict can be detected. This is the distance, for example, between two opposing left turns that would cause the vehicles to sideswipe each other even though the intersection paths do not cross. This value should therefore be a minimum of one vehicle width plus a margin of safety.

3.3 Algorithms For Computation

The traffic simulation processor is designed to simulate the movement of driver-vehicle units on the approaches and through the intersection. To minimize the execution time and computer storage requirements of the traffic simulation processor, the coordinates of the position of each driver-vehicle unit are not calculated or kept during the simulation. Instead of coordinates, the distance that each unit travels along a predefined path is computed, no matter what the configuration of the path. Once a unit reaches the end of a path, it is transferred onto another path in accordance with the desired destination of the unit. It is the function of the geometry processor to calculate the shape and length of all paths that are used by the traffic simulation processor.

3.3.1 Data Structure

GEOPRO uses a special storage management and logic processing routine called COLEASE. Chapter 6 discusses COLEASE in more detail. This program accomplishes two objectives: (1) it provides a mechanism for storing specified variables in a format which maximizes computer bit storage by disregarding normal word boundaries and (2) it establishes an efficient means for processing logical binary networks. The geometry processor does not use the logic processing capabilities of COLEASE.

The user of COLEASE defines entities, which are groups of attributes (variables). GEOPRO has 7 entities whose names are: APPRO (approach attributes), ARC (arc attributes), CONFLT (intersection conflict attributes), LANE (inbound and outbound lane attributes), LINE (line attributes), PATH (intersection path attributes), and SDR (sight distance restriction attributes).

In GEOPRO, there is an array called LIBA, in COMMON block GEOPRO, which is the list of inbound approaches. A value in LIBA serves as a pointer to the entry in the APPRO entity which contains information about the inbound approach. Likewise, there is an array called LOBA, also in COMMON block GEOPRO, which is the list of outbound approaches. A value in LOBA is a pointer to the entry in the APPRO entity which contains the information about the outbound approach. The number of inbound approaches, NIBA, and the number of outbound approaches, NOBA, are also in COMMON block GEOPRO.

An attribute of the APPRO entity is the number of lanes, NLANES, and a corresponding list of lanes, LLANES. A value in LLANES serves as a pointer to the entry in the LANE entity which contains the information about the lane. Another attribute of the APPRO entity is the number of sight distance restrictions, NSDR, the list of sight distance restriction numbers, ISDRN, and the list of sight distance restriction approach numbers for the other approach involved in the sight distance restriction, ISDRA.

An attribute of the LANE entity is the number of intersection paths, NPINT, and the list of intersection paths, LPINT, connected to the lane (if an inbound lane).

An attribute of the PATH entity is the number of geometrically conflicting intersection paths, NGEOCP, and the list of geometrically conflicting intersection paths, IGEOCP. The PATH entity also has attributes which define the linking outbound approach, LOBAP, and the linking outbound lane, LOBL.

The entities in GEOPRO contain numerous other attributes which describe the intersection being processed. A total of 24,782 attributes are stored by COLEASE. On CDC computers, these attributes and their bookkeeping data are stored in 4,254 60-bit computer words (5.83 attributes per computer word) while on IBM computers, these attributes and their bookkeeping data are stored in 7,708 32-bit computer words (3.22 attributes per computer word).

3.3.2 Vehicle Paths

For the paths on the approaches, the traffic simulation processor needs the approach number and the lane number in which each path lies, the portions of the path that are available for traffic flow, the speed limit for vehicles on the path, and the intersection paths which originate from each inbound lane. For the paths within the intersection, the traffic simulation processor must know the approach number and the lane number of the inbound approach from which each path enters the intersection, the approach number and the lane number of the outbound approach where the path departs the intersection, the length of the path, the type of turning movement, the speed limit of vehicles on the path, the minimum turning radius of the path, and the potential points of conflict between other intersection paths.

3.3.3 Approach Paths

For the paths on the approach, the geometry processor generates a path that goes exactly down the middle of the lane if the lane width is an even number of feet. If the lane width is an odd number of feet, the geometry processor generates a path that lies one-half foot (0.1524 meter) towards the median edge (left edge) from the exact middle of the lane.

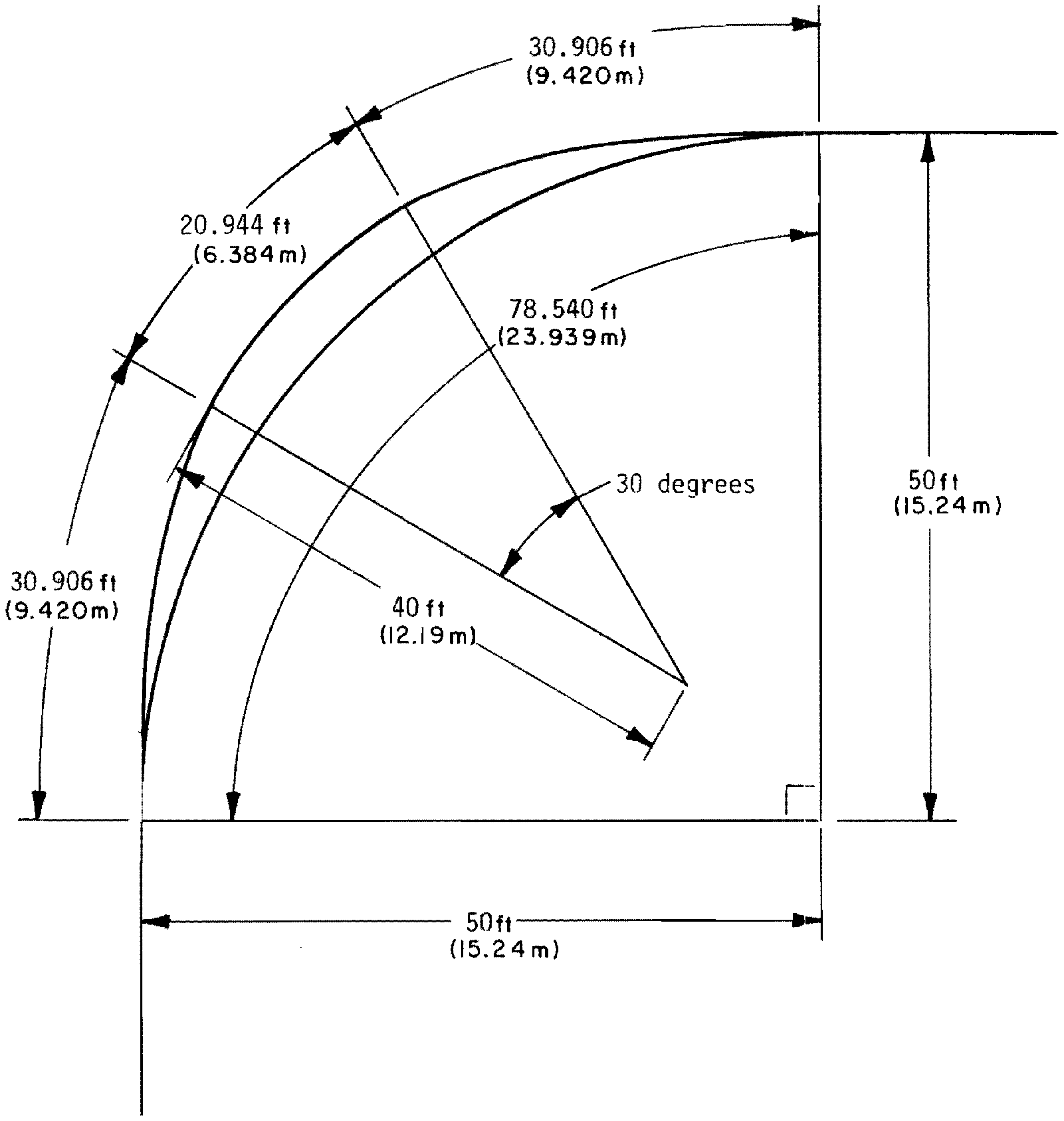
3.3.4 Intersection Paths

For paths within the intersection, an approximation of the actual geometry of turning paths is utilized. When making a turn within an intersection, a vehicle is normally steered from a straight path (a curve that has an infinite radius) to a path which has some finite, constant radius and then again to a straight path. The portion of the path that has a finite constant radius is simply an arc of a circle. Since it is impossible for the path of the vehicle to change instantaneously from an infinite radius to some finite radius, a transition path is developed in entering and leaving the circular portion. A spiral (clothoid) curve, which changes radius in direct proportion to the distance along the curve, is frequently used to approximate this transition curve (Ref 16). To minimize the amount of information required to describe each path within the intersection and to minimize the complexity of the calculations of the coordinates of any point along the simulated vehicle path, no transition curves are used in the geometry processor. Only straight line segments and arcs of circles are used to describe intersection paths. This approximation is felt to be justified since the precision is consistent with other elements in the traffic simulation procedure. For example, there is only about a 5 percent difference in the length of the path described by a simple circular curve and in a comparable path which incorporates two spiral transition curves (see Fig 3.6).

3.3.5 Intersection Path Geometry

In order to be able to plot the intersection path and to possibly calculate the Cartesian coordinates of a vehicle on an intersection path, adequate information must be calculated by GEOPRO to fully describe the geometry of each path. An intersection path has been adopted which contains one or more of four sequential segments. The first segment is a straight line, the second segment is an arc of a circle, the third segment is also an arc of a circle but the rotation is the reverse of that of the second segment, and the fourth segment is a straight line. All paths within the intersection can be described by one or more of these segments in sequence. A segment length of zero means that the segment is not used in describing the intersection path.

For the straight line segments, the Cartesian coordinates of the start and end points of the line and the length of the segment are determined. For the arc segment, the Cartesian coordinates of the center of the circle, the beginning azimuth of the arc, the central angle subtended by the arc (positive for clockwise rotation and negative for counter-clockwise rotation), the radius of the circle, and the length of the arc segment are found.



Length of Simple Circular Curve, R=50ft, 90 Degree Turn	= 78.540 ft (23.939 m)
Length of Spiral Transition Curves Plus Simple Circular Curve Through 30 Degrees, 90 Degree Turn	=82.756 ft (25.224 m)
% Difference	= − 5.095

Fig 3.6. Comparison of the length of paths along a simple circular curve and along spiral transition curves plus a central circular curve.

Using the four segments of the intersection path, the five possible path configurations are (1) a single straight line (segment 1 only), (2) a single arc of a circle (segment 2 only), (3) a reverse circular curve (segment 2 followed by segment 3), (4) a straight line followed by an arc of a circle (segment 1 followed by segment 2), and (5) an arc of a circle followed by a straight line (segment 2 followed by segment 4). Figure 3.7 demonstrates examples of these five path configurations (path 5 in this figure would normally be illegal for the intersection).

3.3.6 Radius Of Arc For Intersection Paths

In selecting the radius of the circular curve used to describe an intersection path, the maximum feasible radius is chosen. This is done because the largest radius allows the maximum speed on the path. This requires the minimum braking and steering wheel rotation by the driver. If the radius of an arc for the path is greater than some specified maximum, a straight line is used instead of an arc of a circle. Figure 3.8 illustrates the difference in length between a 500-foot (152.4-meter) radius reverse circular curve path and a straight line segment path.

3.3.7 Intersection Path Turn Movement Type

To determine the turn movement type, the angle that the vehicle must turn through to negotiate the path is calculated and compared with the angle which defines the type of movement for the approach (see Fig 3.1). The U-turn is normally considered to be a full 180-degree turn, but an allowance has been made to permit the user to specify how many degrees less than a full 180-degree turn is classified a U-turn. Therefore, if the user wanted a 160-degree turn to be classified a U-turn, a value of 20 degrees would be input. The straight-through movement is normally considered to be exactly straight ahead, but again the user may specify how many degrees less than or greater than exactly straight ahead is considered a straight-through movement.

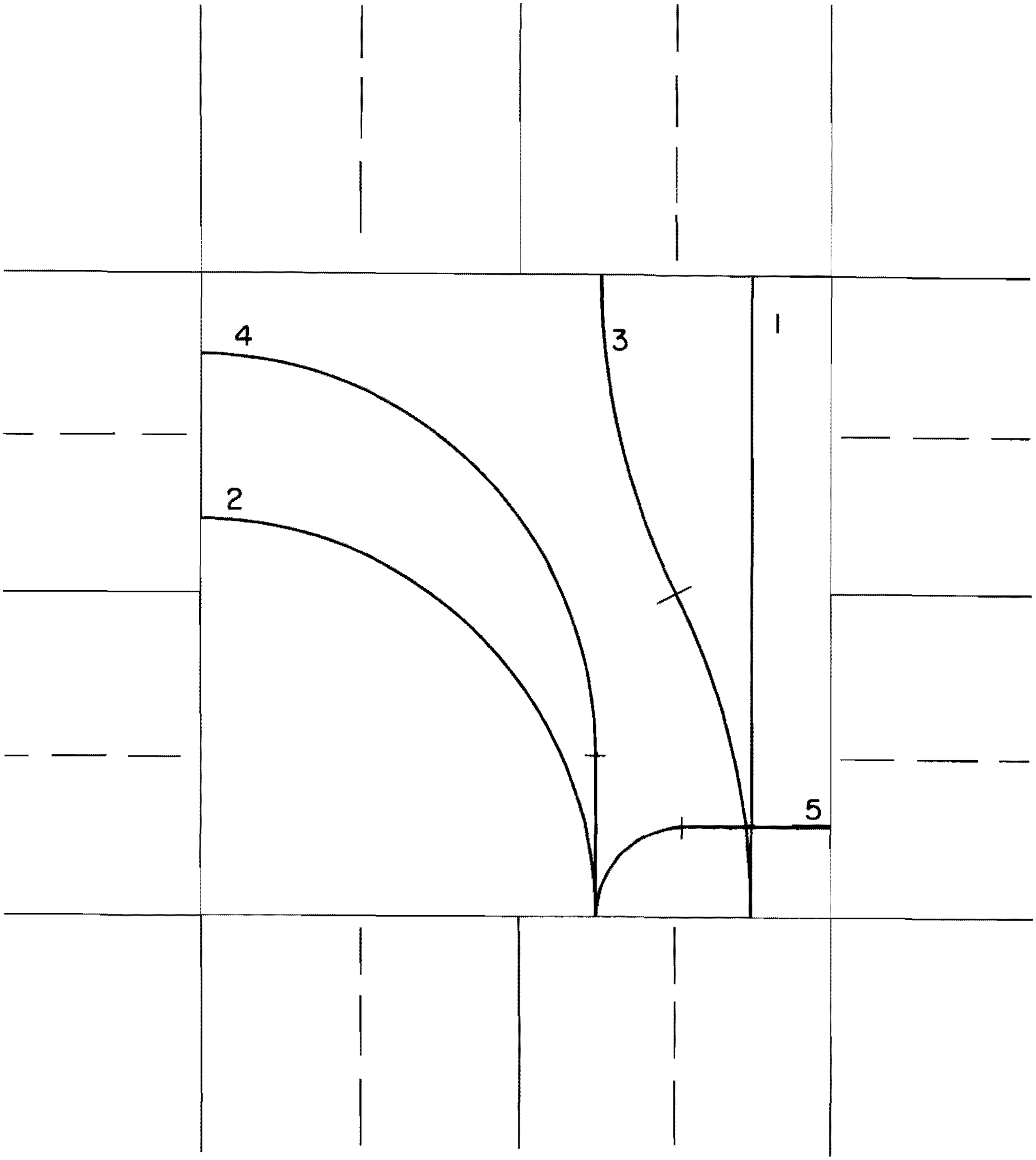
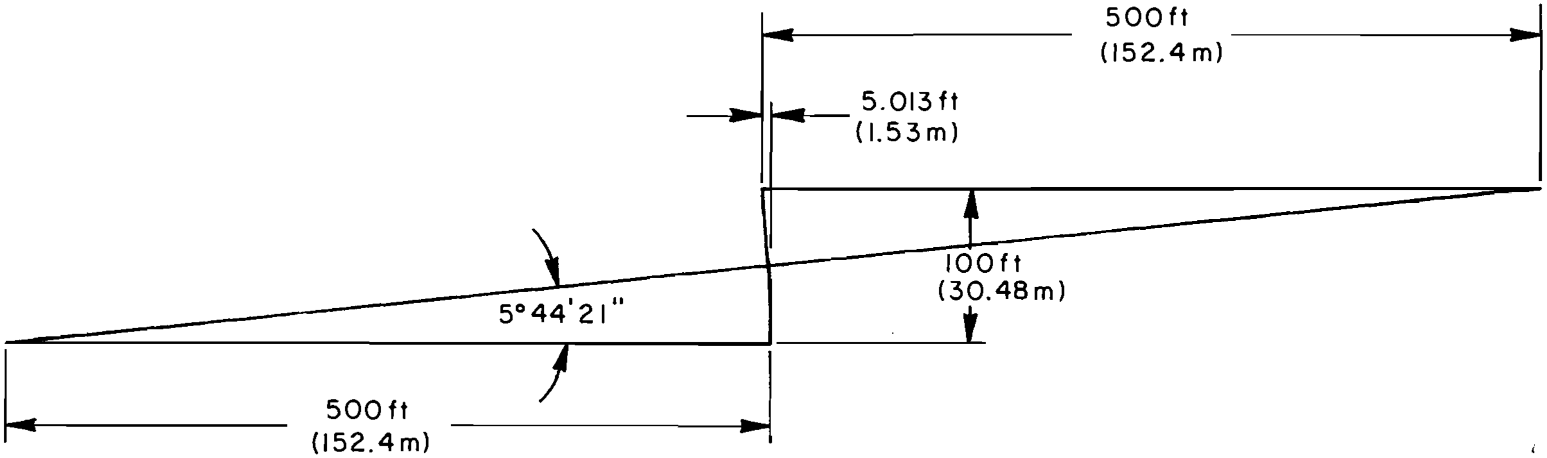


Fig 3.7. Examples of possible intersection path configurations.



Length of 500 ft (152.4m) Radius Reverse Circular Curve = 100.167 ft (30.531m)
Length of Straight Path = 100.126 ft (30.518m)
% Difference = -0.0418

Fig 3.8. Comparison in length between a 500-foot (152.4-meter) radius reverse circular curve path and a straight line segment path.

A left turn is thus any turn to the left that has not been classified as a U-turn or a straight-through movement. A right turn is any turn to the right that has not been classified as a U-turn or a straight-through movement.

Before the paths within the intersection are calculated, the coordinates of the center of the end of each inbound lane and the center of the start of each outbound lane are determined. Because the type of turn is not known until the calculations for the intersection path are finished, a path is generated from each inbound lane to every outbound lane. After the properties of a particular intersection path are calculated, the path turn type is determined and the intersection path is checked to ensure that it is a legal maneuver for the inbound and outbound lanes. Only one intersection path is generated from an inbound lane to an outbound lane. To simplify the calculations of the properties of an intersection path, all necessary coordinates are rotated by the negative value of the azimuth of the inbound lane. This rotation makes the inbound lane artificially point north (zero azimuth); thus, if the rotated X coordinate of the outbound lane is less than the rotated X coordinate of the inbound lane, the intersection path could be a left turn. If the rotated X coordinate of the outbound lane is greater than the rotated X coordinate of the inbound lane, the intersection path could be a right turn.

3.3.8 R Critical And Y Critical

When the properties for an intersection path are being calculated, the angle of the turn is the number of degrees that the vehicle would turn through going from the inbound to the outbound lane (denoted as JANGLE in the following figures and in GEOPRO). The absolute value of the distance perpendicular to the inbound lane from the end point of the inbound lane to the starting point of the outbound lane is called the ADX distance. The absolute value of the distance parallel to the inbound lane from the end point of the inbound lane to the starting point of the outbound lane is called the ADY distance. As shown in Fig 3.9, for a specific ADX distance and a specific JANGLE, there is a unique ADY distance such that an arc of a circle is exactly tangent to both the end of the inbound lane and the start of the outbound

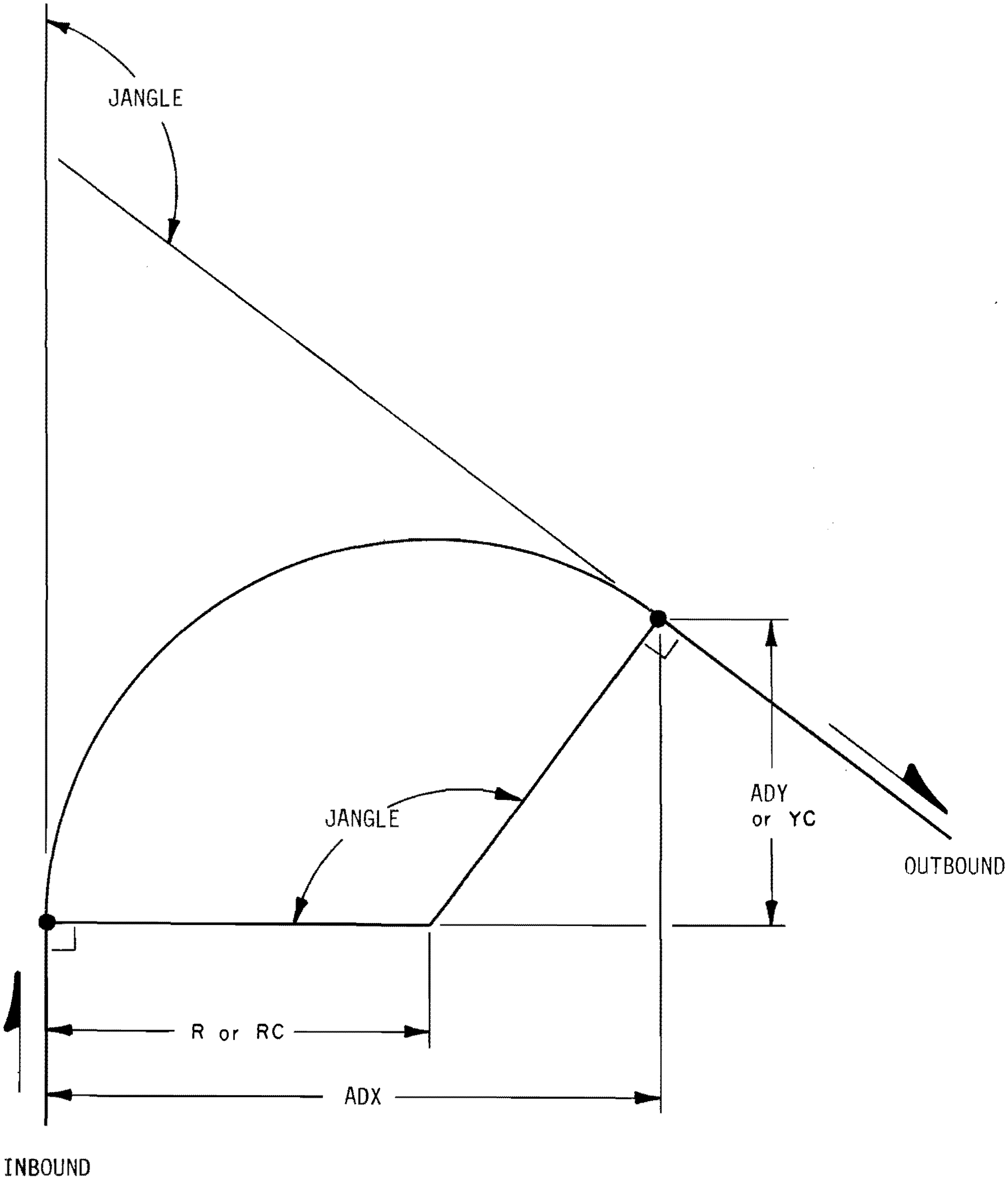


Fig 3.9. Conceptualization of R critical and Y critical.

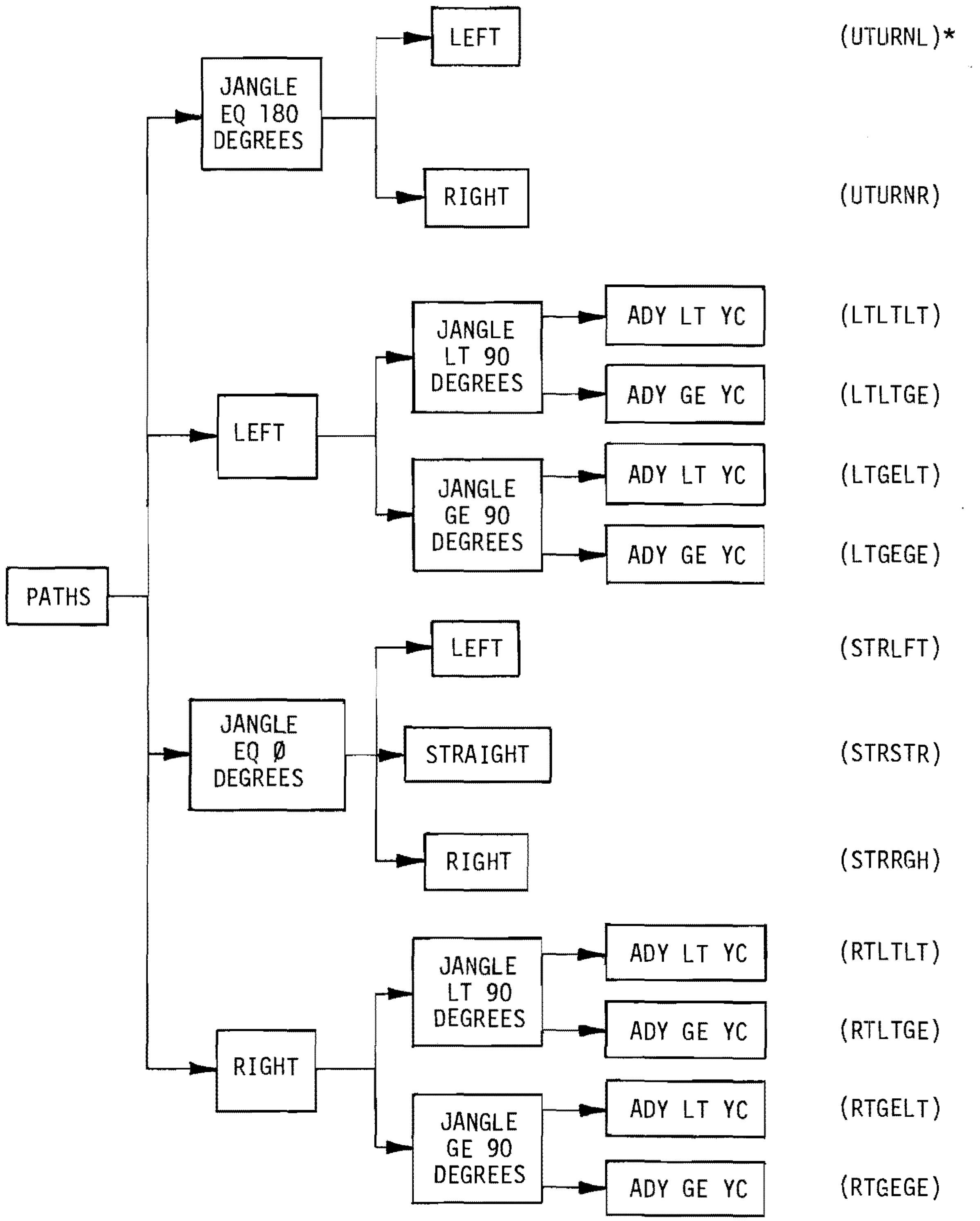
lane. The radius of this arc is called R critical (denoted RC in the figures and GEOPRO) and the ADY distance is called Y critical (denoted YC in the figures and GEOPRO). Figure 3.10 shows the flow process used to determine the appropriate subprogram which GEOPRO uses to calculate the properties for the intersection paths.

3.3.9 U-turns

The calculations for the left and right U-turns (JANGLE equal to 180 degrees) calls for the radius to be one-half of the ADX distance and if there is a non-zero ADY distance, a straight line segment is added before or after the arc segment with a length equal to the ADY distance (see Fig 3.11 and Fig 3.12).

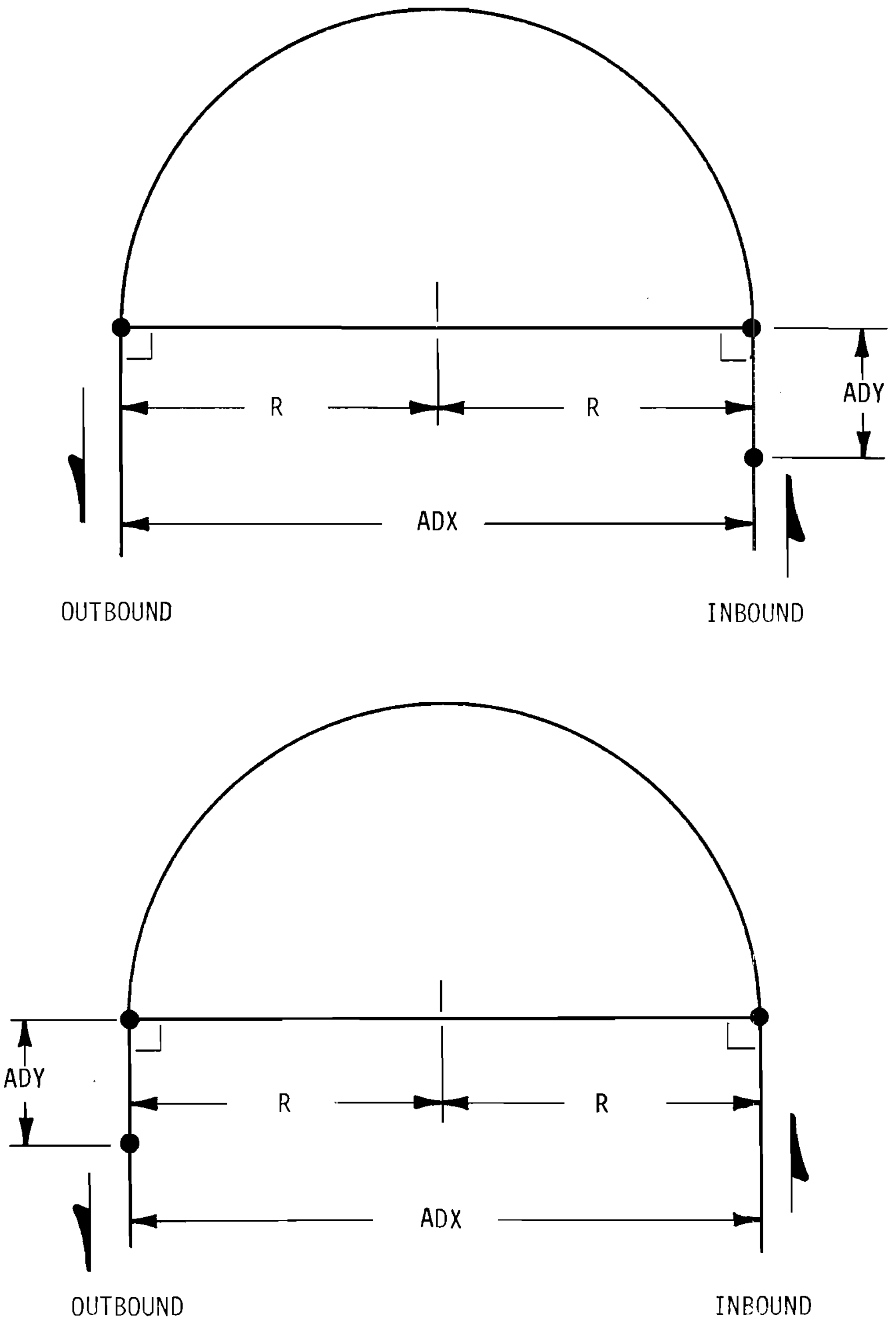
3.3.10 Left Turns

The calculations for R critical and Y critical are shown in Fig 3.13 for left turns of less than 90 degrees (JANGLE not equal to zero degrees). For an ADY distance less than Y critical, a straight line segment is calculated (with a length equal to the Y critical distance minus the ADY distance) following an arc with a radius less than R critical (see Fig 3.14). For the unusual case where the projections of the inbound and outbound approach paths do not intersect within the intersection area, a special reverse circular curve is calculated. The basic premise of the reverse curve is that the radii of both arcs are equal, thus producing the fastest intersection path. From the calculations shown in Fig 3.15, the equation for the radius of the arc is calculated using the quadratic formula. For an ADY distance greater than or equal to Y critical, a straight line segment is calculated (with a length equal to the ADY distance minus the Y critical distance) preceding an arc with a radius equal to R critical (see Fig 3.16).



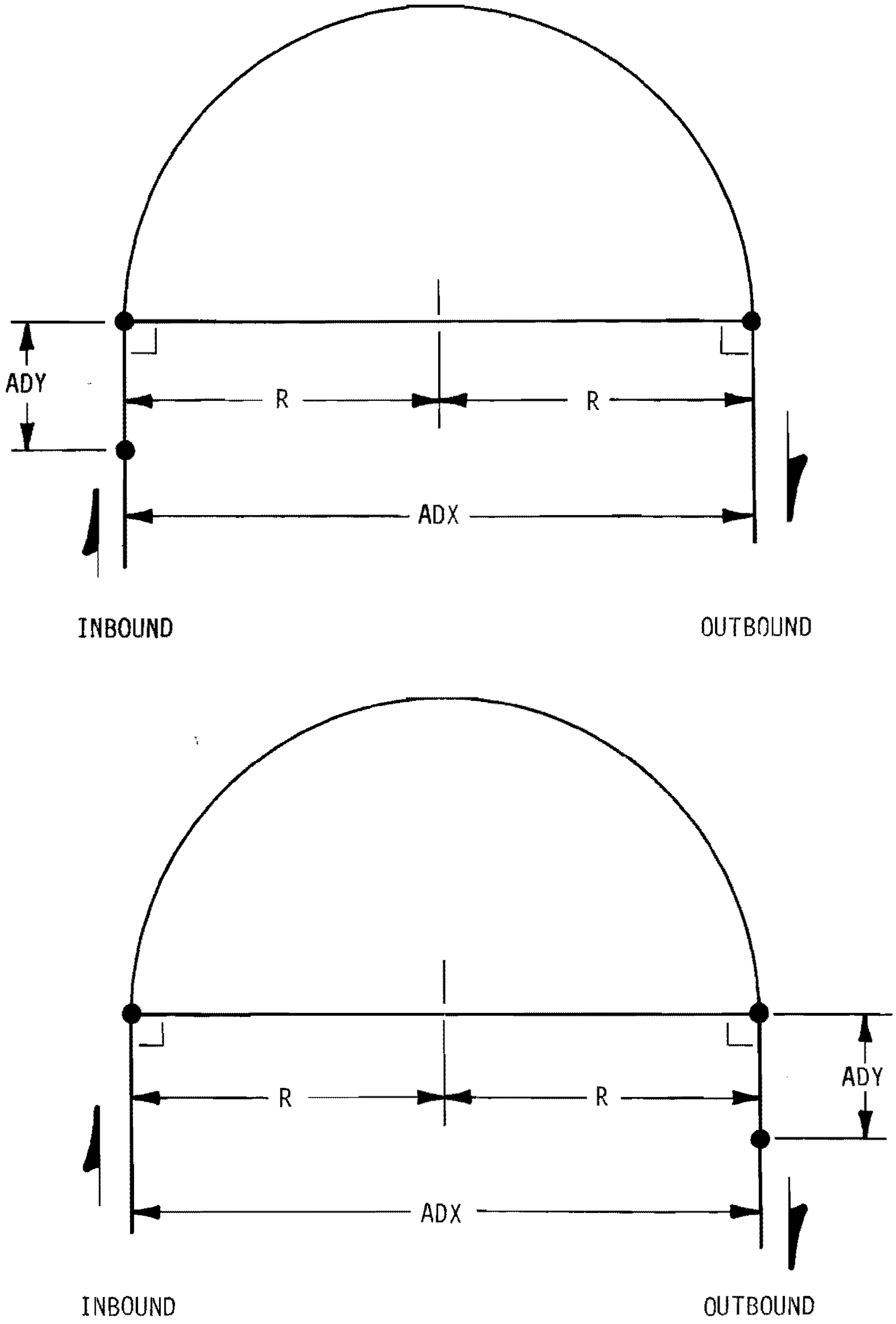
*(name) INDICATES THE SUBROUTINE NAME IN GEOPRO FOR CALCULATION OF PATH

Fig 3.10. Flow process used to determine the appropriate subroutine which GEOPRO uses to calculate the properties for the intersection paths.



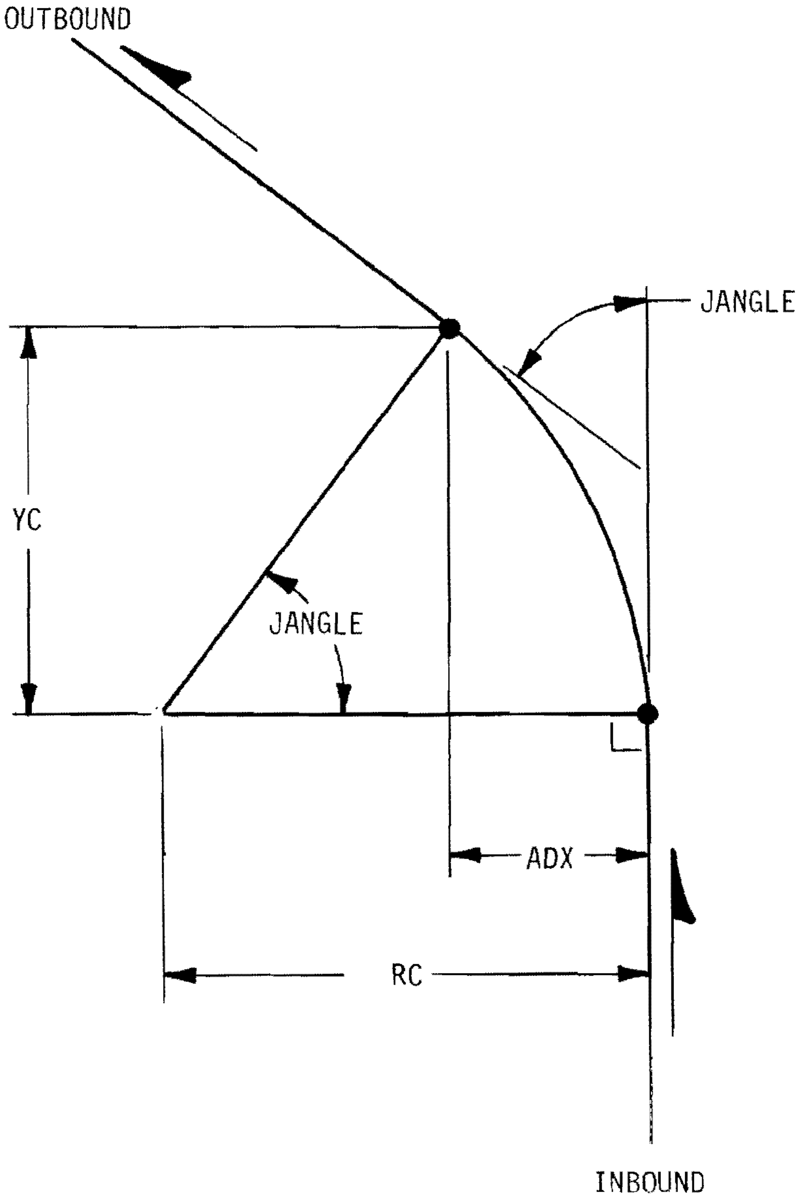
R = ADX / 2

Fig 3.11. **Calculations for left U-turns.**



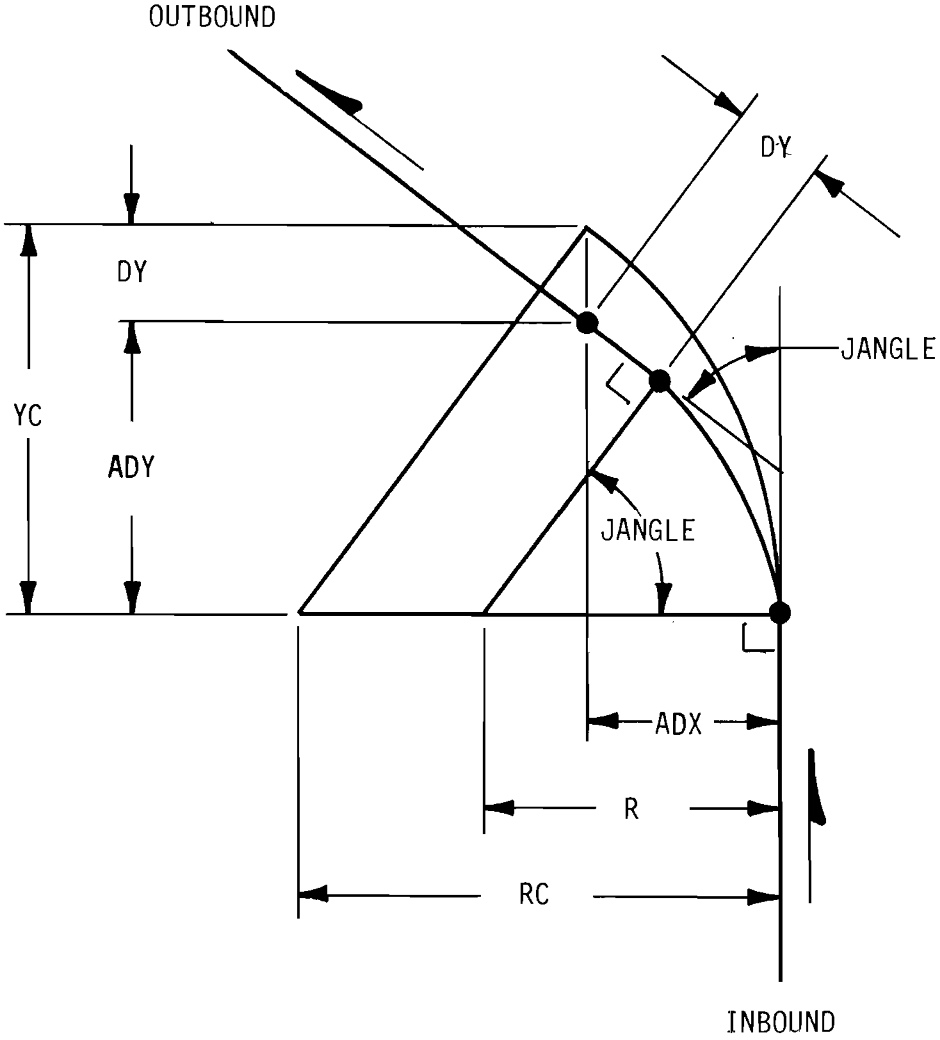
$R = ADX / 2$

Fig 3.12. Calculations for right U-turns.



RC - RC*COS(JANGLE) = ADX
RC*(1-COS(JANGLE)) = ADX
RC = ADX / (1-COS(JANGLE))
YC = RC*SIN(JANGLE)

Fig 3.13. RC and YC calculations for left turns less than 90 degrees.



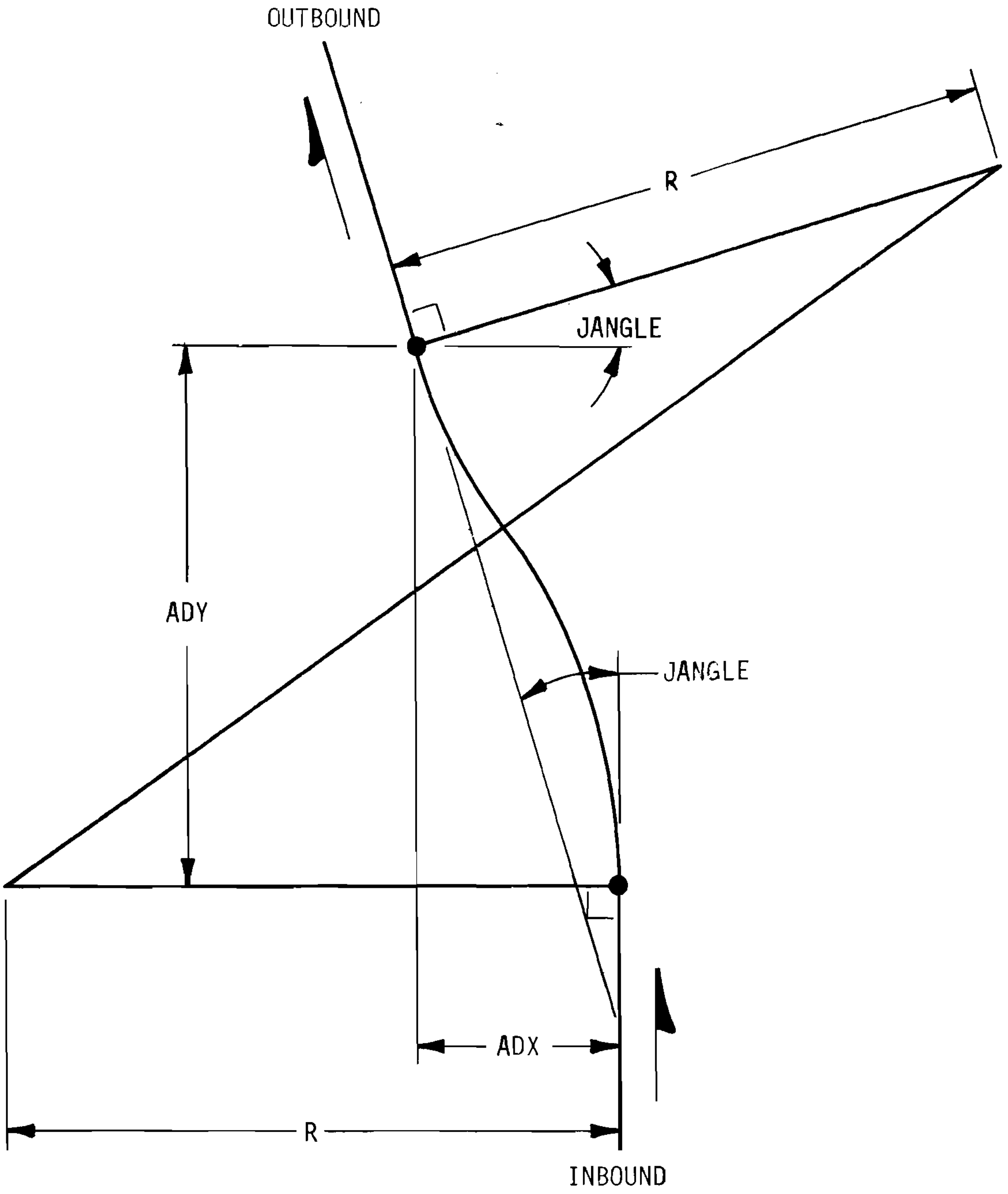
DY = YC - ADY

R - R*COS(JANGLE) + DY*COS(90-JANGLE) = ADX

R*(1-COS(JANGLE)) = ADX - DY*COS(90-JANGLE)

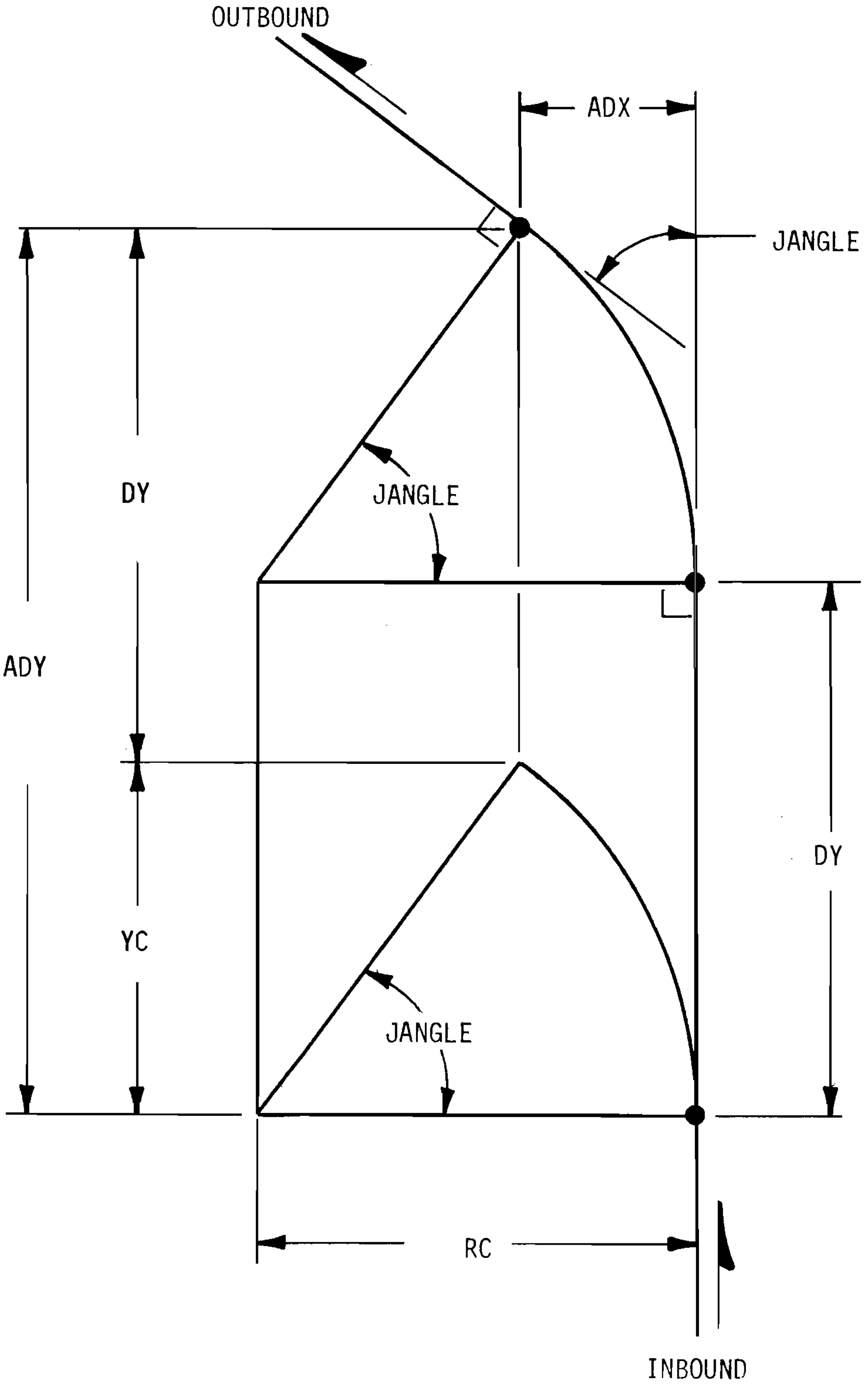
R = (ADX - DY*COS(90-JANGLE)) / (1-COS(JANGLE))

Fig 3.14. **Calculations for left turns less than 90 degrees and ADY less than YC .**



```
2*R = SQRT((R-ADX+R*COS(JANGLE))**2+(ADY+R*SIN(JANGLE))**2)
(2-2*COS(JANGLE))*R**2 + (2*ADX*(1+COS(JANGLE))-2*ADY*SIN(JANGLE))*R +
          (-ADX**2-ADY**2) = 0
A = 2-2*COS(JANGLE)
B = 2*ADX*(1+COS(JANGLE))-2*ADY*SIN(JANGLE)
C = -ADX**2-ADY**2
R = (-B+SQRT(B**2-4*A*C)) / (2*A)
```

Fig 3.15. Calculations for special reverse circular curve for left turns less than 90 degrees and ADY less than YC .



DY = ADY - YC

Fig 3.16. **Calculations for left turns less than 90 degrees and ADY greater than or equal to YC .**

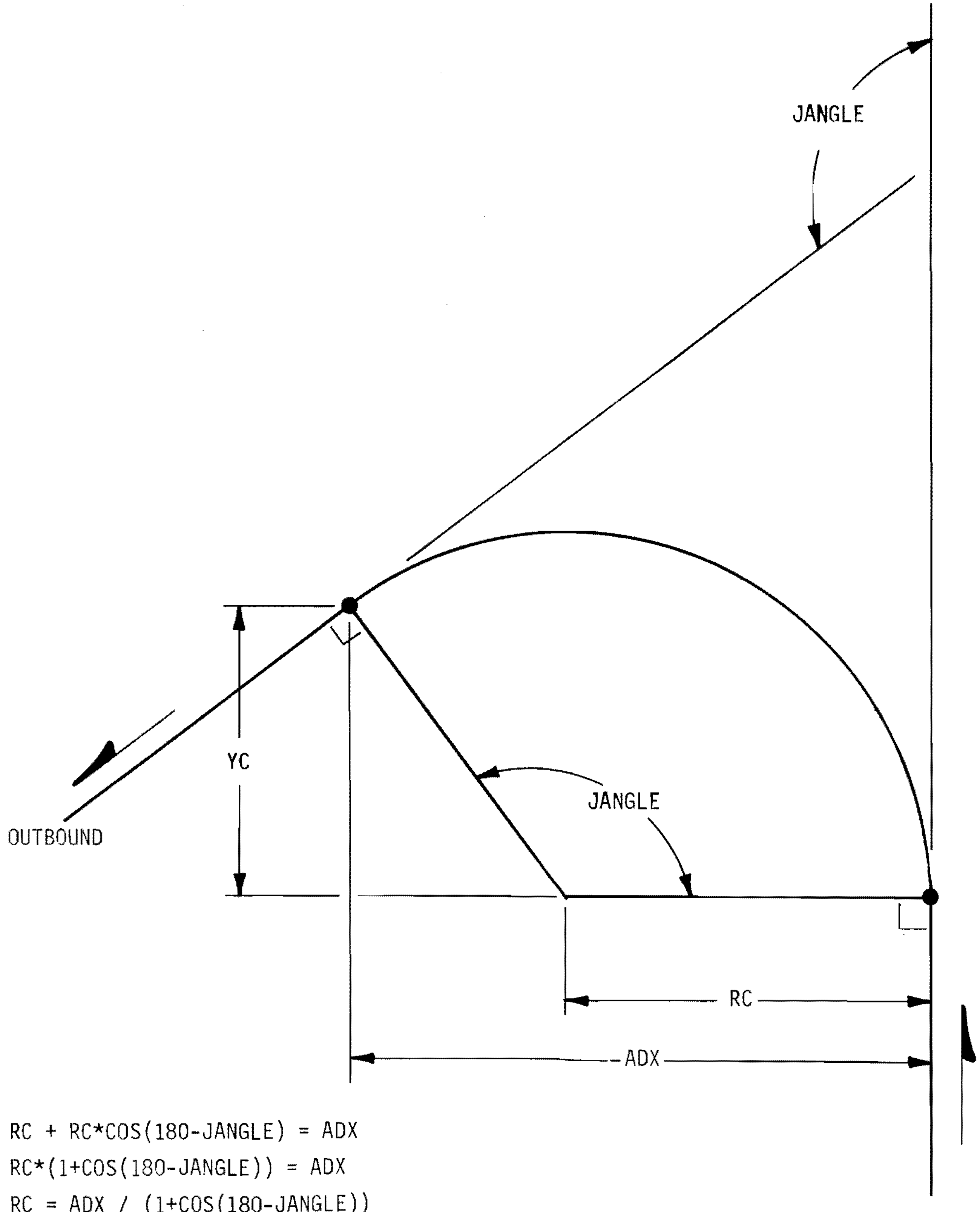
The calculations for R critical and Y critical are shown in Fig 3.17 for left turns greater than or equal to 90 degrees (JANGLE not equal to 180 degrees). For an ADY distance less than Y critical, a straight line segment is calculated (with a length equal to the Y critical distance minus the ADY distance) following an arc with a radius less than R critical (see Fig 3.18). For an ADY distance greater than or equal to Y critical, a straight line segment is calculated (with a length equal to the ADY distance minus the Y critical distance) preceding an arc with a radius equal to R critical (see Fig 3.19).

3.3.11 Straight-through Movements

The calculations for the straight-through movements (JANGLE equal to zero degrees) call for a reverse circular curve to be calculated if there is a non-zero ADX distance and for only a straight line segment to be calculated if there is a zero ADX distance. The calculations for the radius of the arcs are shown in Fig 3.20 and Fig 3.21. The basic premise for the calculations is that the radii for the two arcs are equal, thus producing the fastest intersection path. The formulae for the radius are simplifications of the calculations in Fig 3.15 and Fig 3.24 with JANGLE equal zero.

3.3.12 Right Turns

The calculations for R critical and Y critical are shown in Fig 3.22 for right turns of less than 90 degrees (JANGLE not equal to zero degrees). For an ADY distance less than Y critical, a straight line segment is calculated (with a length equal to the Y critical distance minus the ADY distance) following an arc with a radius less than R critical (see Fig 3.23). For the unusual case where the projections of the inbound and outbound approach paths do not meet within the intersection, a special reverse curve is calculated (see Fig 3.24). The basic premise of the reverse circular curve is that the radii of both arcs are equal, thus producing the fastest path. From the



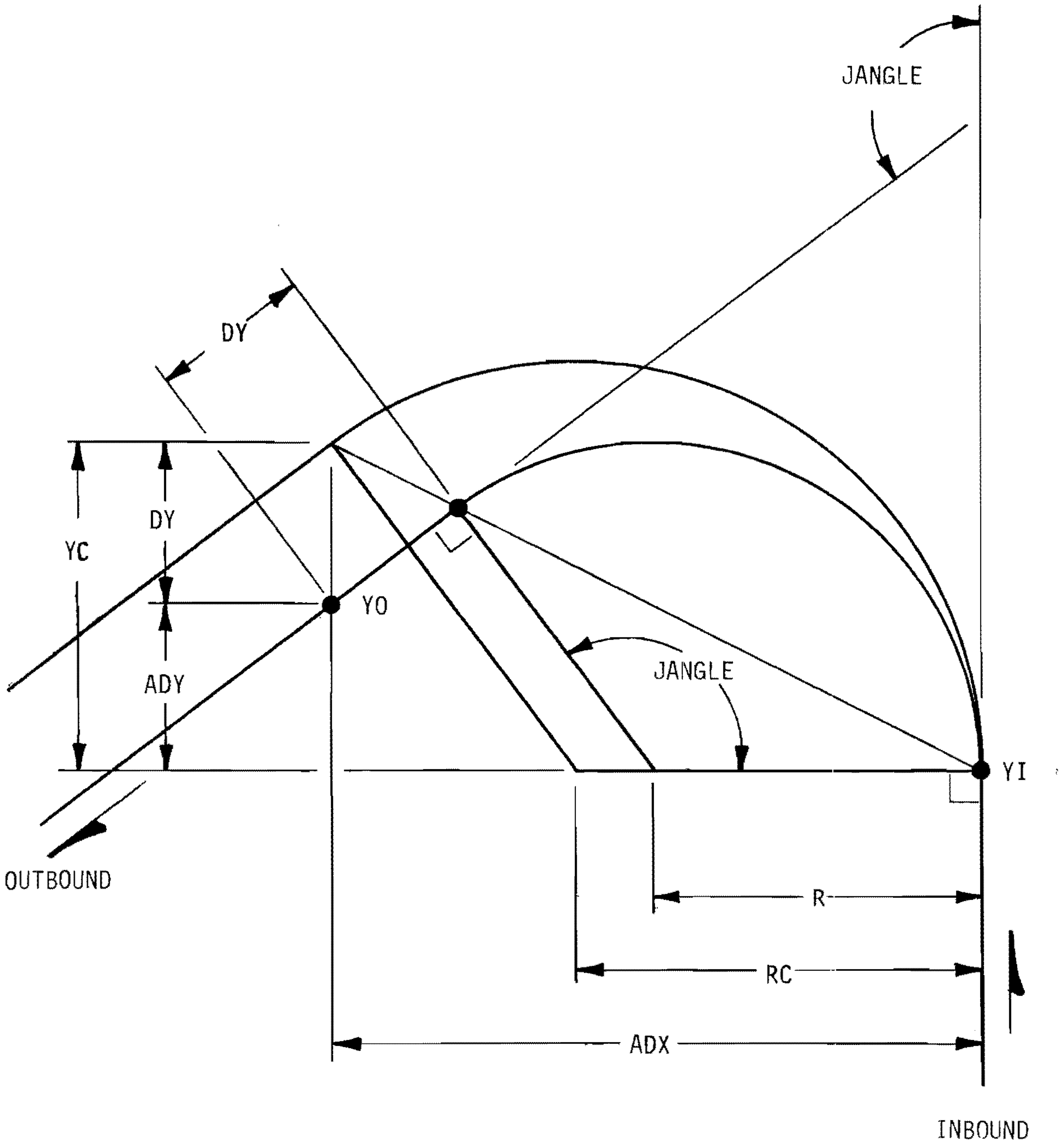
RC + RC*COS(180-JANGLE) = ADX

RC*(1+COS(180-JANGLE)) = ADX

RC = ADX / (1+COS(180-JANGLE))

YC = RC*SIN(180-JANGLE)

Fig 3.17. RC and YC calculations for left turns greater than or equal to 90 degrees.



DY = YC - ADY for YO GE YI

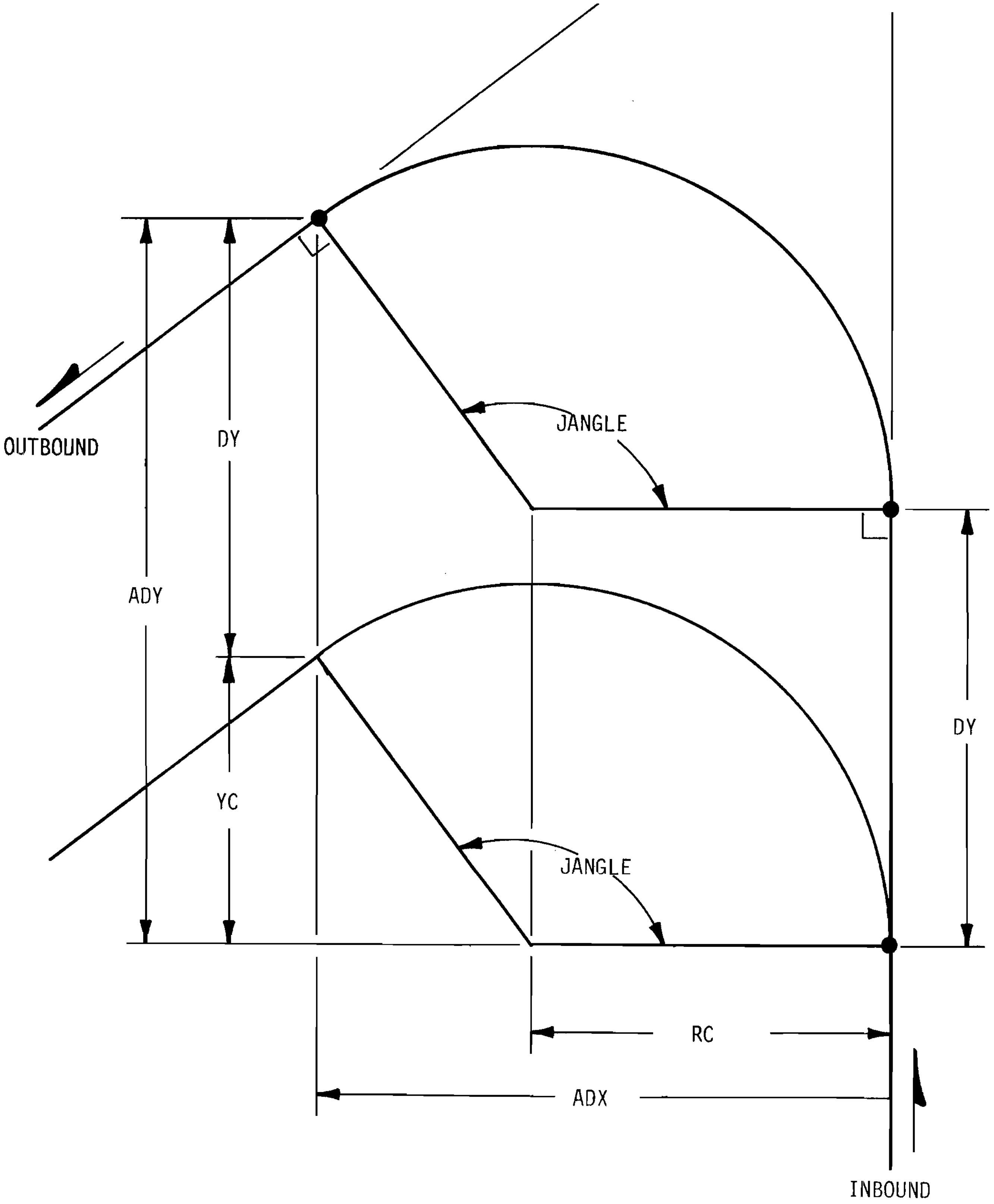
DY = YI + YC - YO for YO LT YI

DY*COS(JANGLE-90) + R*COS(180-JANGLE) + R = ADX

R*(1+COS(180-JANGLE)) = ADX - DY*COS(JANGLE-90)

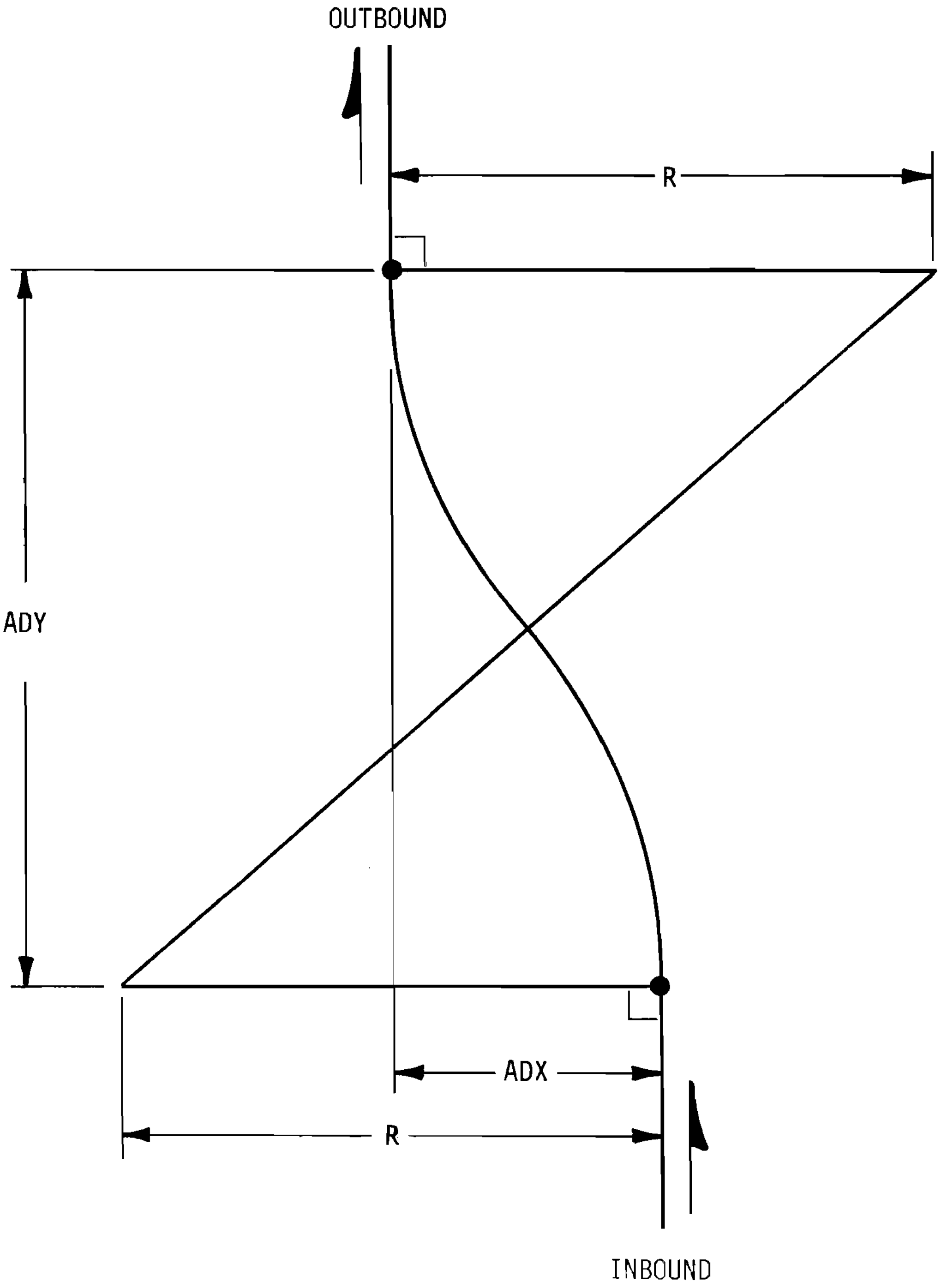
R = (ADX - DY*COS(JANGLE-90)) / (1+COS(180-JANGLE))

Fig 3.18. **Calculations for left turns greater than or equal to 90 degrees and ADY less than YC .**



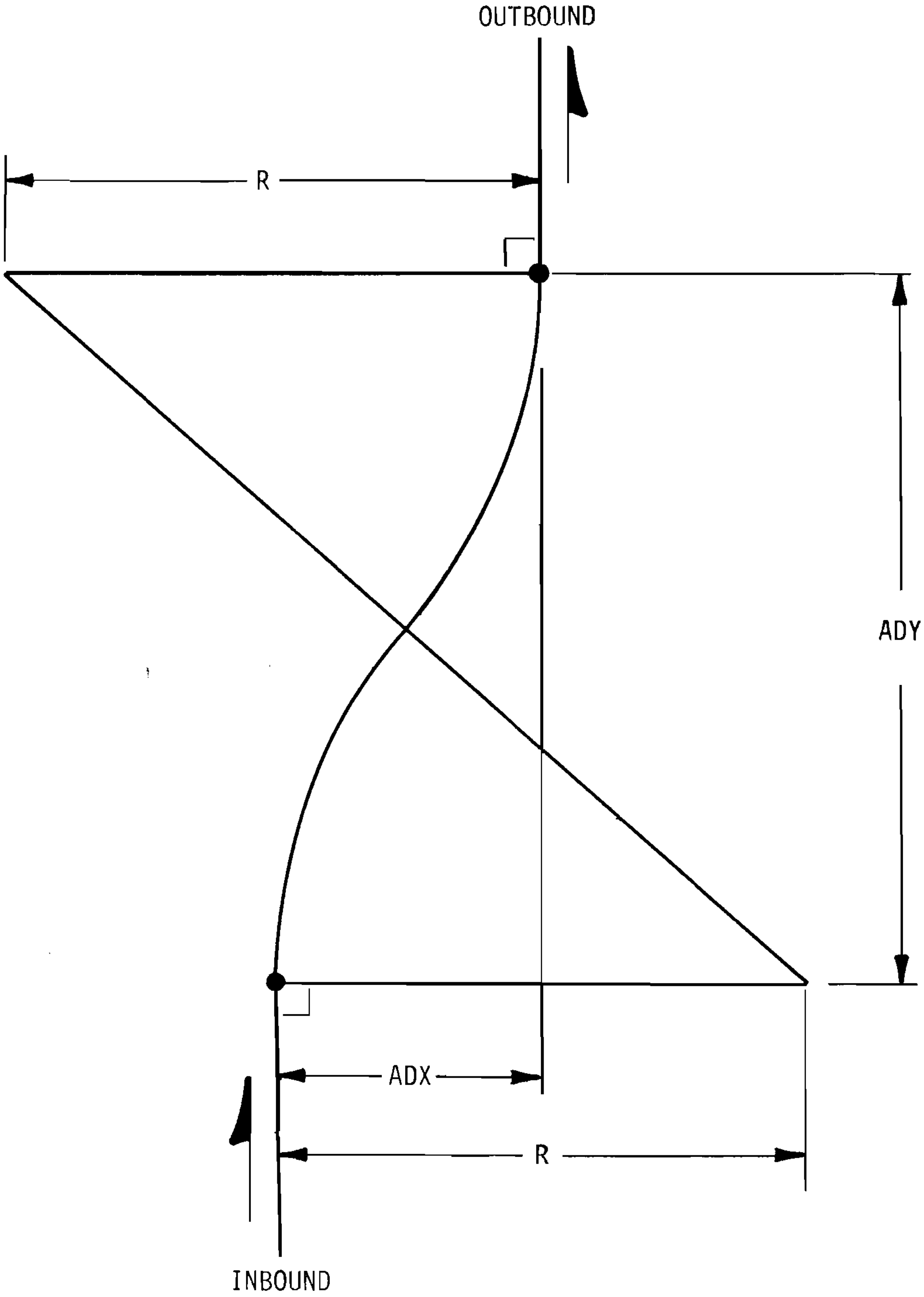
DY = ADY - YC

Fig 3.19. **Calculations for left turns greater than or equal to 90 degrees and ADY greater than or equal to YC .**



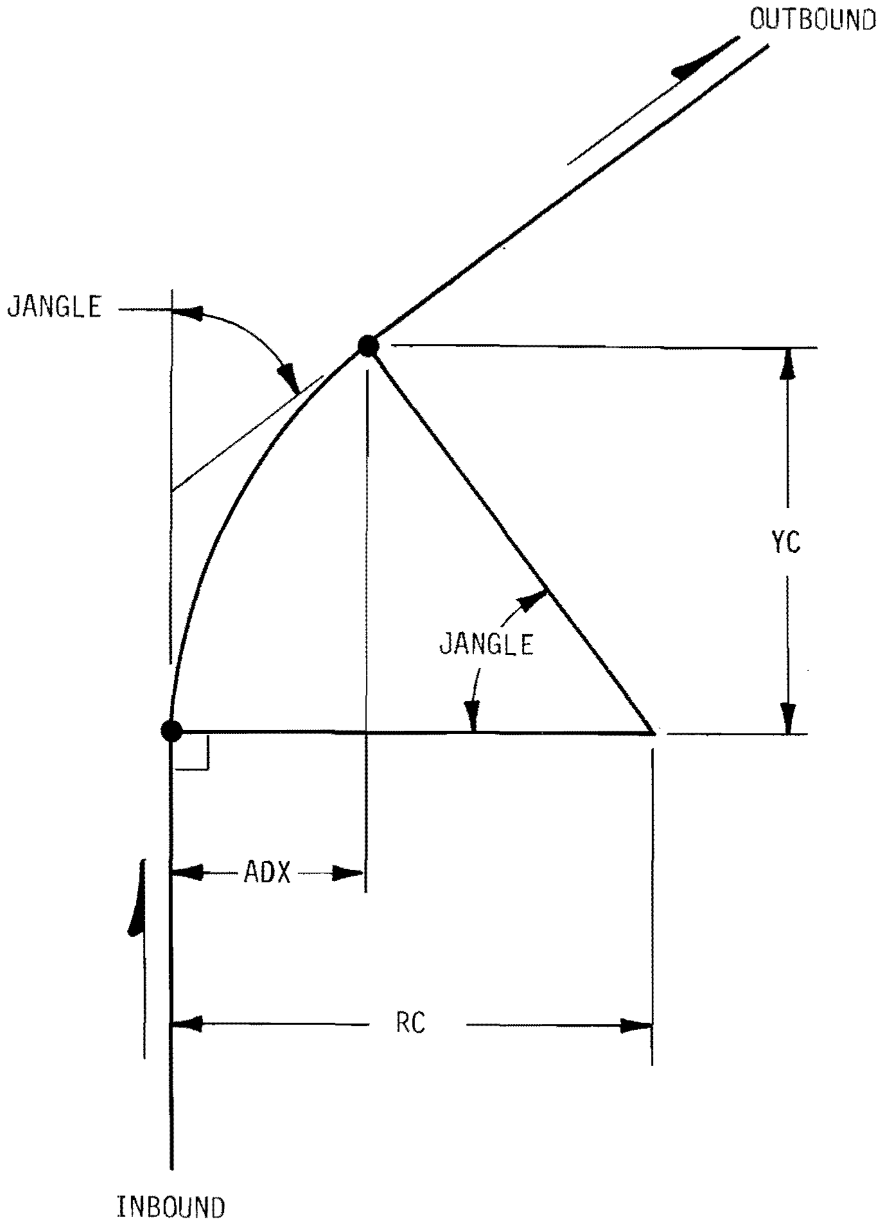
2*R = SQRT((R-ADX+R)**2+ADY**2)
R = (ADX**2+ADY**2) / (4*ADX)

Fig 3.20. **Calculations for straight through movements to the left.**



2*R = SQRT((R-ADX+R)**2+ADY**2)
R = (ADX**2+ADY**2) / (4*ADX)

Fig 3.21. **Calculations for straight through movements to the right.**



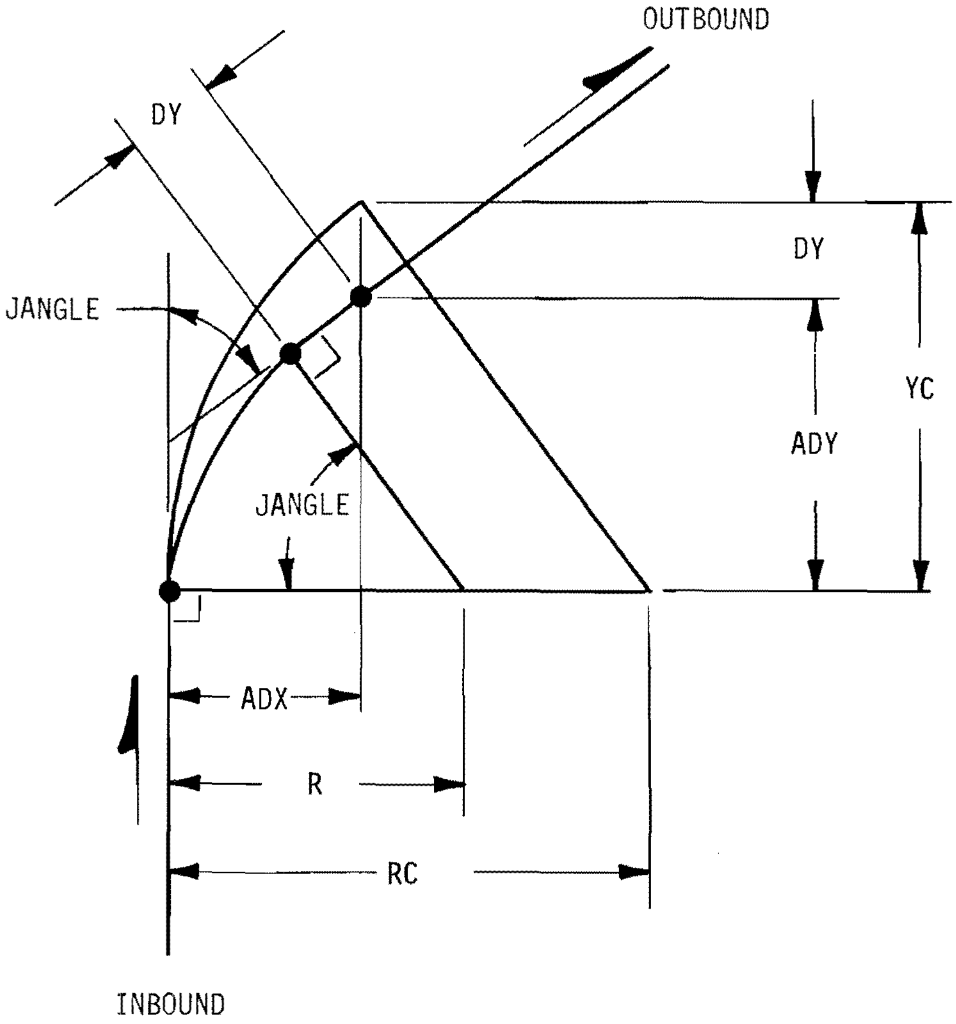
RC - RC*COS(JANGLE) = ADX

RC*(1-COS(JANGLE)) = ADX

RC = ADX / (1-COS(JANGLE))

YC = RC*SIN(JANGLE)

Fig 3.22. RC and YC calculations for right turns less than 90 degrees.



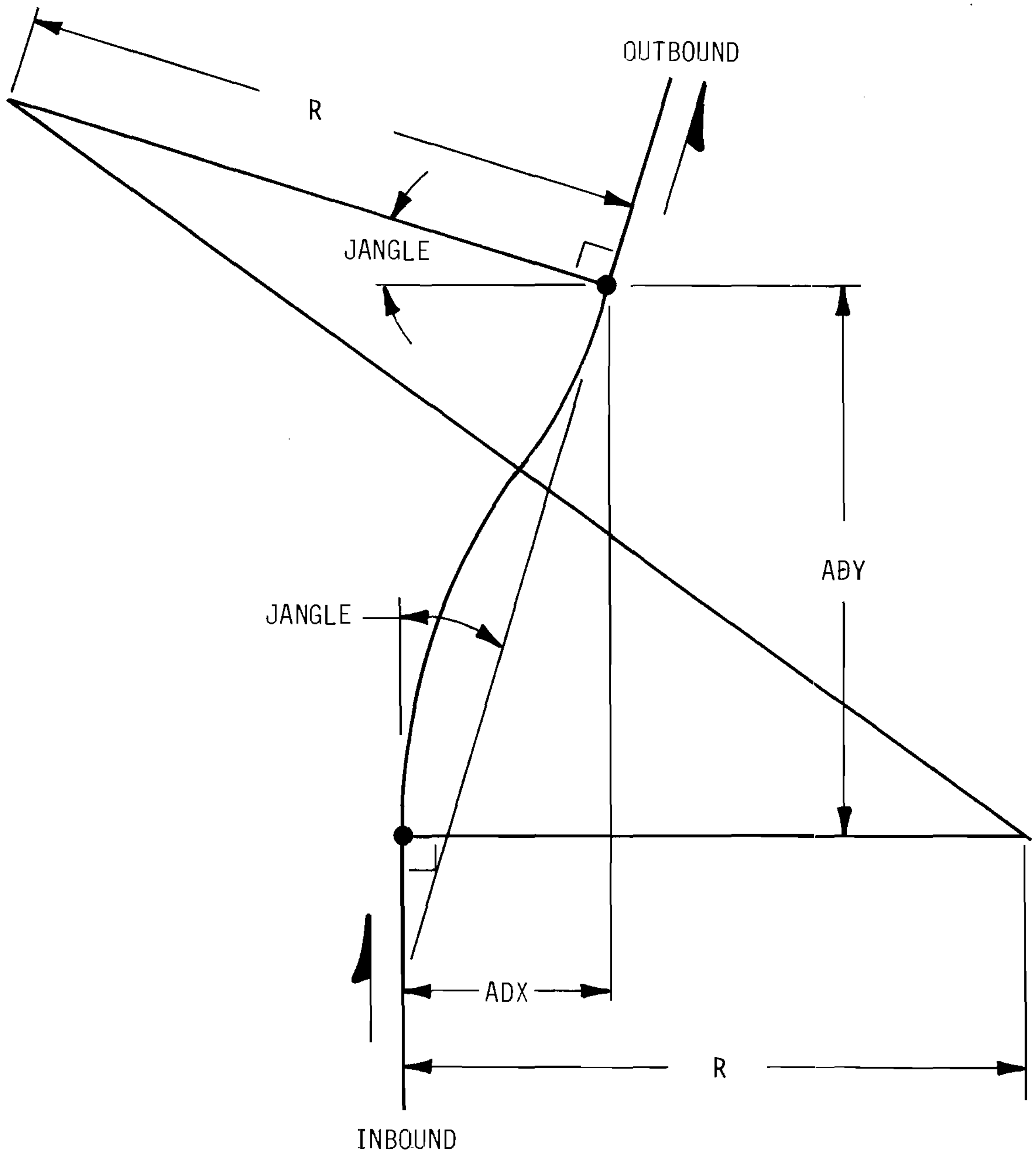
DY = YC - ADY

R - R*COS(JANGLE) + DY*COS(90-JANGLE) = ADX

R*(1-COS(JANGLE)) = ADX - DY*COS(90-JANGLE)

R = (ADX - DY*COS(90-JANGLE)) / (1-COS(JANGLE))

Fig 3.23. **Calculations for right turns less than 90 degrees and** ADY **less than** YC .



```
2*R = SQRT((R-ADX+R*COS(JANGLE))**2+(ADY+R*SIN(JANGLE))**2)
(2-2*COS(JANGLE))*R**2 + (2*ADX*(1+COS(JANGLE))-2*ADY*SIN(JANGLE))*R +
          (-ADX**2-ADY**2) = 0
A = 2-2*COS(JANGLE)
B = 2*ADX*(1+COS(JANGLE))-2*ADY*SIN(JANGLE)
C = -ADX**2-ADY**2
R = (-B+SQRT(B**2-4*A*C)) / (2*A)
```

Fig 3.24. **Calculations for special reverse circular curve for right turns less than 90 degrees and** ADY **less than** YC .

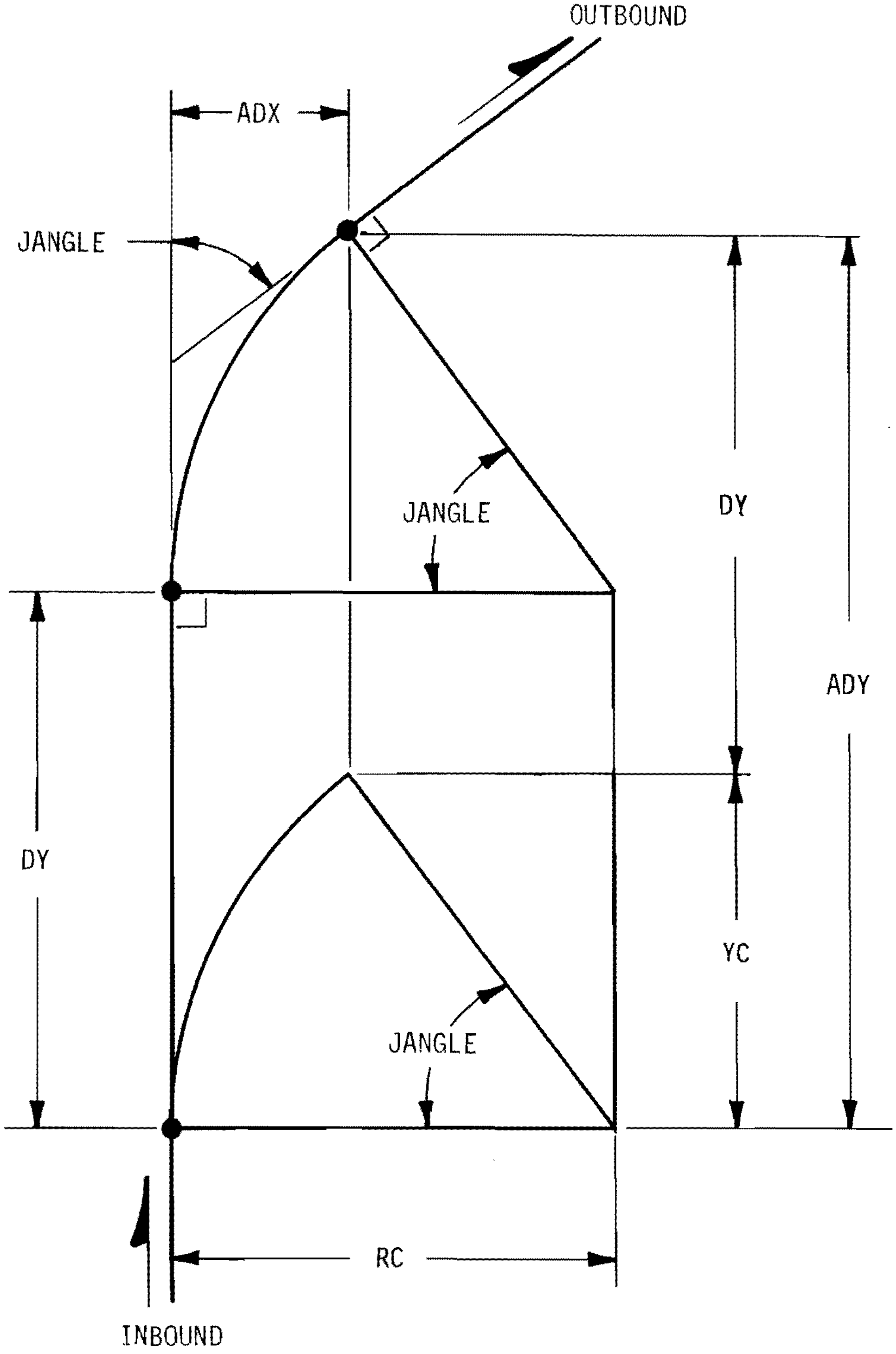
calculations shown in Fig 3.24, the equation for the radius of the arcs is calculated using the quadratic formula. For an ADY distance greater than or equal to Y critical, a straight line segment is calculated (with a length equal to the ADY distance minus the Y critical distance) preceding an arc with a radius equal to R critical (see Fig 3.25).

The calculations for R critical and Y critical are shown in Fig 3.26 for right turns greater than or equal to 90 degrees (JANGLE not equal to 180 degrees). For an ADY distance less than Y critical, a straight line segment is calculated (with a length equal to the Y critical distance minus the ADY distance) following an arc with a radius less than R critical (see Fig 3.27). For an ADY distance greater than or equal to Y critical, a straight line segment is calculated (with a length equal to the ADY distance minus the Y critical distance) preceding an arc with a radius equal to R critical (see Fig 3.28).

3.3.13 Path Type Option

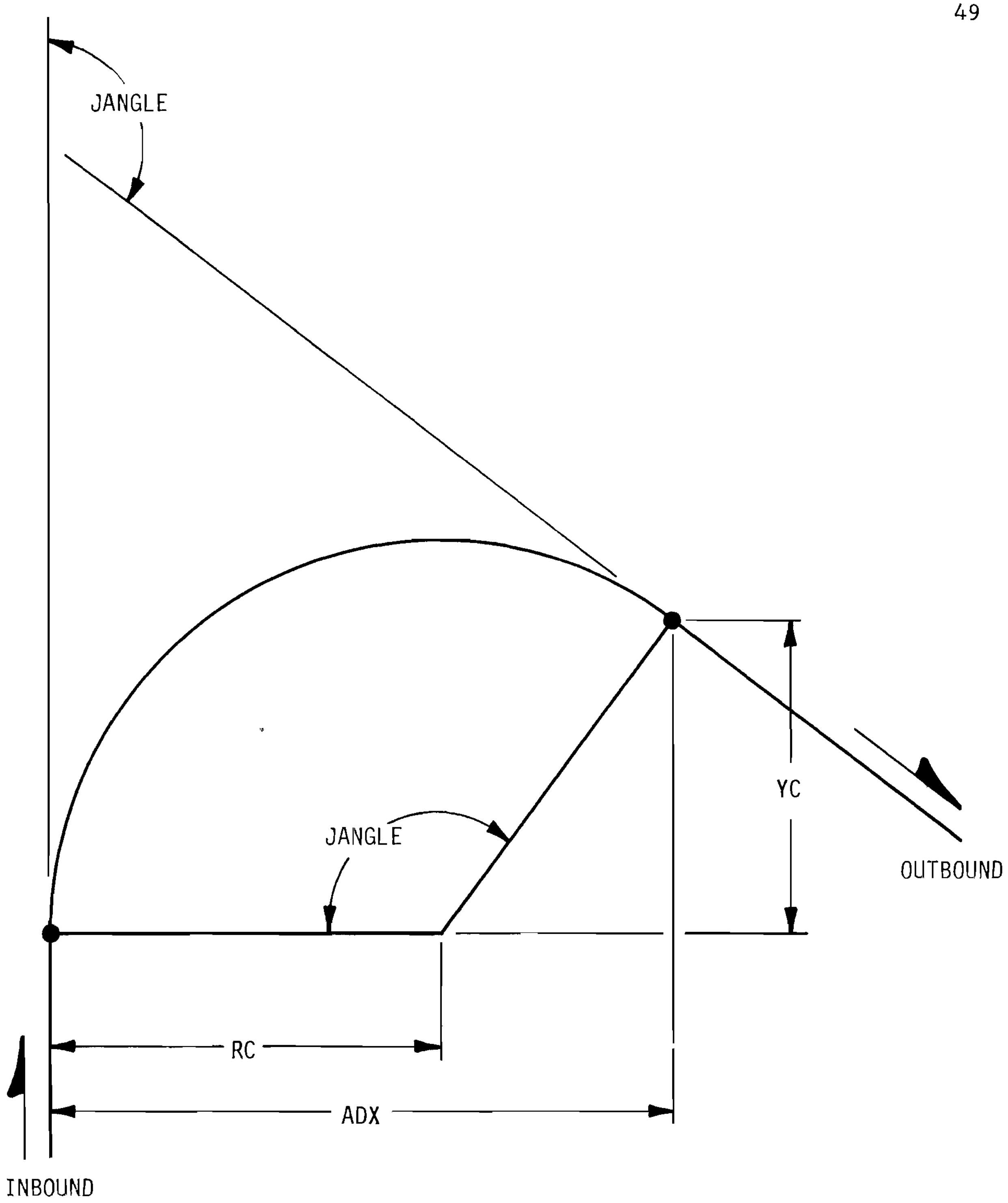
It is unrealistic to assume that every driver always obeys the law. A left turn usually may be made only from the extreme left lane (median lane) and a right turn may be made only from the extreme right lane (curb lane) unless an official traffic control device gives legal authority for other turning movements (Ref 17). Straight-through movements are always legal unless modified by an official traffic control device. In a normal four-leg intersection consisting of two lanes per inbound approach and two lanes per outbound approach, the median lane normally accommodates left turns and straight-through movements and the curb lane provides for straight-through movements and right turns.

Since a prevalent problem with intersection operation is improper lane use within the intersection, a traffic simulation model would be restricted in its application if it calculated and made available only those paths within the intersection which are legally permissible by basic traffic laws or local signing. To allow the user to measure the effects of such maneuvers, two options which control the generation of the paths within the intersection have been established. The path type option may be PRIMARY, which calculates only



DY = ADY - YC

Fig 3.25. **Calculations for right turns less than 90 degrees and ADY greater than or equal to YC .**



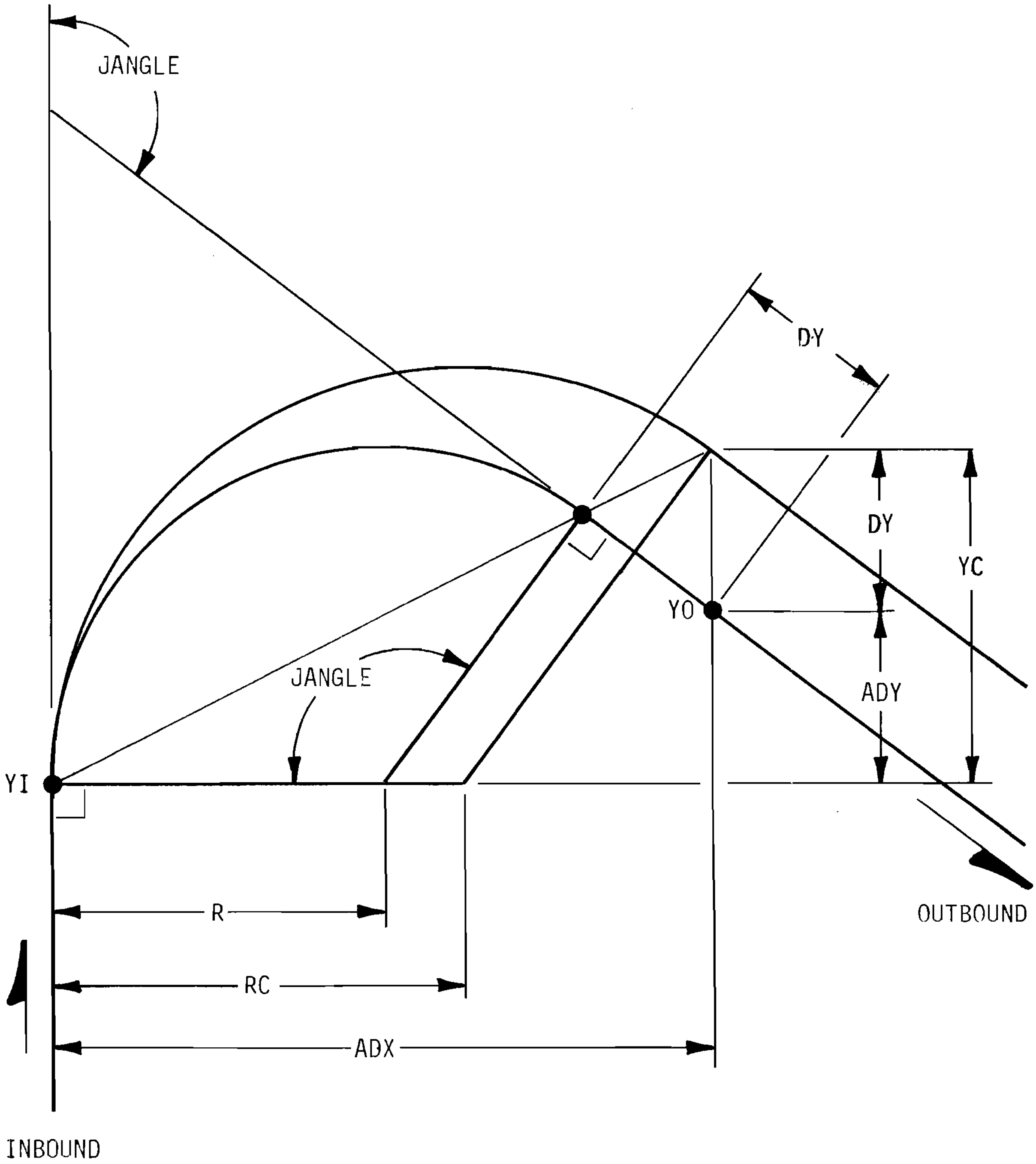
RC + RC*COS(180-JANGLE) = ADX

RC*(1+COS(180-JANGLE) = ADX

RC = ADX / (1+COS(180-JANGLE))

YC = RC*SIN(180-JANGLE)

Fig 3.26. RC and YC calculations for right turns greater than or equal to 90 degrees.



DY = YC - ADY for YO GE YI

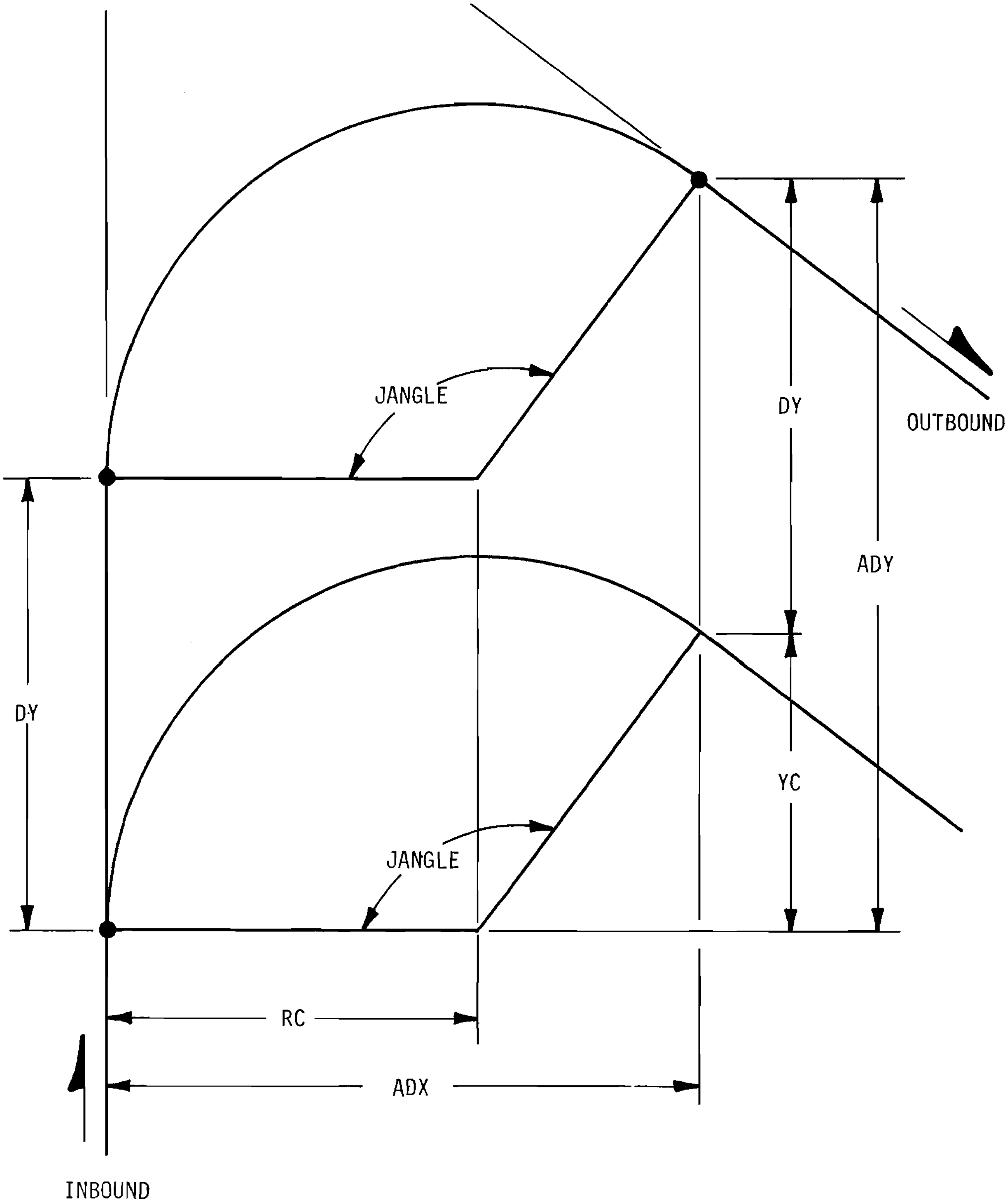
DY = YI + YC - YO for YO LT YI

DY*COS(JANGLE-90) + R*COS(180-JANGLE) + R = ADX

R*(1+COS(180-JANGLE)) = ADX - DY*COS(JANGLE-90)

R = (ADX - DY*COS(JANGLE-90)) / (1+COS(180-JANGLE))

Fig 3.27. **Calculations for right turns greater than or equal to 90 degrees and ADY less than YC .**



DY = ADY - YC

Fig 3.28. **Calculations for right turns greater than or equal to 90 degrees and ADY greater than or equal to YC .**

those intersection paths which are legally permissible according to the basic traffic laws or local signing and do not involve lane changing within the intersection. The path type option may also be OPTION1, which generates all the PRIMARY intersection paths but also calculates intersection paths that change not more than one lane within the intersection. Examples of PRIMARY and OPTION1 intersection paths are found in Fig 3.4 and Fig 3.5.

The geometry processor tries to calculate an intersection path connecting each inbound lane with each outbound lane. If the turning movement type determined for the intersection path has not been specified for the inbound lane and for the outbound lane, then the intersection path is discarded. Next, the geometry processor determines whether the intersection path changes lanes within the intersection. Because U-turns are special turning maneuvers, no checking is performed to determine whether the U-turn involves changing lanes. For left turns and straight-through movements, the geometry processor determines the first lane (from median to curb lane, or from left to right) on the inbound approach which can generate the turning movement type of the intersection path being checked (denoted LNI) and the first lane (from median to curb lane, or from left to right) on the outbound approach which can accept the turning movement type of the intersection path being checked (denoted LNO). If the inbound lane number for the intersection path is not the same relative number from LNI as the outbound lane number for the intersection path relative to LNO, then the intersection path is considered to change lanes. This procedure allows the straight intersection paths at the top of Fig 3.4 to be considered as not changing lanes because they go from the first and second lanes available on the inbound approach for straight-through movements to the first and second lanes available on the outbound approach for straight-through movements, respectively, whereas the other straight intersection paths at the top of Fig 3.5 are considered as changing lanes. If the inbound lane number is 1 or is not the last lane for the inbound approach, then the path type option is determined from this lane-change condition. If the inbound lane number is not 1 and is the last lane for the inbound approach, then the path type option is determined from the lane-change condition calculated when checking from curb to median lane (from right to left). This procedure allows the straight intersection path from the curb lane in the middle of Fig 3.4 to be considered as changing lanes but to be a PRIMARY path. In the traffic simulation processor, driver-vehicle units using this intersection path have to yield to units using the other straight intersection path and try to change lanes to the median lane before the unit enters the intersection. For right turns, the geometry processor determines the first lane (from curb to median lane, or from right to left) on the inbound approach which can generate the turning movement type of the intersection path being checked (denoted LNI) and the first lane (from curb to median lane, or from right to left) on the outbound approach which can accept the turning movement type of the intersection path being checked (denoted LNO). Again, if the inbound lane number for the intersection path is not the same relative number from LNI as the outbound lane number for the intersection path relative to LNO, then the intersection path changes lanes. The path type option is then determined from this lane change condition.

3.3.14 Maximum Speed For Intersection Paths

The maximum speed on the paths within the intersection is a function of the minimum turning radius of the intersection path, the value for safe side friction, and the value of superelevation (the geometry processor does not consider superelevation at the intersection). The value for safe side friction used in the design of horizontal alignment is a function of velocity. At velocities less than 46.7 mi/hr (75.2 km/hr), the functional relationship is parabolic, while at higher velocities it is linear (Ref 18). Figure 3.29 shows the design values for the side friction as a function of velocity and the equations used in GEOPRO. Figure 3.30 and Fig 3.31 show the values for maximum speed on horizontal curves versus values for radius from 0 feet to 4,000 feet (1,219.2 meters) and 0 feet to 1,000 feet (304.8 meters), respectively. If an intersection path is only a straight line segment, then the radius is zero and the speed based on that radius is infinite. The maximum speed of the intersection path is set to the minimum of the inbound approach path speed limit, the speed based on the radius of the intersection path, and the outbound approach path speed limit.

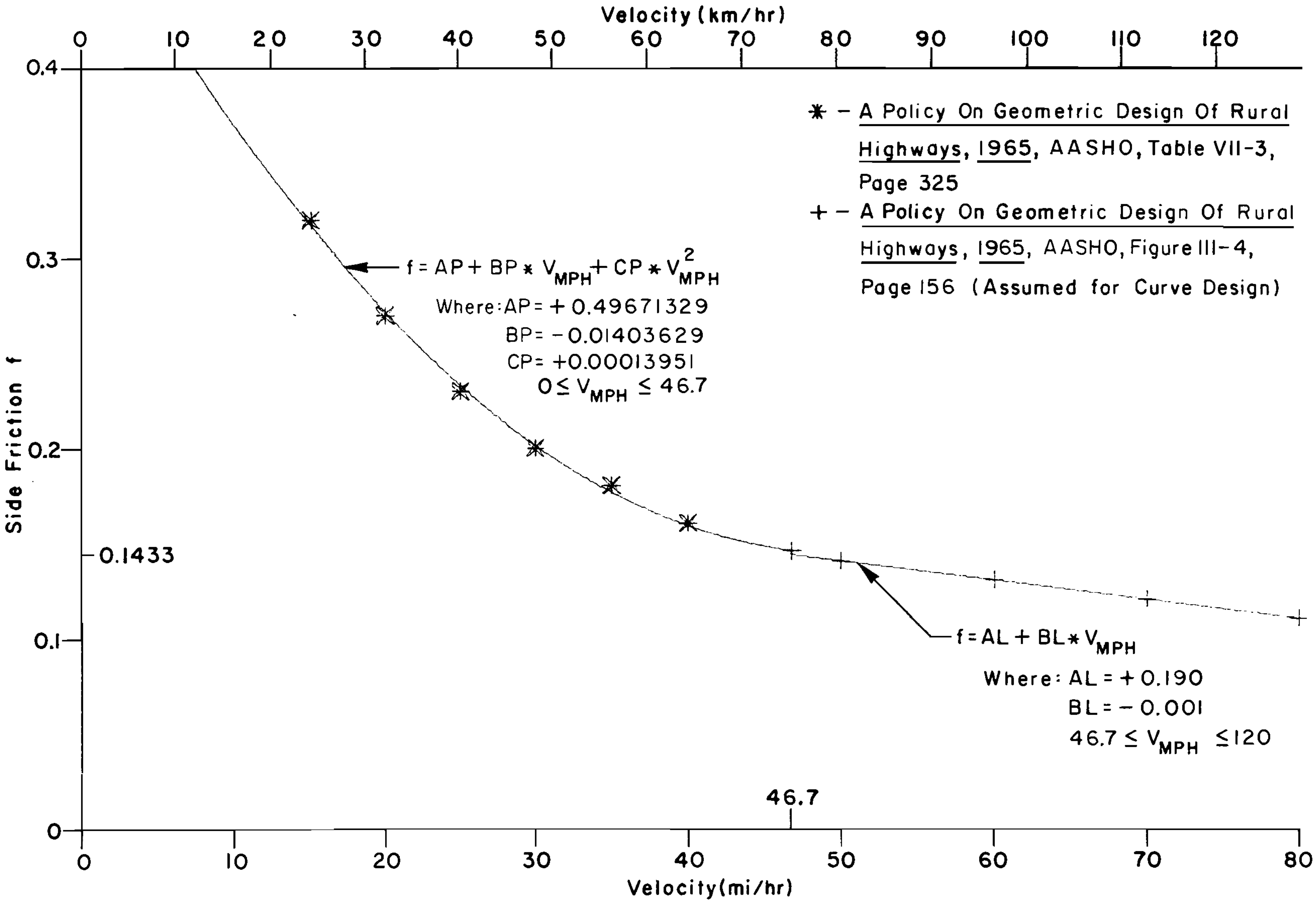


Fig 3.29. Design values of side friction for different velocities.

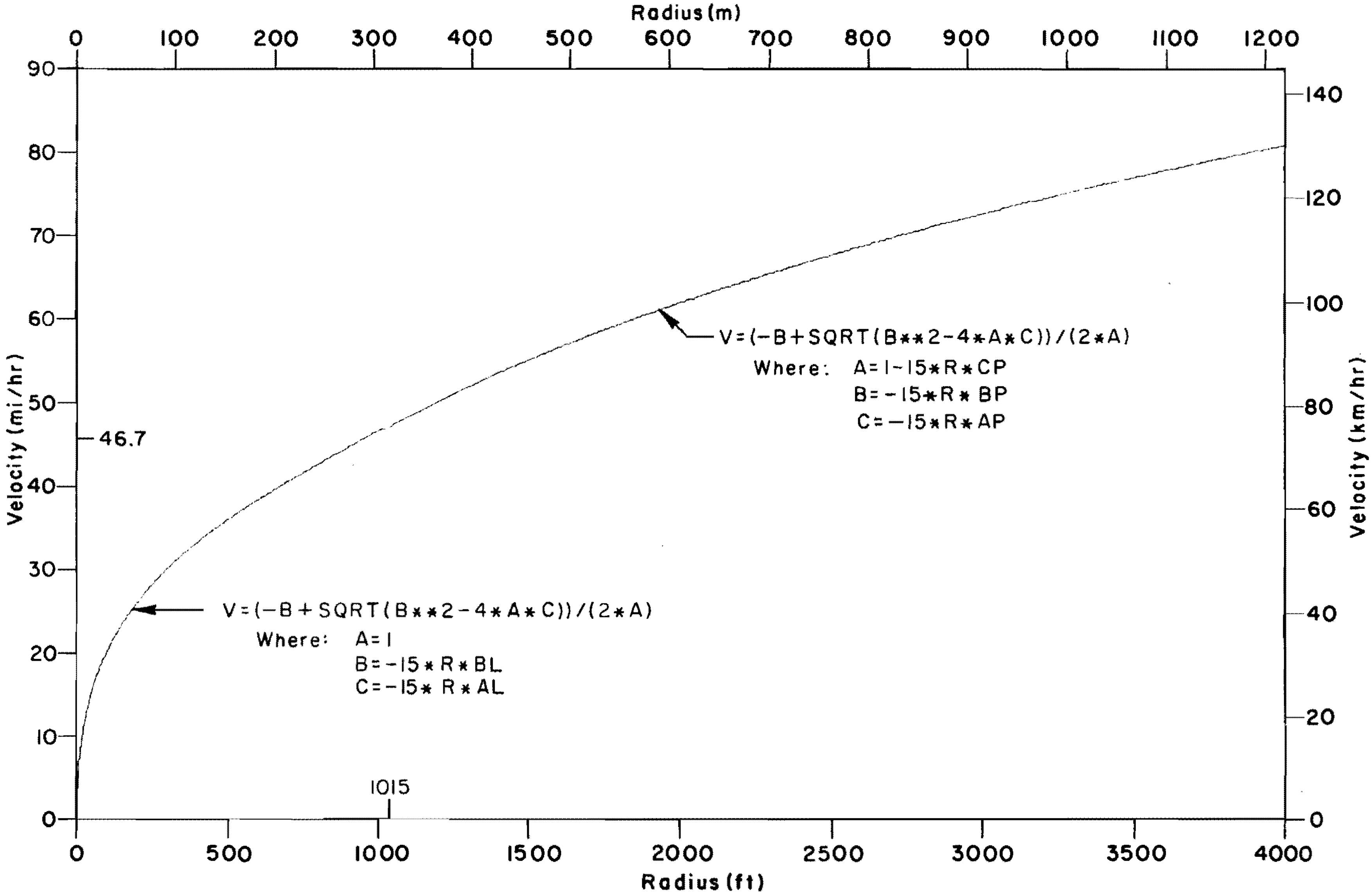


Fig 3.30. Maximum speed on horizontal curves for values of radius from 0 feet (0 meters) to 400 feet (121.9 meters).

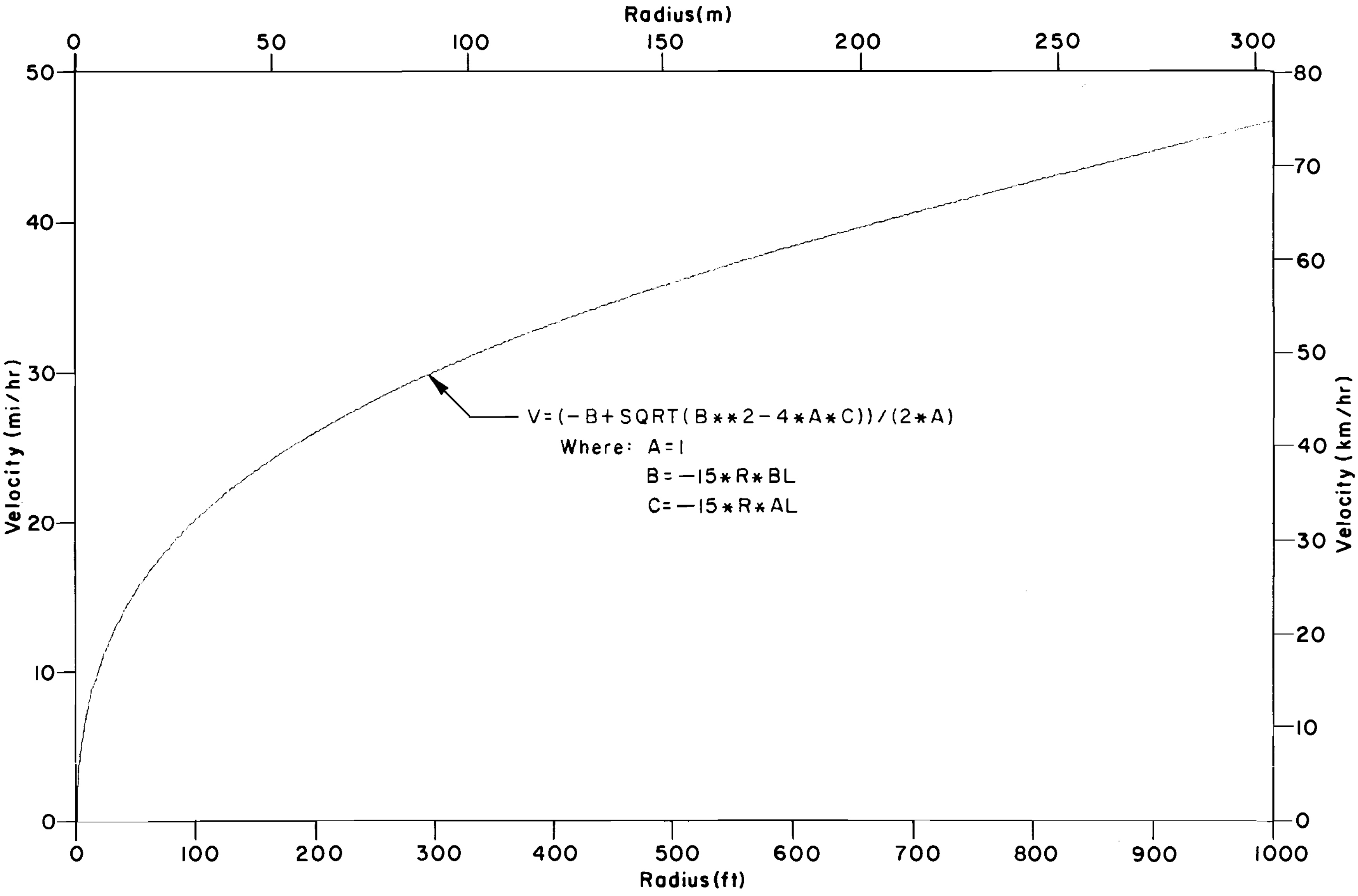


Fig 3.31. Maximum speed on horizontal curves versus values of radius from 0 feet (0 meters) to 1000 feet (304.8 meters).

3.3.15 Sight Distance Restrictions

In developing the computations for sight distance restrictions, the desire to eliminate the need for Cartesian coordinate checking within the traffic simulation processor was fulfilled. For each inbound approach, GEOPRO determines whether there is a sight obstruction with any of the other inbound approaches. The user supplies the coordinates of each sight distance restriction (see Fig 3.32). For each 25-foot (7.62-meter) increment along an inbound approach, the coordinates of the center of the 25-foot (7.62-meter) increment are found and the equation for a line with its origin at the center of the increment and passing through each of the sight distance restriction coordinates is formulated. Then the lines are checked to see whether or not they intersect with a line from the center of the start of an inbound approach to the center of the end of an inbound approach, and if they intersect, then the distance from the center of the start of the other inbound approach to the intersection of the two lines is found and saved. This distance is called LDOWN in Fig 3.33 and GEOPRO. If another driver-vehicle unit's position on the other inbound approach is less than the LDOWN distance, then the unit cannot be seen. If its position is greater than or equal to the LDOWN distance, then the unit can be seen. If the LDOWN distance between any two inbound approaches is zero for each 25-foot (7.62-meter) increment, then there is no sight obstruction between the approaches. For a particular 25-foot (7.62-meter) increment, GEOPRO uses the largest LDOWN distance if there is more than one sight distance restriction coordinate. This procedure ensures that the minimum distance from the intersection (visible distance) is found for each 25-foot (7.62-meter) increment.

3.3.16 Intersection Conflicts

The geometry processor also calculates all the potential points of conflict between intersection paths. It accomplishes this task by determining whether there is a physical point of intersection between any of the component segments of an intersection path. An intersection path is composed of one or more segments in sequence: Segment 1 is a straight line segment; Segment 2

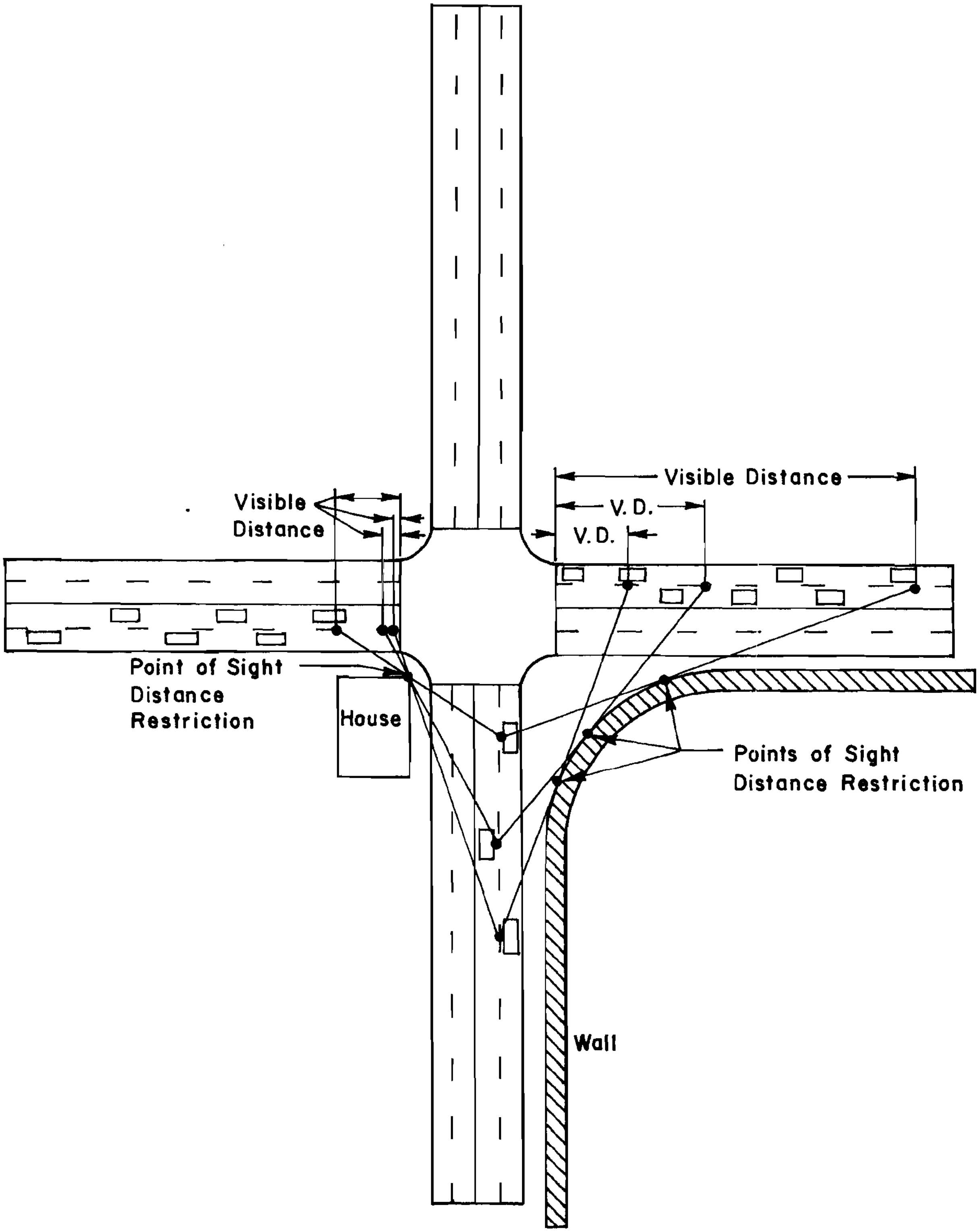
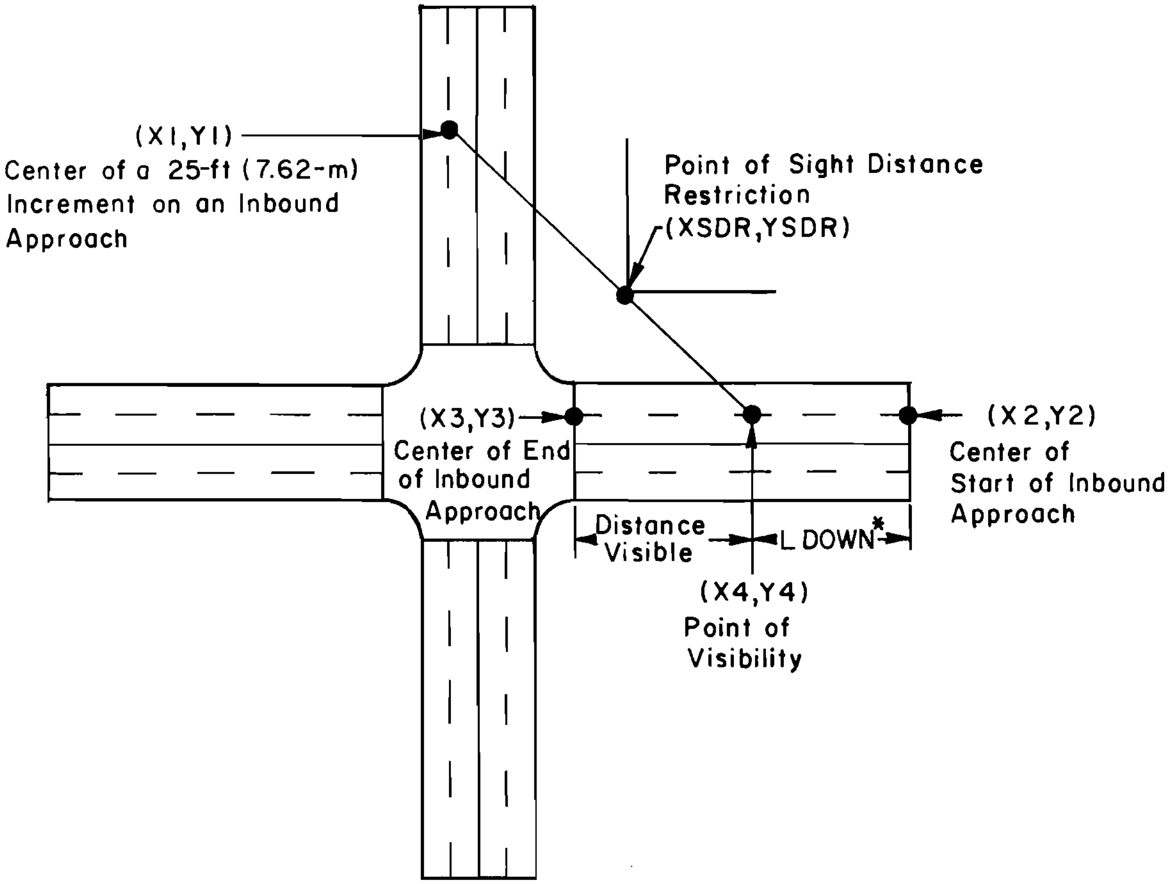


Fig 3.32. Conceptualization of points of sight distance restriction.



*L DOWN= SQRT ((X4-X2)**2+ (Y4-Y2)**2)+0.5

Fig 3.33. Conceptualization of calculation of visible distance.

is an arc of a circle; Segment 3 is an arc of a circle; and Segment 4 is a straight line segment. GEOPRO uses algebraic equations for the intersection of two straight line segments (see Section 3.3.16.1), the intersection of a straight line segment and an arc of a circle (see Section 3.3.16.2), and the intersection of two arcs of circles (see Section 3.3.16.3). These equations may seem trivial, but their derivations and the transformations to computer language were quite involved. GEOPRO checks each intersection path with every other intersection path, checking first for a physical intersection with the actual intersection path (center of the vehicle path), checking next with a path parallel to the actual intersection path which is 1 foot (0.3048 meters) from the actual intersection path (for rounding errors), and lastly checking with a path parallel to the actual intersection path which is ICLOSE feet from the actual intersection path (see Fig 3.34). The value of ICLOSE is input by the user and is the maximum distance between two intersection paths for an intersection conflict to be detected.

It has been found that only left turning and U-turn intersection paths need an outer band of ICLOSE distance because almost all other intersection paths will physically intersect if there is an intersection conflict. Other intersection paths use a 7-foot (2.1336-meter) outer band. It is assumed that intersection paths originating from the same inbound approach and the same inbound lane do not constitute an intersection conflict (see top example in Fig 3.35). Intersection paths which originate from the same inbound approach but go to different outbound lanes and which do not change lanes within the intersection are assumed to have no intersection conflicts (see bottom example in Fig 3.35).

The intersection conflict pointers are ordered for each intersection path by the distance down the intersection path to the point of conflict. By performing this operation, the traffic simulation processor can assume that the next intersection conflict on an intersection path list is further down the intersection path than the previous conflict.

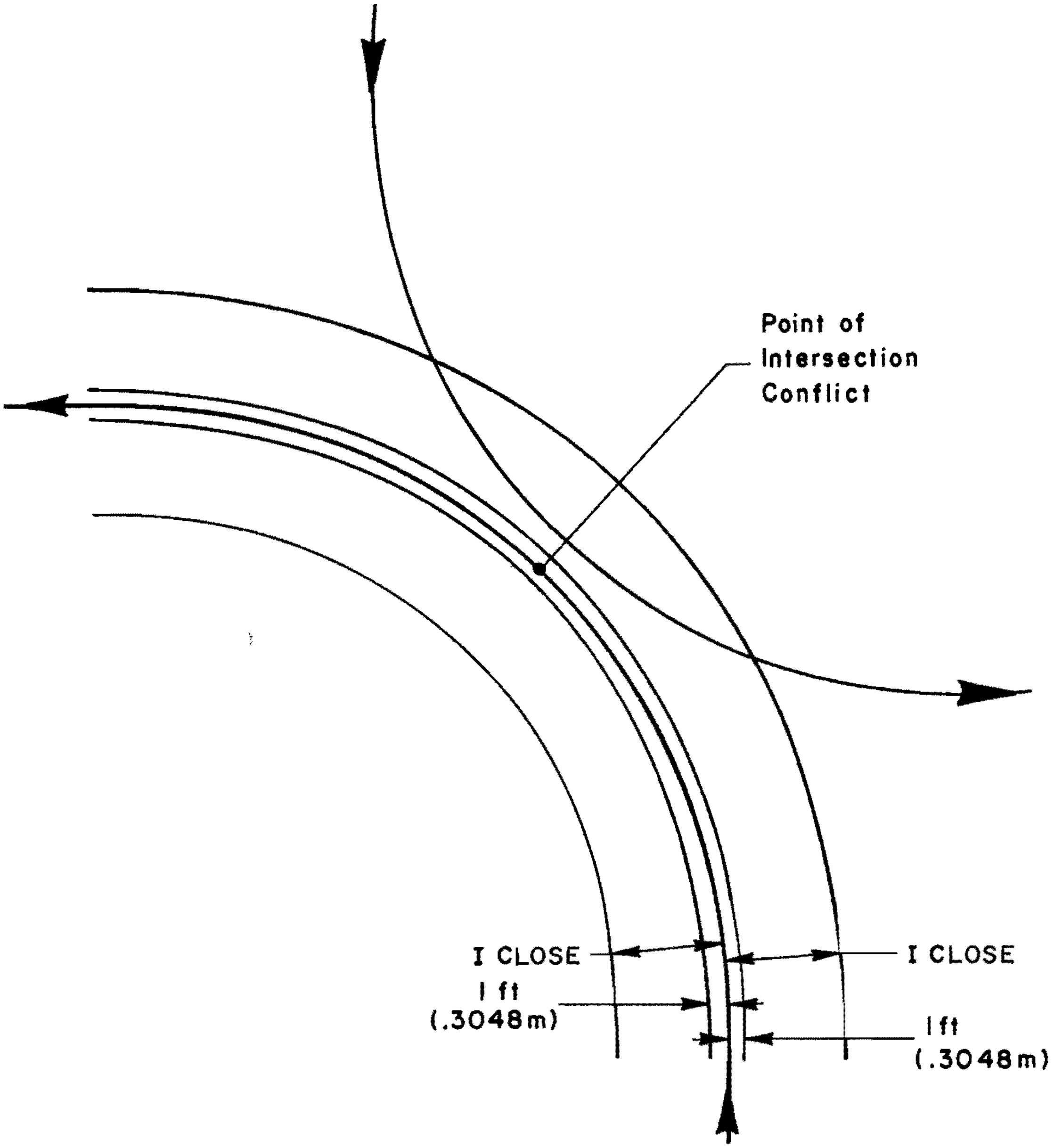
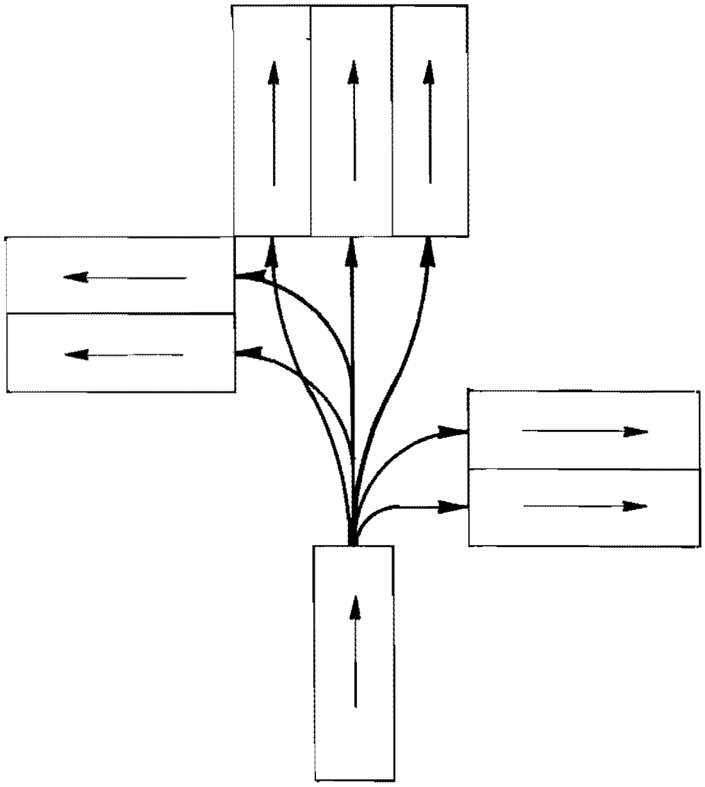
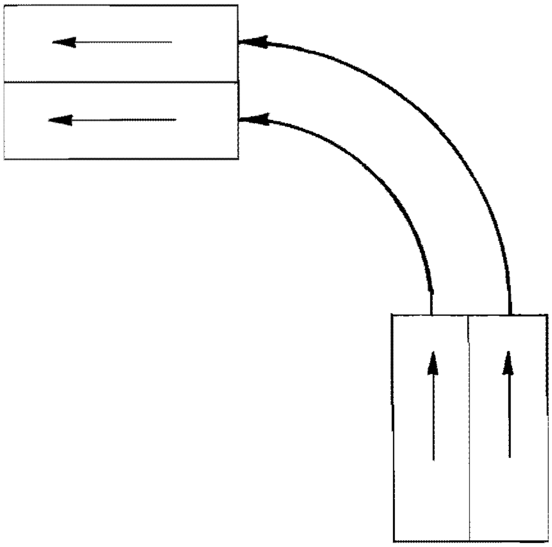


Fig 3.34. Conceptualization of intersection conflicts.



Same inbound approach and same inbound lane



Same inbound approach but different outbound lane
(intersection paths do not lane change within the intersection)

Fig 3.35. Examples of intersection paths with are assumed to have no intersection conflicts.

3.3.16.1 Intersection Of Two Straight Line Segments

Assuming that there are two straight line segments which may or may not intersect, the problem is to discover whether they do or not intersect. There are five distinct cases which must be investigated (see Fig 3.36): (1) neither line segment is vertical and they are not parallel, (2) neither line segment is vertical and they are parallel, (3) line segment A is vertical while line segment B is not vertical, (4) line segment B is vertical while line segment A is not vertical, and (5) both line segments are vertical. Line segment A is defined as a line going from coordinates (X1,Y1) to (X2,Y2) and line segment B goes from coordinates (X3,Y3) to (X4,Y4). For the first case, when neither line segment is vertical and they are not parallel, the equation of line segment A is

$$YA = XMA*XA + XBA \tag{3.1}$$

where XMA is the slope of line segment A and is

$$XMA = (Y2-Y1)/(X2-X1) \tag{3.2}$$

and where XBA is the Y intercept of line segment A and is

$$XBA = Y1 - X1*XMA \tag{3.3}$$

The equation of line segment B is

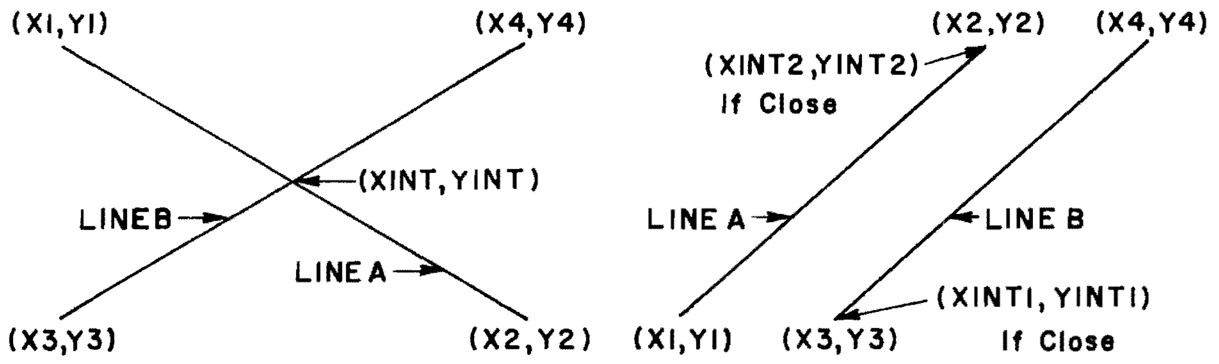
$$YB = XMB*XB + XBB \tag{3.4}$$

where XMB is the slope of line segment B and is

$$XMB = (Y4-Y3)/(X4-X3) \tag{3.5}$$

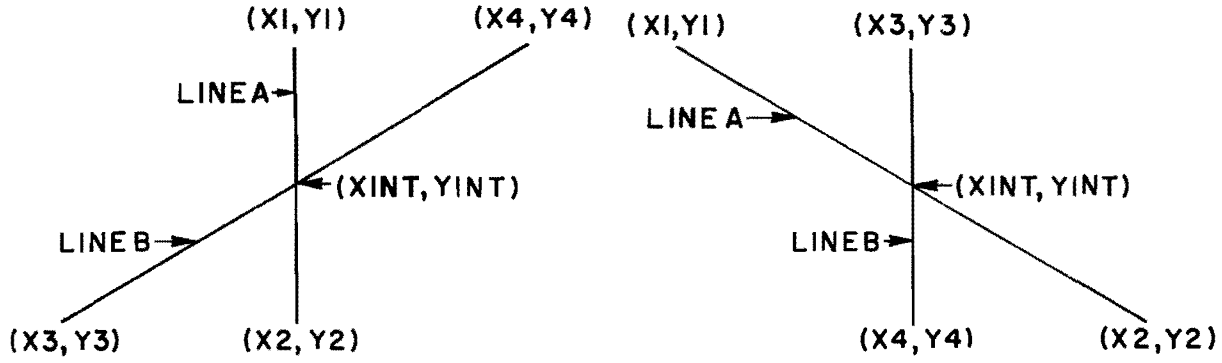
and where XBB is the Y intercept of line segment B and is

$$XBB = Y3 - X3*XMB \tag{3.6}$$



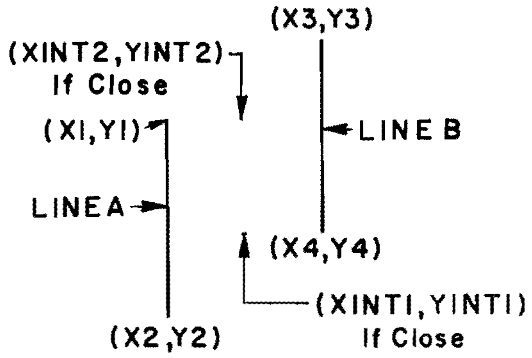
Neither line segment is vertical and they are not parallel

Neither line segment is vertical and they are parallel



Line segment A is vertical while line segment B is not vertical

Line segment B is vertical while line segment A is not vertical



Both line segments are vertical

Fig 3.36. Straight line segment intersections with another straight line segment.

When Eq 3.1 and Eq 3.4 are solved simultaneously, the equation for the X coordinate of the point of intersection is

$$\text{XINT} = (\text{XBB}-\text{XBA})/(\text{XMA}-\text{XMB}) \tag{3.7}$$

while the Y coordinate of the point of intersection is

$$\text{YINT} = \text{XMA}*\text{XINT} + \text{XBA} \tag{3.8}$$

For the second case, when neither line segment is vertical and they are parallel, the equation for line segment A is given by Eq 3.1 through Eq 3.3, and the equation for line segment B is given by Eq 3.4 through Eq 3.6. The perpendicular distance between line segment A and line segment B is given by the following equation

$$\text{DIST} = \text{ABS}(\text{XBA}-\text{XBB})*\text{COS}(\text{ATAN}(0.5*(\text{XMA}+\text{XMB}))) \tag{3.9}$$

If this distance approaches zero, then the line segments possibly intersect continuously; otherwise, the line segments do not intersect. If the line segments intersect continuously, then the minimum X and Y coordinates where the line segments are the same are given by

$$\text{XINT1} = \text{AMAX1}(\text{AMIN1}(\text{X1},\text{X2}),\text{AMIN1}(\text{X3},\text{X4})) \tag{3.10}$$

$$\text{YINT1} = \text{AMAX1}(\text{AMIN1}(\text{Y1},\text{Y2}),\text{AMIN1}(\text{Y3},\text{Y4})) \tag{3.11}$$

and the maximum X and Y coordinates where the line segments are the same are given by

$$\text{XINT2} = \text{AMIN1}(\text{AMAX1}(\text{X1},\text{X2}),\text{AMAX1}(\text{X3},\text{X4})) \tag{3.12}$$

$$\text{YINT2} = \text{AMIN1}(\text{AMAX1}(\text{Y1},\text{Y2}),\text{AMAX1}(\text{Y3},\text{Y4})) \tag{3.13}$$

For the third case, when line segment A is vertical while line segment B is not vertical, the equation for line segment A is

$$XA = 0.5*(X1+X2) \tag{3.14}$$

and the equation for line segment B is given by Eq 3.4 through Eq 3.6. When Eq 3.14 and Eq 3.4 are solved simultaneously, the X coordinate of the point of intersection is

$$XINT = XA \tag{3.15}$$

and the Y coordinate of the point of intersection is

$$YINT = XMB*XINT + XBB \tag{3.16}$$

For the fourth case, when line segment B is vertical while line segment A is not vertical, the equation for line segment A is given by Eq 3.1 through Eq 3.3 and the equation for line segment B is

$$XB = 0.5*(X3+X4) \tag{3.17}$$

When Eq 3.1 and Eq 3.17 are solved simultaneously, the X coordinate of the point of intersection is

$$XINT = XB \tag{3.18}$$

while the Y coordinate of the point of intersection is

$$YINT = XMA*XINT + XBA \tag{3.19}$$

For the last case, when both line segments are vertical, the equation for line segment A is given by Eq 3.14 while the equation for line segment B is given by Eq 3.17. Because both line segments are vertical, the perpendicular distance between line segment A and line segment B is given by the following equation

$$DIST = ABS(XA-XB) \tag{3.20}$$

If this distance approaches zero, then the line segments possibly intersect continuously; otherwise, the line segments do not intersect. If the line segments intersect continuously, the minimum X and Y coordinates where both line segments are the same are given by

$$\mathrm{XINT1} = 0.5*(\mathrm{XA}+\mathrm{XB}) \tag{3.21}$$

$$\mathrm{YINT1} = \mathrm{AMAX1}(\mathrm{AMIN1}(\mathrm{Y1},\mathrm{Y2}),\mathrm{AMIN1}(\mathrm{Y3},\mathrm{Y4})) \tag{3.22}$$

and the maximum X and Y coordinates where both line segments are the same are given by

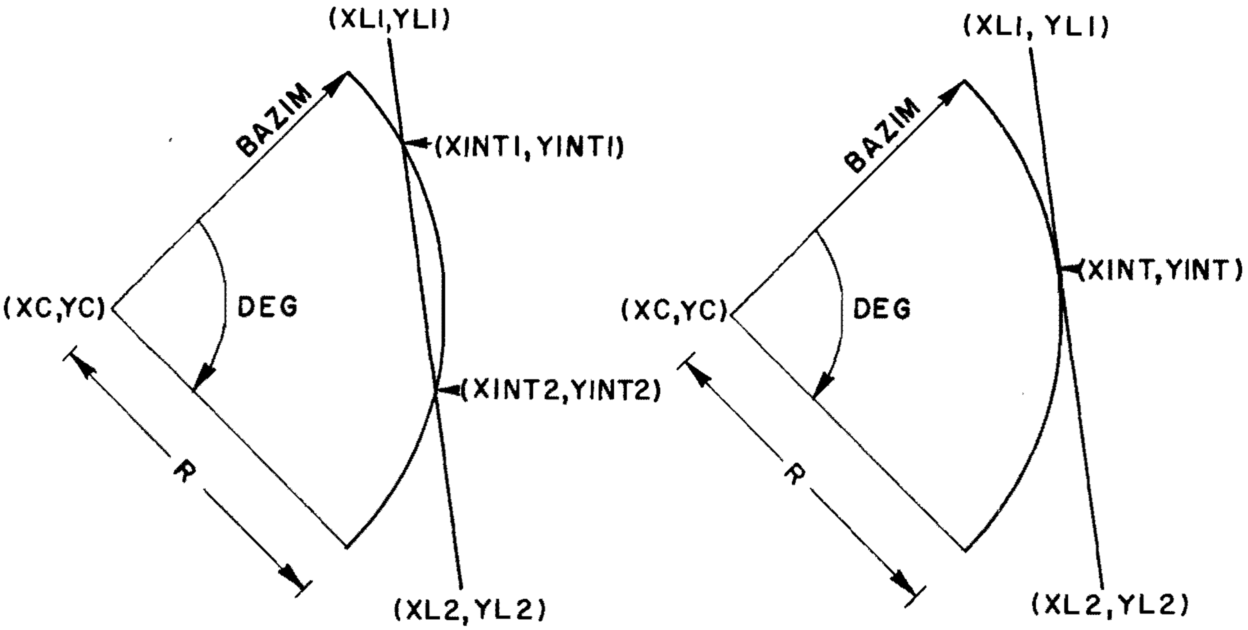
$$\mathrm{XINT2} = \mathrm{XINT1} \tag{3.23}$$

$$\mathrm{YINT2} = \mathrm{AMIN1}(\mathrm{AMAX1}(\mathrm{Y1},\mathrm{Y2}),\mathrm{AMAX1}(\mathrm{Y3},\mathrm{Y4})) \tag{3.24}$$

In each of the cases where there is one point of intersection between the line segments, appropriate tests are made to ensure that the point of intersection lies on both line segment A and line segment B.

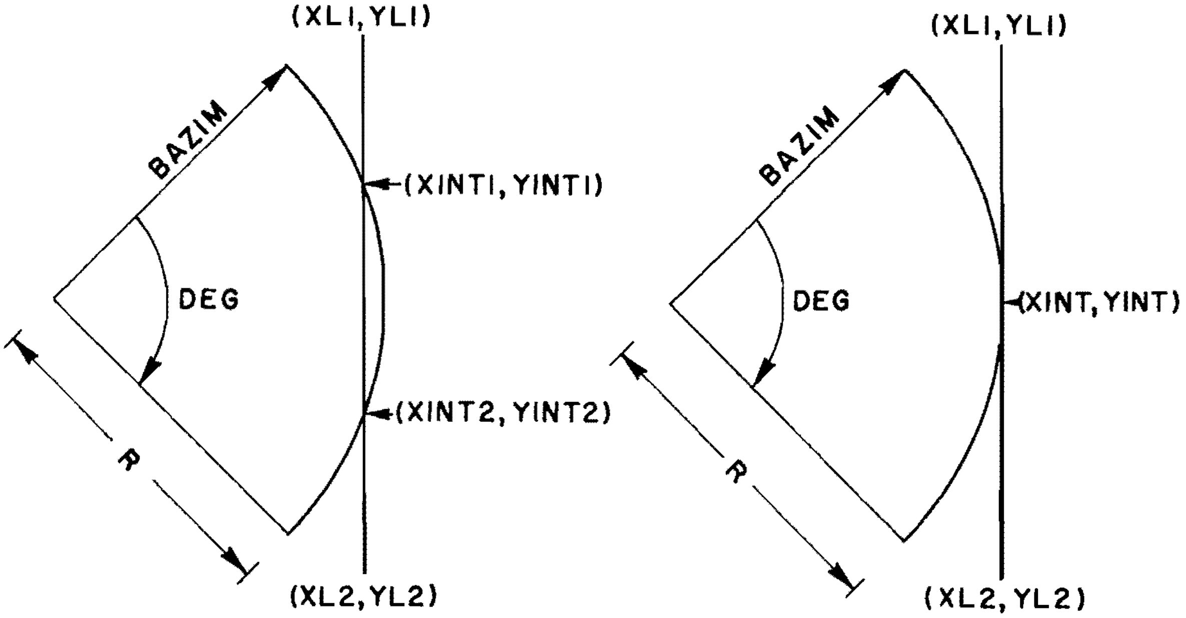
3.3.16.2 Straight Line Segment Intersection With An Arc Of A Circle

Assuming that there is a straight line segment which may or may not intersect with an arc of a circle, the problem is to discover whether they do or do not intersect. There are four distinct cases which must be investigated (see Fig 3.37): (1) the straight line segment is not vertical and intersects the arc of the circle twice, (2) the straight line segment is not vertical and is tangent to the arc of the circle, (3) the straight line segment is vertical and intersects the arc of the circle twice, and (4) the straight line segment is vertical and is tangent to the arc of the circle. The straight line segment is defined as going from coordinate (X1,Y1) to (X2,Y2) and the arc of a circle is defined as having a center-of-circle coordinate of (XC,YC), having a radius equal to R, starting at an azimuth of BAZIM, and having a sweep angle of DEG degrees.



The straight line segment is
not vertical and intersects
the arc of the circle twice

The straight line segment is
not vertical and is tangent
to the arc of the circle



The straight line segment is
vertical and intersects
the arc of the cirlce twice

The straight line segment is
vertical and is tangent to
the arc of the circle

Fig 3.37. Straight line segment intersection with an arc of a circle.

For the first case, when the straight line segment is not vertical and intersects the arc of the circle twice, the equation of the straight line segment is

$$Y = XM*X + XB \tag{3.25}$$

where XM is the slope of the line segment and is

$$XM = (Y2-Y1)/(X2-X1) \tag{3.26}$$

and where XB is the Y intercept of the line segment and is

$$XB = Y1 - X1*XM \tag{3.27}$$

The equation of the arc of the circle isbe

$$(X-XC)**2 + (Y-YC)**2 = R**2 \tag{3.28}$$

When Eq 3.25 and Eq 3.28 are solved simultaneously, the equations for the X and Y coordinate of the points of intersection are

$$XINT1 = (-B+SQRT(B**2-4*A*C))/(2*A) \tag{3.29}$$

$$YINT1 = XM*XINT1 + XB \tag{3.30}$$

$$XINT2 = (-B-SQRT(B**2-4*A*C))/(2*A) \tag{3.31}$$

$$YINT2 = XM*XINT2 + XB \tag{3.32}$$

where A, B, and C are constants of the quadratic equation and are

$$A = 1.0 + XM**2 \tag{3.33}$$

$$B = -2*XC + 2*XM*XB -2*YC*XM \tag{3.34}$$

$$C = XC**2 + YC**2 + XB**2 - R**2 -2*YC*XB \tag{3.35}$$

For the second case, when the straight line segment is not vertical and is tangent to the arc of the circle, the equation of the straight line segment is defined by Eq 3.25 through Eq 3.27 and the equation of the arc of the circle is defined by Eq 3.28. Again, when Eq 3.25 and Eq 3.28 are solved simultaneously, the equations for the X and Y coordinate of the point of intersection are (because B**2-4*A*C approaches zero)

$$\mathrm{XINT} = -\mathrm{B}/(2*\mathrm{A}) \qquad (3.36)$$

$$\mathrm{YINT} = \mathrm{XM}*\mathrm{XINT} + \mathrm{XB} \qquad (3.37)$$

where A, B, and C are constants of the quadratic equation and are defined by Eq 3.33 through Eq 3.35.

For the third case, when the straight line segment is vertical and intersects the arc of the circle twice, the equation of the straight line segment is

$$\mathrm{X} = 0.5*(\mathrm{X1}+\mathrm{X2}) \qquad (3.38)$$

and the equation of the arc of the circle is defined by Eq 3.28. When Eq 3.38 and Eq 3.28 are solved simultaneously, the equations for the X and Y coordinate of the points of intersection is

$$\mathrm{XINT1} = \mathrm{X} \qquad (3.39)$$

$$\mathrm{YINT1} = (-\mathrm{B}+\mathrm{SQRT}(\mathrm{B}**2-4*\mathrm{A}*\mathrm{C}))/(2*\mathrm{A}) \qquad (3.40)$$

$$\mathrm{XINT2} = \mathrm{X} \qquad (3.41)$$

$$\mathrm{YINT2} = (-\mathrm{B}-\mathrm{SQRT}(\mathrm{B}**2-4*\mathrm{A}*\mathrm{C}))/(2*\mathrm{A}) \qquad (3.42)$$

where A, B, and C are constants of the quadratic equation and are

A = 1.0 (3.43)

B = -2*YC (3.44)

C = YC**2 + (X-XC)**2 - R**2 (3.45)

For the last case, when the straight line segment is vertical and is tangent to the arc of the circle, the equation of the straight line segment is defined by Eq 3.38 and the equation of the arc of the circle is defined by Eq 3.28. Again, when Eq 3.38 and Eq 3.28 are solved simultaneously, the equation for the X and Y coordinates of the point of intersection would be (because B**2-4*A*C approaches zero)

XINT = X (3.46)

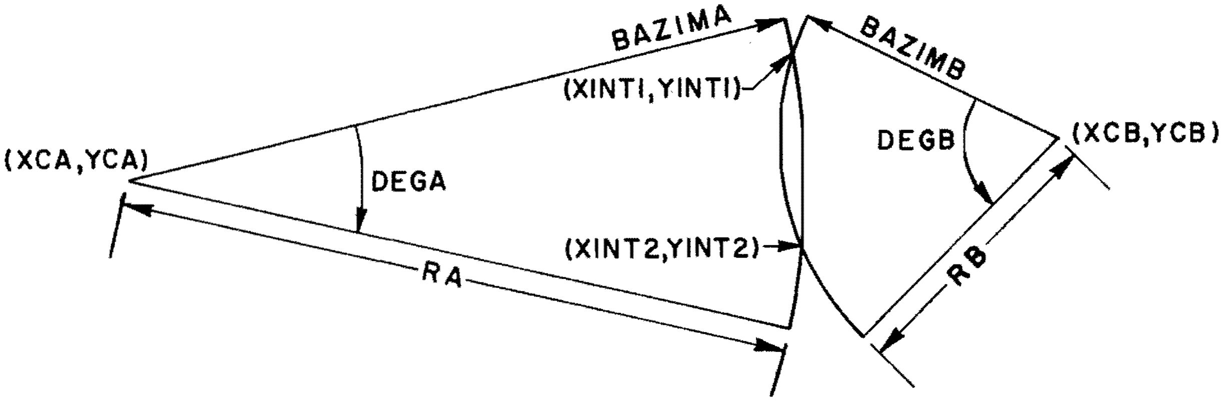
YINT = -B/(2*A) (3.47)

where A, B, and C are constants of the quadratic equation and are defined by Eq 3.43 through Eq 3.45.

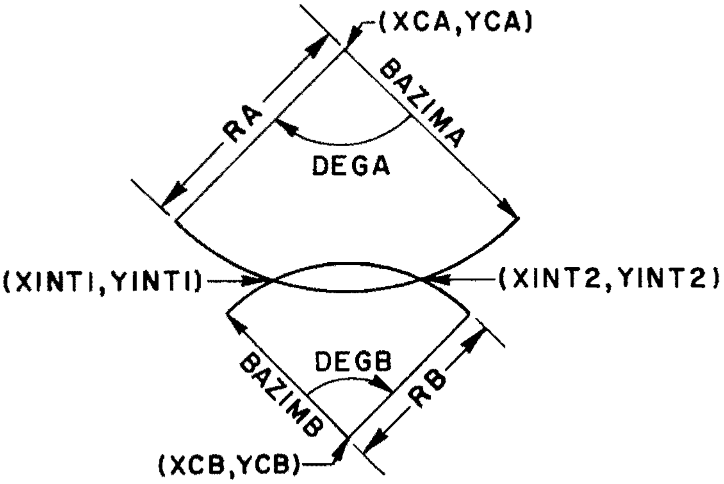
In each of the cases, appropriate tests are made to ensure that the point(s) of intersection lies on both the straight line segment and the arc of the circle.

3.3.16.3 Intersection Of Two Arcs Of Circles

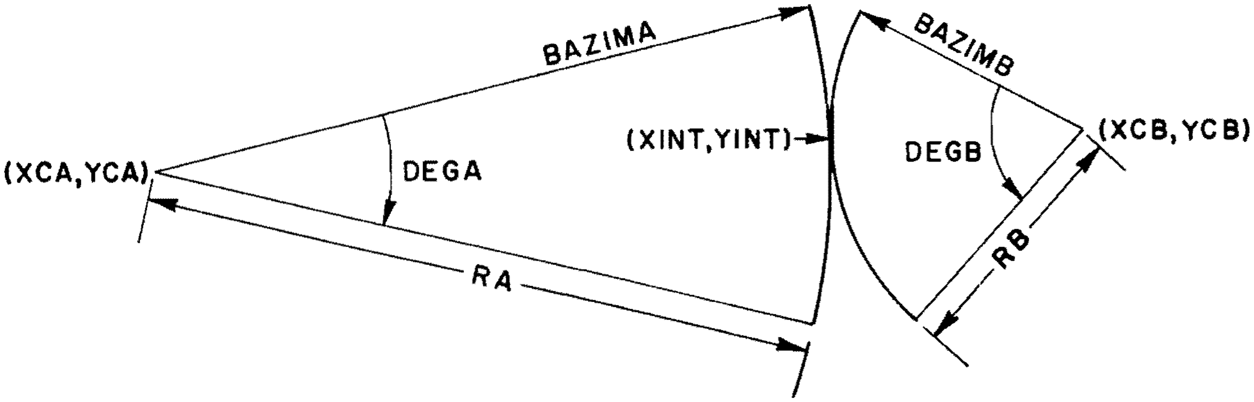
Assuming that there are two arcs of circles which may or may not intersect, the problem is to discover whether they do or do not intersect. There are four distinct cases which must be investigated (see Fig 3.38): (1) the arcs of the circles intersect twice and the Y coordinates of the points of intersection are not the same, (2) the arcs of the circles intersect twice and the Y coordinates of the points of intersection are the same, (3) the arcs of the circles are tangent, and (4) the arcs of the circles intersect continuously. The arc of circle A is defined as having a center-of-circle coordinate of (XCA,YCA), having a radius equal to RA,



The arcs of the circles intersect twice and the Y coordinates of the intersection are not the same



The arcs of the circles intersect twice and the Y coordinates of the intersection are the same



The arcs of the circles are tangent

Fig 3.38. Arc of a circle intersection with another arc of a circle.

starting at an azimuth of BAZIMA, and having a sweep angle of DEGA degrees, while the arc of circle B is defined as having a center-of-circle coordinate of (XCB,YCB), having a radius equal to RB, starting at an azimuth of BAZIMB, and having a sweep angle of DEGB degrees.

For the first case, when the arcs of the circles intersect twice and the Y coordinates of the points of intersection are not the same, the equation of the arc of circle A is

$$\mathrm{(X-XCA)**2 + (Y-YCA)**2 = RA**2} \tag{3.48}$$

while the equation of the arc of circle B is

$$\mathrm{(X-XCB)**2 + (Y-YCB)**2 = RB**2} \tag{3.49}$$

When Eq 3.48 and Eq 3.49 are solved simultaneously, the equations for the Y coordinates of the points of intersection are

$$\mathrm{YINT1 = (-B+SQRT(B**2-4*A*C))/(2*A)} \tag{3.50}$$

$$\mathrm{YINT2 = (-B-SQRT(B**2-4*A*C))/(2*A)} \tag{3.51}$$

where A, B, and C are constants of the quadratic equation, as follows

$$\mathrm{A = 4*((XCB-XCA)**2+(YCB-YCA)**2)} \tag{3.52}$$

$$\begin{aligned}\mathrm{B} &= \mathrm{4*(YCB-YCA)*(RB**2-RA**2+YCA**2-YCB**2)\ -}\\ &\quad \mathrm{4*((XCB-XCA)**2)*(YCA+YCB)}\end{aligned} \tag{3.53}$$

$$\begin{aligned}\mathrm{C} &= \mathrm{((RB**2-RA**2)-(YB**2-YA**2))**2\ +}\\ &\quad \mathrm{((XCB-XCA)**2)*(-2*RB**2-2*RA**2+2*YCA**2}\\ &\quad \mathrm{+2*YCB**2+(XCB-XCA)**2)}\end{aligned} \tag{3.54}$$

The author was unable to develop an equation which would explicitly express the X coordinate of the intersection because the equation would involve a plus or minus square root term and no rule could be formulated for choosing whether the plus case or the minus case should be used. Since the value had to be one or the other, the plus case was calculated and a test was performed to see if the coordinate (XINT,YINT) was RA distance away from (XCA,YCA) and RB distance away from (XCB,YCB). If the test was true, then the plus case was used; otherwise the minus case was used. The equation for an X coordinate of the intersection of the arcs of the circles, given a Y coordinate of the point of intersection YINT, is as follows

$$\mathrm{XINT} = \mathrm{XCA} + \mathrm{SQRT}(\mathrm{RA}{*}{*}2-(\mathrm{YINT}-\mathrm{YCA}){*}{*}2) \tag{3.55}$$

or

$$\mathrm{XINT} = \mathrm{XCA} - \mathrm{SQRT}(\mathrm{RA}{*}{*}2-(\mathrm{YINT}-\mathrm{YCA}){*}{*}2) \tag{3.56}$$

Since the point of intersection should lie on both arcs of the circles, the alternate equations could have been

$$\mathrm{XINT} = \mathrm{XCB} + \mathrm{SQRT}(\mathrm{RB}{*}{*}2-(\mathrm{YINT}-\mathrm{YCB}){*}{*}2) \tag{3.57}$$

or

$$\mathrm{XINT} = \mathrm{XCB} - \mathrm{SQRT}(\mathrm{RB}{*}{*}2-(\mathrm{YINT}-\mathrm{YCB}){*}{*}2) \tag{3.58}$$

It should be noted from this procedure that the X coordinates of the points of intersection could be the same. This is a perfectly acceptable solution when the conditions exist.

For the second case, when the arcs of the circles intersect twice and the Y coordinates of the points of intersection are the same, the equation of the arc of circle A is defined by Eq 3.48 while the equation of the arc of circle B is defined by Eq 3.49. Again when Eq 3.48 and Eq 3.49 are solved simultaneously, the equation for the Y coordinate of the points of intersection are (because $B{*}{*}2-4{*}A{*}C$ approaches zero)

$$\mathrm{YINT1} = -B/(2{*}A) \tag{3.59}$$

$$\mathrm{YINT2} = \mathrm{YINT1} \tag{3.60}$$

where A, B, and C are constants of the quadratic equation and are defined by Eq 3.52 through Eq 3.54. Since there are two points of intersection with the same Y coordinate, the equations for the corresponding X coordinates for the points of intersection are given by Eq 3.55 through Eq 3.58.

For the third case, when the arcs of the circles are tangent, the equation of the arc of circle A is defined by Eq 3.48 while the equation of the arc of circle B is defined by Eq 3.49. Again when Eq 3.48 and Eq 3.49 are solved simultaneously, the equation for the Y coordinate of the point of intersection is (because B**2-4*A*C approaches zero)

$$\text{YINT} = -\text{B}/(2*\text{A}) \tag{3.61}$$

where A, B, and C are constants of the quadratic equation and are defined by Eq 3.52 through Eq 3.54. The equation for the X coordinate of the point of intersection is given by Eq 3.55 through Eq 3.58.

For the last case, when the arcs of the circles intersect continuously, the equation for the arc of circle A is defined by Eq 3.48 while the equation for the arc of circle B is defined by Eq 3.49. In this case, XCA is equal to XCB, YCA is equal to YCB, and RA is equal to RB. In checking for intersection conflicts in GEOPRO, it is impossible for two arcs of circles to intersect continuously.

In each of the cases, appropriate tests are made to ensure that the points of intersection lie within the bounds of the arc of circle A and the arc of circle B.

3.4 Output

Output from the geometry processor includes print, plot, and magnetic tape. The printed output includes the echo print of the input, a listing of the minimum available sight distance between inbound approaches (if there are restrictions), a listing of the intersection paths, and a listing of the intersection conflicts between the intersection paths. If there is an input error, a diagnostic message is printed and GEOPRO stops. There are 59 input errors which are detected and the STOP numbers range from 801 to 859. When an execution error is detected by GEOPRO, a diagnostic message is printed, followed by a print of selected program variables. There are 18 execution errors detected (they are all considered "can't get here halts") and the STOP numbers range from 901 to 918. Several execution errors indicate problems in the input which could not be detected until computations commenced.

Plot output is optional but is highly recommended. There are three basic plots: (1) a plot of the full length of all approaches and all sight distance restriction coordinates, (2) a plot of at least the last 20 feet (6.1 meters) of each inbound approach and at least the first 20 feet (6.1 meters) of each outbound approach (an enlargement of the intersection area), and (3) a plot of at least the last 20 feet (6.1 meters) of each inbound approach, at least the first 20 feet (6.1 meters) of each outbound approach, and all generated intersection paths. The third plot type may be one plot frame for all inbound approaches (plot framing option SAME) or one plot frame for each inbound approach (plot framing option SEPARATE).

Magnetic tape output includes the title for the geometry processor run, the arc information, the line information, the approach information, the lane information, the sight distance restriction information, the intersection path information, and the intersection conflict information. Table 3.2 gives the structure of the data written onto the magnetic tape.

3.5 Verification

Verification of the geometry processor was accomplished by analyzing debug prints of intermediate results and reviewing printed and plotted output of various test data sets. In addition, several selected subprograms were tested independently to ensure that they performed properly.

3.6 Computer Requirements

GEOPRO requires 29,760 words (72,100 octal) of storage on CDC computers and 176,000 bytes of storage on IBM computers. Geometry computations for an

Table 3.2 Magnetic Tape Output from the Geometry Processor

1. Title for geometry processor run
2. Arc information
    a. Number of arcs
    b. Arc attributes (if the number of arcs is not zero)
        1. Arc number
        2. X coordinate for the center of the arc
        3. Y coordinate for the center of the arc
        4. Beginning azimuth of the arc
        5. Sweep angle of the arc
            a. Positive for clockwise
            b. Negative for counter-clockwise
        6. Radius of the arc (ft)
3. Line information
    a. Number of lines
    b. Line attributes (if the number of lines is not zero)
        1. Line number
        2. X coordinate for the start of the line
        3. Y coordinate for the start of the line
        4. X coordinate for the end of the line
        5. Y coordinate for the end of the line
4. Approach information
    a. Number of inbound approaches
    b. List of inbound approaches
    c. Number of outbound approaches
    d. List of outbound approaches
    e. Number of inbound and outbound approaches
    f. Approach attributes
        1. Approach number
        2. Approach azimuth
        3. X coordinate for the start of approach
        4. Y coordinate for the start of approach
        5. Speed limit of approach (ft/sec)

(continued)

Table 3.2 (continued)

    6. Number of lanes for approach
    7. Number of sight distance restrictions
    8. Approach number for approach to the left (zero for no approach)
    9. Approach number for approach to the right (zero for no approach)
    10. List of lane numbers for approach
    11. Sight distance restriction information
        (if number of sight distance restrictions is not zero)
        a. Sight distance restriction number
        b. Approach number of other approach involved in sight distance restriction

5. Lane information
    a. Number of lanes
    b. Lane attributes
        1. Lane width (ft)
        2. Lane turn codes
            a. 0 for outbound
            b. 1 bit set for right turn
            c. 2 bit set for straight through movement
            d. 4 bit set for left turn
            e. 8 bit set for u-turn
        3. Number of intersection paths for lane
        4. Lane number for lane to the left (zero for no lane)
        5. Lane number for lane to the right (zero for no lane)
        6. Approach number for lane
        7. Lane geometry for lane
            a. Begin1 (ft)
            b. End1 (ft)
            c. Begin2 (ft)
            d. End2 (ft)
        8. Distance from median edge to center of lane (ft)
        9. Inbound lane number (zero for outbound lane)

(continued)

Table 3.2 (continued)

        10. List of intersection paths for lane
            (if number of intersection paths for lane is not zero)
6. Sight distance restriction information
    a. Number of sight distance restrictions
    b. Sight distance restriction attributes
        (if number of sight distance restrictions is not zero)
        1. Position on other approach that can be seen for each 25 foot (7.62 meters) increment on the approach (ft) (40 values)
7. Intersection path information
    a. Number of intersection paths
    b. Intersection path attributes
        1. Approach number of linking inbound approach
        2. Lane number of linking inbound lane (1 to 6)
        3. Approach number of linking outbound approach
        4. Lane number of linking outbound lane (1 to 6)
        5. Segment 1 information (line)
            a. X coordinate for start of line
            b. Y coordinate for start of line
            c. Length of line (ft) (zero for segment not used)
            d. X coordinate for end of line
            e. Y coordinate for end of line
        6. Segment 2 information (arc)
            a. X coordinate for center of arc
            b. Y coordinate for center of arc
            c. Length of arc (0 for segment not used)
            d. Radius of arc
            e. Beginning azimuth of arc
            f. Sweep angle for arc
                1. Positive for clockwise
                2. Negative for counter-clockwise

(continued)

Table 3.2 (continued)

7. Segment 3 information (arc)
    a. X coordinate for center of arc
    b. Y coordinate for center of arc
    c. Length of arc (ft) (zero for segment not used)
    d. Radius of arc
    e. Beginning azimuth of arc
    f. Sweep angle of arc
        1. Positive for clockwise
        2. Negative for counter-clockwise
8. Segment 4 information (line)
    a. X coordinate for start of line
    b. Y coordinate for start of line
    c. Length of line (ft) (zero for segment not used)
    d. X coordinate for end of line
    e. Y coordinate for end of line
9. Total length of intersection path (ft)
10. Intersection path turn code
    a. 1 for right turn
    b. 2 for straight through movement
    c. 4 for left turn
    d. 8 for u-turn
11. Path option
    a. 0 for PRIMARY
    b. 1 for OPTION1
12. Lane change flag
    a. 0 for no lane change
    b. 1 for lane change
13. Linking outbound lane number (1 to the total number of lanes)
14. Number of intersection conflicts for intersection path
16. Intersection conflict numbers ordered by distance down this intersection path (if number of intersection conflicts is not zero)

(continued)

Table 3.2 (continued)

8. Intersection conflict information
    a. Number of intersection conflicts
    b. Intersection conflict attributes
        1. Intersection path number for first intersection path
        2. Intersection path number for second intersection path
        3. Inbound approach number for first intersection path
        4. Inbound approach number for second intersection path
        5. Distance down first intersection path to intersection conflict (ft)
        6. Distance down second intersection path to intersection conflict (ft)
        7. Intersection conflict angle measured from the first intersection path to the second intersection path
        8. Index number for this conflict for first intersection path
        9. Index number for this conflict for second intersection path

average intersection (four inbound and four outbound approaches, two lanes per approach, four sight distance restriction coordinates, and PRIMARY intersection paths) take 6.3 central processor seconds on CDC computers and 9.2 central processor seconds (0.153 minutes) on IBM computers.

3.7 Documentation

Documentation for the geometry processor includes an explanation of the input and output contained in a user's guide (Ref 15), numerous COMMENT statements within the computer program, and a programmer's guide (Ref 19). The programmer's guide includes (1) the geometry processor limitations, (2) a listing of the input errors detected, (3) a listing of the execution errors detected, (4) the definition of the attributes in each entity, (5) the definition of the variables in each COMMON block, (6) the definition of the local variables used in each subprogram, (7) an alphabetical listing of all subprograms and the subprograms which can call them, (8) an alphabetical listing of all variables, their storage type, and the subprograms in which they are used, and (9) a generalized calling sequence diagram.

3.8 Additional Information

Appendix A contains example input, printed output, and plot output for a normal four-leg intersection, a six-leg intersection, and a channelized four-leg intersection. A listing of the geometry processor and its programmer's guide are provided in Appendix B. Table 3.3 gives the breakdown of the geometry processor FORTRAN statements.

Table 3.3 Fortran Statement Categorization for the Geometry Processor

```
Number of cards with <BLOCK DATA> ---------     1    .02 Percent
Number of cards with <CALL      > ---------   303   4.87 Percent
Number of cards with <COMMON    > ---------   703  11.29 Percent
Number of cards with <CONTINUE  > ---------   406   6.52 Percent
Number of cards with <DATA      > ---------   217   3.48 Percent
Number of cards with <DIMENSION > ---------    38    .61 Percent
Number of cards with <DO        > ---------    99   1.59 Percent
Number of cards with <DOUBLE PRE> ---------   220   3.53 Percent
Number of cards with <END       > ---------    84   1.35 Percent
Number of cards with <EQUIVALENC> ---------    29    .47 Percent
Number of cards with <FORMAT    > ---------   239   3.84 Percent
Number of cards with <FUNCTION  > ---------     5    .08 Percent
Number of cards with <GO TO     > ---------    64   1.03 Percent
Number of cards with <IF        > ---------   603   9.68 Percent
Number of cards with <PROGRAM   > ---------     1    .02 Percent
Number of cards with <RETURN    > ---------    99   1.59 Percent
Number of cards with <STOP      > ---------    83   1.33 Percent
Number of cards with <SUBROUTINE> ---------    74   1.19 Percent
Number of cards with COMMENTs -------------  1389  22.31 Percent
Number of cards with I/O statements -------   240   3.86 Percent
Number of cards with conditional assembly -   105   1.69 Percent
Number of cards with other statements -----  1225  19.67 Percent

Total number of statements ----------------  6227
```

4.0 THE DRIVER-VEHICLE PROCESSOR

4.1 Introduction And Purpose

The driver-vehicle processor, DVPRO, is the other pre-simulation processor. The purpose of DVPRO is to describe the characteristics of up to 5 driver classes and up to 15 vehicle classes, generate individual driver-vehicle units to be simulated by the traffic simulation processor, order the generated driver-vehicle units sequentially by queue-in time, provide default characteristics for 3 driver classes and 10 vehicle classes, insert special driver-vehicle units into the traffic stream, and write the driver-vehicle information on a magnetic tape for subsequent use by the simulation processor. The user may (1) input all the traffic stream as special driver-vehicle units and have no driver-vehicle units generated, (2) input some of the traffic stream as special driver-vehicle units and have the remainder of the driver-vehicle units generated, or (3) input no special driver-vehicle units and have all the driver-vehicle units generated. All calculations and indexing of the driver-vehicle information for the simulation process are incorporated in DVPRO. Initial development of the driver-vehicle processor is described by King (Ref 20).

4.2 Input Requirements

The driver-vehicle processor accepts input data which describes the traffic stream to be simulated. This input data is normally available from routine traffic studies or from experience with similar intersections. The generalized input to DVPRO is shown in Table 4.1. The driver-vehicle processor options allow the user to define the time for generating traffic, set the values of some parameters used in the calculations, override the program-defined default values for the driver and vehicle characteristics, and request a log-out summary for each driver and/or vehicle class. A detailed

Table 4.1 Generalized Input to the Driver-Vehicle Processor

1. Title for the driver-vehicle processor run
2. Approach information
    - a. Number and list of inbound and outbound approaches
    - b. Azimuth for each approach
    - c. Number of lanes for each approach
    - d. Maximum angular deviation of straight movement for each approach
    - e. Headway distribution and parameter(s) for each approach
        1. Constant (no parameter)
        2. Erlang (K = mean**2/variance)
        3. Gamma (A = mean**2/variance)
        4. Lognormal (standard deviation)
        5. Negative exponential (no parameter)
        6. Shifted negative exponential (TAU = mean - standard deviation)
        7. Uniform (standard deviation)
    - f. Equivalent hourly volume for each approach (veh/hr)
    - g. Mean and 85th percentile speed for each approach (mi/hr)
    - h. Percent of vehicles going from each inbound approach to each outbound approach (turning distribution)
    - i. Percent of each vehicle class making up the traffic stream (optional: program supplied for 10 vehicle classes)
3. Lane information
    - a. Geometry for each lane
        1. Full length of lane available
        2. First of lane available only
        3. Last of lane available only
        4. Lane blocked in middle only
    - b. Percent of approach volume in lane upon entry for each lane (lane occupancy)
4. Driver-vehicle processor options
    - a. Number of minutes for generating traffic (min)
    - b. Minimum time between two vehicles in the same lane (sec)

(continued)

Table 4.1 (continued)

- c. Number of driver and vehicle classes
  (optional: program supplied is 3 and 10 respectively)
- d. Percent of left turning vehicles to be in the median lane (left lane)
- e. Percent of right turning vehicles to be in the curb lane (right lane)
- f. Percent of each driver class for each vehicle class
  (optional: program supplied for 3 driver classes and 10 vehicle classes)
- g. Vehicle characteristics
  (optional: program supplied for 10 vehicle classes)
  - 1. Length of vehicle (ft)
  - 2. Vehicle operational factor
    - a. <100 for sluggish vehicle
    - b. =100 for average vehicle
    - c. >100 for responsive vehicle
  - 3. Maximum uniform deceleration rate (ft/sec/sec)
  - 4. Maximum uniform acceleration rate (ft/sec/sec)
  - 5. Maximum velocity (ft/sec)
  - 6. Minimum turning radius (ft)
- h. Driver characteristics
  (optional: program supplied for 3 driver classes)
  - 1. Driver operational factor
    - a. <100 for slow driver
    - b. =100 for average driver
    - c. >100 for aggressive driver
  - 2. Perception-reaction time (sec)
- i. Logout summary option for each vehicle class (YES/NO)
- j. Logout summary option for each driver class (YES/NO)

5. Special driver-vehicle units
   - a. Queue-in time (sec)
   - b. Driver class number
   - c. Vehicle class number
   - d. Desired speed (ft/sec)
   - e. Desired outbound approach number

(continued)

Table 4.1 (continued)

f. Inbound approach number
g. Inbound lane number
h. Logout summary option
    1. 0 for NO
    2. 1 for YES

explanation of the input and its format is contained in "The TEXAS Model for Intersection Traffic - User's Guide" (Ref 15). Extensive input error checking is performed by DVPRO to ensure that certain data are within defined bounds, that all necessary information is provided, and that some information is not duplicated. The driver-vehicle processor will print a message which describes the input error and stop. There are 62 input errors that are detected by DVPRO. A common input deck is used by GEOPRO and DVPRO since much of the information is the same.

4.2.1 Input For Approaches

In developing the input for DVPRO, as for GEOPRO, the user refers to a plan-view diagram of the intersection under study and determines which direction shall be referenced as zero degrees azimuth. The user then numbers each inbound approach (feeds traffic into the intersection) and each outbound approach (carries traffic away from the intersection). The approach numbers may be arbitrarily assigned but must be in the range from 1 to 12 and must not be duplicated. The recommended procedure is to start numbering the inbound approaches from the top of the diagram (zero degrees azimuth) and proceed sequentially in a counter-clockwise direction until all inbound approaches are numbered, and then to sequentially number the outbound approaches in the same manner. A normal four-leg intersection will have four inbound and four outbound approaches. For the inbound approaches, the southbound approach will be number 1, the eastbound approach will be number 2, the northbound approach will be number 3, and the westbound approach will be number 4. For the outbound approaches, the northbound approach will be number 5, the westbound approach will be number 6, the southbound approach will be number 7, and the eastbound approach will be number 8. The user then determines the direction of traffic flow (azimuth) for each approach.

4.2.1.1 Input For Inbound Approaches

In order to define the type of movement for paths between an inbound approach and an outbound approach when trying to bias the turning movements to specific lanes, the user must supply the number of degrees left or right of approach azimuth that is to be considered a straight-through movement (see Fig 3.1). The user must also select the headway distribution to be used for generating the approach headways and any parameter required for specifying the distribution. The available headway distributions are (1) constant, which requires no parameter, (2) Erlang, which requires the K parameter that is the integer value of the mean squared divided by the variance of the headways, (3) gamma, which requires the A parameter that is the mean squared divided by the variance of the headways, (4) lognormal, which requires the standard deviation of the headways, (5) negative exponential, which requires no parameter, (6) shifted negative exponential, which requires the TAU parameter that is the mean minus the standard deviation of the headways, and (7) uniform, which requires the standard deviation of the headways. The user must also supply the equivalent hourly volume of traffic, the mean and 85th percentile speed, and the percent of vehicles going to each outbound approach (the turning distribution). Optionally, the user may provide the percent of each vehicle class making up the traffic stream, but percentages shown in Table 4.2 are incorporated into DVPRO as program-supplied or default values to be used if this option is not exercised.

4.2.1.2 Input For Inbound Lanes

For each inbound lane, the user must specify where the lane is available and not available for traffic and the percent of the approach traffic volume which enters on the lane. DVPRO accommodates four lane types (see Fig 3.2): (1) the full length of the lane is available, (2) only the first part of the lane is available, (3) only the last part of the lane is available, and (4) the middle part of the lane is not available. The user must specify that zero percent of the approach traffic enters on lane type 3 as this lane type will be accessed only by a lane-change maneuver from the adjacent lane.

TABLE 4.2. DEFAULT DRIVER AND VEHICLE CHARACTERISTICS

	Vehicle Class and Type									
	1	2	3	4	5	6	7	8	9	10
	Small Car	Medium Car	Large Car	Vans, Mini-bus	Single-unit	Semi-trailer	Full-trailer	Recreational	Bus	Sports Car
Length	15	17	19	25	30	50	55	25	35	14
Operating Characteristic Factor	100	110	110	100	85	80	75	90	85	115
Maximum Deceleration	16	16	16	16	12	12	12	12	12	16
Maximum Acceleration	8	9	11	8	8	7	6	6	5	14
Maximum Velocity	150	192	200	150	160	160	150	150	125	205
Minimum Turning Radius	20	22	24	28	42	40	45	28	28	20
Percentage Aggressive Drivers	30	35	20	25	40	50	50	20	25	50
Percentage Average Drivers	40	35	40	50	30	40	40	30	50	40
Percentage Slow Drivers	30	30	40	25	30	10	10	50	25	10
Percentage in Traffic Stream	20	32	30	15	.5	.2	.1	.2	.5	1.5

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

4.2.2 Input For Driver-Vehicle Processor Options

The number of minutes for generating traffic should be specified as the maximum expected start-up time plus simulation time to be used for the traffic simulation processor. DVPRO may generate vehicles for a longer time than is to be simulated with the only adverse effect being the relatively small amount of extra time and storage required for producing more driver-vehicle units. The minimum time between two driver-vehicle units in the same lane is specified in order to ensure that there will be some reasonable separation between driver-vehicle units on the same lane.

The user may specify the number of driver and vehicle classes. DVPRO contains default characteristics for 3 driver classes and 10 vehicle classes, the percent of each vehicle class making up the approach traffic stream, and the percent of each driver class in each vehicle class (see Table 4.2). If the number of specified driver classes is different from the default value of 3, then the user will also need to provide new values for the percent of each driver class in each vehicle class and new driver characteristics. The percent of each driver class in each vehicle class determines the type of driver that will be in each vehicle. The driver characteristics are (1) the driver operational factor (less than 100 for a slow driver, equal to 100 for an average driver, and greater than 100 for an aggressive driver) and (2) the perception-reaction time in seconds.

If the user specifies the number of vehicle classes to be different from the default value of 10, then the user must provide new values for the percent of each vehicle class making up the traffic stream, the percent of each driver class in each vehicle class, and the vehicle characteristics. The percent of each vehicle class making up the traffic stream is input for each inbound approach. The percent of each driver class in each vehicle class determines the type of driver that will be in each vehicle. The vehicle characteristics are (1) the length of the vehicle in feet, (2) the vehicle operational factor (less than 100 for a sluggish vehicle, equal to 100 for an average vehicle, and greater than 100 for a responsive vehicle), (3) the maximum uniform deceleration rate in ft/sec/sec, (4) the maximum uniform acceleration rate in ft/sec/sec, (5) the maximum velocity in ft/sec, and (6) the minimum turning radius in feet.

The percent of left turning vehicles to enter the median lane (left lane) is used in biasing the driver-vehicle unit's inbound lane number. If the median lane (left lane) is available for entering traffic and there is more than one lane for traffic to enter the inbound approach, then DVPRO tries to make this percentage of the left turning driver-vehicle units enter the approach on the median lane (left lane). The percent of right turning vehicles to enter the curb lane (right lane) is also used in biasing the driver-vehicle unit's inbound lane number. If the curb lane (right lane) is available for entering traffic and there is more than one lane for traffic to enter the inbound approach, then DVPRO tries to make this percentage of the right turning driver-vehicle units enter the approach on the curb lane (right lane).

4.2.3 Input For Special Driver-Vehicle Units

To allow the study of special driver-vehicle units, such as police cars, fire trucks, ambulances, and buses on a fixed schedule, the user may specify special driver-vehicle units which will be inserted into the traffic stream. The attributes of the special driver-vehicle unit which must be specified are (1) the queue-in time in seconds into the traffic simulation, (2) the driver class number, (3) the vehicle class number, (4) the desired speed in ft/sec, (5) the desired outbound approach number, (6) the inbound approach number, (7) the inbound lane number, and (8) the log-out summary option (zero for no and 1 for yes). If the log-out summary option is yes then the driver-vehicle unit's individual statistics will be printed when the unit logs out of the system in the traffic simulation processor.

4.3 Algorithms For Computation

Most of the calculations in the driver-vehicle processor involve the generation of random variates of defined probability distribution functions. The probability distribution functions used by DVPRO describe the random variables involved in generating the traffic stream to be simulated by the simulation processor. The random variables are (1) the queue-in time, (2) the driver class number, (3) the vehicle class number, (4) the desired speed, (5) the desired outbound approach number, and (6) the inbound lane number. The inbound approach number is not a random variable for the driver-vehicle unit. For each inbound approach, the driver-vehicle processor generates the queue-in time for the driver-vehicle units and assigns the number of the inbound approach used when generating the queue-in time. The probability density functions used in computing the queue-in time are (1) Erlang, (2) gamma, (3) lognormal, (4) negative exponential, (5) shifted negative exponential, and (6) uniform. The probability distribution function used to define the driver class number, the vehicle class number, the desired outbound approach number, and the inbound lane number is the empirical discrete distribution (percentages of occurrence for a particular class). A normal probability distribution is used to define the desired speed of each vehicle. A short review of probability distributions is presented in the following section, for convenience.

4.3.1 Review Of Probability Distributions

From the viewpoint of probability theory, an experiment represents the act of observing a phenomenon the output of which is subject to chance (unknown) variation (Ref 21, pp 393-400). Such output is usually referred to as the outcome of the experiment. The number of these outcomes may be finite or infinite, depending on the nature of the experiment. A sample space defines the set of observations which includes all possible outcomes of the experiment. A sample space may be finite or infinite depending on whether the number of outcomes is finite or infinite, respectively. An event is a collection of outcomes from within the sample space.

The probability of occurrence [usually written as f(x)] of an event X is a non-negative real number which, after a sufficiently large number of trials are observed, is taken as equal to the fraction of trials for which event X occurred. Mathematically, this means that if N is the total number of trials, of which there are M trials in which X was observed, then

$$f(X) = \lim(M/N) \quad \text{as } N \rightarrow +\infty \text{ and } 0 < f(X) < 1 \qquad (4.1)$$

The outcomes of an experiment are said to be represented by a random variable if these outcomes are themselves numerical or if they have real numbers assigned to them. In a sense then, a random variable is a real-valued function which maps the sample space onto the real line.

A probability distribution is a theoretical model of the relative frequencies of a finite number of observations of a variable (Ref 22, p 181). A function that assigns a probability to each of the elementary events of an experiment is called a probability density function [denoted f(X)]. The cumulative probability density function is defined as the sum of the probabilities of all values of the variate less than or equal to X [denoted F(X)]. A discrete probability density function is a point function that is defined over a finite sample space and takes on only a finite number of values. A continuous probability density function is a set function that expresses a distribution in which a probability is assigned to a given range of values (Ref 22, p 184).

If X is a discrete random variable, then its probability density function must satisfy the following conditions (Ref 21, pp 393-400; Ref 22, pp 181-189; Ref 23, pp 34-35; and Ref 24, p 38)

$$f(X) > 0.0 \qquad \text{for all admissible values of X} \qquad (4.2)$$

$$\Sigma\ f(X) = 1.0 \qquad \text{for all admissible values of X} \qquad (4.3)$$

For a discrete random variable, the cumulative density function is as follows

$$F(X) = \Sigma\ f(X) \qquad \text{for all admissible values} \le \text{X} \qquad (4.4)$$

The equations for the mean and variance of a discrete probability density function are

$$\text{mean} = \Sigma\ X*f(X) \qquad \text{for all admissible values of X} \qquad (4.5)$$

$$\text{variance} = \Sigma\ X**2*f(X) - \text{mean}**2 \qquad \text{for all admissible values of X} \qquad (4.6)$$

For the cumulative density function, some important properties are

$$\lim(F(X)) = \lim(\Sigma \ f(X)) = 1.0 \qquad \text{as } X \to +\infty \tag{4.7}$$

$$\lim(F(X)) = \lim(\Sigma \ f(X)) = 0.0 \qquad \text{as } X \to -\infty \tag{4.8}$$

$$F(X) \ \text{ is a monotone nondecreasing function of } X \tag{4.9}$$

$$f(X) = dF(X)/dX \tag{4.10}$$

If X is a continuous random variable, then its probability density function must satisfy the following conditions (Ref 21, pp 393-400; Ref 22, pp 181-189; Ref 23, pp 34-35; and Ref 24, p 38)

$$f(X) > 0.0 \qquad -\infty < X < +\infty \tag{4.11}$$

$$\int_{-\infty}^{+\infty} f(X) \, dX = 1.0 \tag{4.12}$$

For a continuous random variable, the cumulative density function is as follows

$$F(X) = \int_{-\infty}^{+\infty} f(X) \, dX \qquad \text{for admissible values of } X \tag{4.13}$$

The mean and variance of a continuous probability density function are

$$\text{mean} = \int_{-\infty}^{+\infty} X{*}f(X) \, dX \tag{4.14}$$

$$\text{variance} = \int_{-\infty}^{+\infty} X{*}{*}2{*}f(X) \, dX - \text{mean}{*}{*}2 \tag{4.15}$$

For the cumulative density function, some important properties are

$$\lim(F(X)) = \lim(\int_{-\infty}^{X} f(X) \, dX) = 1.0 \qquad \text{as } X \to +\infty \tag{4.16}$$

$$\lim(F(X)) = \lim(\int_{-\infty}^{X} f(X) \, dX) = 0.0 \qquad \text{as } X \to -\infty \tag{4.17}$$

$$F(X) \ \text{ is a monotone nondecreasing function of } X \tag{4.18}$$

$$f(X) = dF(X)/dX \tag{4.19}$$

The mode of a distribution is the most frequently occuring value and is thus the value of X corresponding to the maximum value for f(X). The median of a distribution is the middle value and is thus the value of X when F(X) is equal to 50 percent. The mean of a distribution is the expected value and thus the arithmetic mean of all values of f(X). For symmetrical distributions, the mode, median, and mean all have the same value. For an asymmetrical distribution, the mode, median, and mean are not the same.

4.3.2 Generation Of A Random Variate

To demonstrate the methodology used in generating random variates of a particular probability density function, a simple example will be examined in detail. Assume that a continuous probability density function has the following equation

$$f(X) = \begin{cases} 0.5*X & \text{for } 0 < X < 2 \\ & \\ 0.0 & \text{elsewhere} \end{cases} \tag{4.20}$$

First, this distribution must be tested to ensure that it is a probability distribution. This distribution satisfies Eq 4.11 because Eq 4.20 defines a non-negative value for f(X) for all values of X . This distribution satisfies Eq 4.12 because Eq 4.20 substituted into Eq 4.12 and evaluated gives

$$\begin{aligned} \int_{-\infty}^{+\infty} f(X)\,dX &= \int_{-\infty}^{0} 0\,dX + \int_{0}^{2} 0.5*X\,dX + \int_{2}^{+\infty} 0\,dX \\ &= 0.0 + (0.25*2**2 - 0.25*0**2) + 0.0 \\ &= 1.0 \end{aligned} \tag{4.21}$$

From Eq 4.13 and Eq 4.20, the cumulative probability density function can be derived as follows

$$F(X) = \begin{cases} \int_{-\infty}^{0} f(X)\,dX = \int_{-\infty}^{0} 0\,dX = 0.0 & \text{for all } X < 0 \\ \int_{-\infty}^{X} f(X)\,dX = \int_{-\infty}^{0} f(X)\,dX + \int_{0}^{X} f(X)\,dX & \\ \qquad = \int_{-\infty}^{0} 0\,dX + \int_{0}^{X} 0.5*X\,dX & \\ \qquad = 0.0 + (0.25*X**2 - 0.25*0**2) & \\ \qquad = 0.25*X**2 & \text{for } 0 < X < 2 \end{cases} \tag{4.22}$$

Using Eq 4.14 and Eq 4.15, the mean and variance of this distribution are as follows

$$\begin{aligned} \text{mean} &= \int_{-\infty}^{+\infty} X*f(X)\,dX \\ &= \int_{-\infty}^{0} X*0\,dX + \int_{0}^{2} X*0.5*X\,dX + \int_{2}^{+\infty} X*0\,dX \\ &= 0.0 + (0.167*2**3 - 0.167*0**3) + 0.0 \\ &= 1.333 \end{aligned} \tag{4.23}$$

$$\begin{aligned} \text{variance} &= \int_{-\infty}^{+\infty} X**2*f(X)\,dX - \text{mean}**2 \\ &= \int_{-\infty}^{0} X**2*0\,dX + \int_{0}^{2} X**2*0.5*X\,dX + \\ &\quad \int_{2}^{+\infty} X**2*0\,dX - \text{mean}**2 \\ &= 0.0 + (0.125*2**4 - 0.125*0**4) + 0.0 - 1.333**2 \\ &= 0.222 \end{aligned} \tag{4.24}$$

This example continuous probability density function and its cumulative probability density function are illustrated in Fig 4.1. Solving Eq 4.22 for X between zero and 2 produces the following equation

$$X = 2*SQRT(F(X)) \tag{4.25}$$

For a specific value of F(X), a value of the variate X can be calculated using Eq 4.25.

If 100 values of this example continuous probability density function are desired, Eq 4.25 can be used with values of F(X) starting at 0.005 and incrementing by 0.01 until F(X) reaches 0.995. This procedure generates 100 values of X that are in ascending order and distributed according to the example continuous probability density function. The values of F(X) used to generate the values of X are a uniform distribution between 0.0 and 1.0. In order to generate 100 random values of the example continuous probability

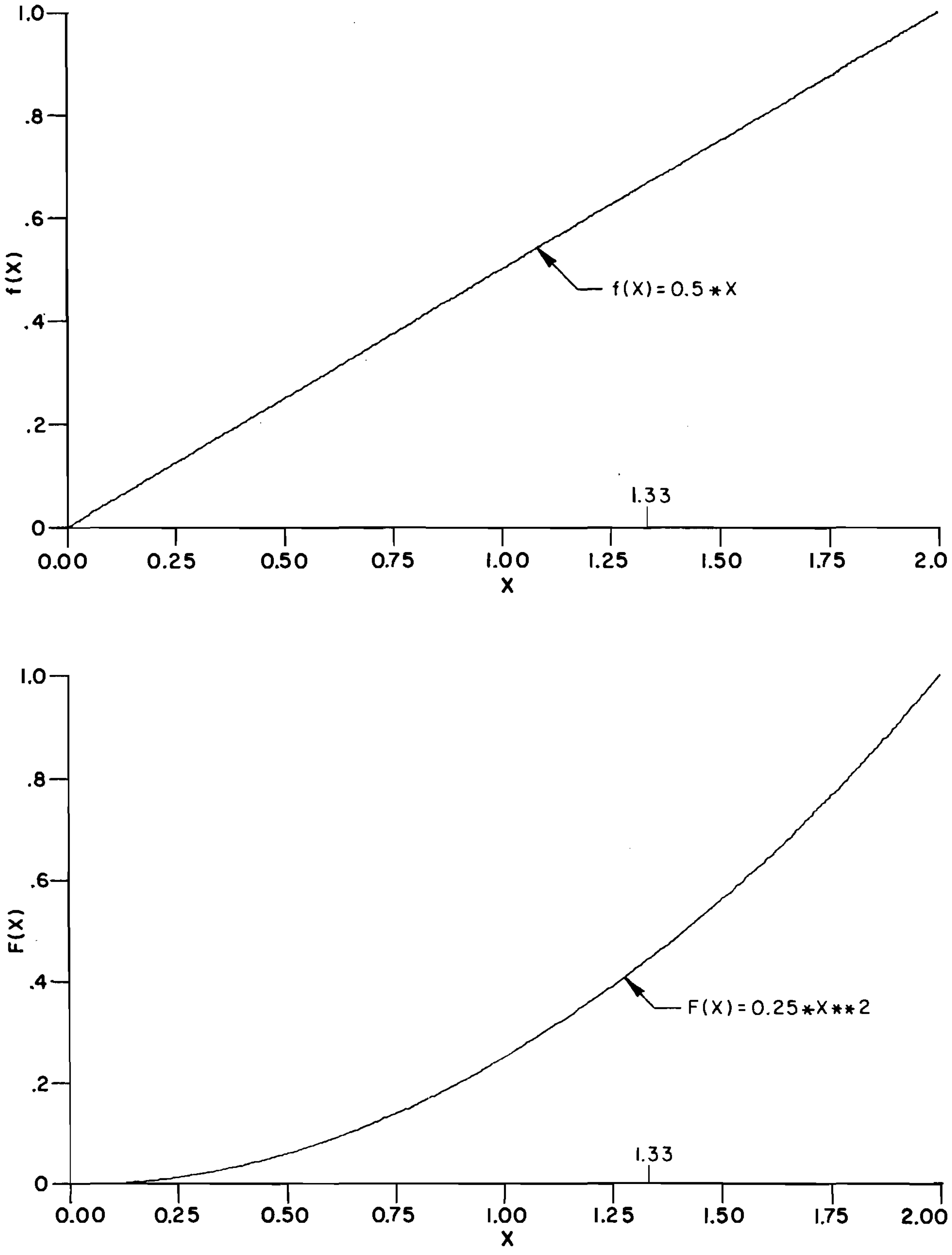


Fig 4.1. Example continuous probability density function and cumulative probability density function.

density function, Eq 4.25 may be used with the values of F(X) being 100 random numbers uniformly distributed between 0.0 and 1.0. This procedure generates 100 values of X that are in random order and distributed according to the example continuous probability density function. This procedure of generating random variates is called the inverse transform method and is described more thoroughly by Naylor (Ref 25).

In adapting this procedure to the digital computer, the problem is how to generate random numbers. On most computer systems, there is a function subprogram which will return a pseudorandom number [denoted RANF(0)]. These functions will yield sequences of numbers which are (1) uniformly distributed, (2) statistically independent, (3) reproducible, and (4) nonrepeating for any desired length. These functions are capable of generating random numbers at high rates of speed yet require a minimum amount of computer memory capacity.

4.3.3 Generation Of Queue-In Time

Queue-in time is the real time into the traffic simulation at which a particular driver-vehicle unit should enter the end of an inbound approach and lane. The queue-in time is also the summation of the headways of the previous driver-vehicle units that have entered a specific inbound approach. The driver-vehicle processor thus generates the approach headways and sums them to define the queue-in time for a specific driver-vehicle unit. The approach headways are generated as random variates of one of the following distributions: (1) Erlang, (2) gamma, (3) lognormal, (4) negative exponential, (5) shifted negative exponential, and (6) uniform. Also available is the option of constant headways. In each of the distributions, the mean headway is calculated from the flow for the approach. The other parameter for some of the distributions is a dispersion factor (a function of the standard deviation) which generally describes the randomness of the flow.

4.3.3.1 Generation Of Erlang Random Variates

For Poisson-distributed arrivals, the Erlang probability distribution can be used to represent the waiting time T until the Kth arrival (Ref 21, p 405; Ref 22, pp 251-254; Ref 23, pp 358-362; Ref 24, pp 78-80; Ref 25, pp 87-89; Ref 26, p 299; and Ref 27, pp 17-19 and 27-28). The Erlang distribution is thus the sum of K negative exponential variates with an identical expected value of 1/ALPHA. The Erlang distribution can be used to represent the distribution of time between vehicle arrivals if the arrivals are not randomly distributed.

The Erlang probability distribution is a gamma probability distribution with an integer value for A. The Erlang probability density function is

$$f(t) = \begin{cases} (ALPHA**K)*(T**(K-1))/FACT(K-1)*EXP(-ALPHA*T) & \\ & \text{for } T > 0,\ ALPHA > 0, \text{ and } K > 0 \\ & \\ 0.0 & \text{elsewhere} \end{cases} \tag{4.26}$$

where FACT(K-1) represents (K-1) factorial. The value of K may be a rough indication of the degree of nonrandomness. When K is equal to 1, the arrivals appear to be random, and, as K increases, the degree of nonrandomness appears to increase. If K is equal to 1, then the Erlang probability distribution is identical to the negative exponential probability distribution. The Erlang distribution is positively skewed for small values of K and as K increases, the Erlang distribution approaches a normal distribution asymptotically.

The cumulative density function for the Erlang distribution does not exist explicitly. The equations for the mean and variance for the Erlang distribution are as follows

$$\text{mean} = K/ALPHA \tag{4.27}$$

$$\text{variance} = K/ALPHA**2 \tag{4.28}$$

When solving these equations for ALPHA and K, the equations are

$$ALPHA = \text{mean}/\text{variance} \tag{4.29}$$

$$K = \text{mean**2/variance} \quad \text{(integer value)} \tag{4.30}$$

If K and the mean of the Erlang distribution are known, then Eq 4.27 can be solved for ALPHA, yielding

$$\text{ALPHA} = \text{K/mean} \tag{4.31}$$

Figure 4.2 illustrates the Erlang probability density function and the cumulative probability density function for various values of K with ALPHA equal to 1, while Fig 4.3 is for various values of ALPHA with K equal to 2.

Since the cumulative density function for an Erlang probability distribution cannot be formulated explicitly, Erlang variates can be generated simply by reproducing the random process on which the Erlang distribution is based. This can be accomplished by taking the sum of K negative exponential variates with identical means of 1/ALPHA. Therefore, the Erlang variate T can be expressed as

$$T = -1/\text{ALPHA}* \sum_{1}^{K} \text{ALOG(random-number)} \tag{4.32}$$

An alternate form of this equation is

$$T = -1/\text{ALPHA*ALOG}(\prod_{1}^{K} \text{random-number}) \tag{4.33}$$

where Π indicates the product of K random numbers. If Eq 4.32 is used then the natural log of K random numbers has to be computed (which involves a series expansion on most computer systems) for each random variate desired, whereas if Eq 4.33 is used then the natural log of the product of K random numbers has to be calculated once for each random variate desired. For values of K greater than 1, Eq 4.33 is superior to Eq 4.32, and, for a value of K equal to 1, the equations are equal when considering computational efficiency. The FORTRAN statements necessary to generate a single Erlang variate T, given a mean headway TMEAN and the parameter K, are as follows

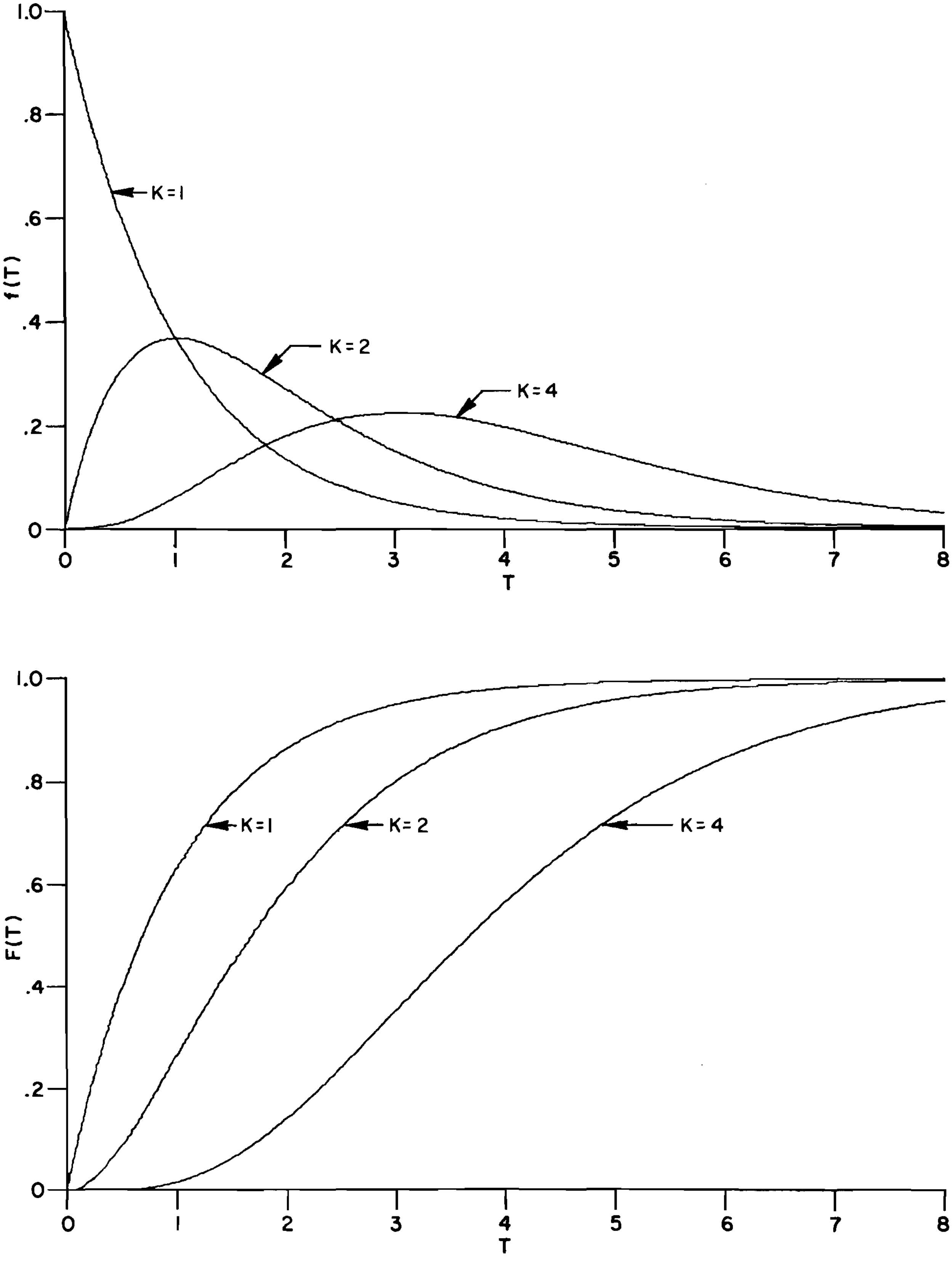


Fig 4.2. The Erlang probability density function and the cumulative probability density function for various values of K with ALPHA equal to one.

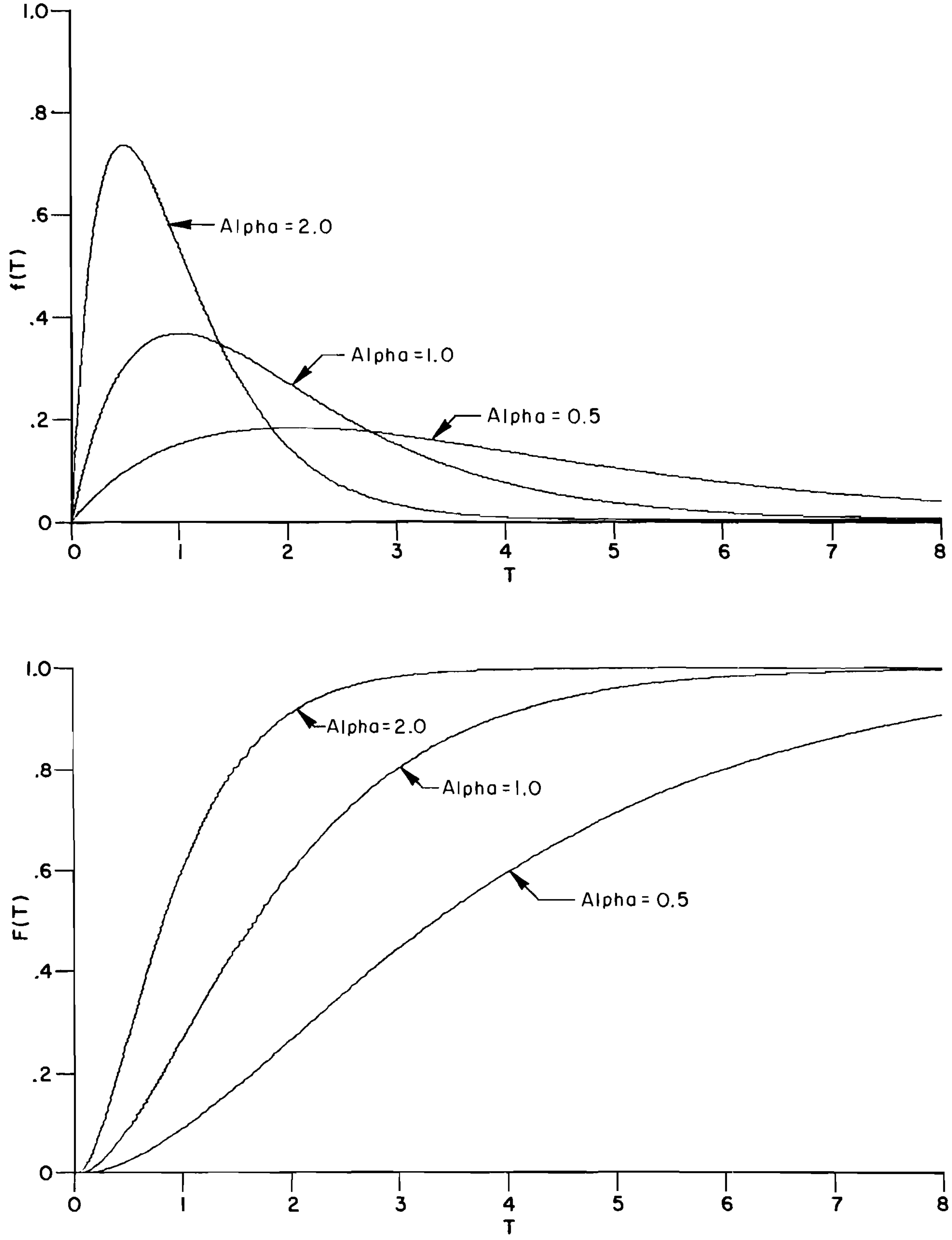


Fig 4.3. The Erlang probability density function and the cumulative probability density function for various values of ALPHA with K equal to 2.

```
          SUBROUTINE ERLANG ( TMEAN,K,T )
          ALPHA = K/TMEAN
          TR = 1.0
          DO 1010  I = 1 , K
          TR = TR*RANF(0)
  0  1010 CONTINUE
          T = -ALOG(TR)/ALPHA
          RETURN
          END
```

4.3.3.2 Generation Of Gamma Random Variates

The gamma probability distribution is a more general form of the Erlang probability distribution (Ref 21, p 405; Ref 22, pp 251-254; Ref 23, pp 358-362; Ref 24, pp 78-80; Ref 25, pp 87-89; Ref 27, pp 27-28; and Ref 28, pp 824-825). The gamma distribution allows for non-integer values of K. The gamma distribution can be used to represent the distribution of time between vehicle arrivals if the arrivals are not randomly distributed.

The gamma probability density function is

$$f(T) = \begin{cases} \text{(ALPHA**A)*(T**(A-1))/GAMMAF(A)*EXP(-ALPHA*T)} & \\ & \text{for } T > 0,\ \text{ALPHA} > 0, \text{ and } A > 0 \\ & \\ 0.0 & \text{elsewhere} \end{cases} \qquad (4.34)$$

The term GAMMAF(A) represents the gamma function for A and is mathematically expressed as

$$\text{GAMMAF(A)} = \int_{0}^{+\infty} \text{(X**(A-1))*EXP(-X)}\ dX \qquad \text{for } A > 0 \qquad (4.35)$$

A useful relationship is

$$\text{GAMMAF(A)} = \text{(A-1)*GAMMAF(A-1)} \qquad \text{for } A > 0 \qquad (4.36)$$

and when A is a positive integer K

GAMMAF(K) = FACT(K-1) for K > 0 (4.37)

where FACT(K-1) is (K-1) factorial. The gamma function used by DVPRO and DISFIT is described by Gautschi (Ref 29).

The value of A may be a rough indication of the degree of nonrandomness. When A is equal to 1, the arrivals appear to be random, and, as A increases, the degree of nonrandomness appears to increase. If A is equal to one, then the gamma probability distribution is identical to the negative exponential probability distribution. If A is a positive integer, then the gamma distribution is identical to the Erlang distribution with K equal to A. The gamma distribution is positively skewed for small values of A and, as A increases, the gamma distribution approaches a normal distribution asymptotically. If the gamma probability distribution has a value of ALPHA equal to 1/2 and a value of A equal to DF/2, then this distribution is called the chi-squared distribution, for which DF is the number of degrees of freedom.

The cumulative density function for the gamma distribution does not exist explicitly. The equations for the mean and variance for the gamma distribution are as follows

mean = A/ALPHA (4.38)

variance = A/ALPHA**2 (4.39)

When solving these equations for ALPHA and A, the following equations are developed

ALPHA = mean/variance (4.40)

A = mean**2/variance (4.41)

If A and the mean of the gamma distribution are known, then Eq 4.38 can be solved for ALPHA, yielding

$$\mathrm{ALPHA} = \mathrm{A/mean} \qquad (4.42)$$

Figure 4.4 illustrates the gamma probability density function and the cumulative probability density function for various values of A with ALPHA equal to 1, while Fig 4.5 is for various values of ALPHA with A equal to 2.5.

Since the cumulative density function for a gamma probability distribution cannot be formulated explicitly, gamma variates may be generated by reproducing the random process on which the gamma distribution is based. Since A is a real number, it can be expressed as the sum of an integer and a fraction such that

$$\mathrm{A} = \mathrm{K1} + \mathrm{Q} \qquad 0 < \mathrm{Q} < 1 \qquad (4.43)$$

Furthermore, if

$$\mathrm{K2} = \mathrm{K1} + 1 \qquad (4.44)$$

then

$$\mathrm{K2} - \mathrm{A} = 1 - \mathrm{Q} \qquad (4.45)$$

Since the mean and the variance of the gamma distribution are both linear functions of A, then a mixture of Erlang variates choosing K2 with probability Q and K1 with probability 1-Q will approximate a gamma distribution with parameter A. This approximation yields better results with higher values of A. If A is equal to an integer, then by Eq 4.43 K1 will be equal to A, and Eq 4.45 will give a value of 1-Q as 1. Thus, this procedure would choose K2 with probability Q of zero (never) and would choose K1 (equal to A) with probability 1-Q of one (always). Therefore, a gamma random variate with A equal to an integer would be identical to an Erlang random variate with K equal to A.

The Erlang variates are generated by taking the sum of K1 or K2 exponential variates with identical mean of 1/ALPHA. Therefore, the gamma variate T can be expressed as

$$\mathrm{T} = -1/\mathrm{ALPHA} * \sum_{1}^{\mathrm{K1\ or\ K2}} \mathrm{ALOG(random\text{-}number)} \qquad (4.46)$$

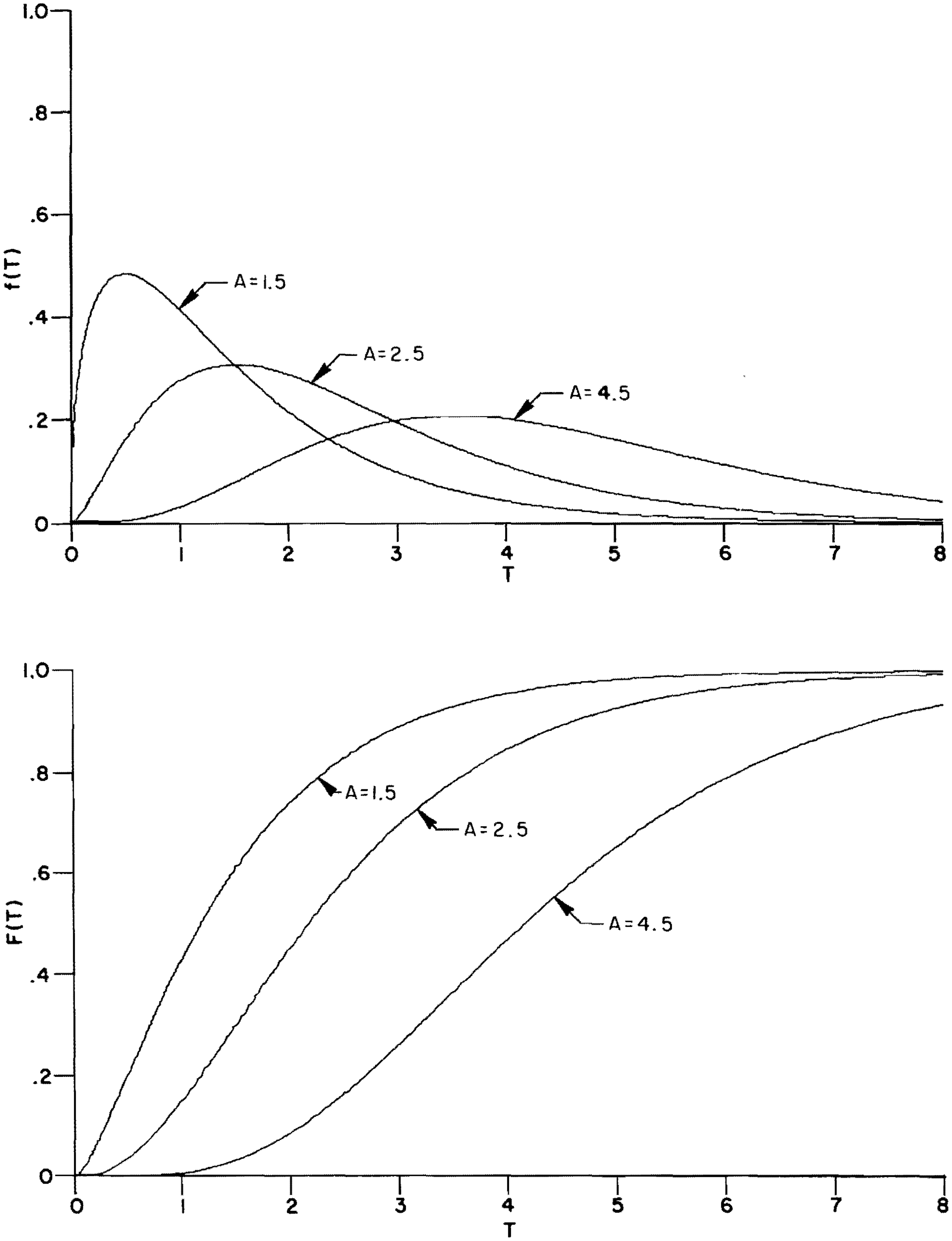


Fig 4.4. The gamma probability density function and the cumulative probability density function for various values of A with ALPHA equal to one.

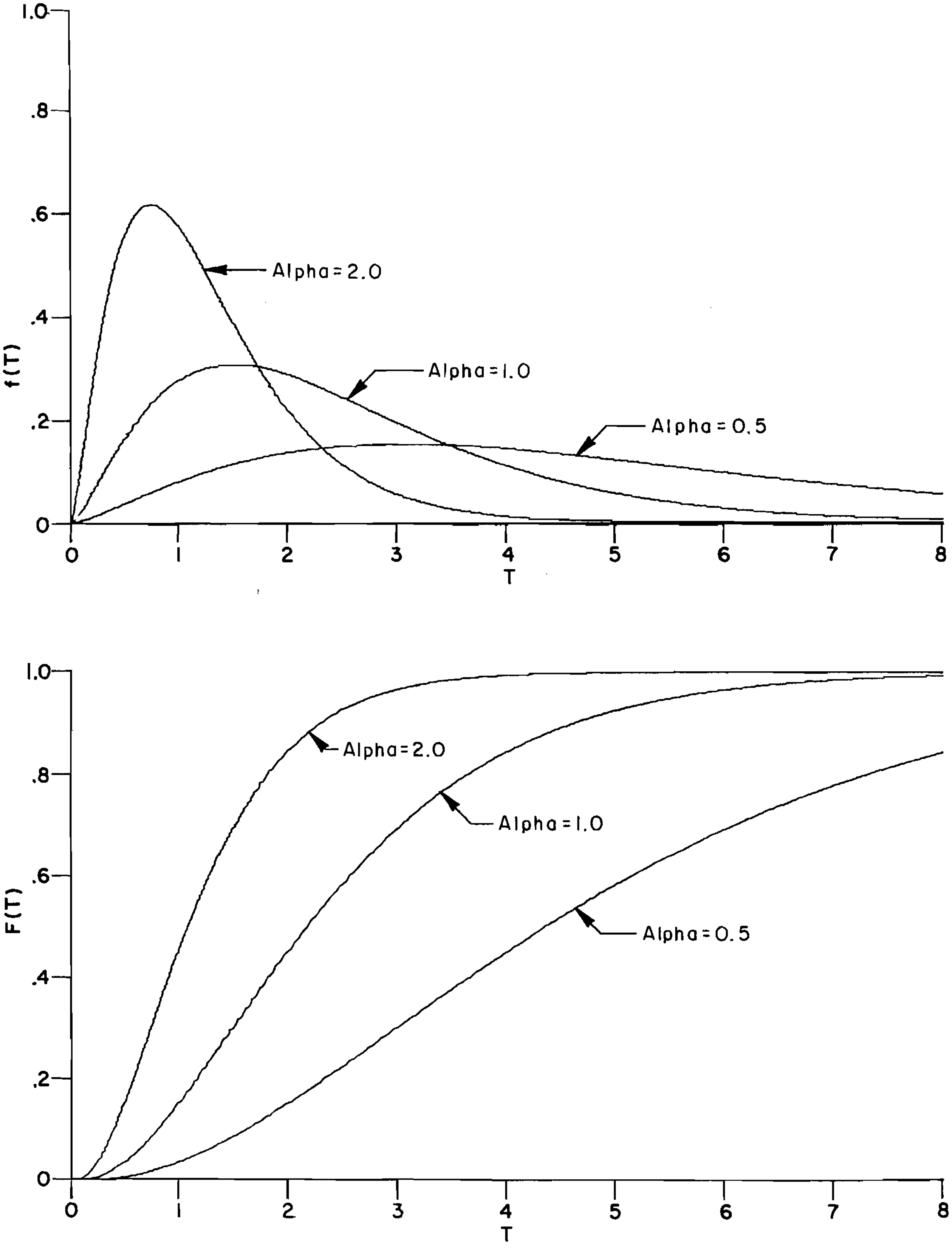


Fig 4.5. The gamma probability density function and the cumulative probability density function for various values of ALPHA with A equal to 2.5.

An alternate form of this equation is

$$T = -1/ALPHA*ALOG(\prod_{1}^{K1 \text{ or } K2} \text{random-number}) \qquad (4.47)$$

where Π indicates the product of K1 or K2 random numbers. If Eq 4.46 is used then the natural log of K1 or K2 random numbers has to be computed (which involves a series expansion on most computer systems) for each random variate desired, whereas if Eq 4.47 is used, then the natural log of the product of K1 or K2 random numbers would has be evaluated once for each random variate desired. For values of K1 or K2 greater than 1, Eq 4.47 is superior to Eq 4.46, and, for a value of K1 or K2 equal to 1, the equations would be equal when considering computational efficiency.

The FORTRAN statements necessary to generate a single gamma variate T, given a mean headway TMEAN and the parameter A, are as follows

```
      SUBROUTINE GAMMA  ( TMEAN,A,T )
      ALPHA = A/TMEAN
      K1 = A
      K2 = A + 1.0
      Q = A - K1
      TR = 1.0
      K = K2
                    IF ( RANF(0) . GT . Q )       K = K1
      DO 1010  I = 1 , K
      TR = TR*RANF(0)
 1010 CONTINUE
      T = -ALOG(TR)/ALPHA
      RETURN
      END
```

4.3.3.3 Generation Of Lognormal Random Variates

If the logarithm of a random variable has a normal distribution, then the random variable has a positively skewed continuous distribution known as the lognormal distribution (Ref 24, pp 76-78; Ref 25, pp 99-101; and Ref 27, pp 28-30 and pp 205-206). The lognormal distribution is frequently used to describe random processes that represent the product of several small independent events. The lognormal probability density function is

```
                { 1/(T*SDY*SQRT(2*PI))*EXP(-0.5*((ALOG(T)-MEANY)/SDY)**2)
                {                                  for T > 0 and SDY > 0
        f(T) =  {                                                     (4.48)
                { 0.0                              elsewhere
```

and

```
                { 1/(SDY*SQRT(2*PI))*EXP(-0.5*((Y-MEANY)/SDY)**2)
                {                                  for Y > 0 and SDY > 0
        f(Y) =  {                                                     (4.49)
                { 0.0                              elsewhere
```

where Y is equal to ALOG(T) and only positive values of T are considered. The term SDY is the standard deviation of the variate Y and the term MEANY is the mean of the variate Y. It should be noted that if the lognormal probability density function is to be integrated using the variate T, then Eq 4.48 should be used; whereas, if the function is to be integrated using the variate Y (equal to the natural log of T), then Eq 4.49 should be used. If the parameters of the lognormal distribution have values of mean of Y equal to zero and the standard deviation of Y equal to one, then the distribution function is known as the standard lognormal distribution with a probability density function denoted by

```
                 { 1/SQRT(2*PI)*EXP(-0.5*Z**2)      for Z > 0
        f(Z) =   {                                                    (4.50)
                 { 0.0                              elsewhere
```

Any value of T or Y can be converted into the standard form by the substitution

$$\mathrm{Z = (Y\text{-}MEANY)/SDY} \qquad \text{or} \qquad \mathrm{Z = (ALOG(T)\text{-}MEANY)/SDY} \tag{4.51}$$

The cumulative density function F(T), F(Y), or F(Z) does not exist in explicit form. The equations for the mean and the variance for the lognormal distribution are as follows

$$\text{mean} = \mathrm{EXP(MEANY + 0.5{*}SDY{*}{*}2)} \tag{4.52}$$

$$\text{variance} = \mathrm{(mean{*}{*}2){*}(EXP(SDY{*}{*}2)-1)} \tag{4.53}$$

When solving these equations for MEANY and SDY, the following equations are developed

$$\mathrm{MEANY} = \mathrm{ALOG(mean)} - \mathrm{0.5{*}SDY{*}{*}2} \tag{4.54}$$

$$\mathrm{SDY} = \mathrm{SQRT(ALOG((variance/mean{*}{*}2)+1))} \tag{4.55}$$

Figure 4.6 illustrates the lognormal probability density function and the cumulative probability density function for various values of the mean with the variance equal to 1, while Fig 4.7 is for various values of the variance with the mean equal to 2. It should be noted in this latter figure that each of the distributions has a different value for the mode and the median, even though the mean is the same. This explains why the distributions do not pass through a common point on the curve showing the cumulative probability density function.

Since the cumulative density function for a lognormal probability distribution does not exist explicitly, lognormal variates are generated by the techniques used to generate normal variates (see Section 4.3.6.2). For the lognormal probability distribution, the lognormal random variate T is as follows

$$\mathrm{T} = \mathrm{EXP(MEANY{+}(SDY{*}(K/12){*}{*}{-}0.5{*}((}\sum_{1}^{K} \text{random-number}\mathrm{){-}0.5{*}K)))} \tag{4.56}$$

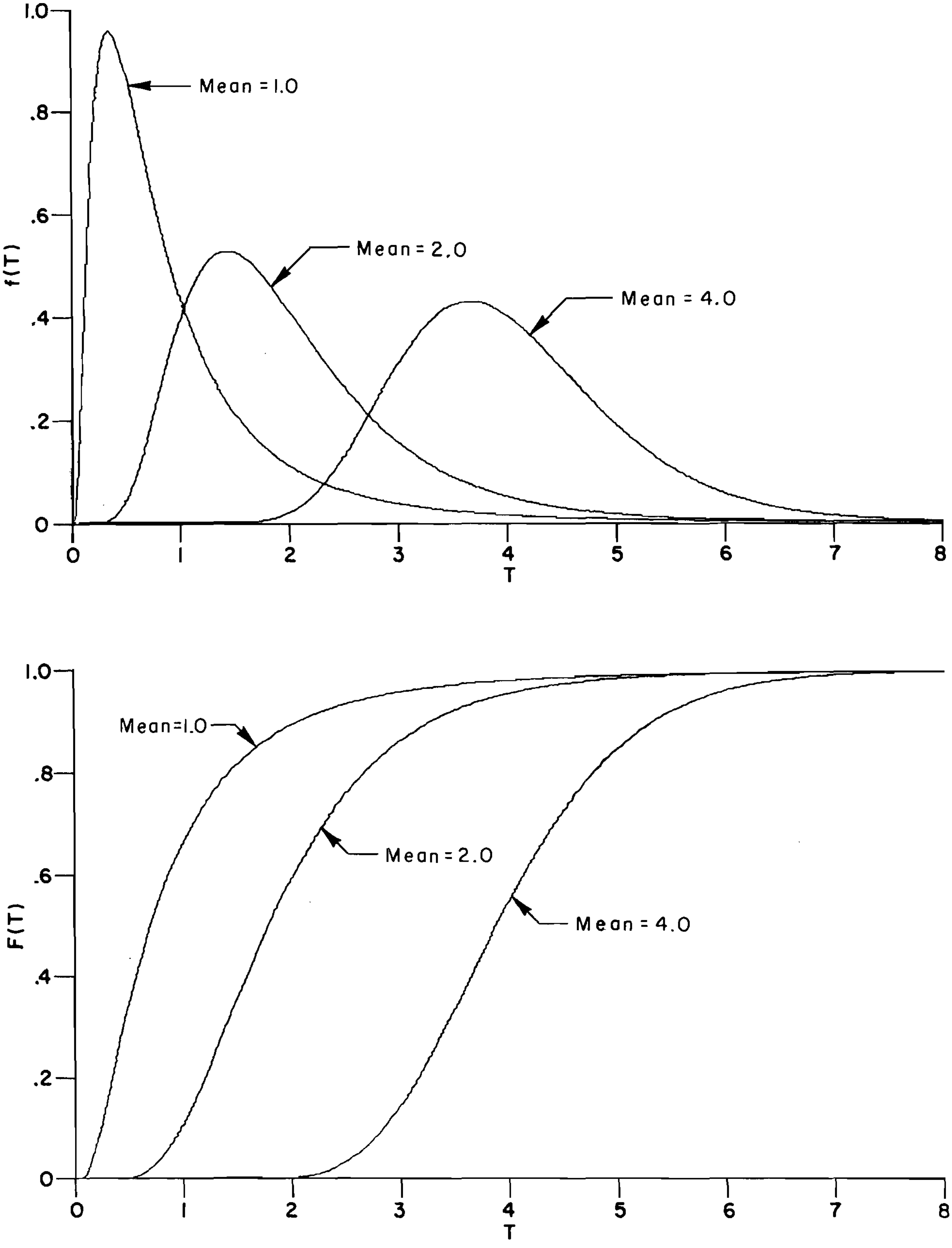
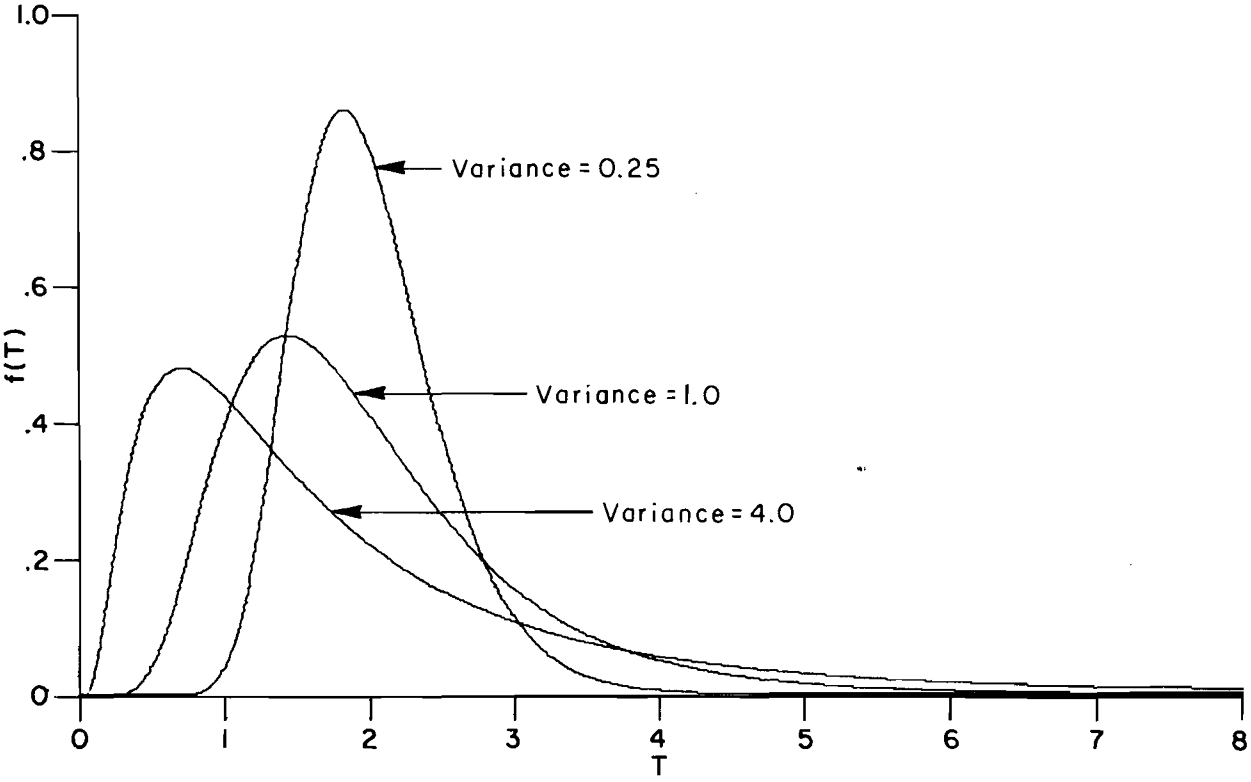


Fig 4.6. The lognormal probability density function and the cumulative probability density function for various values of MEAN with the VARIANCE equal to one.



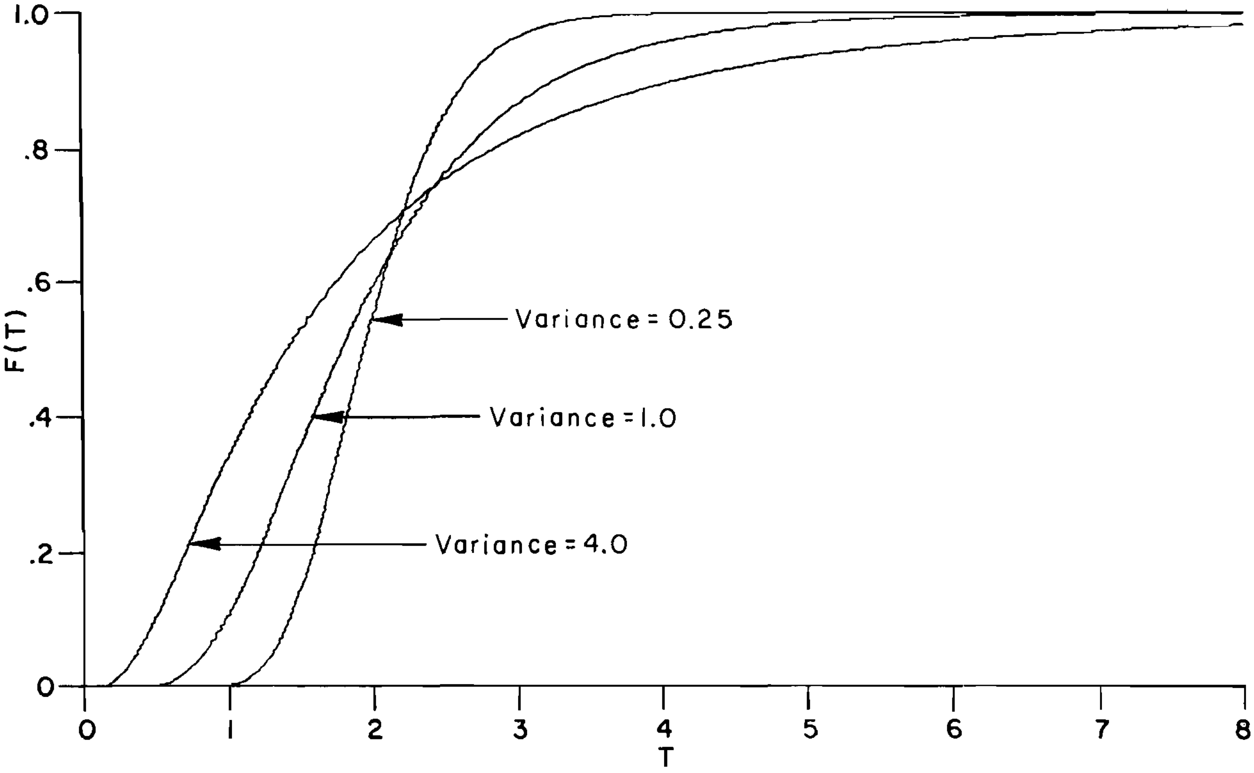


Fig 4.7. The lognormal probability density function and the cumulative probability density function for various values of VARIANCE with the MEAN equal to 2.

If a value of K equal to 12 is used in this equation, a simplified equation for the lognormal random variate is as follows

$$T = EXP(MEANY+SDY*((\sum_{1}^{12} random\text{-}number)-6.0)) \qquad (4.57)$$

The FORTRAN statements necessary to generate a single lognormal variate T, given a mean headway TMEAN and the standard deviation of the headways SD, are as follows

```
          SUBROUTINE LGNRML ( TMEAN,SD,T )
          YVAR = ALOG(((SD**2)/(TMEAN**2))+1.0)
          YMEAN = ALOG(TMEAN) - 0.5*YVAR
          SUM = 0.0
          DO 1010  I = 1 , 12
          SUM = SUM + RANF(0)
     1010 CONTINUE
          T = EXP(YMEAN+SQRT(YVAR)*(SUM-6.0))
          RETURN
          END
```

4.3.3.4 Generation Of Negative Exponential Random Variates

To better understand the negative exponential probability distribution, the Poisson distribution should be investigated (Ref 21, pp 402-405 Ref 22, pp 201-229 and pp 229-234; Ref 23, pp 352-357; Ref 24, pp 79-80 and pp 91-94; Ref 25, pp 81-86; Ref 26, p 298 and p 301; and Ref 27, pp 17-19, pp 21-23, and pp 204-205). Suppose that one is concerned with the occurrence of a certain kind of event and that the probability that it occurs during a very small interval of time dT is given by 1/TBAR*dT. Assume further that the probability of its occurrence more than once during an interval of length dT approaches zero as dT approaches zero and is of a smaller order of magnitude than dT/TBAR; that the occurrence or nonoccurrence of the event during the interval from T to T+dT does not depend on what happened prior to time T; and that 1/TBAR is a constant and independent of T and all other factors. The probability distribution of the number of occurrences of the event during a time interval of length T is given by

$$f(N) = \begin{cases} (T/TBAR)**N/FACT(N)*EXP(-T/TBAR) & \text{for } N \geq 0,\ T \geq 0, \text{ and } TBAR > 0 \\ 0.0 & \text{elsewhere} \end{cases} \qquad (4.58)$$

where FACT(N) is N factorial. This is the Poisson distribution with mean 1/TBAR. It follows that 1/TBAR is the mean number of occurrences of the event per unit of time. A random process satisfying the assumptions described is called a Poisson process with parameter 1/TBAR. If the event is the arrival of a vehicle, then the Poisson distribution describes the number of arrivals per unit time.

If there is no vehicle arrival in a particular interval of time T then there will be a headway of at least T seconds between the previous arrival and the next arrival. Mathematically, this is expressed as

$$\begin{aligned} f(0) &= (T/TBAR)**0/FACT(0)*EXP(-T/TBAR) && (4.59) \\ &= EXP(-T/TBAR) && \text{for } T \geq 0 \text{ and } TBAR > 0 \end{aligned}$$

This is the probability of a headway being equal to or greater than T seconds, which is equal to 1-F(T). Thus, the probability of a headway being less than T seconds would be expressed as

$$F(T) = \begin{cases} 1 - EXP(-T/TBAR) & \text{for } T \geq 0 \text{ and } TBAR > 0 \\ 0.0 & \text{elsewhere} \end{cases} \qquad (4.60)$$

This is the negative exponential cumulative density function. It expresses the time between two successive vehicle arrivals. Therefore, if the arrival of vehicles can be said to be Poisson distributed, then the headways associated with such an arrival distribution are distributed according to the negative exponential probability distribution. Using Eq 4.60, the negative exponential probability density function can be derived as follows

$$f(T) = \begin{cases} 1/TBAR*EXP(-T/TBAR) & \text{for } T \geq 0 \text{ and } TBAR > 0 \\ \\ 0.0 & \text{elsewhere} \end{cases} \quad (4.61)$$

The equations for the mean and the variance for the negative exponential distribution are as follows

$$\text{mean} = TBAR \quad (4.62)$$

$$\text{variance} = TBAR{*}{*}2 \quad (4.63)$$

Thus, from Eq 4.62, the parameter TBAR may be found. Figure 4.8 illustrates the negative exponential probability density function and the cumulative probability density function for various values of the mean. It should be noted from this figure that the probability of occurrence of small headways is very high. Because of the assumption that the arrival of a vehicle is not dependent upon the arrival or nonarrival of a previous vehicle (or the number of vehicles arriving in any interval of time is independent of the number of vehicles that arrived during any previous time interval), the negative exponential distribution is valid for uninterrupted flow rates of 500 vehicles per lane per hour or less (Ref 26, pp 298).

Solving Eq 4.60 for the random variate T, the following equation is defined

$$T = -TBAR*ALOG(1-F(T)) \quad (4.64)$$

Assuming R is a random number, then 1-R is also a random number. Therefore, when a negative exponential random variate is being generated, a random number may replace the term 1-F(T) in Eq 4.64. The FORTRAN statements necessary to generate a single negative exponential random variate T, given a mean headway TMEAN, are as follows

```
SUBROUTINE NEGEXP ( TMEAN,T )
T = -TMEAN*ALOG(RANF(0))
RETURN
END
```

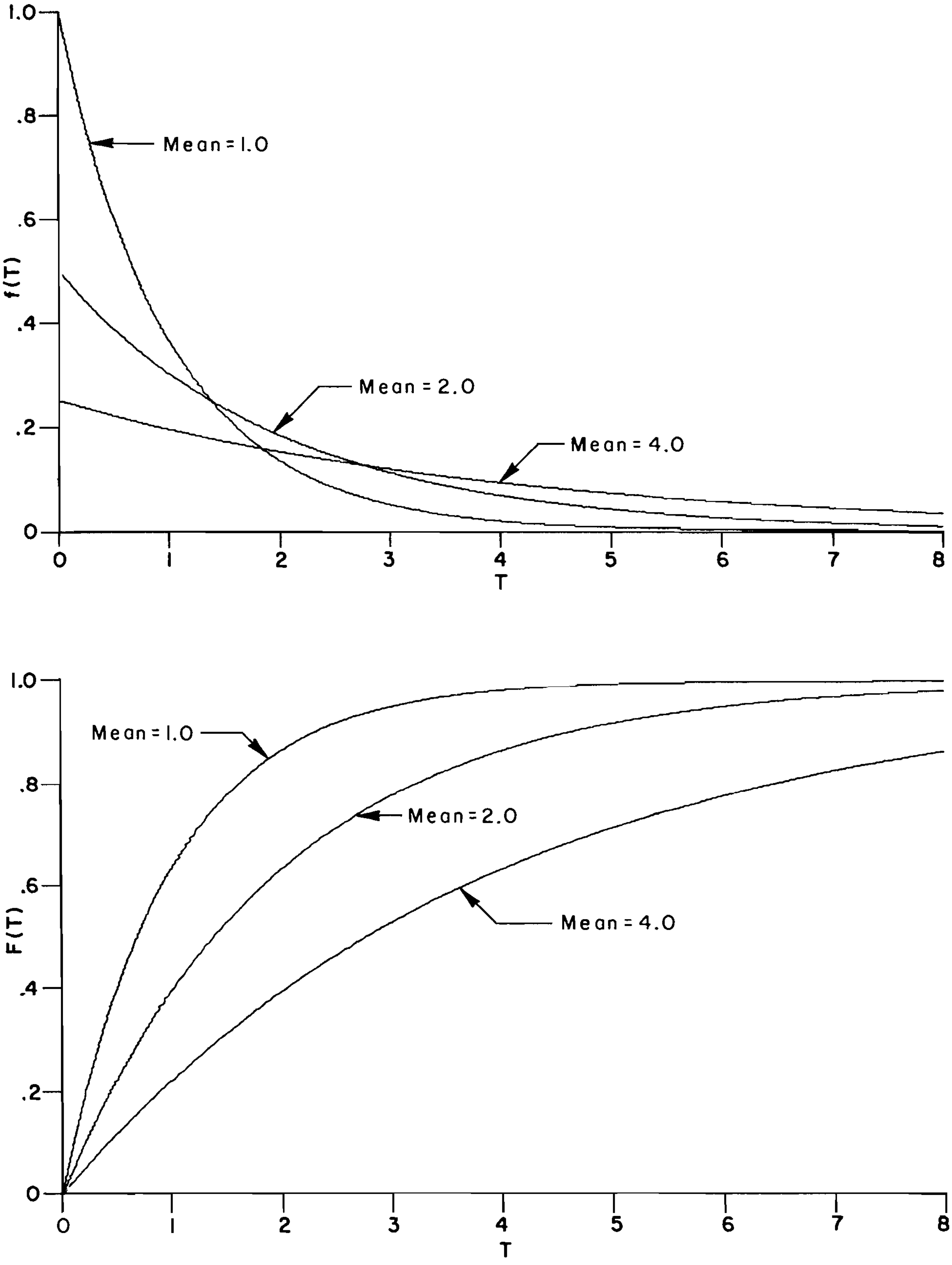


Fig 4.8. The negative exponential probability density function and the cumulative probability density function for various values of the MEAN .

4.3.3.5 Generation Of Shifted Negative Exponential Random Variates

Because the negative exponential distribution has a high probability of occurrence of small headways, the shifted negative exponential distribution was developed which guarantees a zero probability for small headways up to a minimum allowable headway, TAU (Ref 23, pp 356-357; Ref 26, p 299 and pp 301-302; and Ref 27, pp 23-26 and p 205). The occurrence of a large number of zero to 1, or more, second headways is theoretically expected, whereas in practice, the occurrence is virtually impossible if the headways are for a single lane, since vehicles require front bumper to front bumper spacing at least equal to one car length.

The shifted negative exponential probability density function is

$$f(T) = \begin{cases} 1/(TBAR-TAU)*EXP(-(T-TAU)/(TBAR-TAU)) & \\ & \text{for } T \ge TAU,\ TBAR > TAU, \text{ and } TAU \ge 0 \\ & \\ 0.0 & \text{elsewhere} \end{cases} \tag{4.65}$$

If TAU is equal to zero, then the shifted negative exponential distribution is equal to the negative exponential distribution. The cumulative density function for the shifted negative exponential distribution is as follows

$$F(T) = \begin{cases} 1 - EXP(-(T-TAU)/(TBAR-TAU)) & \\ & \text{for } T \ge TAU,\ TBAR > TAU, \text{ and } TAU \ge 0 \\ & \\ 0.0 & \text{elsewhere} \end{cases} \tag{4.66}$$

The equations for the mean and variance for the shifted negative exponential distribution are

$$\text{mean} = TBAR \tag{4.67}$$

$$\text{variance} = (TBAR-TAU)**2 \tag{4.68}$$

When these equations are solved for TBAR and TAU, the equations are

TBAR = mean (4.69)

TAU = mean - SQRT(variance) (4.70)

Figure 4.9 illustrates the shifted negative exponential probability density function and the cumulative probability density function for various values of the mean with TAU equal to 1 while Fig 4.10 is for various values of TAU with the mean equal to 3. It should be noted in this latter figure that each of the distributions has a different value for the mode and the median, even though the mean is the same.

When Eq 4.66 is solved for the random variate T, the following equation is defined

T = TAU - (TBAR-TAU)*ALOG(1-F(T)) (4.71)

If R is assumed to be a random number, then 1-R is also a random number. Therefore, when a shifted negative exponential random variate is being generated, a random number may replace the term 1-F(T) in Eq 4.71. The FORTRAN statements necessary to generate a single shifted negative exponential random variate T, given a mean headway TMEAN and the parameter TAU, assuming TMEAN is greater than TAU, are as follows

```
SUBROUTINE SNGEXP ( TMEAN,TAU,T )
T = TAU - (TMEAN-TAU)*ALOG(RANF(0))
RETURN
END
```

4.3.3.6 Generation Of Uniform Random Variates

Perhaps the simplest continuous probability distribution is the uniform distribution (Ref 22, pp 27-229; Ref 24, p 76 and pp 79-80; and Ref 25, pp 77-80). The uniform probability density function is

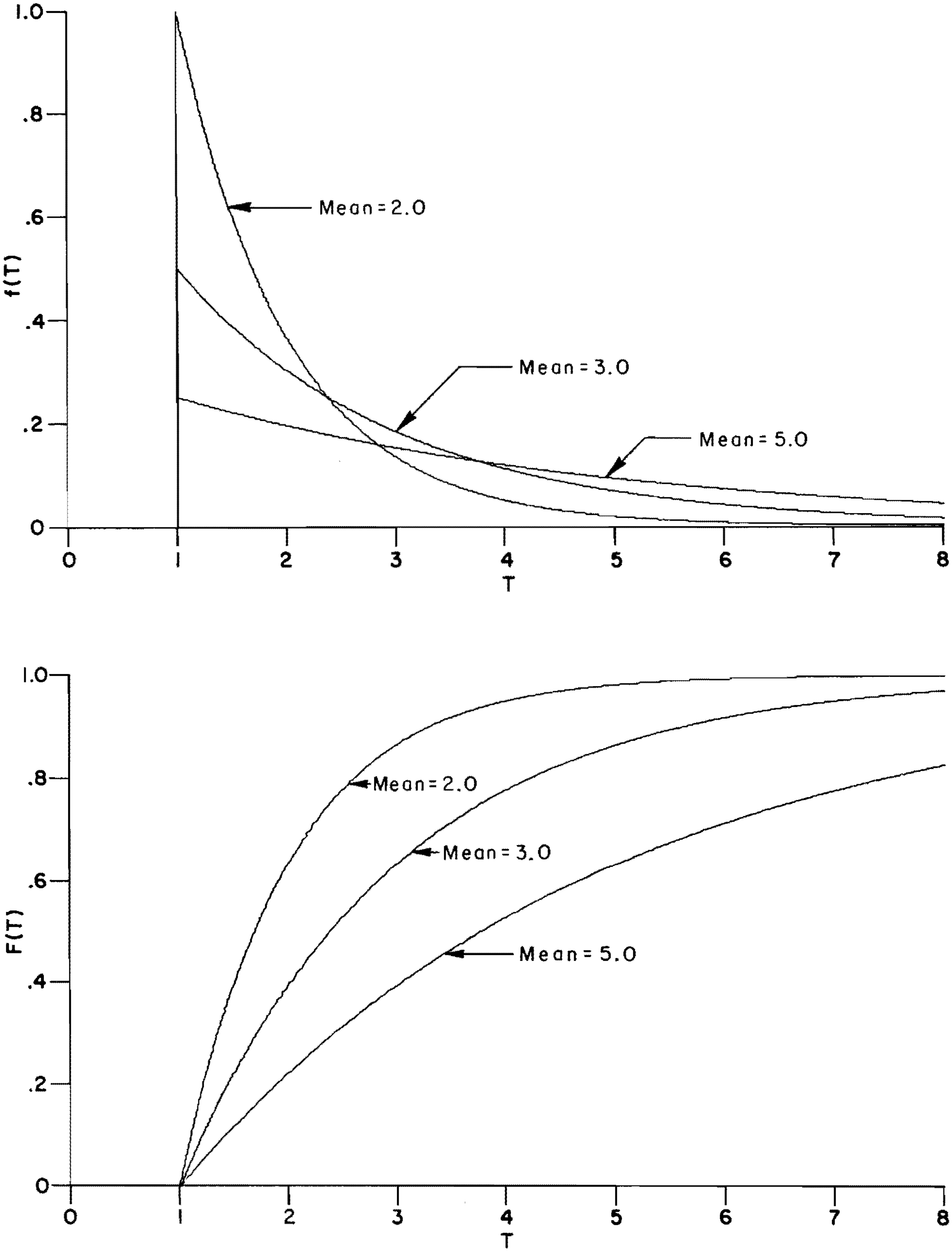


Fig 4.9. The shifted negative exponential probability density function and the cumulative probability density function for various values of the MEAN with TAU equal to one.

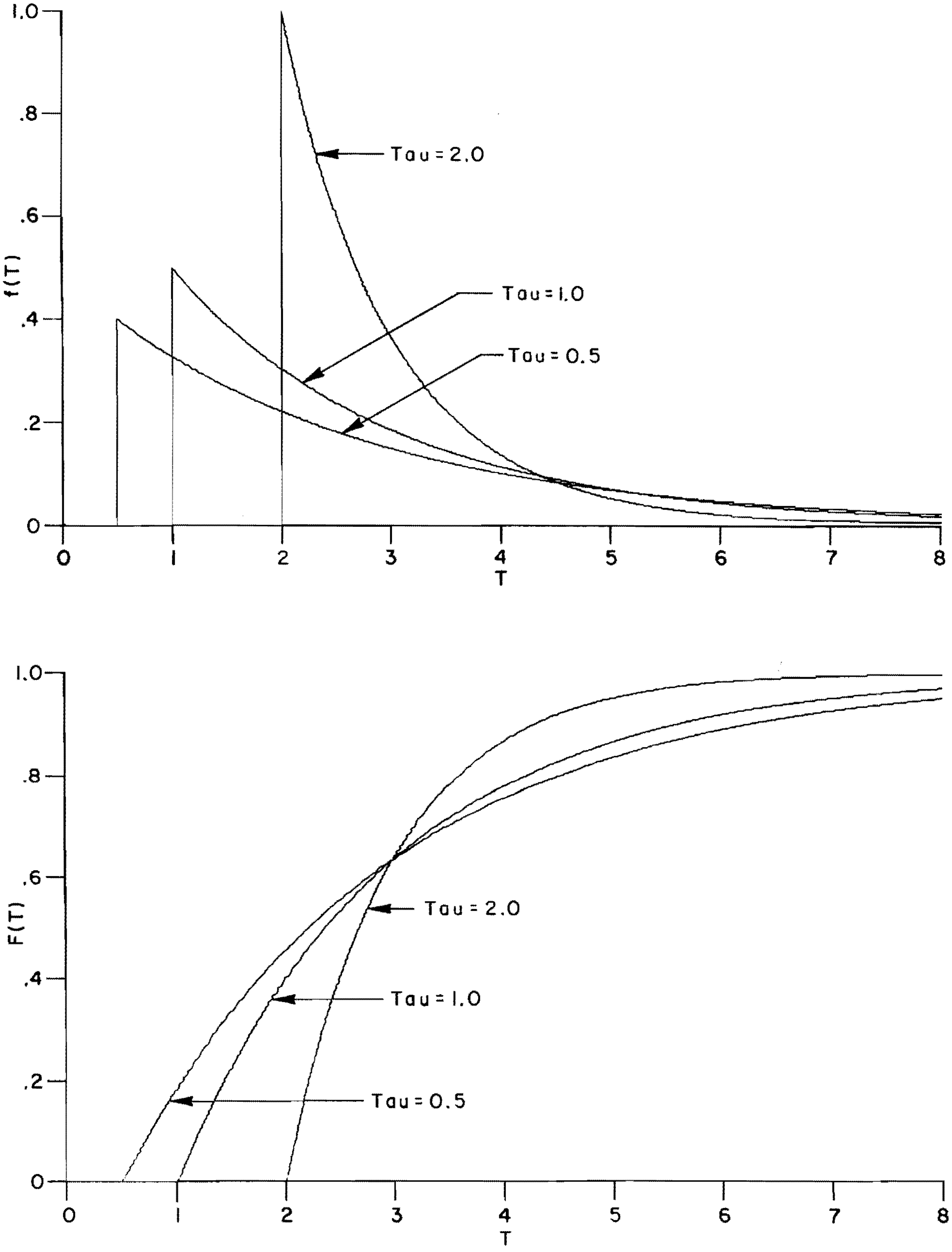


Fig 4.10. The shifted negative exponential probability density function and the cumulative probability density function for various values of TAU with the MEAN equal to 3.

$$f(T) = \begin{cases} 1/(B-A) & A \le T \le B \text{ and } B > A \\ 0.0 & \text{elsewhere} \end{cases} \tag{4.72}$$

The cumulative density function for the uniform distribution is as follows

$$F(T) = \begin{cases} (T-A)/(B-A) & A \le T \le B \text{ and } B > A \\ 0.0 & \text{elsewhere} \end{cases} \tag{4.73}$$

The equation for the mean and variance for the uniform distribution are

$$\text{mean} = (A+B)/2 \tag{4.74}$$

$$\text{variance} = ((B-A)^{**}2)/12 \tag{4.75}$$

When these equations are solved for A and B, the following equations are developed

$$A = \text{mean} - \text{SQRT}(3^*\text{variance}) \tag{4.76}$$

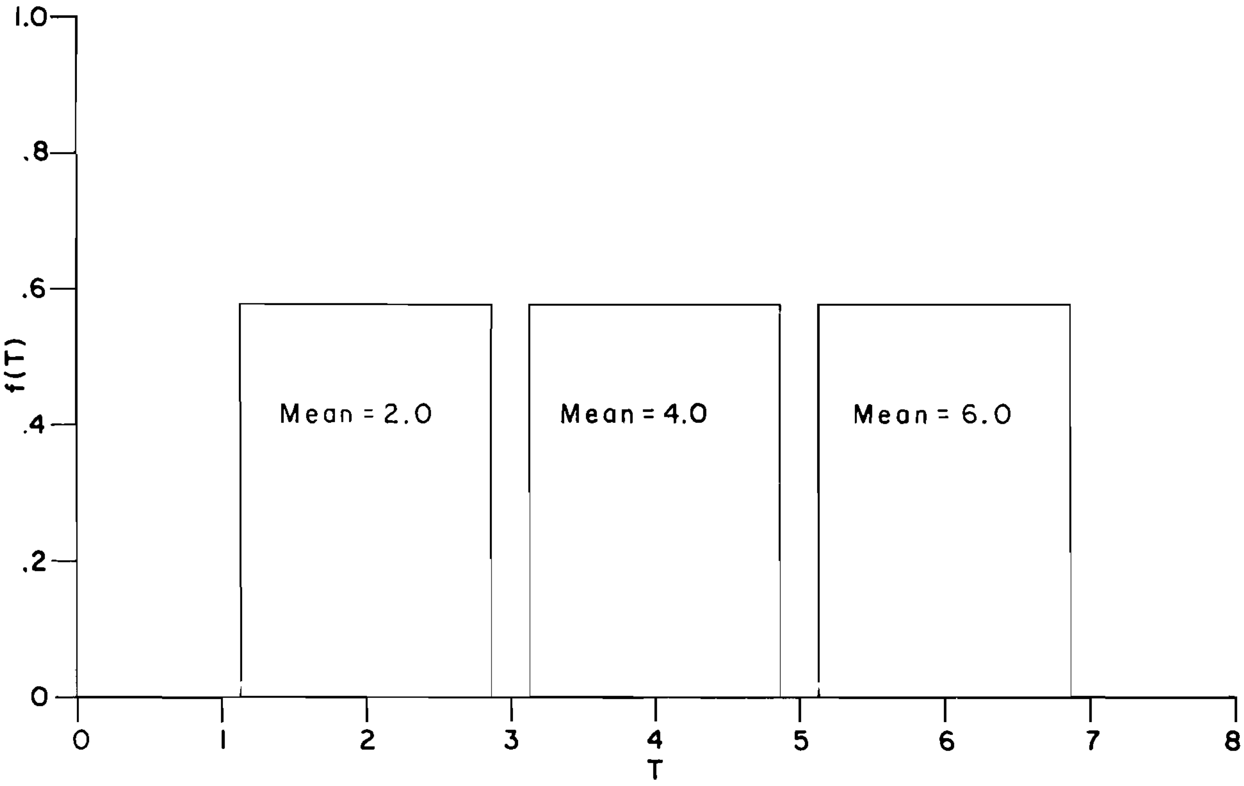
$$B = \text{mean} + \text{SQRT}(3^*\text{variance}) \tag{4.77}$$

Figure 4.11 illustrates the uniform probability density function and the cumulative probability density function for various values of mean with the variance equal to 0.25 while Fig 4.12 is for various values of variance with the mean equal to 4.

When solving Eq 4.73 for the random variate T, the equation is

$$T = A + (B-A)^*F(T) \tag{4.78}$$

The FORTRAN statements necessary to generate a single uniform random variate T, given a mean headway TMEAN and the standard deviation SD, are as follows



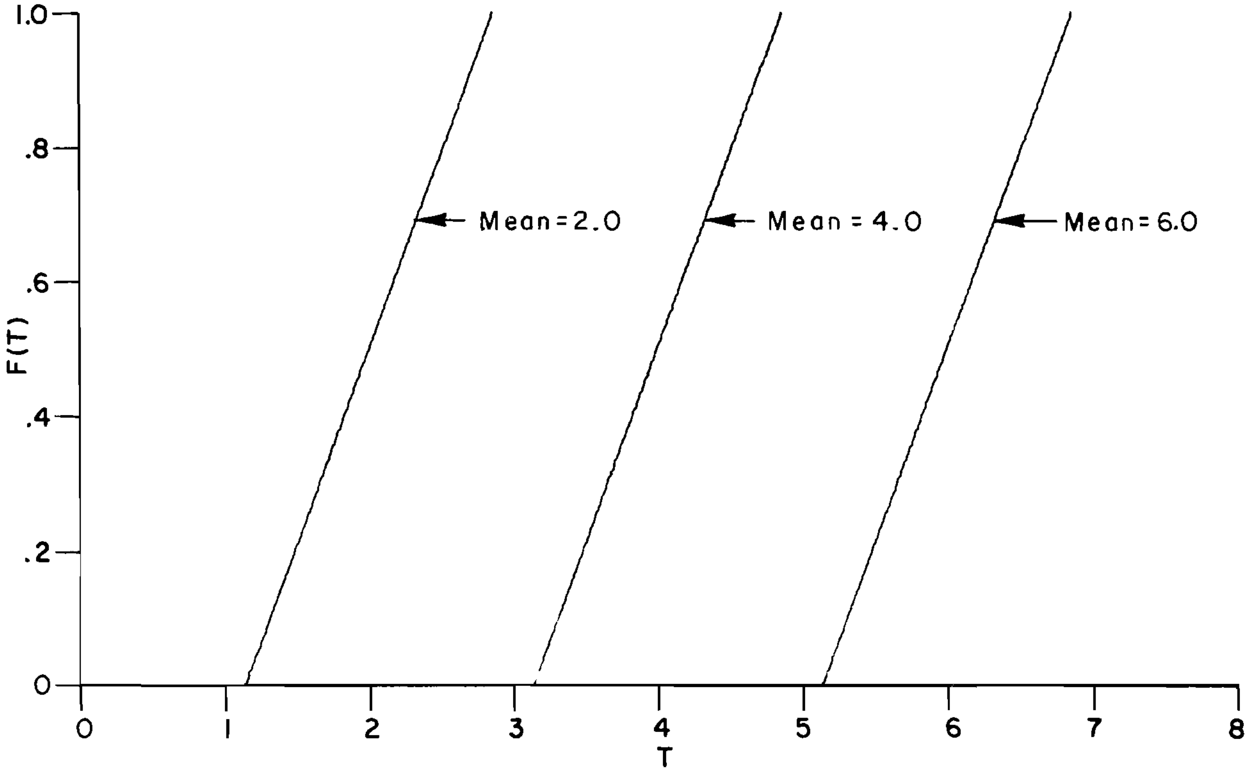


Fig 4.11. The uniform probability density function and the cumulative probability density function for various values of MEAN with the VARIANCE equal to 0.25.

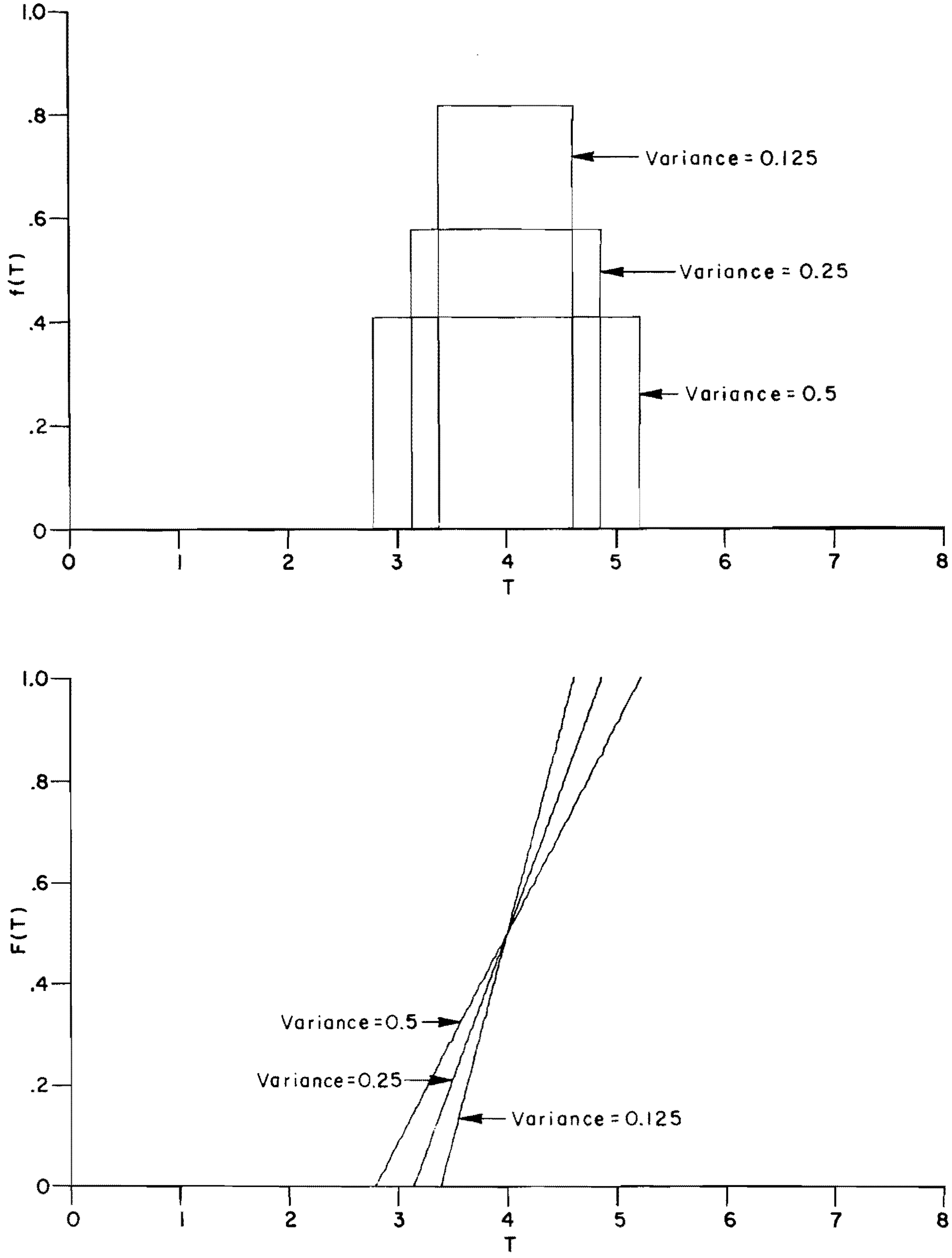


Fig 4.12. The uniform probability density function and the cumulative probability density function for various values of VARIANCE with the MEAN equal to 4.

```
SUBROUTINE UNIFRM ( TMEAN,SD,T )
A = TMEAN - SD*SQRT(3.0)
B = TMEAN + SD*SQRT(3.0)
T = A + (B-A)*RANF(0)
RETURN
END
```

4.3.4 Generation Of Driver Class Number -

The driver class number for a driver-vehicle unit is generated using the empirical discrete probability distribution. The percentage of each driver class is bcsed on the generated vehicle class number and the percent of each driver class in the specified vehicle class (denoted XPERD in DVPRO). The driver class number ranges between 1 and the number of driver classes.

4.3.4.1 Generation Of Empirical Discrete Random Variates

Empirical data are collected or estimated and f(I) is determined (see Section 4.3.1) for each admissible value of I, where I goes from 1 to the number of discrete classes (Ref 22, pp 181-184; Ref 24, p 7; and Ref 25, p 102 and pp 115-116). In the driver-vehicle processor, it is assumed that the sum of the f(I) for all admissible values of I is equal to 100, whereas the sum should be 1.0. The empirical discrete probability density function is

$$\begin{aligned} f(I) &= 100*\lim(M(I)/N) \qquad \text{as } N \rightarrow +\infty \text{ and } 1 \leq I \leq NUM \qquad (4.79) \\ &= 100*P(I) \end{aligned}$$

where f(I) is in the range from 0.0 to 100.0, M(I) is the number of successful outcomes of the event associated with the Ith discrete class, N is the total number of trials [the sum of all M(I)], NUM is the number of discrete classes, and P(I) is the probability of occurrence of the Ith event. The cumulative density function for the empirical discrete distribution is as follows

$$F(J) = \sum_{I=1}^{J} 100*P(I) \qquad (4.80)$$

where F(J) is in the range from 0.0 to 100.0. The equations for the mean and variance of the empirical discrete probability distribution are

$$\text{mean} = \sum_{I=1}^{NUM} I*f(I) \qquad (4.81)$$

$$\text{variance} = \sum_{I=1}^{NUM} I**2*f(I) - \text{mean}**2 \qquad (4.82)$$

Figure 4.13 illustrates an example empirical discrete probability density function and the cumulative probability density function. It is apparent from this figure that the cumulative form of the empirical discrete probability density function is a step function.

The cumulative empirical discrete probability density function can not be solved for the random variate J, but a random number can be generated and multiplied by 100 (so that the range of the random number goes from 0.0 to 100.0) and the f(I) can be summed until it is greater than or equal to the scaled random number. The discrete class number in which this event occurs is the value of the empirical discrete random variate J. The FORTRAN statements necessary to generate a single empirical discrete random deviate J, given the array of f(I) (denoted XPER) and the number of discrete classes NUM, are as follows

```
          SUBROUTINE DISCRT ( XPER,NUM,J )
          DIMENSION        XPER(NUM)
          RANNUM = 100.0*RANF(0)
          SUM = 0.0
          DO 1010  J = 1 , NUM
          SUM = SUM + XPER(J)
                       IF ( SUM . GE . RANNUM )      RETURN
     1010 CONTINUE
          J = NUM
          RETURN
          END
```

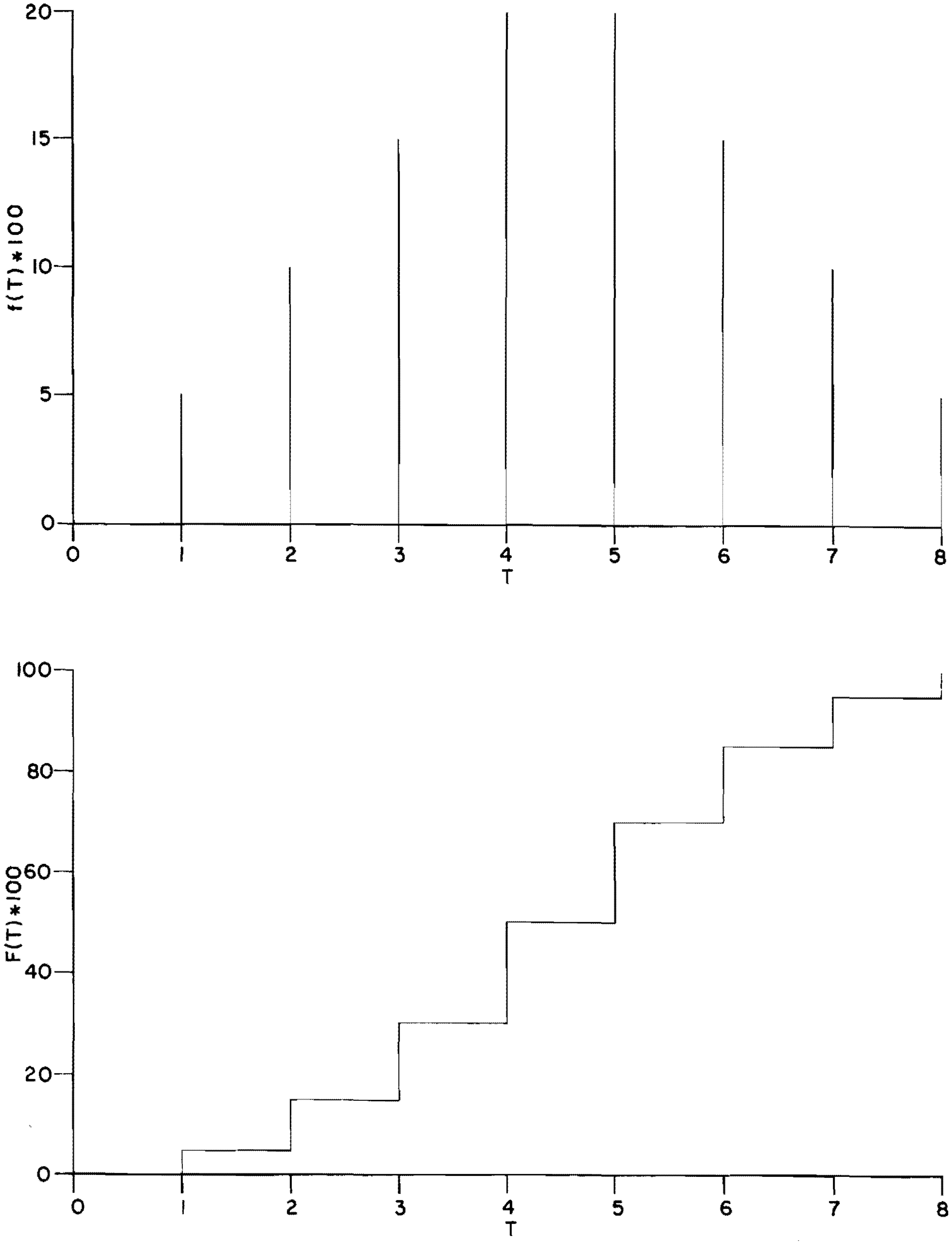


Fig 4.13. Example empirical discrete probability density function and the cumulative probability density function.

4.3.5 Generation Of Vehicle Class Number

The vehicle class number for a driver-vehicle unit is generated using the empirical discrete distribution. The percentage of each vehicle class is different for each inbound approach (denoted XPERV in DVPRO). The vehicle class number ranges from 1 to the number of vehicle classes. Section 4.3.4.1 describes the technique used to generate empirical discrete random variates.

4.3.6 Generation Of Desired Speed

The desired speed for a driver-vehicle unit is generated using the normal probability distribution. The user supplies the mean and 85th percentile speed for each approach. The Z value associated with the probability of 85 percent of the vehicles having a speed less than or equal to Z ($F(Z) = 0.85$) is equal to approximately 1.0364334. Using an equation similar to Eq 4.51 for converting a normal variate to a standard normal variate, the following equation is developed

$$SD = (V85-V50)/1.0364334 \qquad \text{for } V85 > V50 \tag{4.83}$$

where SD is the standard deviation, V85 is the 85th percentile speed, and V50 is the mean speed.

The generated desired speed is rejected if it is less than the driver-vehicle operational factor times the mean minus the standard deviation or if it is greater than the driver-vehicle operational factor times the mean plus the standard deviation. This rejection continues until an acceptable random desired speed is found. This procedure is performed to ensure than an aggressive driver in a responsive vehicle will have higher desired speeds than a slow driver in a sluggish vehicle.

4.3.6.1 Review Of The Normal Probability Distribution

The normal probability distribution is perhaps the best known and the most important of all the probability distributions (Ref 21, pp 403-404; Ref 22, pp 234-251 and pp 285-296; Ref 23, pp 46-51; Ref 24, pp 70-72 and p 79; Ref 25, pp 90-95; Ref 27, pp 37-38; Ref 28, pp 822-824; and Ref 30, pp 130-147, pp 158-181, and pp 230-257). The normal distribution is also referred to as the Gaussian and the Lapacian distribution. The normal distribution is significant because it provides close approximation for a number of other distributions. The normal probability distribution is the limit of the binomial probability distribution as the number of trials increases without limit and regardless of the values of the probability of a success. The normal probability distribution is also the limit of the Poisson probability distribution as the expected number of successes increases without limit. As the number of successes becomes very large, the Pascal distribution of the required number of trials for obtaining a success approaches a normal distribution. The normal distribution is also the limit of the Student's T distribution as the size of the sample increases and the limit of the chi-squared distribution as the number of degrees of freedom increases above approximately 30. In fact, any continuous distribution may be converted into a normal distribution by proper transformation (Ref 22, p 250).

The normal distribution derives its usefulness from the Central Limit Theorem. This theorem states that the probability distribution of the sum of N independently and identically distributed random variates approaches the normal distribution asymptotically as N becomes very large. It is significant that this is true whatever the nature of the probability distribution, unless it has an infinite mean or standard deviation. Thus, the Central Limit Theorem permits the use of a normal distribution to represent overall measurements on effects of independently distributed additive causes regardless of the probability distribution of the measurement of individual causes. If a universe is normal then the distribution of sample means is normal even if the sample size is small. The arithmetic mean of the distribution of sample means is the arithmetic mean of the population. Another theorem about the normal distribution states that for certain specified conditions, the normal limit extends to the sums of independent random variables for which the probability distributions are not alike.

4.3.6.2 Generation Of Normal Random Variates

The normal probability distribution is a continuous distribution neither peaked nor flat (mesokurtic) that has an infinite range (references same as for Section 4.3.6.1). The normal probability density function is

$$f(X) = \begin{cases} 1/(SD*SQRT(2*PI))*EXP(-0.5*((X-MEAN)/SD)**2) & \\ & \text{for } SD > 0 \text{ and } -\infty < X < +\infty \\ & \\ 0.0 & \text{elsewhere} \end{cases} \tag{4.84}$$

where SD is the standard deviation and MEAN is the mean. If the parameters of the normal distribution have values of MEAN equal to zero and SD equal to 1, then the distribution function is known as the standard normal distribution with a probability density function denoted by

$$f(Z) = 1/SQRT(2*PI)*EXP(-0.5*Z**2) \qquad \text{for } -\infty < Z < +\infty \tag{4.85}$$

Any value of X can be converted into the standard form by the following substitution

$$Z = (X-MEAN)/SD \qquad \text{for } SD > 0 \tag{4.86}$$

The cumulative density function F(X) or F(Z) does not exist in explicit form. The mean of the normal distribution is MEAN while the variance is SD squared. Figure 4.14 illustrates the normal probability density function for various values of the mean with the variance equal to one, while Fig 4.15 is for various values of the variance with the mean equal to zero.

Since the cumulative density function for a normal probability distribution does not exist explicitly, normal variates are generated by a method different from the inverse transform method. In order to simulate a normal distribution with a given expected value MEAN and a given standard deviation SD, the following mathematical interpretation of the Central Limit Theorem may be given. If R(1), R(2), R(3) ..., and R(N) are independent random variables each having the same probability distribution with the expected value of R(I) equal to PHI and the variance of R(I) equal to SIGMA

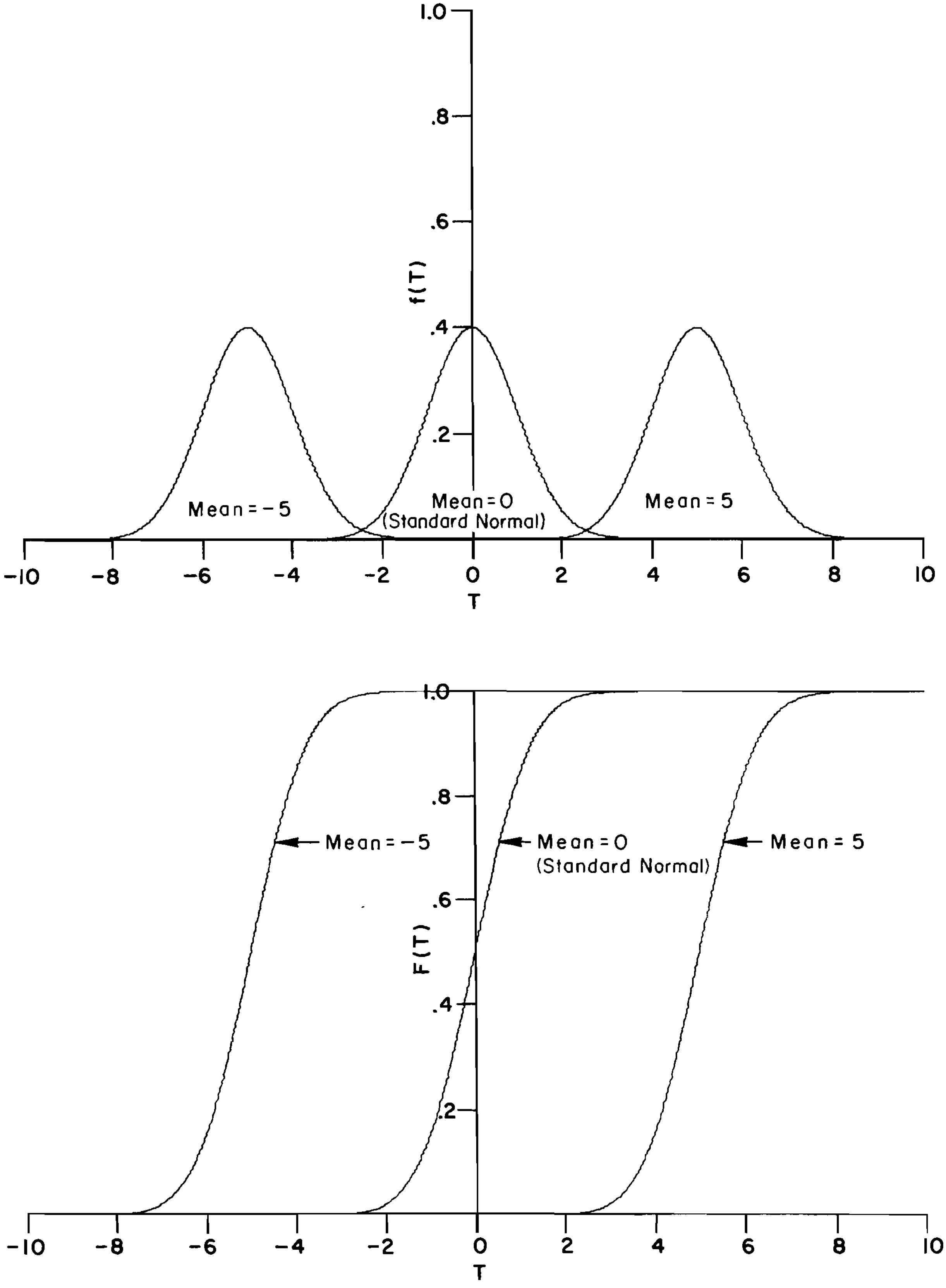
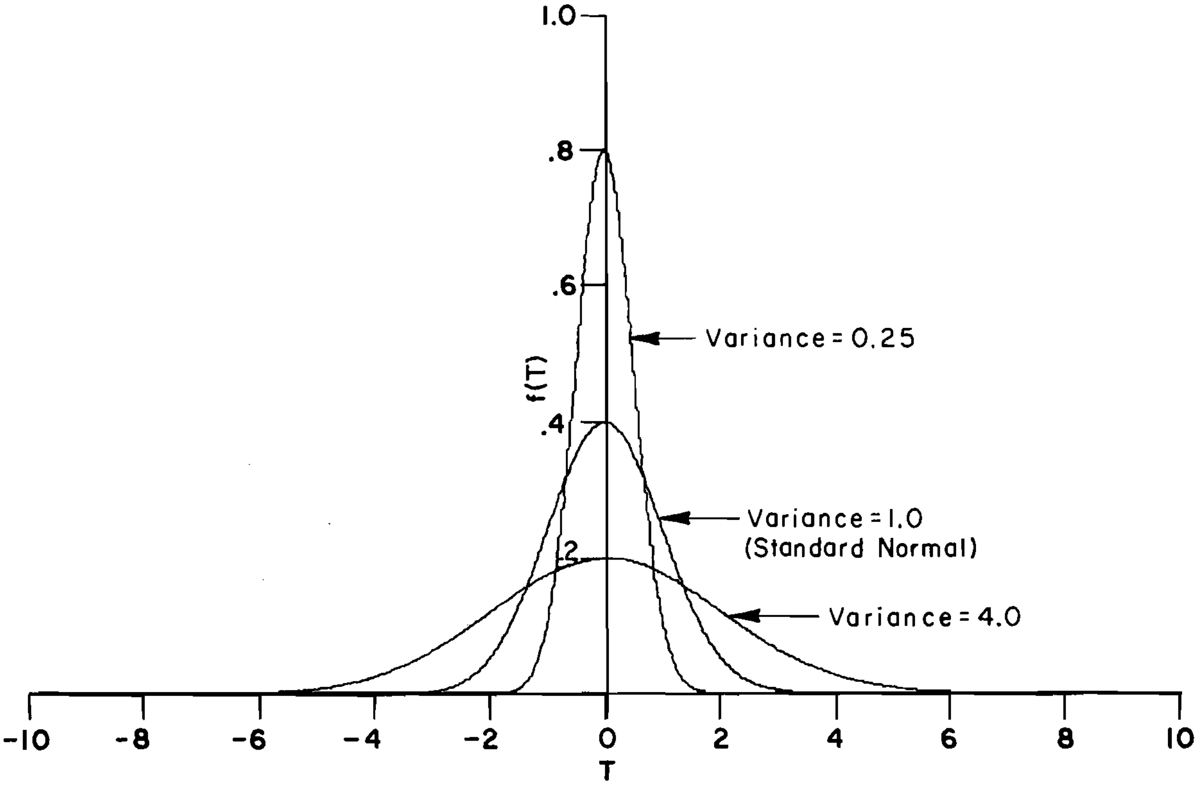


Fig 4.14. The normal probability density function and the cumulative probability density function for various values of MEAN with the VARIANCE equal to one.



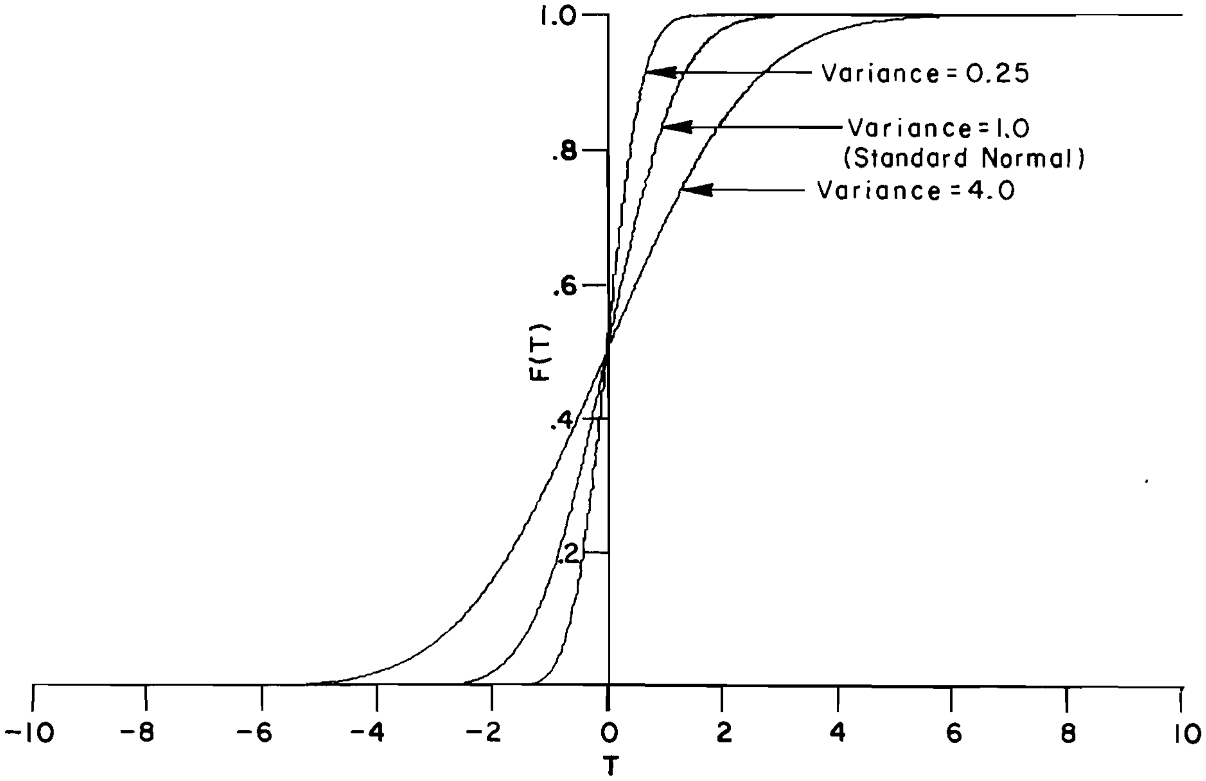


Fig 4.15. The normal probability density function and the cumulative probability density function for various values of VARIANCE with the MEAN equal to zero.

squared, then

$$\mathrm{lim(P(A < (}\sum_{I=1}^{N}\mathrm{R(I)\ -\ N{*}PHI)/(SIGMA{*}SQRT(N))\ <\ B))}\ =\ \mathrm{1/(SQRT(2{*}PI)){*}}\int_{B}^{A}\mathrm{EXP(-0.5{*}Z{*}{*}2)\ dZ}\qquad \text{as } N \rightarrow +\infty \tag{4.87}$$

where the expected value of the sum of N random variables would be equal to N times PHI, the variance of the sum of N random variables would be equal to N times SD squared, and the variable Z would be

$$\mathrm{Z\ =\ (}\sum_{I=1}^{N}\mathrm{R(I)\ \ -\ \ N{*}PHI)/(SD{*}SQRT(N))} \tag{4.88}$$

The procedure for simulating normal variates on a digital computer involves taking the sum of K uniformly distributed random variables R(1), R(2), R(3)..., R(K), where R(I) is defined over the interval 0.0 < R(I) < 1.0. Then applying the notation of the mathematical statement of the Central Limit Theorem and knowledge of the uniform distribution (PHI will have a value of 0.5 and SD will have a value of 1/SQRT(12), and the variable Z would be

$$\mathrm{Z\ =\ (}\sum_{I=1}^{K}\mathrm{R(I)\ \ -\ \ K/2)/SQRT(K/12)} \tag{4.89}$$

Setting Eq 4.86 equal to Eq 4.89 and solving for the normal random variate X gives

$$\mathrm{X\ =\ MEAN\ +\ SD{*}SQRT(12/K){*}(}\sum_{I=1}^{K}\mathrm{R(I)\ \ -\ \ K/2)} \tag{4.90}$$

The value of K to be used in this equation is determined by balancing computational efficiency against accuracy. There is some computational advantage to choosing a value of K equal to 12. This value of K would truncate the distribution at the +6*SD limits and has been found to be unreliable for values of X larger than three standard deviations. Using a value of K equal to 12, Eq 4.90 reduces to

$$\mathrm{X\ =\ MEAN\ +\ SD{*}(}\sum_{I=1}^{12}\mathrm{R(I)\ \ -\ \ 6)} \tag{4.91}$$

The FORTRAN statements necessary to generate a single normal random variate V, given the mean speed VMEAN and the 85th percentive speed V85, are as follows

```
     SUBROUTINE NORMAL ( VMEAN,V85,V )
     SD = (V85-VMEAN)/1.0364334
     SUM = 0.0
     DO 1010  I = 1 , 12
     SUM = SUM + RANF(0)
1010 CONTINUE
     V = VMEAN + SD*(SUM-6.0)
     RETURN
     END
```

4.3.7 Generation Of Desired Outbound Approach Number

The desired outbound approach number for a driver-vehicle unit is generated using the empirical discrete probability distribution. The percentage of vehicles going to each outbound approach is based on the user supplied percentages for each inbound approach (denoted XPERT in DVPRO). The desired outbound approach number ranges between 1 and the number of outbound approaches after initial generation and is then mapped into the list of outbound approach numbers, where it will have a range between 1 and 12. Section 4.3.4.1 describes the techniques used to generate empirical discrete random variates.

4.3.8 Generation Of Inbound Lane Number

The inbound lane number for a driver-vehicle unit is generated using the empirical discrete probability distribution. The user supplies the percent of approach traffic that enters upon each lane for each inbound approach (denoted XPERL in DVPRO).

A unique method of biasing the inbound lane number according to the expected turn type of the driver-vehicle unit was developed. First, the percent of vehicles going from each inbound approach to each outbound approach (denoted XPERT in DVPRO) is summed by the three turn types (U-turn and left turn, straight-through movement, and right turn) (denoted XPERTS in DVPRO). Then the percent of U-turn and left turning driver-vehicle units (denoted XPERLO in DVPRO) is maximized for the median lane (left lane) according to the percent of U-turn and left turning driver-vehicle units to be in the median lane (left lane), ensuring that the percent of driver-vehicle units entering by the median lane (left lane) is not exceeded. Any remaining percent of U-turn and left turning driver-vehicle units is distributed to the remaining lanes for the inbound approach going from left to right and ensuring that the percent of driver-vehicle units entering by the lane is not exceeded. Next, the percent of right turning vehicles is maximized for the curb lane (right lane), ensuring that the percent of driver-vehicle units entering by the curb lane (right lane) is not exceeded. Any remaining percent of right turning driver-vehicle units is distributed to the remaining lanes for the inbound approach going from right to left and ensuring that the percent of driver-vehicle units entering by the lane is not exceeded. Finally, the percent of straight-through driver-vehicle units is allocated to the lanes to make the percent of driver-vehicle units entering the lane correct. If there is only one inbound lane available for entering traffic for an inbound approach, then the percent of U-turn and left turning driver-vehicle units will be 100 and the percent of right turning driver-vehicle units will also be 100.

After the desired outbound approach number is generated, the turning movement type is determined for the driver-vehicle unit. Then the inbound lane number is generated based on the inbound approach number and the turning movement type, using the XPERLO percentages. Table 4.3 illustrates the inbound lane biasing technique.

Section 4.3.4.1 describes the techniques used to generate empirical discrete random variates.

TABLE 4.3. INBOUND LANE BIASING TECHNIQUE

	Lane 1	Lane 2	Lane 3	Total (XPERTS)
U-turn and left turn	8	2	0	10
Straight	22	36	22	80
Right turn	0	2	8	10
Total (XPERL)	30	40	30	100

	Lane 1	Lane 2	Lane 3	Total (XPERTS)
U-turn and left turn	30	10	0	40
Straight	0	30	20	50
Right turn	0	0	10	10
Total (XPERL)	30	40	30	100

	Lane 1	Lane 2	Lane 3	Lane 4	Total (XPERTS)
U-turn and left turn	0	20	0	0	20
Straight	0	40	30	0	70
Right turn	0	0	10	0	10
Total (XPERL)	0	60	40	0	100

FPERL = 80%

FPERR = 80%

4.4 Output

Output from the driver-vehicle processor includes print and magnetic tape. The printed output includes the echo print of the input and the statistics of generation. If there is an input error, a diagnostic message will be printed and DVPRO will stop. There are 62 input errors detected and the STOP numbers range from 801 to 862. If there is an execution error detected by DVPRO, a diagnostic message will be printed followed by a print of selected program variables. There are 2 execution errors detected (they are all considered "can't get here halts") and the STOP numbers range from 901 to 902. Several execution errors indicate problems in the input which could not be detected until computatio.s commenced.

Magnetic tape output includes the title for the driver-vehicle processor run, the number of driver and vehicle classes, the vehicle characteristics, the driver characteristics, and then the individually characterized driver-vehicle units to be simulated by the traffic simulation processor. Table 4.4 gives the structure of the magnetic tape.

4.5 Verification

Verification of the driver-vehicle processor was accomplished by analyzing debug prints of intermediate results, by independently testing selected subprograms to ensure proper performance, and using the headway distribution fitting processor to check the generation of random variates.

4.6 Computer Requirements

DVPRO requires 17,216 words (41,500 octal) of storage on CDC computers and 102,000 bytes of storage on IBM computers. The driver-vehicle processor requires approximately 3 seconds of computer time on CDC computers and 4 seconds (0.067 minutes) on IBM computers to generate a moderate flow of driver-vehicle units for an average intersection of 4 inbound and 4 outbound

Table 4.4 Magnetic Tape Output from the Driver-Vehicle Processor

1. Title for the driver-vehicle processor run
2. Number of driver and vehicle classes
3. Vehicle charactersitics
   a. Length of vehicle (ft)
   b. Vehicle operational factor
   c. Maximum uniform deceleration rate (ft/sec/sec)
   d. Maximum uniform acceleration rate (ft/sec/sec)
   e. Maximum velocity (ft/sec)
   f. Minimum turning radius (ft)
4. Driver characteristics
   a. Driver operational factor
   b. Perception-reaction time and average perception-reaction time (sec)
5. Individual driver-vehicle units to be simulated
   a. Queue-in time (sec)
   b. Driver class number
   c. Vehicle class number
   d. Desired speed (ft/sec)
   e. Desired outbound approach number
   f. Inbound approach number
   g. Inbound lane number
   h. Logout summary option

approaches, 2 lanes per approach.

4.7 Documentation

Documentation for the driver-vehicle processor includes an explanation of the input and output contained in a user's guide (Ref 15), numerous COMMENT statements within the computer program, and a programmer's guide (Ref 19). The programmer's guide includes: (1) the driver-vehicle processor limitations, (2) a listing of the input errors detected, (3) a listing of the execution errors detected, (4) the definition of the variables in each COMMON block, (5) the definition of the local variables used in each subprogram, (6) an alphabetical listing of all subprograms and the subprograms which can call them, (7) an alphabetical listing of all the variables, their storage type, and the subprograms in which they are used, and (8) a generalized calling sequence diagram.

4.8 Additional Information

Appendix A contains example input and output for a normal four-leg intersection, a six-leg intersection, and a channelized four-leg intersection. Appendix C provides a listing of the driver-vehicle processor and its programmer's. Table 4.5 gives the breakdown of the driver-vehicle processor FORTRAN statements.

Table 4.5 Fortran Statement Categorization for the Driver-Vehicle Processor

Number of cards with <BLOCK DATA> ---------	1	.05	Percent
Number of cards with <CALL > ---------	32	1.58	Percent
Number of cards with <COMMON > ---------	163	8.05	Percent
Number of cards with <CONTINUE > ---------	197	9.73	Percent
Number of cards with <DATA > ---------	53	2.62	Percent
Number of cards with <DIMENSION > ---------	12	.59	Percent
Number of cards with <DO > ---------	73	3.61	Percent
Number of cards with <END > ---------	27	1.33	Percent
Number of cards with <EQUIVALENC> ---------	3	.15	Percent
Number of cards with <FORMAT > ---------	266	13.14	Percent
Number of cards with <GO TO > ---------	26	1.28	Percent
Number of cards with <IF > ---------	237	11.71	Percent
Number of cards with <LOGICAL > ---------	19	.94	Percent
Number of cards with <PROGRAM > ---------	1	.05	Percent
Number of cards with <RETURN > ---------	33	1.63	Percent
Number of cards with <STOP > ---------	65	3.21	Percent
Number of cards with <SUBROUTINE> ---------	25	1.24	Percent
Number of cards with COMMENTs -------------	230	11.36	Percent
Number of cards with I/O statements -------	210	10.38	Percent
Number of cards with conditional assembly -	43	2.12	Percent
Number of cards with other statements -----	308	15.22	Percent
Total number of statements ----------------	2024		

5.0 THE TRAFFIC SIMULATION PROCESSOR

5.1 Introduction And Purpose

The traffic simulation processor, SIMPRO, performs the dynamic activity computations in the traffic simulation package. The purpose of this subsystem is to process each individually characterized driver-vehicle unit through the defined intersection area and to gather and report performance statistics about the traffic simulation. SIMPRO includes all the algorithms necessary for simulating each the decision-response actions of each driver and for representing the intersection controls. Before developing the structure for SIMPRO, numerous other traffic simulation models (Ref 1-10) were reviewed and appraised. Development of this component of the package required a major portion of the research effort.

SIMPRO was designed to handle the general case of a single, multi-leg, multi-lane, mixed-traffic intersection operating either without control or with any conventional form of traffic control. Emphasis was placed on making the traffic simulation user-oriented and on minimizing computational requirements. The philosophy of initially incorporating as much detail as possible into the model and then subsequently eliminating any nonessential components was adopted.

In the model, each individually-characterized driver-vehicle unit is examined separately. At selected time intervals, the computer program makes available to the simulated driver information such as desired speed; destination; current position, velocity, acceleration/deceleration, and acceleration/deceleration slope (jerk); relative position and velocity of adjacent vehicles in the system; critical distances which must be maintained; sight restrictions; and the location and status of traffic control devices. Acceleration/deceleration slope, or jerk, is the first derivative of acceleration/deceleration with respect to time and is thus the third derivative of position. The simulated driver may (1) maintain speed, (2) accelerate, (3) decelerate, or (4) maneuver to change lanes. Driver response is a function of driver and vehicle characteristics, roadway geometry, traffic control, and the action of other driver-vehicle units in the system.

The highest-priority logical response of the driver-vehicle unit is determined on the premise that the driver wants to sustain a desired speed, but that he will obey traffic laws and will maintain safety and comfort. To implement the chosen action, a future position, velocity, acceleration/deceleration, and acceleration/deceleration slope for the vehicle under examination are calculated. Each driver-vehicle unit in the intersection and on the approaches is processed in sequence, thereby stepping each unit through the intersection in response to the situation prevailing at the time.

5.2 Input Requirements

The traffic simulation processor accepts as input, information that is stored on the magnetic tape produced by the geometry processor and by the driver-vehicle processor, along with additional card input. The card input consists of (1) the title for the traffic simulation processor run and (2) the traffic simulation processor options, which include (a) the start-up and simulation time; (b) the time-step increment for simulation; (c) speed for "delay below XX miles per hour"; (d) the maximum clear distance for being in a queue, XQDIST; (e) lambda, mu, and alpha values for use in the generalized car-following equation; (f) the type of intersection control; (g) desired summary statistics; (h) time for lead and lag safety zones for intersection conflict checking; (i) punched output option; (j) lane control for each lane; (k) the signal indication information for each inbound lane (if the intersection is signal controlled); (l) the semi-actuated signal information (if the intersection is semi-actuated controlled); (m) the full-actuated signal information (if the intersection is full-actuated controlled); and (n) the detector information (if an actuated signal controller is used). Table 5.1 gives the generalized input for the traffic simulation processor. A detailed explanation of the input and its format is given in "The TEXAS Model for Intersection Traffic - User's Guide" (Ref 15).

Table 5.1 Generalized Input to the Traffic Simulation Processor

1. Magnetic tape produced by the geometry processor
2. Magnetic tape produced by the driver-vehicle processor
3. Card input to the traffic simulation processor
   a. Title for the traffic simulation processor run
   b. Traffic simulation processor options
      1. Start-up and simulation time (min)
      2. Time step increment for simulation (sec)
      3. Speed for "delay below XX mph" (mi/hr)
      4. Maximum clear distance for being in a queue (ft)
      5. Lambda, mu, and alpha values for the car following equation
      6. Type of intersection control
         a. 1 for uncontrolled
         b. 2 for yield sign controlled
         c. 3 for less-than-all-way stop sign controlled
         d. 4 for all-way stop sign controlled
         e. 5 for pretimed signal controled
         f. 6 for semi-actuated signal controlled
         g. 7 for full-actuated signal controlled
      7. Summary statistics for each turning movement option and summary statistics for each inbound approach option (YES/NO)
      8. Time for lead and lag safety zone for intersection conflict checking (sec)
      9. Punched output option (YES/NO)
      10. Lane control for each lane
         a. 1 for outbound lane (or blocked inbound)
         b. 2 for uncontrolled lane
         c. 3 for yield sign controlled lane
         d. 4 for stop sign controlled lane
         e. 5 for signal controlled lane
         f. 6 for signal controlled lane with left-turn-on-red permitted
         g. 7 for signal controlled lane with right-turn-on-red permitted

(continued)

Table 5.1 (continued)

11. Signal indication information for each inbound lane (cam stack) (if intersection signal controlled)
    a. Number of cam stack positions
    b. Cam stack information
        1. Phase number
        2. Time for phase (sec) (if pretimed signal)
        3. Signal indication for each inbound lane
            a. Three-character codes
                1. First character = "A" "L" "S" "R"
                2. Second character = "G" "A" "R" "P"
                3. Third character = "G" "A" "R" " "
                4. "UNS" for unsignalized
                5. "   " for same as last cam stack position
12. Semi-actuated signal information (if intersection semi-actuated signal controlled)
    a. Major street phase information
        1. Minimum assured green (sec)
        2. Amber clearance interval (sec)
        3. All-red clearance interval (sec)
        4. Number and list of signal phases which can be cleared to directly from this signal phase
    b. Minor street(s) phase information
        1. Phase number
        2. Initial interval (sec)
        3. Vehicle interval (sec)
        4. Amber clearance interval (sec)
        5. All-red clearance interval (sec)
        6. Maximum extension after demand on red (sec)
        7. Skip-phase switch option (ON/OFF)
        8. Auto-recall switch option (ON/OFF)
        9. Parent/minor movement option (YES/NO)
        10. Dual left option (YES/NO)

(continued)

Table 5.1 (continued)

        11. Detector connection type (AND/OR)
        12. Number and list of detectors connected to each signal phase
        13. Number and list of signal phases which can be cleared to directly from this signal phase

13. Full-actuated signal information (if intersection full-actuated signal controlled)
    a. Phase number
    b. Initial interval (sec)
    c. Vehicle interval (sec)
    d. Amber clearance interval (sec)
    e. All-red clearance interval (sec)
    f. Maximum extension after demand on red (sec)
    g. Skip-phase switch option (ON/OFF)
    h. Auto-recall switch option (ON/OFF)
    i. Parent/minor movement option (YES/NO)
    j. Dual left option (YES/NO)
    k. Detector connection type (AND/OR)
    l. Number and list of detectors connected to each signal phase
    m. Number and list of signal phases which can be cleared to directly from this signal phase
14. Detector information (if actuated signal controlled)
    a. Number of detectors
    b. Detector information for each detector
        1. Detector type (PULSE/PRESENCE)
        2. Detector location
            a. Approach number and list of lanes served
            b. Starting and stopping position within lane (ft)

Extensive input error checking is performed by SIMPRO on the card input to ensure that certain data are within defined bounds, that all necessary information is provided, and that some information is not duplicated. If an input error is detected, the traffic simulation processor will print a message describing the input error and stop. There are currently 81 input error checks in SIMPRO.

5.2.1 Input For Various Types Of Intersection Control

The available intersection control options include (1) uncontrolled, (2) yield sign controlled, (3) less-than-all-way stop sign controlled, (4) all-way stop sign controlled, (5) pretimed signal controlled, (6) semi-actuated signal controlled, and (7) full-actuated signal controlled.

5.2.2 Input For Lane Control For Each Lane

The available lane control options for each lane include (1) outbound lane (or blocked inbound), (2) uncontrolled, (3) yield sign controlled, (4) stop sign controlled, (5) signal controlled, (6) signal controlled with left-turn-on-red permitted, and (7) signal controlled with right-turn-on-red permitted.

5.2.3 Input For Signal Indication Information For Each Inbound Lane

For a signalized intersection, signal control information is provided to SIMPRO by card input. The signal indication information for each inbound lane consists of input which models the cam stack found in most signal controllers plus the timing scheme for displaying each interval. The cam stack information includes the phase number, duration of the phase (if pre-timed), and the signal indication for each inbound lane. The signal indications are input in character form (see Table 5.2). The first character of a set of three indicates the turning movement type ("A" for all, "L" for U-turn and left turn, "S" for straight-through movement, and "R" for right turn). The second character indicates the signal indication for the turning movement specified by the first character ("G" for unprotected green, "A" for amber, "R" for red, and "P" for protected green). The third character indicates the signal indication for all other turning movements not specified by the first character ("G" for unprotected green, "A" for amber, "R" for red, and " " if the first character was "A"). For an unsignalized lane, the characters "UNS" are input and if the signal indication for an inbound lane is the same as the preceeding entry, "   " can be used.

5.2.4 Input For Semi-Actuated Signal Controller

If the intersection is semi-actuated controlled, additional card input is necessary for describing the major-street phase information and the minor-street(s) phase information. The major-street phase information includes (1) the minimum assured green, (2) the amber clearance interval, (3) the all-red clearance interval, and (4) the number and list of phases which can be cleared to directly from each phase. The minor-street phase information includes (1) the phase number, (2) the initial interval, (3) the vehicle interval, (4) the amber clearance interval, (5) the all-red clearance interval, (6) the maximum extension after demand on red, (7) the skip-phase switch option, (8) the auto-recall switch option, (9) the parent/minor movement option, (10) the dual left option, (11) the detector connection type, (12) the number and list of detectors connected to each phase, and (13) the number and list of phases which can be cleared to directly from each phase.

5.2.5 Input For Full-Actuated Signal Controller

If the intersection is full-actuated controlled, additional card input is necessary for describing the phase information. It includes (1) the phase

Table 5.2 Signal Indications

OPTION	SIGNAL INDICATIONS FOR EACH INBOUND LANE	CODE
1	signal is green and conflicts are checked	AG
2	signal is amber and decision is made to go or stop	AA
3	signal is red and vehicle is stopped	AR
4	signal is protected green and conflicts are not checked	AP

OPTION	SIGNAL INDICATIONS FOR EACH INBOUND LANE		CODE
	left = green(1)	others = green(1)	
5	left = green(1)	others = amber(2)	LGA
6	left = green(1)	others = red(3)	LGR
7	left = amber(2)	others = green(1)	LAG
	left = amber(2)	others = amber(2)	
8	left = amber(2)	others = red(3)	LAR
9	left = red(3)	others = green(1)	LRG
10	left = red(3)	others = amber(2)	LRA
	left = red(3)	others = red(3)	

OPTION	SIGNAL INDICATIONS FOR EACH INBOUND LANE		CODE
	straight = green(1)	others = green(1)	
11	straight = green(1)	others = amber(2)	SGA
12	straight = green(1)	others = red(3)	SGR
13	straight = amber(2)	others = green(1)	SAG
	straight = amber(2)	others = amber(2)	
14	straight = amber(2)	others = red(3)	SAR
15	straight = red(3)	others = green(1)	SRG
16	straight = red(3)	others = amber(2)	SRA
	straight = red(3)	others = red(3)	

(continued)

Table 5.2 (continued)

OPTION	SIGNAL INDICATIONS FOR EACH INBOUND LANE		CODE
	right = green(1)	others = green(1)	
17	right = green(1)	others = amber(2)	RGA
18	right = green(1)	others = red(3)	RGR
19	right = amber(2)	others = green(1)	RAG
	right = amber(2)	others = amber(2)	
20	right = amber(2)	others = red(3)	RAR
21	right = red(3)	others = green(1)	RRG
22	right = red(3)	others = amber(2)	RRA
	right = red(3)	others = red(3)	

OPTION	SIGNAL INDICATIONS FOR EACH INBOUND LANE		CODE
23	protected left = green(4)	others = green(1)	LPG
24	protected left = green(4)	others = amber(2)	LPA
25	protected left = green(4)	others = red(3)	LPR
	protected left = amber(2)	others = green(1)	
	protected left = amber(2)	others = amber(2)	
	protected left = amber(2)	others = red(3)	
	protected left = red(3)	others = green(1)	
	protected left = red(3)	others = amber(2)	
	protected left = red(3)	others = red(3)	

number, (2) the initial interval, (3) the vehicle interval, (4) the amber clearance interval, (5) the all-red clearance interval, (6) the maximum extension after demand on red, (7) the skip-phase switch option, (8) the auto-recall switch option, (9) the parent/minor movement option, (10) the dual left option, (11) the detector connection type, (12) the number and list of detectors connected to each phase, and (13) the number and list of phases which can be cleared to directly from each phase.

5.2.6 Input For Detector Information

If the signal requires detectors, additional information must be provided by card input to detail the location and type of detectors. The detector types include PULSE and PRESENCE. The detector location information includes (1) the approach number, (2) the starting and stopping position for the detector, and (3) the number and list of lanes served.

5.3 Algorithms For Computation

5.3.1 Time Increment And Simulation Time

SIMPRO uses a fixed time increment in the range of one-half second to one second. The simulated position and operational conditions for each driver-vehicle unit in the system are updated during each time increment. Using the minimum time increment produces the most accurate simulation, but requires the most computer time, while using the maximum time increment generally produces a less accurate simulation, but also requires less computer time.

Certain functions must be executed during every time increment because the actions of other driver-vehicle units within the system determine the environment of the driver under consideration at a particular instant. Other functions, such as driver response, need not be evaluated so often. Two timers for each driver-vehicle unit are used in effecting the driver response.

One of the timers evaluates driver reaction time to certain events that are associated with the initiation of acceleration or deceleration of his vehicle (denoted IPRTM in SIMPRO). The other timer controls the checking of intersection conflicts (denoted LOGFLG in SIMPRO). In each case, the time until a certain action needs to be taken or checked again can be computed and used.

Figure 5.1 illustrates the results obtained from several comparison runs in which only the time increment for each simulation update was varied. Based on these results, it seems desirable to use a time increment of one-half second for simulating a non-signalized intersection and a time increment of one second for a signalized intersection. The rationale for this recommendation is that in the non-signalized case, checking for intersection conflicts is more critical as many more driver-vehicle units must check for intersection conflicts. Also, an acceptable gap may not be detected if an excessively long time increment is used. At a signalized intersection, however, only unprotected left turning, left-turn-on-red or right-turn-on-red vehicles normally need to check intersection conflicts, and a longer time increment is adequate.

There are two components to simulation time: (1) start-up time, an initial time interval which begins with an empty system and continues until traffic flow approaches a steady state condition (no summary statistics are gathered), and (2) simulation time, the time interval during which flow through the system is approximately steady state (summary statistics are gathered). A study of the time required to reach a steady state condition involved reporting summary statistics every one-half minute (see Fig 5.2). This study suggested that a minimum start-up time of two minutes is needed to allow the system to reach an approximate steady state. Considerable study by other researchers has been focused on the simulation time required to obtain statistics which compare favorably with actual performance statistics. In field studies, data are usually collected for periods from 15 minutes to several hours; then the data are converted to equivalent hourly statistics. The longer study times are used so that an entire peak period will be included in the field survey and so that sampling errors may be reduced. When using computer simulation, the user simply defines the traffic stream to be studied. Under heavy traffic flow conditions, it is felt that a minimum simulation time of ten minutes will produce reliable simulation statistics. For light flow

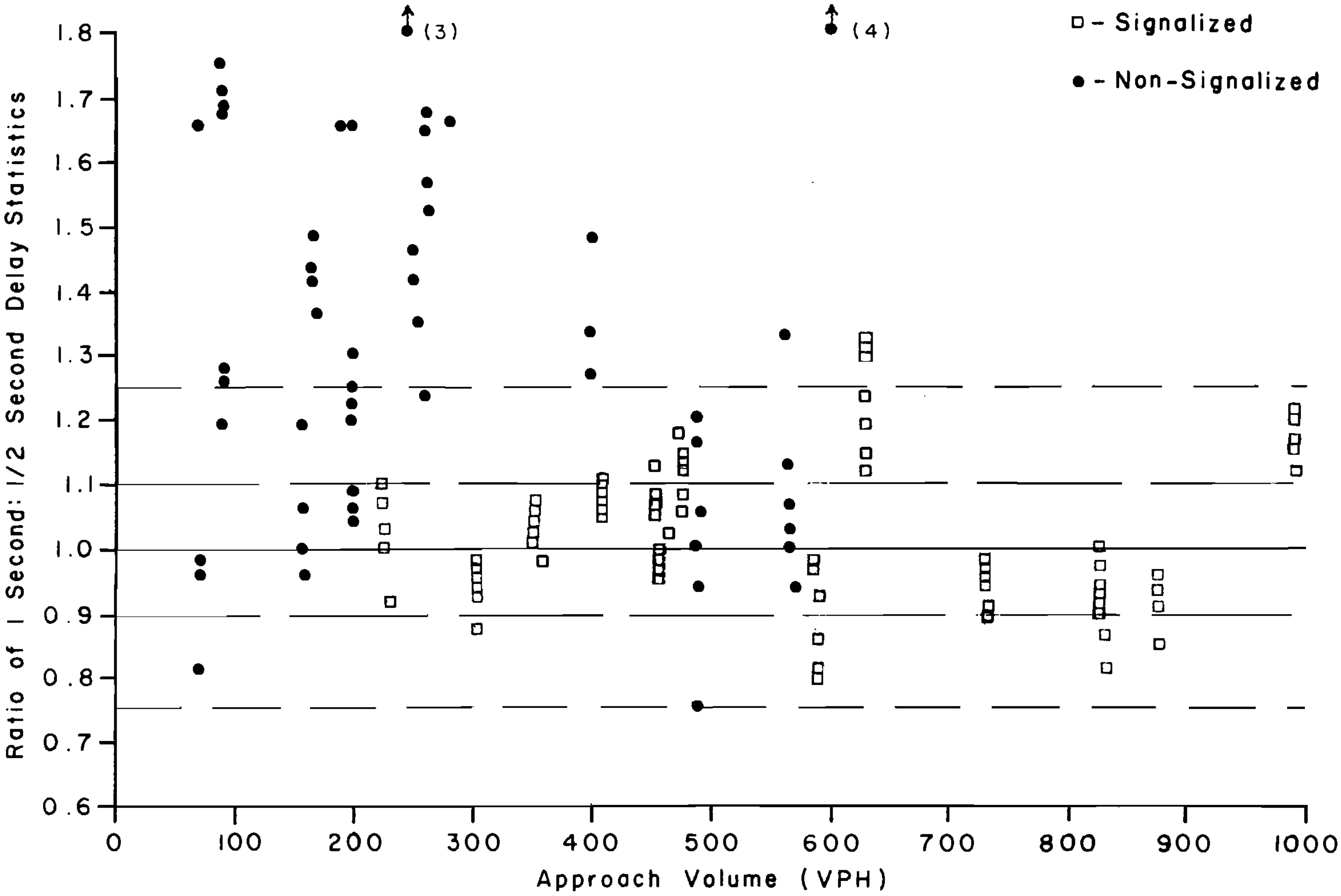


Fig 5.1. Sensitivity of time increment.

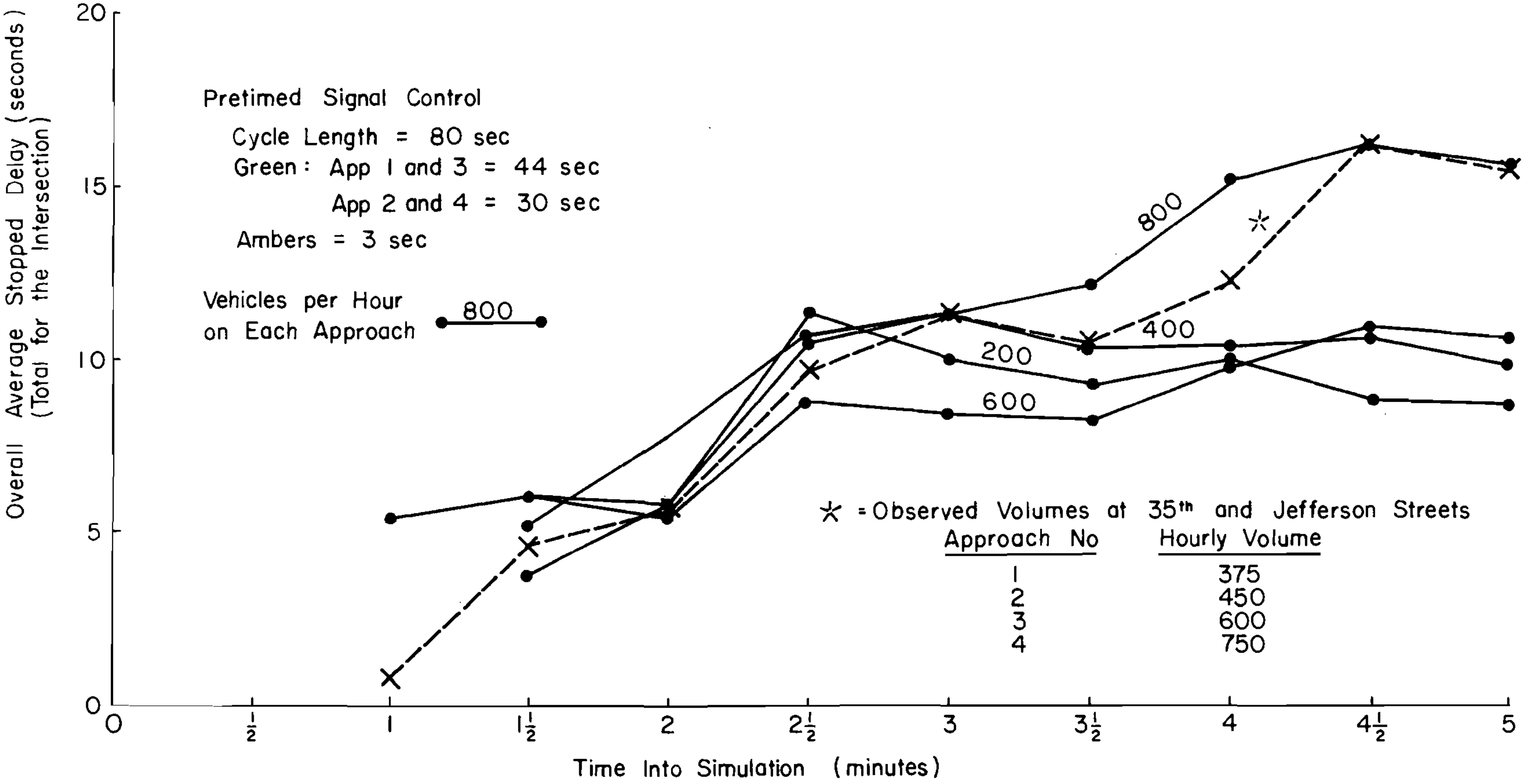


Fig 5.2. Average delay versus time into simulation (start-up time) for approach volumes in range from 200 to 800 vph.

conditions, a longer simulation time is recommended.

5.3.2 Program Structure

SIMPRO was developed using structured programming techniques. Each subprogram is small and performs a single, defined function. Currently, 78 subprograms are included in SIMPRO. There are 3 types of links on which to simulate driver-vehicle units: (1) outbound approaches, where there is no control mechanism at the end of the lane and where lane changing is allowed; (2) intersection paths; and (3) inbound approaches, where there can be some control mechanism which regulates entry into the intersection, where lane changing is allowed, and whereon queue and stopped delay statistics are gathered. The generalized flow of the program is shown in Fig 5.3.

SIMPRO first reads the magnetic tape produced by the geometry processor and the driver-vehicle processor, reads the card input to the simulation processor, and initializes all pertinent simulation variables. These tasks are accomplished by subprogram INITIAL. Next, the queue of driver-vehicle units that is scheduled to enter the system is interrogated to find which units, if any, should enter during the current time increment (processed by QUEUE). Then the units on the outbound approaches are processed by OBAP, while any vehicle with a projected position beyond the end of the outbound lane is logged out of the system by LOGOUT. The driver-vehicle units on the intersection paths are then processed by INTERP. Following this, IBAP processes the units on the inbound approaches and LOGIN enters new units into the system. If there is a signal, it is processed by PRESIG or ACTSIG. Finally, the time into the simulation is advanced by one time increment. If the time into the simulation is less than or equal to the start-up time plus the simulation time, then the program goes back to QUEUE, and repeats the update process. When the time into the simulation progresses to a value that is greater than the start-up time plus the simulation time, the specified summary statistics are printed (and punched if requested) and the simulation run is ended.

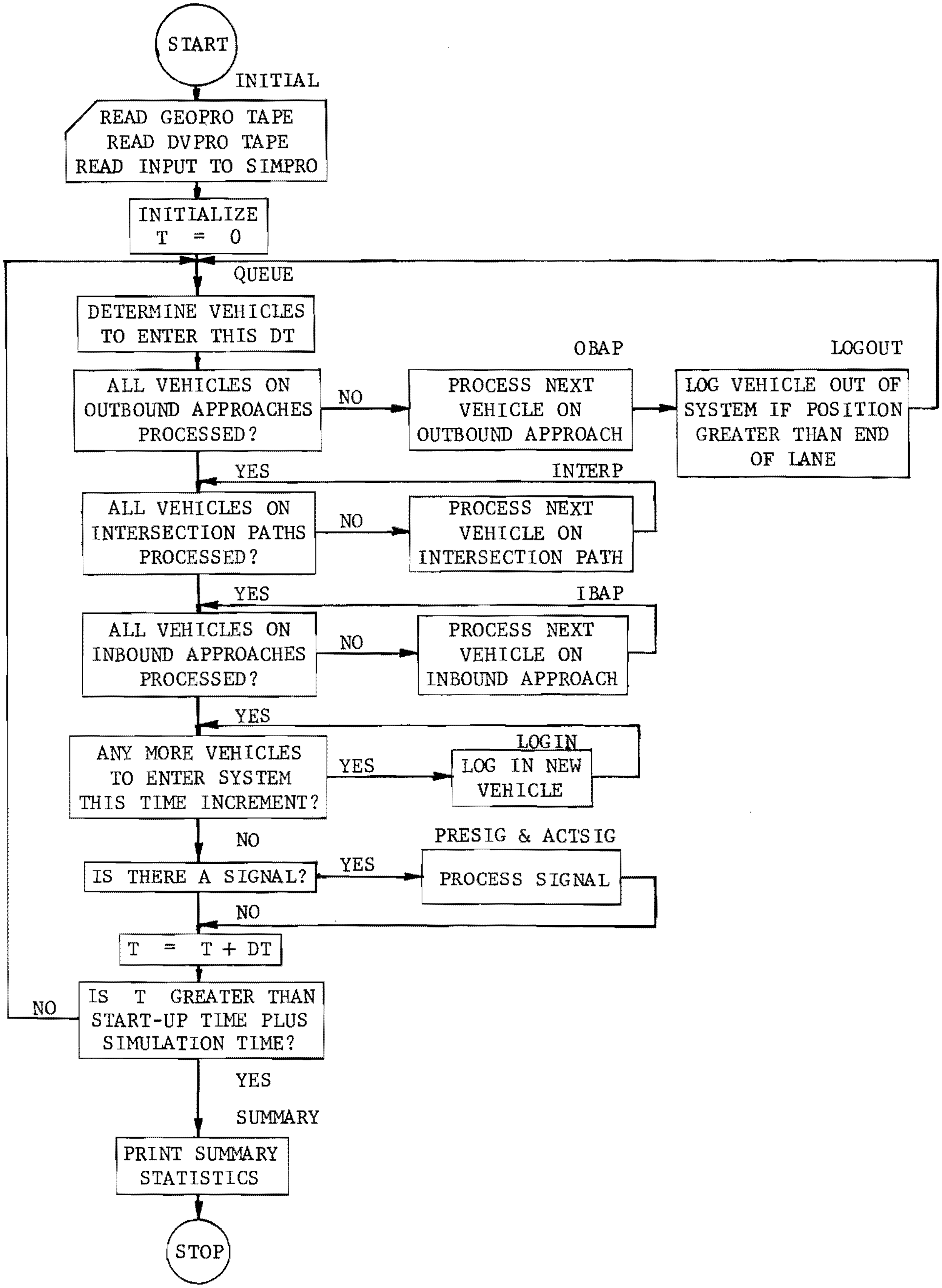


Fig 5.3. Generalized flow process for SIMPRO.

A driver-vehicle unit which is first on its link and has the right to enter the next link may look forward into the link ahead and react to the last driver-vehicle unit on the next link. This provides continuity between the various links in the system.

5.3.3 Data Structure

SIMPRO uses a special storage management and logic processing routine called COLEASE. Chapter 6 discusses COLEASE in more detail. This program accomplishes two objectives: (1) it provides a mechanism for storing specified variables in a format which maximizes computer bit storage by disregarding normal word boundaries and (2) it establishes an efficient means for processing logical binary networks.

The user of COLEASE defines entities, which are groups of attributes (variables). SIMPRO has 8 entities: APPRO (approach attributes), CONFLT (intersection conflict attributes), LANE (inbound and outbound lane attributes), PATH (intersection path attributes), SDR (sight distance restriction attributes), VEHD (dynamic driver-vehicle unit attributes), VEHF (fixed driver-vehicle unit attributes), and VEHIL (intersection logic driver-vehicle attributes).

In the traffic simulation processor, an array called LIBA, in COMMON block INTER, which contains the list of inbound approaches. A value in LIBA serves as a pointer to the entry in the APPRO entity which contains information about the inbound approach. There is also an array called LOBA, in COMMON block INTER, which contains the list of outbound approaches. A value in LOBA is a pointer to the entry in the APPRO entity which contains the information about the outbound approach. The number of inbound approaches, NIBA, and the number of outbound approaches, NOBA, are also contained in COMMON block INTER.

An attribute of the APPRO entity specifies the number of lanes, NLANES, and a corresponding list of lanes, LLANES. A value in LLANES serves as a pointer to the entry in the LANE entity which contains the information about the lane. Another attribute of the APPRO entity contains the number of sight distance restrictions, NSDR, the list of sight distance restriction numbers, ISDRN, and the list of sight distance restriction approach numbers for the other approach involved in the sight distance restriction, ISDRA.

An attribute of the LANE entity is the first driver-vehicle unit on the lane, IFVL, and the last driver-vehicle unit on the lane, ILVL. These are pointers to the entries in the VEHD, VEHF, and VEHIL entities which contain the information about the driver-vehicle units. Another attribute of the LANE entity specifies the number of intersection paths, NPINT, and the list of intersection paths, LPINT, connected to the lane (if an inbound lane). Also, the LANE entity has the number of detectors, NLDL, and the list of detectors, LLDL, for the lane (if an inbound lane).

An attribute of the PATH entity specifies the first driver-vehicle unit on the intersection path, IFVP, and the last driver-vehicle unit on the intersection path, ILVP. These are pointers to the entries in the VEHD, VEHF, and VEHIL entities which contain information about the driver-vehicle units. Other attributes of the PATH entity are the number of geometrically conflicting intersection paths, NGEOCP, the list of geometrically conflicting intersection paths, IGEOCP, the current number of intersection conflicts where another driver-vehicle unit has the right-of-way, NCPSET, and the list of intersection conflicts where another driver-vehicle unit has the right-of-way, ICPSET. The PATH entity also has attributes which define the linking outbound approach, LOBAP, and the linking outbound lane, LOBL.

An attribute of the VEHF entity is the entry number for the driver-vehicle unit forward, NOF, and the entry number for the driver-vehicle unit to the rear, NOR. These are pointers to the VEHD, VEHF, and VEHIL entities which contain information about the driver-vehicle unit immediately ahead of the driver-vehicle unit on the same lane or intersection path and the driver-vehicle unit immediately behind the driver-vehicle unit on the same lane or intersection path, respectively.

As an example, Fig 5.4 illustrates an intersection with three vehicles on an inbound approach (see Appendix A.1.1 for geometry information). In Fig 5.5, if the position of the second vehicle on the third inbound approach is desired, the value of LIBA(3) would point to entry 3 in the APPRO entity. An attribute of the third entry of the APPRO entity would be LLANES(2) which would point to entry 6 in the LANE entity. An attribute of the LANE entity would be the first vehicle in the lane, IFVL, which would point to entry 3 in the VEHD, VEHF, and VEHIL entities. An attribute of the VEHF entity is the

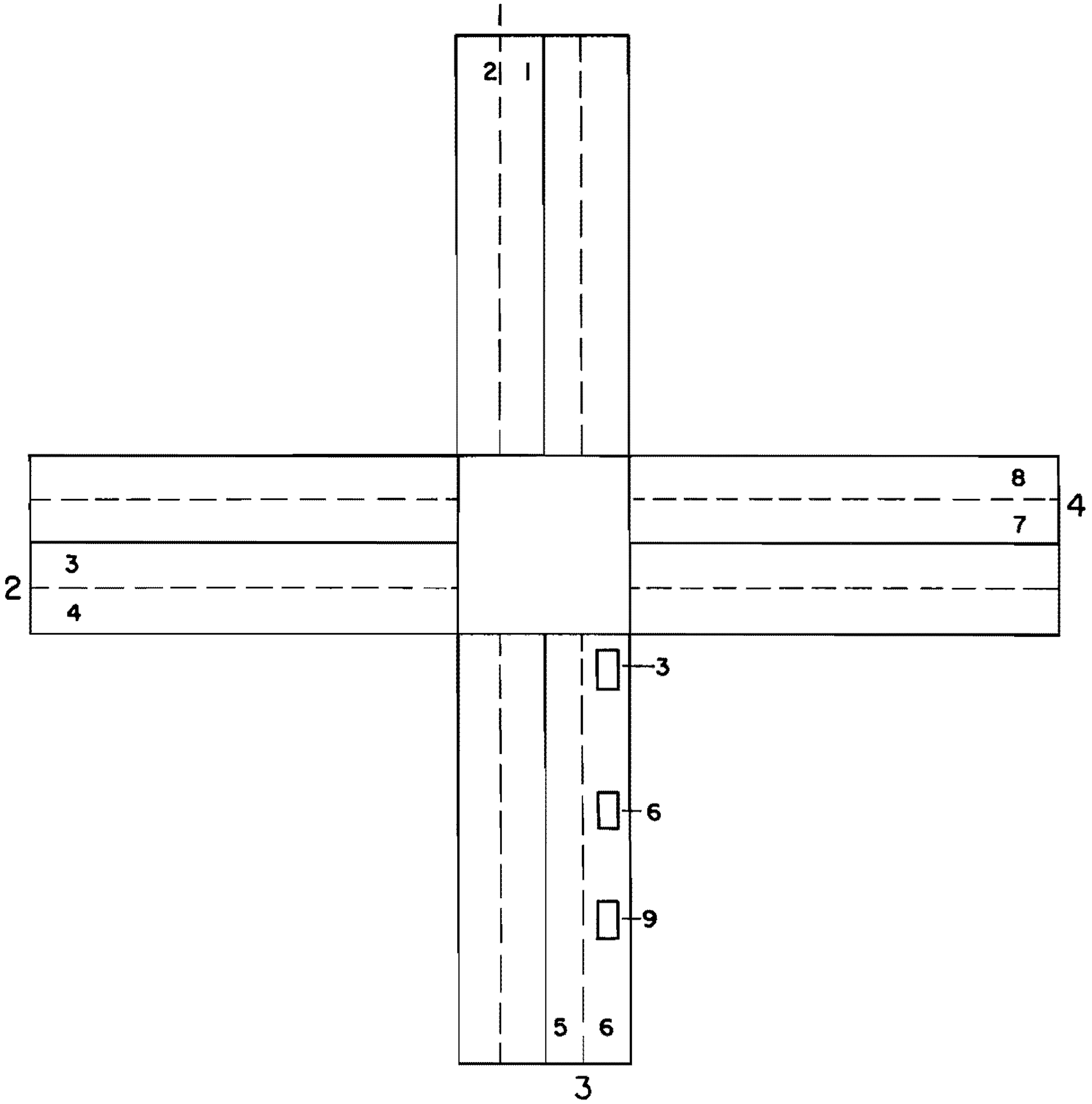


Fig 5.4. Example intersection for illustrating SIMPRO data structure.

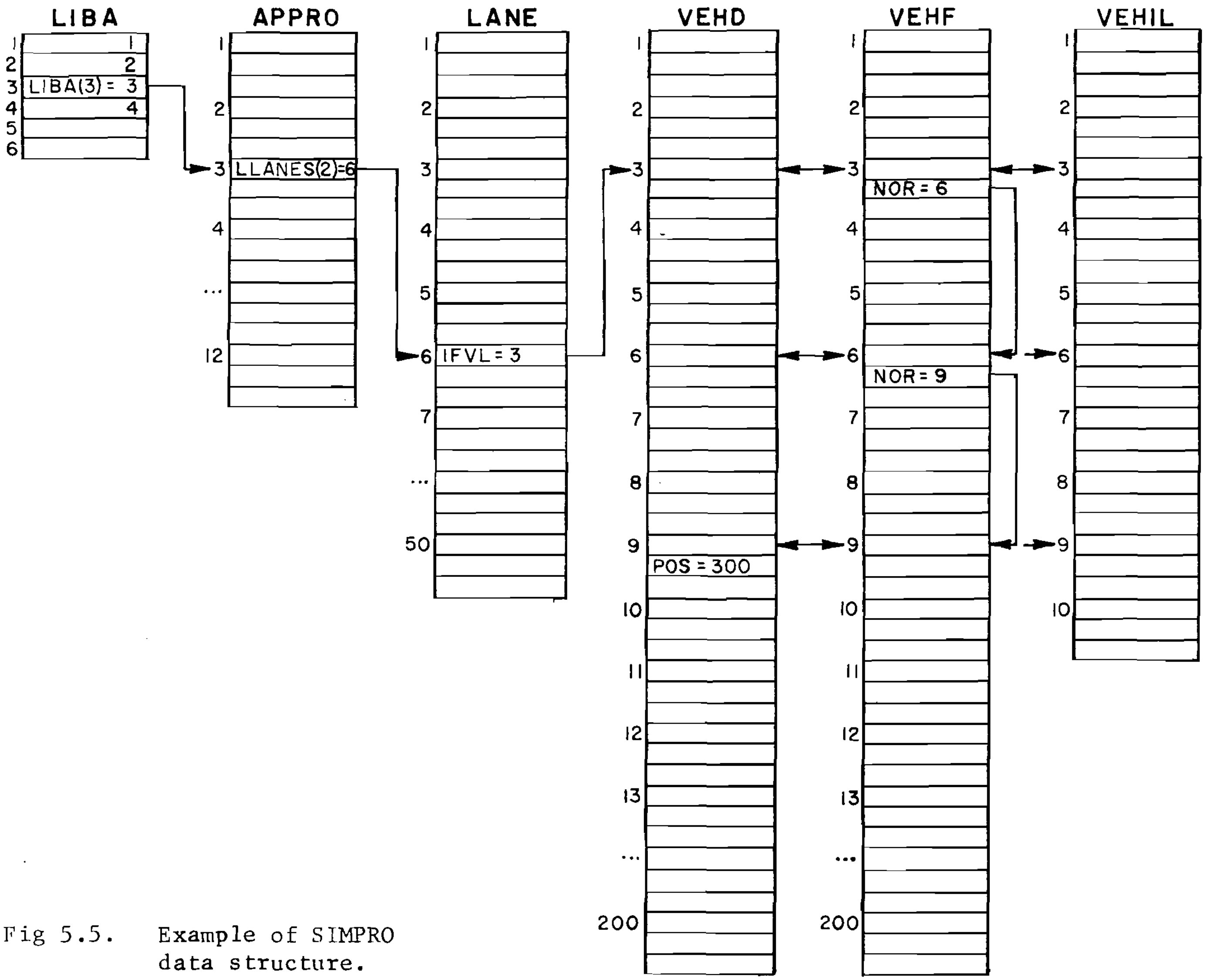


Fig 5.5. Example of SIMPRO data structure.

driver-vehicle unit to the rear, NOR, which would point to entry 6 in the VEHD, VEHF, and VEHIL entities. The position of the driver-vehicle unit in question would be found as an attribute of the VEHD entity and would be 300 feet (91.44 meters).

The entities in SIMPRO contain numerous other attributes which describe the intersection being simulated. A total of 45,812 attributes are stored by COLEASE. On CDC computers, these attributes and their bookkeeping data are stored in 7,133 60-bit computer words (6.42 attributes per computer word) while, on IBM computers, these attributes and their bookkeeping data are stored in 10,692 32-bit computer words (4.28 attributes per computer word).

5.3.4 Linear Acceleration Model

Before attempting to develop a model of actual traffic behavior, an investigation of existing acceleration models was undertaken. The uniform acceleration model, which is frequently used, does not match observed behavior accurately when considered on a microscopic scale. Using a Chi-Squared goodness-of-fit test, a best-fit uniform acceleration model was calculated and the results are plotted in Fig 5.6 along with data points observed by Beakey (Ref 31). This figure illustrates that the uniform acceleration model computes velocities which are too low during initial acceleration and which result in the vehicle's reaching desired velocity much sooner than it should.

A linear acceleration model which hypothesizes use of maximum acceleration when vehicular velocity is zero, zero acceleration at desired velocity, and a linear variation of acceleration over time, has been adopted for SIMPRO. Comparisons of this model with observed data (see Fig 5.6) indicate excellent agreement. This model also compares favorably with the non-uniform acceleration theory (Ref 32) used in describing the maximum available acceleration for the vehicle. The equations of motion developed for such a model are

$$AF = AI + S*T \tag{5.1}$$

$$VF = VI + AI*T + 0.5*S*T**2 \tag{5.2}$$

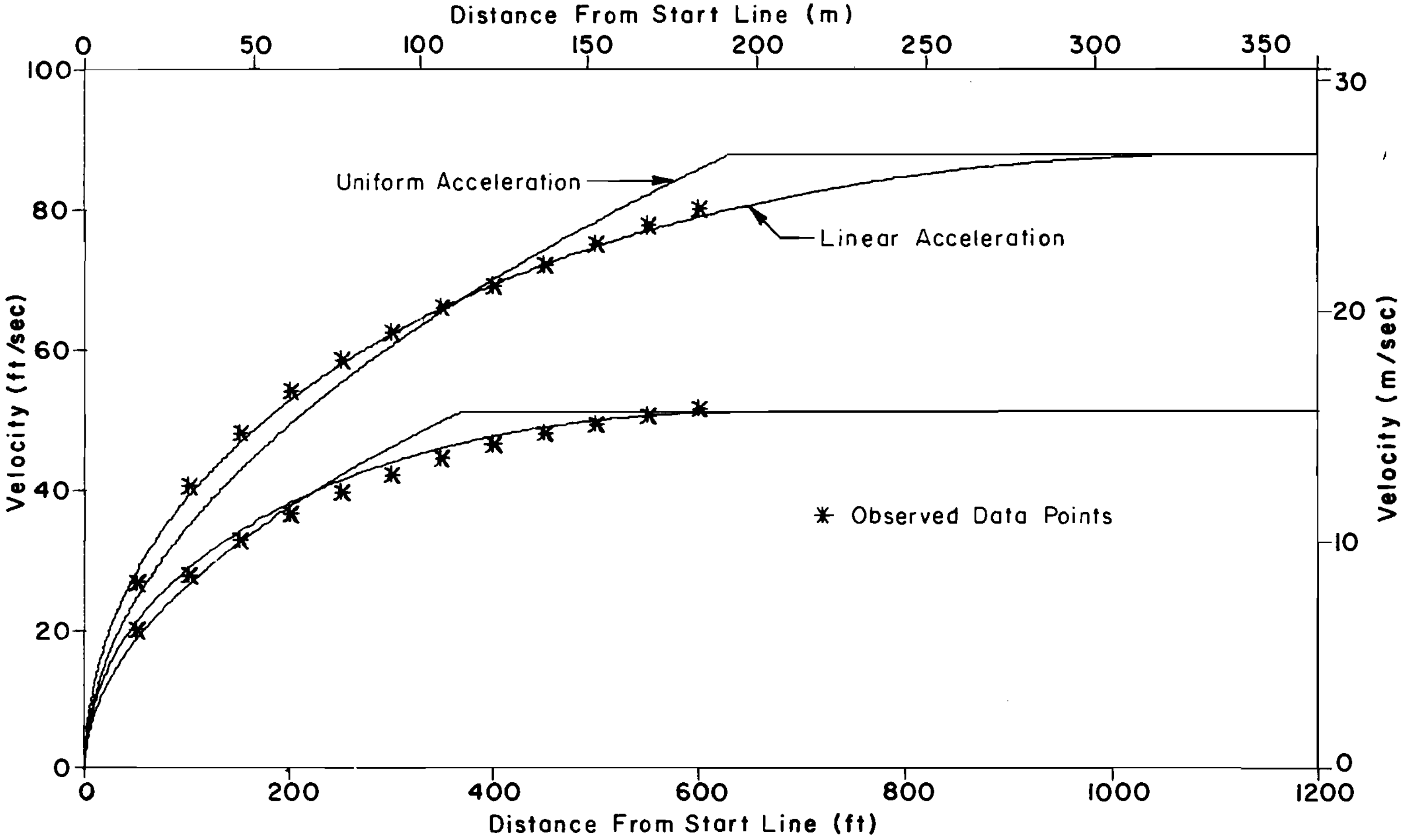


Fig 5.6. Uniform and linear acceleration for observed data.

$$XF = XI + VI*T + 0.5*AI*T**2 + 0.167*S*T**3 \qquad (5.3)$$

where T is time in seconds, S is acceleration slope (jerk) in ft/sec/sec/sec, AI is initial acceleration in ft/sec/sec, AF is final acceleration in ft/sec/sec, VI is initial velocity in ft/sec, VF is final velocity in ft/sec, XI is initial distance in feet, and XF is final distance in feet.

From these equations, numerous boundary conditions can be set and the equations can be solved for the unknown variable(s). The parameter that is determined by driver desire in effecting the position, velocity, and acceleration of his vehicle is assumed to be acceleration slope (jerk). Dramatic changes in acceleration in a short period of time are restricted in SIMPRO by limiting the range of acceleration slope to plus or minus 4 ft/sec/sec/sec (1.2192 m/sec/sec/sec).

Further comparisons of the uniform and linear acceleration models may be made. For the final velocity at time T to be the same when starting from a stopped position, AI for the linear acceleration model will be 2.0 times the uniform acceleration model value. For the distance traveled at time T to be the same when starting from a stopped position, AI for the linear acceleration model must be 1.5 times the uniform acceleration model value (see Fig 5.7).

The linear acceleration model is applied for two cases in SIMPRO. The first case involves the acceleration of a driver-vehicle unit to some desired velocity, DESVEL, in ft/sec from a stopped condition. In this case, the desired speed of a driver-vehicle unit (denoted ISPD) in ft/sec does not change unless the speed limit for the link on which the unit is operating is different from the speed limit of the previous link; however, the desired velocity of a driver-vehicle unit (DESVEL) may be different for each time increment. Referring to Eq 5.1 and Eq 5.2, AI will have some defined value; AF will be zero; VI will be zero; and VF will be DESVEL. Studies by Bulloch (Ref 33) led to the development of the following equation which relates initial acceleration, AI, in ft/sec/sec and desired velocity, DESVEL, in ft/sec

$$AI = AUTOL*(3.2+0.08*DESVEL)*DCHAR \qquad (5.4)$$

where AUTOL is a constant that is needed to convert uniform acceleration to linear acceleration (1.7 used in SIMPRO) and DCHAR is a driver operational

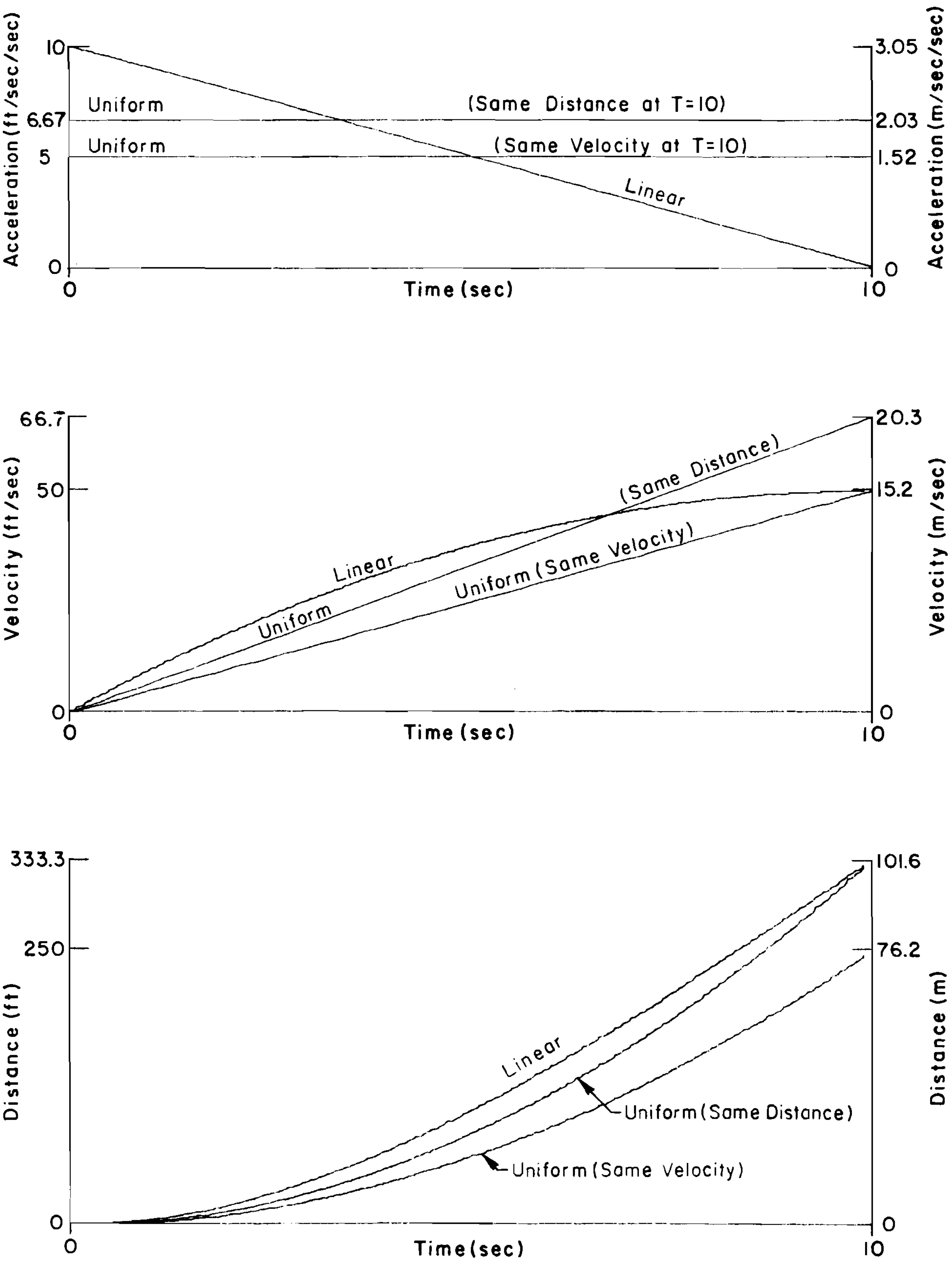


Fig 5.7. Acceleration, velocity, and distance comparisons between uniform and linear acceleration models.

factor.

By solving Eq 5.1 and Eq 5.2 simultaneously, the value of acceleration slope, S, in ft/sec/sec/sec is found to be

$$S = -0.5*AI**2/DESVEL \tag{5.5}$$

For this case, a driver-vehicle unit can accelerate from a stop with an initial acceleration given by Eq 5.4 and an acceleration slope given by Eq 5.5; and, when acceleration reaches zero, the driver-vehicle unit will be at its desired velocity.

A second case involves the acceleration of a driver-vehicle unit from some initial velocity which is not zero to some desired velocity, DESVEL. Referring to Eq 5.1 and Eq 5.2, AI will have some defined value; AF will be zero; VI will be the current velocity in ft/sec; and VF will be DESVEL. Again, Eq 5.4 relates initial acceleration and desired velocity, but it must be modified to reflect the fact that the driver-vehicle unit is already moving. The following equation is used to modify AI

$$AI = AI*(1.0-VI/DESVEL) \tag{5.6}$$

Bulloch (Ref 33) observed that drivers actually accelerate as if they are attempting to reach a desired velocity which is approximately 15 percent higher than their actual desired velocity. By solving Eq 5.1 and Eq 5.2 simultaneously for this case, the value of acceleration slope, S, in ft/sec/sec/sec is found to be

$$S = -0.5*AI**2/(DESVEL-VI) \tag{5.7}$$

For this case, a driver-vehicle unit can be traveling at a specified initial velocity; can accelerate with an initial acceleration given by Eq 5.4 and Eq 5.6 and an acceleration slope defined by Eq 5.7; and, when acceleration reaches zero, the driver-vehicle unit will be at its desired velocity.

In SIMPRO, subprogram ACCEL controls the acceleration of each driver-vehicle unit. A value of initial acceleration, AI, as calculated using Eq 5.4 (denoted ACCMAX). It should be noted that if a user determines that Eq 5.4 is inadequate, he may simply replace it in subprograms ACCEL, PREDTV, and CARFOL without affecting the operation of SIMPRO. This modification should be undertaken only after a thorough investigation of the new equation relating initial acceleration and desired velocity has been made, however. Next, ACCEL calculates the maximum acceleration available for the vehicle using the non-uniform acceleration theory (Ref 32). This theory states that the maximum acceleration of a vehicle (denoted ACCVEH) in ft/sec/sec at any velocity, V, in ft/sec is given by

$$\mathrm{ACCVEH} = \mathrm{ALPHA} - \mathrm{BETA}*V \qquad (5.8)$$

where ALPHA and BETA are constants for a specific vehicle. It follows that at a velocity of zero, the acceleration of the vehicle will be greatest (denoted AMAX) and, when the vehicle is at its maximum velocity (denoted VMAX), the acceleration will be zero. These properties are stated as follows

$$\mathrm{AMAX} = \mathrm{ALPHA} - \mathrm{BETA}*0 \qquad (5.9)$$

$$0 = \mathrm{ALPHA} - \mathrm{BETA}*\mathrm{VMAX} \qquad (5.10)$$

By solving Eq 5.9 and Eq 5.10 simultaneously for ALPHA and BETA, the following equations are formulated

$$\mathrm{ALPHA} = \mathrm{AMAX} \qquad (5.11)$$

$$\mathrm{BETA} = \mathrm{AMAX}/\mathrm{VMAX} \qquad (5.12)$$

By substituting Eq 5.11 and Eq 5.12 in Eq 5.8 and by simplifying, the maximum acceleration, ACCVEH, in ft/sec/sec of a vehicle at any velocity, V, in ft/sec is defined as

$$\mathrm{ACCVEH} = \mathrm{AMAX}*(1.0-V/\mathrm{VMAX}) \qquad (5.13)$$

In SIMPRO, the computed value of AI is not allowed to exceed the computed value of ACCVEH and thus AI is modified using an equation similar in form to Eq 5.6. If the current acceleration is less than AI, an acceleration slope is calculated which brings the acceleration of the driver-vehicle unit to AI within the perception-reaction time, PIJR, of the driver, and checks to ensure that the acceleration slope does not exceed a maximum value for jerk. As the velocity of the driver-vehicle unit increases, the value of AI from Eq 5.6 will decrease if the desired velocity is the same. If the current acceleration is greater than AI, then an acceleration slope is calculated which brings the acceleration to AI within one time increment, thereby ensuring that the acceleration slope does not exceed acceptable limits.

Several other conditions are checked by ACCEL to ensure that acceleration will be similar to that used by normal drivers.

In validating the linear acceleration models, position, velocity, and acceleration versus time plots were produced by SIMPRO and analyzed to determine whether or not vehicles responded in a reasonable manner under varying conditions.

5.3.5 Linear Deceleration Model

The uniform deceleration model, which is frequently used, does not accurately match observed behavior of actual drivers when considered on a microscopic scale. Using a Chi-Squared goodness-of-fit test, the best-fit uniform deceleration model was calculated and the results are plotted in Fig 5.8 along with data points observed by Beakey (Ref 31). This figure illustrates that the uniform deceleration model yields a higher velocity during the first part of the deceleration maneuver and, as the velocity approaches zero, produces values that are lower than observed values.

A linear deceleration model which hypothesizes use of a zero initial deceleration, maximum deceleration at the instant the driver-vehicle unit stops, and a linear variation of the deceleration over time from zero to the maximum, was adopted for use in SIMPRO. Comparison of this model with observed data (see Fig 5.8) indicates excellent agreement. The equations of motion developed for such a model are

$$DF = DI + S*T \tag{5.14}$$

$$VF = VI + DI*T + 0.5*S*T**2 \tag{5.15}$$

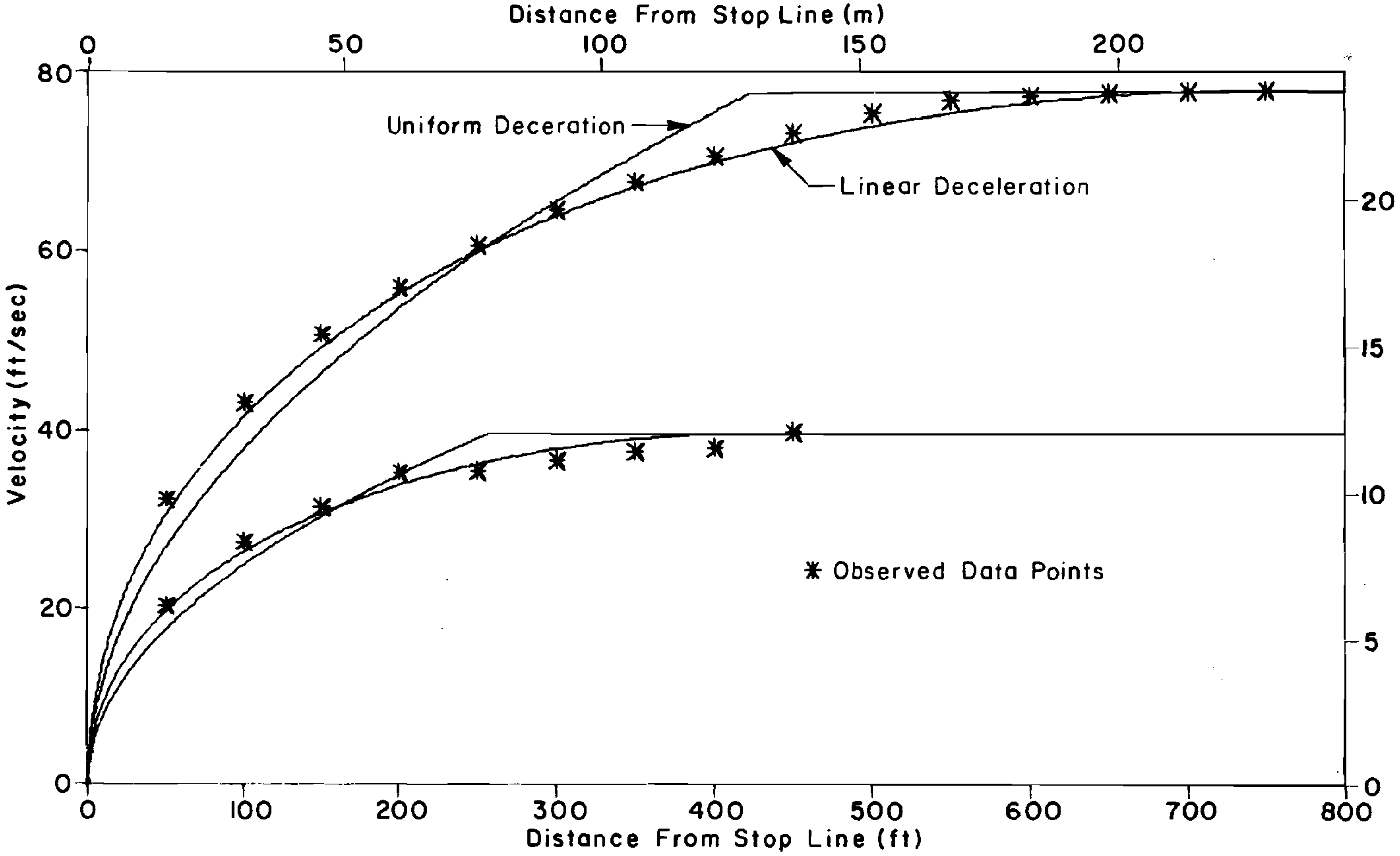


Fig 5.8. Uniform and linear deceleration for observed data.

$$XF = XI + VI*T + 0.5*DI*T**2 + 0.167*S*T**3 \tag{5.16}$$

where T is time in seconds, S is deceleration slope (jerk) in ft/sec/sec/sec, DI is initial deceleration, DF is final deceleration in ft/sec/sec, VI is initial velocity in ft/sec, VF is final velocity in ft/sec, XI is initial distance in feet, and XF is final distance in feet. These equations are quite similar to Eq 5.1 through Eq 5.3. For these deceleration equations, numerous boundary conditions can be set and the equations can be solved for the unknown variable(s). The parameter that is determined by driver desire in effecting the position, velocity, and deceleration of his vehicle is deceleration slope (jerk). Dramatic changes in deceleration in a short period of time are restricted in SIMPRO by limiting the range of deceleration slope to plus or minus 4 ft/sec/sec/sec (1.2192 m/sec/sec/sec).

Further comparisons of the uniform and linear deceleration models may be made. For the vehicle to stop in the same time T when starting from the same initial velocity, DF for the linear deceleration model will be 2.0 times the uniform deceleration model value. For the vehicle to stop in the same distance when starting from the same initial velocity, DF for the linear deceleration model must be 3.0 times the uniform deceleration model value (see Fig 5.9).

The linear deceleration model is used in SIMPRO for the case of specifying the deceleration of a driver-vehicle unit from some initial velocity, VELOLD, in ft/sec to a complete stop. Referring to Eq 5.14 through Eq 5.16, DI has some defined value; DF is the maximum deceleration, DECMAX in ft/sec/sec; VI has some defined value; VF is zero; and XF minus XI is defined as RELOLD in feet. Studies by Bulloch (Ref 33) led to the development of the following equation, which relates final maximum deceleration and initial velocity, VELOLD in ft/sec

$$DECMAX = DUTOL*(-6.0-VELOLD/44.0)*DCHAR \tag{5.17}$$

where DUTOL is a constant that is needed to convert uniform deceleration to linear deceleration value (value of 2.67 used in SIMPRO) and DCHAR is the driver operational factor. By solving Eq 5.14 through Eq 5.16 simultaneously, the value of deceleration slope in ft/sec/sec/sec is determined to be

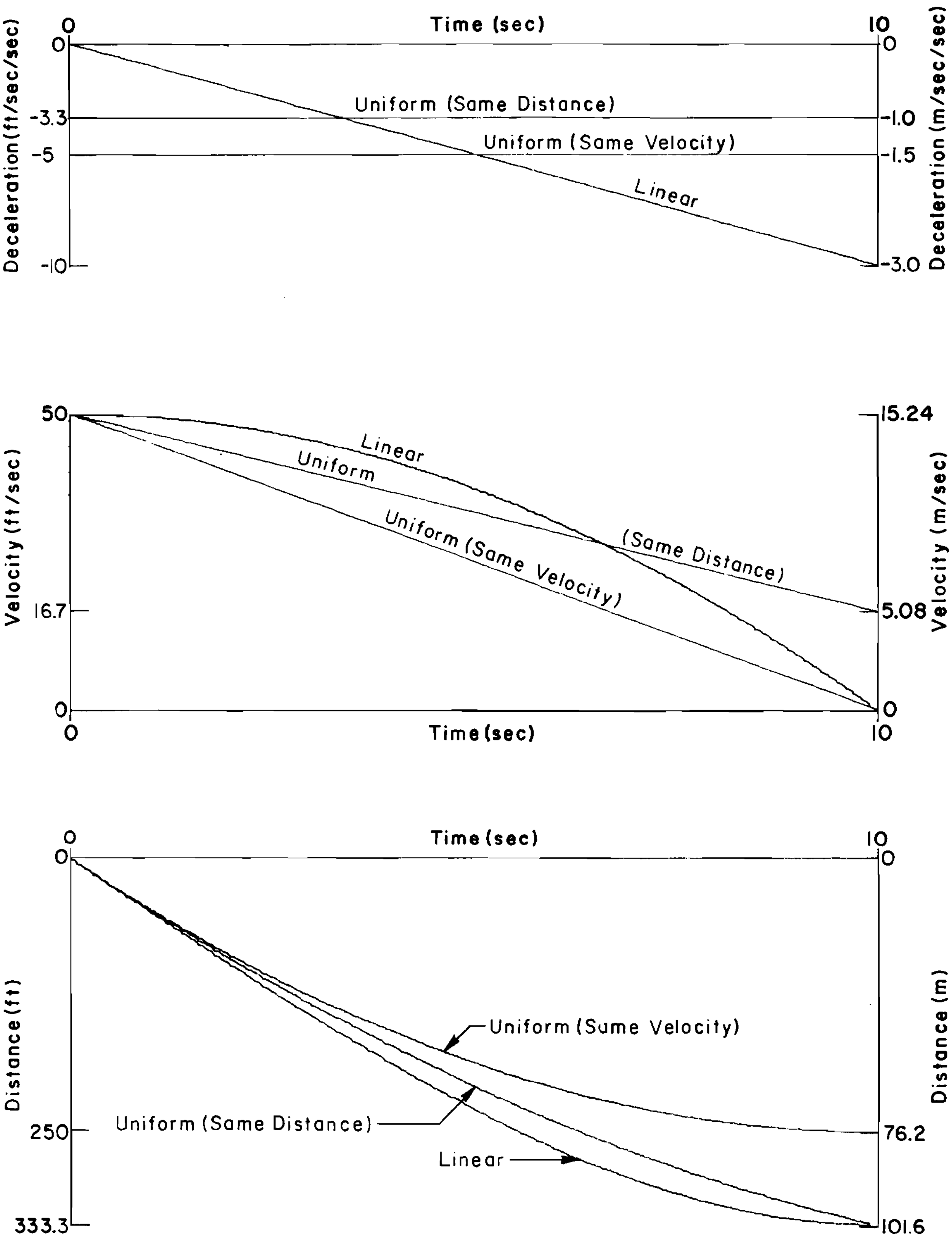


Fig 5.9. Deceleration, velocity, and distance comparisons between uniform and linear deceleration models.

S = 0.5*(DI**2-DECMAX**2)/VELOLD (5.18)

For this case, a driver-vehicle unit can decelerate to a stop from an initial velocity, VELOLD, by initiating a deceleration slope given by Eq 5.18 and using a maximum deceleration defined by Eq 5.17.

Difficulty arises in SIMPRO in determining when the deceleration to a stop maneuver should commence. As an example, assume that there is only one driver-vehicle unit in the traffic simulation system, that the unit is on an inbound approach, and that the lane is controlled by a stop sign. The driver knows that he must stop at the stop line, but he must decide how far away from the stop sign the deceleration to a stop must be initiated. This distance can be determined by substituting Eq 5.18 in Eq 5.14 and in Eq 5.16 and solving for XF minus XI to give

XF-XI = (-0.667*VI**2)*(2.0-DI/(DI+DECMAX))/(DI+DECMAX) (5.19)

This equation can also be written as

XF-XI = (-0.667*VI**2)*(DI+2.0*DECMAX)/(DI+DECMAX)**2 (5.20)

These two equations define the distance in feet needed for the unit to stop from an initial velocity, VI, with an initial deceleration, DI, and using a maximum final deceleration, DECMAX, as defined by Eq 5.17.

In SIMPRO, subprogram CRIDIS controls the deceleration to a stop of a driver-vehicle unit. If the driver-vehicle unit has a positive value for initial deceleration, a reaction time is included in the calculations during which acceleration is reduced to zero. A value for DECMAX is computed for the unit using Eq 5.17 and checked to ensure that it does not exceed the maximum deceleration rate for the vehicle. It should be noted that if a user determines that Eq 5.17 is inadequate, he may replace it in subprograms CRIDIS, LOGIN, and SIGRES without affecting the operation of other components in SIMPRO. This substitution should be undertaken, however, only after a thorough investigation of the new equation relating final deceleration and initial velocity has been made. Next, CRIDIS calculates a value of critical stopping distance, XCRIT, in feet equal to XF minus XI by using an equation similar to Eq 5.19 but including a term for reaction time and assuming an initial deceleration, DI, of zero

$$XCRIT = VI*REACTT - 1.333*VI**2/DECMAX \tag{5.21}$$

If the distance to the place where the driver-vehicle unit needs to stop is less than or equal to XCRIT, deceleration to a stop is initiated. If this critical stopping distance will be violated within another perception-reaction time interval for the driver, acceleration is reduced in SIMPRO to zero before the critical stopping distance is reached; otherwise, the driver-vehicle unit will not need to decelerate and may accelerate according to the desired velocity of the driver.

When initiating deceleration to a stop, the actual distance to the place where the driver-vehicle unit must stop is used in calculating the required deceleration slope. With the initial deceleration, DI, and the actual stopping distance, X, known, Eq 5.19 and Eq 5.20 can be solved for the maximum deceleration, DECMAX, in ft/sec/sec required to stop the vehicle

$$DECMAX = -DI - (4*VI**2+2*VI*SQRT(4*VI**2+6*X*DI))/(6*X) \tag{5.22}$$

For this value of DECMAX, the required deceleration slope can be calculated using Eq 5.18. In SIMPRO, any required perception-reaction time of the driver-vehicle unit is entered, and a logic flag is set indicating that a deceleration-to-a-stop value has already been calculated. In subsequent update intervals, if the driver-vehicle unit continues to decelerate to a stop, the initially calculated value for deceleration slope is used repeatedly.

In validating the linear deceleration models, position, velocity, and deceleration versus time plots were produced by the traffic simulation processor and checked to ensure that the vehicles responded in a reasonable manner under varying conditions.

5.3.6 Car Following

Accelerating or decelerating a driver-vehicle unit in response to the action of a lead driver-vehicle unit is called car-following. Several car-following techniques were investigated, but the non-integer, microscopic, generalized car-following equation (Ref 34) was selected for use in SIMPRO because of its superiority and flexibility. The car-following equation chosen is

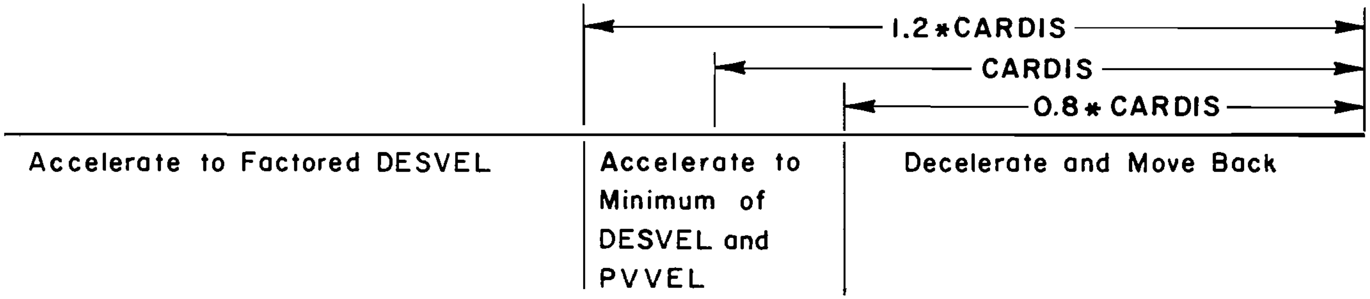
```
CARDEC = CAREQA*((VELOLD**CAREQM)/(RELPOS**CAREQL))*RELVEL  (5.23)
```

where CARDEC is a value of deceleration in ft/sec/sec; CAREQL, CAREQM, and CAREQA are the lambda, mu, and alpha parameters, respectively, for the generalized car-following equation; VELOLD is the velocity in ft/sec of the driver-vehicle unit at the start of the time increment ; RELPOS is the relative position of the driver-vehicle unit (equal to the position of the lead driver-vehicle unit minus the position of the unit being examined) in feet; and RELVEL is the relative velocity of the driver-vehicle unit (equal to the velocity of the lead driver-vehicle unit minus the velocity of the unit being examined) in ft/sec.

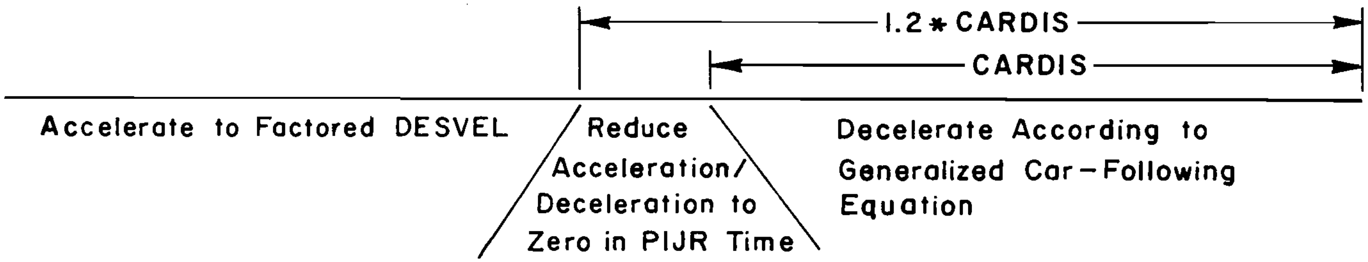
If a following driver-vehicle unit is close behind the leading unit, car-following logic is used in lieu of the acceleration subprogram ACCEL and the deceleration subprogram CRIDIS that are described above. Figure 5.10 illustrates the six states of car-following which are used in SIMPRO.

The first major decision in applying car-following logic is to ascertain whether the lead driver-vehicle unit is going faster than the driver-vehicle unit that is under examination. If it is, the relationships shown in Fig 5.10(a) are used in determining the proper action for the following driver-vehicle unit. This situation usually exists when driver-vehicle units change lanes and when the lane control allows units to discharge into the intersection. The key to this diagram is the definition of an acceptable car-following distance, CARDIS, in ft/sec. In CARFOL, CARDIS is defined as follows

```
CARDIS = 1.7*PVVEL/DCHAR                                    (5.24)
```



(a) Leading driver-vehicle unit is going faster than the following driver-vehicle unit.



(b) Following driver-vehicle unit is going faster than the leading driver-vehicle unit.

Fig 5.10. Conceptualization of car-following states.

where PVVEL is the velocity in ft/sec of the lead driver-vehicle unit and DCHAR is the driver operational factor.

If relative position is greather than 1.2 times CARDIS, then the driver-vehicle unit is caused to accelerate to a factored desired velocity by using subprogram ACCEL. The factor used in CARFOL to modify desired velocity for this purpose is

```
        FACT  =  AMIN!((RELPOS-CARDIS)/(4.0*CARDIS),1.0)                (5.25)
```

where RELPOS is the relative position in feet and CARDIS is defined by Eq 5.24. The desired velocity, DESVEL, in ft/sec thus is

```
        DESVEL  =  PVVEL  +  (DESVEL-PVVEL)*FACT                         (5.26)
```

where PVVEL is the velocity in ft/sec of the lead driver-vehicle unit, DESVEL is the desired velocity in ft/sec of the following unit, and FACT is defined by Eq 5.25.

If relative position, RELPOS, is equal to CARDIS, then the driver-vehicle unit is allowed to accelerate to the velocity of the lead unit, PVVEL. When RELPOS is greater than or equal to 5 times CARDIS, then the driver-vehicle unit is allowed to accelerate to its desired velocity, DESVEL.

If relative position is greater than 0.8 times CARDIS but less than 1.2 times CARDIS as defined by Eq 5.24, the following driver-vehicle unit accelerates to the minimum of (1) the desired velocity of the driver-vehicle unit or (2) the velocity of the lead unit.

If relative position is less than 0.8 times CARDIS as defined by Eq 5.24, the following driver-vehicle unit initiates an intricate deceleration maneuver which moves it back to the car-following distance and makes it travel at its desired speed with zero acceleration.

If the following driver-vehicle unit is going faster than the lead unit, the relationships shown in Fig 5.10(b) are used in determining the proper action for the following unit. This situation usually occurs when driver-vehicle units are stopping because of the lane control or because of the development of a stopped queue of vehicles waiting to enter the intersection. The definition of an acceptable car-following distance, CARDIS, in feet used for this condition in CARFOL is as follows

$$\mathrm{CARDIS} = (1.7*\mathrm{PVVEL}+4.0*\mathrm{RELVEL}**2)/\mathrm{DCHAR} \tag{5.27}$$

where PVVEL is the velocity in ft/sec of the lead driver-vehicle unit, RELVEL is the relative velocity (equal to the velocity of the lead driver-vehicle unit minus the velocity of the following driver-vehicle unit) in ft/sec, and DCHAR is the driver operational factor. This car-following distance equation contains a relative velocity term so that high-speed units will begin to react to lead driver-vehicle units when the two units are relatively far apart and their relative velocity is large.

If relative position is greater than 1.2 times CARDIS, then the driver-vehicle unit may accelerate to a factored desired speed by using subprogram ACCEL. The factor is given by Eq 5.25, CARDIS is defined by Eq 5.27, and the desired velocity is defined by Eq 5.26. If relative position, RELPOS, is equal to CARDIS, then the driver-vehicle unit is allowed to accelerate to the velocity of the lead unit, PVVEL. When RELPOS is greater than or equal to 5 times CARDIS, then the driver-vehicle unit is allowed to accelerate to its desired velocity, DESVEL.

If relative position is greater than CARDIS but less than 1.2 times CARDIS, the driver-vehicle unit will reduce acceleration or deceleration to zero within the perception-reaction time of the driver of the following unit. This maneuver makes the following unit trail the lead driver-vehicle unit at between CARDIS and 1.2 times CARDIS at a steady velocity.

If relative position is less than CARDIS, the driver-vehicle unit will decelerate according to the generalized car-following equation (see Eq 5.23). A value of deceleration in ft/sec/sec is computed from the equation; then a deceleration slope in ft/sec/sec/sec is determined which will bring the driver-vehicle unit to the computed value of deceleration in one time increment.

In each of the car-following states, appropriate tests are performed to ensure that the acceleration/deceleration slope does not exceed tolerable limits.

5.3.6.1 Car-Following Equation Parameters

Much work has been done by researchers to define the microscopic and macroscopic models of traffic flow. The microscopic models generally use the spacing and speed of individual vehicles while the macroscopic models deal primarily with traffic stream flows, densities, and average speeds. A particular microscopic model may be integrated to develop a corresponding macroscopic model. Figure 5.11 illustrates a generalized flow versus density curve and denotes the relevant macroscopic statistics: free speed - the speed of traffic under free flow conditions, or the slope of the curve as it leaves the origin; optimum speed - the speed of the traffic at maximum flow; jam density - the density when the traffic stream is stopped; optimum density - the density at maximum flow; and maximum flow.

Studies by May (Ref 35) indicate the sensitivity of the lambda and mu parameters for the generalized car-following equation with respect to free speed, optimum speed, jam density, optimum density, and maximum flow (see Fig 5.12).

For isolated urban intersection conditions, limiting ranges for lambda and mu were determined by using a free speed of less than 55 mi/hr (89 km/hr); an optimum speed above 20 mi/hr (32 km/hr); a jam density between 185 veh/mi (115 veh/km) (about 25 percent trucks) and 265 veh/mi (165 veh/km) (all cars); and an optimum density less than 70 veh/mi (48 veh/km). These restrictions bound lambda with a range of 2.3 to 4.0 and bound mu with a range of 0.6 to 1.0. Figure 5.13 illustrates these limits. A maximum flow between 1720 and 2000 veh/hr results from these values. The critical factor affecting mu is the jam density, therefore relatively liberal limits were established for the upper and lower bounds (all cars and 25 percent trucks). Likewise, the critical factor affecting lambda is the free speed; again relatively liberal limits were established for the upper bound [55 mi/hr (89 km/hr)]. The user should exercise caution when changing from the recommended range of values for lambda and mu. In determining the value for alpha, trial and error techniques were used on numerous test examples.

In validating the car-following model, position, velocity, and acceleration versus time plots were produced by the traffic simulation processor and checked to ensure that the driver-vehicle units responded in a reasonable manner under various conditions. The model was also checked to

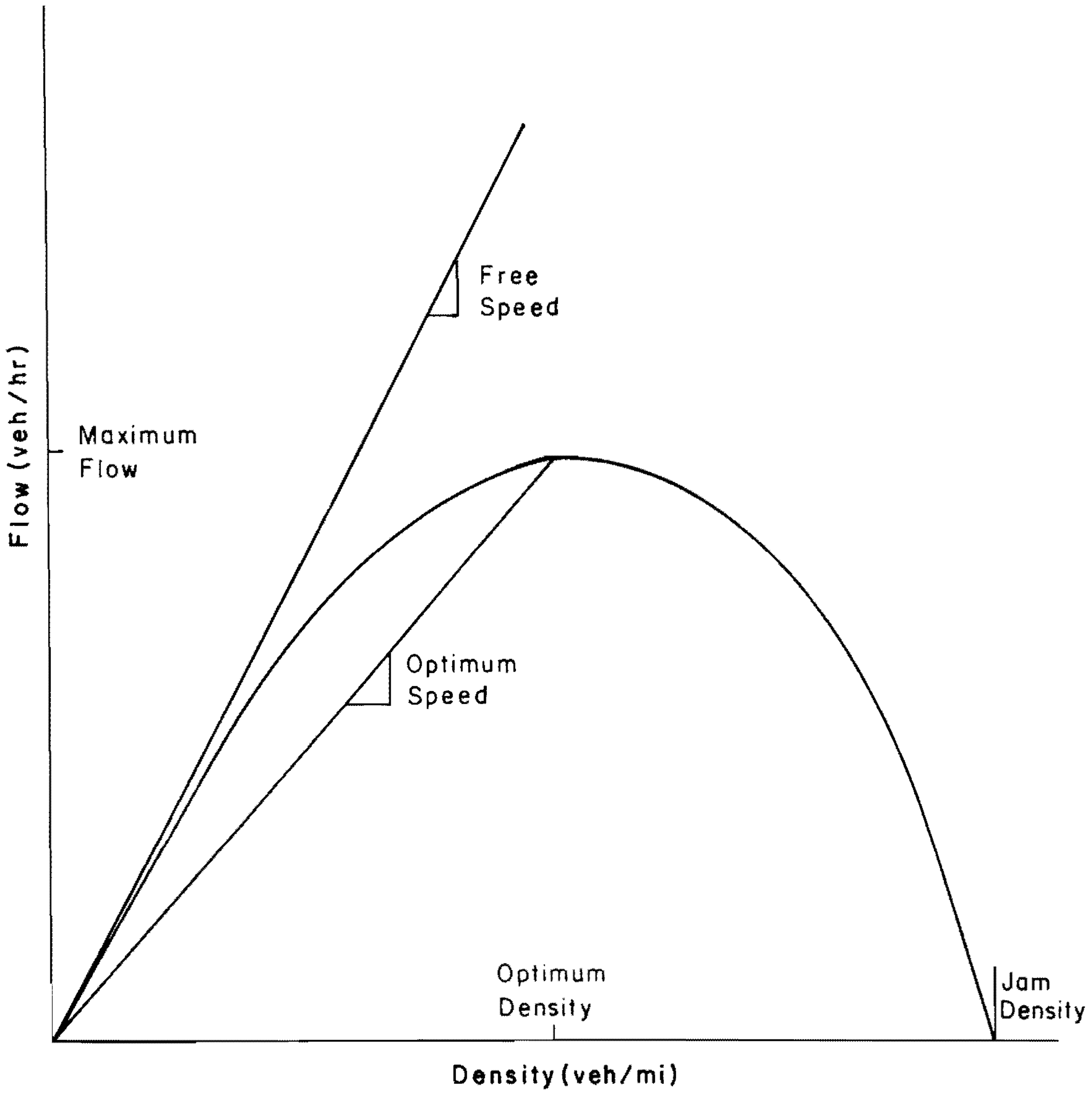
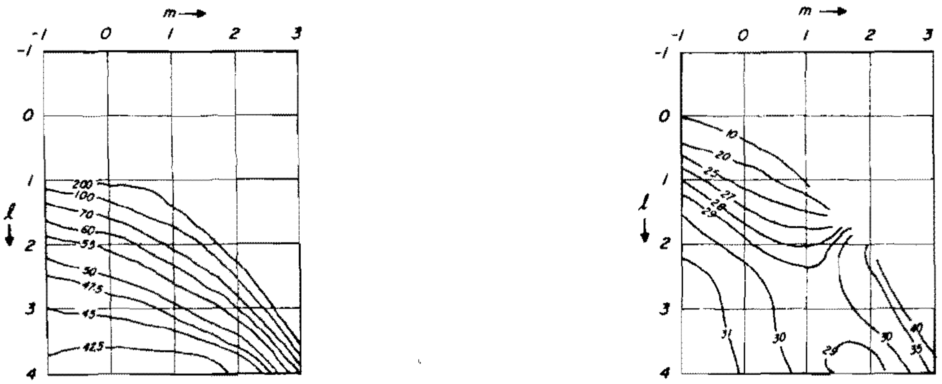
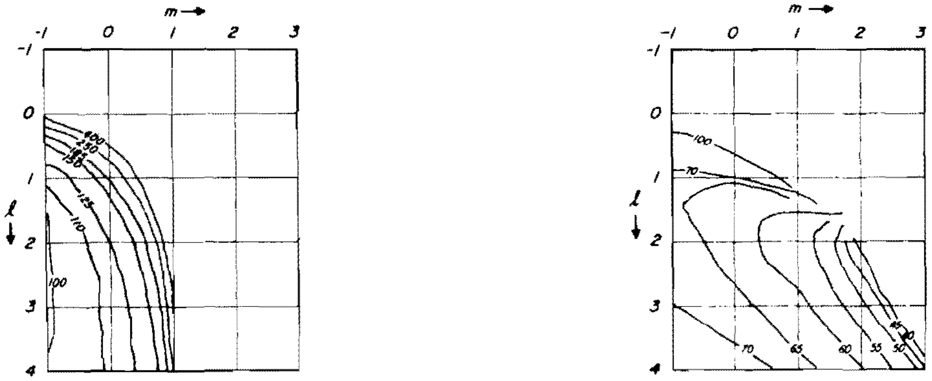


Fig 5.11. Generalized flow versus density curve.



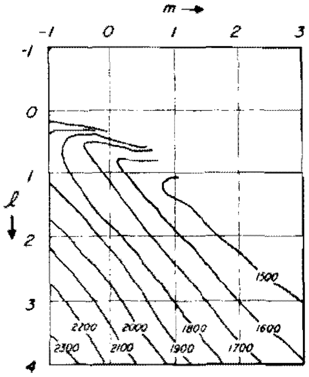
Free speed

Optimum speed



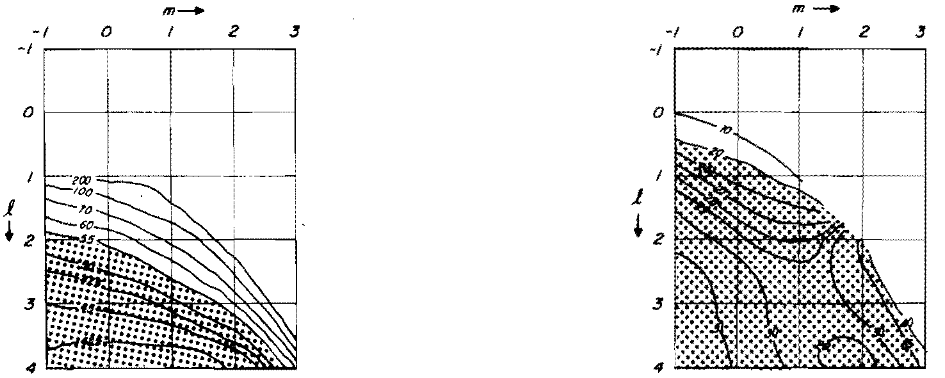
Jam density

Optimum density



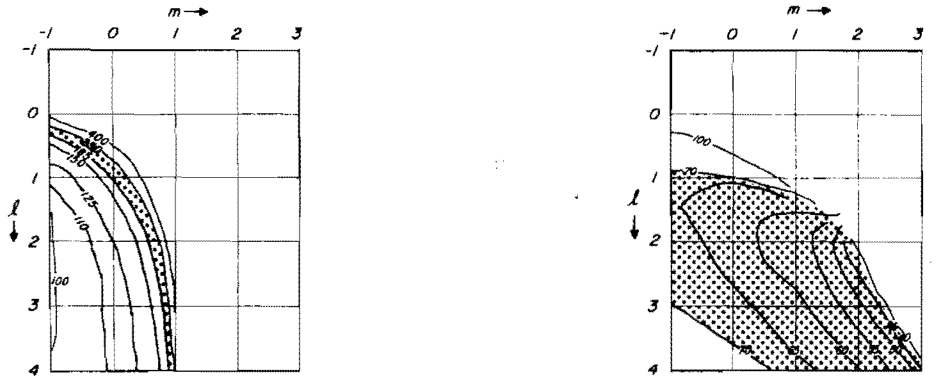
Maximum flow

Fig 5.12. Variation of free speed, optimum speed, jam density, optimum density, and maximum flow for values of lambda and mu.



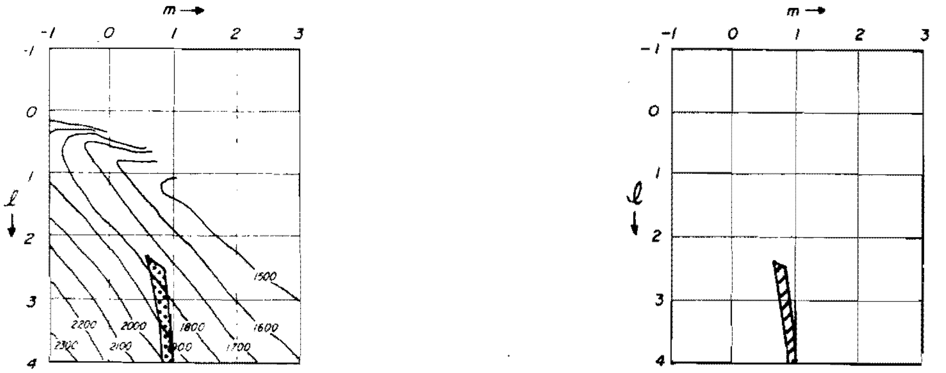
free speed

optimum speed



jam density

optimum density



maximum flow

combinations of limits

Fig 5.13. Acceptable limits for free speed, optimum speed, jam density, and optimum density for determining values of lambda and mu.

ensure that there was a smooth transition from car-following mode to and from acceleration or deceleration, that a faster vehicle overtaking a slower vehicle slowed and trailed the lead driver-vehicle unit at a reasonable distance, and that driver-vehicle units which changed lanes transitioned into the new lane smoothly.

5.3.7 Log-in Velocity

Traffic simulation would be simplified if each driver-vehicle unit could enter the traffic simulation system while traveling at its desired speed. This is not always practicable, however, as short headways and previously developed queues of vehicles sometimes make entry at desired speed impossible.

One solution to this problem is to determine the maximum velocity at which a driver-vehicle unit can enter the traffic simulation system without exceeding its desired speed and without causing future collisions. This analysis, which is used in LOGIN, can be considered in three cases. First, if the driver-vehicle unit is the first in the lane, it may enter the traffic simulation system at its desired speed.

In the second case, the lead driver-vehicle unit is either accelerating or traveling at a steady speed. If the desired speed is less than or equal to the current velocity of the leading unit, the entering unit may enter the traffic simulation system at its desired speed. For this case in SIMPRO, if there is not at least one car-following distance, as defined by Eq 5.24, available at the entry point on the lane, the driver-vehicle unit enters the traffic simulation system at the current velocity of the lead driver-vehicle unit. For all other situations under this case, SIMPRO computes an entry speed (not greater than desired speed) such that the entering unit can reduce its velocity to the current velocity of the lead driver-vehicle unit by the time the two units are one car-following distance apart. This is done without exceeding a maximum deceleration slope or a maximum deceleration value. Referring to Eq 5.14 through Eq 5.16, S will be equal to CRISLP; DI will be equal to zero; DF will be defined by Eq 5.14; VI is the unknown variable; VF equals the current velocity of the lead unit, PVVEL; XF is equal to the available distance at the start of the lane, DIST, plus the velocity of the lead driver-vehicle unit times time, T, in seconds; and XI is equal to zero. By solving Eq 5.14 through Eq 5.16 simultaneously, the time required to decelerate is found to be

```
          T  =  (-3.0*DIST/CRISLP)**0.333                          (5.28)
```

and the initial velocity, VI, in ft/sec will be

```
          VI  =  PVVEL  -  0.5*CRISLP*T**2                         (5.29)
```

The value for DF must be checked to ensure that it does not exceed DECMAX, where DF is defined by Eq 5.14 with DI equal to zero and T defined by Eq 5.28, and where DECMAX is defined by Eq 5.17 multiplied by a factor representing the percent of DECMAX that may be used in decelerating from VI to PVVEL. This factor is

```
          FACT  =  (VI**2-PVVEL**2)/VI**2                          (5.30)
```

If DF exceeds DECMAX, then a smaller value of VI must be used. Again, solving Eq 5.14 through Eq 5.16 simultaneously using the same definition as before except that DF will be DECMAX as defined by Eq 5.17 multiplied by Eq 5.30, yields a value of VI based upon PVVEL, DECMAX, and DIST that is

```
          VI  =  PVVEL  +  SQRT(-0.75*DIST*DECMAX)                 (5.31)
```

The time, T, in seconds required to decelerate is

```
          T  =  -2.0*(VI-PVVEL)/DECMAX                             (5.32)
```

where VI is defined by Eq 5.31 and DECMAX is defined by Eq 5.17 multiplied by the factor that is defined by Eq 5.30. The deceleration slope, SLOPE, in ft/sec/sec/sec would then be

```
          SLOPE  =  DECMAX/T                                       (5.33)
```

where DECMAX is defined by Eq 5.17 multiplied by the factor that is defined by

Eq 5.30 and T is defined by Eq 5.32. If this value of deceleration slope exceeds the critical deceleration slope for the driver-vehicle unit, a smaller value of VI must be used. Since DECMAX is a function of VI, several iterations may be required before an acceptable value of VI is found.

The third case occurs when the lead driver-vehicle unit is decelerating. Referring to Eq 5.14 through Eq 5.16 for the lead driver-vehicle unit, S is the maximum critical deceleration slope, SLPMAX; DI is some defined value; DF is defined by Eq 5.14; VI is the current velocity of the lead driver-vehicle unit, PVVEL; VF is zero; XI is the distance from the start of the lane to the rear bumper of the lead driver-vehicle unit, DIST; and XF is defined by Eq 5.15 as XSTOP. By solving Eq 5.14 through Eq 5.16 simultaneously, the time, TSTOP, in seconds for the lead driver-vehicle unit to stop is found to be

$$\texttt{TSTOP = (-DI-SQRT(DI**2-2.0*SLPMAX*PVVEL))/SLPMAX} \qquad (5.34)$$

and the distance, XSTOP, in feet from the beginning of the lane to the rear bumper of the lead driver-vehicle unit when it is stopped is

$$\texttt{XSTOP = DIST + PVVEL*TSTOP + DI*TSTOP/2 + SLPMAX*TSTOP**3/6} \qquad (5.35)$$

In determining a maximum entry velocity, VI, such that the driver-vehicle unit may decelerate to a stop in XSTOP distance without exceeding a critical deceleration slope nor a maximum value of deceleration, the variables needed for Eq 5.14 through Eq 5.16 are: S is equal to the critical deceleration slope for the driver-vehicle unit, CRISLP; DI is equal to zero; DF is as defined by Eq 5.14; VI is the unknown variable; VF is zero; XI is zero; and XF is equal to XSTOP. Solving Eq 5.14 through Eq 5.16 simultaneously, the time, T, in seconds required for the driver-vehicle unit to decelerate to a stop is found to be

$$\texttt{T = (-3.0*XSTOP/CRISLP)**0.333} \qquad (5.36)$$

and the initial velocity, VI, in ft/sec is

$$\texttt{VI = -0.5*CRISLP*T**2} \qquad (5.37)$$

The value for DF must be checked to ensure that it does not exceed DECMAX, where DF is defined by Eq 5.14 with DI equal to zero and T defined by Eq 5.35; and where DECMAX is defined by Eq 5.17. If DF exceeds DECMAX, then a smaller value of VI must be used. Again solving Eq 5.14 through Eq 5.16 simultaneously using the same definition as before, the value of VI based upon XSTOP as defined by Eq 5.35 and DECMAX as defined by Eq 5.17, is found to be

$$\mathrm{VI} = \mathrm{SQRT}(-0.75*\mathrm{XSTOP}*\mathrm{DECMAX}) \tag{5.38}$$

The time, T, in seconds to decelerate to the stop is

$$\mathrm{T} = -2.0*\mathrm{VI}/\mathrm{DECMAX} \tag{5.39}$$

and the deceleration slope, SLOPE, in ft/sec/sec/sec is

$$\mathrm{SLOPE} = \mathrm{DECMAX}/\mathrm{T} \tag{5.40}$$

If this value of deceleration slope exceeds the critical deceleration slope for the driver-vehicle unit, then a smaller value of VI must be used. Since DECMAX is a function of VI, several iterations may be required before an acceptable value of VI is found.

If the acceleration/deceleration slope determined by subprogram CARFOL is less than 80 percent of the maximum deceleration slope for the driver, then the log-in velocity is reset to 95 percent of its current value and subprogram CARFOL is executed again. This procedure ensures that the new driver-vehicle unit should be able to decelerate to a safe car-following condition without causing a collision shortly after entry into the system.

If the position of the rear bumper of the last driver-vehicle unit in the lane is less than the starting position of the inbound lane, then the driver-vehicle unit is eliminated from the traffic simulation and a message is printed. After an entry velocity has been found and the driver-vehicle unit has been updated for the portion of the time increment to be used, checks are made to determine whether the driver-vehicle unit has a collision with the last driver-vehicle unit in the lane or whether the driver-vehicle unit stopped. If either occurred, the driver-vehicle unit is eliminated from the traffic simulation and a message is printed.

5.3.8 Changing Intersection Path Desired Speed

When transferring from one link to another within SIMPRO, the desired speed of each driver-vehicle unit is adjusted to maintain the same percentage of the speed limit for the next link by using the following formula

ISPD = ISPD*SLIMN/SLIMO (5.41)

where ISPD is the desired speed in ft/sec of the driver-vehicle unit, SLIMN is the speed limit in ft/sec for the new link, and SLIMO is the speed limit in ft/sec for the old link. The problem then is to determine when (or where) the driver-vehicle unit is to change its desired speed on a link to the desired speed for the next link so that the unit can reduce its speed to the new desired speed by the end of the current link. The desired speed on an outbound approach is always greater than or equal to the desired speed on an intersection path, and thus, the determination of when to change the desired speed of the driver-vehicle unit is performed only for units on an inbound approach by subprogram CHKDSP. Referring to Eq 5.14 through Eq 5.16, S is an acceptable value of deceleration slope, CRISLP; DI has some defined value; DF is defined by Eq 5.14; VI has some defined value; VF is the desired speed of the driver-vehicle unit for its intersection path, as defined by Eq 5.41; XI is zero; and XF is the unknown critical distance to the end of the inbound lane, XCRIT. By solving Eq 5.15 for the time, T, needed to reduce speed on the inbound approach to the desired speed for the intersection path, the relevant equation is found to be

T = (-DI-SQRT(DI**2-2.0*CRISLP*(VI-ISPD)))/CRISLP (5.42)

and the critical distance, XCRIT, is defined by Eq 5.16 using T from Eq 5.42

XCRIT = VI*T + 0.5*DI*T**2 + 0.167*CRISLP*T**3 (5.43)

When the distance to the end of the inbound lane for a driver-vehicle unit becomes less than or equal to XCRIT, the driver-vehicle unit changes desired speed using Eq 5.41 and sets a flag indicating that it has made the change. In subprogram ACCEL and CARFOL appropriate adjustments are employed to reduce the velocity of the driver-vehicle unit when its current velocity is greater than its desired speed.

5.3.9 Deceleration To Desired Speed

When the current velocity of a driver-vehicle unit is greater than its desired speed, the unit will reduce its speed to the desired speed within the available distance. This maneuver is accomplished by decelerating the driver-vehicle unit for some period of time and then reducing the deceleration of the driver-vehicle unit to zero by the time the velocity reaches the desired speed. Referring to Eq 5.14 through Eq 5.16, S has some unknown deceleration slope, SLOPED; DI has some defined value; DF is defined by Eq 5.14; VI has some defined value; VF is the desired speed, ISPD; XI is some defined value; and XF is the minimum of either the position of the lead unit's rear bumper, PVPOS, or the position of the end of the inbound lane, ENDLN. By solving Eq 5.15 and Eq 5.16 simultaneously, the time, T, in seconds to decelerate to the driver-vehicle unit's desired speed is found to be

$$\mathrm{T} = (-\mathrm{B}+\mathrm{SQRT}(\mathrm{B}^{**}2-4.0^{*}\mathrm{A}^{*}\mathrm{C}))/(2.0^{*}\mathrm{A}) \tag{5.44}$$

where A, B, and C are constants of the quadratic equation and are

$$\mathrm{A} = 0.167^{*}\mathrm{DI} \tag{5.45}$$

$$\mathrm{B} = 0.667^{*}\mathrm{VI} + 0.333^{*}\mathrm{ISPD} \tag{5.46}$$

$$\mathrm{C} = \mathrm{XI} - \mathrm{AMIN1}(\mathrm{ENDLN},\mathrm{PVPOS}) \tag{5.47}$$

and where the negative deceleration slope, SLOPED, in ft/sec/sec/sec is

$$\mathrm{SLOPED} = 2.0^{*}(\mathrm{ISPD}-\mathrm{VI}-\mathrm{DI}^{*}\mathrm{T})/\mathrm{T}^{**}2 \tag{5.48}$$

After the deceleration slope has been in effect for some time, a check must be made to determine when the deceleration should be decreased to zero by the time the driver-vehicle unit reaches its desired speed. Again, referring to Eq 5.14 and Eq 5.15, S is the unknown deceleration slope, SLOPEU; DI has some defined value; DF is zero; VI has some defined value; and VF is the desired speed for the driver-vehicle unit, ISPD. By solving Eq 5.14 and Eq 5.15 simultaneously, the required positive deceleration slope in ft/sec/sec/sec is found to be

$$\text{SLOPEU} = -0.5*\text{DI}**2/(\text{ISPD}-\text{VI}) \tag{5.49}$$

In SIMPRO, when the positive deceleration slope, SLOPEU, defined by Eq 5.49 becomes greater than 40 percent of the normal critical deceleration slope for the driver, the positive deceleration slope is initiated.

When this procedure is implemented, the deceleration slope defined by Eq 5.48 or Eq 5.49 is not used in subprogram CARFOL unless it is less than the deceleration slope determined by the car-following calculations.

5.3.10 Acceleration And Deceleration Logical Binary Network

In order to determine a unique response for each driver (accelerating to desired speed, accelerating to lead vehicle speed, following the car ahead, remaining stopped, checking whether deceleration to a stop is necessary, or continuing deceleration to a stop), a logical binary network for acceleration and deceleration was developed and used in SIMPRO (see Fig 5.14). This network contains logical independent and logical dependent attributes. The logical independent attributes provide a true or false answer to selected questions. There can be only one true branch and one false branch leading from each logical independent attribute, but there can be one or more true or false branches leading into each logical independent attribute. The logical dependent attributes define a response for the driver-vehicle unit. There can be no true or false branch leading from each logical dependent attribute while there can be one or more true or false branches leading into each logical dependent attribute.

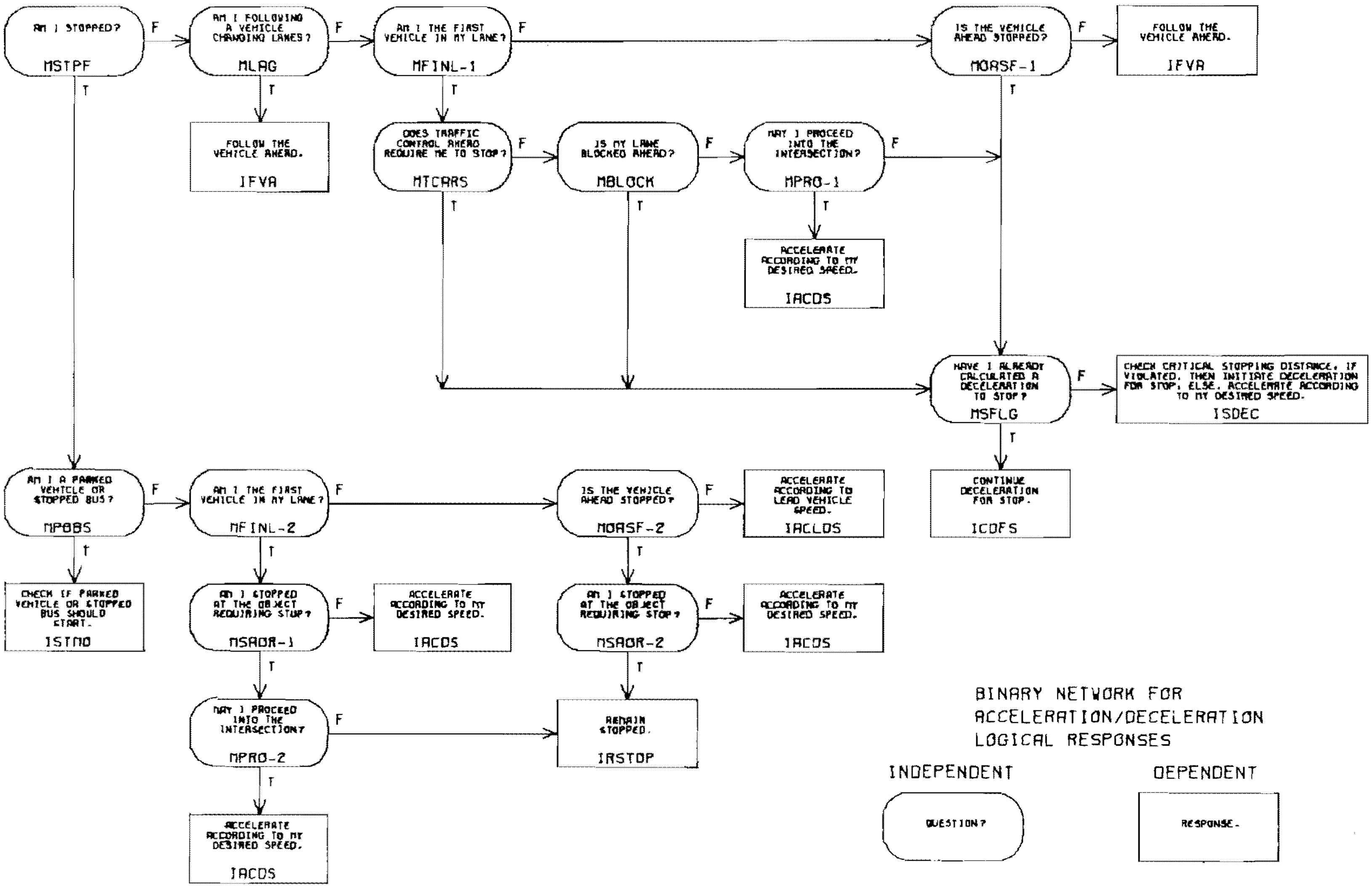


Fig 5.14. Logical binary network for acceleration and deceleration responses.

The traffic simulation processor maintains current values for all logical independent attributes in the network and executes a special logic routine generated by COLEASE to determine the appropriate value for the logical dependent attributes. A logical dependent attribute may be true, false, or both true and false if one or more of the branches leading into the logical dependent attribute is true and one or more of the branches leading into the logical dependent attribute is false. Only one logical dependent attribute may be true in the network (or true and false). The traffic simulation processor checks the logical dependent attributes to determine which is true (or true and false) and then the appropriate action is initiated. COLEASE is described in more detail in Chapter 6.

In SIMPRO, subprogram ACDCP checks the value of the acceleration/deceleration logical dependent attributes and executes the appropriate subprogram to implement the driver's response.

5.3.11 Lane Control Strategies

In SIMPRO, subprogram INFLZN determines the values for most of the intersection control logical independent attributes and is executed only once when each driver-vehicle unit comes within the influence zone of the intersection. Subprogram INTLOG checks the value of the intersection control logical dependent attributes and executes the appropriate subprogram to implement the driver's response.

5.3.11.1 Uncontrolled Lanes At An Uncontrolled Intersection

When an intersection is uncontrolled, no driver-vehicle unit has the right-of-way, and each driver-vehicle unit must check sight distance restrictions and intersection conflicts before entering the intersection. Until the driver-vehicle unit gains the right to enter the intersection, the driver assumes that he must stop his vehicle at the stop line. If the driver-vehicle unit stops at the stop line because the right to enter the intersection has not been gained, the stop controlled logic that is described in Section 5.3.11.4 is followed. If sight restrictions and intersection conflicts are cleared without its stopping, the unit simply accelerates as necessary to reach the desired speed.

5.3.11.2 Uncontrolled Lanes At A Controlled Intersection

When the intersection is controlled by yield signs or two-way stop signs, driver-vehicle units on uncontrolled lanes are assumed to have the right-of-way in SIMPRO. If the driver-vehicle unit on an uncontrolled lane is going to turn left or change lanes in the intersection, the unit must check for sight distance restrictions and also check intersection path conflicts. Upon finding no reason to stop, the driver-vehicle unit gains the right-of-way to enter the intersection and sets a flag on all other intersection paths with which the path of the unit conflicts geometrically to indicate that the driver-vehicle unit has been given authorization to enter the intersection.

5.3.11.3 Yield Sign Controlled Lanes

Driver-vehicle units on lanes controlled by yield signs must yield the right-of-way to other units on conflicting paths. Until a driver-vehicle unit has gained the right to enter the intersection, the driver assumes that he must stop at the stop line. In determining whether the unit may enter the intersection, SIMPRO uses the same logic as for the stop sign controlled lanes (see Section 5.3.11.4). The difference is that for yield sign controlled situations, the logic which determines the right to enter the intersection is executed while the driver-vehicle unit is still traveling on the inbound lane; whereas, the right-of-way logic for driver-vehicle units which are on lanes controlled by stop signs is not executed until after the unit has stopped at the stop line. On a yield sign controlled lane, a check for the right to enter the intersection is made only if the driver-vehicle unit under consideration is the first vehicle in the lane or is following another unit which has been cleared to enter the intersection. It is quite possible at low volumes that a driver-vehicle unit will never need to begin decelerating to a stop.

5.3.11.4 Stop Sign Controlled Lanes

The stop sign control logic forms the basis for simulating all sign controlled and uncontrolled intersections. Timing for the right-of-way to enter the intersection from an inbound lane is determined by this logic.

When a driver-vehicle unit first stops at the stop line, the unit is eligible for addition to the list of units already stopped at the intersection (processed by ADLVAI). If SIMPRO determines that any unit in the list of units has stopped at the stop line of the inbound approach to the immediate left of the approach under examination within the perception-reaction time of the newly stopped driver-vehicle unit, this is considered to be a simultaneous arrival and time precedence for the right-of-way is assigned to the new driver-vehicle unit by entering it into the list of stopped vehicles ahead of the stopped vehicle to the left. If no simultaneous arrival is detected, the new driver-vehicle unit is added to the end of the list of driver-vehicle units that are stopped at the intersection. This procedure maintains a list of driver-vehicle units which are arranged according to time of arrival, are stopped at the stop line, and are ready to enter the intersection. When a driver-vehicle unit enters the intersection, it is removed from the list.

In SIMPRO, subprogram LSTOP determines when a driver-vehicle unit gains the right to enter the intersection. This involves three steps. First, the following conditions are evaluated: (1) the list of vehicles stopped at the intersection is empty, (2) there are no geometric conflicts with the path of the unit being examined, and (3) after each vehicle on the list of vehicles waiting at a stop line is examined, the unit takes time precedence over other units which stopped earlier than the unit under examination (such precedence is warranted when (a) the other stopped unit is not on an uncontrolled lane at a controlled intersection, and when (b) the other unit is being delayed by a previously detected intersection conflict or there is no geometric conflict with the path of the other vehicle). If any of these conditions exists, the second step is to check and clear all sight restrictions. The final step is to clear intersection conflicts. Before actually entering the intersection, the unit experiences a delay which results from the hesitancy of the driver to enter the intersection. These steps are repeated in each succeeding time increment until the right to enter the intersection has been gained.

5.3.11.5 Signal Controlled Lanes

The control strategy for signal controlled lanes involves (1) recording detector actuations, (2) determining whether a left-turn-on-red or a right-turn-on-red is permissible, (3) defining the driver response to the signal indications, (4) setting the driver response for a green indication, (5) setting the driver response for an amber indication, (6) setting the driver response for a red indication, (7) setting the driver response for a green protected indication, and (8) setting and unsetting intersection conflicts.

5.3.11.5.1 Detector Actuation

During every time increment, each driver-vehicle unit on an inbound lane checks to determine whether its current position has actuated a detector in its lane. The start and end position for the detector and whether the detector is a PRESENCE or a PULSE type is defined by input to SIMPRO. For both detector types, the following conditions are checked: (1) has the front bumper crossed the start of the detector, (2) has the rear bumper crossed the start of the detector, (3) is the front bumper between the start and end position of the detector, and (4) is the rear bumper between the start and end position of the detector? If the detector is a presence type, a check is made to see whether the vehicle is straddling the detector. If any of these conditions is satisfied, the detector is set in the actuated state.

5.3.11.5.2 Left-Turn-On-Red And Right-Turn-On-Red

When a driver-vehicle unit first stops at the stop line, a check is performed to determine whether the unit may make a left-turn-on-red or a right-turn-on-red. If the lane control (see Section 5.2.2) permits the left-turn-on-red maneuver and the vehicle will turn left, an intersection control logical independent attribute is set, which allows the vehicle to attempt the maneuver. If the lane control permits the right-turn-on-red maneuver and the vehicle will turn right, the intersection control logical independent attribute is set, which allows the vehicle to attempt the maneuver. After the vehicle has cleared its intersection conflicts, it may enter the intersection.

5.3.11.5.3 Driver Response To Signal Indications

Section 5.2.3 describes the user-supplied input of signal indication information for each inbound lane, and Table 5.2 provides a list of the 25 unique signal indications which are available in SIMPRO. Subprogram IBAP determines when it is necessary to compute a driver response to a new signal indication. Each time a different signal indication is displayed to a lane, IBAP executes subprogram SIGRES for each driver-vehicle unit in the lane that is dedicated to an intersection path, as described in Section 5.3.18.

Subprogram SIGRES determines one of the following driver responses to the signal indication: (1) go on green and check for intersection conflicts, (2) go on amber and do not check for intersection conflicts, (3) stop on amber, (4) stop on red, and (5) go on green and do not check for intersection conflicts. Four major signal indications are provided in SIGRES: (1) green, (2) amber, (3) red, and (4) green protected. The turning movement type for the driver-vehicle unit being examined is compared with the primary turn code (the first character of the three-character code) for the signal indication. If they are equal, the driver responds to the signal indication for the primary turn code (the second character of the three-character code); otherwise, he responds to the signal indication for the other turn codes (the third character of the three-character code).

As a general example, consider a driver approaching on a lane displaying a circular green signal indication. The three-character code for this situation has been specified by the user as "AG " (all green). Every driver-vehicle unit will respond to the all-green indication as described in Section 5.3.11.5.4 below. As another example, assume that the signal indication is "LGR" (left turn green and all others red). Any vehicles that are turning left will respond to the green indication while all other vehicles will stop in response to the red indication.

5.3.11.5.4 Driver Response To A Green Indication

In determining driver response to a green indication, SIMPRO sets the intersection control logical independent attributes that are associated with the driver-vehicle unit to indicate that the unit desires to go. Straight-through and right-turning units that will not change lanes in the intersection assume that their movement is protected and they therefore have the right to enter the intersection; otherwise, they must check intersection conflicts before entering. If the unit is the first stopped vehicle in the queue, it is delayed by SIGRES for one perception-reaction time for the driver before it actually enters the intersection; other units respond to the green indication without such a delay being assigned by SIGRES.

5.3.11.5.5 Driver Response To An Amber Indication

For the amber indication, the driver must decide whether to stop or go on amber. Special cases which are considered in SIGRES are: (1) if the preceding driver-vehicle unit on the inbound lane has decided to stop on amber, the vehicle being examined will also stop on amber, (2) if the unit is currently decelerating to a stop, it will stop on amber, and (3) if a unit is the first in its lane, stopped at the stop line, and required to check intersection conflicts, it will go on amber and enter the intersection after it has cleared applicable intersection conflicts. The last special case possibly allows one unit to enter the intersection during the amber signal interval.

In the usual case, SIGRES calculates the critical stopping distance using Eq 5.19 or Eq 5.20, where DECMAX is defined by an equation which is similar in form to Eq 5.17 but defines constants that allow for harder braking. If the distance to the end of the lane is less than the critical stopping distance thus calculated, the driver-vehicle unit will go on amber; otherwise, it will stop on amber.

To implement the go-on-amber decision, the intersection control logical independent attributes for the unit under examination are set to indicate the go-on-amber decision. The driver does not have to check further for intersection conflicts.

To implement the stop-on-amber decision, the intersection control logical independent attributes are set for the driver-vehicle unit to indicate the stop on amber decision and the acceleration/deceleration logical dependent attributes are automatically set to make the vehicle check for a required deceleration to a stop or follow the car ahead.

5.3.11.5.6 Driver Response To A Red Indication

SIGRES sets the intersection control logical independent attributes for the driver-vehicle units to indicate a stop on red decision. The red indication must be preceded by an amber indication.

5.3.11.5.7 Driver Response To A Green Protected Indication

This response is similar to that for an unprotected green indication except for the fact that intersection conflicts are not checked for any vehicle on the inbound lane. If the unit is the first stopped vehicle in the queue, it is delayed by SIGRES for one perception-reaction time for the driver before it actually enters the intersection; other units respond to the green indication without such a delay being assigned by SIGRES.

5.3.11.5.8 Setting And Unsetting Intersection Conflicts

If the driver-vehicle unit may enter the intersection, then each intersection path that conflicts geometrically with the intersection path for the driver-vehicle unit is flagged to indicate that the driver-vehicle unit has been assigned the right-of-way to enter the intersection. This procedure is referred to as setting conflicts. Other driver-vehicle units which are seeking the right-of-way must yield to the unit which has been assigned the right-of-way.

If the driver-vehicle unit may not enter the intersection, then each intersection path that conflicts geometrically with the vehicle's intersection path is flagged to indicate that a driver-vehicle unit no longer has the right-of-way to enter the intersection. This procedure is referred to as unsetting conflicts.

5.3.12 Intersection Control Logical Binary Network

To determine a unique response for each simulated driver (check to see if the driver-vehicle unit should choose an intersection path, check to see if the driver vehicle unit should be in the influence zone of the intersection, follow the uncontrolled logic, follow the yield control logic, follow the stop control logic, continue present actions, and check intersection conflicts), a logical binary network for intersection control has been developed for use in SIMPRO (see Fig 5.15). This network contains logical independent and logical dependent attributes. The logical independent attributes are questions to which there is a true or a false answer. While there can be one or more true or false branches leading into each logical independent attribute, there can be only one true branch and one false branch leading from each logical independent attribute. The logical dependent attributes define a response for the driver-vehicle unit, and, while there can be one or more true or false branches leading into each logical dependent attribute, no true or false branch can lead from a logical dependent attribute.

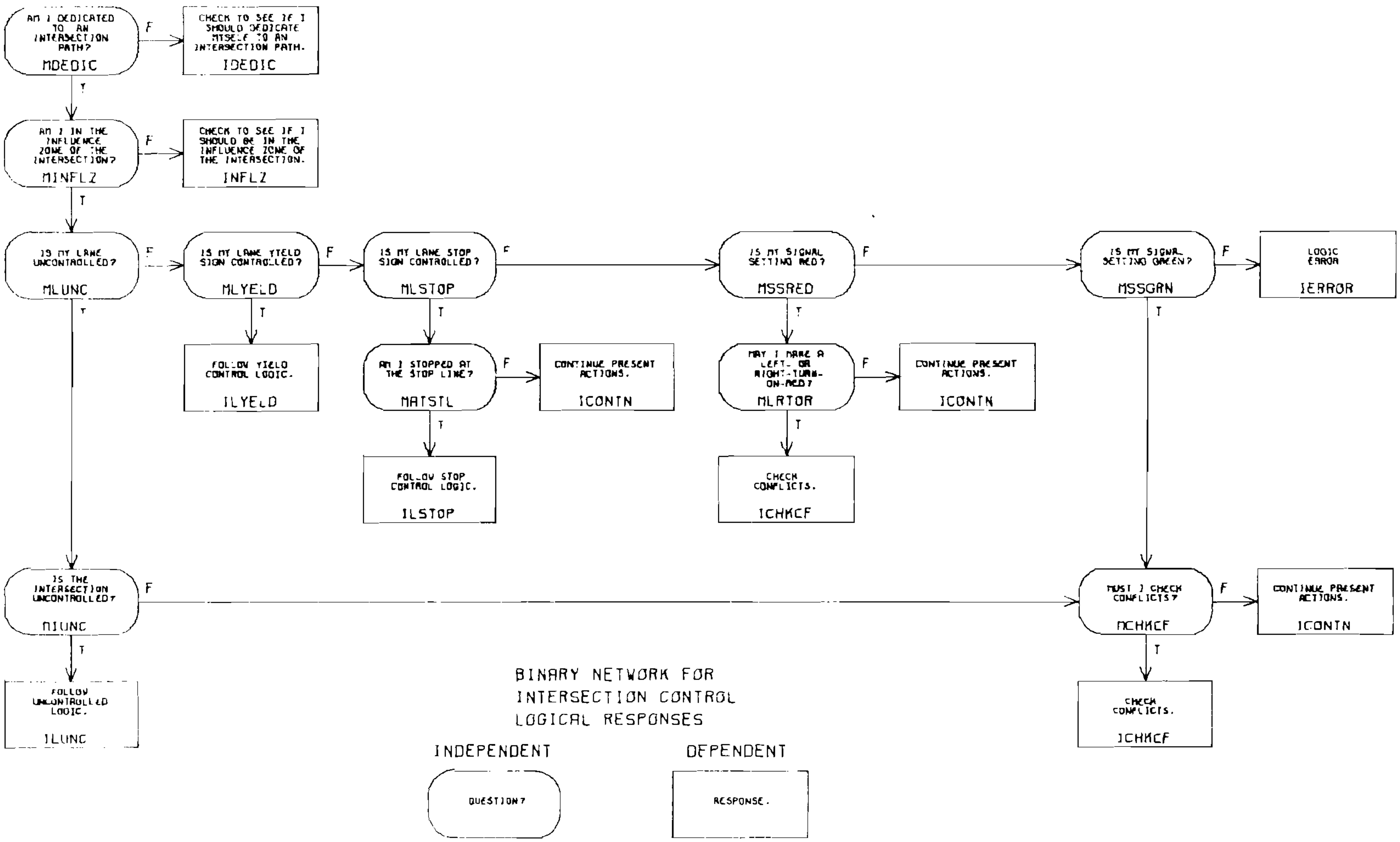


Fig 5.15. Logical binary network for intersection entry control.

The traffic simulation processor maintains current values for all logical independent attributes in the network and executes a special logic routine generated by COLEASE to determine the appropriate value for the logical dependent attributes. A logical dependent attribute may be true, false, or both true and false if one or more of the branches leading into the logical dependent attribute is true and one or more of the branches leading into the logical dependent attribute is false. Only one logical dependent attribute may be true in the network (or true and false). The traffic simulation processor checks the logical dependent attributes to determine which is true (or true and false) and then the appropriate action is then initiated. COLEASE is described in more detail in Chapter 6.

5.3.13 Simulation Of A Pre-timed Signal Controller

Before simulating a pre-timed signal controller, the phase number, the phase sequence, the duration of each signal interval, and the signal indications for each inbound lane for each signal interval must be defined by input information. At the start of the simulation process, SIMPRO begins in the first signal interval (analogous to cam stack position 1 in a conventional controller) and sets the time into the signal phase, TP, equal to zero and the time remaining in the signal interval, TR, equal to the duration of the first signal interval.

Subprogram PRESIG simulates pre-timed signal controllers and determines the order in which signal intervals are to be displayed. At the end of each simulation time increment, the time into the signal phase, TP, is incremented by one time increment, the time remaining in the signal interval, TR, is decremented by one time increment, and the previous signal interval (cam stack position) is set to the current signal interval. As long as the time remaining in the signal interval, TR, is greater than zero, the signal remains in the same interval. When the time remaining in the signal interval becomes less than or equal to zero, the current signal interval (cam stack position), ICAMPC, is incremented by one (if it is then greater than the number of intervals in the signal cycle, it is set equal to one), the current signal phase, ICPHAS, is set to the signal phase for the new signal interval, the time into the signal phase, TP, is set equal to zero, and the time remaining is the signal interval, TR, is set equal to the duration of the new signal interval (cam stack position).

5.3.14 Simulation Of An Actuated Signal Controller

For simulating semi-actuated and full-actuated signal controllers, the user must define (1) the phase number, (2) the permissible phase sequence, (3) the signal indications which will be displayed to each inbound lane during each signal interval, (4) the signal timing information, and (5) the detector information. In SIMPRO, the signal timing information needed for simulating full-actuated phases is the same as that needed for simulating minor street phases under semi-actuated control. Table 5.3 summarizes the information for actuated phases and demonstrates the equivalent settings for the main street phase for a semi-actuated controller. SIMPRO processes all phases of either a semi-actuated or a full-actuated controller in exactly the same way. Certain values of intervals and options related to the main street phase are supplied internally by the program for a semi-actuated controller, and minimum assured green is converted to the initial interval plus the vehicle interval.

At the start of the actuated signal simulation, SIMPRO begins in the first signal phase declared. The simulated cam stack is positioned at the starting cam stack position for the signal phase; the time into the signal phase, TP, is set equal to zero; and the time remaining in the signal interval, TR, is set equal to the initial interval, TII, plus the vehicle interval, TVI, for the signal phase.

Subprogram ACTSIG simulates all types of actuated signal controllers and determines which signal interval should be displayed. At the end of each simulation time increment, the time into the signal phase, TP, is incremented by one time increment; the time remaining in the signal interval, TR, is decremented by one time increment; and the old cam stack position is set to the current cam stack position. The signal simulation is then considered in three time intervals: (1) the green interval for the signal phase, (2) the amber clearance interval for the signal phase, and (3) the all-red clearance interval for the signal phase. The simulation starts in the green interval.

Table 5.3 Signal Controller Simulator Settings

INTERVAL OR OPTION	SYMBOL	ACTUATED PHASE	SEMI-ACTUATED MAIN STREET PHASE
Initial interval --------------	TII	seconds	minimum assured green
Vehicle interval --------------	TVI	seconds	0
Amber clearance interval ------	TCI	seconds	seconds
All-red clearance interval ----	TAR	seconds	seconds
Maximum extension after demand on red ----------------------	TMX	seconds	0
Skip phase switch -------------	ISKP	ON/OFF	OFF
Auto-recall switch ------------	IREC	ON/OFF	ON
Parent/minor movement option --	IMINOR	YES/NO	NO
Dual left option --------------	IDUALL	YES/NO	NO
Type of detector connection ---	IANDOR	AND/OR	N.A.
Number of detectors connected to phase --------------------	NLD	n	0
List of detectors connected to phase --------------------	LLD	list	N.A.
Number of phases which can be cleared to directly ------	NPHNXT	n	n
List of phases which can be cleared to directly ---------	LPHNXT	list	list

During the green interval, the signal may max-out, gap-out, or continue in the current phase. ACTSIG first determines whether there is a demand for continuation of the current green phase (denoted as IDOG) by examining all positively connected detectors that are associated with the green phase. Next, demand on red (denoted as IDOR) is examined. Once any demand on red is detected, further checking for IDOR is unnecessary. For example, if demand for another signal phase has been previously indicated or if the parent/minor phase option is YES, demand on red is present. ACTSIG moves directly to the next step in the program. If the current signal phase is for dual left turns, the two following phases which permit single left turns along with through and right turn movements are not checked for demand on red.

If there is demand on green, IDOG, and the time into the signal phase, TP, is greater than or equal to the initial interval, TII, the time remaining in the signal interval, TR, is set equal to the vehicle interval, TVI. Thus, the minimum duration of the actuated phase will be the initial interval plus one vehicle interval. When there is a demand on red, IDOR, and the timer for end of max, EOM, has not been previously set, then the time for EOM is set equal to the maximum of either the time into the signal phase, TP, plus the maximum extension after demand on red, TMX, or the initial interval, TII, plus the vehicle interval, TVI. If there has not yet been a demand on red, IDOR, (the time for end of max EOM has not been set) and the time remaining in the signal interval, TR, is less than or equal to zero, the signal phase gaps-out. If the time into the signal phase, TP, is greater than the time for end of max EOM, the signal maxes-out. If the signal has not gapped-out or maxed-out, the signal remains in the current phase. In order to be able to detect actuations during the coming simulation time increment, all detectors which are connected positively to the current signal phase are reset.

When the signal gaps-out of the current signal phase, the finder for the next signal phase begins searching through the list of phases to which the current phase may clear, LPHNXT, to find the first phase in the list with a demand. If the current signal phase is any phase other than a dual left, (1) the next signal phase with demand is found, (2) the detectors which are connected positively to the signal phase are set as not being tripped, and (3) end of max is set to the not set condition.

If the current signal phase is a dual left phase, a series of checks is performed in order to determine whether there is a need to continue either of the left turn movements. Minimum assured green (TVI plus TII) for both single left turn phases that may follow must have been satisfied, but it is possible that both of these will have been provided during the dual left phase. Remaining demand for either single left turn phase must also be satisfied by the phase with the larger value for minimum assured green. Based on these checks, ACTSIG selects the appropriate succeeding phase.

Summary statistics regarding the number of gap-outs and the average time into the signal phase when the gap-outs occurred are updated if time into the simulation is greater than the start-up time specified by the user.

When the signal maxes-out of the current signal phase, the finder for the next signal phase begins searching through the list of signal phases to which the current phase can clear, LPHNXT, to find the first phase in the list with a demand. If the current signal phase is not a dual left, the next signal phase is found.

If the current signal phase is a dual left, ACTSIG checks to determine whether a need exists for continuing either left turn movement. The maximum extension after a demand on red must be satisfied for both single left turn phases that may follow. If these maximums have been provided by the dual left phase, neither of the single left turn phases will be entered; otherwise, the single left turn phase with the longer maximum extension after demand on red,TMX, will be entered.

During the traffic simulation time after start-up time, summary statistics are accumulated to define the number of max-outs and the average time into the phase when the max-outs occurred. If the current phase is not a dual left phase and a gap-out or max-out in a dual left phase has not mandated that one of the left turn movements continue, ACTSIG searches through the list of signal phases to which it is possible to clear, in the specified order, to find a phase with demand. Both positively and negatively connected detectors are used in determining demand for a phase. A check is also made to ensure that non-skippable phases are entered in the specified order. After demand has been satisfied on a minor movement phase, control will normally return to the parent phase with which the minor movement is associated when no demand is present for any phase on the list to which the minor movement phase may clear.

After the next signal phase has been found, ACTSIG resets several variables in preparation for entering the amber clearance interval. The time for end of max, EOM, is changed to a not set condition unless the next phase is a single left turn continuation of a dual left phase. Time remaining in the signal interval, TR, is then set to the amber clearance interval, TCI, associated with the current signal phase, the appropriate amber indications to clear to the next signal phase are selected, and ACTSIG begins processing the amber clearance interval.

For each simulation time increment during the amber clearance interval, time into the phase, TP, is incremented by one time increment, the time remaining in the signal interval, TR, is decremented by one time increment, and the old cam stack position is set to the current cam stack position. When the time remaining in the signal interval, TR, becomes less than or equal to zero, the time remaining in the signal interval, TR, is set to the all-red clearance interval, TAR, (may equal zero) for the current signal phase, the cam stack is rotated to the all-red indications, and the signal simulator is set for being in the all-red clearance interval. ACTSIG then proceeds to process the all-red clearance interval.

During the all-red clearance interval, the time into the signal phase, TP, is incremented by one time increment, the time remaining in the signal interval, TR, is decremented by one time increment, and the old cam stack position is set to the current cam stack position. When the time remaining in the signal interval, TR, becomes less than or equal to zero, the current signal phase is set to the next signal phase, the cam stack is rotated to the starting cam stack position for the new signal phase, ACTSIG is set as being in the succeeding green interval, and the demand on red, IDOR, is set to false. In the normal situation, the end of max, EOM, will have been reset to not set; therefore, the time into the signal phase, TP, is set equal to zero and the time remaining in the signal interval, TR, is set to the initial interval for the new signal phase, TII, plus the vehicle interval for the new signal phase, TVI.

When proceeding from an all-red clearance interval following a dual left phase to a continuing green indication for a single left turn phase, the time for end of max, EOM, is reset to reflect the change in the value for maximum extension after demand on red, TMX, that is associated with the new single left turn. If the minimum assured green has been satisfied, the green interval is checked immediately to see whether the new signal phase has gapped-out or maxed-out during the amber or all-red clearance interval of the dual left phase. If the minimum assured green has not been satisfied, the time remaining in the signal interval, TR, is set to the initial interval, TII, for the new signal phase plus the vehicle interval, TVI, for the new signal phase minus the time into the current signal phase, TP. Again, the green interval is checked immediately to see whether the new signal phase has gapped-out or maxed-out during the amber or all-red clearance interval of the dual left phase.

This actuated signal controller simulator, ACTSIG, can accommodate all but volume-density controllers, mini-computer controllers, and some non-standard actuated controllers.

5.3.15 Sight Distance Restrictions

The user defines the coordinates of all critical points needed to locate sight obstructions in the intersection area, and the geometry processor calculates the distance that is visible between pairs of inbound approaches for every 25-foot (7.62-meter) increment along each inbound approach. In SIMPRO, subprogram CHKSDR checks sight distance restrictions. Each driver-vehicle unit on an inbound approach assumes that it must stop at the stop line until it gains the right to enter the intersection. If the inbound lane is stop sign controlled or signal controlled, the assumption is made that sight distance restrictions are not critical and, therefore, do not need to be checked. If adequate sight distance is not available to a unit stopped at the stop line, this will not be detected in SIMPRO.

For vehicles on inbound lanes to an uncontrolled intersection, if there are units stopped at a stop line waiting to enter the intersection and the inbound driver-vehicle unit being examined is not stopped at the stop line, the approaching unit will continue to decelerate to a stop at the stop line without checking sight distance restrictions again until it is stopped at the stop line or until there are no driver-vehicle units stopped at a stop line. This procedure eliminates unnecessary computation and gives the right of way to other driver-vehicle units already stopped at the stop line when the intersection is uncontrolled. If there are no sight distance restrictions for units on an inbound approach, then intersection conflicts are checked. If (1) a driver vehicle unit is on an uncontrolled lane approaching a yield sign controlled intersection, (2) the unit is stopped at the stop line, or (3) the intersection path of the unit has no geometric intersection conflicts, it is assumed that there are no sight distance restrictions.

The maximum time from the end of the inbound lane that the driver-vehicle unit is permitted to begin checking sight distance restrictions, so that it may decide to proceed to intersection conflict checking if sight distance restrictions are clear, is initially set as three seconds for all intersections. This prohibition prevents the unit from gaining the right to enter the intersection when it is relatively far away from the intersection and thereby unnecessarily affecting the behavior of units on other inbound approaches. If the inbound lane is an uncontrolled lane approaching a yield-sign controlled intersection, the time is increased by two seconds plus the time for the lead safety zone for intersection conflict checking. This longer time allows units on the uncontrolled lanes to gain the right to enter the intersection ahead of other units on the yield sign controlled lanes. If the intersection is uncontrolled, the time is reduced to two seconds.

In SIMPRO, the time required for the driver-vehicle unit being checked to travel to the end of the lane is predicted. If this predicted time is greater than the maximum time from the end of the lane that the unit may decide to proceed to intersection conflict checking, the unit cannot clear its sight distance restrictions, but an intersection control logic timer is set to delay further sight distance restriction checking until the unit is closer to the intersection.

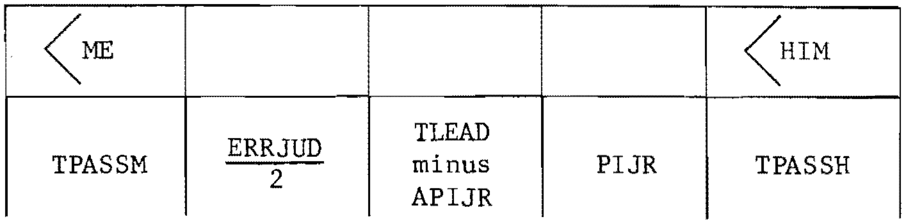
The order in which sight distance restrictions are checked by SIMPRO is determined by the sequence in which intersection conflicts might occur. The sight distance restriction associated with the longest traveling time to an intersection conflict is checked first, then other sight distance restrictions are checked in descending order of travel time to an intersection conflict. This order of checking facilitates early detection of an opportunity to pass in front of a vehicle approaching on a sight-restricted lane. Checking continues until all inbound approaches which have possible sight distance restrictions with the subject inbound approach are cleared.

To check sight distance restrictions in SIMPRO, the time required for a fictitious driver-vehicle unit, traveling at the speed limit of the approach, to travel from a position that is just visible on the inbound approach to the point of intersection conflict is predicted. Next, the time required for the driver-vehicle unit being examined to travel to the point of intersection conflict is predicted. This prediction assumes that the driver-vehicle unit under examination has gained the right to enter the intersection and that it may accelerate to its desired speed. The desired speed of the following unit will be the minimum of the desired speed of the lead unit or that of the following unit. If the unit being checked may not safely pass through the point of intersection conflict ahead of the fictitious driver-vehicle unit, then the unit may not clear its sight distance restriction (see Fig 5.16). An intersection control logic timer is set to delay further sight distance restriction checking until the unit is closer to the intersection. Otherwise, the driver-vehicle unit being checked clears the sight distance restriction with the other inbound approach and continues checking other sight distance restrictions.

This procedure ensures that a driver-vehicle unit may safely enter the intersection even if a driver-vehicle unit were to appear from behind the sight distance restriction just after the decision to enter the intersection was made.

5.3.16 Intersection Conflicts

The geometry processor calculates the points of intersection conflict between all generated intersection paths. This involves the calculation of (1) the distance along each intersection path to the intersection conflict and (2) the intersection conflict angle. In most other simulation models, either large geometric areas are considered, or acceptable gaps are located so that vehicles can travel through the intersection. In this model, the potential presence of another vehicle at a point of intersection conflict is used to determine whether an approaching vehicle can proceed safely through the intersection or not.



where:

TPASSM	is the time for ME to pass through the point of intersection conflict
ERRJUD	is the judgment error
TLEAD	is the time for the lead safety zone
APIJR	is the average PIJR time for all drivers
PIJR	is the perception-reaction time for the driver, ME
TPASSH	is the time for HIM to pass through the point of intersection conflict

Fig 5.16. Sight distance restriction checking safety zone.

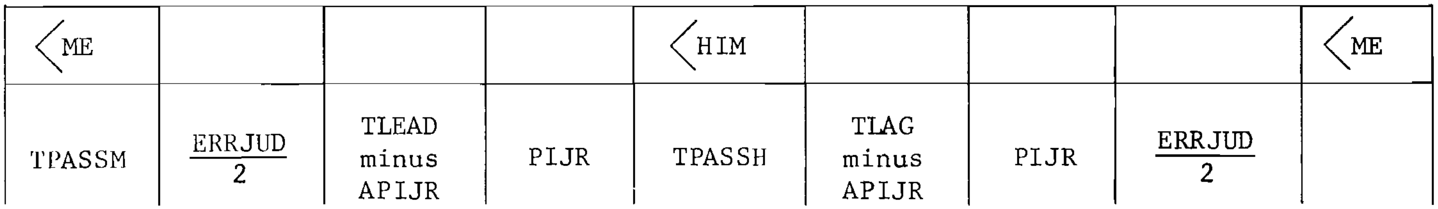
In SIMPRO, subprogram CHKCON checks critical intersection conflicts. Each driver-vehicle unit bases its decision to enter the intersection on whether or not it may safely pass through all points of intersection conflict either in front of or behind other driver-vehicle units already in the intersection or already committed to entering the intersection. Every approaching driver-vehicle unit assumes that it must stop at the stop line until it gains the right to enter the intersection.

Several special situations are evaluated by CHKCON to determine whether detailed checking of potential intersection conflicts with other vehicles is necessary. First, a driver-vehicle unit may enter the intersection if there are no geometric intersection conflicts along the intersection path of the unit. Second, the maximum time from the end of the inbound lane that the driver-vehicle unit is permitted to gain the right to enter the intersection, if intersection conflicts are clear, is initially set as three seconds for all intersections. This prohibition prevents the unit from gaining the right to enter the intersection when it is relatively far away from the intersection and will thereby possibly adversely affect the behavior of units on other inbound approaches. If the inbound lane is an uncontrolled lane approaching a yield sign controlled intersection, the time is increased by two seconds plus the time for the lead safety zone for intersection conflict checking. This longer time allows units on the uncontrolled lanes to gain the right to enter the intersection ahead of other units on the yield sign controlled lanes. If the intersection is uncontrolled, the time is reduced to two seconds. In SIMPRO, the time required for the driver-vehicle unit being checked to travel to the end of the lane is predicted. If this predicted time is greater than the maximum time from the end of the lane that the unit may decide to proceed, the unit cannot clear its intersection conflicts, but an intersection control logic timer is set to delay further intersection conflict checking until the unit is closer to the intersection. Third, if no driver-vehicle unit in the system has set a flag which indicates to the driver-vehicle unit being checked that some other unit has the right-of-way through the intersection, the unit being checked may enter the intersection.

For the general case of intersection conflict checking, CHKCON determines whether the driver-vehicle unit being examined can safely pass through the intersection. Each geometric intersection conflict, which has been previously flagged to indicate that another driver-vehicle unit has the right-of-way, is checked. An attribute of the intersection conflict is the next driver-vehicle unit on the intersection path, or dedicated to the intersection path, whose rear bumper has not cleared the intersection conflict, ICONV. There may be more than one unit on the intersection path, or dedicated to the intersection path, whose rear bumper has not cleared the intersection conflict. An attribute of the VEHD entity is the entry number of the driver-vehicle unit to the rear which has to clear the same intersection conflict, NORC. The last driver-vehicle unit in the linked list has NORC equal to zero.

In CHKCON, the time, TCM, required for the driver-vehicle unit being checked, ME, to tbavel to the intersection conflict is predicted. This prediction assumes that the unit, ME, has gained the right to enter the intersection and thus may accelerate to its desired speed. If the acceleration/deceleration logic for the driver-vehicle unit, ME, indicates car following, the desired speed will be the minimum of the desired speed for the lead driver-vehicle unit and the desired speed of ME. The time, TCH, required for the driver-vehicle unit with the right-of-way, HIM, to travel to the intersection conflict is predicted. CHKCON builds safety zones (see Fig 5.17) before and after the predicted arrival time, TCH, of the driver-vehicle unit with the right-of-way, HIM. The front safety zone is made up of (1) the time, TPASSM, required for the driver-vehicle unit being checked, ME, to pass through the point of intersection conflict ahead of the driver-vehicle unit with the right-of-way, HIM, (2) half the judgement error, (3) the time specified by the user for the lead safety zone for intersection conflict checking, TLEAD, minus the average perception-reaction time, APIJR, and (4) the perception-reaction time for the driver being checked, ME. The rear safety zone is made up of (1) the time, TCH, required for the driver-vehicle unit with the right-of-way, HIM, to pass through the point of intersection conflict , (2) the time specified by the user for the lag safety zone for intersection conflict checking, TLAG, minus the average perception-reaction time, APIJR, (3) the perception-reaction time for the driver being checked, ME, and (4) half the judgement error.

Finally, if the predicted time of arrival at the intersection conflict, TCM, for the driver-vehicle unit being checked, ME, is (1) less than or equal to the predicted time of arrival at the intersection conflict, TCH, for the driver-vehicle unit with the right-of-way, HIM, minus the time for the front safety zone, or if TCM is (2) greater than or equal to the predicted time of



where:

TPASSM	is the time for ME to pass through the point of intersection conflict
ERRJUD	is the judgment error
TLEAD	is the time for the lead safety zone
APIJR	is the average PIJR time for all drivers
PIJR	is the perception-reaction time for the driver, ME
TPASSH	is the time for HIM to pass through the point of intersection conflict
TLAG	is the time for the lag safety zone

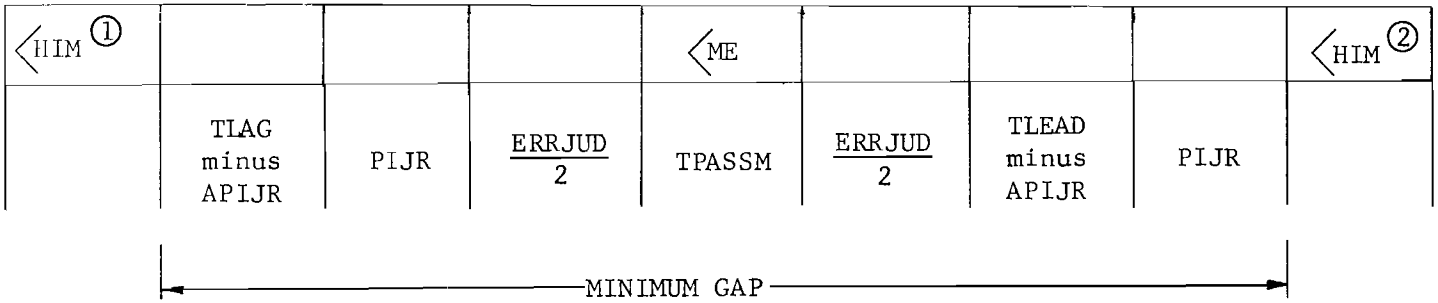


Fig 5.17. Intersection conflict checking safety zones.

arrival at the intersection conflict, TCH, for the driver-vehicle unit with the right-of-way, HIM, plus the time for the rear safety zone, then the driver-vehicle unit being checked, ME, does not have an intersection conflict with the driver-vehicle unit with the right-of-way, HIM, and continues checking intersection conflicts. Otherwise, the driver-vehicle unit with the right-of-way, HIM, blocks the entry of the driver-vehicle unit being checked, ME, into the intersection but the intersection control logic timer is set to resume intersection conflict checking when the driver-vehicle unit being checked, ME, should be able to clear the rear of the safety zone.

If the driver-vehicle unit being checked, ME, can clear the driver-vehicle unit with the right-of-way, HIM, by passing through the point of intersection conflict before the driver-vehicle unit with the right-of-way, HIM, then any remaining driver-vehicle units which are to pass through the same intersection conflict after the driver-vehicle unit with the right-of-way, HIM, need not be checked because each of them will arrive at the point of intersection conflict later than the driver-vehicle unit with the right-of-way, HIM. If ME can pass behind HIM, the next driver-vehicle unit following HIM that will pass through the same point of intersection conflict must must then be checked.

When all intersection conflicts are cleared, the driver-vehicle unit being checked, ME, may enter the intersection with the right-of-way and does not have to check sight distance restrictions or intersection conflicts again. The driver-vehicle unit being checked, ME, is assured of a safe path through the intersection. The driver-vehicle unit being checked, ME, will set a flag for each intersection path with which his intersection path conflicts geometrically, thereby indicating that a driver-vehicle unit has gained the right to enter the intersection and has the right-of-way.

As a driver-vehicle unit travels through the intersection, each intersection conflict that the rear bumper of the unit passes is cleared for this unit by subprogram CLRCON. The variable that defines the next driver-vehicle unit that has not cleared the intersection conflict is set to the entry number for the next unit following HIM which must also pass through the same point of intersection conflict. If there are no more driver-vehicle units which need to pass through the intersection conflict, then the intersection conflict flag is cleared for the other intersection path involved in the intersection conflict.

Several refinements to the intersection conflict checking algorithm are necessary to more accurately predict a safe passage through the intersection. First, CHKCON checks to see whether the driver-vehicle unit between the last unit checked and the next unit to be checked may enter the intersection. If one of these units may not enter the intersection, then it will block the next unit to be checked; thus there can be no intersection conflict with the next unit to be checked. Second, when the time, TCH, required for the driver-vehicle unit with the right-of-way, HIM, to travel to the point of intersection conflict becomes greater than 5 seconds, the ability of ME to predict this time accurately decreases; therefore, a judgement error time, ERRJUD, in seconds is defined as

$$\mathrm{ERRJUD} = \mathrm{PIJR}*(\mathrm{TCH}-5.0)/7.0 \qquad (5.50)$$

where PIJR is the perception-reaction time in seconds for ME. Finally, if the unit being checked, ME, will be traveling slower than the unit with the right-of-way, HIM, at the intersection conflict, then the time for the front safety zone is MAXed with the time required for the driver-vehicle unit with the right-of-way, HIM, to reduce its speed to the speed of the driver-vehicle unit being checked, ME, multiplied by the cosine of the intersection conflict angle and plus the perception-reaction time for the driver being checked, ME. If the unit being checked, ME, will be traveling faster than the unit with the right-of-way, HIM, at the intersection conflict, then the time for the rear safety zone is MAXed with the time required for the unit being checked, ME, to reduce its speed to the speed of the unit with the right-of-way, HIM, multiplied by the cosine of the intersection conflict angle and plus the perception-reaction time for the unit being checked, ME.

5.3.17 Lane Changing

The traffic simulation processor distinguishes between two types of lane changes: (1) the forced lane change, wherein the currently occupied lane does not provide an intersection path to the desired outbound approach, and (2) the optional lane change, wherein less delay can be expected by changing to an adjacent lane which also connects to the desired outbound approach. Field studies utilizing time-lapse photography served as the basis for the development of equations for acceptable lead and lag gaps for a lane-change maneuver. The time required to complete a lane-change maneuver has been found to be 3 to 4 seconds for any reasonable speed. Initial development of the lane-changing decision and lane-changing geometry is described by Fett (Ref 36)

In SIMPRO, subprogram LCHDES controls the lane changing decision process and subprogram LCHGEO calculates the geometry for the lane-change maneuver. The need or the desirability for a lane change is based on an attribute of the VEHD entity named LEGAL. This attribute defines whether (1) the turn is legal from the approach but not from the current lane, thus mandating a lane change, or (2) the turn is legal from the current lane, thus an optional lane change should be investigated.

When lane changing is forced, a check is made to determine whether an alternate lane is geometrically available adjacent to the current position of the driver-vehicle unit being examined and is continuous to the intersection ahead. In the case of the alternate lane not being accessible from the current position, but available ahead, one of the two following conditions exists: (1) there is a lead driver-vehicle unit in the alternate lane ahead (LCHDES sets the lane-change acceleration/deceleration slope of the unit under examination to car-follow the unit in the alternate lane); or (2) there is not a lead driver-vehicle unit in the alternate lane ahead, (LCHDES sets the lane-change acceleration/deceleration slope of the unit under examination to stop at the end of the alternate lane). If the end of the alternate lane has already been passed by the driver-vehicle unit when the check for an available alternate lane is made, then the unit is forced to choose one of the available intersection paths leading from the currently occupied lane and abandon the original destination. Otherwise, the driver-vehicle unit checks for an acceptable gap for lane changing.

When the lane change is optional, LCHDES delays further lane-change checking until the driver-vehicle unit is dedicated to an intersection path. If there are no lane alternatives adjacent to the current lane, the lane change status flag, ISET, is set to indicate that lane-change checking need not be executed any more. If the driver-vehicle unit is the first unit in the currently-occupied lane and its intersection path does not change lanes within the intersection, the lane-change status flag, ISET, is set to indicate that lane changing need not be checked further. The expected delay is then computed for the driver-vehicle unit's current lane as well as for its alternate lane(s). If less delay can be expected when the driver-vehicle unit changes into one of the alternate lanes, that alternate lane is checked for the presence of acceptable gaps; otherwise, LCHDES waits until the next time increment to check for lane changing. If there is an acceptable gap in the alternate lane, then the driver-vehicle unit is logged into the new lane, and the lane-change maneuver is initiated.

Expected queue delay is determined by subprogram DELAY. The equivalent number of driver-vehicle units on the inbound approach in front of the driver-vehicle unit being checked is determined for the current lane, for the lane immediately to the left (if available), and for the lane immediately to the right (if available). A penalty is added to the actual number of vehicles in the queue based on the turn code of the last driver-vehicle unit in the queue and based also on the turn code of the unit being checked. Table 5.4 summarizes these penalties.

In the case of a stopped unit blocking the portion of the lane ahead of it, the number of vehicles in the queue ahead is artificially computed as the number of units that would occupy the remaining distance to the end of the lane. If the intersection path of the unit being examined changes lanes within the intersection, the number of vehicles in the queue is increased by 10 to make the use of this lane less desirable as the unit will have to yield to other traffic from the same inbound approach when it uses this intersection path.

In SIMPRO, subprogram GAPACC checks for acceptable lead and lag gaps and controls the maneuvering of the driver-vehicle unit to match the gaps. Field observations of lane-changing maneuvers indicated minimum values for acceptable lead and lag gap distances, and a correlation study by Fett (Ref 36) related an assumed safe car-following distance with these values. This study revealed that a factor, FACT, with a value equal to 2.0, was needed to adjust computed distances to match observed distances with only a small probability of rejection error. In order to simulate the variability in driver and vehicle characteristics, FACT is multiplied by the driver operational factor and by the vehicle operational factor in subprogram GAPACC. The acceptable lead gap, ALEGAP, in feet is

TABLE 5.4. LANE CHANGING TURN CODE PENALTIES FOR CALCULATING EXPECTED DELAY

		Turning Movement Type of Driver-Vehicle Unit Being Checked		
		U-Turn and Left Turn	Straight-Through Movement	Right Turn
Turning Movement Type of Last Driver-Vehicle Unit in the Queue	U-Turn and Left Turn	1	4	4
	Straight Through Movement	0	0	0
	Right Turn	2	2	1

$$\mathrm{ALEGAP} = (2.0+0.7*\mathrm{VI}+(\mathrm{ABS}(\mathrm{RESPLE})*\mathrm{RESPLE}*0.05))/\mathrm{FACT} \qquad (5.51)$$

where VI is the initial velocity of the driver-vehicle unit in ft/sec and RESPLE is the relative speed of the lead driver-vehicle unit (VI minus the speed of the lead unit) in ft/sec. This acceptable lead gap is MAXed with the minimum gap of 8 feet (2.4384 meters) divided by the driver operational factor. The acceptable lag gap, ALAGAP, in feet is

$$\mathrm{ALAGAP} = (4.0+1.4*\mathrm{VI}+(\mathrm{ABS}(\mathrm{RESPLA})*\mathrm{RESPLA}*0.10))/\mathrm{FACT} \qquad (5.52)$$

where VI is the initial velocity of the driver-vehicle unit in ft/sec and RESPLA is the relative speed of the lag driver-vehicle unit (the speed for the lag driver-vehicle unit minus VI) in ft/sec. This acceptable lag gap is also MAXed with the minimum gap of 8 feet (2.4384 meters) divided by the driver operational factor. These equations may be replaced if the user developes more accurate or reliable estimates of the acceptable lead and lag gaps for lane changing. The remainder of subprogram GAPACC and the traffic simulation model should perform properly.

Several conditions are investigated to determine whether the driver-vehicle unit under examination should accept or reject the currently adjacent gap. If (a) the lag driver-vehicle unit in the adjacent lane is almost stopped or (b) the actual lead gap is not acceptable and the lead driver-vehicle unit is almost stopped, then (1) the gap is rejected and (2) if the lane change is forced, then the lane-change acceleration/deceleration slope of the unit under examination is set to car-follow the lead driver-vehicle unit in the adjacent lane or to stop in half the remaining distance to the end of the adjacent lane, whichever is critical.

If both the currently-available lead and lag gaps are acceptable, then a check is performed to ensure that the lead gap is adequate for the lane-changing unit to decelerate to the speed of the lead driver-vehicle unit in the adjacent lane and to ensure that the lag gap is adequate for the lag driver-vehicle unit in the adjacent lane to decelerate to the speed of the lane-changing unit. When these conditions exits, the lane-change flag is set to initiate the lane-change maneuver.

If the available lead gap is not acceptable and the available lag gap is acceptable, then (1) the gap is rejected and (2) the lane-change acceleration/deceleration slope of the unit under examination is set to car-follow the lead driver-vehicle unit in the adjacent lane and, if the lane change is forced, then the lane-change acceleration/deceleration slope of the unit under examination is set to the minimum of its current value or the value required to stop the unit under examination in half the remaining distance to the end of the adjacent lane. If the available lag gap is not acceptable and the available lead gap is acceptable, a check is made to determine whether the unit can accelerate for the gap and change lanes ahead of the lag unit. Very strict conditions are set for allowing a driver-vehicle unit to accelerate for the gap because, if the available lead gap subsequently becomes unacceptable, the gap is accepted unconditionally. If neither the available lead gap nor the available lag gap is acceptable, (1) the gap is rejected and (2) if the lane change is forced, the lane-change acceleration/deceleration slope of the unit under examination is set to car-follow the lead driver-vehicle unit in the adjacent lane or to stop in half the remaining distance to the end of the lane, whichever is critical.

In SIMPRO, subprogram CHGMLN logs the driver-vehicle unit out of the current lane, sets the appropriate acceleration/deceleration logical dependent attributes for the driver-vehicle unit, logs the unit into the new lane, initializes the parameters for the lane change-geometry, unsets the intersection conflicts for the unit's old intersection path, finds an intersection path for the unit based on the new lane, and resets the unit's intersection control logical independent attributes for the new lane.

Generally, the value for lane-change acceleration/deceleration slope is zero for all computations. If, however, GAPACC has set a non-zero value for this slope so that a driver-vehicle unit may maneuver to accept a gap, the value thus set is substituted for the normal acceleration/deceleration slope if it is less than the normal slope.

Verification of the lane-change maneuver was accomplished by examining debug prints of numerous test cases for lane changing, including both forced and optional.

5.3.17.1 Lane Change Geometry

In SIMPRO, subprogram LCHGEO computes the new lateral position for a lane-change maneuver using a cosine curve. An attribute of the VEHD entity is a biased value for the current lateral position (denoted LATPOS) in feet and a biased value for the total lateral distance for the lane change (temporarily uses attribute LEGAL) in feet. Each time increment, the total length of the lane-change maneuver, XTOT, in feet is defined as 3.5 seconds times the current velocity of the driver-vehicle unit divided by both the driver operational factor, DCHAR, and the vehicle operational factor, VCHAR. The current position on the cosine curve, XOLD, is given by

$$\text{XOLD} = \text{XTOT*ACOS(2.0*ABS(POSOLD)/TLDIST-1.0)/PI} \qquad (5.53)$$

where POSOLD is the current lateral position in feet and TLDIST is the total lateral distance for the lane change in feet. Figure 5.18 illustrates these calculations. POSOLD starts at TLDIST and decreases to zero when the lane-change maneuver is completed. The new position on the cosine curve, XNEW, in feet is calculated as the old position on the cosine curve, XOLD, plus the driver-vehicle unit's current velocity in ft/sec times one time increment. If the new position on the cosine curve, XNEW, is greater than 95 percent of the total length of the lane-change maneuver, XTOT, the lane-change maneuver is completed. The new lateral position for the lane change, POSNEW, in feet is

$$\text{POSNEW} = \text{0.5*TLDIST*(1.0+COS(PI*XNEW/XTOT))} \qquad (5.54)$$

If this new lateral position for the lane change, POSNEW, is less than 0.3 feet (0.09144 meters), then the lane-change maneuver is completed.

5.3.18 Choosing An Intersection Path

In SIMPRO, soon after a unit enters the system, a check is made to determine whether an intersection path connects the currently-occupied lane

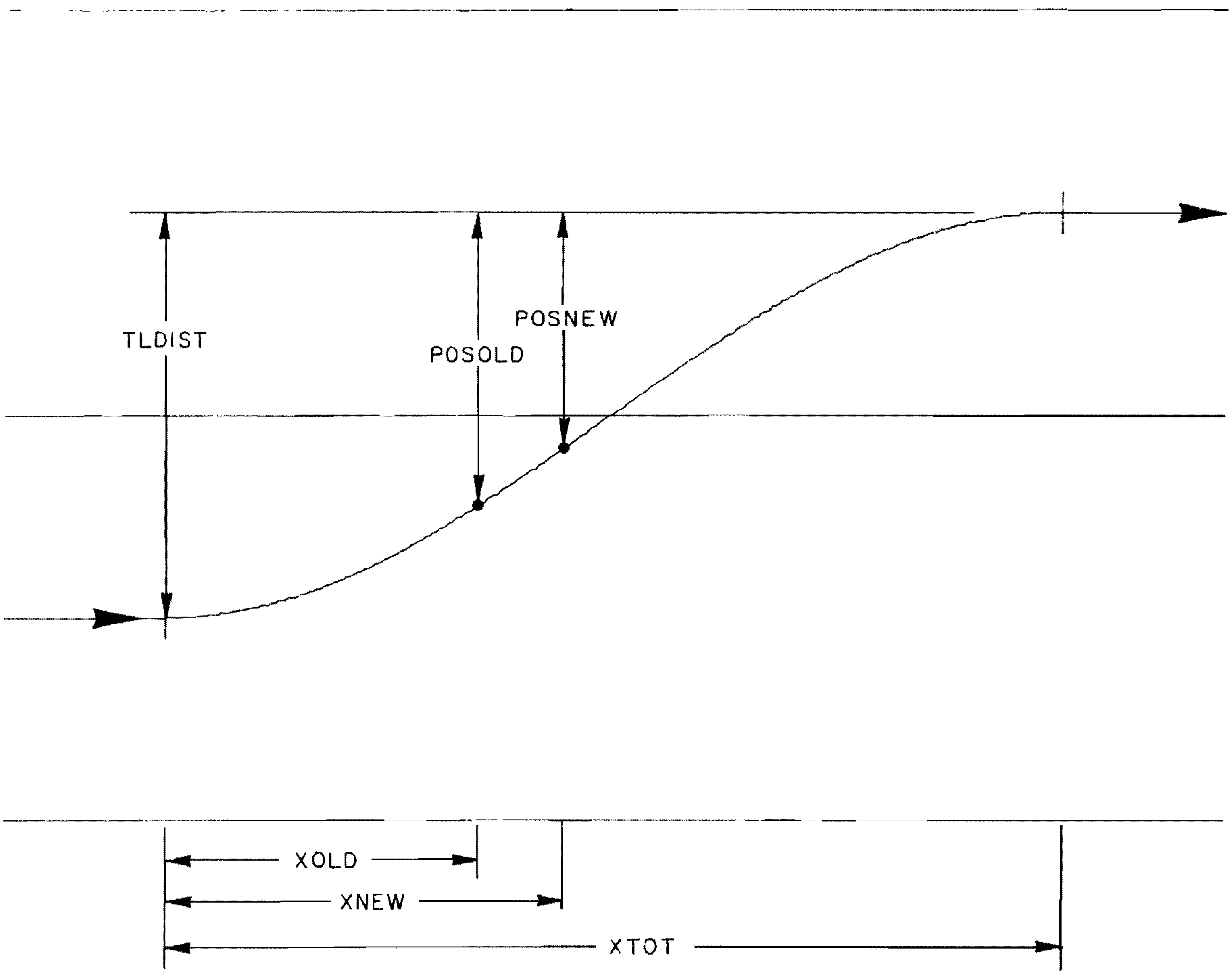


Fig 5.18. Lane change geometry.

with the unit's desired outbound approach, NOBAPD. The unit is immediately dedicated to using the available intersection path and will continue through the intersection on this intersection path unless an optional lane change subsequently allows the unit to use another inbound lane. A driver-vehicle unit will abandon its desired outbound approach, NOBAPD, and choose an available intersection path leading from the currently occupied lane when a forced lane-change maneuver can not be executed before the unit is within 2 vehicle lengths of the end of the inbound lane.

Subprogram PATHF chooses an intersection path for each driver-vehicle unit. The selection of an intersection path may be forced or not, depending upon a parameter to the subprogram, IFORCE. The currently-occupied lane is checked to determine whether any intersection paths connect to this lane. If intersection paths are available, each is checked to determine whether it leads to the unit's desired outbound approach, NOBAPD. If there is no intersection path available, the adjacent lane(s) is checked to determine whether any appropriate intersection path is available.

To determine the acceptability of the intersection path(s) from the currently-occupied inbound lane, the forced intersection path is initialized to the first intersection path on the list of intersection paths leading from the currently-occupied lane. If there is no intersection path leading from the currently-occupied inbound lane, then the adjacent lane(s) on the inbound approach is checked to determine whether it has an acceptable intersection path; otherwise, the intersection paths leading from the currently-occupied inbound lane are checked. The forced intersection path is initialized to the first intersection path leading from the current inbound lane. If an intersection path on the list of intersection paths for the lane is an OPTION1 intersection path (see Section 3.2.5 and Section 3.3.12), then the unit is not allowed to choose it. If the linking outbound approach, LOBAP, for the intersection path is equal to the desired outbound approach, NOBAPD, for the driver-vehicle unit, then the unit dedicates itself to using this connecting intersection path. If the turn code for the intersection path is straight, then the intersection path is set as the forced intersection path. If none of the intersection paths leading from the driver-vehicle unit's current lane go to the desired outbound approach, NOBAPD, and if the driver-vehicle unit is being forced to choose an intersection path, then the unit dedicates itself to using the forced intersection path; otherwise, each available adjacent lane on the inbound approach is checked to determine whether any intersection path is appropriate for the unit. Then, the lane change flag is set to indicate a forced lane change in the direction of the inbound lane that has an intersection path leading to the driver-vehicle unit's desired outbound approach.

5.3.19 Collisions

Occasionally, rear end collisions occur during traffic simulation. Most of these are minor impact types that may occur on the approaches or in the intersection. If one driver-vehicle unit runs into the rear of another unit, the former unit is automatically positioned by SIMPRO 6 feet (1.8288 meters) behind the latter unit and the speed of the rear unit is set to the minimum of its current speed, its desired speed, or 95 percent of the lead unit's speed. Detailed information is printed about the current status of the units that were involved in collisions and the traffic simulation continues. The relative velocity, RELVEL, in ft/sec and the relative position, RELPOS, in feet can be interpreted to indicate the severity of the collision.

In SIMPRO, driver-vehicle units within the intersection are furnished information only about other driver-vehicle units on the same intersection path. Therefore, only rear-end collisions on the same intersection path are detected by the traffic simulation processor. Other types of collisions that may possibly occur in the intersection are not detected by SIMPRO as the intersection conflict checking procedure is designed to prevent collisions with vehicles on other intersection paths.

5.3.20 Effects Of The Driver Operational Factor

Each driver is characterized in SIMPRO according to his relative aggressiveness and expected driving skill by an input variable called the driver operation factor, DCHAR. This operational factor directly affects (1) the maximum acceleration/deceleration slope, (2) maximum acceleration to be used in accelerating to desired speed, (3) deceleration to the speed of the leading vehicle when checking intersection conflicts, (4) deceleration slope used in calculating the time (and distance) required to decelerate to the desired speed for the intersection path, (5) maximum deceleration to be used in decelerating to a stop, (6) lane-changing turn code penalties, (7) the lane-changing factor, which in turn indirectly affects the acceptable lead and lag gaps, (8) the acceleration that a driver-vehicle unit uses when accelerating to maneuver into an acceptable lane-change gap, (9) maximum deceleration slope used when calculating the log-in velocity, and (10) deceleration used to separate a following driver-vehicle unit from the leading unit when the former unit is following the faster lead unit too closely.

The driver operational factor indirectly affects (1) car-following distance, (2) minimum lane-change gap length, (3) the maximum deceleration used in the decelerate-to-a-stop calculations when making the amber-go or amber-stop decision.

5.3.21 Effects Of The Vehicle Operational Factor

A factor called VCHAR is used in SIMPRO to characterize the relative maneuverability of each vehicle. This vehicle operational factor is an input variable that directly affects the lane-changing factor, which in turn indirectly affects the acceptable lead and lag gaps. It also indirectly affects the time used to complete a lane-change maneuver.

5.3.22 Effects Of Perception-Rction Time

Perception-reaction time, PIJR, in seconds is used in SIMPRO (1) as the time interval in which acceleration/deceleration of a driver-vehicle unit is increased to its new acceleration value when the old acceleration/deceleration is less than the new acceleration, (2) as the time for determining whether a driver-vehicle unit stopped at the stop line should yield to another unit stopped at the stop line, (3) as the time for reducing acceleration/deceleration to zero when the driver-vehicle unit is between 1.0 and 1.2 times the car-following distance behind a slower unit, (4) as the basis for the hesitation of a driver-vehicle unit stopped at the stop line in non-signalized lanes, (5) as a factor in determining the judgment error when checking for intersection conflicts, (6) as a component of the front and rear safety zones when checking intersection conflicts, (7) as a component of the front safety zone when checking sight distance restrictions, (8) as the perception-reaction time used when initiating deceleration to a stop, (9) as the time for determining whether deceleration to a stop is imminent, (10) as a factor for determining whether a driver-vehicle unit is in the influence zone of the intersection, (11) as the perception-reaction time used to delay acceleration/deceleration logic after the driver-vehicle unit stops, and (12) as a component of the delay to the first driver-vehicle unit in the queue when the signal indication changes to green.

5.3.23 Summary Statistics

Numerous summary statistics are gathered, reported, and optionally punched by the traffic simulation processor. Individual performance statistics are gathered about each driver-vehicle unit as it is processed through the simulated intersection system. These statistics are accumulated during simulation time according to the inbound approach and turn code (U-turn and left turn, straight-through-movement, or right turn) of each driver-vehicle unit and are summed as each unit logs out of the traffic simulation system. Statistics that result from the performance of individual driver-vehicle units are (1) total delay, (2) queue delay, (3) stopped delay, (4) delay below XX miles per hour, (5) vehicle miles of travel, (6) travel time, (7) average velocity, (8) average desired speed, (9) maximum acceleration, and (10) maximum deceleration. The user may request that the individual performance statistics related to any selected driver-vehicle unit be printed. Other statistics that are gathered and reported include (1) the number of driver-vehicle units processed for each inbound approach and turn code, (2) the maximum and average queue length for each inbound approach and turn code, (2) the maximum and average queue length for each inbound lane, (3) the number of driver-vehicle units eliminated from each inbound approach because the entry lane was full, (4) the number of collisions for each inbound approach, (5) the average of the log-in speed divided by the desired speed for each inbound approach, (6) the number of driver-vehicle units processed during start-up time, (7) the number of driver-vehicle units in the traffic simulation system at the end of simulation, and (8) the average and maximum number of driver-vehicle units in the traffic simulation system during each time increment. Several statistics are also gathered about the performance of actuated signal controllers: (1) the number and average time into the phase for max-outs and (2) the number and average time into the phase for gap-outs.

Since computational efficiency is a primary concern, selected indicators are included in the summary statistics. For CDC and IBM computers, the following statistics are gathered: (1) the initialization computer time, (2) the simulation computer time and the real-time to computer-time ratio, (3) the summary computer time, (5) the total computer time for the traffic simulation, (6) the vehicle-seconds of simulation for computer time, (7) the number of vehicle updates per computer time, and (8) the cost associated with the initial, start-up, simulation, summary, and total computer times.

Total delay is defined as the actual travel time through the simulated intersection system minus the travel time that would have been required had the driver been able to maintain his desired speed throughout the system. The shaded area in Fig 5.19 illustrates the conceptualization of total delay. Total delay is thus the time lost because the intersection exists, controls are in effect, traffic congestion occurs, and acceleration and deceleration maneuvers are necessary.

Queue delay is the amount of time that the driver-vehicle unit is in a queue waiting to enter the intersection. This queue can form only at the stop line on an inbound approach. Queue delay is a significant statistic at unsignalized intersections because it includes move-up time. The technique that is used in SIMPRO to compute queue delay involves the following operations. A variable which defines whether a queue exists, INQUE, is initialized to true at the beginning of the processing of vehicles on an inbound lane. If a driver-vehicle unit has already begun accumulating queue delay, it continues to experience queue delay until it enters the intersection, and its presence maintains the queue. If the queue has not been

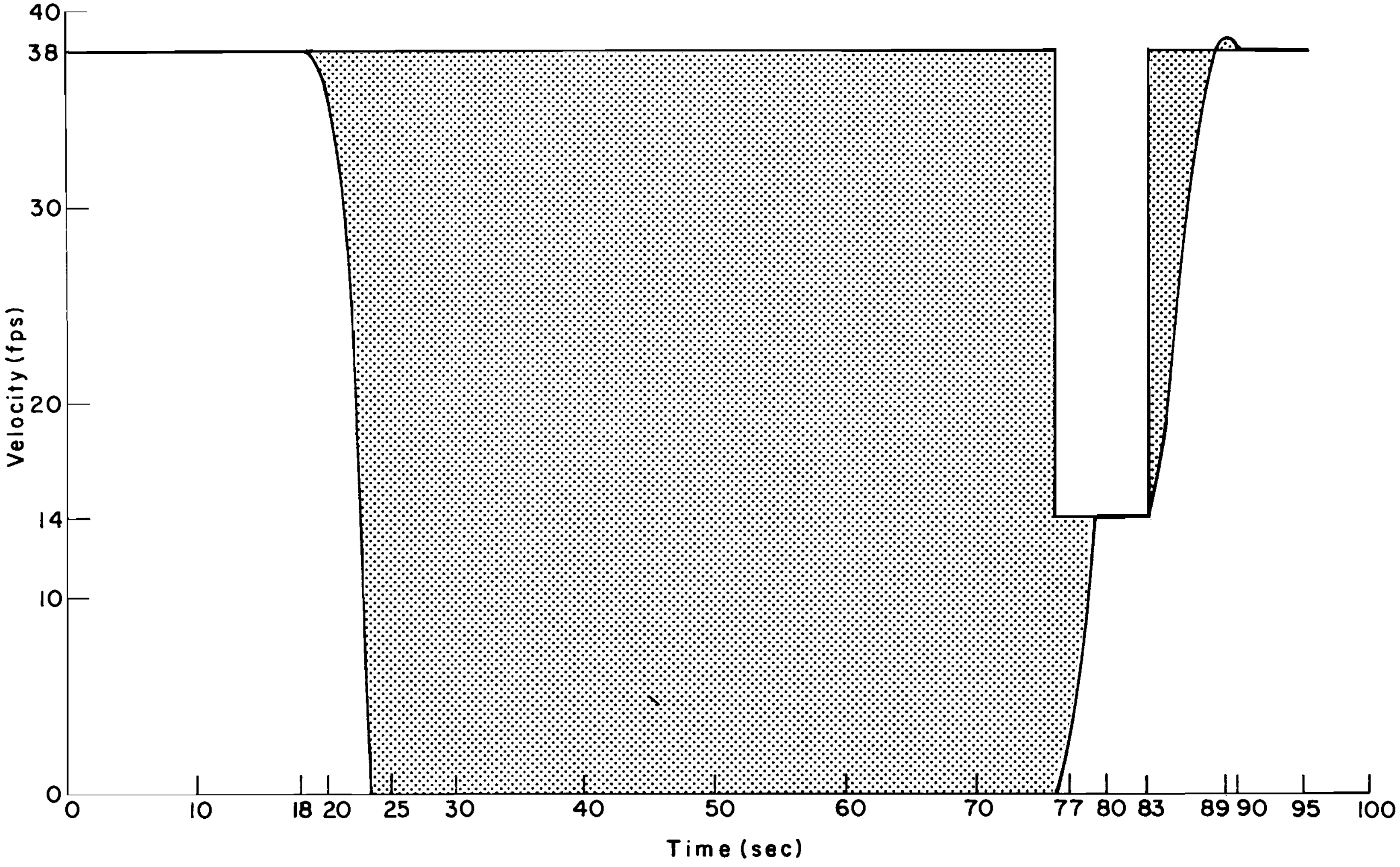


Fig 5.19. Total delay.

previously broken, the driver-vehicle unit under examination is traveling less than 3.0 ft/sec (0.9144 m/sec), and the driver-vehicle unit is less than a specified distance, XQDIST (see Section 5.2), from the stop line (for the first driver-vehicle unit in the lane) or from the lead driver-vehicle unit, the queue is considered to be maintained; otherwise, the queue is said to be broken by this unit. For each time increment that the driver-vehicle unit is to accumulate queue delay, a counter is incremented by one. When the driver-vehicle unit logs out of the traffic simulation system, this counter is multiplied by the time increment to calculate queue delay.

Stopped delay is defined as the amount of time that a driver-vehicle unit is stopped in a queue waiting to enter the intersection. Stopped delay is a significant statistic at signalized intersections because it does not include move-up time to the intersection after the signal turns green. In SIMPRO, if the driver-vehicle unit is in a queue and its velocity is less than 3 ft/sec (0.9144 m/sec), a counter is incremented by one. When the driver-vehicle unit logs out of the traffic simulation system, this counter is multiplied by the time increment to calculate stopped delay.

The delay below XX miles per hour, where the value for XX is read from card input directly to SIMPRO (see Section 5.2), is defined as the amount of time the driver-vehicle unit is traveling at a velocity less than or equal to XX miles per hour anywhere within the traffic simulation system.

5.3.24 Compile Options

SIMPRO has numerous compile options which can activate (1) printing of individual driver-vehicle trace information for outbound approaches, intersection paths, and inbound approaches; (2) plotting of position, velocity, and acceleration versus time for outbound approaches, intersection paths, and inbound approaches; (3) printing of subprogram names entered to update a driver-vehicle unit for outbound approaches, intersection paths, and inbound approaches; (4) echo printing of all input; (5) general debug printing; (6) production of a page plot of position; (7) printing intermediate statistics, (8) debug printing for actuated signal controller, (9) printing the time each driver-vehicle unit enters the intersection,

(10) CDC computer dependent code; and (11) IBM computer dependent code. These compile options are not mandatory, except Option 10 or Option 11. These options are implemented in SIMPRO by having a "C" in Column 1 and a unique character in Column 2, followed by the rest of the statement. Normally, this statement is considered as a COMMENT statement by a FORTRAN compiler; however, if the user substitutes two blanks for the "C" in Column 1 and the unique character in Column 2, the FORTRAN compiler will consider the statement as a normal statement. A list of the unique characters and their function is provided in subprogram EXEC.

5.4 Output

Output from the traffic simulation processor includes print and punch. The printed output includes (1) a listing of the title from the geometry processor magnetic tape, (2) a listing of the title from the driver-vehicle processor magnetic tape, (3) a listing of the title from the card input directly to the traffic simulation processor, (4) the echo print of the card input directly to the traffic simulation processor, (5) information about any driver-vehicle unit forced to change desired outbound approach because it was unable to change into a lane which provides an intersection path to the original desired outbound approach, (6) information about any collisions, (7) information about any driver-vehicle units eliminated from the traffic simulation because the entry lane was full, and (8) summary statistics. If there is an input error, a diagnostic message will be printed and SIMPRO will stop. There are 82 input errors detected and the STOP numbers range from 801 to 882. If there is an execution error detected by SIMPRO, a diagnostic message will be printed followed by a print of selected program variables. There are 21 execution errors detected (they are all considered "can't get here halts") and the STOP numbers range from 901 to 921. Several execution errors indicate problems in the input which cannot be detected until after computations commence.

The summary statistics can be printed according to turn code (if requested) and then summarized for the inbound approach (if requested). Next, the summary statistics are printed for the intersection. Following this is a summary of the actuated signal controller operation (if the intersection is actuated signal controlled) and then the computer time statistics.

Delays are reported as (1) the number of vehicle-seconds of delay for those driver-vehicle units incurring the delay, (2) the number of units incurring the delay, (3) the average delay for the units incurring the delay, and (4) the overall average delay for all the driver-vehicle units. Also reported are (1) the total and average vehicle-miles of travel, (2) the total and average travel time, (3) the number of driver-vehicle units processed and the equivalent hourly volume of traffic, (4) the average desired speed, (5) the time and the space mean speed, (6) the average maximum uniform acceleration and deceleration, (7) the average and maximum queue lengths for each inbound lane, (8) the average ratio of entry speed to desired speed, (9) the number of driver-vehicle units eliminated from the simulation because the entry lane was full, and (10) the number of collisions.

The punched output is optional and includes the titles for the run, the traffic simulation processor options, and related summary statistics. The structure of the punched output is given in Table 5.5.

5.5 Verification

Verification of the traffic simulation processor was accomplished by independently testing selected subprograms to ensure proper performance; review of position, velocity, and acceleration versus time plots; analysis of debug prints of intermediate results; and examination of the interactive graphics display of the movement of driver-vehicle units through the traffic simulation system. The interactive graphics display utilized a CDC 252 display system which had a 4095-word display buffer, a 60-times per second refresh rate, a 1024 by 1024 first quadrant coordinate system, a light pen, and a standard keyboard entry device (see Fig 5.20 and Fig 5.21). Each driver-vehicle unit was individually characterized, had blinking left and right turn signals, and had brake lights. The user could interrupt the traffic simulation at any time increment and investigate problems.

Table 5.5 Punched Output from the Traffic Simulation Processor

1. Title from the geometry processor tape
2. Title from the driver-vehicle processor tape
3. Title from card input to the traffic simulation processor
4. Traffic simulation processor options
   a. Start-up and simulation time (min)
   b. Time step increment for simulation (sec)
   c. Speed for "delay below XX mph" (mi/hr)
   d. Maximum clear distance for being in a queue (ft)
   e. Lambda, mu, and alpha values for the car following equation
   f. Type of intersection control
      1. 1 for uncontrolled
      2. 2 for yield sign controlled
      3. 3 for less-than-all-way stop sign controlled
      4. 4 for all-way stop sign controlled
      5. 5 for pretimed signal controlled
      6. 6 for semi-actuated signal controlled
      7. 7 for full-actuated signal controlled
   g. Summary statistics for each turning movement option and summary statistics for each inbound approach option (YES/NO)
   h. Time for lead and lag safety zone for intersection conflict checking (sec)
   i. Number of inbound approaches
   j. Number of signal phases
5. Summary statistics
   a. Inbound approach number
      1. Equal to 1 through 12 for an approach
      2. Equal to 99 for all approaches
   b. Turn code number
      1. Equal to 1 for u-turn and left turn
      2. Equal to 2 for straight-through movement
      3. Equal to 3 for right turn
      4. Equal to 9 for all turn codes

(continued)

Table 5.5 (continued)

c. Total delay (total (veh-sec) and number incuring)
d. Queue delay (total (veh-sec) and number incuring)
e. Stopped delay (total (veh-sec) and number incuring)
f. Delay below XX mph (total (veh-sec) and number incuring)
g. Average vehicle-miles of travel (veh-mi)
h. Average travel time (sec)
i. Number of vehicles processed
j. Time mean and space mean speeds (ft/sec)
k. Average desired speed (ft/sec)
l. Average maximum uniform acceleration and deceleration (ft/sec/sec)
m. Actuated signal performance (if actuated signal controlled)
    1. Phase information from card input
    2. Number and average time into phase for max-outs (sec)
    3. Number and average time into phase for gap-outs (sec)

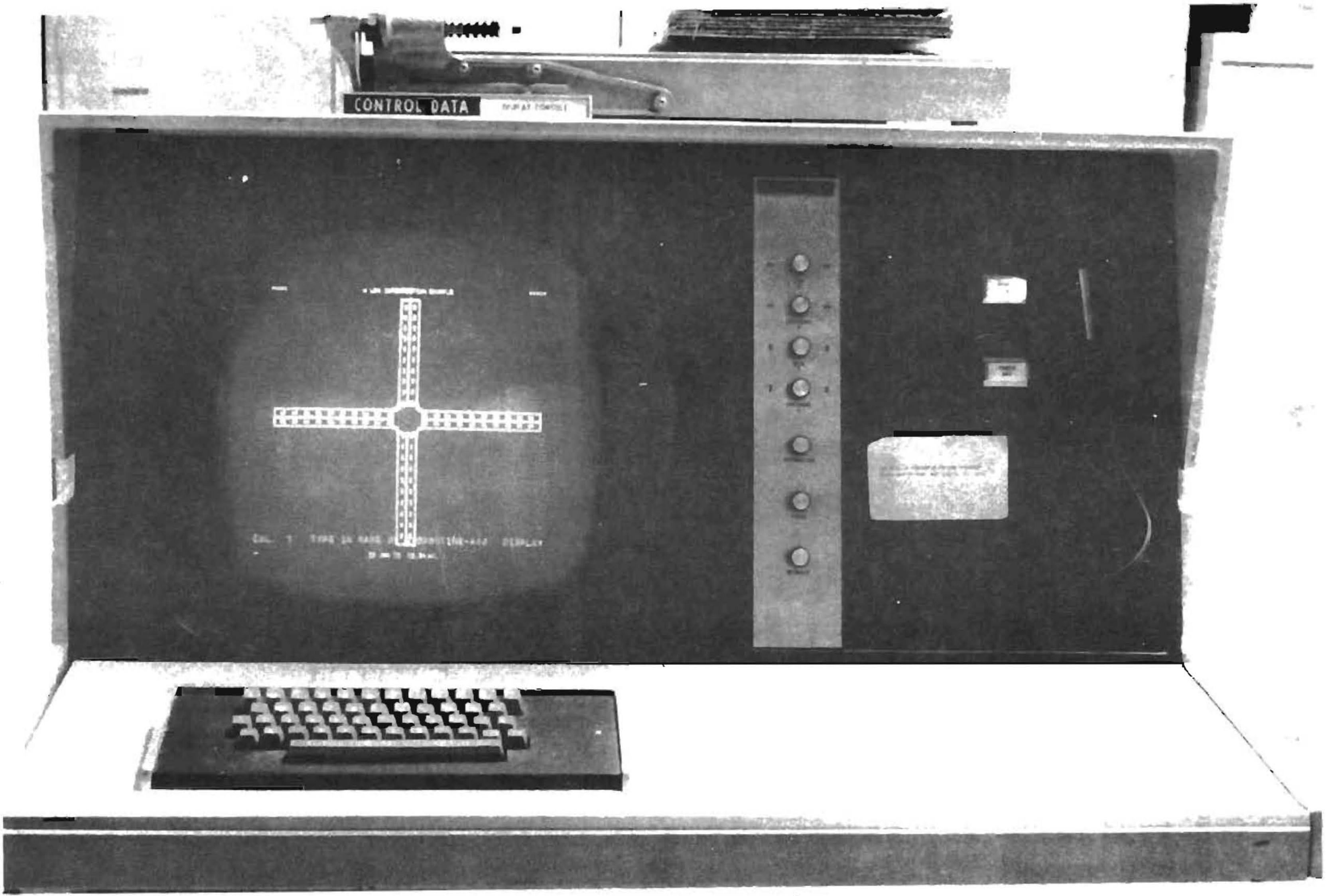


Fig 5.20. Interactive graphics display of traffic simulation.

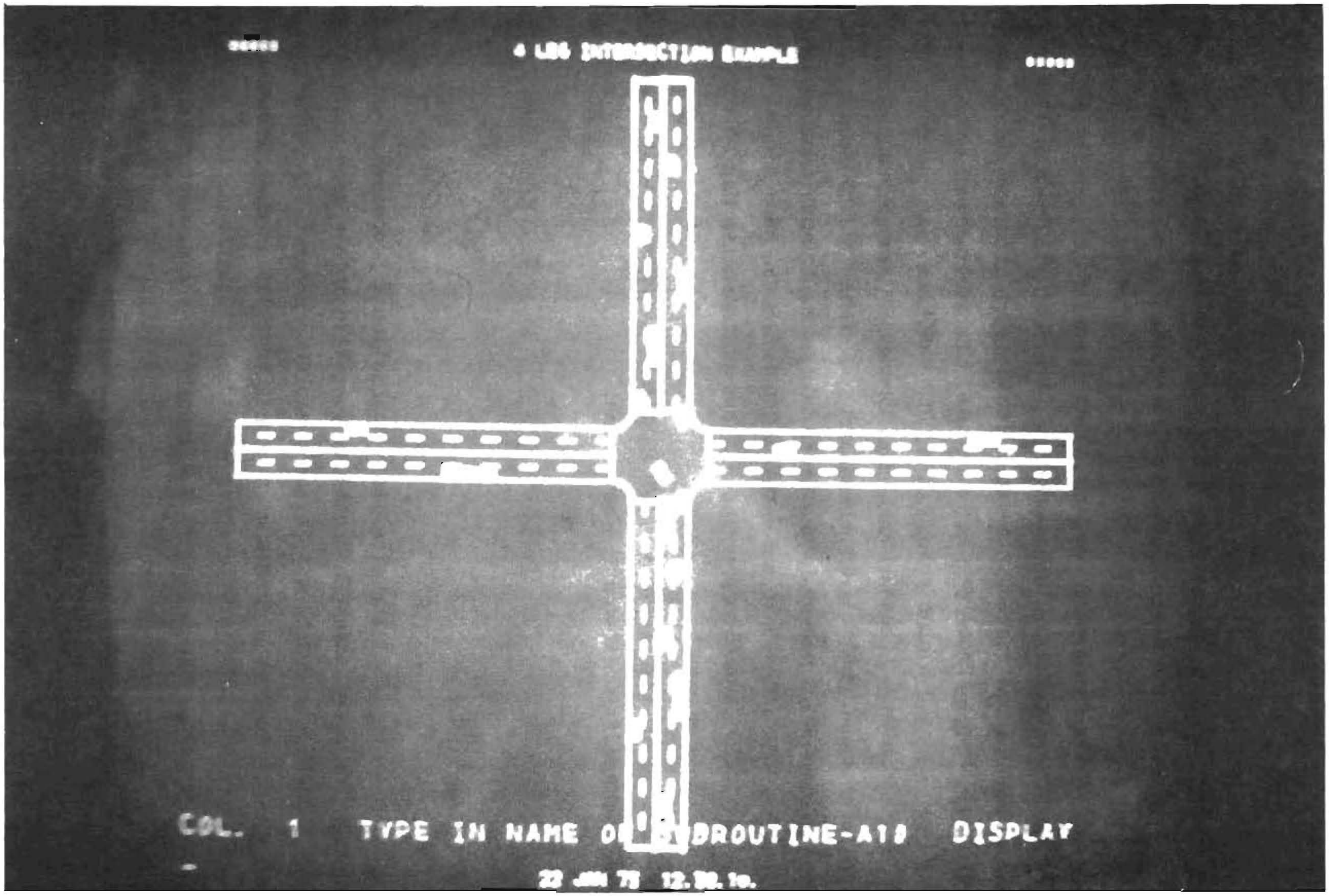


Fig 5.21. Interactive graphics display of traffic simulation (close-up).

5.6 Computer Requirements

The computer time requirements for SIMPRO are difficult to reduce to a single value. As an indication of the efficiency of the model, a simulation time to computer time ratio for CDC computers has been calculated for each run of SIMPRO. This ratio varies with the type of intersection control, the lane lengths, the time increment, and the total number of driver-vehicle units processed. For signalized intersections, 600-foot (182.88-meter) lanes, and a time increment of one second, the lower limit of efficiency (worst case) is in the general range from 30 at a total equivalent hourly volume of 1,000 vehicles per hour to 8 at a volume of 2,000 vehicles per hour. The upper limit of efficiency (best case) is 45 and 15, respectively, for the same volumes. For non-signalized intersections, 600-foot (182.88-meter) lanes, and a time increment of 1 second, the lower limit of efficiency (worst case) is in the general range from 40 at a volume of 750 vehicles per hour to 8 at a volume of 1,250 vehicles per hour. These efficiencies may be different for other computer systems.

SIMPRO uses 32,704 words (77,700 octal) of storage on CDC computers and 210,000 bytes of storage on IBM computers.

5.7 Documentation

Documentation for the traffic simulation processor includes an explanation of the input and output, contained in a user's guide (Ref 15), numerous COMMENT statements within the computer program (29 percent of program statements), and a programmer's guide (Ref 19). The programmer's guide includes (1) the traffic simulation processor limitations, (2) a listing of the input errors detected, (3) a listing of the execution errors detected, (4) the definition of the attributes in each entity, (5) the definition of the variables in each COMMON block, (6) the definition of the local variables used in each subprogram, (7) an alphabetical listing of all subprograms and the subprograms which can call them, (8) an alphabetical listing of all the variables, their storage type, and the subprograms in which they are used, and (9) a generalized calling sequence diagram.

5.8 Additional Information

Appendix A provides example input and output for each of the three sample runs using the geometry and the driver-vehicle units from previous examples. A listing of the traffic simulation processor and its programmer's guide are provided in Appendix D. Table 5.6 gives the categorization of the traffic simulation processor FORTRAN statements.

Table 5.6 Fortran Statement Categorization for Traffic Simulation Processor

```
Number of cards with <BLOCK DATA> ---------     1    .01 Percent
Number of cards with <CALL      > ---------   441   3.87 Percent
Number of cards with <COMMON    > ---------  1858  16.30 Percent
Number of cards with <CONTINUE  > ---------   631   5.53 Percent
Number of cards with <DATA      > ---------   337   2.96 Percent
Number of cards with <DIMENSION > ---------    42    .37 Percent
Number of cards with <DO        > ---------   102    .89 Percent
Number of cards with <END       > ---------    77    .68 Percent
Number of cards with <EQUIVALENC> ---------    26    .23 Percent
Number of cards with <FORMAT    > ---------   418   3.67 Percent
Number of cards with <GO TO     > ---------   145   1.27 Percent
Number of cards with <IF        > ---------   960   8.42 Percent
Number of cards with <LOGICAL   > ---------    12    .11 Percent
Number of cards with <PROGRAM   > ---------     2    .02 Percent
Number of cards with <RETURN    > ---------   112    .98 Percent
Number of cards with <STOP      > ---------   111    .97 Percent
Number of cards with <SUBROUTINE> ---------    75    .66 Percent
Number of cards with COMMENTs -------------  3320  29.12 Percent
Number of cards with I/O statements -------   298   2.61 Percent
Number of cards with conditional assembly -   786   6.89 Percent
Number of cards with other statements -----  1648  14.45 Percent


Total number of statements ---------------- 11402
```

6.0 STORAGE MANAGEMENT AND LOGIC PROCESSING

6.1 Introduction And Purpose

The geometry processor and the traffic simulation processor use a special storage management and logic processing program called COLEASE (COordinated Logic Entity Attribute Simulation Environment). This program accomplishes two objectives: (1) it provides a mechanism which maximizes computer bit usage by disregarding normal word boundaries and (2) it establishes an efficient means for processing logical binary networks. COLEASE is written in FORTRAN IV computer language and is operational only on CDC computers. Programs processed by COLEASE can, however, be executed on any computer. Initial development and use of COLEASE is described by Walker (Ref 37).

6.2 Input Requirements

The input to COLEASE is broken into four paragraphs of information. Paragraph I contains information which describes the program name and files, the number of bits used to store a normal integer variable for the target computer (the computer that is to be used to execute the program being processed by COLEASE), and the print option. Paragraph II contains information which describes the entities; these are groups of attributes (variables). For each entity, the name of the entity, the number of entries for each entity, and the attributes associated with each entity are specified. For each ordinary attribute (non-logical), the user must define the name and the maximum integer value of the attribute. Optionally he may give a single dimension. For logical independent attributes and logical dependent attributes, the user defines the attribute name and the logical binary network which associates the logical independent and the logical dependent attributes. Paragraph III contains information which defines the entity usage for specified subroutines and the subroutine name with which to begin execution.

Paragraph IV contains intermixed FORTRAN statements and COLEASE statements. The COLEASE statements are TASK, EXTRAC, FIND, REPACK, STORE, and LOGIC. The COLEASE statement TASK defines the subroutine name and associated parameters for the various subroutines which need access to the attributes. The COLEASE statement EXTRAC defines the entity name and the entry number to be extracted from the storage stack. The COLEASE statement FIND defines the entity name, the entry numbgr, and the attribute to be found in the storage stack and placed in the named local variable. The COLEASE statement REPACK defines the entity name and the entry number to be repacked into the storage stack. The COLEASE statement STORE defines the entity name, the entry number, and the attribute into which the value of the specified variable is to be stored. The COLEASE statement LOGIC defines the entity name and the entry number for computing new logical dependent attribute values. Table 6.1 shows the input and format for COLEASE.

6.3 Algorithms For Computation

Computer memory is made up of a collection of elementary storage cells called bits. A bit may have a value of zero (off) or one (on). A computer word is a continuous string or series of bits which may be addressed (located) by the computer. Often, the computer word is broken into smaller units called bytes. On the CDC 6600 computer, a byte is 12 bits long, while a computer word is 5 bytes, or 60 bits long. A peripheral processor may address each byte (12 bits) contained in its memory. The peripheral processor may be programmed only by system programmers because the peripheral processor processes data transfer requests between memory and external devices and have the capability of accessing privileged information. The central processor may address each word (5 bytes or 60 bits) within its allocated portion of memory. This processor may be programmed by the general user.

On the IBM 370-155 computer, a byte is 8 bits long and a computer word is normally 4 bytes, or 32 bits, long. The central processor may address each byte (8 bits) within its allocated portion of memory. In the IBM FORTRAN compiler, the user may specify the number of bytes for storing program variables. The defaults are 8 bytes (2 words) for double precision floating

Table 6.1 Input and Format for COLEASE

1. Paragraph I
    a. Program identification
        1. "IDENTIFY" starting in column 3
        2. Program name
        3. Number of bits in target computer word
        4. Print option
            a. 1 for header message and the "IDENTIFY" statement from Paragraph I
            b. 2 for header message, the Paragraph I input, the Paragraph II input, the Paragraph III input, and the COLEASE statements in Paragraph IV
            c. 3 for header message, the Paragraph I input, the Paragraph II input, the listing of the bookkeeping information for each entity, the listing of the paths within the logical binary network for each entity, the Paragraph III input, and the COLEASE statements in Paragraph IV
            d. 4 for header message, the Paragraph I input, the Paragraph II input, the listing of the bookkeeping information for each entity, the listing of the paths within the logical binary network for each entity, the Paragraph III input, and the Paragraph IV input
    b. File declaration(s)
        1. "FILES" starting in column 5
        2. File name(s)
2. Paragraph II
    a. "ENTITY" starting in column 3
    b. Entity declaration(s)
        1. "NAME" starting in column 5
        2. Entity name
        3. Number of entries
    c. Ordinary attributes
        1. "ORDINARY" starting in column 5
        2. Attribute name
        3. Single dimension (optional)

(continued)

Table 6.1 (continued)

        4. Maximum positive integer value
    d. Logical independent attributes
        1. "LOGICI" starting in column 5
        2. Attribute name(s)
    e. Logical dependent attributes
        1. "LOGICD" starting in column 5
        2. Attribute name(s)
    f. Logical binary network
        1. "FUNCTION" starting in column 5
        2. Binary network node
            a. Logical independent attribute name
            b. True branch (logical independent or dependent attribute name)
            c. False branch (logical independent or dependent attribute name)
3. Paragraph III
    a. "EXECUTIVE" starting in column 3
    b. Entity usage for each subroutine
        1. "ROUTINE" starting in column 5
        2. Subroutine name
        3. Entity name(s)
    c. Executive subroutine
        1. "EXECUTE" starting in column 5
        2. Subroutine name
4. Paragraph IV
    a. "TASKS" starting in column 3
    b. User's BLOCK DATA statements and END statement
    c. User's FORTRAN statements
    d. COLEASE statements
        1. TASK statement - define subroutine name which uses entities and define parameter(s) to subroutine
            a. "TASK" in column 5
            b. Subroutine name
            c. Subroutine parameter(s)

(continued)

Table 6.1 (continued)

2. EXTRAC statement - retrieves all attributes for a particular entry of an entity from the storage stack and puts them in the COMMON block for the entity
    a. "COLEASE" starting in column 5
    b. "EXTRAC"
    c. Entity name
    d. Entry number
3. FIND statement - retrieves the value of a specified attribute from a particular entry of an entity in the storage stack and puts it in the prescribed local variable
    a. "COLEASE" starting in column 5
    b. "FIND"
    c. Local variable name for storage for value of attribute
    d. Entity name
    e. Entry number
    f. Attribute name
4. REPACK statement - stores the current value of all attributes for an entity into the particular entry in the storage stack
    a. "COLEASE" starting in column 5
    b. "REPACK"
    c. Entity name
    d. Entry number
5. STORE statement - stores a prescribed value into the specified attribute for a particular entry of an entity in the storage stack
    a. "COLEASE" starting in column 5
    b. "STORE"
    c. Local variable name for value to store in attribute
    d. Entity name
    e. Entry number
    f. Attribute name

(continued)

Table 6.1 (continued)

    6. LOGIC statement - uses the values of the logical independent attributes for a particular entry of an entity in the storage stack to determine the appropriate value for the logical dependent attributes and stores the appropriate values for the logical dependent attributes in the particular entry for the entity in the storage stack
        a. "COLEASE" starting in column 5
        b. "EXTRAC"
        c. Entity name
        d. Entry number

5. Terminate
    a. "TERMINATE" starting in column 3

point variables, 4 bytes (1 word) for single precision floating point variables, and 4 bytes (1 word) for integers.

In traffic simulation models, many variables are small, positive integers which can be defined by one to ten bits. Logical independent and logical dependent attributes require only 2 bits each. Storing only one such variable in a CDC 6600 60-bit word or in an IBM 370-155 32-bit word is very wasteful. COLEASE establishes a storage stack that is a continuous series of computer words used for saving the attributes for each entry of all the entities. Several attributes are stored in each computer word, using the number of bits required to store the maximum integer value. COLEASE also establishes a labeled COMMON block for each entity. Each COMMON block contains a single integer variable named for each attribute within the entity. The attributes are stored in standard integer format in the COMMON block. The subroutines necessary for the execution-time storage management and logic processing are added to the user's program at its end. The necessary bookkeeping is also established by COLEASE.

All statements generated by COLEASE have the characters COLEASE starting in Column 74. Each statement in Paragraph I, Paragraph II, and Paragraph III will be copied to the generated program with the character "C" placed in Column 1. Each COLEASE statement in Paragraph IV will also be copied to the generated program with the character "C" placed in Column 1.

By appropriate scaling, floating point numbers may be transformed to integers. The user must determine the smallest value, XMIN, the lmrgest value, XMAX, and the desired accuracy, XSCALE. The required maximum integer value, IMAX, will then be

$$\text{IMAX} = (\text{XMAX}-\text{XMIN})/\text{XSCALE} + 0.5 \tag{6.1}$$

Assume that the minimum value for deceleration is -32.0, the maximum value for acceleration is +32.0, and the desired accuracy is 0.001; the value of IMAX by Eq 6.1 would be 64,000, which would require 16 bits. To convert the scaled value of an attribute, IVAL, to a floating point number, XVAL, the equation would be

$$\text{XVAL} = \text{IVAL}*\text{XSCALE} + \text{XMIN} \tag{6.2}$$

Assume that IVAL has a value of 16,000 and the same XMIN and XSCALE as the above example. The value of XVAL would be -16.0. To convert a floating point number, XVAL, to the scaled value for an attribute, IVAL, the equation would be

$$IVAL = (XVAL-XMIN)/XSCALE + 0.5 \tag{6.3}$$

Assume that XVAL has a value of +16.0 and the same XMIN and XSCALE as in the above examples. The value of IVAL would be 48,000.

6.3.1 Paragraph I

The number of bits used to store a normal integer variable for the target computer is used to determine the maximum size integer that may be stored in a computer word. When the end of Paragraph III is detected, a PROGRAM statement is generated with the name and the files declared by the user in the Paragraph I input.

6.3.2 Paragraph II

COLEASE determines the number of bits required to store the maximum integer value of each ordinary attribute. An ordinary attribute may have a single dimension associated with it; otherwise, it is assumed to be one. The ordinary attributes are packed into the storage stack starting at bit 0 of word 0 for the entity. When the number of bits remaining in the computer word is less than the number of bits needed to store an attribute, the attribute is stored starting at bit 0 of the next computer word. An entity need not have any ordinary attributes.

Logical independent attributes require 2 bits and are packed in the storage stack starting at bit 0 of the next computer word after the ordinary attributes (if any). The logical dependent attributes also require 2 bits and are packed in the storage stack starting at bit 0 of the next computer word following the logical independent attributes. An entity need not have any logical independent and logical dependent attributes.

COLEASE computes and stores (1) the number of bits needed to store each attribute, (2) the word within the entity assigned, (3) the starting bit position within the word for storage of the attribute, and (4) the attribute name. Each element of a dimensioned attribute occupies a separate position in the bookkeeping. The total number of words required to store an entry of each entity is determined and saved. The number of words which must be reserved in the storage stack is the total number of words required to store an entry of an entity times the number of entries.

For the logical binary network for each entity, COLEASE determines every path through the logical binary network that leads to each dependent attribute. The status of each logical independent attribute required to mmke the path true, and thus the logical dependent attribute true, is determined and saved. Also saved is the logical dependent attribute name to which the path leads. The status of a logical independent attribute may be either true (a 2-bit value of 01 binary or 1 decimal), or false (a 2-bit value of 10 binary or 2 decimal). A function mask which contains the status of each logical independent attribute that is required to make the path true (in the same bit positions as they are stored in the storage stack) is built. If a logical independent attribute is not on the path, its status does not matter, and the function mask will contain a 2-bit value of 00 binary or 0 decimal.

When the end of Paragraph III is detected, a labeled COMMON block statement is generated for each entity (the name of the COMMON block is the entity name) and storage is provided for the attributes of one entry of the entity (following the generated PROGRAM statement). It is important that these COMMON blocks occupy a continuous space in memory in the order declared. Because the IBM 370-155 loader ensures that COMMON blocks start on a two-word boundary, it is necessary that some entities have a dummy attribute (maximum value equal to zero) to make the number of attributes in the entity an even number. Next, a labeled COMMON block named ATTB is generated and storage is provided for the bookkeeping associated with all the attributes; a labeled COMMON block named FUN is generated and storage is provided for the bookkeeping related to all the paths within the logical binary network; a labeled COMMON block named ENTITY is generated and storage is provided for the bookkeeping for the information for all the entities; and then a labeled

COMMON block named STACK is generated and storage is provided for all entries of all the entities. Finally, the FORTRAN statements that are necessary to finish the bookkeeping are generated and followed by a CALL statement to the declared execution routine and the rest of the program statements.

A BLOCK DATA routine which contains the COMMON blocks and DATA statements needed to initialize the bookkeeping variables is generated (following the END statement for the generated program). An entry in the ATTB COMMON block contains three words: the first is the storage stack word relative to the first word in the stack for the entry of the entity for the attribute; the second is the starting bit position within the stack word for the attribute; and the third is the numer of bits required to store the attribute. After the computer code generated in the program is executed, this third word will contain a computer mask for the attribute positioned where the attribute is located in the storage stack. An entry in the ENTITY COMMON block contains 9 words, as follows: (1) the number of entries for the entity, (2) the number of attributes in the entity (an attribute dimensioned to N will be considered as N attributes), (3) the number of computer words in the storage stack required for a single entry of the entity, (4) the starting computer word in the storage stack for the first entry of an entity, (5) the number of computer words in the stack required to store the logical independent attributes for an entry of an entity, (6) the location of the first logical independent attribute in the stack for an entry of an entity, (7) the number of paths in the logical binary network, (8) the location of the first path for the entity in the FUN COMMON block, and (9) the location of the first attribute for the entity in the ATTB COMMON block. An entry in the FUN COMMON block contains two words: the first is the function mask containing the appropriate status of each logical independent attribute required to make the logical dependent attribute true; and the second is the pointer to the ATTB COMMON block for the logical dependent attribute. After the computer code generated in the program is executed, this second word will contain the starting bit position within the logical dependent storage stack word for the attribute. COLEASE, in its current form, can accommodate only one logical independent attribute computer word (16 logical independent attributes for an IBM computer).

COLEASE defines two entities for the user which do not require any storage in the storage stack and are stored in their labeled COMMON block. The first such entity is LOGICV, which contains two attributes: (1) the value for logical true, LTRUE, and (2) the value for logical false, LFALSE. The other entity is NOATTB, which contains a single attribute NOATTB that is dimensioned to the number of entities and contains the number of$attributes in each entity. The DATA statements necessary for these entities are generated next.

An END statement for the BLOCK DATA routine is not generated because it is assumed that the user will also need to enter data into the BLOCK DATA routine. The first part of Paragraph IV is considered to be the remainder of the BLOCK DATA routine.

6.3.3 Paragraph III

Paragraph III contains input information that specifies the use for each entity and the name of the subroutine with which execution is to begin. Each time the COLEASE TASK statement is encountered in Paragraph IV, COLEASE searches the data that have been entered in Paragraph III to determine the entities which will be used by the subroutine. In the program generated by COLEASE, a CALL statement is provided to the executive routine that is declared in the input to Paragraph III.

6.3.4 Paragraph IV

Paragraph IV contains intermixed FORTRAN statements, which comprise the main body of the program, and COLEASE statements, which request some action by COLEASE.

The TASK statement causes COLEASE to generate a SUBROUTINE statement with the declared parameters and to generate a labeled COMMON block for each requested entity.

The EXTRAC statement causes COLEASE to generate a CALL statement to subroutine EXTRAC with the entity name changed to an entity number. The attributes for the specified entry of the entity are retrieved from the storage stack and put in the COMMON block for the entity, one attribute per computer word, in integer format.

The FIND statement causes COLEASE to generate a CALL statement to subroutine FIND with the entity name changed to an entity number and the attribute name changed to an attribute number. The declared attribute of the specified entry of the entity is retrieved from the storage stack and put in the prescribed local variables in integer format. An EXTRAC can be thought of as a FIND for each attribute for an entry of an entity.

The REPACK statement causes COLEASE to generate a CALL statement to subroutine REPACK with the entity name changed to an entity number. The values of the attributes from the COMMON block for the entity are packed into the specified entry for the entity in the storage stack.

The STORE statement causes COLEASE to generate a CALL statement to subroutine STORE with the entity name changed to an entity number and the attribute name changed to an attribute number. The value of the local variable is stored in the declared attribute of the specified entry of the entity in the storage stack. The declared attribute is not updated in the COMMON block for the entity. A REPACK can be thought of as a STORE for each attribute for an entry of an entity.

The LOGIC statement causes COLEASE to generate a CALL statement to subroutine LOGIC with the entity name changed to an entity number. The value for each logical dependent attribute is determined for the specified entry of the entity based on the value of the logical independent attributes for the same entry of the entity in the storage stack. The value for the logical dependent attributes are stored in the same entry of the entity in the storage stack. Initially, the logical dependent attribute computer word in the storage stack is set to/zero. The logical independent attribute computer word in the storage stack is ANDed with a function mask, and, if the result is equal to the function mask, then the logical dependent attribute is ORed with a true status; otherwise, the logical dependent attribute is ORed with a false status. Thus, it is possible to have a logical dependent attribute status of both true and false; this indicates that one or more paths to the logical dependent attribute were true and one or more paths were also false. This indication should be considered as a true status.

6.4 Output

Output from COLEASE includes both printed output and magnetic tape. The amount and format of printed output depends upon the value of the print option that is specified in the Paragraph I input (see Section 6.2). If the print option is one, only the header message and the IDENTIFY statement from Paragraph I input are printed. If the print option is two, the header message, the Paragraph I input, the Paragraph II input, the Paragraph III input, and the COLEASE statements in Paragraph IV are printed. If the print option is three, the header message, the Paragraph I input, the Paragraph II input, the listing of the bookkeeping information for each entity, the listing of the paths within the logical binary network for each entity, the Paragraph III input, and the COLEASE statements in Paragraph IV are printed. If the print option is four, the header message, the Paragraph I input, the Paragraph II input, the listing of the bookkeeping information for each entity, the listing of the paths within the logical binary network for each entity, the Paragraph III input, and the Paragraph IV input are printed.

Magnetic tape output takes the form of an entire FORTRAN program ready to be compiled, and includes (1) the Paragraph I input with the character "C" in Column 1, (2) the Paragraph II input with the character "C" in Column 1, (3) the Paragraph III input with the character "C" in Column 1, (4) the PROGRAM and BLOCK DATA routine generated by COLEASE with the characters "COLEASE" starting in Column 74, (5) the Paragraph IV FORTRAN statement, (6) the Paragraph IV COLEASE statements with the character "C" in Column 1, (7) the FORTRAN code generated for each Paragraph IV COLEASE statement with the characters "COLEASE" starting in Column 74, and (8) the FORTRAN subroutines generated by COLEASE to process the COLEASE requests at program execution time with the characters "COLEASE" starting in Column 74.

6.5 Verification

Verification of COLEASE was accomplished by examining debug prints of intermediate results, independently testing selected subprograms, performing several runs on test data sets, and reviewing the printed output and the magnetic tape produced by each run of COLEASE.

6.6 Computer Requirements

COLEASE is written for execution only on the CDC 6600 computer. Any program processed by COLEASE can be executed on a computer with the computer word size (in bits) as specified in the Paragraph I input. COLEASE requires 12,544 words (30,400 octal) to execute on the CDC 6600 computer. Typically, the geometry processor (6,227 statements) takes 19.8 seconds for COLEASE to execute while the traffic simulation processor (11,402 statements) takes 38.2 seconds.

6.7 Documentation

Documentation for COLEASE includes an in-house user's guide and COMMENT statements within COLEASE.

6.8 Additional Information

Table 6.2 provides a comparison between conventional storage and COLEASE storage for the geometry processor, and Table 6.3 is for the traffic simulation processor.

Conventional storage requires a computer word for each attribute. Thus the number of words required to store an entity is the number of entries times the number of attributes for the entity. The number of words required to

TABLE 6.2. GEOMETRY PROCESSOR STORAGE COMPARISON

Entity	Number of Entries I	Number of Attributes J	Conventional Storage I*J	Number of Words Per Entry K		COLEASE Storage I*K + 4*J + 9	
				CDC	IBM	CDC	IBM
APPRO	12	26	312	3	5	149	173
ARC	20	6	120	1	2	53	73
CONFLT	1,000	10	10,000	1	2	1,049	2,049
LANE	50	20	1,000	3	5	239	339
LINE	100	4	400	1	2	125	225
PATH	125	94	11,750	15	31	2,260	4,260
SDR	30	40	1,200	7	14	379	589
Total			24,782			4,254	7,708

TABLE 6.3. TRAFFIC SIMULATION PROCESSOR STORAGE COMPARISON

Entity	Number of Entries	Number of Attributes	Conventional Storage	Number of Words Per Entry K		COLEASE Storage I*K + 4*J + 9	
	I	J	I*J	CDC	IBM	CDC	IBM
APPRO	12	26	312	3	5	149	173
CONFLT	1,000	12	12,000	2	3	2,057	3,057
LANE	50	28	1,400	3	6	271	421
PATH	125	132	16,500	13	24	2,162	3,537
SDR	30	40	1,200	7	14	379	589
VEHD	200	40	8,000	6	9	1,369	1,969
VEHF	200	12	2,400	1	2	257	457
VEHIL	200	20	4,000	2	2	489	489
Total			45,812			7,133	10,692

store an entity by COLEASE is the number of words for the storage stack (the number of entries times the number of words per entry) plus one word for each attribute for the COMMON block for the entity, plus the bookkeeping storage (three words for each attribute plus nine words for the entity). The logical binary network storage requirements have not been included in this discussion, but they would be two words for each path in the network. The number of words required to store an entry of an entity is dependent upon the maximum value for each attribute. As the number of bits for an attribute approaches one computer word, COLEASE storage becomes less efficient.

COLEASE stores an average of 5.83 attributes per computer word for CDC 6600 computers and 3.22 attributes per computer word for IBM 370-155 computers for the geometry processor. Colease stores an average of 6.42 attributes per computer word for CDC 6600 computers and 4.28 attributes per computer word for IBM 370-155 computers for the traffic simulation processor. Appendix E contains the printed output from COLEASE for the geometry processor and the traffic simulation processor with the print option equal to three.

As with any storage management technique, increased execution time is traded for decreased storage requirements.

The subroutines generated by COLEASE to process the execution-time requests are available in FORTRAN IV, CDC assembly language (COMPASS), and IBM assembly language (ALC). The assembly language versions provide faster execution than is possible with the FORTRAN version.

7.0 FIELD DATA COLLECTION AND ANALYSIS

7.1 Introduction And Purpose

To aid in collecting real-world traffic performance statistics which could be used for calibrating the simulation model and which would serve as input to the traffic simulation pre-processors, a new generation of field data collection and recording devices was developed. A delay recording device was developed to record observed stopped delay, queue delay, volumes, headways, and signal indications on voice-grade cassette tapes. A special time recording device was also developed to record observed headways and to time selected critical traffic maneuvers.

To retrieve the data stored by the delay recording device, a computer program, called ADPRO, was developed for processing analog-to-digital conversion. This program (1) reads the coded analog signals from the cassette tapes produced by the delay recording device and (2) produces a digital tape containing the recorded data. A delay, volume, and headway processor, DVHPRO, (1) accepts the digital tapes produced by ADPRO and (2) gathers and prints observed traffic performance statistics for selected time intervals. These performance statistics may be used as input to the traffic simulation processor or to calibrate the model.

A headway distribution fitting processor, DISFIT, was developed to aid in selecting appropriate mathematical descriptors of observed traffic headway distributions. DISFIT (1) reads headways recorded by the delay recording device, the time recording device, or other event timing device; (2) computes location and dispersion parameters for the data, fits selected mathematical distributions to the empirical headway data, calculates Chi-Square for the Chi-Squared goodness-of-fit test, and determines the maximum cumulative difference for the Kolmogorov-Smirnov one-sample test; and (3) plots a histogram of the input headway data and of each distribution fitted. The interrelation among these processors is shown in Fig 2.2.

7.1.1 Past Field Studies

A previous research project at the Center for Highway Research, The University of Texas at Austin, was concerned with the measurement of volume and delay at street and highway intersections (Ref 38). Extensive field measurements of traffic characteristics that were observed at 19 locations were recorded and analyzed. The locations ranged in complexity from low-volume intersections operating under stop sign control to high-volume, signalized intersections. These data were readily available for evaluating and calibrating the traffic simulation model.

In the earlier study, an electro-mechanical device was used to record the observed data on punched paper tape. The deficiencies noted in the electro-mechanical delay recording device were (1) the lack of a specific time reference recorded in each data record, (2) the bulk of the equipment, (3) its complex operation, (4) its lack of portability, (5) its dependence upon an AC power supply, (6) the requirement that each observer input module be physically connected to the central recording unit, and (7) the difficulty with displaying current counter readings to the observer. Over 240 hours of field studies were recorded in Texas using this device from 1965 to 1967.

7.1.2 Data Requirements

The inputs to the traffic simulation package are described in Section 3.2, Section 4.2, and Section 5.2. To prepare the input, the following data are needed: (1) the equivalent hourly volume of traffic to enter each inbound approach during the study time, (2) the mathematical distribution to be used to describe the headways of vehicles entering each inbound approach, (3) the lane occupancy percentages for each inbound approach lane, (4) the distribution of turning vehicles for each inbound approach, (5) the vehicle mix for each inbound approach, and (6) the driver mix for each vehicle class. In addition to these statistics, the geometry of the intersection is recorded and signal indications and settings are noted. Less field data are required if the user is willing to accept estimates or program-supplied default values for some of the data.

Field delay measurements were taken as the overall basis for validating the traffic simulation model. At unsignalized intersections, the statistic of most interest is the queue delay. This is the time each vehicle spends in a queue waiting to enter the intersection; it includes move-up time within the queue. At signalized intersections, the statistic of most interest is stopped delay. This is the time each vehicle spends stopped in a queue waiting to enter the intersection; it does not include move-up time within the queue.

7.2 The Delay Recording Device

A new generation delay recording device was designed and built to gather field data. Its features were designed to overcome most of the limitations in previous devices.

7.2.1 Design Criteria

The new delay recording device was to (1) be portable; (2) use an independent DC power supply (a small motorcycle battery); (3) incorporate solid state electronic component reliability; (4) have a data sampling rate of 1 second; (5) provide an accurate, synchronized time base; (6) display current counter readings to observers; (7) record time, counter information, and device number onto inexpensive voice-grade cassette tape in analog form; and (8) be economical in construction and maintenance. The delay recording device was designed and constructed by the staff at the Center for Highway Research. Figure 7.1 presents the block diagram and the photograph for the delay recording device while Fig 7.2 gives the schematic diagram.

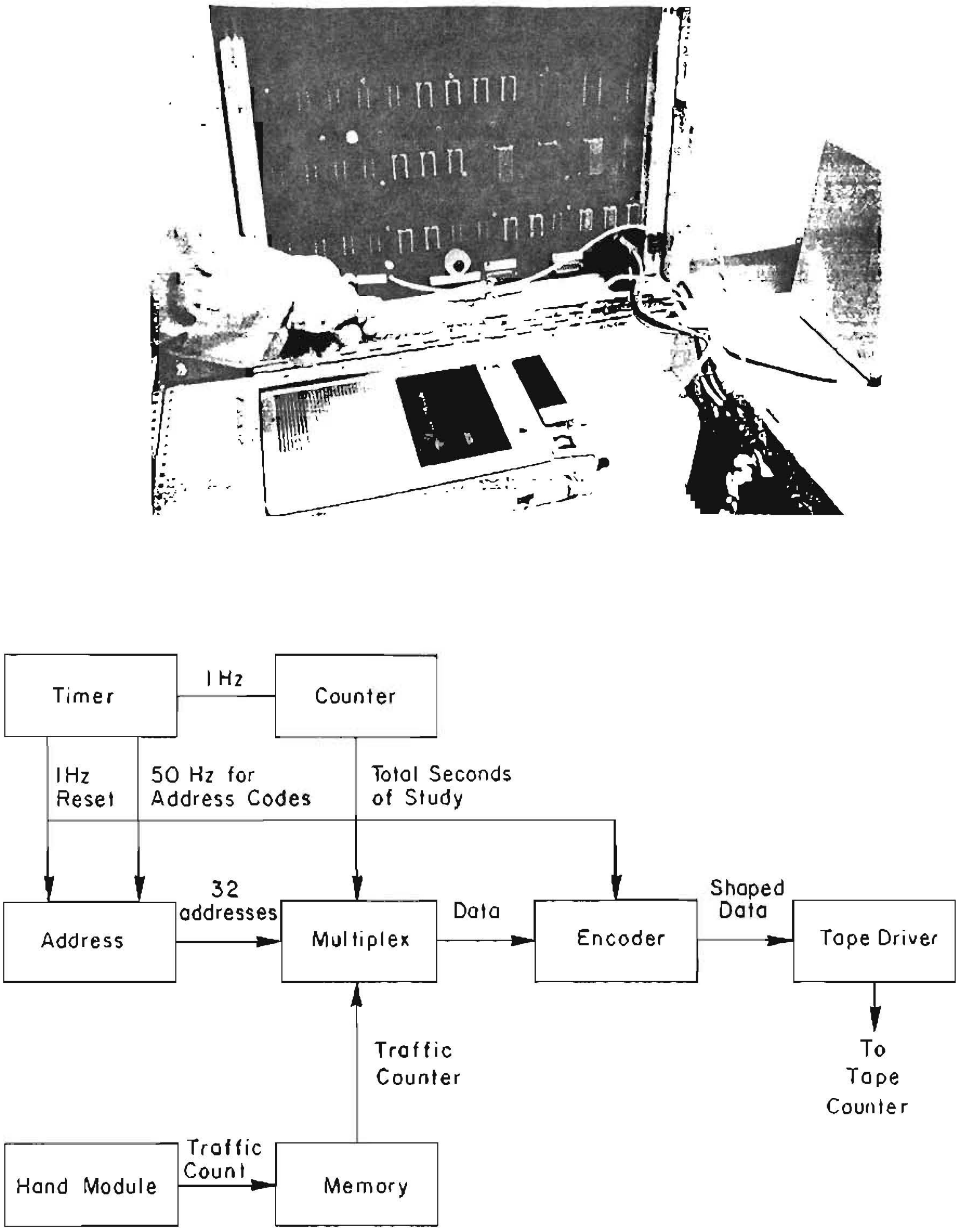


Fig 7.1. Photograph and block diagram of the delay recording device.

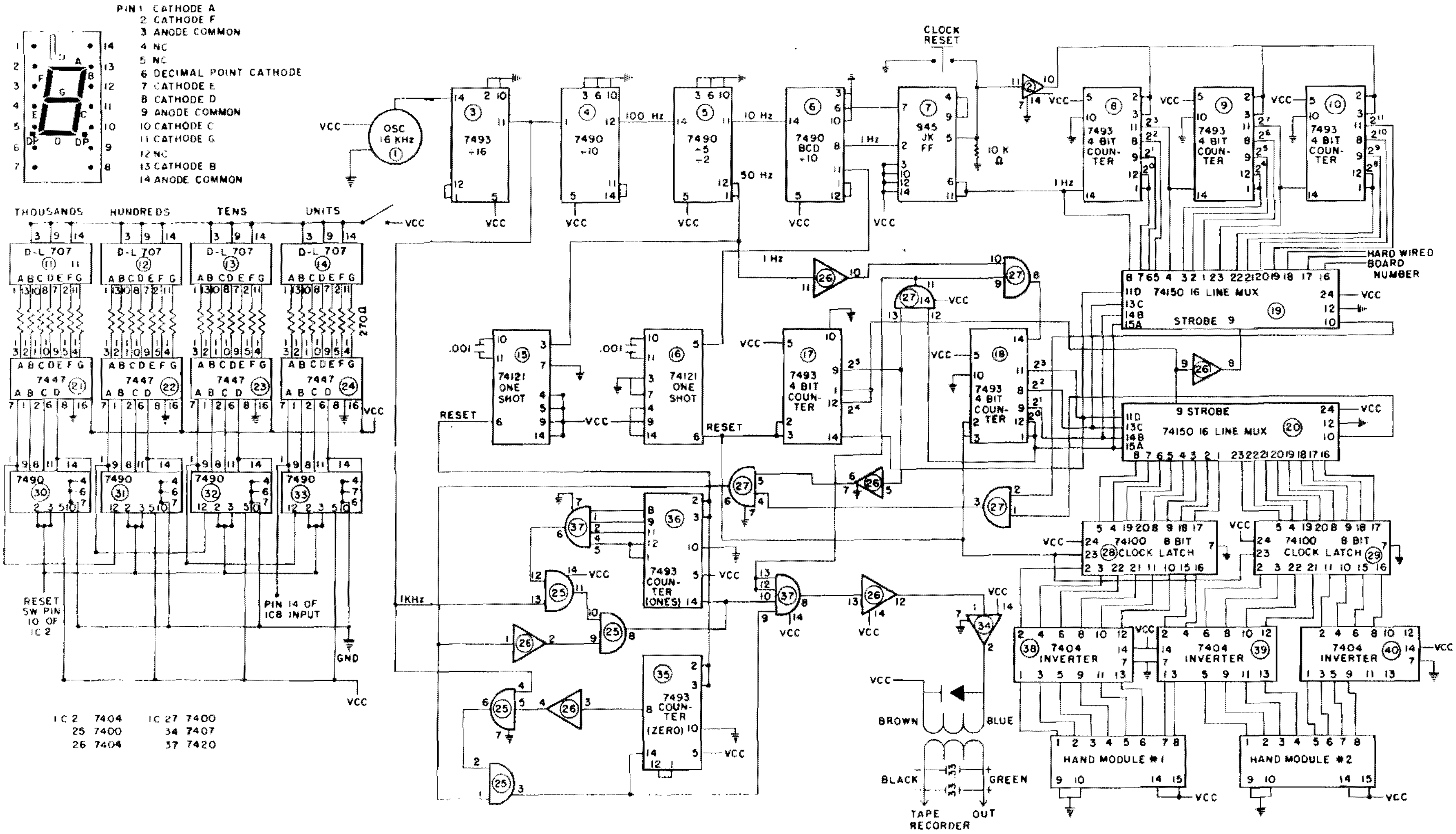


Fig 7.2. Schematic diagram for the delay recording device.

7.2.2 Input Requirements

There are two types of counters which can be connected to the delay recording device. An electronic counter was designed to incorporate increment, decrement, and zero switches. This counter uses a light emitting diode, LED, display to provide the user with a current counter reading. The counter may register digits from 0 to 99. Figure 7.3 gives the block diagram and the photograph for the electronic counter while Fig 7.4 gives the schematic diagram.

A mechanical counter is also available for use with the delay recording device. This input device is simply a pair of manually rotated thumb wheel switches. Each unit of the pair can be rotated separately; thus the counters are particularly useful when volume or headway data are being gathered, as adequate information can be obtained from a single digit of the counter. Thus, two channels of digital information can be entered by each mechanical counter. The mechanical counters require physical dexterity in the observer as the incrementing lever on both digits must be actuated simultaneously to go from 9 to 10 or vice versa.

7.2.3 Output

Each delay recording device is capable of recording data from two counter units. Figure 7.5 illustrates the 32 bits of numerical information that are recorded each second. An internal, crystal-controlled, resettable timer generates the one-second time reference. These bits are written as analog signals onto a voice-grade cassette tape recorded as damped (low amplitude) and undamped (high amplitude) sine waves. Each bit is 0.020 seconds long: a zero is 0.004 seconds of undamped sine waves (high amplitude) followed by 0.016 seconds of damped sine waves (low amplitude) and a one is 0.016 seconds of undamped sine waves followed by 0.004 seconds of damped sine waves. Each bit thus has 0.004 seconds of undamped sine waves followed by 0.012 seconds of either damped or undamped sine waves followed by 0.004 seconds of damped sine waves. It is the middle 0.012 seconds of each bit that is different and determines its value. Thus, 32 bits of information takes 0.640 seconds and is

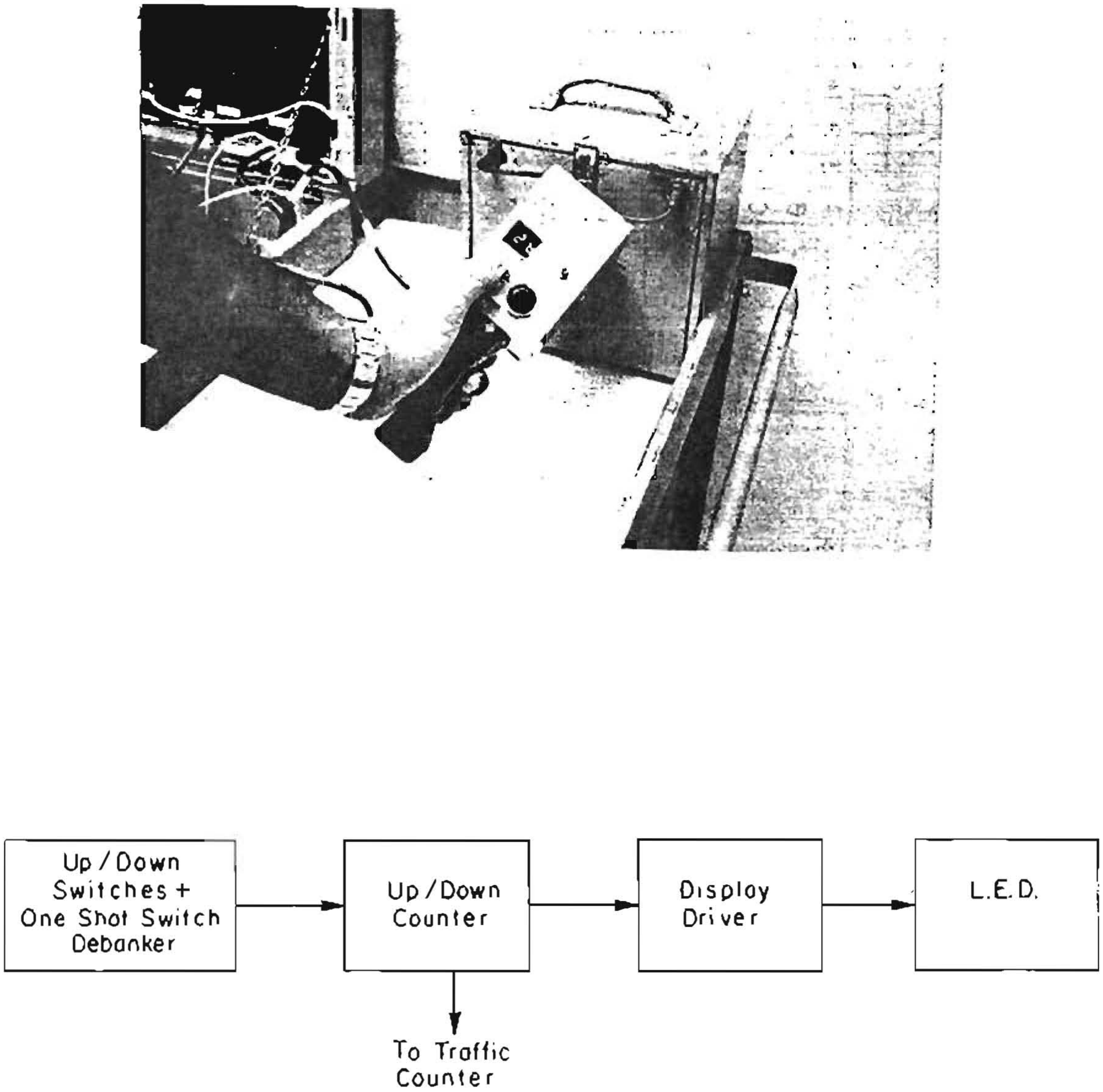
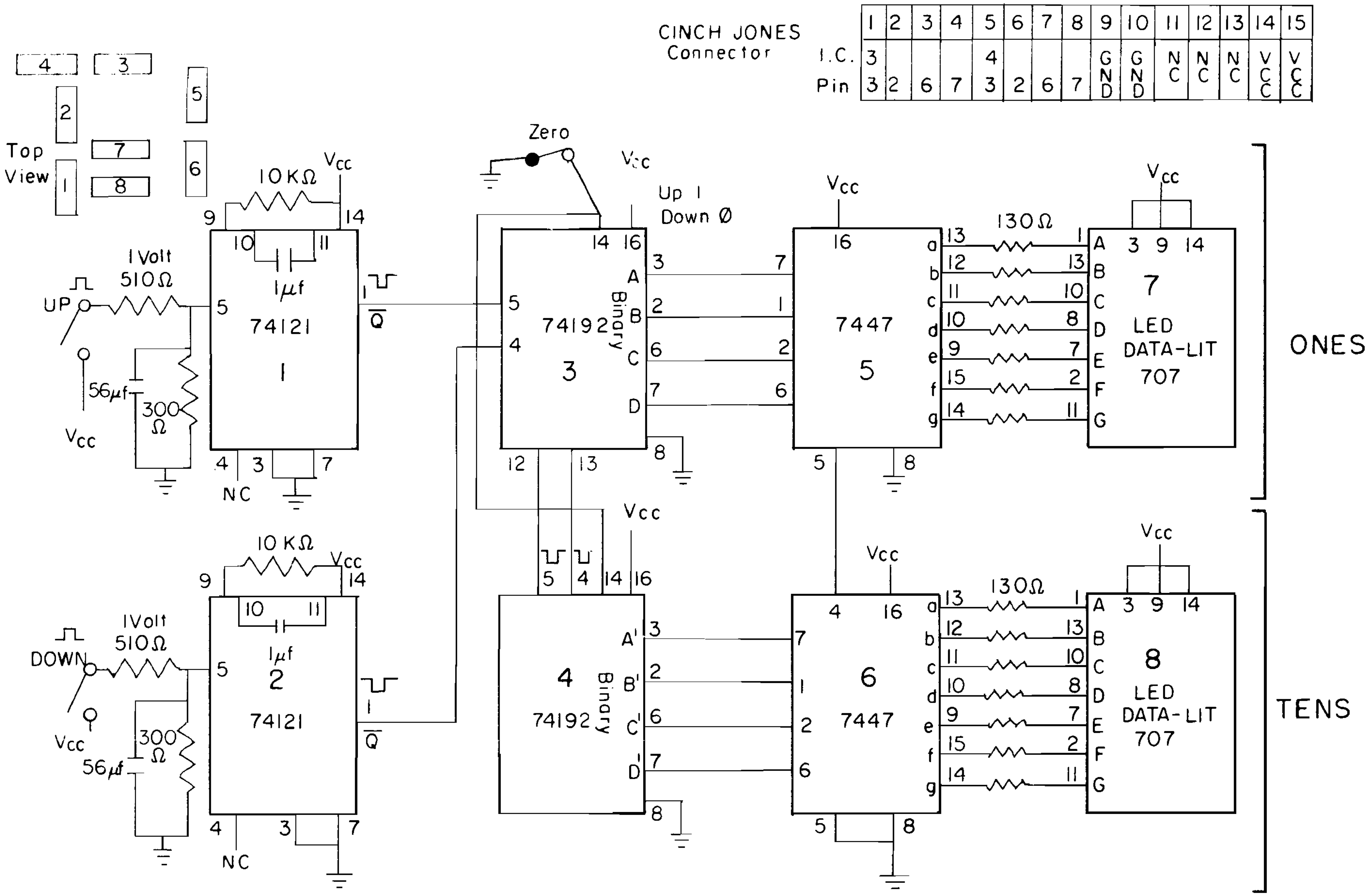


Fig 7.3. Photograph and block diagram of remote input counter.



CINCH JONES Connector

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
I.C.	3				4				GND	GND	NC	NC	NC	VCC	VCC
Pin	3	2	6	7	3	2	6	7							

Fig 7.4. Schematic diagram of remote input counter.

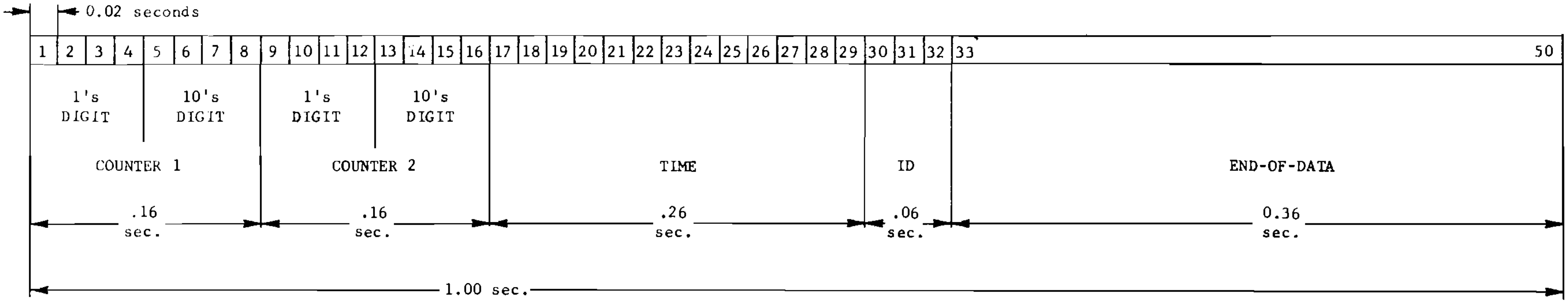


Fig 7.5. Data record for delay recording device.

ended by an end-of-data signal that consists of 0.004 seconds of undamped sine waves followed by 0.356 seconds of damped sine waves. The frequency of the sine waves is 1000 Hz (cycles per second); therefore, the cycle length of each sine wave is 0.001 second.

7.2.4 Field Observation Technique

The field observation technique that was used to measure queue delay at non-signalized intersections called for an observer to increment a counter each time a vehicle joined the queue of vehicles waiting to enter the intersection and to decrement the counter each time a vehicle crossed the stop line and entered the intersection. Thus, the current number of vehicles in the observed queue was indicated by the counter.

The field observation technique that was used to measure stopped delay at signalized intersections called for an observer to increment the counter each time a vehicle joined the queue of vehicles waiting to enter the intersection and to decrement the counter each time a vehicle in the queue started to move forward. In this manner, the current number of vehicles stopped in the observed queue was indicated by the counter.

The field observation technique that was used to measure volume called for an observer to increment a counter each time a vehicle crossed the stop line and entered the intersection. A single digit of the mechanical counter was used to record the volume data for a lane or for an approach.

The field observation technique that was used to record headways called for an observer to increment a counter each time a vehicle crossed a screen line that was located some specified distance away from the stop line on an inbound approach. A single digit of the mechanical counter could be used to record the headway data for an approach.

To record signal indications, a special relay device was developed. Up to 12 bits of information could be recorded on both input channels to a recorder. Normally a wire was connected from the green indication for each signal phase to a relay coil. When the green indication was on, the recorded data bit was one, but, when the indication was off, the bit was zero.

The delay recorder can be used to record digital information about any discrete phenomenon with respect to a one-second time base. The time history of the counter readings is recorded. Events can be timed by incrementing the counter each time an event occurs and then determining the time between two successive events.

7.3 Time Recording Device

Another new recording device was designed and built to gather field data. In effect, this device is a storage stopwatch.

7.3.1 Design Criteria

It was necessary for the time recording device to (1) be portable; (2) use an independent DC power supply (a small motorcycle battery); (3) incorporate solid state electronic component reliability; (4) store up to 32 time intervals; (5) have selectable time increments of 1.0 second, 0.1 second, and 0.01 second; and (6) be economical in construction and maintenance. The time recording device was designed and constructed by the staff at the Center for Highway Research. Figure 7.6 gives the block diagram and the photograph for the time recording device while Fig 7.7 gives the schematic diagram.

7.3.2 Input Requirements

The user must first position the time increment switch to the desired basis for timing: 1.0 second, 0.1 second, or 0.01 second. Next, the user must set the record/display switch to the record function. Timing of the first event is initiated by pressing the zero button. Each time the event button is depressed thereafter, the duration of the current event is stored in

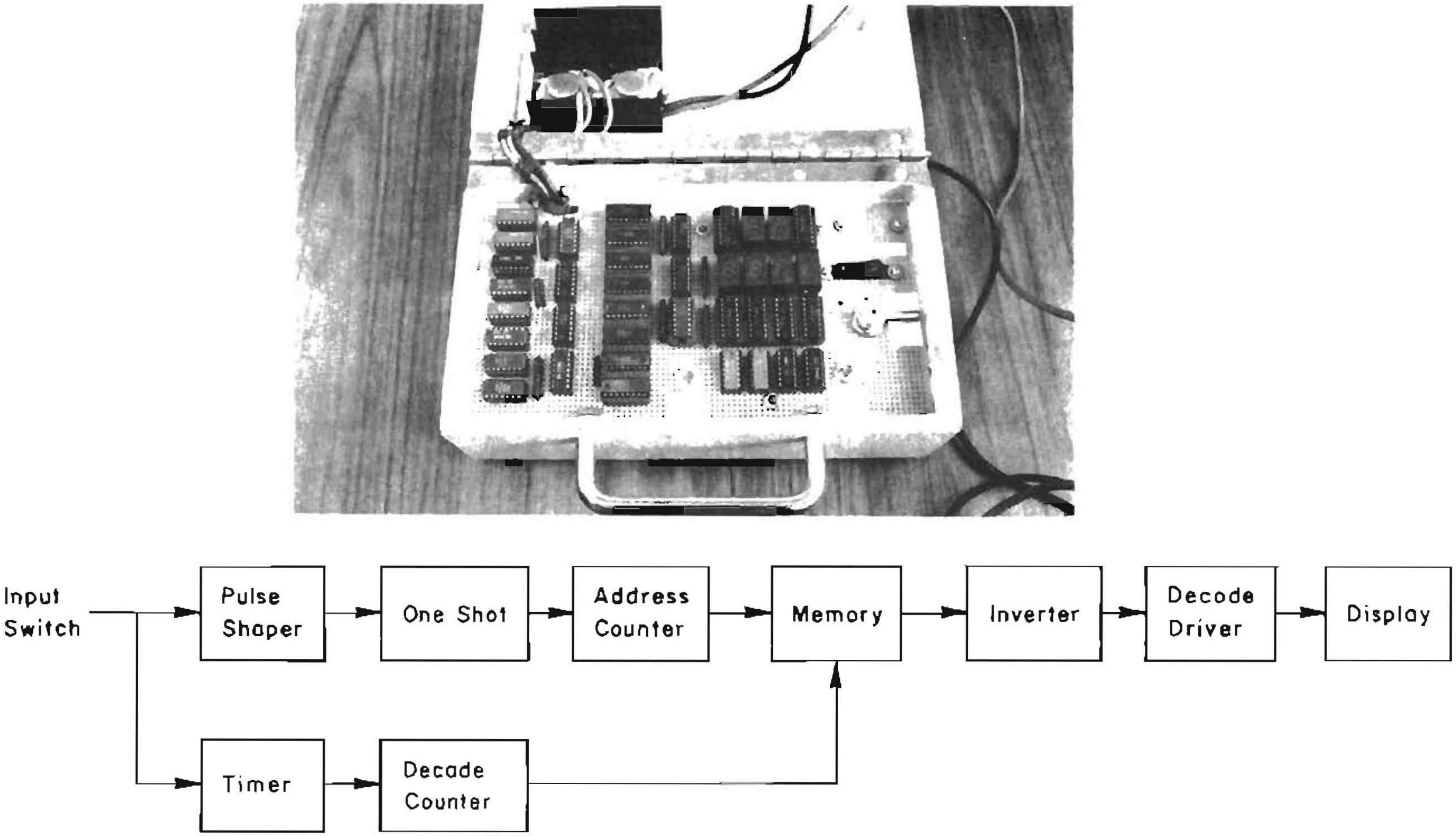


Fig 7.6. Photograph and block diagram of the time recording device.

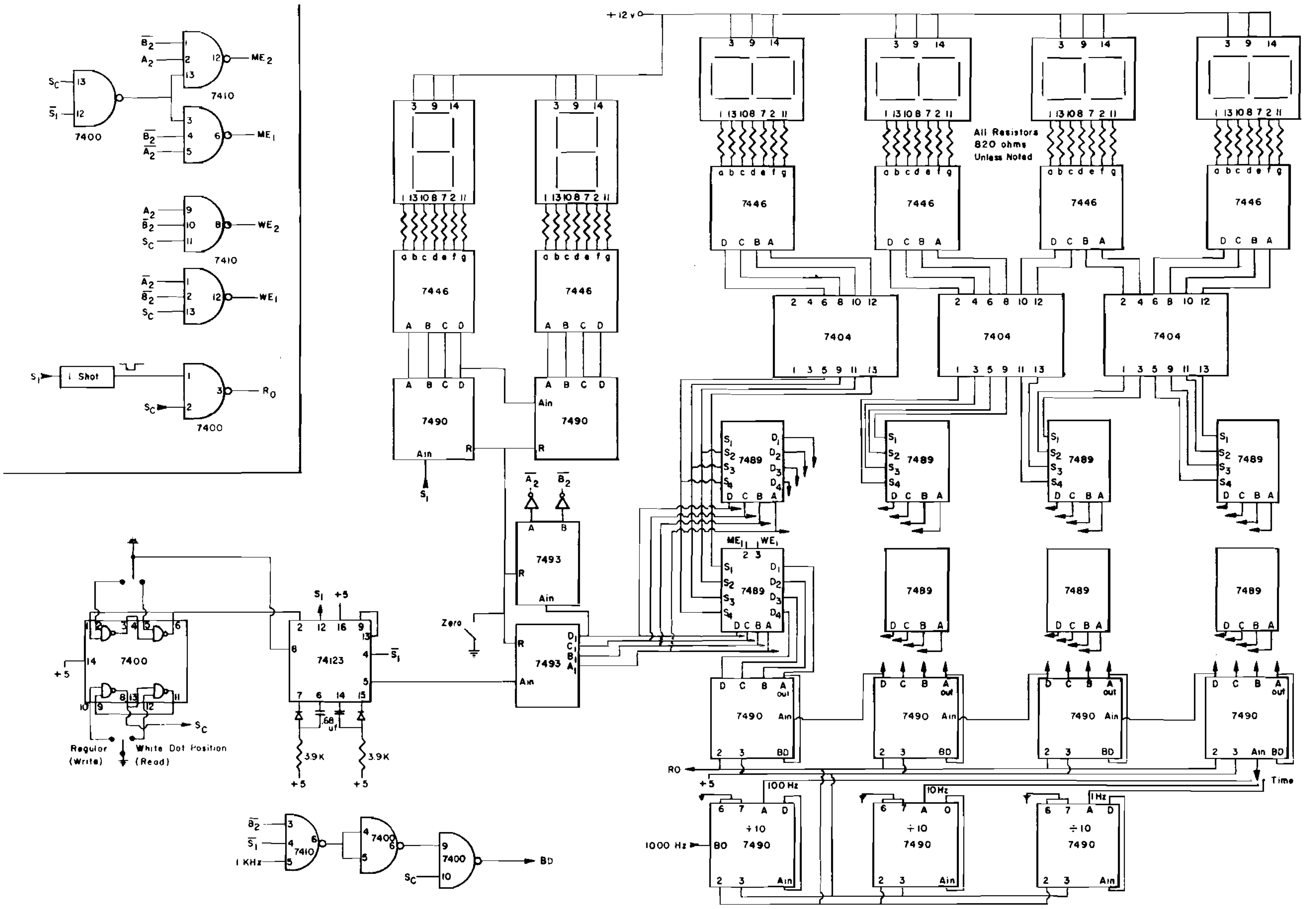


Fig 7.7. Schematic diagram for the time recording device.

a 32-position register stack and timing of a new event is begun. The current stack position is displayed for the user.

7.3.3 Output

After storing the desired number of timed intervals, not to exceed 32, the user may position the record/display switch to the display function and read the stored data. This display selectively shows the number of each stack position and the value of the measured time interval that is stored in each position. The entire stack can be examined in sequence by repeatedly depressing the event button. Displayed information can be transferred to a data sheet. The recorded time information can be displayed as often as needed.

7.3.4 Field Observation Technique

The field observation technique that was used to measure headways called for an observer to depress the event button on the time recorder each time a vehicle crossed a screen line that was located some specified distance away from the stop line. After 32 headways had been recorded, the observer would display each headway and transfer the information to a field data log book. A similar technique can be used to measure the time between any two events in a series.

7.4 Analog-to-Digital Conversion

Observed numerical information is recorded in analog form by each delay recording device. This information must be converted to digital form for recovery and subsequent interpretation.

7.4.1 Introduction And Purpose

The delay recording device writes the observed numerical information and time information onto voice-grade cassette recording tapes. To retrieve these data, a computer program called ADPRO was developed. This program supervises the operation of a special analog-to-digital conversion system, the HP2115A computer system, operated at the Division of Automation, D-19, of the Texas State Department of Highways and Public Transportation in Austin. Operationally, ADPRO (1) reads the analog data from up to 6 voice-grade cassettes simultaneously, (2) converts the analog data to digital data, and (3) writes a digital tape containing the digitized data. ADPRO consists of two programs: (1) PR18416, which digitizes the data and writes a 9-track magnetic tape, and (2) HPCDC, which transfers the 9-track magnetic tape to 7-track magnetic tape compatible with CDC computers.

7.4.2 Input Requirement

Up to 6 cassette tape play-back units (most recorders can play back also) are connected to a special wave-shaping instrument that operates external to the HP2115A system. This wave-shaping instrument converts all high-amplitude sine waves to a constant-level analog signal of approximately 5 volts. Low-level sine waves are converted to a signal of zero volts. The duration of each level of the two-level signal corresponds to the duration of the sine waves of different amplitude. Figure 7.8 illustrates the conversions performed by the wave-shaping instrument. Figure 7.9 gives the block diagram and the photograph of the wave shaping instrument while Fig 7.10 gives the schematic diagram.

The two-level analog signal from the wave-shaping instrument serves as input to the HP2115A system for conversion to digital form. The sampling rate for digitizing is selected such that at least three samples are taken during the minimum duration of the high-level signal (0.004 seconds). Data in a digital form are then processed by the HP2115A system.

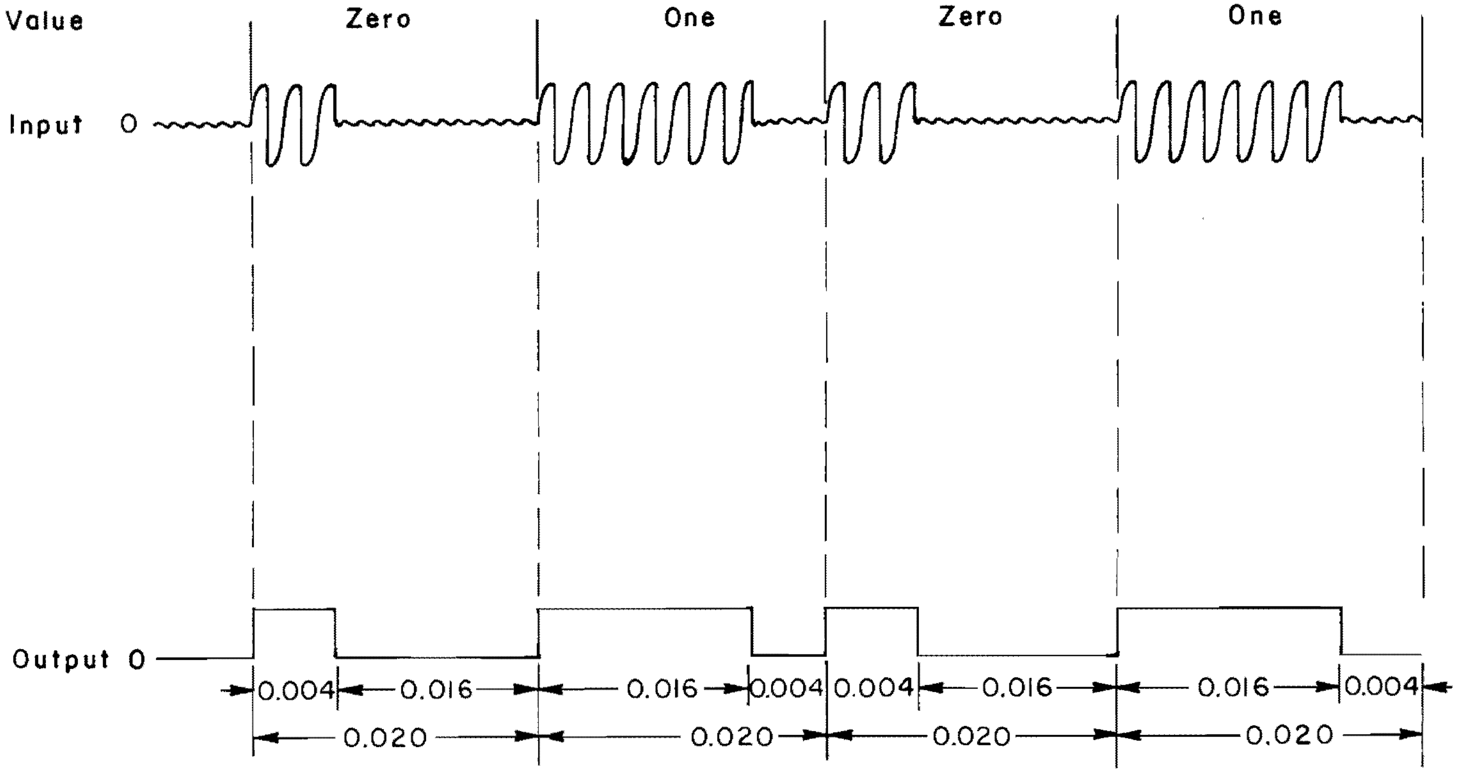


Fig 7.8. Input and output signals from the wave forming unit.

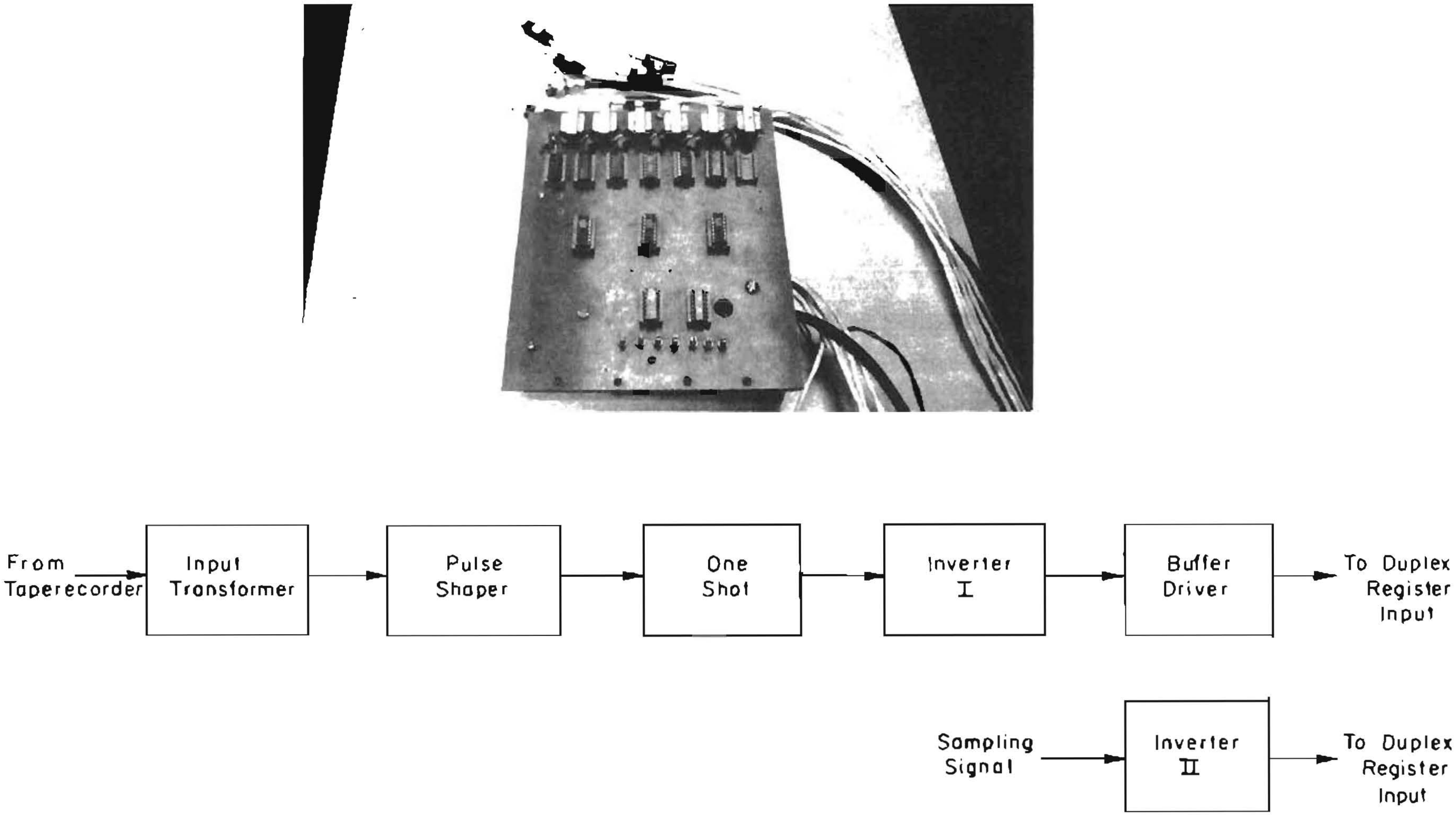


Fig 7.9. Photograph and block diagram of wave forming device.

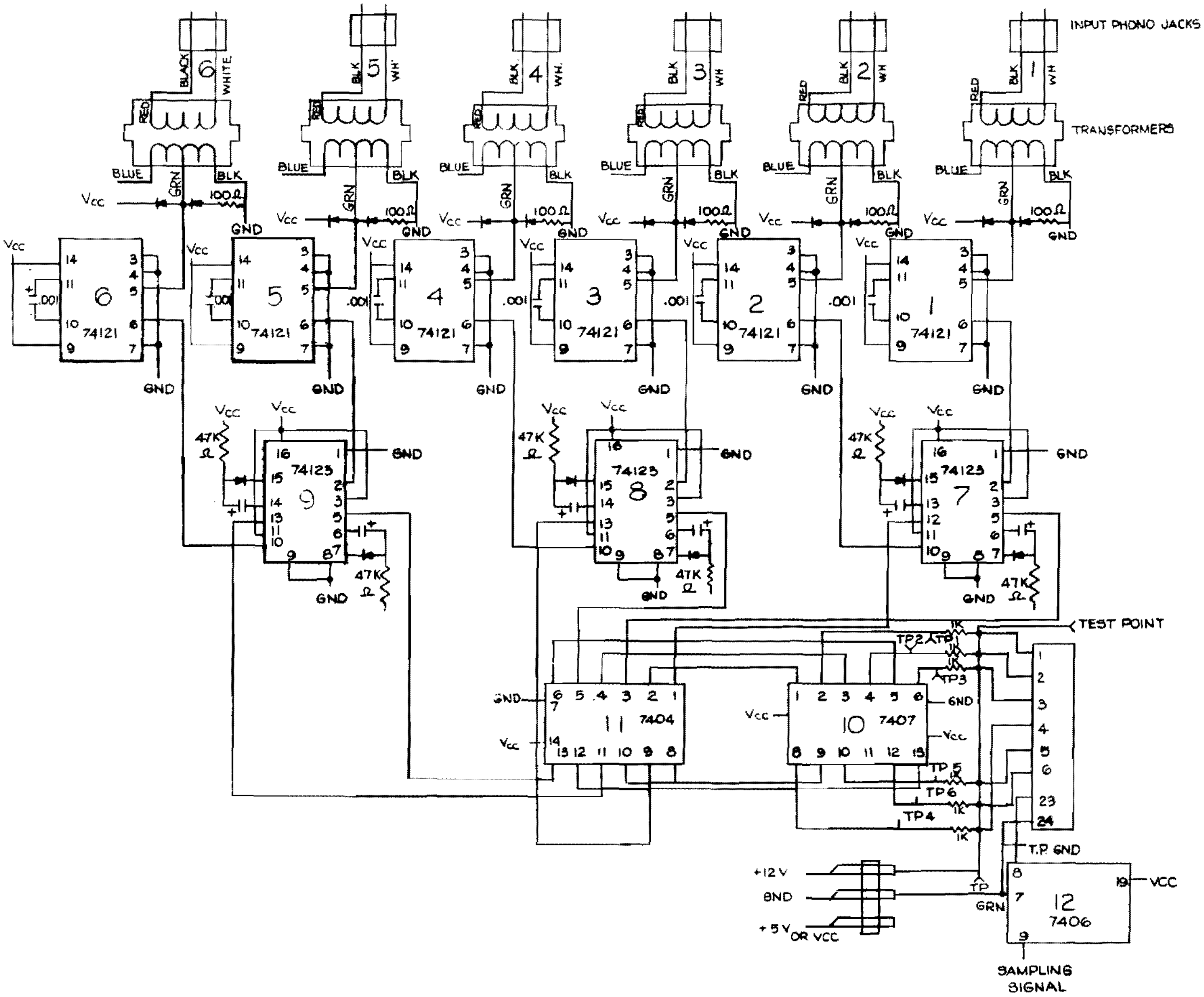


Fig 7.10. Schematic diagram for the wave forming device.

Options in PR18416 include (1) the number of cassette tapes to be processed, (2) the 60-character title for the run, (3) the digital filter option, (4) the halt-on-error option, and (5) the 9-track tape positioning option. The number of cassette tapes may range from 1 to 6. The 60-character title for the run identifies the data being processed. The digital filter option ensures proper bit identification. The halt-on-error option allows an automatic stop in the program if any data structure error is detected. The tape positioning option provides the user a means for (1) continuing from the current position, (2) beginning from the start of the tape, or (3) adding data at the end of previously recorded data sets.

The input required by HPCDC includes (1) the 9-track tape produced by PR18416, (2) the 60-character title for the run to be processed, (3) the 9-track tape positioning option, (4) the 7-track tape positioning option, and (5) the list ident option. The 9-track tape positioning option allows the user to rewind this tape or continue from the current position before searching for the title to be processed. The 7-track positioning option provides for (1) starting from the current position, (2) starting at the beginning of the tape, or (3) adding data at the end of data sets previously recorded.

7.4.3 Algorithms For Computation

The generalized flow of PR18416 is illustrated in Fig 7.11. The computer that is utilized in the HP2115A system has two DMA (direct memory access) channels (input and output). When the DMA channels are activated, data are transferred between an external device (e.g., an analog-to-digital converter or tape drives) and the computer memory while the computer may at the same time be performing other functions. PR18416 has two input buffers and two output buffers. While the DMA input channel is transferring data from the A/D converter into one of the input buffers, PR18416 may access the other to obtain data for computation. While PR18416 fills an output buffer, the DMA output channel may access the other output buffer and transfer data to the 9-track tape. The buffers are accessed alternately by the DMA channels and by PR18416. Provisions are made in PR18416 to ensure that no buffer being

PR18416

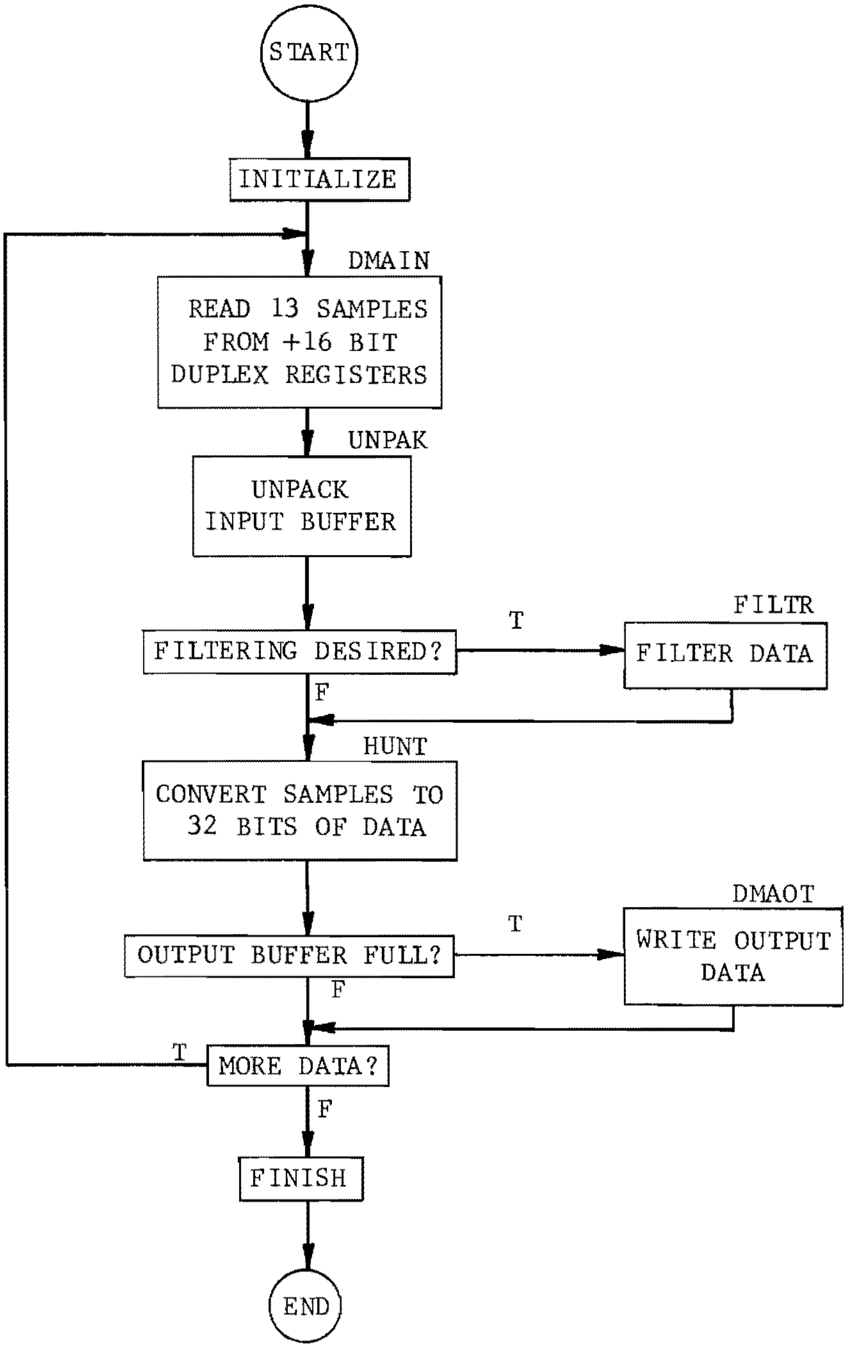


Fig 7.11. Generalized flow of PR18416.

accessed by a DMA channel overflows, which causes data to be lost.

Analog signals from the wave-shaping instrument are processed by the analog-to-digital converter and the digitized information is stored serially in a 16-bit register as a 1 for the high-level signal and as a 0 for the low-level signal. The 1 or the 0 from the first tape recorder occupies bit position zero in the register and data from successively sampled recorders follow in sequential higher order bit positions. All recorders are sampled on command from an external pulse generator at a design rate of approximately 1000 samples per second. Sampling rates between 750 and 1500 samples per second, depending on the number of recorders being processed, may be used successfully. The DMA feature of the HP2115A system automatically transfers the data from the 16-bit register to the available input buffer.

Subprogram DMAIN initiates the DMA process to read 13 cycles of data (normally 0.013 seconds of real time). Subprogram UNPAK simultaneously transforms the previously-read column-oriented data array into a row-oriented array that is stored as one word for each cassette tape. If digital filtering is requested, each set of 4 bits is checked for proper content. If a "0100" series is found, it is converted to "0000"; if a "1011" series appears, it is changed to "1111"; and if a "1101" series occurs, it is converted to "1111". Experience has shown that digital filtering is not necessary, however, if the analog recording is of good quality.

Next, each row-oriented 16-bit word (3 previously unprocessed bits plus 13 new data bits) is processed by HUNT to determine, by identifying a unique series of one zero followed by three ones, the beginning of a new data bit. During this search process, the number of samples with a 1 is counted by one counter, and the number of samples is registered on a second counter. If the number of samples with a 1 is less than half the number of samples, the bit is identified as a zero; otherwise, the bit is called a one. This bit is added to the data already detected for the appropriate cassette tape recorder. The end-of-data for the 32-bit record that represents one second of real time is detected when the number of samples exceeds 32. Then, the number which identifies the channel number corresponding to a particular cassette tape, along with the 32 bits of data, is added to the output buffer. When the output buffer is full, the DMA channel is activated to write the buffer content onto the 9-track tape. The 9-track tape is used because the 7-track tape drive is not fast enough to keep up with the DMA process. The operator must command PR18416 to discontinue input and complete the processing of data in the output buffer. The 9-track tape is IBM compatible.

HPCDC converts the 9-track magnetic tape to a 7-track CDC-compatible magnetic tape. The 60-character ident is converted from ASCII character format to CDC display code and written as a 6-word (60 bits per word) record. The data are then read and output as 500-word (60 bits per word) records.

7.4.4 Output

Output from PR18416 includes printed output and a 9-track magnetic tape. The printed output consists of informative messages printed on the HP2115A teleprinter. The 9-track magnetic tape includes the title for the run and the digitized field data. Table 7.1 gives the structure of the 9-track magnetic tape.

Output from HPCDC includes printed output and a 7-track magnetic tape. The printed output consists of informative messages printed on the HP2115A teleprinter. The 7-track magnetic tape includes the title for the run and the digitized field data. Table 7.2 gives the structure of the 7-track magnetic tape.

7.4.5 Verification

Verification of PR18416 was accomplished by using a test data set punched on paper tape and substituted for the cassette tape input. An ancillary program to list the 9-track magnetic tape on the teleprinter, LIST9, was used to verify that the test data set had been properly digitized. Also, a test data set on cassette tape was printed using a strip chart recorder and hand digitized. These data were then compared with the output from PR18416.

Verification of HPCDC was accomplished by using the two test data sets mentioned previously. Another ancillary program to list the 7-track magnetic tape on the teleprinter, LIST7, was used to verify that the test data set had been properly converted from the 9-track magnetic tape to the 7-track magnetic

Table 7.1 Data Structure for the 9 Track Tape

1. Start-of-tape marker
2. First data set
   a. 1st record (30 words) - 60 character title for run
   b. 2nd record (30 words) - 10 sets of data containing 32 bits of information and cassette tape number
   c. 3rd record (30 words) - same as 2nd record

   .

   .

   .

   y. nth record (30 words) - same as 2nd record
   z. End-of-file
3. Second data set
   a. 1st record (30 words) - 60 character title for run
   b. 2nd record (30 words) - 10 sets of data
   c. 3rd record (30 words) - same as 2nd record

   .

   .

   .

   y. nth record (30 words) - same as 2nd record
   z. End-of-file
4. Other data sets ended with end-of-file

   .

   .

   .

5. End-of-file (end-of-data marker)
6. Blank tape
7. End-of-tape marker

Table 7.2 Data Structure for the 7 Track Tape

1. Start-of-tape marker
2. First data set
    a. 1st record (6 words) - 60 character title for run
    b. 2nd record (500 words) - 500 sets of data containing 32 bits of information and cassette tape number
    c. 3rd record (500 words) - same as 2nd record
    .
    .
    .
    y. nth record (<500 words) - same as 2nd record
    z. End-of-file
3. Second data set
    a. 1st record (6 words) - 60 character title for run
    b. 2nd record (500 words) - 500 sets of data
    c. 3rd record (500 words) - same as 2nd record
    .
    .
    .
    y. nth record (<500 words) - same as 2nd record
    z. End-of-file
4. Other data sets with end-of-file
    .
    .
    .
5. End-of-file (end-of-data marker)
6. Blank tape
7. End-of-tape marker

tape.

7.4.6 Computer Requirements

ADPRO requires an HP2115A computer system with (1) 8K of core memory, (2) teleprinter terminal, (3) 9-track and 7-track magnetic tape drives, (4) DMA channels 1 and 2, (5) +16-bit duplex registers, (6) a 1000-Hz pulse generator, and (7) an analog-to-digital converter. The standard operating system included (1) a magnetic tape absolute loader, (2) a paper tape absolute loader, (3) a relocatable loader, (4) a FORTRAN compiler, (5) an HP2115 assembly language assembler, and (6) a relocatable library of standard software.

PR18416 requires the same amount of time to digitize the data as it originally took to record the data on cassette tapes. One hour of field data on 6 cassette tapes takes one hour to digitize. Two studies, each being for a duration of one hour and using 3 cassette tapes, could be digitized in a single one-hour session.

HPCDC requires about 2 minutes to convert each hour of data from all 6 cassette tapes to 7-track form.

7.4.7 Documentation

Documentation for ADPRO consists of numerous COMMENT statements within each of the programs and an in-house user's guide. Appendix F.1 gives the listing for PR18416, HPCDC, and several common subprograms used by each.

7.5 The Delay, Volume, And Headway Processor

7.5.1 Introduction And Purpose

The purpose of the delay, volume, and headway processor, DVHPRO, is to (1) read the digital 7-track magnetic tape produced by ADPRO and (2) gather and print the observed performance statistics for selected time intervals. These performance statistics can be used as input to the traffic simulation processor or to calibrate the model. DVHPRO is capable of gathering queue or stopped delay, volume, average delay, headways, and signal indications for selected time intervals.

7.5.2 Input Requirements

DVHPRO accepts as input the 7-track magnetic tape produced by ADPRO and several options, which include (1) the title of the ADPRO run to be processed, (2) the number of cassette tapes from the magnetic tape to be processed, (3) the tape positioning option, (4) the time interval for summarizing statistics, and (5) the desired statistics. Table 7.3 gives the input and its format for DVHPRO.

7.5.3 Algorithms For Computation

DVHPRO reads the 7-track magnetic tape and separates the data according to the cassette tape numbers. A disk file named TAPE1 will have only the data digitized from cassette tape 1, and so on. To gather queue or stopped delay, the program sums the prescribed counter reading for the specified time interval, stores the sum, and reports the sum. In the summation process, some data points are synthesized when there is a time gap in the data. Also, a counter series of, say, 8, 9, 0, and 11 will be changed to 8, 9, 10, and 11 to reduce the error when using the mechanical counters. The amount and percent of data synthesized are reported. The delay will be in units of vehicle-seconds.

Table 7.3 Input and Format for DVHPRO

1. 7 track tape produced by ADPRO
2. Delay, volume, and headway processor options
   a. 60 character title from adpro run for desired run
   b. Number of CASSETTE TAPES to process
   c. Tape positioning option
   d. Time interval for SUMMARIZING statistics
   e. Desired statistics
      1. Queue or stopped delay
         a. Tape number
         b. Counter number
         c. Type of counter
            1. Electronic
            2. Mechanical
      2. Volume
         a. Tape number
         b. Counter number
         c. Counter digit
         d. Type of counter
            1. Electronic
            2. Mechanical
      3. Average delay
         a. Queue or stopped delay
            1. Tape number
            2. Counter number
         b. Volume
            1. Tape number
            2. Counter number
            3. Counter digit
      4. Headway
         a. Tape number
         b. Counter number
         c. Counter digit

(continued)

Table 7.3 (continued)

- d. Type of counter
  - 1. Electronic
  - 2. Mechanical
- 5. Signal indications
  - a. Tape number

To gather volume statistics, each time the prescribed counter reading changes values, the absolute value of the change is added to the sum. This sum is then stored and reported for each specified time interval. Thus, when the counter reading goes from 9 to 0, the sum is incremented by 1.

To report average delay, DVHPRO divides the delay (converted to an equivalent hourly delay) by the volume (converted to an equivalent hourly volume) for the specified cassette tape number and counter.

To determine headways, each time the prescribed counter reading changes, the elapsed time is written onto the specified disk file. The headways will thus be accurate only to the nearest second. For low-volume approaches, this seems to be adequate.

7.5.4 Output

Output from DVHPRO includes printed output and optionally a disk file. The printed output includes (1) the 60-character title of the run processed, (2) the number of data points on each cassette tape, (3) the cumulative desired statistics by time increment, (4) the number and percent of data points synthesized, and (5) any error messages. The disk file output is produced if headways are processed. It includes the 60-character title of the run processed and the headways. The data are formatted to be used directly as input to the headway distribution fitting processor.

7.5.5 Verification

Verification of DVHPRO was accomplished by examining debug prints of intermediate results and by comparing the output from test runs with the results obtained by hand calculations for the same data.

7.5.6 Computer Requirements

DVHPRO requires 9152 words (21700 octal) on CDC computers. A typical run of one hour of data from 4 cassette tapes takes 30 computer seconds on CDC computers.

7.5.7 Documentation

Documentation for DVHPRO includes numerous COMMENT statements within the program and an in-house user's guide. Appendix F.2 provides a listing of DVHPRO.

7.6 The Headway Distribution Fitting Processor

7.6.1 Introduction And Purpose

The purpose of the headway distribution fitting processor, DISFIT, is to aid the user in the selection of an appropriate mathematical description of observed headway distributions. DISFIT (1) reads headways recorded by the delay recording device, the time recording device, or other event timing devices; (2) computes the location and dispersion parameters for the data, fits selected mathematical distributions to the empirical headway data based on the best-fit parameters calculated from the mean and variance of the data, calculates Chi-Squared, alpha, and the confidence level for the Chi-Squared goodness-of-fit test, and determines the maximum cumulative difference for the Kolmogorov-Smirnov one-sample test; and (3) plots a histogram of the input headway data and of each distribution fitted.

7.6.2 Input Requirements

The input required by DISFIT is very simple: (1) a 60-character title for the run and (2) one headway per input card image. The headways are assumed to be in seconds.

7.6.3 Algorithms For Computation

The headway distributions fitted are: (1) Erlang, (2) gamma, (3) lognormal, (4) negative exponential, (5) shifted negative exponential, and (6) uniform.

For the Erlang distribution (described in more detail in Section 4.3.3.1), the K and ALPHA parameters are

K = mean**2/variance (integer value) (7.1)

ALPHA = K/mean (7.2)

For the gamma distribution (described in more detail in Section 4.3.3.2), the A and ALPHA parameters are

A = mean**2/variance (7.3)

ALPHA = A/mean (7.4)

For the lognormal distribution (described in more detail in Section 4.3.3.3), the MEANY and the SDY parameters are

MEANY = ALOG(mean) - 0.5*ALOG((variance/mean**2)+1) (7.5)

SDY = SQRT(ALOG((variance/mean**2)+1)) (7.6)

For the negative exponential distribution (described in more detail in Section 4.3.3.4), the TBAR parameter is

$$\text{TBAR} = \text{mean} \tag{7.7}$$

For the shifted negative exponential distribution (described in more detail in Section 4.3.3.5), the TBAR and TAU parameters are

$$\text{TBAR} = \text{mean} \tag{7.8}$$

$$\text{TAU} = \text{mean} - \text{SQRT(variance)} \tag{7.9}$$

For the uniform distribution (described in more detail in Section 4.3.3.6), the A and B parameters are

$$A = \text{mean} - \text{SQRT(3*variance)} \tag{7.10}$$

$$B = \text{mean} + \text{SQRT(3*variance)} \tag{7.11}$$

For each distribution fitted, the expected number of occurrences is found for each one-second class from zero to fifty seconds. The Chi-Squared statistic is computed using the one-second classes. If the expected number of occurrences is less than 5, the classes are combined until it is 5. The number of degrees of freedom is then the actual number of classes, minus one, and minus one for each parameter estimated from the data. Alpha and the confidence level are then determined for each distribution fitted using the Chi-Square statistic and the number of degrees of freedom. The distribution that has the highest confidence level will be the best.

The maximum cumulative difference is calculated using the one-second classes from zero to fifty seconds. Since there is no degree of freedom for the maximum cumulative difference, the data should have more properly been randomly divided into two sets, the parameters for the distribution calculated from one of the sets of data, and the maximum cumulative difference found from the other set of data. Since this was not done, an alpha value cannot be correctly computed. The distribution that has the lowest maximum cumulative difference value will be best.

7.6.4 Output

Printed output from DISFIT includes (1) the title for the run; (2) the location and dispersion parameters for the input headway data; (3) a review of the analysis of each distribution fitted, including (a) the best fit parameters needed by the driver-vehicle processor, (b) the Chi-Squared statistic, the number of degrees of freedom, the alpha value, and the confidence level, (c) the maximum cumulative difference statistic, and (d) any error noted; (4) a histogram for each distribution fitted, including the input data and the distribution fitted; and (5) any execution error and a print of selected program variables (if there is an execution error).

7.6.5 Verification

Verification of DISFIT was accomplished by examining debug prints of intermediate results, independent testing of selected subprograms, and analysis of test data sets.

7.6.6 Computer Requirements

DISFIT requires 7,488 words (16,500 octal) of storage on CDC computers and 45,400 bytes of storage on IBM computers. Typical execution times for 100 headways takes 8.9 seconds on CDC computers and 13.4 seconds (0.223 minutes) on IBM computers.

7.6.7 Documentation

Documentation for DISFIT includes an explanation of the input and output contained in a user's guide (Ref 15), numerous COMMENT statements within the computer program, and a programmer's guide (Ref 19). The programmer's guide includes (1) the headway distribution fitting processor limitations, (2) a listing of the input errors detected, (3) a listing of the execution errors detected, (4) the definition of the variables in each COMMON block, (5) the definition of the local variables used in each subprogram, (6) an alphabetical listing of all subprograms and the subprograms which can call them, (7) an alphabetical listing of all the variables, their storage types, and the subprograms in which they are used, and (8) a generalized calling sequence diagram. Appendix F.3 contains the listing of DISFIT.

8.0 CALIBRATION

Verification of the traffic simulation model, the process of ensuring that a particular algorithm for computation has been properly implemented in computer language, has been described for the major components of the traffic simulation model in previous chapters. Calibration of the traffic simulation model involved modifying the computer program such that statistics gathered and reported by the model reasonably agree with the statistics gathered from field studies under similar conditions.

8.1 Sources Of Error

There are two major sources of error; one is the field data collection technique and the other is the traffic simulation model.

The major cause of error in the field data collection techniques seem to be in the observer. Observers found difficulty in maintaining the proper counter reading. When collecting queue delay, the observer keeps the current queue length on the counter. As the queue length becomes large, both the start and end of the queue must be observed to detect when new vehicles join the queue and when vehicles leave the queue. When collecting stopped delay, the observer keeps the current number of vehicles stopped in a queue on the counter. As the queue length becomes large, the entire queue must be observed to detect when a vehicle stops or starts. The observer must also keep an eye on the cassette tape recorder to ensure its proper functioning and to turn the cassette tape over when it nears the end of a reel. There also seemed to be a difference in judgment as to when the vehicle actually stopped. Measurement of volumes and headways did not seem to contain significant observer error.

Another source of error in the field data could be in the delay recording device and the time recording device. Numerous tests of the equipment were performed to ensure that they functioned properly. Occasionally, though, one of the devices would fail in the field and would have to be repaired later.

If the battery was not charged adequately, the device might not perform properly or operate for the required amount of time. Proper setting of the volume and tone controls on the cassette tape recorder was required to produce an acceptable tape.

The analog-to-digital process did not seem to contain errors. Adequate checks in the digitizing process cause a bad data record to be detected. The program can be made to halt on the error or discard the record. Several hours of data were digitized using the halt-on-error option (see Section 7.4.2) and none were detected.

When statistics are gathered from the raw field data, several checks are performed to correct the observer's input. The volume and headway algorithms performed properly whether the observer used the increment or decrement button on the device. In the same fashion, delay measurements were monitored for large fluctuations in the counter reading in a short amount of time and were corrected. There seems to be little error introduced by this step in the process.

The other major cause of error would result from the traffic simulation model's ability to accurately replicate the actions of the driver. The model is very precise. The driver is able to accurately predict his position and velocity in the future as well as other vehicles' position and velocity. In real life, a driver's judgment is not so accurate. The model also allows a driver to know exactly what another driver is doing in addition to having precise data about his current position and velocity. Accurate determination of acceleration and deceleration required to maneuver the vehicle is also possible. Any simulated driver can decelerate to a stop to within 0.25 feet (0.0762 meters) of his desired position if acceptable limits of deceleration and deceleration slope are not violated.

Several judgment variables are included in the driver's response. These variables are discussed in more detail in the next section.

The traffic simulation model's logic is precise. Criteria are established which determine the conditions under which a particular action can be made. When the conditions exist, the action is taken. Drivers do not change their minds in the model.

There are several driver responses which were not programmed: (1) drivers will not jump the green signal, (2) left turning vehicles will not move part of the way into the intersection when the signal turns green,

(3) drivers will not enter the intersection unless there is a clear path through the entire intersection, (4) not more than one driver will enter the intersection on the amber, (5) drivers will not run a red light, (6) drivers will not block other vehicles who already have the right-of-way, and (7) there is no pedestrian influence. On the other hand, drivers will always make simultaneous movements, such as left turns, if there are no intersection conflicts. The model can also determine exactly when a vehicle is stopped and can record minor move-up maneuvers within the queue which were undetected in the field data.

One of the more vague areas is the assignment of different driver types to particular classes of vehicles and the characterization of the driver and vehicle characteristics.

8.2 Parameters Modified

Several parameters within the traffic simulation model were modified so that statistics gathered and reported by the model would reasonably agree with the statistics gathered from field data under similar conditions. The basic logic of the model was not altered. The parameters modified were all in the driver judgment area.

The velocity at which a driver-vehicle unit is considered to be stopped was set at 3 ft/sec (0.9144 m/sec). This action was warranted because most observers recorded a virtual stop rather than an absolute stop when gathering stopped and queue delay. The model components affected are (1) the time when a driver-vehicle unit joins a queue, (2) the average and maximum queue lengths, (3) the queue delay for a driver-vehicle unit, and (4) the stopped delay for a driver-vehicle unit.

The value for the lead and lag safety zones for intersection conflict checking determines the availability of a clear path through the intersection. The recommended value for the lead safety zone is 1.5 seconds and for the lag safety zone is 2.5 seconds (see Fig 5.15). Assuming that (1) the judgment error is zero, (2) the driver's perception-reaction time is equal to the average perception-reaction time, (3) the vehicle would be traveling at 16 ft/sec (4.8768 m/sec), and (4) the vehicle's length would be 16 feet (4.8768 meters)], then the minimum acceptable gap for an average driver is found to be 5 seconds. The intersection conflict checking is a very important phase in non-signalized intersection control. It is less critical at signalized intersections because many movements are protected. The model components affected are (1) the sight distance restriction checking; (2) the intersection conflict checking; (3) all of the delay statistics gathered and reported by the traffic simulation model; (4) the travel time; and (5) the average and maximum queue length.

The hesitation time for vehicles entering the intersection at unsignalized intersections is an attempt to account for the time delay that drivers experience because of their perception-reaction time and because they are reluctant to immediately enter the intersection when the path is clear because of uncertainty of the right-of-way. The hesitation time, THES, in seconds used in SIMPRO is:

$$\text{THES} = 3.0*\text{PIJR} + \text{AMIN1}((\text{PIJR}+1)*\text{NVATIN}/6.0,1.5) \tag{8.1}$$

where PIJR is the perception-reaction time of the driver in seconds and NVATIN is the number of vehicles stopped at the stop line at the intersection. It is to be remembered that the average PIJR time is usually 1 second. In such a case, THES would be 4.5 seconds when NVATIN is 6. The model components affected are (1) all of the delay statistics gathered and reported by the traffic simulation model, (2) the travel time, and (3) the average and maximum queue lengths.

The hesitation time for the first vehicle in a queue entering the intersection when the signal turns green at signalized intersections is an attempt to account for the time delay that drivers experience because of their perception-reaction time. Only the first vehicle in the queue experiences the delay. The other vehicles in the queue react to the move-out of the lead vehicle. The march-out headways are illustrated in the next chapter. The model components affected are (1) all of the delay statistics gathered and reported by the traffic simulation model; (2) the travel time; (3) the average and maximum queue lengths; and (4) the march-out headways.

The final modification was made in the parameters for the generalized car-following equation; lambda, mu, and alpha (discussed in Section 5.3.6). Acceptable limits have been determined for lambda and mu. An increased value of lambda decreases the free speed, barely increases the optimum speed, slightly decreases the jam density, and moderately increases the optimum density. An increased value of mu slightly increases free speed, barely increases optimum speed, greatly increases jam density, and decreases optimum density. In the car-following equation, an increased value of lambda decreases the computed value of deceleration, while an increased value of mu increases the computed value of deceleration. An increased value for alpha directly increases the computed value for deceleration. Vehicles can be made to follow closer or farther apart and at a lower or higher velocity. The model components affected are (1) the position, velocity, and acceleration/deceleration of the vehicle; (2) the time when a vehicle joins a queue; (3) all of the delay statistics gathered and reported by the traffic simulation model; (4) the travel time; and (5) the average and maximum queue lengths.

In all cases, changes in the model parameters were restricted to reasonable values for the parameters.

9.0 VALIDATION

Validation is defined as the process of ensuring that the calibrated model is valid over a wide range of conditions. Numerous runs of the traffic simulation model were performed to validate the individual components of the model and the summary statistics. One of the most important components of the model is the acceleration, deceleration, and car-following concepts used in the model. As an example of the validity of these concepts, Fig 9.1 illustrates the position and velocity versus time plot for a test case. The first vehicle entered the system at a desired speed of 30 ft/sec (9.144 m/sec) and 7 seconds later, the second vehicle entered the system at a desired speed of 50 ft/sec (15.24 m/sec). After about 12 seconds, the second vehicle overtook the first and decelerated until the speeds approximately matched. The first vehicle later decelerated to a stop at the intersection in response to a stop sign and the second vehicle stopped behind the first. After the first vehicle entered the intersection, the second vehicle advanced to the stop line and then entered the intersection also. The second vehicle again caught up with the first and trailed at a safe following distance. This example illustrates the car-following, linear deceleration, and linear acceleration concepts used in SIMPRO. The smooth trajectory of each vehicle indicates that all components of the model functioned properly for this test case.

An additional check of the internal components was made by plotting the march-out headways of vehicles at signal controlled intersections (see Fig 9.2). These headways compared favorably with observed values (Ref 39). In this comparison, particular attention was given to the location of the screen line, as suggested by Berry (Ref 40). It is interesting to note that SIMPRO delays only the first vehicle in the queue. The screen line basis for the comparison was the stop line.

Overall validation of the traffic simulation package was accomplished by comparing queue delay at non-signalized intersections (see Fig 9.3) with data collected from field studies. The resulting agreement between the observed and simulated delay values is an example of the validity of the model.

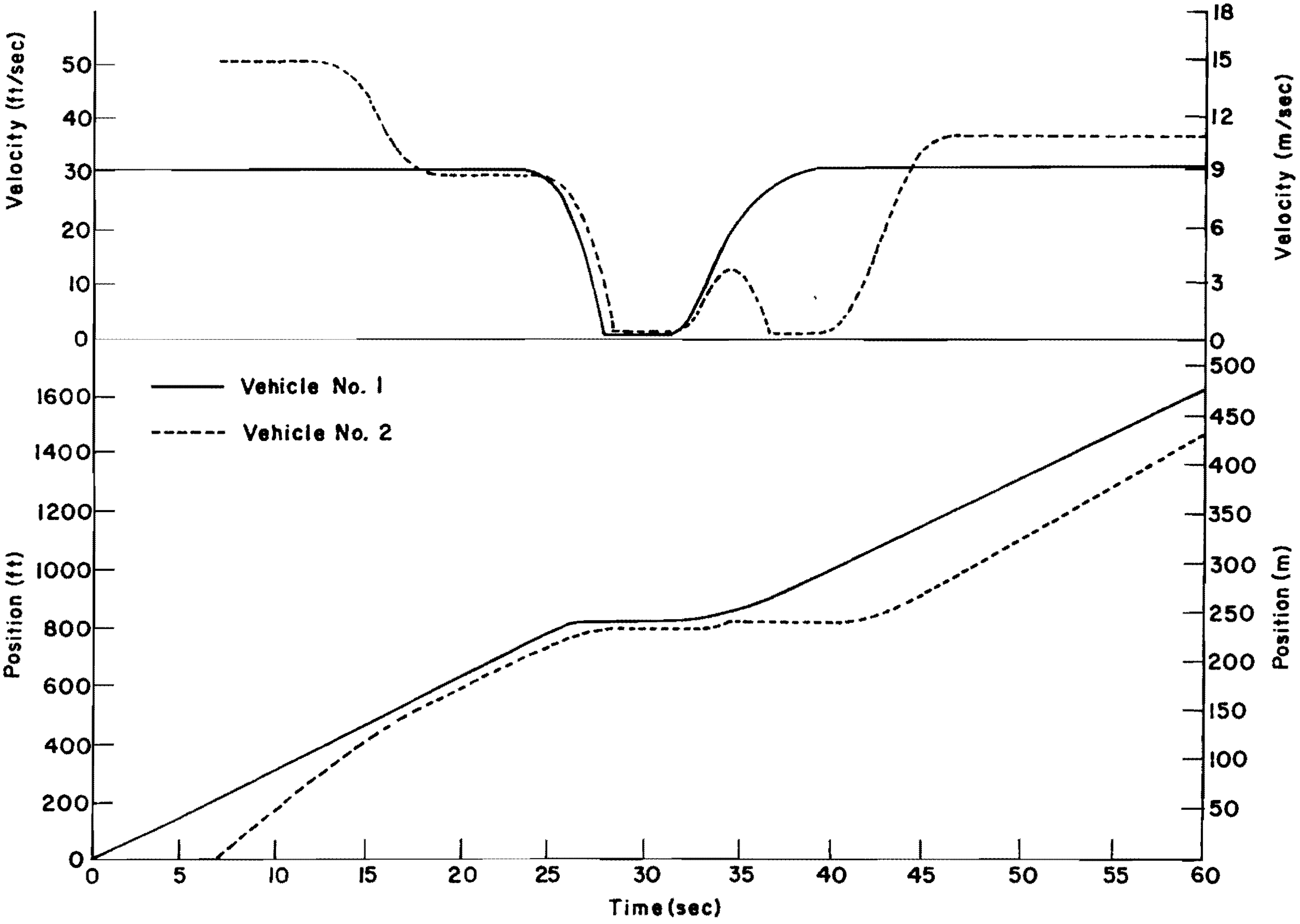


Fig 9.1. Position and velocity versus time trajectories for two vehicles.

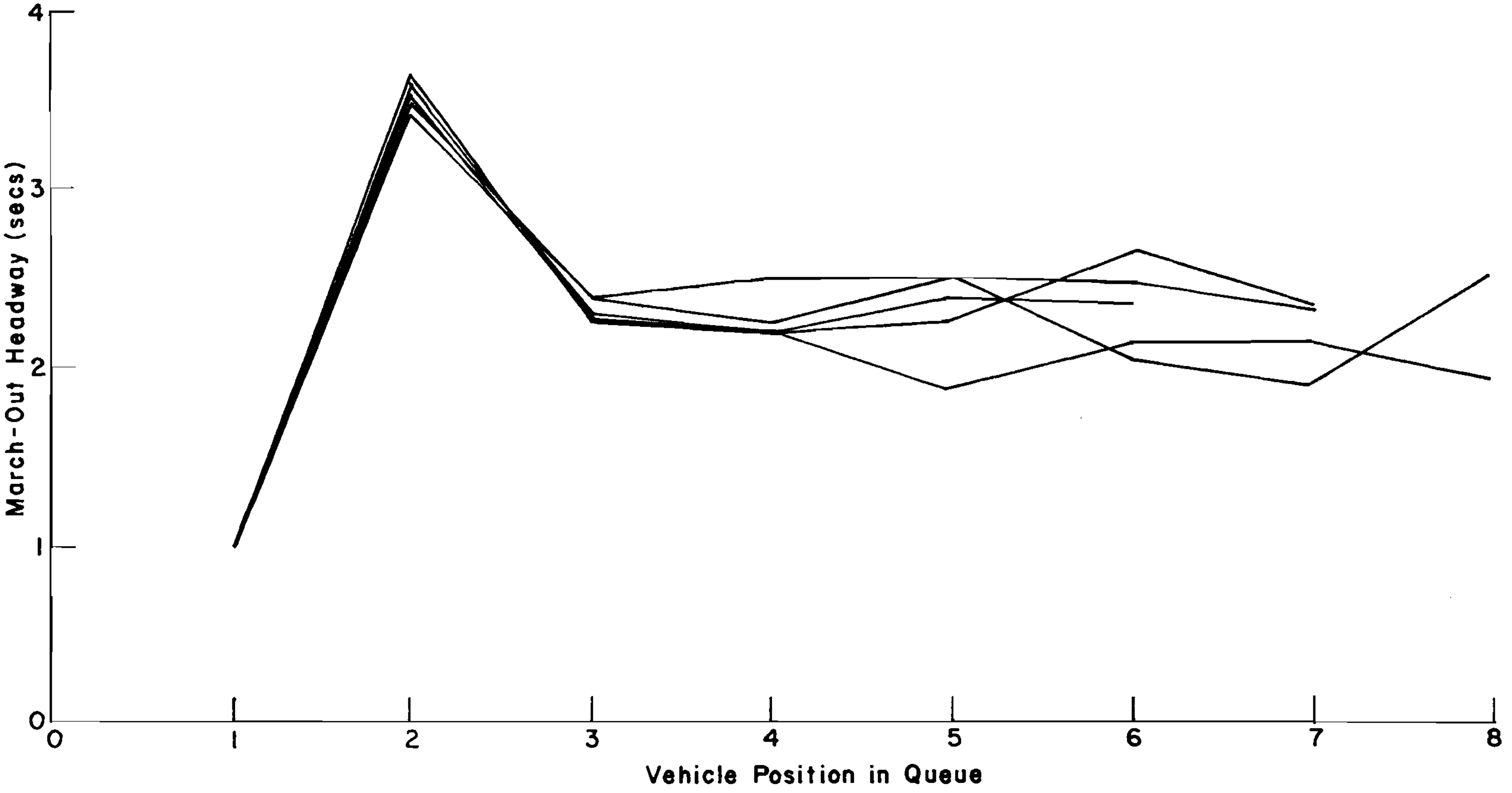


Fig 9.2. March-out headways at signal-controlled intersections.

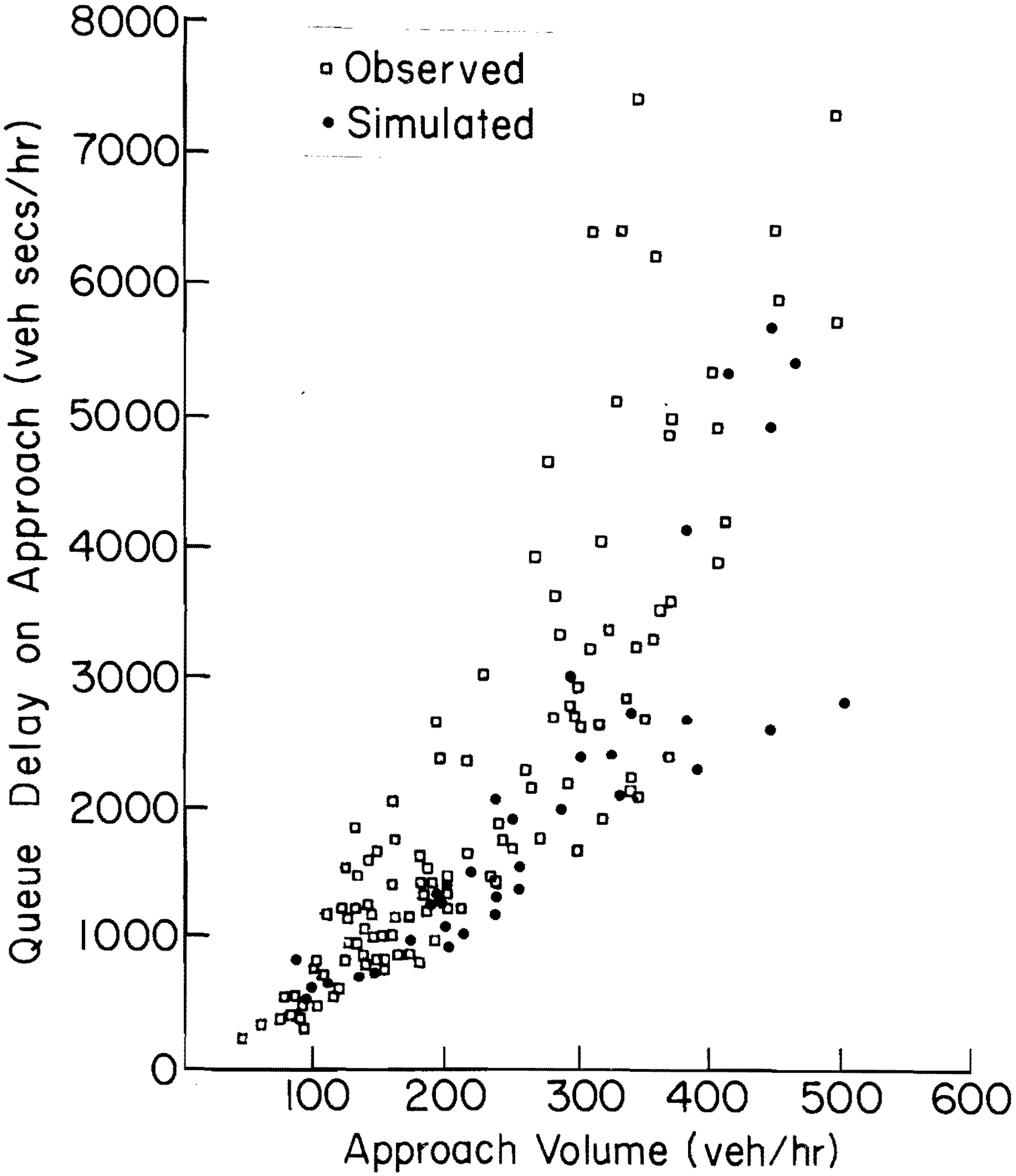


Fig 9.3. Queue delays at five non-signalized intersections in Austin, Texas.

10.0 POTENTIAL USES FOR THE TRAFFIC SIMULATION PACKAGE

This model may be used to study traffic behavior at a single intersection that is operating either uncontrolled or under any conventional type of control. Features of the model which make it particularly suitable include accommodation of 5 driver classes and 15 vehicle classes; 6 approaches with 6 lanes per approach; 1000-foot (304.8-meter) lane lengths; sight restrictions; uncontrolled operation; 8-phase signal control with skip-phase, dual-left, and parent/minor options; 2 detector types and 5 detectors per lane; 72 signal intervals (cam stack positions); geometrically correct lane-changing maneuvers and paths through the intersection; and left-turn-on-red and right-turn-on-red options. Table 10.1 suggests some possible applications for the model.

In recent months, more than 600 runs of the model have been made and the results have been evaluated in relation to capacity analysis of unsignalized intersections (Ref 41) and warrants for various types of control (Ref 42).

Table 10.1 Potential Uses for Simulation Package

1. Evaluation of existing conditions
2. Evaluation of roadway geometry changes
   - A. Adding/deleting/modifying an approach
   - B. Adding/deleting/modifying a lane
   - C. Adding/deleting/modifying a special left/right turn lane
   - D. Modifying permissable turning movements for a lane
   - E. Adding/deleting/modifying a point of sight distance restriction
3. Evaluation of driver and vehicle changes
   - A. Modifying percentages of vehicle types
   - B. Modifying percentages of driver types
   - C. Modifying driver characteristics
   - D. Modifying vehicle charactersitics
   - E. Adding/deleting/modifying special drivers
   - F. Adding/deleting/modifying special vehicles
4. Evaluation of flow changes
   - A. Modifying volumes
   - B. Modifying headway distributions
   - C. Modifying lane occupancy
   - D. Modifying turning distribution
5. Evaluation of intersection control changes
   - A. Uncontrolled
   - B. Yield sign controlled
   - C. Less-than-all-way stop sign controlled
   - D. All-way stop sign controlled
   - E. Pre-timed signal controlled
   - F. Semi-actualed signal controlled
   - G. Full-actuated signal controlled
6. Evaluation of lane control changes
   - A. Uncontrolled lane
   - B. Yield sign controlled lane
   - C. Stop sign controlled lane
   - D. Signal controlled lane

(continued)

Table 10.1 (continued)

  - E. Signal controlled lane with left turn on red permitted
  - F. Signal controlled lane with right turn on red permitted

7. Evaluation of signal controller option changes
   - A. Lengthening/shortening cycle length
   - B. Modifying cycle split
   - C. Location and type of vehicle detectors
   - D. Modifying controller timing
   - E. Adding/deleting single movement phases
8. Evaluation of capacity
9. Evaluation of warrants for traffic control devices

11.0 RECOMMENDATIONS

There are several recommendations that can be made concerning the traffic simulation package. Further research; additional modifications and capabilities; further validation; and a sensitivity analysis of selected model variables are proposed.

11.1 Further Research

When implementing the linear acceleration algorithm, there was inadequate information defining the maximum initial acceleration used by a driver to accelerate to his desired speed (see Section 5.3.4). Most of the information related to the uniform acceleration used by a driver to accelerate to his desired speed. The difficulty in adapting to the linear acceleration algorithm is that the linear and uniform acceleration models are not compatible. There exists no non-zero value of acceleration slope (jerk) which will make a vehicle accelerate from a stopped position to the same speed in the same distance. Re-analysis of existing data or further research into this area could provide more accurate estimates.

When implementing the linear deceleration algorithm, there was also inadequate information defining the maximum final deceleration used by a driver to decelerate to a stop (see Section 5.3.5). Most of the information related to the uniform deceleration used by a driver to decelerate to a stop. The difficulty in adapting to the linear deceleration algorithm is that the linear and uniform deceleration models are not compatible. There exists no non-zero value of deceleration slope (jerk) which will make a vehicle stop in the same distance from the same speed. Re-analysis of existing data or further research into this area could provide more accurate estimates.

Much theoretical research has been devoted to car-following. This traffic simulation model represents the first major work to use the generalized, non-integer car following equation (see Section 5.3.6 and

Section 5.3.6.1). May (Ref 35) provided valuable insight into the sensitivity and range of lambda and mu to free speed, optimum speed, jam density, optimum density, and maximum flow. Better estimators for these variables are needed so that the general user may determine lambda and mu. There seems to be little information on methods for determining alpha. Most of the field data gathered for validating car-following models have been for the open road or freeway conditions. It is necessary to take and analyze additional data in the low velocity, congested flow region. SIMPRO uses equations developed by the Center For Highway Research staff defining the car-following distance under various conditions. This determines what mode of car-following the driver should be operating in. Research into this area should prove beneficial in refining the equations to more adequately represent the real world.

Most of the research on lane changing concentrated on the gap acceptance aspects. Particular attention focused on the probability of acceptance or rejection of a given length gap. SIMPRO needs equations relating acceptable lead and lag gaps with current velocity (see Section 5.3.17 and Section 5.3.17.1). Additional research could develop better estimators for these values. Further research might find some better relationship for the time required to complete a lane-change maneuver.

Several parameters for intersection control suggest additional study. Acceptable values for the lead and lag safety zones for intersection conflict checking and sight distance restriction checking need to be investigated (see Section 5.3.15 and Section 5.3.16). Also the time or distance from the intersection that drivers are willing to dedicate themselves to entering the intersection should be studied. The willingness of drivers to make simultaneous movements within the intersection should be investigated along with the conditions under which a driver jumps the green for left turns (see Section 5.3.11.5). Finally, the maximum clear distance for being in a queue should be researched and the limits defined (see Section 5.3.23).

11.2 Additional Modifications And Capabilities

The geometry processor should be modified to accommodate bus-only lanes and diamond intersections. This would improve the usefulness of the package. To increase efficiency of GEOPRO, the storage management techniques should be removed.

The driver-vehicle processor should be modified so that a traffic stream could be generated which represented the effects of an upstream signal; so that the volume could change and the headway distribution parameters could change as the queue-in time increases; allowing buses to be generated using a bus schedule and a dwell-time distribution; adding fuel consumption and pollution emission values for the default vwhicles; adding pedestrians; and allowing diamond intersections.

The traffic simulation processor should be modified to allow a driver more freedom in the selection of intersection paths; add fuel consumption and pollution emission statistics for summary by approach and turn code; add pedestrian influences; allow a vehicle to occupy both lanes in a lane change maneuver until it is completed; remove the storage management techniques to increase efficiency; allow optional lane changes on outbound approaches to reduce total delay and travel time; allow the simulation of diamond intersections; allow buses to stop and load passengers; allow drivers to jump the green when turning left; and reduce a vehicle's deceleration to zero before a deceleration-to-a-stop maneuver is completed.

11.3 Further Validation

The traffic simulation package should be further validated for each type of intersection control: uncontrolled, yield sign controlled, less-than-all-way stop sign controlled, all-way stop sign controlled, pretimed signal controlled, semi-actuated signal controlled, and full-actuated signal controlled. The traffic simulation package should be cross-validated with other functioning microscopic traffic simulation models.

11.4 Sensitivity Analysis Of Selected Model Variables

A sensitivity analysis should be performed for the following model variables to determine their effect upon the summary statistics: driver operational factor; driver perception-reaction time; the driver mix in the various vehicle types; the vehicle operating characteristics; the vehicle mix in the traffic stream; the parameters for the linear acceleration model; the parameters for the linear deceleration model; the values for lambda, mu, alpha for the generalized car-following equation; the step increment for simulation time; the start-up and simulation times; the maximum clear distance for being in a queue; the headway distributions; the time for the lead and lag safety zones for intersection conflict checking; the velocity at which a vehicle is considered stopped; and the hesitation time for vehicles entering the intersection at non-signalized intersections.

12.0 SUMMARY

The Center For Highway Research at The University of Texas at Austin has developed a new microscopic traffic simulation package, called the TEXAS Model, which can be used as a tool by transportation engineers to evaluate traffic performance at isolated intersections operating under various types of control. The package consists of a geometry processor, called GEOPRO, a driver-vehicle processor, called DVPRO, and a traffic simulation processor, called SIMPRO.

GEOPRO calculates the geometric paths of vehicles on the approaches and in the intersection, identifies points of conflict between intersection paths, and determines the minimum available sight distance along each inbound approach. This information is written onto a magnetic tape for subsequent use by SIMPRO.

DVPRO characterizes the traffic stream to be simulated by generating queue-in time and other random descriptors for individually characterized driver-vehicle units, describes pertinent characteristics of up to 5 classes of drivers and up to 15 classes of vehicles, and writes this information on a tape for later use by SIMPRO. An auxiliary headway-distribution-fitting processor aids the user in selecting appropriate headway distributions that appropriately describe observed or predicted traffic patterns.

SIMPRO processes each driver-vehicle unit through the intersection system and gathers and reports a large selection of performance statistics. Linear acceleration and deceleration models are incorporated within the TEXAS Model, and a non-integer, microscopic, generalized car-following equation is used. Traffic signal simulators are included for pretimed, semi-actuated, and full-actuated controllers. Other intersection control options include uncontrolled, yield sign controlled, less-than-all-way stop sign controlled, and all-way stop sign controlled. Several new techniques of traffic simulation are implemented, including a geometrically accurate lane-change maneuver; sight distance restriction checking; intersection conflict checking; and efficient storage and logic processing methods. New field data recording devices which aid in collecting data for validation of the traffic simulation package and in determining suitable input for the model are described.

Input to the TEXAS Model has been designed to be user-oriented and minimal while output is concise and functional. Documentation has been developed for both users and programmers.

The TEXAS Model may be applied in evaluating existing or proposed intersection designs and for assessing the effects of changes in roadway geometry, driver and vehicle characteristics, flow conditions, intersection control, lane control, and signal timing plans upon traffic operations.

The TEXAS Model is a useful and effective method for predicting traffic performance at existing and proposed intersections. The summary statistics that are reported can be obtained for a fraction of the cost of conventional field study techniques. The detail that has been incorporated into the model gives the user confidence that the behavior of the simulated driver-vehicle units is similar to that which is observed in the real world.

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APPENDIX A

EXAMPLE RUNS USING THE TEXAS TRAFFIC AND INTERSECTION SIMULATION PACKAGE

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    *******  PRINT OF FILE IN4X4    -  14 NOV 77  -  19.35.16.  -  PAGE   1  *******

             1         2         3         4         5         6         7         8
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
    ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
 1 <       *****            NORMAL 4 X 4 INTERSECTION EXAMPLE            *****     >    1
 2 <   4                                                                            >    2
 3 <   1   2   3   4                                                                >    3
 4 <   4                                                                            >    4
 5 <   5   6   7   8                                                                >    5
 6 <   8  12                                                                        >    6
 7 <   1   0 840   0  30   2 20 10 LOGNRML  300   1.7 25.0 30.0  0 15 75 10       NO>    7
 8 <  10   0 800   0 800  LS        45        10   0 800   0 800   SR        55     >    8
 9 <   2 2701680 840  30   2 20 10 SNEGEXP  650   1.2 30.0 35.0 10 00 15 75       NO>    9
10 <  10   0 800   0 800  LS        55        10   0 800   0 800   SR        45     >   10
11 <   3 180 8401680  30   2 20 10 LOGNRML  500   2.7 25.0 30.0 75 10 00 15       NO>   11
12 <  10   0 800   0 800  LS        60        10   0 800   0 800   SR        40     >   12
13 <   4  90   0 840  30   2 20 10 SNEGEXP  900   1.1 30.0 35.0 15 75 10 00       NO>   13
14 <  10   0 800   0 800  LS        55        10   0 800   0 800   SR        45     >   14
15 <   5 180 840 800  30   2                                                        >   15
16 <  10   0 400   0 400  LS                  10   0 400   0 400   SR               >   16
17 <   6  90 880 840  30   2                                                        >   17
18 <  10   0 400   0 400  LS                  10   0 400   0 400   SR               >   18
19 <   7   0 840 880  30   2                                                        >   19
20 <  10   0 400   0 400  LS                  10   0 400   0 400   SR               >   20
21 <   8 270 800 840  30   2                                                        >   21
22 <  10   0 400   0 400  LS                  10   0 400   0 400   SR               >   22
23 <   4                                                                            >   23
24 <   1 800 800   0  90  20                                                        >   24
25 <   2 880 800   0 -90  20                                                        >   25
26 <   3 880 880 180  90  20                                                        >   26
27 <   4 800 880 180 -90  20                                                        >   27
28 <   0                                                                            >   28
29 <   0                                                                            >   29
30 <PRIMARY   PLOTI     SEPARATE      280.00    20.00                  12          >   30
    vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv
             1         2         3         4         5         6         7         8
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
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  GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE     PAGE  1

*****              NORMAL 4 X 4 INTERSECTION EXAMPLE            *****

TABLE  1  -  LISTING OF INBOUND APPROACH NUMBERS

              1
              2
              3
              4

    TOTAL NUMBER OF INBOUND APPROACHES =  4

TABLE  2  -  LISTING OF OUTBOUND APPROACH NUMBERS

              5
              6
              7
              8

    TOTAL NUMBER OF OUTBOUND APPROACHES =  4

    TOTAL NUMBER OF INBOUND AND OUTBOUND APPROACHES =  8

TABLE  3  -  LISTING OF APPROACHES

    APPROACH NUMBER -------------------      1
    APPROACH AZIMUTH ------------------      0
    BEGINNING CENTERLINE X COORDINATE -    840
    BEGINNING CENTERLINE Y COORDINATE -      0
    SPEED LIMIT (MPH) -----------------     30
    NUMBER OF DEGREES FOR STRAIGHT ----     20
    NUMBER OF DEGREES FOR U-TURN ------     10
    NUMBER OF LANES -------------------      2

    LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
      1   1   1   10       0  800    0  800   ( LS )       (MEDIAN LANE)
      2   2   2   10       0  800    0  800   (  SR)       (CURB LANE)

    APPROACH NUMBER -------------------      2
    APPROACH AZIMUTH ------------------    270
    BEGINNING CENTERLINE X COORDINATE -   1680
    BEGINNING CENTERLINE Y COORDINATE -    840
    SPEED LIMIT (MPH) -----------------     30
    NUMBER OF DEGREES FOR STRAIGHT ----     20
    NUMBER OF DEGREES FOR U-TURN ------     10
    NUMBER OF LANES -------------------      2

    LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
      1   3   3   10       0  800    0  800   ( LS )       (MEDIAN LANE)
      2   4   4   10       0  800    0  800   (  SR)       (CURB LANE)
```

```
  GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE     PAGE  2

*****              NORMAL 4 X 4 INTERSECTION EXAMPLE            *****

    APPROACH NUMBER -------------------      3
    APPROACH AZIMUTH ------------------    180
    BEGINNING CENTERLINE X COORDINATE -    840
    BEGINNING CENTERLINE Y COORDINATE -   1680
    SPEED LIMIT (MPH) -----------------     30
    NUMBER OF DEGREES FOR STRAIGHT ----     20
    NUMBER OF DEGREES FOR U-TURN ------     10
    NUMBER OF LANES -------------------      2

    LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
      1   5   5   10       0  800    0  800   ( LS )       (MEDIAN LANE)
      2   6   6   10       0  800    0  800   (  SR)       (CURB LANE)

    APPROACH NUMBER -------------------      4
    APPROACH AZIMUTH ------------------     90
    BEGINNING CENTERLINE X COORDINATE -      0
    BEGINNING CENTERLINE Y COORDINATE -    840
    SPEED LIMIT (MPH) -----------------     30
    NUMBER OF DEGREES FOR STRAIGHT ----     20
    NUMBER OF DEGREES FOR U-TURN ------     10
    NUMBER OF LANES -------------------      2

    LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
      1   7   7   10       0  800    0  800   ( LS )       (MEDIAN LANE)
      2   8   8   10       0  800    0  800   (  SR)       (CURB LANE)

    APPROACH NUMBER -------------------      5
    APPROACH AZIMUTH ------------------    180
    BEGINNING CENTERLINE X COORDINATE -    840
    BEGINNING CENTERLINE Y COORDINATE -    800
    SPEED LIMIT (MPH) -----------------     30
    NUMBER OF DEGREES FOR STRAIGHT ----     20
    NUMBER OF DEGREES FOR U-TURN ------     10
    NUMBER OF LANES -------------------      2

    LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
      1   9   0   10       0  400    0  400   ( LS )       (MEDIAN LANE)
      2  10   0   10       0  400    0  400   (  SR)       (CURB LANE)

    APPROACH NUMBER -------------------      6
    APPROACH AZIMUTH ------------------     90
    BEGINNING CENTERLINE X COORDINATE -    880
    BEGINNING CENTERLINE Y COORDINATE -    840
    SPEED LIMIT (MPH) -----------------     30
    NUMBER OF DEGREES FOR STRAIGHT ----     20
    NUMBER OF DEGREES FOR U-TURN ------     10
    NUMBER OF LANES -------------------      2

    LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
      1  11   0   10       0  400    0  400   ( LS )       (MEDIAN LANE)
      2  12   0   10       0  400    0  400   (  SR)       (CURB LANE)
```

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   GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE      PAGE  3

*****              NORMAL 4 X 4 INTERSECTION EXAMPLE              *****


     APPROACH NUMBER -------------------     7
     APPROACH AZIMUTH ------------------     0
     BEGINNING CENTERLINE X COORDINATE -   840
     BEGINNING CENTERLINE Y COORDINATE -   880
     SPEED LIMIT (MPH) -----------------    30
     NUMBER OF DEGREES FOR STRAIGHT ----    20
     NUMBER OF DEGREES FOR U-TURN ------    10
     NUMBER OF LANES -------------------     2

     LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
       1  13   0   10       0  400    0  400   ( LS )        (MEDIAN LANE)
       2  14   0   10       0  400    0  400   (  SR)        (CURB LANE)


     APPROACH NUMBER -------------------     8
     APPROACH AZIMUTH ------------------   270
     BEGINNING CENTERLINE X COORDINATE -   800
     BEGINNING CENTERLINE Y COORDINATE -   840
     SPEED LIMIT (MPH) -----------------    30
     NUMBER OF DEGREES FOR STRAIGHT ----    20
     NUMBER OF DEGREES FOR U-TURN ------    10
     NUMBER OF LANES -------------------     2

     LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
       1  15   0   10       0  400    0  400   ( LS )        (MEDIAN LANE)
       2  16   0   10       0  400    0  400   (  SR)        (CURB LANE)


     TOTAL NUMBER OF APPROACHES =  8


TABLE  4  -  LISTING OF ARCS (FOR PLOTTING ONLY)


     ARC NUMBER -------------------------     1
     CENTER X COORDINATE ---------------   800
     CENTER Y COORDINATE ---------------   800
     BEGINNING AZIMUTH -----------------     0
     SWEEP ANGLE -----------------------    90
     RADIUS OF ARC ---------------------    20
     ROTATION FROM BEGINNING AZIMUTH --- CLOCKWISE


     ARC NUMBER -------------------------     2
     CENTER X COORDINATE ---------------   880
     CENTER Y COORDINATE ---------------   800
     BEGINNING AZIMUTH -----------------     0
     SWEEP ANGLE -----------------------   -90
     RADIUS OF ARC ---------------------    20
     ROTATION FROM BEGINNING AZIMUTH --- COUNTER CLOCKWISE


     ARC NUMBER -------------------------     3
     CENTER X COORDINATE ---------------   880
     CENTER Y COORDINATE ---------------   880
     BEGINNING AZIMUTH -----------------   180
     SWEEP ANGLE -----------------------    90
     RADIUS OF ARC ---------------------    20
     ROTATION FROM BEGINNING AZIMUTH --- CLOCKWISE
```

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   GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE      PAGE  4

*****              NORMAL 4 X 4 INTERSECTION EXAMPLE              *****


     ARC NUMBER -------------------------     4
     CENTER X COORDINATE ---------------   800
     CENTER Y COORDINATE ---------------   880
     BEGINNING AZIMUTH -----------------   180
     SWEEP ANGLE -----------------------   -90
     RADIUS OF ARC ---------------------    20
     ROTATION FROM BEGINNING AZIMUTH --- COUNTER CLOCKWISE


     TOTAL NUMBER OF ARCS =  4


TABLE  5  -  LISTING OF OPTIONS AND ADDITIONAL DATA


     PRIMARY PATHS SELECTED

     PLOT SELECTED USING INK PEN

     APPROACH PATHS PLOTTED ON SEPARATE FRAMES

     APPROACH SCALE FACTOR FROM INPUT IS 280.0 FEET PER INCH

     INTERSECTION SCALE FACTOR FROM INPUT IS  20.0 FEET PER INCH

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

     PROGRAM CHECKS TO SEE IF THE CENTER TO CENTER DISTANCE
         BETWEEN VEHICLES BECOMES LESS THAN OR EQUAL TO 10 FEET

     PLOT PAPER WIDTH = 12 INCHES

     APPROACH SCALE FACTOR TO BE USED IS 280.0 FEET PER INCH

     INTERSECTION SCALE FACTOR TO BE USED IS  20.0 FEET PER INCH


TABLE  6  -  LISTING OF PATHS


     PATH   1 GOES FROM LANE 1 OF APPROACH  1 TO LANE 1 OF APPROACH  7
        LENGTH OF PATH =  80 FEET AND SPEED OF PATH = 44 FEET PER SECOND
        NUMBER OF CONFLICTS =  7 AND TURN CODE FOR PATH IS STRAIGHT
        CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
               7    1    5    2    4    3    6


     PATH   2 GOES FROM LANE 1 OF APPROACH  1 TO LANE 1 OF APPROACH  8
        LENGTH OF PATH =  71 FEET AND SPEED OF PATH = 22 FEET PER SECOND
        NUMBER OF CONFLICTS =  7 AND TURN CODE FOR PATH IS LEFT
        CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
               8   14   10   12   11   13    9


     PATH   3 GOES FROM LANE 2 OF APPROACH  1 TO LANE 2 OF APPROACH  6
        LENGTH OF PATH =  39 FEET AND SPEED OF PATH = 17 FEET PER SECOND
        NUMBER OF CONFLICTS =  1 AND TURN CODE FOR PATH IS RIGHT
        CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              15
```

```
PATH   4 GOES FROM LANE 2 OF APPROACH  1 TO LANE 2 OF APPROACH  7
   LENGTH OF PATH =  80 FEET AND SPEED OF PATH = 44 FEET PER SECOND
   NUMBER OF CONFLICTS =  7 AND TURN CODE FOR PATH IS STRAIGHT
   CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
         22    21    16    20    17    19    18

PATH   5 GOES FROM LANE 1 OF APPROACH  2 TO LANE 1 OF APPROACH  5
   LENGTH OF PATH =  71 FEET AND SPEED OF PATH = 22 FEET PER SECOND
   NUMBER OF CONFLICTS =  7 AND TURN CODE FOR PATH IS LEFT
   CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
         24    16    25     1    26     8    23

PATH   6 GOES FROM LANE 1 OF APPROACH  2 TO LANE 1 OF APPROACH  8
   LENGTH OF PATH =  80 FEET AND SPEED OF PATH = 44 FEET PER SECOND
   NUMBER OF CONFLICTS =  7 AND TURN CODE FOR PATH IS STRAIGHT
   CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
         17    28     2    27    30    29     9

PATH   7 GOES FROM LANE 2 OF APPROACH  2 TO LANE 2 OF APPROACH  7
   LENGTH OF PATH =  39 FEET AND SPEED OF PATH = 17 FEET PER SECOND
   NUMBER OF CONFLICTS =  1 AND TURN CODE FOR PATH IS RIGHT
   CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
         18

PATH   8 GOES FROM LANE 2 OF APPROACH  2 TO LANE 2 OF APPROACH  8
   LENGTH OF PATH =  80 FEET AND SPEED OF PATH = 44 FEET PER SECOND
   NUMBER OF CONFLICTS =  7 AND TURN CODE FOR PATH IS STRAIGHT
   CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
         19     3    32    35    31    33    34

PATH   9 GOES FROM LANE 1 OF APPROACH  3 TO LANE 1 OF APPROACH  5
   LENGTH OF PATH =  80 FEET AND SPEED OF PATH = 44 FEET PER SECOND
   NUMBER OF CONFLICTS =  7 AND TURN CODE FOR PATH IS STRAIGHT
   CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
         31    37    27    36    10    38    23

PATH  10 GOES FROM LANE 1 OF APPROACH  3 TO LANE 1 OF APPROACH  6
   LENGTH OF PATH =  71 FEET AND SPEED OF PATH = 22 FEET PER SECOND
   NUMBER OF CONFLICTS =  7 AND TURN CODE FOR PATH IS LEFT
   CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
         40    32     4    28    20    24    39

PATH  11 GOES FROM LANE 2 OF APPROACH  3 TO LANE 2 OF APPROACH  5
   LENGTH OF PATH =  80 FEET AND SPEED OF PATH = 44 FEET PER SECOND
   NUMBER OF CONFLICTS =  7 AND TURN CODE FOR PATH IS STRAIGHT
   CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
         33    29    42    11    41    44    43

PATH  12 GOES FROM LANE 2 OF APPROACH  3 TO LANE 2 OF APPROACH  8
   LENGTH OF PATH =  39 FEET AND SPEED OF PATH = 17 FEET PER SECOND
   NUMBER OF CONFLICTS =  1 AND TURN CODE FOR PATH IS RIGHT
   CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
         34
```

```
PATH  13 GOES FROM LANE 1 OF APPROACH  4 TO LANE 1 OF APPROACH  6
   LENGTH OF PATH =  80 FEET AND SPEED OF PATH = 44 FEET PER SECOND
   NUMBER OF CONFLICTS =  7 AND TURN CODE FOR PATH IS STRAIGHT
   CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
         41    12    36     5    25    21    39

PATH  14 GOES FROM LANE 1 OF APPROACH  4 TO LANE 1 OF APPROACH  7
   LENGTH OF PATH =  71 FEET AND SPEED OF PATH = 22 FEET PER SECOND
   NUMBER OF CONFLICTS =  7 AND TURN CODE FOR PATH IS LEFT
   CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
         13    42    30    37    35    40     6

PATH  15 GOES FROM LANE 2 OF APPROACH  4 TO LANE 2 OF APPROACH  5
   LENGTH OF PATH =  39 FEET AND SPEED OF PATH = 17 FEET PER SECOND
   NUMBER OF CONFLICTS =  1 AND TURN CODE FOR PATH IS RIGHT
   CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
         43

PATH  16 GOES FROM LANE 2 OF APPROACH  4 TO LANE 2 OF APPROACH  6
   LENGTH OF PATH =  80 FEET AND SPEED OF PATH = 44 FEET PER SECOND
   NUMBER OF CONFLICTS =  7 AND TURN CODE FOR PATH IS STRAIGHT
   CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
         44    38    14    26     7    22    15

TOTAL NUMBER OF PATHS CALCULATED =  16

TABLE  7  -  LISTING OF CONFLICTS

CONFLICT  PATH1 PATH2  APPR1 APPR2  DIST1 DIST2  ANGLE  INDEX1 INDEX2

    1        1     5      1     2     28    40    219      2      4
    2        1     6      1     2     45    35    270      4      3
    3        1     8      1     2     55    35    270      6      2
    4        1    10      1     3     52    31    141      5      3
    5        1    13      1     4     35    45     90      3      4
    6        1    14      1     4     60    71      0      7      7
    7        1    16      1     4     25    45     90      1      5
    8        2     5      1     2     21    49    235      1      6
    9        2     6      1     2     71    80      0      7      7
   10        2     9      1     3     31    52    219      3      5
   11        2    11      1     3     44    43    236      5      4
   12        2    13      1     4     40    28    141      4      2
   13        2    14      1     4     49    21    125      6      1
   14        2    16      1     4     27    37    124      2      3
   15        3    16      1     4     39    80      0      1      7
   16        4     5      1     2     37    27    236      3      2
   17        4     6      1     2     45    25    270      5      1
   18        4     7      1     2     80    39      0      7      1
   19        4     8      1     2     55    25    270      6      1
   20        4    10      1     3     43    44    124      4      5
   21        4    13      1     4     35    55     90      2      6
   22        4    16      1     4     25    55     90      1      6
   23        5     9      2     3     71    80      0      7      7
   24        5    10      2     3     21    49    236      1      6
   25        5    13      2     4     31    52    220      3      5
   26        5    16      2     4     44    43    237      5      4
   27        6     9      2     3     45    35    271      4      3
   28        6    10      2     3     28    40    220      2      4
   29        6    11      2     3     55    35    271      6      2
   30        6    14      2     4     52    31    142      5      3
   31        6     9      2     3     45    25    271      5      1
```

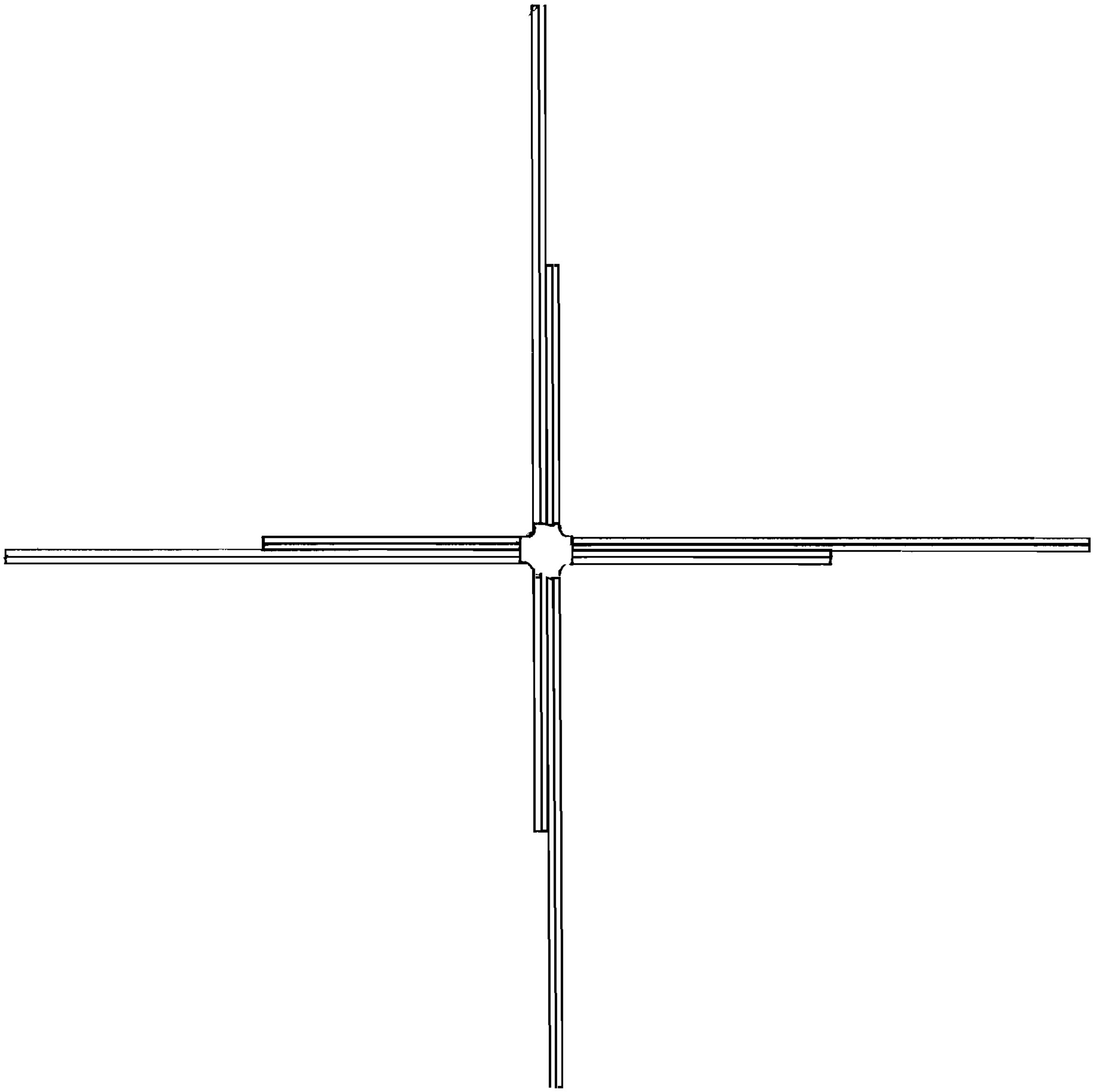
```
   GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE     PAGE  7

*****             NORMAL 4 X 4 INTERSECTION EXAMPLE             *****


       32       8     10      2      3     37     27     237      3      2
       33       8     11      2      3     55     25     271      6      1
       34       8     12      2      3     80     39       0      7      1
       35       8     14      2      4     43     44     125      4      5
       36       9     13      3      4     45     35     271      4      3
       37       9     14      3      4     28     40     220      2      4
       38       9     16      3      4     55     35     271      6      2
       39      10     13      3      4     71     80       0      7      7
       40      10     14      3      4     21     49     236      1      6
       41      11     13      3      4     45     25     271      5      1
       42      11     14      3      4     37     27     237      3      2
       43      11     15      3      4     80     39       0      7      1
       44      11     16      3      4     55     25     271      6      1

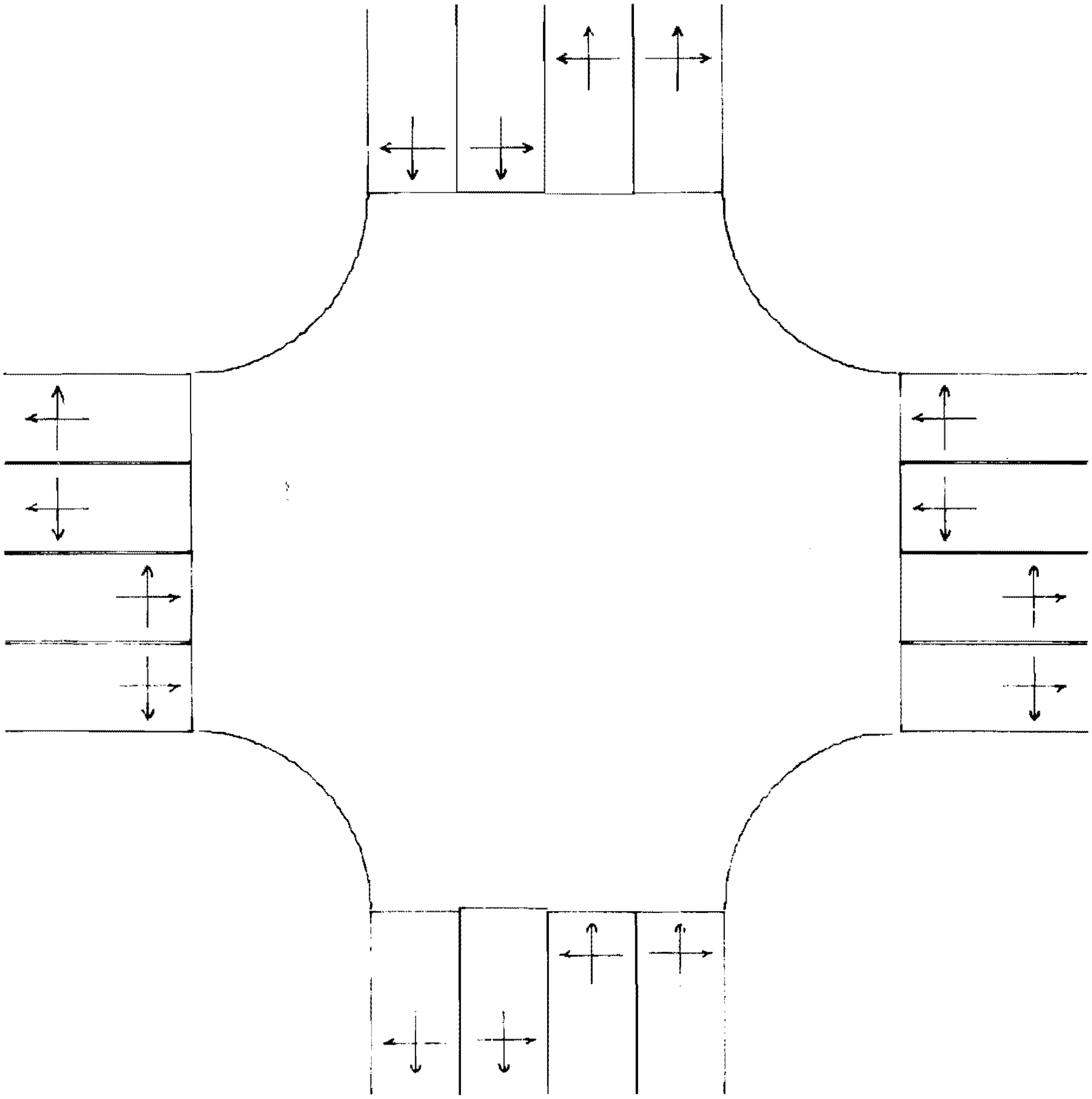
    TOTAL NUMBER OF CONFLICTS =    44
```

***** NORMAL 4 X 4 INTERSECTION EXAMPLE *****



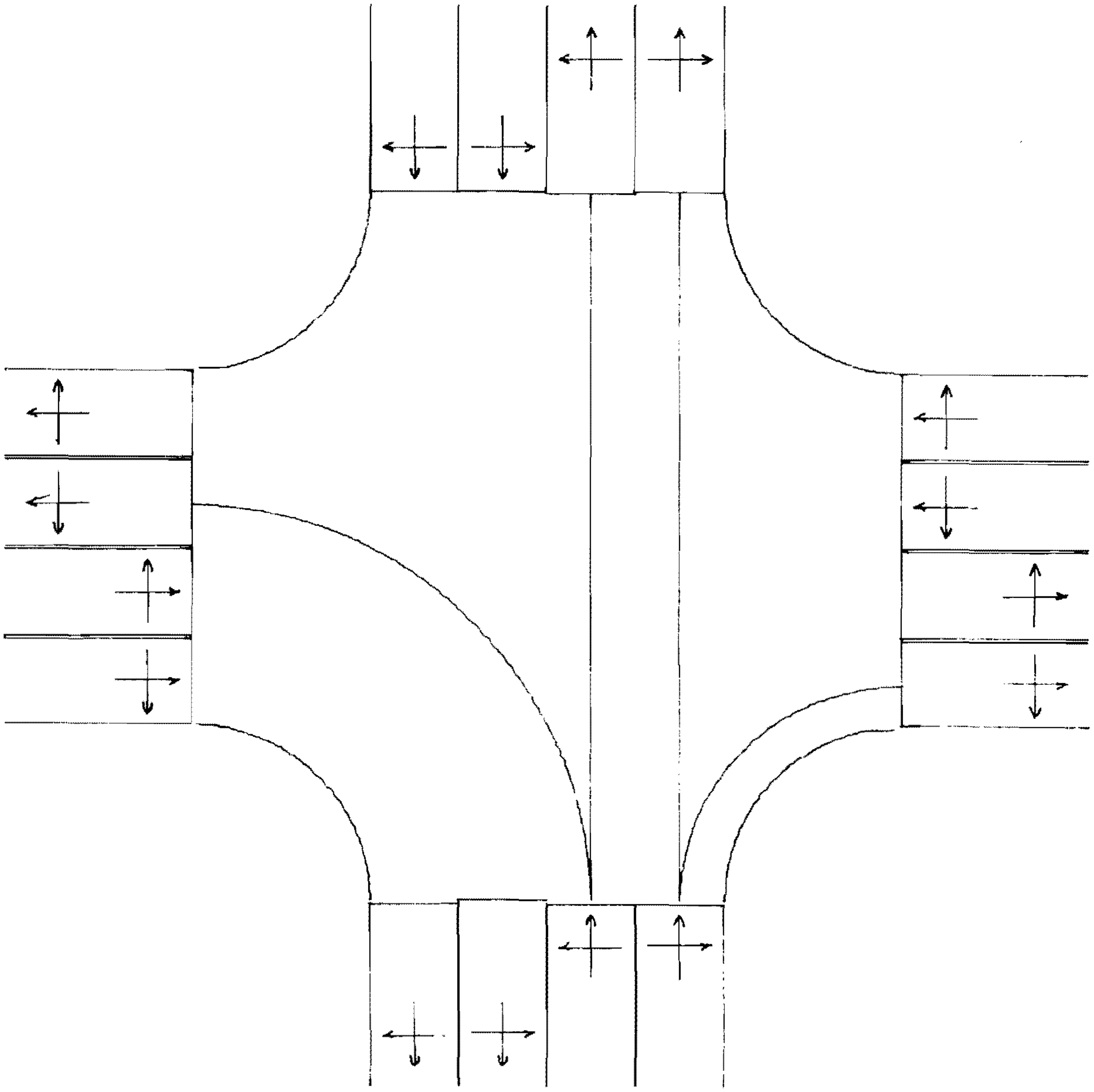
SCALE FACTOR IS 280.0 FEET PER INCH

***** NORMAL 4 X 4 INTERSECTION EXAMPLE *****



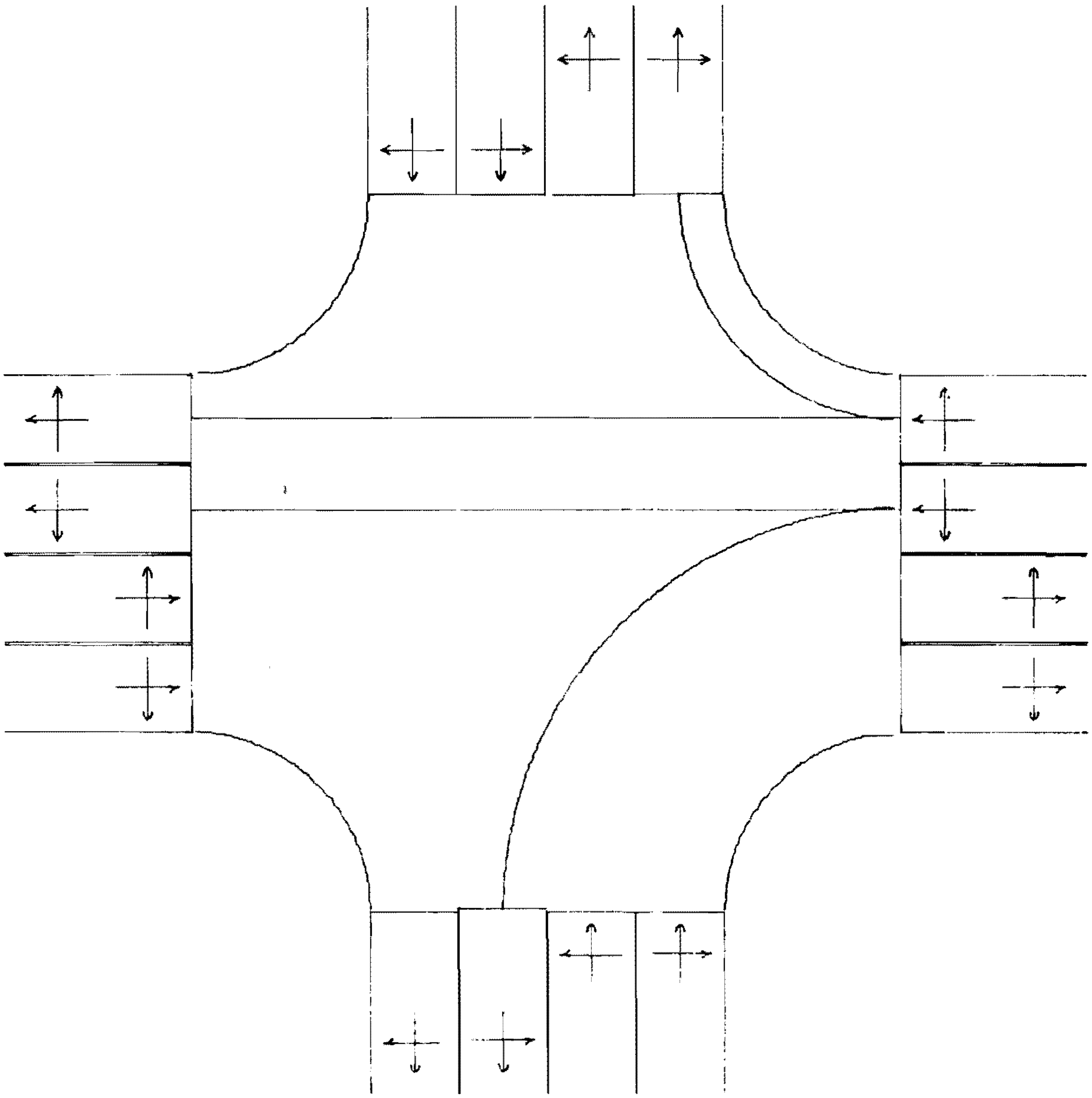
SCALE FACTOR IS 20.0 FEET PER INCH

***** NORMAL 4 X 4 INTERSECTION EXAMPLE *****



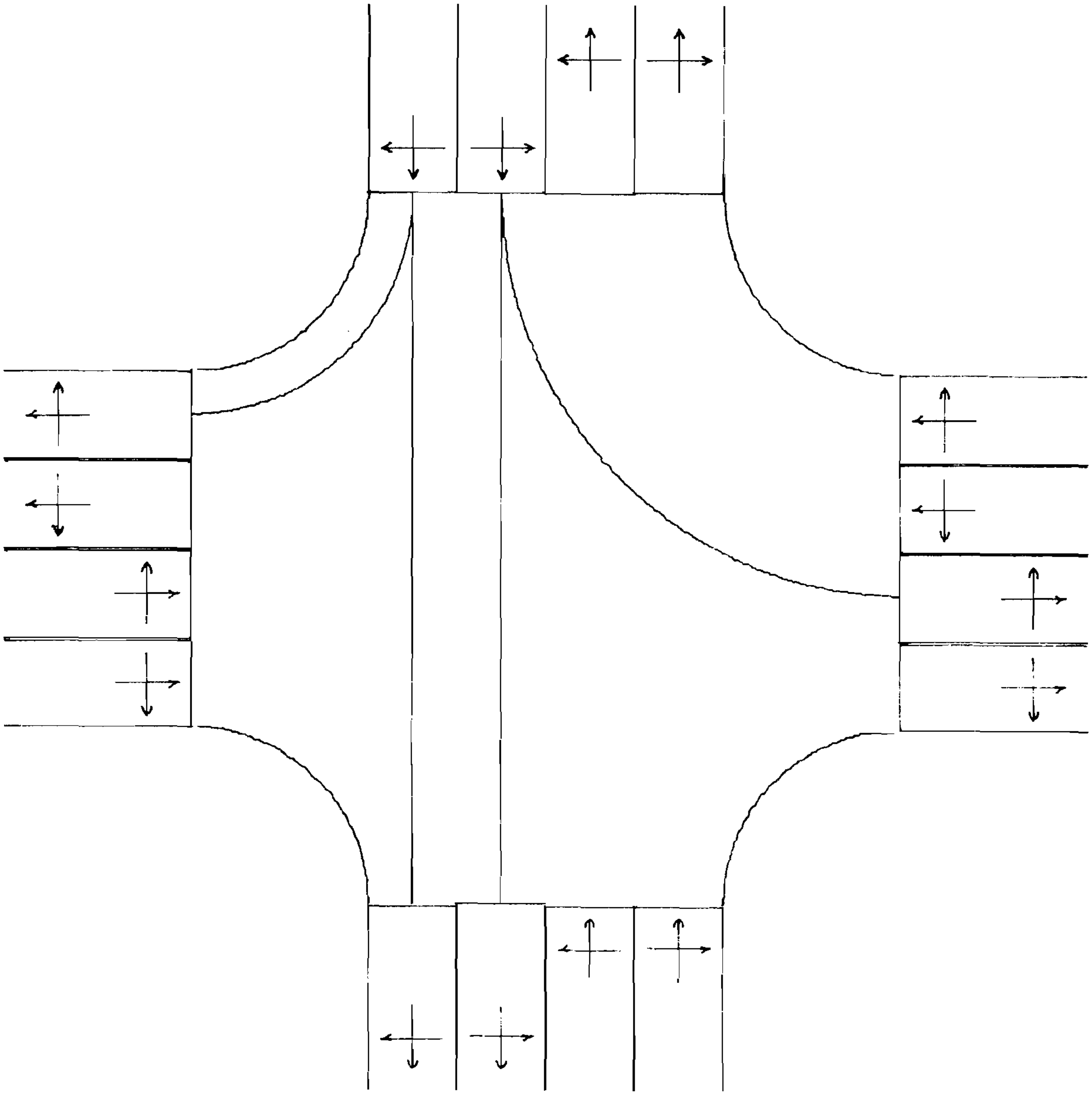
SCALE FACTOR IS 20.0 FEET PER INCH

***** NORMAL 4 X 4 INTERSECTION EXAMPLE *****



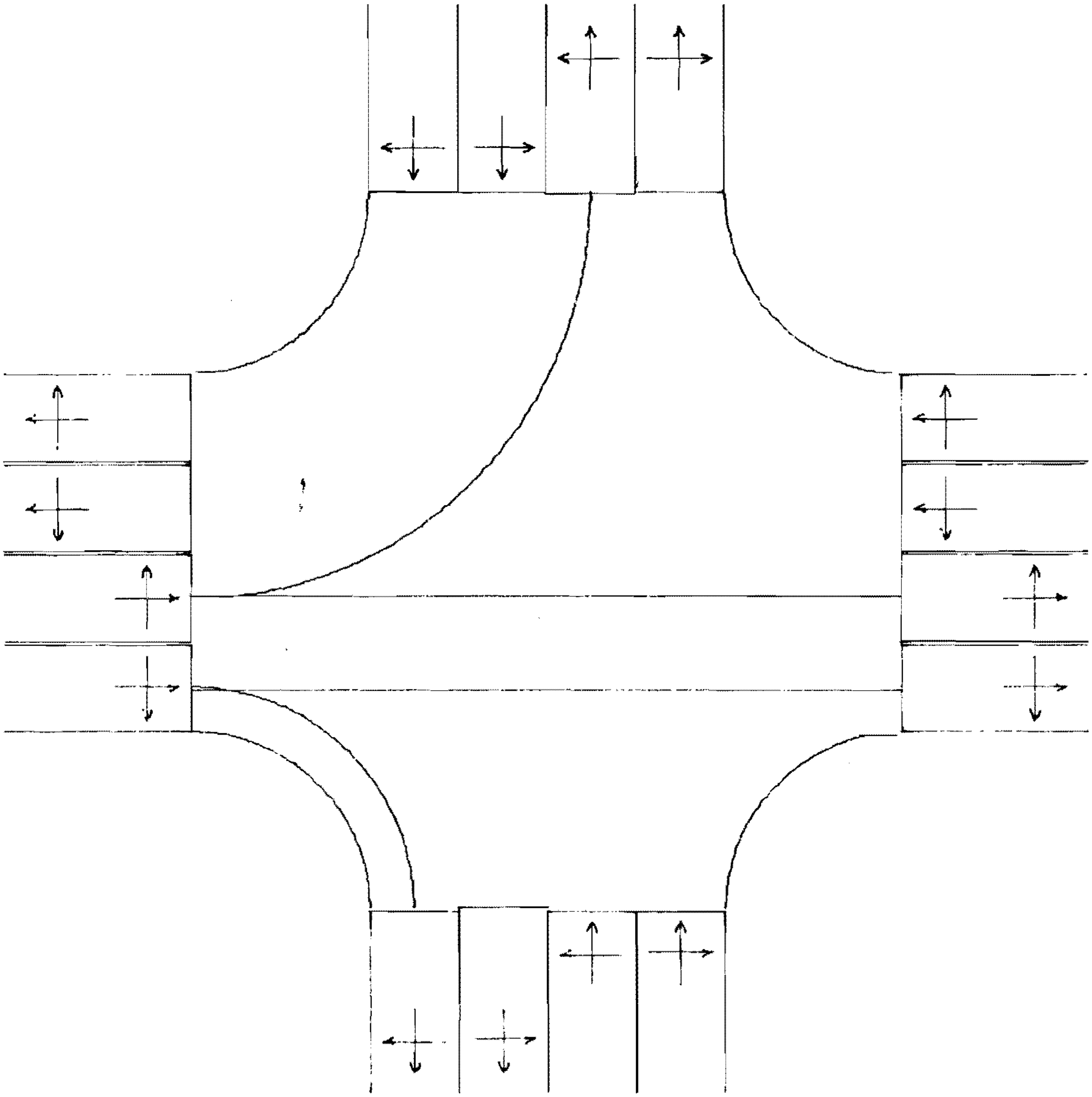
SCALE FACTOR IS 20.0 FEET PER INCH

***** NORMAL 4 X 4 INTERSECTION EXAMPLE *****



SCALE FACTOR IS 20.0 FEET PER INCH

***** NORMAL 4 X 4 INTERSECTION EXAMPLE *****



SCALE FACTOR IS 20.0 FEET PER INCH

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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE                                      PAGE  1

      *****              NORMAL 4 X 4 INTERSECTION EXAMPLE              *****

TABLE  1  -  LISTING OF INBOUND APPROACH NUMBERS


             1
             2
             3
             4


    TOTAL NUMBER OF INBOUND APPROACHES =  4



TABLE  2  -  LISTING OF OUTBOUND APPROACH NUMBERS


             5
             6
             7
             8


    TOTAL NUMBER OF OUTBOUND APPROACHES =  4



    TOTAL NUMBER OF INBOUND AND OUTBOUND APPROACHES =  8



TABLE  3  -  DRIVER-VEHICLE PROCESSOR OPTIONS


    TIME FOR GENERATING VEHICLES (MIN) ----   12
    MINIMUM HEADWAY FOR VEHICLES (SEC) ----    1.0
    NUMBER OF VEHICLE CLASSES -------------   10
    NUMBER OF DRIVER CLASSES --------------    3
    PERCENT OF LEFT TURNS IN MEDIAN LANE --   80.
    PERCENT OF RIGHT TURNS IN CURB LANE ---   80.



TABLE  4  -  LISTING OF APPROACHES


    APPROACH NUMBER -----------------------    1
    APPROACH AZIMUTH ----------------------    0
    NUMBER OF LANES -----------------------    2
    NUMBER OF DEGREES FOR STRAIGHT --------   20
    HEADWAY DISTRIBUTION NAME ------------- LOGNRML   PARAMETER =     1.70
    EQUIVALENTLY HOURLY VOLUME (VPH) ------  300
    APPROACH MEAN SPEED (MPH) -------------   25.0
    APPROACH 85 PERCENTILE SPEED (MPH) ----   30.0
        OUTBOUND APPROACH NUMBER ----------    5    6    7    8
    PERCENT GOING TO OUTBOUND APPROACHES --     0  15.  75.  10.
    USER SUPPLIED PERCENT OF VEHICLES -----   NO
        VEHICLE CLASS NUMBER --------------    1    2    3    4     5     6     7     8     9    10
    PROGRAM SUPPLIED PERCENT OF VEHICLES --  20.0 32.0 30.0 15.0    .5    .2    .1    .2    .5   1.5
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -   45. (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -   55. (CURB LANE)
```

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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC STMULATION PACKAGE                       PAGE  2

    *****             NORMAL 4 X 4 INTERSECTION EXAMPLE             *****


   APPROACH NUMBER -----------------------    2
   APPROACH AZIMUTH ----------------------  270
   NUMBER OF LANES -----------------------    2
   NUMBER OF DEGREES FOR STRAIGHT --------   20
   HEADWAY DISTRIBUTION NAME ------------- SNEGEXP   PARAMETER =    1.20
   EQUIVALENTLY HOURLY VOLUME (VPH) ------  650
   APPROACH MEAN SPEED (MPH) -------------   30.0
   APPROACH 85 PERCENTILE SPEED (MPH) ----   35.0
       OUTBOUND APPROACH NUMBER ----------    5    6    7    8
   PERCENT GOING TO OUTBOUND APPROACHES --   10.    0  15.  75.
   USER SUPPLIED PERCENT OF VEHICLES -----   NO
       VEHICLE CLASS NUMBER --------------    1    2    3    4     5    6    7    8    9   10
   PROGRAM SUPPLIED PERCENT OF VEHICLES --  20.0 32.0 30.0 15.0    .5   .2   .1   .2   .5  1.5
   PERCENT OF TRAFFIC ENTERING ON LANE 1 -   55. (MEDIAN LANE)
   PERCENT OF TRAFFIC ENTERING ON LANE 2 -   45. (CURB LANE)


   APPROACH NUMBER -----------------------    3
   APPROACH AZIMUTH ----------------------  180
   NUMBER OF LANES -----------------------    2
   NUMBER OF DEGREES FOR STRAIGHT --------   20
   HEADWAY DISTRIBUTION NAME ------------- LOGNRML   PARAMETER =    2.70
   EQUIVALENTLY HOURLY VOLUME (VPH) ------  500
   APPROACH MEAN SPEED (MPH) -------------   25.0
   APPROACH 85 PERCENTILE SPEED (MPH) ----   30.0
       OUTBOUND APPROACH NUMBER ----------    5    6    7    8
   PERCENT GOING TO OUTBOUND APPROACHES --   75.  10.    0  15.
   USER SUPPLIED PERCENT OF VEHICLES -----   NO
       VEHICLE CLASS NUMBER --------------    1    2    3    4     5    6    7    8    9   10
   PROGRAM SUPPLIED PERCENT OF VEHICLES --  20.0 32.0 30.0 15.0    .5   .2   .1   .2   .5  1.5
   PERCENT OF TRAFFIC ENTERING ON LANE 1 -   60. (MEDIAN LANE)
   PERCENT OF TRAFFIC ENTERING ON LANE 2 -   40. (CURB LANE)


   APPROACH NUMBER -----------------------    4
   APPROACH AZIMUTH ----------------------   90
   NUMBER OF LANES -----------------------    2
   NUMBER OF DEGREES FOR STRAIGHT --------   20
   HEADWAY DISTRIBUTION NAME ------------- SNEGEXP   PARAMETER =    1.10
   EQUIVALENTLY HOURLY VOLUME (VPH) ------  900
   APPROACH MEAN SPEED (MPH) -------------   30.0
   APPROACH 85 PERCENTILE SPEED (MPH) ----   35.0
       OUTBOUND APPROACH NUMBER ----------    5    6    7    8
   PERCENT GOING TO OUTBOUND APPROACHES --   15.  75.  10.    0
   USER SUPPLIED PERCENT OF VEHICLES -----   NO
       VEHICLE CLASS NUMBER --------------    1    2    3    4     5    6    7    8    9   10
   PROGRAM SUPPLIED PERCENT OF VEHICLES --  20.0 32.0 30.0 15.0    .5   .2   .1   .2   .5  1.5
   PERCENT OF TRAFFIC ENTERING ON LANE 1 -   55. (MEDIAN LANE)
   PERCENT OF TRAFFIC ENTERING ON LANE 2 -   45. (CURB LANE)


   APPROACH NUMBER -----------------------    5
   APPROACH AZIMUTH ----------------------  180
   NUMBER OF LANES -----------------------    2


   APPROACH NUMBER -----------------------    6
   APPROACH AZIMUTH ----------------------   90
   NUMBER OF LANES -----------------------    2


   APPROACH NUMBER -----------------------    7
   APPROACH AZIMUTH ----------------------    0
   NUMBER OF LANES -----------------------    2


   APPROACH NUMBER -----------------------    8
   APPROACH AZIMUTH ----------------------  270
   NUMBER OF LANES -----------------------    2


   TOTAL NUMBER OF APPROACHES =  8
```

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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE                        PAGE  3

       *****            NORMAL 4 X 4 INTERSECTION EXAMPLE              *****

TABLE  5  -  DRIVER AND VEHICLE CLASS CHARACTERISTICS


    USER SUPPLIED DRIVER CLASS SPLIT ------    NO
    USER SUPPLIED VEHICLE CHARACTERISTICS -    NO
    USER SUPPLIED DRIVER CHARACTERISTICS --    NO
        VEHICLE CLASS NUMBER --------------     1    2    3    4    5    6    7    8    9   10
    VEHICLE LOGOUT SUMMARY REQUESTED ------    NO   NO   NO   NO   NO   NO   NO   NO   NO   NO
        DRIVER CLASS NUMBER ---------------     1    2    3
    DRIVER LOGOUT SUMMARY REQUESTED -------    NO   NO   NO


    DRIVER CLASS SPLIT           (PROGRAM SUPPLIED VALUES)

        DRIVER CLASS NUMBER ---------------     1    2    3

        VEHICLE CLASS NUMBER  1 -----------  30.0 40.0 30.0
        VEHICLE CLASS NUMBER  2 -----------  35.0 35.0 30.0
        VEHICLE CLASS NUMBER  3 -----------  20.0 40.0 40.0
        VEHICLE CLASS NUMBER  4 -----------  25.0 50.0 25.0
        VEHICLE CLASS NUMBER  5 -----------  40.0 30.0 30.0
        VEHICLE CLASS NUMBER  6 -----------  50.0 40.0 10.0
        VEHICLE CLASS NUMBER  7 -----------  50.0 40.0 10.0
        VEHICLE CLASS NUMBER  8 -----------  20.0 30.0 50.0
        VEHICLE CLASS NUMBER  9 -----------  25.0 50.0 25.0
        VEHICLE CLASS NUMBER 10 -----------  50.0 40.0 10.0


    VEHICLE CHARACTERISTICS      (PROGRAM SUPPLIED VALUES)

        VEHICLE CLASS NUMBER --------------     1    2    3    4    5    6    7    8    9   10

        LENGTH OF VEHICLES (FT) -----------    15   17   19   25   30   50   55   25   35   14
        VEHICLE OPERATIONAL FACTOR --------   100  110  110  100   85   80   75   90   85  115
        MAXIMUM DECELERATION (FT/SEC/SEC) -     8   11   11    8   11   11   11    8   11   12
        MAXIMUM ACCELERATION (FT/SEC/SEC) -     8    9   11    8    8    7    6    6    5   14
        MAXIMUM VELOCITY (FT/SEC) ---------   150  192  200  150  160  160  150  150  125  205
        MINIMUM TURNING RADIUS (FT) -------    20   22   24   28   42   40   45   28   28   20


    DRIVER CHARACTERISTICS       (PROGRAM SUPPLIED VALUES)

        DRIVER CLASS NUMBER ---------------     1    2    3

        DRIVER OPERATIONAL FACTOR ---------   110  100   85
        DRIVER REACTION TIME (SEC) --------    .5  1.0  1.5


TABLE  6  -  GENERATION OF APPROACH HEADWAYS


    APPROACH  DISTRIBUTION   NUMBER    VOLUME    INPUT   PERCENT
     NUMBER       NAME      GENERATED GENERATED  VOLUME  DIFFERENCE

        1        LOGNRML        59        295      300      -1.67
        2        SNEGEXP       124        620      650      -4.62
        3        LOGNRML        97        485      500      -3.00
        4        SNEGEXP       177        885      900      -1.67

     TOTAL                     457       2285     2350      -2.77
```

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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE                          PAGE  4

      *****           NORMAL 4 X 4 INTERSECTION EXAMPLE            *****

TABLE  7  -  FINAL APPROACH VOLUMES

                  SPECIAL  VEHICLES         GENERATED  VEHICLES         TOTAL  VEHICLES
                 ---------------------     ---------------------     ---------------------
    APPROACH    NUMBER FOR  VOLUME FOR     NUMBER FOR  VOLUME FOR    NUMBER FOR  VOLUME FOR     INPUT
     NUMBER     SIMULATION  SIMULATION     SIMULATION  SIMULATION    SIMULATION  SIMULATION     VOLUME

       1            0           0              59         295            59          295          300
       2            0           0             124         620           124          620          650
       3            0           0              97         485            97          485          500
       4            0           0             177         885           177          885          900

     TOTAL          0           0             457        2285           457         2285         2350

    THE INTERSECTION HAS A JAM DENSITY OF 235 VEHICLES PER MILE


TABLE  8  -  STATISTICS OF GENERATION

    APPROACH STATISTICS
    -------------------

    APPROACH NUMBER -----------------------     1
        OUTBOUND APPROACH NUMBER ----------     5    6    7    8
    PERCENT GOING TO OUTBOUND APPROACHES --     0  8.5 79.7 11.9
        VEHICLE CLASS NUMBER --------------     1    2    3    4    5    6    7    8    9   10
    GENERATION PERCENT OF VEHICLES --------   8.5 44.1 28.8 15.3    0    0    0  1.7    0  1.7
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  40.7 (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  59.3 (CURB LANE)

    APPROACH NUMBER -----------------------     2
        OUTBOUND APPROACH NUMBER ----------     5    6    7    8
    PERCENT GOING TO OUTBOUND APPROACHES --  12.1    0 16.1 71.8
        VEHICLE CLASS NUMBER --------------     1    2    3    4    5    6    7    8    9   10
    GENERATION PERCENT OF VEHICLES --------  15.3 42.7 24.2 14.5   .8    0    0    0   .8  1.6
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  55.6 (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  44.4 (CURB LANE)

    APPROACH NUMBER -----------------------     3
        OUTBOUND APPROACH NUMBER ----------     5    6    7    8
    PERCENT GOING TO OUTBOUND APPROACHES --  75.3  9.3    0 15.5
        VEHICLE CLASS NUMBER --------------     1    2    3    4    5    6    7    8    9   10
    GENERATION PERCENT OF VEHICLES --------  29.9 26.8 29.9  9.3  1.0    0    0    0  2.1  1.0
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  61.9 (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  38.1 (CURB LANE)

    APPROACH NUMBER -----------------------     4
        OUTBOUND APPROACH NUMBER ----------     5    6    7    8
    PERCENT GOING TO OUTBOUND APPROACHES --  13.0 78.0  9.0    0
        VEHICLE CLASS NUMBER --------------     1    2    3    4    5    6    7    8    9   10
    GENERATION PERCENT OF VEHICLES --------  17.5 36.7 31.6 12.4    0    0    0   .6  1.1    0
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  49.7 (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  50.3 (CURB LANE)
```

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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE                                   PAGE  5

      *****            NORMAL 4 X 4 INTERSECTION EXAMPLE            *****

    DRIVER CLASS SPLIT STATISTICS
    -----------------------------

    DRIVER CLASS NUMBER -------------------      1     2     3

    VEHICLE CLASS NUMBER  1 (  84 VEH) -----  20.2  52.4  27.4
    VEHICLE CLASS NUMBER  2 ( 170 VEH) -----  40.0  30.0  30.0
    VEHICLE CLASS NUMBER  3 ( 132 VEH) -----  16.7  43.2  40.2
    VEHICLE CLASS NUMBER  4 (  58 VEH) -----  25.9  51.7  22.4
    VEHICLE CLASS NUMBER  5 (   2 VEH) -----     0  50.0  50.0
    VEHICLE CLASS NUMBER  6 (   0 VEH) -----     0     0     0
    VEHICLE CLASS NUMBER  7 (   0 VEH) -----     0     0     0
    VEHICLE CLASS NUMBER  8 (   2 VEH) -----     0  50.0  50.0
    VEHICLE CLASS NUMBER  9 (   5 VEH) -----  40.0  20.0  40.0
    VEHICLE CLASS NUMBER 10 (   4 VEH) -----  75.0  25.0     0
```

```
    *******  PRINT OF FILF SIMSA    -  14 NOV 77  -  22.43.51.  -  PAGE   1  *******

             1         2         3         4         5         6         7         8
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
    ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
 1 <     ***** SEMI-ACTUATED SIGNAL CONTROLLER WITH PRESENCE LOOPS  *****           >      1
 2 <2.00 10.00 1.00 10 30 2.800 0.800 4000 6 NO  YES NO  NO  1.50 2.50              >      2
 3 <5757575711111111                                                                >      3
 4 <   4                                                                            >      4
 5 < 1   AR AR AG AG AR AR AG AG                                                    >      5
 6 < 1         AA AA       AA AA                                                    >      6
 7 < 2   AG AG AR AR AG AG AR AR                                                    >      7
 8 < 2   AA AA       AA AA                                                          >      8
 9 <   2                                                                            >      9
10 < 1 27.0       3.0  0.0                                 1 2                      >     10
11 < 2  3.0  2.0  3.0  0.0  22.0 OFF OFF NO  NU  OR    2   1 1                      >     11
12 <   1   2                                                                        >     12
13 <   2                                                                            >     13
14 < 1 PRESENCE  740 790   1   2   1   2                                            >     14
15 < 2 PRESENCE  740 790   3   2   1   2                                            >     15
    vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv
             1         2         3         4         5         6         7         8
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
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ECHO-PRINT OF TITLE FROM GEOMETRY PROCESSOR
      *****              NORMAL 4 X 4 INTERSECTION EXAMPLE              *****

ECHO-PRINT OF TITLE FROM DRIVER-VEHICLE PROCESSOR
      *****              NORMAL 4 X 4 INTERSECTION EXAMPLE              *****

ECHO-PRINT OF TITLE FROM SIMULATION PROCESSOR INPUT
    ***** SEMI-ACTUATED SIGNAL CONTROLLER WITH PRESENCE LOOPS  *****


START-UP TIME (MINUTES) --------------------------- =      2.00
SIMULATION TIME (MINUTES) ------------------------- =     10.00
STEP INCREMENT FOR SIMULATION TIME (SECONDS) ------ =      1.00

SPEED FOR DELAY BELOW XX MPH (MPH) ---------------- =     10.00

MAXIMUM CLEAR DISTANCE FOR BEING IN A QUEUE (FT) -- =     30.00

CAR FOLLOWING EQUATION LAMBDA --------------------- =      2.80000
CAR FOLLOWING EQUATION MU ------------------------- =       .80000
CAR FOLLOWING EQUATION ALPHA ---------------------- =   4000.00000

SUMMARY STATISTICS PRINTED BY TURNING MOVEMENTS --- =    NO
SUMMARY STATISTICS PRINTED BY INBOUND APPROACH ---- =    YES

PUNCHED OUTPUT OF STATISTICS ---------------------- =    NO

WRITE TAPE FOR POLLUTION DISPERSION MODEL --------- =    NO

LEAD TIME GAP FOR CONFLICT CHECKING (SECONDS) ----- =      1.50
LAG TIME GAP FOR CONFLICT CHECKING (SECONDS) ------ =      2.50

INTERSECTION TRAFFIC CONTROL ---------------------- =      6  (SEMI-ACTUATED)
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         SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

     ***** SEMI-ACTUATED SIGNAL CONTROLLER WITH PRESENCE LOOPS  *****

LANE CONTROL FOR THE 16 LANES = 5 7 5 7 5 7 5 7 1 1 1 1 1 1 1 1

     WHERE  1 = OUTBOUND (OR BLOCKED INBOUND) LANE
            2 = UNCONTROLLED
            3 = YIELD SIGN
            4 = STOP SIGN
            5 = SIGNAL
            6 = SIGNAL WITH LEFT TURN ON RED
            7 = SIGNAL WITH RIGHT TURN ON RED


A TOTAL OF  4 CAM STACK ENTRIES

ENTRY  1 PHASE  1  AR  AR  AG  AG  AR  AR  AG  AG
ENTRY  2 PHASE  1          AA  AA          AA  AA
ENTRY  3 PHASE  2  AG  AG  AR  AR  AG  AG  AR  AR
ENTRY  4 PHASE  2  AA  AA          AA  AA
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         SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

      ***** SEMI-ACTUATED SIGNAL CONTROLLER WITH PRESENCE LOOPS  *****

A TOTAL OF 2 SIGNAL PHASES


SEMI-ACTUATED SIGNAL MAIN STREET INFORMATION
MAIN STREET PHASE NUMBER ------------------------- =    1
MAIN STREET MINIMUM ASSURED GREEN (SECONDS) ------ =  27.0
MAIN STREET AMBER CLEARANCE INTERVAL (SECONDS) --- =   3.0
MAIN STREET ALL-RED CLEARANCE INTERVAL (SECONDS) - =     0
MAIN STREET NUMBER OF PHASES CLEARED TO ----------=    1
MAIN STREET LIST OF PHASES CLEARED TO ------------=    2


SIGNAL PHASE NUMBER ------------------------------ =    2
INITIAL INTERVAL (SECONDS) ----------------------- =   3.0
VEHICLE INTERVAL (SECONDS) ----------------------- =   2.0
AMBER CLEARANCE INTERVAL (SECONDS) --------------- =   3.0
ALL-RED CLEARANCE INTERVAL (SECONDS) ------------- =     0
MAXIMUM EXTENSION AFTER DEMAND ON RED (SECONDS) -- =  22.0
SKIP-PHASE SWITCH (ON/OFF) ----------------------- =   OFF
AUTO-RECALL SWITCH (ON/OFF) ---------------------- =   OFF
PARENT/MINOR MOVEMENT PHASE OPTION (YES/NO) ------ =   NO
DUAL LEFT OPTION (YES/NO) ------------------------ =   NO
DETECTOR CONNECTION TYPE (AND/OR) ---------------- =   OR
NUMBER OF DETECTORS CONNECTED TO PHASE ----------- =   2
NUMBER OF PHASES CLEARED TO ---------------------- =   1
LIST OF PHASES CLEARED TO ------------------------ =   1
LIST OF DETECTORS CONNECTED TO PHASE ------------- =   1    2




A TOTAL OF  2 DETECTORS


DETECTOR NUMBER ------------ =     1
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =  740
STOPPING POSITION (FEET) --- =  790
APPROACH NUMBER ------------ =     1
NUMBER OF LANES ------------ =     2
LIST OF LANE NUMBERS ------- =     1     2


DETECTOR NUMBER ------------ =     2
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =  740
STOPPING POSITION (FEET) --- =  790
APPROACH NUMBER ------------ =     3
NUMBER OF LANES ------------ =     2
LIST OF LANE NUMBERS ------- =     1     2
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         SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

      ***** SEMI-ACTUATED SIGNAL CONTROLLER WITH PRESENCE LOOPS  *****

SUMMARY STATISTICS FOR INBOUND APPROACH  1


TOTAL DELAY (VEHICLE-SECONDS) ---------------------- =     706.8
NUMBER OF VEHICLES INCURRING TOTAL DELAY ---------- =      44
PERCENT OF VEHICLES INCURRING TOTAL DELAY --------- =      91.7
AVERAGE TOTAL DELAY (SECONDS) --------------------- =      16.1
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ----------- =      32.8 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) --------------------- =     577.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ---------- =      33
PERCENT OF VEHICLES INCURRING QUEUE DELAY --------- =      68.8
AVERAGE QUEUE DELAY (SECONDS) --------------------- =      17.5
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ----------- =      35.7 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) ------------------- =     536.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY -------- =      33
PERCENT OF VEHICLES INCURRING STOPPED DELAY ------- =      68.8
AVERAGE STOPPED DELAY (SECONDS) ------------------- =      16.2
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME --------- =      33.1 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------ =     635.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH - =      34
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH  =      70.8
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------ =      18.7
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =      38.1 PERCENT

VEHICLE-MILES OF TRAVEL --------------------------- =      11.944
AVERAGE VEHICLE-MILES OF TRAVEL ------------------- =        .249
TRAVEL TIME (VEHICLE-SECONDS) ---------------------=    2352.7
AVERAGE TRAVEL TIME (SECONDS) --------------------- =      49.0
NUMBER OF VEHICLES PROCESSED ---------------------- =      48
VOLUME PROCESSED (VEHICLES/HOUR) ------------------ =     288.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS  =      19.5
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =      18.3
AVERAGE DESIRED SPEED (MPH) ----------------------- =      26.4
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) --------- =       3.9
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) --------- =       3.9

OVERALL AVERAGE TOTAL DELAY (SECONDS) ------------- =      14.7
OVERALL AVERAGE QUEUE DELAY (SECONDS) ------------- =      12.0
OVERALL AVERAGE STOPPED DELAY (SECONDS) ----------- =      11.2
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ---- =      13.2

PERCENT OF VEHICLES MAKING A U-TURN OR A LEFT TURN  =       8.3
PERCENT OF VEHICLES GOING STRAIGHT ---------------- =      81.3
PERCENT OF VEHICLES MAKING A RIGHT TURN ----------- =      10.4

AVERAGE QUEUE LENGTH FOR LANE 1 ------------------- =        .5   MAX =  2
AVERAGE QUEUE LENGTH FOR LANE 2 ------------------- =        .5   MAX =  2

AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ---- =      99.9
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          SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

      ***** SEMI-ACTUATED SIGNAL CONTROLLER WITH PRESENCE LOOPS  *****

SUMMARY STATISTICS FOR INBOUND APPROACH  2


TOTAL DELAY (VEHICLE-SECONDS) ---------------------- =   1241.6
NUMBER OF VEHICLES INCURRING TOTAL DELAY ---------- =     94
PERCENT OF VEHICLES INCURRING TOTAL DELAY --------- =     88.7
AVERAGE TOTAL DELAY (SECONDS) --------------------- =     13.2
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ----------- =     31.8 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) --------------------- =    879.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ---------- =     52
PERCENT OF VEHICLES INCURRING QUEUE DELAY --------- =     49.1
AVERAGE QUEUE DELAY (SECONDS) --------------------- =     16.9
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ----------- =     40.6 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) ------------------- =    729.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY -------- =     52
PERCENT OF VEHICLES INCURRING STOPPED DELAY ------- =     49.1
AVERAGE STOPPED DELAY (SECONDS) ------------------- =     14.0
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME --------- =     33.7 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------ =    981.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH - =     61
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH  =     57.5
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------ =     16.1
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =     38.7 PERCENT

VEHICLE-MILES OF TRAVEL --------------------------- =     26.432
AVERAGE VEHICLE-MILES OF TRAVEL ------------------- =       .249
TRAVEL TIME (VEHICLE-SECONDS) ----------------------=   4408.6
AVERAGE TRAVEL TIME (SECONDS) --------------------- =     41.6
NUMBER OF VEHICLES PROCESSED ---------------------- =    106
VOLUME PROCESSED (VEHICLES/HOUR) ------------------ =    636.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS  =     23.7
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =     21.6
AVERAGE DESIRED SPEED (MPH) ----------------------- =     30.0
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) --------- =      3.6
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) --------- =      3.4

OVERALL AVERAGE TOTAL DELAY (SECONDS) ------------- =     11.7
OVERALL AVERAGE QUEUE DELAY (SECONDS) ------------- =      8.3
OVERALL AVERAGE STOPPED DELAY (SECONDS) ----------- =      6.9
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ---- =      9.3

PERCENT OF VEHICLES MAKING A U-TURN OR A LEFT TURN  =     12.3
PERCENT OF VEHICLES GOING STRAIGHT ---------------- =     70.8
PERCENT OF VEHICLES MAKING A RIGHT TURN ----------- =     17.0

AVERAGE QUEUE LENGTH FOR LANE 1 ------------------- =      1.0  MAX =  4
AVERAGE QUEUE LENGTH FOR LANE 2 ------------------- =       .5  MAX =  4

AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ---- =     99.4
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          SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

      ***** SEMI-ACTUATED SIGNAL CONTROLLER WITH PRESENCE LOOPS  *****

SUMMARY STATISTICS FOR INBOUND APPROACH  3


TOTAL DELAY (VEHICLE-SECONDS) ---------------------- =   1718.5
NUMBER OF VEHICLES INCURRING TOTAL DELAY ---------- =     77
PERCENT OF VEHICLES INCURRING TOTAL DELAY --------- =     97.5
AVERAGE TOTAL DELAY (SECONDS) --------------------- =     22.3
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ----------- =     38.4 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) --------------------- =   1324.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ---------- =     66
PERCENT OF VEHICLES INCURRING QUEUE DELAY --------- =     83.5
AVERAGE QUEUE DELAY (SECONDS) --------------------- =     20.1
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ----------- =     34.5 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) ------------------- =   1140.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY -------- =     66
PERCENT OF VEHICLES INCURRING STOPPED DELAY ------- =     83.5
AVERAGE STOPPED DELAY (SECONDS) ------------------- =     17.3
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME --------- =     29.7 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------ =   1560.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH - =     68
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH  =     86.1
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------ =     22.9
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =     39.4 PERCENT

VEHICLE-MILES OF TRAVEL --------------------------- =     19.586
AVERAGE VEHICLE-MILES OF TRAVEL ------------------- =       .248
TRAVEL TIME (VEHICLE-SECONDS) ----------------------=   4596.8
AVERAGE TRAVEL TIME (SECONDS) --------------------- =     58.2
NUMBER OF VEHICLES PROCESSED ---------------------- =     79
VOLUME PROCESSED (VEHICLES/HOUR) ------------------ =    474.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS  =     16.3
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =     15.3
AVERAGE DESIRED SPEED (MPH) ----------------------- =     24.9
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) --------- =      3.8
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) --------- =      3.5

OVERALL AVERAGE TOTAL DELAY (SECONDS) ------------- =     21.8
OVERALL AVERAGE QUEUE DELAY (SECONDS) ------------- =     16.8
OVERALL AVERAGE STOPPED DELAY (SECONDS) ----------- =     14.4
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ---- =     19.7

PERCENT OF VEHICLES MAKING A U-TURN OR A LEFT TURN  =      7.6
PERCENT OF VEHICLES GOING STRAIGHT ---------------- =     75.9
PERCENT OF VEHICLES MAKING A RIGHT TURN ----------- =     16.5

AVERAGE QUEUE LENGTH FOR LANE 1 ------------------- =      1.2  MAX =  4
AVERAGE QUEUE LENGTH FOR LANE 2 ------------------- =      1.2  MAX =  4

AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ---- =     99.9
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          SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

      ***** SEMI-ACTUATED SIGNAL CONTROLLER WITH PRESENCE LOOPS  *****

SUMMARY STATISTICS FOR INBOUND APPROACH  4


TOTAL DELAY (VEHICLE-SECONDS) --------------------- =   1564.0
NUMBER OF VEHICLES INCURRING TOTAL DELAY ---------- =    131
PERCENT OF VEHICLES INCURRING TOTAL DELAY --------- =     89.7
AVERAGE TOTAL DELAY (SECONDS) --------------------- =     11.9
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ----------- =     29.3 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) --------------------- =    809.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ---------- =     62
PERCENT OF VEHICLES INCURRING QUEUE DELAY --------- =     42.5
AVERAGE QUEUE DELAY (SECONDS) --------------------- =     13.0
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ----------- =     32.0 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) ------------------- =    656.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY -------- =     62
PERCENT OF VEHICLES INCURRING STOPPED DELAY ------- =     42.5
AVERAGE STOPPED DELAY (SECONDS) ------------------- =     10.6
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME --------- =     26.0 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------ =   1127.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH - =     84
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH  =     57.5
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------ =     13.4
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =     32.9 PERCENT

VEHICLE-MILES OF TRAVEL --------------------------- =     36.441
AVERAGE VEHICLE-MILES OF TRAVEL ------------------- =       .250
TRAVEL TIME (VEHICLE-SECONDS) ---------------------=   5947.9
AVERAGE TRAVEL TIME (SECONDS) --------------------- =     40.7
NUMBER OF VEHICLES PROCESSED ---------------------- =    146
VOLUME PROCESSED (VEHICLES/HOUR) ------------------ =    876.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS  =     23.2
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =     22.1
AVERAGE DESIRED SPEED (MPH) ----------------------- =     30.2
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) --------- =      3.4
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) --------- =      3.0

OVERALL AVERAGE TOTAL DELAY (SECONDS) ------------- =     10.7
OVERALL AVERAGE QUEUE DELAY (SECONDS) ------------- =      5.5
OVERALL AVERAGE STOPPED DELAY (SECONDS) ----------- =      4.5
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ---- =      7.7

PERCENT OF VEHICLES MAKING A U-TURN OR A LEFT TURN  =     10.3
PERCENT OF VEHICLES GOING STRAIGHT ---------------- =     76.0
PERCENT OF VEHICLES MAKING A RIGHT TURN ----------- =     13.7

AVERAGE QUEUE LENGTH FOR LANE 1 ------------------- =       .8  MAX =   4
AVERAGE QUEUE LENGTH FOR LANE 2 ------------------- =       .6  MAX =   4

AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ---- =     98.7
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          SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

      ***** SEMI-ACTUATED SIGNAL CONTROLLER WITH PRESENCE LOOPS  *****

SUMMARY STATISTICS FOR ALL APPROACHES


TOTAL DELAY (VEHICLE-SECONDS) --------------------- =   5230.9
NUMBER OF VEHICLES INCURRING TOTAL DELAY ---------- =    346
PERCENT OF VEHICLES INCURRING TOTAL DELAY --------- =     91.3
AVERAGE TOTAL DELAY (SECONDS) --------------------- =     15.1
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ----------- =     33.1 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) --------------------- =   3589.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ---------- =    213
PERCENT OF VEHICLES INCURRING QUEUE DELAY --------- =     56.2
AVERAGE QUEUE DELAY (SECONDS) --------------------- =     16.8
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ----------- =     36.9 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) ------------------- =   3061.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY -------- =    213
PERCENT OF VEHICLES INCURRING STOPPED DELAY ------- =     56.2
AVERAGE STOPPED DELAY (SECONDS) ------------------- =     14.4
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME --------- =     31.5 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------ =   4303.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH - =    247
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH  =     65.2
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------ =     17.4
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =     38.2 PERCENT

VEHICLE-MILES OF TRAVEL --------------------------- =     94.402
AVERAGE VEHICLE-MILES OF TRAVEL ------------------- =       .249
TRAVEL TIME (VEHICLE-SECONDS) ---------------------=  17306.0
AVERAGE TRAVEL TIME (SECONDS) --------------------- =     45.7
NUMBER OF VEHICLES PROCESSED ---------------------- =    379
VOLUME PROCESSED (VEHICLES/HOUR) ------------------ =   2274.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS  =     21.4
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =     19.6
AVERAGE DESIRED SPEED (MPH) ----------------------- =     28.7
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) --------- =      3.6
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) --------- =      3.3

OVERALL AVERAGE TOTAL DELAY (SECONDS) ------------- =     13.8
OVERALL AVERAGE QUEUE DELAY (SECONDS) ------------- =      9.5
OVERALL AVERAGE STOPPED DELAY (SECONDS) ----------- =      8.1
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ---- =     11.4

AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ---- =     99.3
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        SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

     ***** SEMI-ACTUATED SIGNAL CONTROLLER WITH PRESENCE LOOPS  *****


SUMMARY STATISTICS FOR SEMI-ACTUATED SIGNAL

MAIN STREET PHASE NUMBER ----------------------------- =    1
MAIN STREET MINIMUM ASSURED GREEN (SECONDS) -------- =  27.0
MAIN STREET AMBER CLEARANCE INTERVAL (SECONDS) ---- =   3.0
MAIN STREET ALL-RED CLEARANCE INTERVAL (SECONDS) -- =     0
MAIN STREET NUMBER OF PHASES CLEARED TO ------------=    1
MAIN STREET LIST OF PHASES CLEARED TO --------------=    2
NUMBER OF MAIN STREET GREEN PHASES----------------- =  12
AVERAGE LENGTH OF MAIN STREET GREEN (SECONDS) ----- =  28.0


SIGNAL PHASE NUMBER -------------------------------- =    2
INITIAL INTERVAL (SECONDS) ------------------------ =   3.0
VEHICLE INTERVAL (SECONDS) ------------------------ =   2.0
AMBER CLEARANCE INTERVAL (SECONDS) ---------------- =   3.0
ALL-RED CLEARANCE INTERVAL (SECONDS) -------------- =     0
MAXIMUM EXTENSION AFTER DEMAND ON RED (SECONDS) --- =  22.0
SKIP-PHASE SWITCH (ON/OFF) ------------------------ =   OFF
AUTO-RECALL SWITCH (ON/OFF) ----------------------- =   OFF
PARENT/MINOR MOVEMENT PHASE OPTION (YES/NO) ------- =   NO
DUAL LEFT OPTION (YES/NO) ------------------------- =   NO
DETECTOR CONNECTION TYPE (AND/OR) ----------------- =   OR
NUMBER OF DETECTORS CONNECTED TO PHASE ------------ =   2
NUMBER OF PHASES CLEARED TO ----------------------- =   1
LIST OF PHASES CLEARED TO ------------------------- =   1
LIST OF DETECTORS CONNECTED TO PHASE -------------- =   1    2
NUMBER OF MAX-OUTS -------------------------------- =   1
AVERAGE TIME INTO PHASE FOR MAX-OUT (SECONDS) ----- =  23.8
NUMBER OF GAP-OUTS -------------------------------- =  11
AVERAGE TIME INTO PHASE FOR GAP-OUT (SECONDS) ----- =  14.1
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     SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

***** SEMI-ACTUATED SIGNAL CONTROLLER WITH PRESENCE LOOPS  *****

START-UP TIME    =  120.000 SECONDS      NUMBER OF VEHICLES PROCESSED =    49

SIMULATION TIME =  600.000 SECONDS      NUMBER OF VEHICLES PROCESSED =  379

NUMBER OF VEHICLES IN THE SYSTEM AT SUMMARY =   29
AVERAGE NUMBER OF VEHICLES IN THE SYSTEM -- =   29.4  MAX =  42



INITIAL     TM TIME =      .431 SECONDS   COST = $   .03

START-UP    TM TIME =     6.668 SECONDS   COST = $   .43
            REAL/TM =    17.996

SIMULATION TM TIME =    46.597 SECONDS   COST = $  2.98
            REAL/TM =    12.876

SUMMARY     TM TIME =      .416 SECONDS   COST = $   .03


TOTAL       TM TIME =    54.112 SECONDS   COST = $  3.46


VEHICLE-SECONDS OF SIMULATION PER TM TIME =  371.398

VEHICLE UPDATES PER TM TIME =  371.398
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    ********* PRINT OF FILE SIXPS    -  31 MAY 78  -  15.42.53.  -  PAGE    1  ********

             1         2         3         4         5         6         7         8
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
    ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
 1 <    *****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)     *****    >     1
 2 <   6                                                                            >     2
 3 <   1   3   5   7   9  11                                                        >     3
 4 <   6                                                                            >     4
 5 <   2   4   6   8  10  12                                                        >     5
 6 <  12  12 1.1         100 100                                                    >     6
 7 <   1 180 450 900  30   2  0  0 LOGNRML  450  8.06 30.0 34.3 00 09 09 40 27 15NO >     7
 8 <  15   0 383   0 383  LS        45        15   0 383   0 383   SR       55      >     8
 9 <   2   0 450 517  30   2                                                        >     9
10 <  15   0 383   0 383  LS                  15   0 383   0 383   SR               >    10
11 <   3 232 882 793  30   2  0  0 LOGNRML  725  4.73 19.0 25.7 13 00 07 08 42 30NO >    11
12 <  15   0 486   0 486  LS        40        15   0 486   0 486   SR       60      >    12
13 <   4  52 499 494  30   2                                                        >    13
14 <  15   0 486   0 486  LS                  15   0 486   0 486   SR               >    14
15 <   5 270 900 440  30   2 30  0 LOGNRML  470  6.23 19.0 25.7 25 10 00 11 09 45NO >    15
16 <  15   0 383   0 383  LS        45        15   0 383   0 383   SR       55      >    16
17 <   6  90 517 440  30   2                                                        >    17
18 <  15   0 383   0 383  LS                  15   0 383   0 383   SR               >    18
19 <   7   0 465   0  30   2  0  0 SNEGEXP  550  2.18 25.0 28.6 38 27 20 00 05 10NO >    19
20 <  15   0 388   0 388  LS        50        15   0 388   0 388   SR       50      >    20
21 <   8 180 465 388  30   2                                                        >    21
22 <  15   0 388   0 388  LS                  15   0 388   0 388   SR               >    22
23 <   9  59  19 190  30   2  0  0 LOGNRML  575  4.99 23.9 28.6 07 45 25 12 00 11NO >    23
24 <  15   0 439   0 439  LS        50        15   0 439   0 439   SR       50      >    24
25 <  10 239 395 416  30   2                                                        >    25
26 <  15   0 439   0 439  LS                  15   0 439   0 439   SR               >    26
27 <  11 120  15 703  30   2 30  0 SNEGEXP  500  2.18 24.5 27.7 09 06 37 26 22 00NO >    27
28 <  15   0 433   0 433  LS        50        15   0 433   0 433   SR       50      >    28
29 <  12 300 390 487  30   2                                                        >    29
30 <  15   0 433   0 433  LS                  15   0 433   0 433   SR               >    30
31 <   4                                                                            >    31
32 <   1 413 517  90 120   7                                                        >    32
33 <   2 517 388 270  90  22                                                        >    33
34 <   3 425 388 330 120  10                                                        >    34
35 <   4 376 449  30 120   8                                                        >    35
36 <   3                                                                            >    36
37 <   1 410 390 420 396                                                            >    37
38 <   2 375 459 380 456                                                            >    38
39 <   3 405 513 409 511                                                            >    39
40 <   0                                                                            >    40
41 <PRIMARY   PLOTI     SAME          150.00     30.00                  12          >    41
42 <NO NO NO NO NO NO NO NO NO NO NO NO NO                NO NO NO                  >    42
    vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv
             1         2         3         4         5         6         7         8
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

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     GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE    PAGE  1

*****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)      *****


  TABLE  1  -  LISTING OF INBOUND APPROACH NUMBERS


                 1
                 3
                 5
                 7
                 9
                11


     TOTAL NUMBER OF INBOUND APPROACHES =  6


  TABLE  2  -  LISTING OF OUTBOUND APPROACH NUMBERS


                 2
                 4
                 6
                 8
                10
                12


     TOTAL NUMBER OF OUTBOUND APPROACHES =  6


     TOTAL NUMBER OF INBOUND AND OUTBOUND APPROACHES = 12


  TABLE  3  -  LISTING OF APPROACHES

     APPROACH NUMBER -------------------     1
     APPROACH AZIMUTH ------------------   180
     BEGINNING CENTERLINE X COORDINATE -   450
     BEGINNING CENTERLINE Y COORDINATE -   900
     SPEED LIMIT (MPH) -----------------    30
     NUMBER OF DEGREES FOR STRAIGHT ----    20
     NUMBER OF DEGREES FOR U-TURN ------    10
     NUMBER OF LANES -------------------     2

     LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
       1   1   1   15      0  383    0  383   ( LS )       (MEDIAN LANE)
       2   2   2   15      0  383    0  383   (  SR)       (CURB LANE)

     APPROACH NUMBER -------------------     2
     APPROACH AZIMUTH ------------------     0
     BEGINNING CENTERLINE X COORDINATE -   450
     BEGINNING CENTERLINE Y COORDINATE -   517
     SPEED LIMIT (MPH) -----------------    30
     NUMBER OF DEGREES FOR STRAIGHT ----    20
     NUMBER OF DEGREES FOR U-TURN ------    10
     NUMBER OF LANES -------------------     2

     LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
       1   3   0   15      0  383    0  383   ( LS )       (MEDIAN LANE)
       2   4   0   15      0  383    0  383   (  SR)       (CURB LANE)
```

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     GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE    PAGE  2

*****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)      *****

     APPROACH NUMBER -------------------     3
     APPROACH AZIMUTH ------------------   232
     BEGINNING CENTERLINE X COORDINATE -   882
     BEGINNING CENTERLINE Y COORDINATE -   793
     SPEED LIMIT (MPH) -----------------    30
     NUMBER OF DEGREES FOR STRAIGHT ----    20
     NUMBER OF DEGREES FOR U-TURN ------    10
     NUMBER OF LANES -------------------     2

     LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
       1   5   3   15      0  486    0  486   ( LS )       (MEDIAN LANE)
       2   6   4   15      0  486    0  486   (  SR)       (CURB LANE)

     APPROACH NUMBER -------------------     4
     APPROACH AZIMUTH ------------------    52
     BEGINNING CENTERLINE X COORDINATE -   499
     BEGINNING CENTERLINE Y COORDINATE -   494
     SPEED LIMIT (MPH) -----------------    30
     NUMBER OF DEGREES FOR STRAIGHT ----    20
     NUMBER OF DEGREES FOR U-TURN ------    10
     NUMBER OF LANES -------------------     2

     LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
       1   7   0   15      0  486    0  486   ( LS )       (MEDIAN LANE)
       2   8   0   15      0  486    0  486   (  SR)       (CURB LANE)

     APPROACH NUMBER -------------------     5
     APPROACH AZIMUTH ------------------   270
     BEGINNING CENTERLINE X COORDINATE -   900
     BEGINNING CENTERLINE Y COORDINATE -   440
     SPEED LIMIT (MPH) -----------------    30
     NUMBER OF DEGREES FOR STRAIGHT ----    30
     NUMBER OF DEGREES FOR U-TURN ------    10
     NUMBER OF LANES -------------------     2

     LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
       1   9   5   15      0  383    0  383   ( LS )       (MEDIAN LANE)
       2  10   6   15      0  383    0  383   (  SR)       (CURB LANE)

     APPROACH NUMBER -------------------     6
     APPROACH AZIMUTH ------------------    90
     BEGINNING CENTERLINE X COORDINATE -   517
     BEGINNING CENTERLINE Y COORDINATE -   440
     SPEED LIMIT (MPH) -----------------    30
     NUMBER OF DEGREES FOR STRAIGHT ----    20
     NUMBER OF DEGREES FOR U-TURN ------    10
     NUMBER OF LANES -------------------     2

     LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
       1  11   0   15      0  383    0  383   ( LS )       (MEDIAN LANE)
       2  12   0   15      0  383    0  383   (  SR)       (CURB LANE)
```

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      GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE     PAGE  3

*****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)      *****


        APPROACH NUMBER -------------------     7
        APPROACH AZIMUTH ------------------     0
        BEGINNING CENTERLINE X COORDINATE -   465
        BEGINNING CENTERLINE Y COORDINATE -     0
        SPEED LIMIT (MPH) -----------------    30
        NUMBER OF DEGREES FOR STRAIGHT ----    20
        NUMBER OF DEGREES FOR U-TURN ------    10
        NUMBER OF LANES -------------------     2

        LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
          1  13   7   15       0  388    0  388   ( LS )        (MEDIAN LANE)
          2  14   8   15       0  388    0  388   (  SR)        (CURB LANE)


        APPROACH NUMBER -------------------     8
        APPROACH AZIMUTH ------------------   180
        BEGINNING CENTERLINE X COORDINATE -   465
        BEGINNING CENTERLINE Y COORDINATE -   388
        SPEED LIMIT (MPH) -----------------    30
        NUMBER OF DEGREES FOR STRAIGHT ----    20
        NUMBER OF DEGREES FOR U-TURN ------    10
        NUMBER OF LANES -------------------     2

        LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
          1  15   0   15       0  388    0  388   ( LS )        (MEDIAN LANE)
          2  16   0   15       0  388    0  388   (  SR)        (CURB LANE)


        APPROACH NUMBER -------------------     9
        APPROACH AZIMUTH ------------------    59
        BEGINNING CENTERLINE X COORDINATE -    19
        BEGINNING CENTERLINE Y COORDINATE -   190
        SPEED LIMIT (MPH) -----------------    30
        NUMBER OF DEGREES FOR STRAIGHT ----    20
        NUMBER OF DEGREES FOR U-TURN ------    10
        NUMBER OF LANES -------------------     2

        LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
          1  17   9   15       0  439    0  439   ( LS )        (MEDIAN LANE)
          2  18  10   15       0  439    0  439   (  SR)        (CURB LANE)


        APPROACH NUMBER -------------------    10
        APPROACH AZIMUTH ------------------   239
        BEGINNING CENTERLINE X COORDINATE -   395
        BEGINNING CENTERLINE Y COORDINATE -   416
        SPEED LIMIT (MPH) -----------------    30
        NUMBER OF DEGREES FOR STRAIGHT ----    20
        NUMBER OF DEGREES FOR U-TURN ------    10
        NUMBER OF LANES -------------------     2

        LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
          1  19   0   15       0  439    0  439   ( LS )        (MEDIAN LANE)
          2  20   0   15       0  439    0  439   (  SR)        (CURB LANE)
```

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      GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE     PAGE  4

*****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)      *****


        APPROACH NUMBER -------------------    11
        APPROACH AZIMUTH ------------------   120
        BEGINNING CENTERLINE X COORDINATE -    15
        BEGINNING CENTERLINE Y COORDINATE -   703
        SPEED LIMIT (MPH) -----------------    30
        NUMBER OF DEGREES FOR STRAIGHT ----    30
        NUMBER OF DEGREES FOR U-TURN ------    10
        NUMBER OF LANES -------------------     2

        LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
          1  21  11   15       0  433    0  433   ( LS )        (MEDIAN LANE)
          2  22  12   15       0  433    0  433   (  SR)        (CURB LANE)


        APPROACH NUMBER -------------------    12
        APPROACH AZIMUTH ------------------   300
        BEGINNING CENTERLINE X COORDINATE -   390
        BEGINNING CENTERLINE Y COORDINATE -   487
        SPEED LIMIT (MPH) -----------------    30
        NUMBER OF DEGREES FOR STRAIGHT ----    20
        NUMBER OF DEGREES FOR U-TURN ------    10
        NUMBER OF LANES -------------------     2

        LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
          1  23   0   15       0  433    0  433   ( LS )        (MEDIAN LANE)
          2  24   0   15       0  433    0  433   (  SR)        (CURB LANE)


        TOTAL NUMBER OF APPROACHES = 12



     TABLE  4  -  LISTING OF ARCS (FOR PLOTTING ONLY)


        ARC NUMBER -------------------------     1
        CENTER X COORDINATE ---------------    413
        CENTER Y COORDINATE ---------------    517
        BEGINNING AZIMUTH -----------------     90
        SWEEP ANGLE -----------------------    120
        RADIUS OF ARC ---------------------      7
        ROTATION FROM BEGINNING AZIMUTH --- CLOCKWISE


        ARC NUMBER -------------------------     2
        CENTER X COORDINATE ---------------    517
        CENTER Y COORDINATE ---------------    388
        BEGINNING AZIMUTH -----------------    270
        SWEEP ANGLE -----------------------     90
        RADIUS OF ARC ---------------------     22
        ROTATION FROM BEGINNING AZIMUTH --- CLOCKWISE


        ARC NUMBER -------------------------     3
        CENTER X COORDINATE ---------------    425
        CENTER Y COORDINATE ---------------    388
        BEGINNING AZIMUTH -----------------    330
        SWEEP ANGLE -----------------------    120
        RADIUS OF ARC ---------------------     10
        ROTATION FROM BEGINNING AZIMUTH --- CLOCKWISE
```

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     GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE    PAGE  5

*****      SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)      *****


        ARC NUMBER ------------------------     4
        CENTER X COORDINATE ---------------   376
        CENTER Y COORDINATE ---------------   449
        BEGINNING AZIMUTH -----------------    30
        SWEEP ANGLE -----------------------   120
        RADIUS OF ARC ---------------------     8
        ROTATION FROM BEGINNING AZIMUTH --- CLOCKWISE


        TOTAL NUMBER OF ARCS =   4



     TABLE  5  -  LISTING OF LINES (FOR PLOTTING ONLY)


        LINE NUMBER -----------------------     1
        START X COORDINATE ----------------   410
        START Y COORDINATE ----------------   390
        END X COORDINATE ------------------   420
        END Y COORDINATE ------------------   396


        LINE NUMBER -----------------------     2
        START X COORDINATE ----------------   375
        START Y COORDINATE ----------------   459
        END X COORDINATE ------------------   380
        END Y COORDINATE ------------------   456


        LINE NUMBER -----------------------     3
        START X COORDINATE ----------------   405
        START Y COORDINATE ----------------   513
        END X COORDINATE ------------------   409
        END Y COORDINATE ------------------   511


        TOTAL NUMBER OF LINES =   3



     TABLE  6  -  LISTING OF OPTIONS AND ADDITIONAL DATA


        PRIMARY PATHS SELECTED

        PLOT SELECTED USING INK PEN

        APPROACH PATHS PLOTTED ON THE SAME FRAME

        APPROACH SCALE FACTOR FROM INPUT IS 150.0 FEET PER INCH

        INTERSECTION SCALE FACTOR FROM INPUT IS  30.0 FEET PER INCH

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

        PROGRAM CHECKS TO SEE IF THE CENTER TO CENTER DISTANCE
            BETWEEN VEHICLES BECOMES LESS THAN OR EQUAL TO 10 FEET

        PLOT PAPER WIDTH = 12 INCHES

        APPROACH SCALE FACTOR TO BE USED IS 150.0 FEET PER INCH

        INTERSECTION SCALE FACTOR TO BE USED IS  30.0 FEET PER INCH
```

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     GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE    PAGE  6

*****      SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)      *****


   TABLE  7  -  LISTING OF PATHS


       PATH   1 GOES FROM LANE 1 OF APPROACH  1 TO LANE 1 OF APPROACH  4
          LENGTH OF PATH =  85 FEET AND SPEED OF PATH = 20 FEET PER SECOND
          NUMBER OF CONFLICTS = 12 AND TURN CODE FOR PATH IS LEFT
          CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
                 5   11    4    9    7    3    2    8    1    6
                12   10


       PATH   2 GOES FROM LANE 1 OF APPROACH  1 TO LANE 1 OF APPROACH  6
          LENGTH OF PATH = 128 FEET AND SPEED OF PATH = 26 FEET PER SECOND
          NUMBER OF CONFLICTS = 18 AND TURN CODE FOR PATH IS LEFT
          CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
                17   28   16   21   25   15   29   20   26   14
                22   19   27   23   18   24   13   30


       PATH   3 GOES FROM LANE 1 OF APPROACH  1 TO LANE 1 OF APPROACH  8
          LENGTH OF PATH = 130 FEET AND SPEED OF PATH = 43 FEET PER SECOND
          NUMBER OF CONFLICTS = 18 AND TURN CODE FOR PATH IS STRAIGHT
          CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
                34   45   38   33   46   32   37   41   40   42
                36   47   43   48   39   44   31   35


       PATH   4 GOES FROM LANE 2 OF APPROACH  1 TO LANE 2 OF APPROACH  8
          LENGTH OF PATH = 130 FEET AND SPEED OF PATH = 43 FEET PER SECOND
          NUMBER OF CONFLICTS = 18 AND TURN CODE FOR PATH IS STRAIGHT
          CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
                51   54   62   53   56   50   63   49   64   57
                52   58   55   65   59   60   61   66


       PATH   5 GOES FROM LANE 2 OF APPROACH  1 TO LANE 2 OF APPROACH 10
          LENGTH OF PATH =  97 FEET AND SPEED OF PATH = 28 FEET PER SECOND
          NUMBER OF CONFLICTS = 12 AND TURN CODE FOR PATH IS RIGHT
          CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
                68   70   69   71   73   72   74   75   76   77
                67   78


       PATH   6 GOES FROM LANE 2 OF APPROACH  1 TO LANE 2 OF APPROACH 12
          LENGTH OF PATH =  35 FEET AND SPEED OF PATH = 14 FEET PER SECOND
          NUMBER OF CONFLICTS =  2 AND TURN CODE FOR PATH IS RIGHT
          CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
                79   80


       PATH   7 GOES FROM LANE 1 OF APPROACH  3 TO LANE 1 OF APPROACH  6
          LENGTH OF PATH =  94 FEET AND SPEED OF PATH = 20 FEET PER SECOND
          NUMBER OF CONFLICTS = 14 AND TURN CODE FOR PATH IS LEFT
          CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
                87   84    1   91   89   85   90   83   82   86
                88   81   13   92


       PATH   8 GOES FROM LANE 1 OF APPROACH  3 TO LANE 1 OF APPROACH  8
          LENGTH OF PATH = 123 FEET AND SPEED OF PATH = 29 FEET PER SECOND
          NUMBER OF CONFLICTS = 18 AND TURN CODE FOR PATH IS LEFT
          CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
                96  101    2   97  105   98   95   14  102   94
               106  100  103  107   99  104   31   93
```

```
*****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)     *****

      PATH   9 GOES FROM LANE 1 OF APPROACH  3 TO LANE 1 OF APPROACH 10
         LENGTH OF PATH = 129 FEET AND SPEED OF PATH = 42 FEET PER SECOND
         NUMBER OF CONFLICTS = 18 AND TURN CODE FOR PATH IS STRAIGHT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              110  115    3  112  111   15  118   32  109  116
              114   49  119  117  120  121  108  113

      PATH  10 GOES FROM LANE 2 OF APPROACH  3 TO LANE 2 OF APPROACH  2
         LENGTH OF PATH =  17 FEET AND SPEED OF PATH = 10 FEET PER SECOND
         NUMBER OF CONFLICTS =  2 AND TURN CODE FOR PATH IS RIGHT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              122  123

      PATH  11 GOES FROM LANE 2 OF APPROACH  3 TO LANE 2 OF APPROACH 10
         LENGTH OF PATH = 128 FEET AND SPEED OF PATH = 43 FEET PER SECOND
         NUMBER OF CONFLICTS = 19 AND TURN CODE FOR PATH IS STRAIGHT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              125  129  127    4  130   16  126   33  132  124
              128   50  133  131  134  135  136   67  137

      PATH  12 GOES FROM LANE 2 OF APPROACH  3 TO LANE 2 OF APPROACH 12
         LENGTH OF PATH =  89 FEET AND SPEED OF PATH = 26 FEET PER SECOND
         NUMBER OF CONFLICTS = 12 AND TURN CODE FOR PATH IS RIGHT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              138  141  140  142  143    5   17   34   51   68
              139   79

      PATH  13 GOES FROM LANE 1 OF APPROACH  5 TO LANE 1 OF APPROACH  8
         LENGTH OF PATH =  94 FEET AND SPEED OF PATH = 24 FEET PER SECOND
         NUMBER OF CONFLICTS = 12 AND TURN CODE FOR PATH IS LEFT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
               81  148   18  147  150  144  151  146  145  149
               35   93

      PATH  14 GOES FROM LANE 1 OF APPROACH  5 TO LANE 1 OF APPROACH 10
         LENGTH OF PATH = 130 FEET AND SPEED OF PATH = 37 FEET PER SECOND
         NUMBER OF CONFLICTS = 19 AND TURN CODE FOR PATH IS LEFT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              157   82  156  161   19  152   94  155   36  162
              159   52  158  163  164  160  153  108  154

      PATH  15 GOES FROM LANE 1 OF APPROACH  5 TO LANE 1 OF APPROACH 12
         LENGTH OF PATH = 133 FEET AND SPEED OF PATH = 36 FEET PER SECOND
         NUMBER OF CONFLICTS = 18 AND TURN CODE FOR PATH IS STRAIGHT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              168   83  172  167  165  170   95   20   37  109
              169  174  124   53  173   69  171  166

      PATH  16 GOES FROM LANE 2 OF APPROACH  5 TO LANE 2 OF APPROACH  2
         LENGTH OF PATH =  79 FEET AND SPEED OF PATH = 21 FEET PER SECOND
         NUMBER OF CONFLICTS = 13 AND TURN CODE FOR PATH IS RIGHT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              177  179  178  180    6   84   96  110  175  125
              138  122  176
```

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*****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)     *****

      PATH  17 GOES FROM LANE 2 OF APPROACH  5 TO LANE 2 OF APPROACH  4
         LENGTH OF PATH =  18 FEET AND SPEED OF PATH = 10 FEET PER SECOND
         NUMBER OF CONFLICTS =  2 AND TURN CODE FOR PATH IS RIGHT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              181  182

      PATH  18 GOES FROM LANE 2 OF APPROACH  5 TO LANE 2 OF APPROACH 12
         LENGTH OF PATH = 125 FEET AND SPEED OF PATH = 35 FEET PER SECOND
         NUMBER OF CONFLICTS = 18 AND TURN CODE FOR PATH IS STRAIGHT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              185  188   85  187  184  190   97  183  111  186
               21  126   38  189   54   70  139   80

      PATH  19 GOES FROM LANE 1 OF APPROACH  7 TO LANE 1 OF APPROACH  2
         LENGTH OF PATH = 138 FEET AND SPEED OF PATH = 43 FEET PER SECOND
         NUMBER OF CONFLICTS = 18 AND TURN CODE FOR PATH IS STRAIGHT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              194  198  144  197  193  152   22  165  192   98
              196  183  112    7  127  140  191  195

      PATH  20 GOES FROM LANE 1 OF APPROACH  7 TO LANE 1 OF APPROACH 10
         LENGTH OF PATH = 111 FEET AND SPEED OF PATH = 22 FEET PER SECOND
         NUMBER OF CONFLICTS = 14 AND TURN CODE FOR PATH IS LEFT
         CONFLICT ENTNY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              145  203   99   39  202  204   55  200  199  205
              201  153  113  154

      PATH  21 GOES FROM LANE 1 OF APPROACH  7 TO LANE 1 OF APPROACH 12
         LENGTH OF PATH = 140 FEET AND SPEED OF PATH = 30 FEET PER SECOND
         NUMBER OF CONFLICTS = 18 AND TURN CODE FOR PATH IS LEFT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              210  146  214  209  100  213  155  207   40  206
              114  212  128   56  211   71  208  166

      PATH  22 GOES FROM LANE 2 OF APPROACH  7 TO LANE 2 OF APPROACH  2
         LENGTH OF PATH = 130 FEET AND SPEED OF PATH = 43 FEET PER SECOND
         NUMBER OF CONFLICTS = 21 AND TURN CODE FOR PATH IS STRAIGHT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              217  220  219  107   23   86  156  216  167  215
              184  218    8  101   87  115  175  129  141  123
              176

      PATH  23 GOES FROM LANE 2 OF APPROACH  7 TO LANE 2 OF APPROACH  4
         LENGTH OF PATH =  96 FEET AND SPEED OF PATH = 25 FEET PER SECOND
         NUMBER OF CONFLICTS = 12 AND TURN CODE FOR PATH IS RIGHT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              222  224  223   24  148   88  157  168  185  177
              221  181

      PATH  24 GOES FROM LANE 2 OF APPROACH  7 TO LANE 2 OF APPROACH  6
         LENGTH OF PATH =  46 FEET AND SPEED OF PATH = 18 FEET PER SECOND
         NUMBER OF CONFLICTS =  2 AND TURN CODE FOR PATH IS RIGHT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              225  226
```

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*****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)     *****


   PATH  25 GOES FROM LANE 1 OF APPROACH  9 TO LANE 1 OF APPROACH  2
      LENGTH OF PATH = 128 FEET AND SPEED OF PATH = 32 FEET PER SECOND
      NUMBER OF CONFLICTS = 18 AND TURN CODE FOR PATH IS LEFT
      CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
           231  199  230  158   57  229  206  116  169   41
           228   25  186    9  130  142  191  227


   PATH  26 GOES FROM LANE 1 OF APPROACH  9 TO LANE 1 OF APPROACH  4
      LENGTH OF PATH = 131 FEET AND SPEED OF PATH = 44 FEET PER SECOND
      NUMBER OF CONFLICTS = 18 AND TURN CODE FOR PATH IS STRAIGHT
      CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
           235  200  234   58  159  233   42  207   26  102
           170  192  215  187   89  178  232   10


   PATH  27 GOES FROM LANE 1 OF APPROACH  9 TO LANE 1 OF APPROACH 12
      LENGTH OF PATH = 102 FEET AND SPEED OF PATH = 22 FEET PER SECOND
      NUMBER OF CONFLICTS = 12 AND TURN CODE FOR PATH IS LEFT
      CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
           201  160  240  239  117  238  131  237   72  236
           208  171


   PATH  28 GOES FROM LANE 2 OF APPROACH  9 TO LANE 2 OF APPROACH  4
      LENGTH OF PATH = 132 FEET AND SPEED OF PATH = 44 FEET PER SECOND
      NUMBER OF CONFLICTS = 18 AND TURN CODE FOR PATH IS STRAIGHT
      CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
           243   59  202  242   43  183  209  241  193   27
           161  216  172   90  188  179  221  182


   PATH  29 GOES FROM LANE 2 OF APPROACH  9 TO LANE 2 OF APPROACH  6
      LENGTH OF PATH = 114 FEET AND SPEED OF PATH = 34 FEET PER SECOND
      NUMBER OF CONFLICTS = 12 AND TURN CODE FOR PATH IS RIGHT
      CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
           245   60   44  104  203  149  210  194  217  222
           225  244


   PATH  30 GOES FROM LANE 2 OF APPROACH  9 TO LANE 2 OF APPROACH  8
      LENGTH OF PATH =  47 FEET AND SPEED OF PATH = 14 FEET PER SECOND
      NUMBER OF CONFLICTS =  2 AND TURN CODE FOR PATH IS RIGHT
      CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
            61  246


   PATH  31 GOES FROM LANE 1 OF APPROACH 11 TO LANE 1 OF APPROACH  2
      LENGTH OF PATH = 100 FEET AND SPEED OF PATH = 22 FEET PER SECOND
      NUMBER OF CONFLICTS = 13 AND TURN CODE FOR PATH IS LEFT
      CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
           236   73  211  173   62  132  189   45   28   11
           143  195  227


   PATH  32 GOES FROM LANE 1 OF APPROACH 11 TO LANE 1 OF APPROACH  4
      LENGTH OF PATH = 125 FEET AND SPEED OF PATH = 30 FEET PER SECOND
      NUMBER OF CONFLICTS = 18 AND TURN CODE FOR PATH IS LEFT
      CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
            74  237  133   63  212  174   46  228  118   29
           196  105  190  218   91  180  232   12
```

```
*****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)     *****


   PATH  33 GOES FROM LANE 1 OF APPROACH 11 TO LANE 1 OF APPROACH  6
      LENGTH OF PATH = 142 FEET AND SPEED OF PATH = 37 FEET PER SECOND
      NUMBER OF CONFLICTS = 18 AND TURN CODE FOR PATH IS STRAIGHT
      CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
            75  134  238  119   64  229  233   47  162  213
           106  241  197  150  219  223   30   92


   PATH  34 GOES FROM LANE 2 OF APPROACH 11 TO LANE 2 OF APPROACH  6
      LENGTH OF PATH = 149 FEET AND SPEED OF PATH = 38 FEET PER SECOND
      NUMBER OF CONFLICTS = 19 AND TURN CODE FOR PATH IS STRAIGHT
      CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
            76  135  120  239  163  230  234   65  204  242
            48  107  214  151  198  220  224  226  244


   PATH  35 GOES FROM LANE 2 OF APPROACH 11 TO LANE 2 OF APPROACH  8
      LENGTH OF PATH = 107 FEET AND SPEED OF PATH = 26 FEET PER SECOND
      NUMBER OF CONFLICTS = 12 AND TURN CODE FOR PATH IS RIGHT
      CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
            77  136  121  240  164  205  231  235  243  245
            66  246


   PATH  36 GOES FROM LANE 2 OF APPROACH 11 TO LANE 2 OF APPROACH 10
      LENGTH OF PATH =  40 FEET AND SPEED OF PATH = 14 FEET PER SECOND
      NUMBER OF CONFLICTS =  2 AND TURN CODE FOR PATH IS RIGHT
      CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
            78  137


   TOTAL NUMBER OF PATHS CALCULATED =  36


TABLE  8  -  LISTING OF CONFLICTS

   CONFLICT  PATH1 PATH2  APPR1 APPR2  DIST1 DIST2  ANGLE  INDEX1 INDEX2

        1       1     7      1     3     60    25    104      9      3
        2       1     8      1     3     54    28    117      7      3
        3       1     9      1     3     49    32    125      6      3
        4       1    11      1     3     32    38    101      3      4
        5       1    12      1     3     22    41    116      1      6
        6       1    16      1     5     63    39    235     10      5
        7       1    19      1     7     38    96    231      5     14
        8       1    22      1     7     55    91    256      8     13
        9       1    25      1     9     33   100    243      4     14
       10       1    26      1     9     82   127    180     12     18
       11       1    31      1    11     26    74    254      2     10
       12       1    32      1    11     75   114    352     11     18
       13       2     7      1     3    128    94      0     17     13
       14       2     8      1     3     67    55     62     10      8
       15       2     9      1     3     51    52     83      6      6
       16       2    11      1     3     36    49     72      3      6
       17       2    12      1     3     21    46     95      1      7
       18       2    13      1     5     95    33    123     15      3
       19       2    14      1     5     79    46    138     12      5
       20       2    15      1     5     64    58    151      8      8
       21       2    18      1     5     38    72    138      4     11
       22       2    19      1     7     71    65    214     11      7
       23       2    22      1     7     93    52    233     14      5
       24       2    23      1     7     99    49    259     16      4
       25       2    25      1     9     46    83    229      5     12
       26       2    26      1     9     66    78    276      9      9
       27       2    28      1     9     82    82    288     13     10
       28       2    31      1    11     32    64    242      2      9
```

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GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE    PAGE 11

*****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)     *****

  29     2   32     1   11    52    70   295     7    10
  30     2   33     1   11   128   142     0    18    17
  31     3    8     1    3   129   123     0    17    17
  32     3    9     1    3    54    59    63     6     8
  33     3   11     1    3    37    52    60     4     8
  34     3   12     1    3    21    46    91     1     8
  35     3   13     1    5   129    94     0    18    11
  36     3   14     1    5    72    66    91    11     9
  37     3   15     1    5    54    72   126     7     9
  38     3   18     1    5    36    76   125     3    13
  39     3   20     1    7    91    43   136    15     4
  40     3   21     1    7    64    71   154     9     9
  41     3   25     1    9    54    74   216     8    10
  42     3   26     1    9    70    63   245    10     7
  43     3   28     1    9    87    56   241    13     5
  44     3   29     1    9   102    52   266    16     3
  45     3   31     1   11    33    63   234     2     8
  46     3   32     1   11    51    63   277     5     7
  47     3   33     1   11    72    74   304    12     8
  48     3   34     1   11    89    86   298    14    11
  49     4    9     1    3    65    76    66     8    12
  50     4   11     1    3    47    69    62     6    12
  51     4   12     1    3    20    61   103     1     9
  52     4   14     1    5    75    81    86    11    12
  53     4   15     1    5    45    91   129     4    14
  54     4   18     1    5    26    95   125     2    15
  55     4   20     1    7    83    61   115    13     7
  56     4   21     1    7    46    97   137     5    14
  57     4   25     1    9    72    52   227    10     5
  58     4   26     1    9    80    47   244    12     4
  59     4   28     1    9    97    40   241    15     2
  60     4   29     1    9   105    37   259    16     2
  61     4   30     1    9   129    47     0    17     1
  62     4   31     1   11    42    46   257     3     5
  63     4   32     1   11    51    48   285     7     4
  64     4   33     1   11    65    56   312     9     5
  65     4   34     1   11    83    68   305    14     8
  66     4   35     1   11   129   107     0    18    11
  67     5   11     1    3    83   113     6    11    18
  68     5   12     1    3    20    63    90     1    10
  69     5   15     1    5    40   103    97     3    16
  70     5   18     1    5    25    99   106     2    16
  71     5   21     1    7    40   110    97     4    16
  72     5   27     1    9    47    71   127     6     9
  73     5   31     1   11    46    33   239     5     2
  74     5   32     1   11    50    31   255     7     1
  75     5   33     1   11    55    31   269     8     1
  76     5   34     1   11    70    29   259     9     1
  77     5   35     1   11    70    29   259    10     1
  78     5   36     1   11    93    34   348    12     1
  79     6   12     1    3    27    81    11     1    12
  80     6   18     1    5    33   124   180     2    18
  81     7   13     3    5    66    27   112    12     1
  82     7   14     3    5    58    32   126     9     2
  83     7   15     3    5    54    33   131     8     2
  84     7   16     3    5    22    42   127     2     6
  85     7   18     3    5    37    38   108     6     3
  86     7   22     3    7    62    53   211    10     6
  87     7   22     3    7    21    97   153     1    15
  88     7   23     3    7    65    55   242    11     6
  89     7   26     3    9    36    99   235     5    15
  90     7   28     3    9    53    94   260     7    14
  91     7   32     3   11    30    96   242     4    15
  92     7   33     3   11    94   142     0    14    18
  93     8   13     3    5   123    94     0    18    12
  94     8   14     3    5    65    57    69    10     7
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GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE    PAGE 12

*****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)     *****

  95     8   15     3    5    53    55    89     7     7
  96     8   16     3    5    21    46   111     1     7
  97     8   18     3    5    38    49    79     4     7
  98     8   19     3    7    51    71   146     6    10
  99     8   20     3    7    88    40   133    15     3
 100     8   21     3    7    70    55   140    12     5
 101     8   22     3    7    27    92   136     2    14
 102     8   26     3    9    55    78   214     9    10
 103     8   28     3    9    79    61   220    13     6
 104     8   29     3    9    96    54   261    16     4
 105     8   32     3   11    39    85   226     5    12
 106     8   33     3   11    69    82   279    11    11
 107     8   34     3   11    85    89   288    14    12
 108     9   14     3    5   120   122     5    17    18
 109     9   15     3    5    60    72    63     9    10
 110     9   16     3    5    21    49   101     1     8
 111     9   18     3    5    43    58    59     5     9
 112     9   19     3    7    42    86   119     4    13
 113     9   20     3    7   121   104     4    18    13
 114     9   21     3    7    64    88    84    11    11
 115     9   22     3    7    24    97   121     2    16
 116     9   25     3    9    60    73   153    10     8
 117     9   27     3    9    92    42   137    14     5
 118     9   32     3   11    54    67   212     7     9
 119     9   33     3   11    77    55   247    13     4
 120     9   34     3   11    93    49   249    15     3
 121     9   35     3   11    95    48   263    16     3
 122    10   16     3    5    17    79     1     1    12
 123    10   22     3    7    17   129     0     2    20
 124    11   15     3    5    67    89    68    10    13
 125    11   16     3    5    15    65   122     1    10
 126    11   18     3    5    51    75    66     7    12
 127    11   19     3    7    33   104   123     3    15
 128    11   21     3    7    68    96    76    11    13
 129    11   22     3    7    15   115   125     2    18
 130    11   25     3    9    38   100   141     5    15
 131    11   27     3    9    82    60   115    14     7
 132    11   31     3   11    54    58   181     9     6
 133    11   32     3   11    74    43   226    13     3
 134    11   33     3   11    83    39   249    15     2
 135    11   34     3   11    99    32   248    16     2
 136    11   35     3   11    99    32   250    17     2
 137    11   36     3   11   124    36   349    19     2
 138    12   16     3    5    14    66   113     1    11
 139    12   18     3    5    78   114     8    11    17
 140    12   19     3    7    30   110   101     3    16
 141    12   22     3    7    14   116   115     2    19
 142    12   25     3    9    32   110   112     4    16
 143    12   31     3   11    35    79   128     5    11
 144    13   19     5    7    53    38   134     6     3
 145    13   20     5    7    65    30   117     9     1
 146    13   21     5    7    58    34   128     8     2
 147    13   22     5    7    35    50   115     4     4
 148    13   23     5    7    28    54   131     2     5
 149    13   29     5    9    85    61   236    10     6
 150    13   33     5   11    39   105   230     5    14
 151    13   34     5   11    57   100   250     7    14
 152    14   19     5    7    50    60    85     6     6
 153    14   20     5    7   106    87     7    17    12
 154    14   20     5    7   123   104     0    19    14
 155    14   21     5    7    62    61    66     8     7
 156    14   22     5    7    35    60    80     3     7
 157    14   23     5    7    25    61   111     1     7
 158    14   25     5    9    84    47   144    13     4
 159    14   26     5    9    70    59   155    11     5
 160    14   27     5    9    99    34   129    16     2
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      GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE    PAGE 13

*****      SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)      *****

       161       14    28      5     9    40    86    145     4    11
       162       14    33      5    11    67    74    214    10     9
       163       14    34      5    11    90    57    227    14     5
       164       14    35      5    11    95    54    249    15     5
       165       15    19      5     7    53    68     59     5     8
       166       15    21      5     7   133   140      0    18    18
       167       15    22      5     7    37    65     65     4     9
       168       15    23      5     7    24    62    104     1     8
       169       15    25      5     9    72    73     91    11     9
       170       15    26      5     9    54    79    125     6    11
       171       15    27      5     9   129    98    182    17    12
       172       15    28      5     9    35    92    131     3    13
       173       15    31      5    11    95    43    133    15     4
       174       15    32      5    11    79    57    153    12     6
       175       16    22      5     7    63   112      5     9    17
       176       16    22      5     7    79   129      0    13    21
       177       16    23      5     7    15    81    109     1    10
       178       16    26      5     9    33   109    100     3    16
       179       16    28      5     9    17   116    121     2    16
       180       16    32      5    11    36   103    109     4    16
       181       17    23      5     7    14    92     21     1    12
       182       17    28      5     9    14   128     27     2    18
       183       18    19      5     7    57    85     60     8    12
       184       18    22      5     7    40    80     65     5    11
       185       18    23      5     7    16    79    121     1     9
       186       18    25      5     9    67    88     84    10    13
       187       18    26      5     9    39    98    129     4    14
       188       18    28      5     9    19   112    136     2    15
       189       18    31      5    11    78    60    112    14     7
       190       18    32      5    11    48    86    146     6    13
       191       19    25      7     9   129   128      1    17    17
       192       19    26      7     9    69    80     66     9    12
       193       19    28      7     9    53    74     63     5     9
       194       19    29      7     9    29    68     93     1     8
       195       19    31      7    11   129    99      1    18    12
       196       19    32      7    11    80    78     88    11    11
       197       19    33      7    11    51    92    116     4    13
       198       19    34      7    11    35   103    111     2    15
       199       20    25      7     9    71    40    127     9     2
       200       20    26      7     9    65    43    132     8     2
       201       20    27      7     9    80    33    118    11     1
       202       20    28      7     9    47    53    109     5     3
       203       20    29      7     9    30    60    120     2     5
       204       20    34      7    11    55    75    180     6     9
       205       20    35      7    11    75    57    233    10     6
       206       21    25      7     9    78    68     70    10     7
       207       21    26      7     9    65    66     88     8     8
       208       21    27      7     9   136    97    183    17    11
       209       21    28      7     9    49    66     79     4     7
       210       21    29      7     9    29    66    102     1     7
       211       21    31      7    11   102    42    129    15     3
       212       21    32      7    11    89    53    140    12     5
       213       21    33      7    11    57    81    141     6    10
       214       21    34      7    11    36    99    126     3    13
       215       22    26      7     9    79    97     63    10    13
       216       22    28      7     9    63    91     65     8    12
       217       22    29      7     9    29    83     96     1     9
       218       22    32      7    11    84    93     79    12    14
       219       22    33      7    11    47   109    110     3    15
       220       22    34      7    11    32   119    106     2    16
       221       23    28      7     9    91   127      5    11    17
       222       23    29      7     9    29    85     90     1    10
       223       23    33      7    11    46   113     92     3    16
       224       23    34      7    11    31   120     99     2    17
       225       24    29      7     9    46   114      0     1    11
       226       24    34      7    11    46   150      0     2    18
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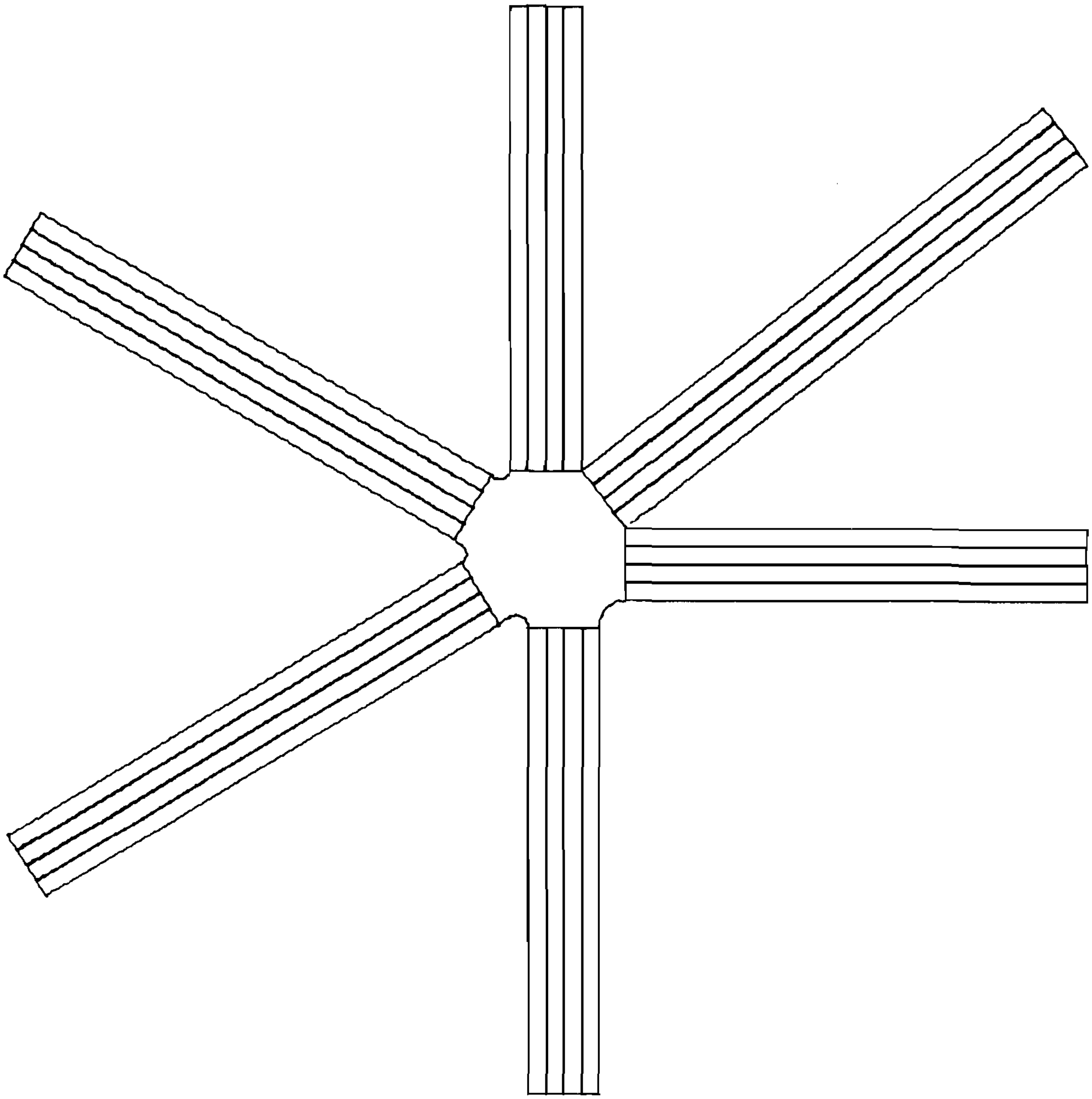
      GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE    PAGE 14

*****      SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)      *****

       227       25    31      9    11   128    99      0    18    13
       228       25    32      9    11    77    64     62    11     8
       229       25    33      9    11    58    62     84     6     6
       230       25    34      9    11    43    60     78     3     6
       231       25    35      9    11    37    59    101     1     7
       232       26    32      9    11   116   110      8    17    17
       233       26    33      9    11    61    72     60     6     7
       234       26    34      9    11    45    66     62     3     7
       235       26    35      9    11    36    63     91     1     8
       236       27    31      9    11    71    32    114    10     1
       237       27    32      9    11    67    34    124     8     2
       238       27    33      9    11    59    40    132     6     3
       239       27    34      9    11    41    49    111     4     4
       240       27    35      9    11    38    50    123     3     4
       241       28    33      9    11    72    90     55     8    12
       242       28    34      9    11    54    83     58     4    10
       243       28    35      9    11    35    78    103     1     9
       244       29    34      9    11   114   150      0    12    19
       245       29    35      9    11    34    84     90     1    10
       246       30    35      9    11    87   107      0     2    12

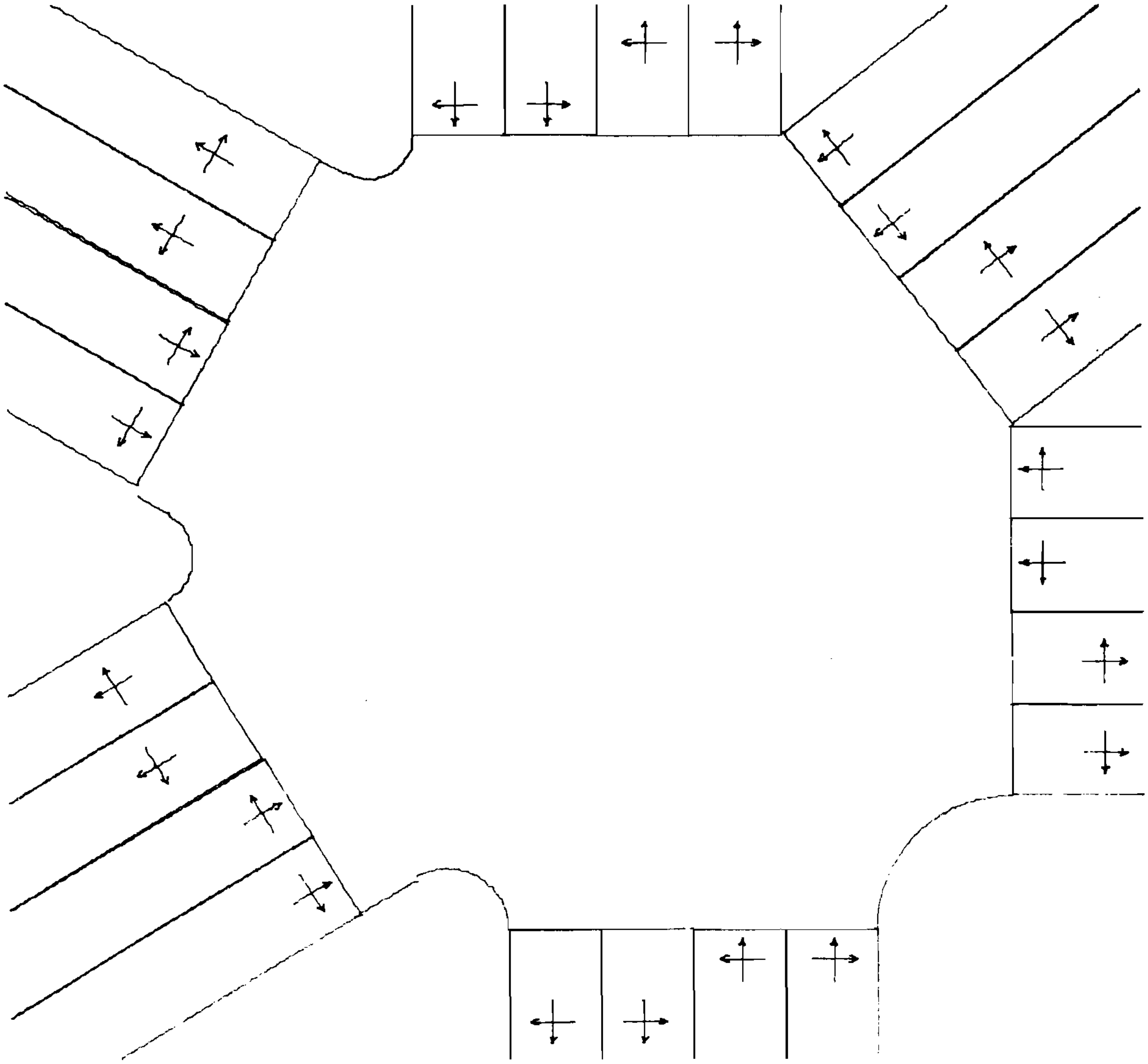
     TOTAL NUMBER OF CONFLICTS =  246
```

***** SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES) *****



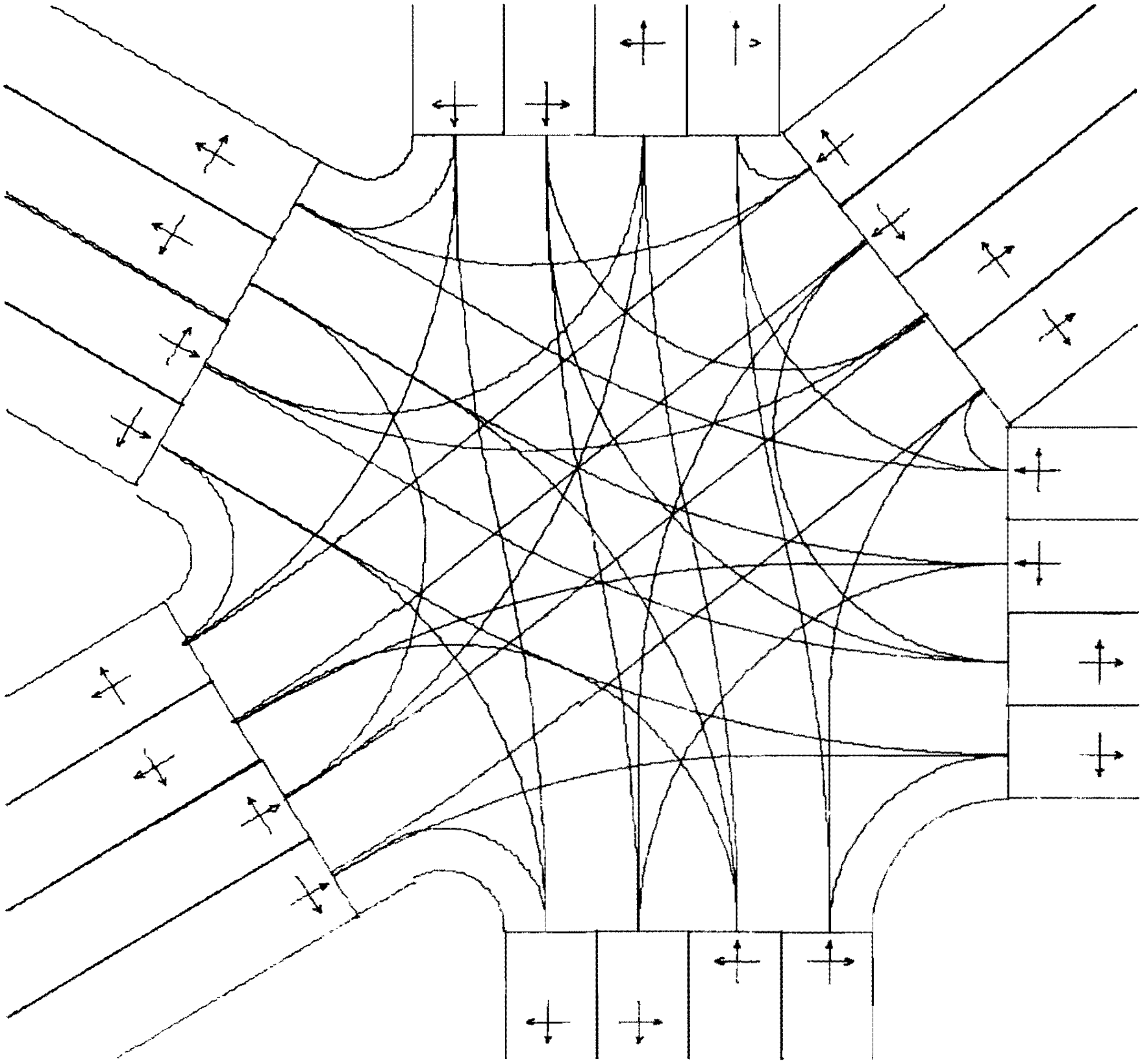
SCALE FACTOR IS 150.0 FEET PER INCH

***** SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES) *****



SCALE FACTOR IS 30.0 FEET PER INCH

***** SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES) *****



SCALE FACTOR IS 30.0 FEET PER INCH

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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE                                   PAGE  1

    *****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)     *****

TABLE  1  -  LISTING OF INBOUND APPROACH NUMBERS


             1
             3
             5
             7
             9
            11


    TOTAL NUMBER OF INBOUND APPROACHES =  6


TABLE  2  -  LISTING OF OUTBOUND APPROACH NUMBERS


             2
             4
             6
             8
            10
            12


    TOTAL NUMBER OF OUTBOUND APPROACHES =  6


    TOTAL NUMBER OF INBOUND AND OUTBOUND APPROACHES = 12


TABLE  3  -  DRIVER-VEHICLE PROCESSOR OPTIONS

    TIME FOR GENERATING VEHICLES (MIN) ----   12
    MINIMUM HEADWAY FOR VEHICLES (SEC) ----    1.1
    NUMBER OF VEHICLE CLASSES ------------   10
    NUMBER OF DRIVER CLASSES -------------    3
    PERCENT OF LEFT TURNS IN MEDIAN LANE --  100.
    PERCENT OF RIGHT TURNS IN CURB LANE ---  100.


TABLE  4  -  LISTING OF APPROACHES


    APPROACH NUMBER ----------------------    1
    APPROACH AZIMUTH ---------------------  180
    NUMBER OF LANES ----------------------    2
    NUMBER OF DEGREES FOR STRAIGHT --------   20
    HEADWAY DISTRIBUTION NAME ------------- LOGNRML   PARAMETER =     8.00
    EQUIVALENTLY HOURLY VOLUME (VPH) ------  450
    APPROACH MEAN SPEED (MPH) ------------   30.0
    APPROACH 85 PERCENTILE SPEED (MPH) ----   34.3
        OUTBOUND APPROACH NUMBER ----------    2     4     6     8    10    12
    PERCENT GOING TO OUTBOUND APPROACHES --    0    9.    9.   40.   27.   15.
    USER SUPPLIED PERCENT OF VEHICLES -----   NO
        VEHICLE CLASS NUMBER -------------    1     2     3     4     5     6     7     8     9    10
    PROGRAM SUPPLIED PERCENT OF VEHICLES --  20.0 32.0 30.0 15.0    .5    .2    .1    .2    .5   1.5
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -   45. (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -   55. (CURB LANE)


    APPROACH NUMBER ----------------------    2
    APPROACH AZIMUTH ---------------------    0
    NUMBER OF LANES ----------------------    2
```

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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE                                 PAGE  2

    *****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)     *****


    APPROACH NUMBER ----------------------    3
    APPROACH AZIMUTH ---------------------  232
    NUMBER OF LANES ----------------------    2
    NUMBER OF DEGREES FOR STRAIGHT -------   20
    HEADWAY DISTRIBUTION NAME ------------ LOGNRML   PARAMETER =    4.73
    EQUIVALENTLY HOURLY VOLUME (VPH) ------  725
    APPROACH MEAN SPEED (MPH) ------------   19.0
    APPROACH 85 PERCENTILE SPEED (MPH) ----  25.7
        OUTBOUND APPROACH NUMBER ---------   2    4    6    8   10   12
    PERCENT GOING TO OUTBOUND APPROACHES --  13.    0   7.   8.  42.  30.
    USER SUPPLIED PERCENT OF VEHICLES -----  NO
        VEHICLE CLASS NUMBER -------------   1    2    3    4    5    6    7    8    9   10
    PROGRAM SUPPLIED PERCENT OF VEHICLES -- 20.0 32.0 30.0 15.0   .5   .2   .1   .2   .5  1.5
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  40. (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  60. (CURB LANE)


    APPROACH NUMBER ----------------------    4
    APPROACH AZIMUTH ---------------------   52
    NUMBER OF LANES ----------------------    2


    APPROACH NUMBER ----------------------    5
    APPROACH AZIMUTH ---------------------  270
    NUMBER OF LANES ----------------------    2
    NUMBER OF DEGREES FOR STRAIGHT -------   30
    HEADWAY DISTRIBUTION NAME ------------ LOGNRML   PARAMETER =    6.23
    EQUIVALENTLY HOURLY VOLUME (VPH) ------  470
    APPROACH MEAN SPEED (MPH) ------------   19.0
    APPROACH 85 PERCENTILE SPEED (MPH) ----  25.7
        OUTBOUND APPROACH NUMBER ---------   2    4    6    8   10   12
    PERCENT GOING TO OUTBOUND APPROACHES --  25.  10.    0  11.   9.  45.
    USER SUPPLIED PERCENT OF VEHICLES -----  NO
        VEHICLE CLASS NUMBER -------------   1    2    3    4    5    6    7    8    9   10
    PROGRAM SUPPLIED PERCENT OF VEHICLES -- 20.0 32.0 30.0 15.0   .5   .2   .1   .2   .5  1.5
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  45. (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  55. (CURB LANE)


    APPROACH NUMBER ----------------------    6
    APPROACH AZIMUTH ---------------------   90
    NUMBER OF LANES ----------------------    2


    APPROACH NUMBER ----------------------    7
    APPROACH AZIMUTH ---------------------    0
    NUMBER OF LANES ----------------------    2
    NUMBER OF DEGREES FOR STRAIGHT -------   20
    HEADWAY DISTRIBUTION NAME ------------ SNEGEXP   PARAMETER =    2.18
    EQUIVALENTLY HOURLY VOLUME (VPH) ------  550
    APPROACH MEAN SPEED (MPH) ------------   25.0
    APPROACH 85 PERCENTILE SPEED (MPH) ----  28.6
        OUTBOUND APPROACH NUMBER ---------   2    4    6    8   10   12
    PERCENT GOING TO OUTBOUND APPROACHES --  38.  27.  20.    0   5.  10.
    USER SUPPLIED PERCENT OF VEHICLES -----  NO
        VEHICLE CLASS NUMBER -------------   1    2    3    4    5    6    7    8    9   10
    PROGRAM SUPPLIED PERCENT OF VEHICLES -- 20.0 32.0 30.0 15.0   .5   .2   .1   .2   .5  1.5
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  50. (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  50. (CURB LANE)


    APPROACH NUMBER ----------------------    8
    APPROACH AZIMUTH ---------------------  180
    NUMBER OF LANES ----------------------    2
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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE                                   PAGE  3

    *****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)     *****


    APPROACH NUMBER ----------------------   9
    APPROACH AZIMUTH ---------------------  59
    NUMBER OF LANES ----------------------   2
    NUMBER OF DEGREES FOR STRAIGHT -------  20
    HEADWAY DISTRIBUTION NAME ------------ LOGNRML   PARAMETER =    4.99
    EQUIVALENTLY HOURLY VOLUME (VPH) ----- 575
    APPROACH MEAN SPEED (MPH) ------------  23.9
    APPROACH 85 PERCENTILE SPEED (MPH) ---  28.6
        OUTBOUND APPROACH NUMBER ---------   2    4    6    8   10   12
    PERCENT GOING TO OUTBOUND APPROACHES --   7.  45.  25.  12.    0  11.
    USER SUPPLIED PERCENT OF VEHICLES ----  NO
        VEHICLE CLASS NUMBER -------------   1    2    3    4     5     6     7     8     9    10
    PROGRAM SUPPLIED PERCENT OF VEHICLES -- 20.0 32.0 30.0 15.0   .5    .2    .1    .2    .5   1.5
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  50. (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  50. (CURB LANE)


    APPROACH NUMBER ----------------------  10
    APPROACH AZIMUTH --------------------- 239
    NUMBER OF LANES ----------------------   2


    APPROACH NUMBER ----------------------  11
    APPROACH AZIMUTH --------------------- 120
    NUMBER OF LANES ----------------------   2
    NUMBER OF DEGREES FOR STRAIGHT -------  30
    HEADWAY DISTRIBUTION NAME ------------ SNEGEXP   PARAMETER =    2.18
    EQUIVALENTLY HOURLY VOLUME (VPH) ----- 500
    APPROACH MEAN SPEED (MPH) ------------  24.5
    APPROACH 85 PERCENTILE SPEED (MPH) ---  27.7
        OUTBOUND APPROACH NUMBER ---------   2    4    6    8   10   12
    PERCENT GOING TO OUTBOUND APPROACHES --   9.   6.  37.  26.  22.    0
    USER SUPPLIED PERCENT OF VEHICLES ----  NO
        VEHICLE CLASS NUMBER -------------   1    2    3    4     5     6     7     8     9    10
    PROGRAM SUPPLIED PERCENT OF VEHICLES -- 20.0 32.0 30.0 15.0   .5    .2    .1    .2    .5   1.5
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  50. (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  50. (CURB LANE)


    APPROACH NUMBER ----------------------  12
    APPROACH AZIMUTH --------------------- 300
    NUMBER OF LANES ----------------------   2

    TOTAL NUMBER OF APPROACHES = 12


TABLE  5  -  DRIVER AND VEHICLE CLASS CHARACTERISTICS


    USER SUPPLIED DRIVER CLASS SPLIT -----  NO
    USER SUPPLIED VEHICLE CHARACTERISTICS - NO
    USER SUPPLIED DRIVER CHARACTERISTICS -- NO
        VEHICLE CLASS NUMBER -------------   1    2    3    4    5    6    7    8    9   10
    VEHICLE LOGOUT SUMMARY REQUESTED -----  NO   NO   NO   NO   NO   NO   NO   NO   NO   NO
       DRIVER CLASS NUMBER ---------------   1    2    3
    DRIVER LOGOUT SUMMARY REQUESTED ------  NO   NO   NO
```

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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE                                PAGE  4

    *****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)      *****

    DRIVER CLASS SPLIT           (PROGRAM SUPPLIED VALUES)

        DRIVER CLASS NUMBER ---------------    1    2    3

        VEHICLE CLASS NUMBER  1 -----------  30.0 40.0 30.0
        VEHICLE CLASS NUMBER  2 -----------  35.0 35.0 30.0
        VEHICLE CLASS NUMBER  3 -----------  20.0 40.0 40.0
        VEHICLE CLASS NUMBER  4 -----------  25.0 50.0 25.0
        VEHICLE CLASS NUMBER  5 -----------  40.0 30.0 30.0
        VEHICLE CLASS NUMBER  6 -----------  50.0 40.0 10.0
        VEHICLE CLASS NUMBER  7 -----------  50.0 40.0 10.0
        VEHICLE CLASS NUMBER  8 -----------  20.0 30.0 50.0
        VEHICLE CLASS NUMBER  9 -----------  25.0 50.0 25.0
        VEHICLE CLASS NUMBER 10 -----------  50.0 40.0 10.0

    VEHICLE CHARACTERISTICS      (PROGRAM SUPPLIED VALUES)

        VEHICLE CLASS NUMBER --------------    1    2    3    4    5    6    7    8    9   10

        LENGTH OF VEHICLES (FT) -----------   15   17   19   25   30   50   55   25   35   14
        VEHICLE OPERATIONAL FACTOR --------  100  110  110  100   85   80   75   90   85  115
        MAXIMUM DECELERATION (FT/SEC/SEC) -    8   11   11    8   11   11   11    8   11   12
        MAXIMUM ACCELERATION (FT/SEC/SEC) -    8    9   11    8    8    7    6    6    5   14
        MAXIMUM VELOCITY (FT/SEC) ---------  150  192  200  150  160  160  150  150  125  205
        MINIMUM TURNING RADIUS (FT) -------   20   22   24   28   42   40   45   28   28   20

    DRIVER CHARACTERISTICS       (PROGRAM SUPPLIED VALUES)

        DRIVER CLASS NUMBER ---------------    1    2    3

        DRIVER OPERATIONAL FACTOR ---------  110  100   85
        DRIVER REACTION TIME (SEC) --------   .5  1.0  1.5

TABLE  6  -  GENERATION OF APPROACH HEADWAYS

    APPROACH  DISTRIBUTION   NUMBER     VOLUME     INPUT    PERCENT
     NUMBER       NAME      GENERATED  GENERATED   VOLUME  DIFFERENCE

        1       LOGNRML         86        430        450       -4.44
        3       LOGNRML        138        690        725       -4.83
        5       LOGNRML        103        515        470        9.57
        7       SNEGEXP        111        555        550         .91
        9       LOGNRML        116        580        575         .87
       11       SNEGEXP        100        500        500           0

     TOTAL                     654       3270       3270           0

TABLE  7  -  EXPLANATION OF SPECIAL CASES

    QTIME  VEHICLE DRIVER VELOCITY OUTBOUND  INBOUND  LANE  LOGOUT NOTE
            CLASS  CLASS    (FPS)  APPROACH  APPROACH  NO.  PRINT

    86.15                                        3                  1
   345.04                                        3                  1
   446.91                                        3                  1

    NOTE  EXPLANATION OF THE NOTE(S)

      1   HEADWAY LESS THAN 1.1 SECONDS FROM PREVIOUS VEHICLE FOR THIS APPROACH AND ITS LANE(S)
          GENERATED VEHICLE IGNORED
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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE                                      PAGE  5

    *****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)        *****

TABLE  8  -  FINAL APPROACH VOLUMES


                 SPECIAL  VEHICLES        GENERATED  VEHICLES         TOTAL  VEHICLES
               ---------------------    ---------------------    ---------------------
    APPROACH   NUMBER FOR  VOLUME FOR   NUMBER FOR  VOLUME FOR   NUMBER FOR  VOLUME FOR    INPUT
     NUMBER    SIMULATION  SIMULATION   SIMULATION  SIMULATION   SIMULATION  SIMULATION    VOLUME

       1           0           0            86         430           86         430          450
       3           0           0           135         675          135         675          725
       5           0           0           103         515          103         515          470
       7           0           0           111         555          111         555          550
       9           0           0           116         580          116         580          575
      11           0           0           100         500          100         500          500

     TOTAL         0           0           651        3255          651        3255         3270

    THE INTERSECTION HAS A JAM DENSITY OF 234 VEHICLES PER MILE


TABLE  9  -  STATISTICS OF GENERATION


    APPROACH STATISTICS
    -------------------

    APPROACH NUMBER -------------------------    1
        OUTBOUND APPROACH NUMBER ----------    2    4    6    8   10   12
    PERCENT GOING TO OUTBOUND APPROACHES --    0  7.0 11.6 40.7 23.3 17.4
        VEHICLE CLASS NUMBER --------------    1    2    3    4    5    6    7    8    9   10
    GENERATION PERCENT OF VEHICLES --------  20.9 36.0 29.1  9.3    0  1.2    0    0  1.2  2.3
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  46.5 (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  53.5 (CURB LANE)


    APPROACH NUMBER -------------------------    3
        OUTBOUND APPROACH NUMBER ----------    2    4    6    8   10   12
    PERCENT GOING TO OUTBOUND APPROACHES --  8.9    0  8.1  5.9 43.0 34.1
        VEHICLE CLASS NUMBER --------------    1    2    3    4    5    6    7    8    9   10
    GENERATION PERCENT OF VEHICLES --------  22.2 25.9 36.3 14.1    0    0    0    0    0  1.5
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  40.7 (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  59.3 (CURB LANE)


    APPROACH NUMBER -------------------------    5
        OUTBOUND APPROACH NUMBER ----------    2    4    6    8   10   12
    PERCENT GOING TO OUTBOUND APPROACHES --  21.4  9.7    0  6.8 14.6 47.6
        VEHICLE CLASS NUMBER --------------    1    2    3    4    5    6    7    8    9   10
    GENERATION PERCENT OF VEHICLES --------  17.5 30.1 31.1 13.6  1.0    0    0  1.0  2.9  2.9
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  53.4 (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  46.6 (CURB LANE)


    APPROACH NUMBER -------------------------    7
        OUTBOUND APPROACH NUMBER ----------    2    4    6    8   10   12
    PERCENT GOING TO OUTBOUND APPROACHES --  45.9 31.5 11.7    0   .9  9.9
        VEHICLE CLASS NUMBER --------------    1    2    3    4    5    6    7    8    9   10
    GENERATION PERCENT OF VEHICLES --------  16.2 38.7 31.5 13.5    0    0    0    0    0    0
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  48.6 (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  51.4 (CURB LANE)


    APPROACH NUMBER -------------------------    9
        OUTBOUND APPROACH NUMBER ----------    2    4    6    8   10   12
    PERCENT GOING TO OUTBOUND APPROACHES --   8.6 42.2 31.0 11.2    0  6.9
        VEHICLE CLASS NUMBER --------------    1    2    3    4    5    6    7    8    9   10
    GENERATION PERCENT OF VEHICLES --------  19.0 36.2 31.9  8.6    0  1.7    0  1.7    0   .9
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  52.6 (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  47.4 (CURB LANE)
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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE                        PAGE  6

    *****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)     *****

    APPROACH NUMBER -----------------------   11
        OUTBOUND APPROACH NUMBER ----------     2    4    6    8   10   12
    PERCENT GOING TO OUTBOUND APPROACHES --   6.0  9.0 42.0 18.0 25.0    0
        VEHICLE CLASS NUMBER --------------     1    2    3    4    5    6    7    8    9   10
    GENERATION PERCENT OF VEHICLES -------- 19.0 38.0 24.0 17.0    0    0    0    0    0  2.0
    PERCENT OF TRAFFIC ENTERING ON LANE 1 - 57.0 (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 - 43.0 (CURB LANE)

    DRIVER CLASS SPLIT STATISTICS
    -----------------------------

    DRIVER CLASS NUMBER -------------------      1     2     3

    VEHICLE CLASS NUMBER  1 ( 125 VEH) -----   30.4  42.4  27.2
    VEHICLE CLASS NUMBER  2 ( 220 VEH) -----   33.6  39.1  27.3
    VEHICLE CLASS NUMBER  3 ( 202 VEH) -----   23.3  35.6  41.1
    VEHICLE CLASS NUMBER  4 (  83 VEH) -----   27.7  48.2  24.1
    VEHICLE CLASS NUMBER  5 (   1 VEH) -----      0     0 100.0
    VEHICLE CLASS NUMBER  6 (   3 VEH) ----- 100.0     0     0
    VEHICLE CLASS NUMBER  7 (   0 VEH) -----      0     0     0
    VEHICLE CLASS NUMBER  8 (   3 VEH) -----   66.7     0  33.3
    VEHICLE CLASS NUMBER  9 (   4 VEH) -----   25.0  25.0  50.0
    VEHICLE CLASS NUMBER 10 (  10 VEH) -----   50.0  50.0     0
```

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    *******  PRINT OF FILE SIXSIM   -  31 MAY 78  -  15.42.56.  -  PAGE   1  *******

             1         2         3         4         5         6         7         8
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
    ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
 1 <       *****     90 SECOND PRE-TIMED SIGNAL WITH 30/40/30 SPLIT     *****       >      1
 2 <2.00 10.00 1.00 10 30 2.800 0.800 4000 5 NO  YES NO  NO  1.50 2.50              >      2
 3 <551155115511551155115511                                                        >      3
 4 <   6                                                                            >      4
 5 < 1 23AG AG AR AR AR AR AG AG AR AR AR AR                                        >      5
 6 < 1  4AA AA             AA AA                                                    >      6
 7 < 2 32AR AR AG AG       AR AR AG AG                                              >      7
 8 < 2  4      AA AA             AA AA                                              >      8
 9 < 3 23      AR AR AG AG       AR AR AG AG                                        >      9
10 < 3  4            AA AA             AA AA                                        >     10
    vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv
             1         2         3         4         5         6         7         8
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
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ECHO-PRINT OF TITLE FROM GEOMETRY PROCESSOR
    *****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)     *****

ECHO-PRINT OF TITLE FROM DRIVER-VEHICLE PROCESSOR
    *****     SIX POINTS INTERSECTION (12 APPROACHES WITH 2 LANES)     *****

ECHO-PRINT OF TITLE FROM SIMULATION PROCESSOR INPUT
       *****     90 SECOND PRE-TIMED SIGNAL WITH 30/40/30 SPLIT     *****


START-UP TIME (MINUTES) --------------------------- =      2.00
SIMULATION TIME (MINUTES) ------------------------- =     10.00
STEP INCREMENT FOR SIMULATION TIME (SECONDS) ------ =      1.00

SPEED FOR DELAY BELOW XX MPH (MPH) ---------------- =     10.00

MAXIMUM CLEAR DISTANCE FOR BEING IN A QUEUE (FT) -- =     30.00

CAR FOLLOWING EQUATION LAMBDA --------------------- =      2.80000
CAR FOLLOWING EQUATION MU ------------------------- =       .80000
CAR FOLLOWING EQUATION ALPHA ---------------------- =   4000.00000

SUMMARY STATISTICS PRINTED BY TURNING MOVEMENTS --- =    NO
SUMMARY STATISTICS PRINTED BY INBOUND APPROACH ---- =    YES

PUNCHED OUTPUT OF STATISTICS ---------------------- =    NO

WRITE TAPE FOR POLLUTION DISPERSION MODEL --------- =    NO

LEAD TIME GAP FOR CONFLICT CHECKING (SECONDS) ----- =      1.50
LAG TIME GAP FOR CONFLICT CHECKING (SECONDS) ------ =      2.50

INTERSECTION TRAFFIC CONTROL ---------------------- =      5  (PRE-TIMED)
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          SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

        *****     90 SECOND PRE-TIMED SIGNAL WITH 30/40/30 SPLIT     *****


LANE CONTROL FOR THE 24 LANES = 5 5 1 1 5 5 1 1 5 5 1 1 5 5 1 1 5 5 1 1 5 5 1 1

     WHERE  1 = OUTBOUND (OR BLOCKED INBOUND) LANE
            2 = UNCONTROLLED
            3 = YIELD SIGN
            4 = STOP SIGN
            5 = SIGNAL
            6 = SIGNAL WITH LEFT TURN ON RED
            7 = SIGNAL WITH RIGHT TURN ON RED


A TOTAL OF  6 CAM STACK ENTRIES

ENTRY  1 PHASE  1 TIME =  23  AG  AG  AR  AR  AR  AR  AG  AG  AR  AR  AR  AR
ENTRY  2 PHASE  1 TIME =   4  AA  AA                  AA  AA
ENTRY  3 PHASE  2 TIME =  32  AR  AR  AG  AG          AR  AR  AG  AG
ENTRY  4 PHASE  2 TIME =   4          AA  AA                  AA  AA
ENTRY  5 PHASE  3 TIME =  23          AR  AR  AG  AG          AR  AR  AG  AG
ENTRY  6 PHASE  3 TIME =   4                  AA  AA                  AA  AA
```

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          SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

     *****     90 SECOND PRE-TIMED SIGNAL WITH 30/40/30 SPLIT     *****

SUMMARY STATISTICS FOR INBOUND APPROACH  1


TOTAL DELAY (VEHICLE-SECONDS) ---------------------- =   4245.4
NUMBER OF VEHICLES INCURRING TOTAL DELAY ---------- =    72
PERCENT OF VEHICLES INCURRING TOTAL DELAY --------- =    98.6
AVERAGE TOTAL DELAY (SECONDS) --------------------- =    59.0
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ----------- =    74.1 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) --------------------- =   3885.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ---------- =    61
PERCENT OF VEHICLES INCURRING QUEUE DELAY --------- =    83.6
AVERAGE QUEUE DELAY (SECONDS) --------------------- =    63.7
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ----------- =    80.0 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) ------------------- =   3447.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY -------- =    61
PERCENT OF VEHICLES INCURRING STOPPED DELAY ------- =    83.6
AVERAGE STOPPED DELAY (SECONDS) ------------------- =    56.5
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME --------- =    71.0 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------ =   4069.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH - =    66
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH  =    90.4
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------ =    61.7
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =    77.4 PERCENT

VEHICLE-MILES OF TRAVEL --------------------------- =    13.041
AVERAGE VEHICLE-MILES OF TRAVEL ------------------- =      .179
TRAVEL TIME (VEHICLE-SECONDS) ----------------------=   5812.2
AVERAGE TRAVEL TIME (SECONDS) --------------------- =    79.6
NUMBER OF VEHICLES PROCESSED ---------------------- =    73
VOLUME PROCESSED (VEHICLES/HOUR) ------------------ =   438.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS  =    11.5
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =     8.1
AVERAGE DESIRED SPEED (MPH) ----------------------- =    30.4
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) --------- =     4.4
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) --------- =     4.1

OVERALL AVERAGE TOTAL DELAY (SECONDS) ------------- =    58.2
OVERALL AVERAGE QUEUE DELAY (SECONDS) ------------- =    53.2
OVERALL AVERAGE STOPPED DELAY (SECONDS) ----------- =    47.2
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ---- =    55.7

PERCENT OF VEHICLES MAKING A U-TURN OR A LEFT TURN  =    19.2
PERCENT OF VEHICLES GOING STRAIGHT ---------------- =    39.7
PERCENT OF VEHICLES MAKING A RIGHT TURN ----------- =    41.1

AVERAGE QUEUE LENGTH FOR LANE 1 ------------------- =     3.6  MAX =  8
AVERAGE QUEUE LENGTH FOR LANE 2 ------------------- =     2.7  MAX =  7

NUMBER OF COLLISIONS ------------------------------ =     2
AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ---- =    99.7
```

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          SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

     *****     90 SECOND PRE-TIMED SIGNAL WITH 30/40/30 SPLIT     *****

SUMMARY STATISTICS FOR INBOUND APPROACH  3


TOTAL DELAY (VEHICLE-SECONDS) ---------------------- =   6190.8
NUMBER OF VEHICLES INCURRING TOTAL DELAY ---------- =   114
PERCENT OF VEHICLES INCURRING TOTAL DELAY --------- =    99.1
AVERAGE TOTAL DELAY (SECONDS) --------------------- =    54.3
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ----------- =    58.4 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) --------------------- =   5426.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ---------- =   108
PERCENT OF VEHICLES INCURRING QUEUE DELAY --------- =    93.9
AVERAGE QUEUE DELAY (SECONDS) --------------------- =    50.2
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ----------- =    54.0 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) ------------------- =   3801.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY -------- =   108
PERCENT OF VEHICLES INCURRING STOPPED DELAY ------- =    93.9
AVERAGE STOPPED DELAY (SECONDS) ------------------- =    35.2
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME --------- =    37.9 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------ =   6668.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH - =   110
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH  =    95.7
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------ =    60.6
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =    65.2 PERCENT

VEHICLE-MILES OF TRAVEL --------------------------- =    22.584
AVERAGE VEHICLE-MILES OF TRAVEL ------------------- =      .196
TRAVEL TIME (VEHICLE-SECONDS) ----------------------=  10691.9
AVERAGE TRAVEL TIME (SECONDS) --------------------- =    93.0
NUMBER OF VEHICLES PROCESSED ---------------------- =   115
VOLUME PROCESSED (VEHICLES/HOUR) ------------------ =   690.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS  =     8.5
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =     7.6
AVERAGE DESIRED SPEED (MPH) ----------------------- =    18.7
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) --------- =     3.7
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) --------- =     3.2

OVERALL AVERAGE TOTAL DELAY (SECONDS) ------------- =    53.8
OVERALL AVERAGE QUEUE DELAY (SECONDS) ------------- =    47.2
OVERALL AVERAGE STOPPED DELAY (SECONDS) ----------- =    33.1
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ---- =    58.0

PERCENT OF VEHICLES MAKING A U-TURN OR A LEFT TURN  =    13.9
PERCENT OF VEHICLES GOING STRAIGHT ---------------- =    40.0
PERCENT OF VEHICLES MAKING A RIGHT TURN ----------- =    46.1

AVERAGE QUEUE LENGTH FOR LANE 1 ------------------- =     2.9  MAX =  8
AVERAGE QUEUE LENGTH FOR LANE 2 ------------------- =     5.9  MAX = 14

AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ---- =    94.2
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           SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

       *****      90 SECOND PRE-TIMED SIGNAL WITH 30/40/30 SPLIT      *****

SUMMARY STATISTICS FOR INBOUND APPROACH  5


TOTAL DELAY (VEHICLE-SECONDS) --------------------- =   5130.9
NUMBER OF VEHICLES INCURRING TOTAL DELAY ---------- =     74
PERCENT OF VEHICLES INCURRING TOTAL DELAY --------- =    100.0
AVERAGE TOTAL DELAY (SECONDS) --------------------- =     69.3
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ----------- =     67.3 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) --------------------- =   4721.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ---------- =     72
PERCENT OF VEHICLES INCURRING QUEUE DELAY --------- =     97.3
AVERAGE QUEUE DELAY (SECONDS) --------------------- =     65.6
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ----------- =     63.6 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) ------------------- =   3867.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY -------- =     72
PERCENT OF VEHICLES INCURRING STOPPED DELAY ------- =     97.3
AVERAGE STOPPED DELAY (SECONDS) ------------------- =     53.7
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME --------- =     52.1 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------ =   5296.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH - =     73
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH  =     98.6
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------ =     72.5
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =     70.4 PERCENT

VEHICLE-MILES OF TRAVEL --------------------------- =     13.238
AVERAGE VEHICLE-MILES OF TRAVEL ------------------- =       .179
TRAVEL TIME (VEHICLE-SECONDS) ----------------------=   7623.9
AVERAGE TRAVEL TIME (SECONDS) --------------------- =    103.0
NUMBER OF VEHICLES PROCESSED ---------------------- =     74
VOLUME PROCESSED (VEHICLES/HOUR) ------------------ =    444.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS  =      6.9
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =      6.3
AVERAGE DESIRED SPEED (MPH) ----------------------- =     19.8
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) --------- =      3.6
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) --------- =      2.9

OVERALL AVERAGE TOTAL DELAY (SECONDS) ------------- =     69.3
OVERALL AVERAGE QUEUE DELAY (SECONDS) ------------- =     63.8
OVERALL AVERAGE STOPPED DELAY (SECONDS) ----------- =     52.3
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ---- =     71.6

PERCENT OF VEHICLES MAKING A U-TURN OR A LEFT TURN  =     17.6
PERCENT OF VEHICLES GOING STRAIGHT ---------------- =     54.1
PERCENT OF VEHICLES MAKING A RIGHT TURN ----------- =     28.4

AVERAGE QUEUE LENGTH FOR LANE 1 ------------------- =      5.7  MAX = 10
AVERAGE QUEUE LENGTH FOR LANE 2 ------------------- =      4.8  MAX = 10

AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ---- =     96.2
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           SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

       *****      90 SECOND PRE-TIMED SIGNAL WITH 30/40/30 SPLIT      *****

SUMMARY STATISTICS FOR INBOUND APPROACH  7


TOTAL DELAY (VEHICLE-SECONDS) --------------------- =   3854.1
NUMBER OF VEHICLES INCURRING TOTAL DELAY ---------- =     85
PERCENT OF VEHICLES INCURRING TOTAL DELAY --------- =     98.8
AVERAGE TOTAL DELAY (SECONDS) --------------------- =     45.3
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ----------- =     63.6 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) --------------------- =   3381.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ---------- =     74
PERCENT OF VEHICLES INCURRING QUEUE DELAY --------- =     86.0
AVERAGE QUEUE DELAY (SECONDS) --------------------- =     45.7
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ----------- =     64.1 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) ------------------- =   2855.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY -------- =     74
PERCENT OF VEHICLES INCURRING STOPPED DELAY ------- =     86.0
AVERAGE STOPPED DELAY (SECONDS) ------------------- =     38.6
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME --------- =     54.1 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------ =   3717.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH - =     79
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH  =     91.9
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------ =     47.1
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =     66.0 PERCENT

VEHICLE-MILES OF TRAVEL --------------------------- =     15.539
AVERAGE VEHICLE-MILES OF TRAVEL ------------------- =       .181
TRAVEL TIME (VEHICLE-SECONDS) ----------------------=   6127.8
AVERAGE TRAVEL TIME (SECONDS) --------------------- =     71.3
NUMBER OF VEHICLES PROCESSED ---------------------- =     86
VOLUME PROCESSED (VEHICLES/HOUR) ------------------ =    516.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS  =     10.8
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =      9.1
AVERAGE DESIRED SPEED (MPH) ----------------------- =     24.8
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) --------- =      3.8
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) --------- =      3.1

OVERALL AVERAGE TOTAL DELAY (SECONDS) ------------- =     44.8
OVERALL AVERAGE QUEUE DELAY (SECONDS) ------------- =     39.3
OVERALL AVERAGE STOPPED DELAY (SECONDS) ----------- =     33.2
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ---- =     43.2

PERCENT OF VEHICLES MAKING A U-TURN OR A LEFT TURN  =     10.5
PERCENT OF VEHICLES GOING STRAIGHT ---------------- =     46.5
PERCENT OF VEHICLES MAKING A RIGHT TURN ----------- =     43.0

AVERAGE QUEUE LENGTH FOR LANE 1 ------------------- =      3.3  MAX =  8
AVERAGE QUEUE LENGTH FOR LANE 2 ------------------- =      3.3  MAX =  9

AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ---- =     99.5
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          SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

     *****      90 SECOND PRE-TIMED SIGNAL WITH 30/40/30 SPLIT      *****

SUMMARY STATISTICS FOR INBOUND APPROACH  9


TOTAL DELAY (VEHICLE-SECONDS) --------------------- =   3926.2
NUMBER OF VEHICLES INCURRING TOTAL DELAY ---------- =     95
PERCENT OF VEHICLES INCURRING TOTAL DELAY --------- =     97.9
AVERAGE TOTAL DELAY (SECONDS) --------------------- =     41.3
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ----------- =     59.2 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) --------------------- =   3552.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ---------- =     70
PERCENT OF VEHICLES INCURRING QUEUE DELAY --------- =     72.2
AVERAGE QUEUE DELAY (SECONDS) --------------------- =     50.7
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ----------- =     72.7 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) ------------------- =   3084.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY -------- =     70
PERCENT OF VEHICLES INCURRING STOPPED DELAY ------- =     72.2
AVERAGE STOPPED DELAY (SECONDS) ------------------- =     44.1
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME --------- =     63.1 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------ =   3873.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH - =     82
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH  =     84.5
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------ =     47.2
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =     67.6 PERCENT

VEHICLE-MILES OF TRAVEL --------------------------- =     18.823
AVERAGE VEHICLE-MILES OF TRAVEL ------------------- =       .194
TRAVEL TIME (VEHICLE-SECONDS) ----------------------=   6774.3
AVERAGE TRAVEL TIME (SECONDS) --------------------- =     69.8
NUMBER OF VEHICLES PROCESSED ---------------------- =     97
VOLUME PROCESSED (VEHICLES/HOUR) ------------------ =    582.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS  =     12.6
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =     10.0
AVERAGE DESIRED SPEED (MPH) ----------------------- =     24.1
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) --------- =      3.8
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) --------- =      3.0

OVERALL AVERAGE TOTAL DELAY (SECONDS) ------------- =     40.5
OVERALL AVERAGE QUEUE DELAY (SECONDS) ------------- =     36.6
OVERALL AVERAGE STOPPED DELAY (SECONDS) ----------- =     31.8
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ---- =     39.9

PERCENT OF VEHICLES MAKING A U-TURN OR A LEFT TURN  =     13.4
PERCENT OF VEHICLES GOING STRAIGHT ---------------- =     46.4
PERCENT OF VEHICLES MAKING A RIGHT TURN ----------- =     40.2

AVERAGE QUEUE LENGTH FOR LANE 1 ------------------- =      3.4  MAX =  7
AVERAGE QUEUE LENGTH FOR LANE 2 ------------------- =      2.5  MAX =  7

AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ---- =     98.7
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          SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

     *****      90 SECOND PRE-TIMED SIGNAL WITH 30/40/30 SPLIT      *****

SUMMARY STATISTICS FOR INBOUND APPROACH 11


TOTAL DELAY (VEHICLE-SECONDS) --------------------- =   5036.4
NUMBER OF VEHICLES INCURRING TOTAL DELAY ---------- =     68
PERCENT OF VEHICLES INCURRING TOTAL DELAY --------- =     98.6
AVERAGE TOTAL DELAY (SECONDS) --------------------- =     74.1
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ----------- =     73.8 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) --------------------- =   4718.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ---------- =     62
PERCENT OF VEHICLES INCURRING QUEUE DELAY --------- =     89.9
AVERAGE QUEUE DELAY (SECONDS) --------------------- =     76.1
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ----------- =     75.8 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) ------------------- =   4108.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY -------- =     62
PERCENT OF VEHICLES INCURRING STOPPED DELAY ------- =     89.9
AVERAGE STOPPED DELAY (SECONDS) ------------------- =     66.3
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME --------- =     66.0 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------ =   5025.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH - =     67
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH  =     97.1
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------ =     75.0
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =     74.7 PERCENT

VEHICLE-MILES OF TRAVEL --------------------------- =     12.823
AVERAGE VEHICLE-MILES OF TRAVEL ------------------- =       .186
TRAVEL TIME (VEHICLE-SECONDS) ----------------------=   6927.6
AVERAGE TRAVEL TIME (SECONDS) --------------------- =    100.4
NUMBER OF VEHICLES PROCESSED ---------------------- =     69
VOLUME PROCESSED (VEHICLES/HOUR) ------------------ =    414.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS  =      8.7
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =      6.7
AVERAGE DESIRED SPEED (MPH) ----------------------- =     24.6
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) --------- =      4.1
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) --------- =      3.1

OVERALL AVERAGE TOTAL DELAY (SECONDS) ------------- =     73.0
OVERALL AVERAGE QUEUE DELAY (SECONDS) ------------- =     68.4
OVERALL AVERAGE STOPPED DELAY (SECONDS) ----------- =     59.5
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ---- =     72.8

PERCENT OF VEHICLES MAKING A U-TURN OR A LEFT TURN  =     11.6
PERCENT OF VEHICLES GOING STRAIGHT ---------------- =     43.5
PERCENT OF VEHICLES MAKING A RIGHT TURN ----------- =     44.9

AVERAGE QUEUE LENGTH FOR LANE 1 ------------------- =      5.3  MAX = 10
AVERAGE QUEUE LENGTH FOR LANE 2 ------------------- =      4.0  MAX = 11

AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ---- =     98.3
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          SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

      *****      90 SECOND PRE-TIMED SIGNAL WITH 30/40/30 SPLIT      *****

SUMMARY STATISTICS FOR ALL APPROACHES


TOTAL DELAY (VEHICLE-SECONDS) --------------------- =  28383.8
NUMBER OF VEHICLES INCURRING TOTAL DELAY ---------- =    508
PERCENT OF VEHICLES INCURRING TOTAL DELAY --------- =     98.8
AVERAGE TOTAL DELAY (SECONDS) --------------------- =     55.9
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ----------- =     65.3 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) --------------------- =  25683.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ---------- =    447
PERCENT OF VEHICLES INCURRING QUEUE DELAY --------- =     87.0
AVERAGE QUEUE DELAY (SECONDS) --------------------- =     57.5
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ----------- =     67.2 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) ------------------- =  21162.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY -------- =    447
PERCENT OF VEHICLES INCURRING STOPPED DELAY ------- =     87.0
AVERAGE STOPPED DELAY (SECONDS) ------------------- =     47.3
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME --------- =     55.4 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------ =  28648.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH - =    477
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH  =     92.8
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------ =     60.1
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =     70.2 PERCENT

VEHICLE-MILES OF TRAVEL --------------------------- =     96.047
AVERAGE VEHICLE-MILES OF TRAVEL ------------------- =       .187
TRAVEL TIME (VEHICLE-SECONDS) ---------------------=  43957.7
AVERAGE TRAVEL TIME (SECONDS) --------------------- =     85.5
NUMBER OF VEHICLES PROCESSED ---------------------- =    514
VOLUME PROCESSED (VEHICLES/HOUR) ------------------ =   3084.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS  =      9.9
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =      7.9
AVERAGE DESIRED SPEED (MPH) ----------------------- =     23.4
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) --------- =      3.9
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) --------- =      3.2

OVERALL AVERAGE TOTAL DELAY (SECONDS) ------------- =     55.2
OVERALL AVERAGE QUEUE DELAY (SECONDS) ------------- =     50.0
OVERALL AVERAGE STOPPED DELAY (SECONDS) ----------- =     41.2
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ---- =     55.7

NUMBER OF COLLISIONS ------------------------------ =      2
AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ---- =     97.6
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     SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

 *****      90 SECOND PRE-TIMED SIGNAL WITH 30/40/30 SPLIT      *****

START-UP TIME    =  120.000 SECONDS      NUMBER OF VEHICLES PROCESSED =   40

SIMULATION TIME =  600.000 SECONDS      NUMBER OF VEHICLES PROCESSED =  514

NUMBER OF VEHICLES IN THE SYSTEM AT SUMMARY =    97
AVERAGE NUMBER OF VEHICLES IN THE SYSTEM -- =   78.9  MAX =  98



INITIAL     TM TIME =      .896 SECONDS   COST = $   .06

START-UP    TM TIME =   10.661 SECONDS   COST = $   .60
            REAL/TM =   11.256

SIMULATION TM TIME =  107.279 SECONDS   COST = $  6.85
            REAL/TM =    5.593

SUMMARY     TM TIME =      .495 SECONDS   COST = $   .03


TOTAL       TM TIME =  119.331 SECONDS   COST = $  7.62


VEHICLE-SECONDS OF SIMULATION PER TM TIME =  409.751

VEHICLE UPDATES PER TM TIME =  409.751
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    *******  PRINT OF FILE CAMDB    -  29 NOV 77  -  21.28.24.  -  PAGE   1  *******

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 1 <     US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK     >     1
 2 <   4                                                                            >     2
 3 <   3   2   1   4                                                                >     3
 4 <   4                                                                            >     4
 5 <   5   6   7   8                                                                >     5
 6 <   8  12 1.0  10   3  90  90                                                    >     6
 7 <   1 180 5651130  45   2       NEGEXP   150       40.0 45.0 00 26 49 25      YES>     7
 8 <15.3 49.2  6.5  4.0 23.4  0.8  0.0  0.8  0.0  0.0                               >     8
 9 <  13   0 485   0 485  LS       100        14   0   0 150 425    R               >     9
10 <   2  90   0 534  55   4       LOGNRML  383  1.00 50.0 55.0 07 00 08 85      YES>    10
11 <09.7 36.4 10.6  4.4 31.3  3.2  3.0  0.7  0.2  0.5                               >    11
12 <  10   0   0 300 520 UL                   12   0 520   0 520   S       45       >    12
13 <  12   0 520   0 520   S        55        14   0   0 250 460    R               >    13
14 <   3   0 570   0  45   3       NEGEXP   170       40.0 45.0 26 63  0 11      YES>    14
15 < 9.1 59.4  9.8  7.0 13.3  0.7  0.0  0.7  0.0  0.0                               >    15
16 <  10   0 485   0 485  L         51        15   0 485   0 485  LS       49       >    16
17 <  14   0   0 200 425    R                                                       >    17
18 <   4 2701130 596  55   4       LOGNRML  541  1.00 50.0 55.0 20 73 07 00      YES>    18
19 < 8.8 37.9  9.3  3.0 34.2  2.7  2.7  0.3  0.3  0.8                               >    19
20 <  10   0   0 300 537 UL                   12   0 537   0 537   S       51       >    20
21 <  12   0 537   0 537   S        49        14   0   0 150 477    R               >    21
22 <   5   0 565 645  45   2                                                        >    22
23 <  13   0 485   0 485  LS                  14  60 260 485 485    R               >    23
24 <   6 270 537 606  55   3                                                        >    24
25 <  12   0 537   0 537 ULS                  12   0 537   0 537  LS                >    25
26 <  14  60 360 537 537    R                                                       >    26
27 <   7 180 560 485  45   3                                                        >    27
28 <  10   0 485   0 485  LS                  15   0 485   0 485   S                >    28
29 <  14  60 260 485 485    R                                                       >    29
30 <   8  90 610 524  55   3                                                        >    30
31 <  12   0 520   0 520 ULS                  12   0 520   0 520   S                >    31
32 <  14  60 360 520 520    R                                                       >    32
33 <  15                                                                            >    33
34 <   1 670 425 270  90  75                                                        >    34
35 <   2 670 425 270  90  61                                                        >    35
36 <   3 610 485 270  90  15                                                        >    36
37 <   4 460 425  90 -90  75                                                        >    37
38 <   5 460 425  90 -90  61                                                        >    38
39 <   6 520 485  90 -90  15                                                        >    39
40 <   7 477 705 180 -90  75                                                        >    40
41 <   8 477 705 180 -90  61                                                        >    41
42 <   9 653 705 180  90  75                                                        >    42
43 <  10 653 705 180  90  61                                                        >    43
44 <  11 631 560 180 180  36                                                        >    44
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46 <  13 565 485 270 180   5                                                        >    46
47 <  14 537 645 180 -90  15                                                        >    47
48 <  15 593 645 180  90  15                                                        >    48
49 <   4                                                                            >    49
50 <   1 565 646 552 646                                                            >    50
51 <   2 519 534 519 500                                                            >    51
52 <   3 570 484 595 484                                                            >    52
53 <   4 594 630 594 596                                                            >    53
54 <   0                                                                            >    54
55 <PRIMARY   PLOTI     SAME                                            12          >    55
56 <NO NO NO NO NO NO NO NO NO NO NO NO NO                NO NO NO                  >    56
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  GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE     PAGE  1

US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK


TABLE  1  -  LISTING OF INBOUND APPROACH NUMBERS


             3
             2
             1
             4


    TOTAL NUMBER OF INBOUND APPROACHES =  4


TABLE  2  -  LISTING OF OUTBOUND APPROACH NUMBERS


             5
             6
             7
             8


    TOTAL NUMBER OF OUTBOUND APPROACHES =  4


    TOTAL NUMBER OF INBOUND AND OUTBOUND APPROACHES =  8


TABLE  3  -  LISTING OF APPROACHES


    APPROACH NUMBER -------------------     1
    APPROACH AZIMUTH ------------------   180
    BEGINNING CENTERLINE X COORDINATE -   565
    BEGINNING CENTERLINE Y COORDINATE -  1130
    SPEED LIMIT (MPH) -----------------    45
    NUMBER OF DEGREES FOR STRAIGHT ----    20
    NUMBER OF DEGREES FOR U-TURN ------    10
    NUMBER OF LANES -------------------     2

    LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
      1   1   1   13       0  485    0  485   ( LS )       (MEDIAN LANE)
      2   2   2   14       0    0  150  425   (   R)       (CURB LANE)


    APPROACH NUMBER -------------------     2
    APPROACH AZIMUTH ------------------    90
    BEGINNING CENTERLINE X COORDINATE -     0
    BEGINNING CENTERLINE Y COORDINATE -   534
    SPEED LIMIT (MPH) -----------------    55
    NUMBER OF DEGREES FOR STRAIGHT ----    20
    NUMBER OF DEGREES FOR U-TURN ------    10
    NUMBER OF LANES -------------------     4

    LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
      1   3   3   10       0    0  300  520   (UL  )       (MEDIAN LANE)
      2   4   4   12       0  520    0  520   (  S )
      3   5   5   12       0  520    0  520   (  S )
      4   6   6   14       0    0  250  460   (   R)       (CURB LANE)
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  GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE     PAGE  2

US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK


    APPROACH NUMBER -------------------     3
    APPROACH AZIMUTH ------------------     0
    BEGINNING CENTERLINE X COORDINATE -   570
    BEGINNING CENTERLINE Y COORDINATE -     0
    SPEED LIMIT (MPH) -----------------    45
    NUMBER OF DEGREES FOR STRAIGHT ----    20
    NUMBER OF DEGREES FOR U-TURN ------    10
    NUMBER OF LANES -------------------     3

    LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
      1   7   7   10       0  485    0  485   ( L  )       (MEDIAN LANE)
      2   8   8   15       0  485    0  485   ( LS )
      3   9   9   14       0    0  200  425   (   R)       (CURB LANE)


    APPROACH NUMBER -------------------     4
    APPROACH AZIMUTH ------------------   270
    BEGINNING CENTERLINE X COORDINATE -  1130
    BEGINNING CENTERLINE Y COORDINATE -   596
    SPEED LIMIT (MPH) -----------------    55
    NUMBER OF DEGREES FOR STRAIGHT ----    20
    NUMBER OF DEGREES FOR U-TURN ------    10
    NUMBER OF LANES -------------------     4

    LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
      1  10  10   10       0    0  300  537   (UL  )       (MEDIAN LANE)
      2  11  11   12       0  537    0  537   (  S )
      3  12  12   12       0  537    0  537   (  S )
      4  13  13   14       0    0  150  477   (   R)       (CURB LANE)


    APPROACH NUMBER -------------------     5
    APPROACH AZIMUTH ------------------     0
    BEGINNING CENTERLINE X COORDINATE -   565
    BEGINNING CENTERLINE Y COORDINATE -   645
    SPEED LIMIT (MPH) -----------------    45
    NUMBER OF DEGREES FOR STRAIGHT ----    20
    NUMBER OF DEGREES FOR U-TURN ------    10
    NUMBER OF LANES -------------------     2

    LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
      1  14   0   13       0  485    0  485   ( LS )       (MEDIAN LANE)
      2  15   0   14      60  260  485  485   (   R)       (CURB LANE)


    APPROACH NUMBER -------------------     6
    APPROACH AZIMUTH ------------------   270
    BEGINNING CENTERLINE X COORDINATE -   537
    BEGINNING CENTERLINE Y COORDINATE -   606
    SPEED LIMIT (MPH) -----------------    55
    NUMBER OF DEGREES FOR STRAIGHT ----    20
    NUMBER OF DEGREES FOR U-TURN ------    10
    NUMBER OF LANES -------------------     3

    LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
      1  16   0   12       0  537    0  537   (ULS )       (MEDIAN LANE)
      2  17   0   12       0  537    0  537   ( LS )
      3  18   0   14      60  360  537  537   (   R)       (CURB LANE)
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   GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE     PAGE  3

US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK


     APPROACH NUMBER -------------------    7
     APPROACH AZIMUTH ------------------  180
     BEGINNING CENTERLINE X COORDINATE -  560
     BEGINNING CENTERLINE Y COORDINATE -  485
     SPEED LIMIT (MPH) -----------------   45
     NUMBER OF DEGREES FOR STRAIGHT ----   20
     NUMBER OF DEGREES FOR U-TURN ------   10
     NUMBER OF LANES -------------------    3

     LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
       1  19   0   10      0  485    0  485   ( LS )       (MEDIAN LANE)
       2  20   0   15      0  485    0  485   (  S )
       3  21   0   14     60  260  485  485   (   R)       (CURB LANE)


     APPROACH NUMBER -------------------    8
     APPROACH AZIMUTH ------------------   90
     BEGINNING CENTERLINE X COORDINATE -  610
     BEGINNING CENTERLINE Y COORDINATE -  524
     SPEED LIMIT (MPH) -----------------   55
     NUMBER OF DEGREES FOR STRAIGHT ----   20
     NUMBER OF DEGREES FOR U-TURN ------   10
     NUMBER OF LANES -------------------    3

     LANE IL IBLN WIDTH ---LANE GEOMETRY--- LEGAL TURNS
       1  22   0   12      0  520    0  520   (ULS )       (MEDIAN LANE)
       2  23   0   12      0  520    0  520   (  S )
       3  24   0   14     60  360  520  520   (   R)       (CURB LANE)


     TOTAL NUMBER OF APPROACHES =  8


TABLE  4  -  LISTING OF ARCS (FOR PLOTTING ONLY)


     ARC NUMBER ------------------------    1
     CENTER X COORDINATE ---------------  670
     CENTER Y COORDINATE ---------------  425
     BEGINNING AZIMUTH -----------------  270
     SWEEP ANGLE -----------------------   90
     RADIUS OF ARC ---------------------   75
     ROTATION FROM BEGINNING AZIMUTH --- CLOCKWISE


     ARC NUMBER ------------------------    2
     CENTER X COORDINATE ---------------  670
     CENTER Y COORDINATE ---------------  425
     BEGINNING AZIMUTH -----------------  270
     SWEEP ANGLE -----------------------   90
     RADIUS OF ARC ---------------------   61
     ROTATION FROM BEGINNING AZIMUTH --- CLOCKWISE


     ARC NUMBER ------------------------    3
     CENTER X COORDINATE ---------------  610
     CENTER Y COORDINATE ---------------  485
     BEGINNING AZIMUTH -----------------  270
     SWEEP ANGLE -----------------------   90
     RADIUS OF ARC ---------------------   15
     ROTATION FROM BEGINNING AZIMUTH --- CLOCKWISE
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   GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE     PAGE  4

US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK


     ARC NUMBER ------------------------    4
     CENTER X COORDINATE ---------------  460
     CENTER Y COORDINATE ---------------  425
     BEGINNING AZIMUTH -----------------   90
     SWEEP ANGLE -----------------------  -90
     RADIUS OF ARC ---------------------   75
     ROTATION FROM BEGINNING AZIMUTH --- COUNTER CLOCKWISE


     ARC NUMBER ------------------------    5
     CENTER X COORDINATE ---------------  460
     CENTER Y COORDINATE ---------------  425
     BEGINNING AZIMUTH -----------------   90
     SWEEP ANGLE -----------------------  -90
     RADIUS OF ARC ---------------------   61
     ROTATION FROM BEGINNING AZIMUTH --- COUNTER CLOCKWISE


     ARC NUMBER ------------------------    6
     CENTER X COORDINATE ---------------  520
     CENTER Y COORDINATE ---------------  485
     BEGINNING AZIMUTH -----------------   90
     SWEEP ANGLE -----------------------  -90
     RADIUS OF ARC ---------------------   15
     ROTATION FROM BEGINNING AZIMUTH --- COUNTER CLOCKWISE


     ARC NUMBER ------------------------    7
     CENTER X COORDINATE ---------------  477
     CENTER Y COORDINATE ---------------  705
     BEGINNING AZIMUTH -----------------  180
     SWEEP ANGLE -----------------------  -90
     RADIUS OF ARC ---------------------   75
     ROTATION FROM BEGINNING AZIMUTH --- COUNTER CLOCKWISE


     ARC NUMBER ------------------------    8
     CENTER X COORDINATE ---------------  477
     CENTER Y COORDINATE ---------------  705
     BEGINNING AZIMUTH -----------------  180
     SWEEP ANGLE -----------------------  -90
     RADIUS OF ARC ---------------------   61
     ROTATION FROM BEGINNING AZIMUTH --- COUNTER CLOCKWISE


     ARC NUMBER ------------------------    9
     CENTER X COORDINATE ---------------  653
     CENTER Y COORDINATE ---------------  705
     BEGINNING AZIMUTH -----------------  180
     SWEEP ANGLE -----------------------   90
     RADIUS OF ARC ---------------------   75
     ROTATION FROM BEGINNING AZIMUTH --- CLOCKWISE


     ARC NUMBER ------------------------   10
     CENTER X COORDINATE ---------------  653
     CENTER Y COORDINATE ---------------  705
     BEGINNING AZIMUTH -----------------  180
     SWEEP ANGLE -----------------------   90
     RADIUS OF ARC ---------------------   61
     ROTATION FROM BEGINNING AZIMUTH --- CLOCKWISE
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    GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE     PAGE  5

US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK


      ARC NUMBER -----------------------   11
      CENTER X COORDINATE ---------------  631
      CENTER Y COORDINATE ---------------  560
      BEGINNING AZIMUTH -----------------  180
      SWEEP ANGLE -----------------------  180
      RADIUS OF ARC ---------------------   36
      ROTATION FROM BEGINNING AZIMUTH --- CLOCKWISE


      ARC NUMBER -----------------------   12
      CENTER X COORDINATE ---------------  498
      CENTER Y COORDINATE ---------------  570
      BEGINNING AZIMUTH -----------------  180
      SWEEP ANGLE ----------------------- -180
      RADIUS OF ARC ---------------------   36
      ROTATION FROM BEGINNING AZIMUTH --- COUNTER CLOCKWISE


      ARC NUMBER -----------------------   13
      CENTER X COORDINATE ---------------  565
      CENTER Y COORDINATE ---------------  485
      BEGINNING AZIMUTH -----------------  270
      SWEEP ANGLE -----------------------  180
      RADIUS OF ARC ---------------------    5
      ROTATION FROM BEGINNING AZIMUTH --- CLOCKWISE


      ARC NUMBER -----------------------   14
      CENTER X COORDINATE ---------------  537
      CENTER Y COORDINATE ---------------  645
      BEGINNING AZIMUTH -----------------  180
      SWEEP ANGLE -----------------------  -90
      RADIUS OF ARC ---------------------   15
      ROTATION FROM BEGINNING AZIMUTH --- COUNTER CLOCKWISE


      ARC NUMBER -----------------------   15
      CENTER X COORDINATE ---------------  593
      CENTER Y COORDINATE ---------------  645
      BEGINNING AZIMUTH -----------------  180
      SWEEP ANGLE -----------------------   90
      RADIUS OF ARC ---------------------   15
      ROTATION FROM BEGINNING AZIMUTH --- CLOCKWISE


      TOTAL NUMBER OF ARCS = 15



TABLE  5  -  LISTING OF LINES (FOR PLOTTING ONLY)


      LINE NUMBER ----------------------    1
      START X COORDINATE ---------------  565
      START Y COORDINATE ---------------  646
      END X COORDINATE -----------------  552
      END Y COORDINATE -----------------  646


      LINE NUMBER ----------------------    2
      START X COORDINATE ---------------  519
      START Y COORDINATE ---------------  534
      END X COORDINATE -----------------  519
      END Y COORDINATE -----------------  560
```

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    GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE     PAGE  6

US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK


      LINE NUMBER ----------------------    3
      START X COORDINATE ---------------  570
      START Y COORDINATE ---------------  484
      END X COORDINATE -----------------  595
      END Y COORDINATE -----------------  484


      LINE NUMBER ----------------------    4
      START X COORDINATE ---------------  594
      START Y COORDINATE ---------------  630
      END X COORDINATE -----------------  594
      END Y COORDINATE -----------------  596


      TOTAL NUMBER OF LINES =  4



TABLE  6  -  LISTING OF OPTIONS AND ADDITIONAL DATA


      PRIMARY PATHS SELECTED

      PLOT SELECTED USING INK PEN

      APPROACH PATHS PLOTTED ON THE SAME FRAME

      APPROACH SCALE FACTOR FROM INPUT IS    -0 FEET PER INCH

      INTERSECTION SCALE FACTOR FROM INPUT IS    -0 FEET PER INCH

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

      PROGRAM CHECKS TO SEE IF THE CENTER TO CENTER DISTANCE
          BETWEEN VEHICLES BECOMES LESS THAN OR EQUAL TO 10 FEET

      PLOT PAPER WIDTH = 12 INCHES

      APPROACH SCALE FACTOR TO BE USED IS 200.0 FEET PER INCH

      INTERSECTION SCALE FACTOR TO BE USED IS  40.0 FEET PER INCH


TABLE  7  -  LISTING OF PATHS


      PATH   1 GOES FROM LANE 1 OF APPROACH  3 TO LANE 1 OF APPROACH  6
         LENGTH OF PATH = 149 FEET AND SPEED OF PATH = 20 FEET PER SECOND
         NUMBER OF CONFLICTS = 11 AND TURN CODE FOR PATH IS LEFT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
               4     3     9     6     2     1     8    10     7     5
              11


      PATH   2 GOES FROM LANE 2 OF APPROACH  3 TO LANE 1 OF APPROACH  5
         LENGTH OF PATH = 162 FEET AND SPEED OF PATH = 49 FEET PER SECOND
         NUMBER OF CONFLICTS = 11 AND TURN CODE FOR PATH IS STRAIGHT
         CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              16    15    19    17    14    13    18    20    21    22
              12
```

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   GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE     PAGE  7

US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK


     PATH   3 GOES FROM LANE 2 OF APPROACH  3 TO LANE 2 OF APPROACH  6
        LENGTH OF PATH = 168 FEET AND SPEED OF PATH = 23 FEET PER SECOND
        NUMBER OF CONFLICTS = 11 AND TURN CODE FOR PATH IS LEFT
        CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              25    24    30    27    29    31    23    32    28    26
              33


     PATH   4 GOES FROM LANE 3 OF APPROACH  3 TO LANE 3 OF APPROACH  8
        LENGTH OF PATH = 107 FEET AND SPEED OF PATH = 25 FEET PER SECOND
        NUMBER OF CONFLICTS =  0 AND TURN CODE FOR PATH IS RIGHT


     PATH   5 GOES FROM LANE 1 OF APPROACH  2 TO LANE 1 OF APPROACH  5
        LENGTH OF PATH = 146 FEET AND SPEED OF PATH = 23 FEET PER SECOND
        NUMBER OF CONFLICTS = 11 AND TURN CODE FOR PATH IS LEFT
        CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              36    38    34    35     1    37    39    23    40    41
              12


     PATH   6 GOES FROM LANE 1 OF APPROACH  2 TO LANE 1 OF APPROACH  6
        LENGTH OF PATH = 147 FEET AND SPEED OF PATH = 21 FEET PER SECOND
        NUMBER OF CONFLICTS = 12 AND TURN CODE FOR PATH IS U-TURN
        CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              47    43    49    45     2    14    13    46    48    44
              42    50


     PATH   7 GOES FROM LANE 2 OF APPROACH  2 TO LANE 1 OF APPROACH  8
        LENGTH OF PATH =  90 FEET AND SPEED OF PATH = 81 FEET PER SECOND
        NUMBER OF CONFLICTS =  8 AND TURN CODE FOR PATH IS STRAIGHT
        CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              53    51     3    15    24    54    52    55


     PATH   8 GOES FROM LANE 3 OF APPROACH  2 TO LANE 2 OF APPROACH  8
        LENGTH OF PATH =  90 FEET AND SPEED OF PATH = 81 FEET PER SECOND
        NUMBER OF CONFLICTS =  5 AND TURN CODE FOR PATH IS STRAIGHT
        CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              56    57     4    16    25


     PATH   9 GOES FROM LANE 4 OF APPROACH  2 TO LANE 3 OF APPROACH  7
        LENGTH OF PATH = 107 FEET AND SPEED OF PATH = 25 FEET PER SECOND
        NUMBER OF CONFLICTS =  0 AND TURN CODE FOR PATH IS RIGHT


     PATH  10 GOES FROM LANE 1 OF APPROACH  1 TO LANE 1 OF APPROACH  7
        LENGTH OF PATH = 166 FEET AND SPEED OF PATH = 66 FEET PER SECOND
        NUMBER OF CONFLICTS = 13 AND TURN CODE FOR PATH IS STRAIGHT
        CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              63    26    62    42     5    60    58    34    61    43
              51    56    59


     PATH  11 GOES FROM LANE 1 OF APPROACH  1 TO LANE 1 OF APPROACH  8
        LENGTH OF PATH = 157 FEET AND SPEED OF PATH = 23 FEET PER SECOND
        NUMBER OF CONFLICTS = 14 AND TURN CODE FOR PATH IS LEFT
        CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              68    28    67    44     7    65    64    35    45     6
              17    27    52    66
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   GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE     PAGE  8

US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK


     PATH  12 GOES FROM LANE 2 OF APPROACH  1 TO LANE 3 OF APPROACH  6
        LENGTH OF PATH = 107 FEET AND SPEED OF PATH = 25 FEET PER SECOND
        NUMBER OF CONFLICTS =  0 AND TURN CODE FOR PATH IS RIGHT


     PATH  13 GOES FROM LANE 1 OF APPROACH  4 TO LANE 1 OF APPROACH  7
        LENGTH OF PATH = 138 FEET AND SPEED OF PATH = 20 FEET PER SECOND
        NUMBER OF CONFLICTS = 12 AND TURN CODE FOR PATH IS LEFT
        CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              29    18    37    46     8    64    58    36    47    53
              57    59


     PATH  14 GOES FROM LANE 1 OF APPROACH  4 TO LANE 1 OF APPROACH  8
        LENGTH OF PATH = 147 FEET AND SPEED OF PATH = 21 FEET PER SECOND
        NUMBER OF CONFLICTS = 16 AND TURN CODE FOR PATH IS U-TURN
        CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              31    20    39    48    10    65    60    38    61    49
               9    19    30    54    55    66


     PATH  15 GOES FROM LANE 2 OF APPROACH  4 TO LANE 1 OF APPROACH  6
        LENGTH OF PATH =  56 FEET AND SPEED OF PATH = 81 FEET PER SECOND
        NUMBER OF CONFLICTS =  7 AND TURN CODE FOR PATH IS STRAIGHT
        CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              21    40    32    67    62    50    11


     PATH  16 GOES FROM LANE 3 OF APPROACH  4 TO LANE 2 OF APPROACH  6
        LENGTH OF PATH =  56 FEET AND SPEED OF PATH = 81 FEET PER SECOND
        NUMBER OF CONFLICTS =  5 AND TURN CODE FOR PATH IS STRAIGHT
        CONFLICT ENTRY NUMBERS ORDERED BY DISTANCE DOWN THIS PATH ARE
              22    41    63    68    33


     PATH  17 GOES FROM LANE 4 OF APPROACH  4 TO LANE 2 OF APPROACH  5
        LENGTH OF PATH = 107 FEET AND SPEED OF PATH = 25 FEET PER SECOND
        NUMBER OF CONFLICTS =  0 AND TURN CODE FOR PATH IS RIGHT


     TOTAL NUMBER OF PATHS CALCULATED =  17


TABLE  8  -  LISTING OF CONFLICTS

     CONFLICT  PATH1 PATH2  APPR1 APPR2  DIST1 DIST2  ANGLE  INDEX1 INDEX2

          1        1     5     3     2    104    90     23      6      5
          2        1     6     3     2     68    64     25      5      5
          3        1     7     3     2     33    55     90      2      3
          4        1     8     3     2     21    55     90      1      3
          5        1    10     3     1    127    39    239     10      5
          6        1    11     3     1     47   118    132      4     10
          7        1    11     3     1    126    39    236      9      5
          8        1    13     3     4    109    25    263      7      5
          9        1    14     3     4     37   113    115      3     11
         10        1    14     3     4    111    26    268      8      5
         11        1    15     3     4    149    56      0     11      7
         12        2     5     3     2    159   146      1     11     11
         13        2     6     3     2     99    98    349      6      7
         14        2     6     3     2     81    82     13      5      6
         15        2     7     3     2     33    67     95      2      4
         16        2     8     3     2     21    67     93      1      4
         17        2    11     3     1     39   132    123      4     11
         18        2    13     3     4    110    19    250      7      2
         19        2    14     3     4     34   126    104      3     12
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   GEOMETRY PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE    PAGE  9

US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK


      20        2    14        3      4     111    19     252      8      2
      21        2    15        3      4     126    20     276      9      1
      22        2    16        3      4     138    20     274     10      1
      23        3     5        3      2     130   111      47      7      8
      24        3     7        3      2      33    68      90      2      5
      25        3     8        3      2      21    68      90      1      5
      26        3    10        3      1     147    25     247     10      2
      27        3    11        3      1      38   134     115      4     12
      28        3    11        3      1     146    26     246      9      2
      29        3    13        3      4     115    12     282      5      1
      30        3    14        3      4      33   127      97      3     13
      31        3    14        3      4     116    13     284      6      1
      32        3    15        3      4     132    23     320      8      3
      33        3    16        3      4     168    56       0     11      5
      34        5    10        2      1      40   101     135      3      8
      35        5    11        2      1      49    95     121      4      8
      36        5    13        2      4      38    80     132      1      8
      37        5    13        2      4      96    22     236      6      3
      38        5    14        2      4      38    84     107      2      8
      39        5    14        2      4      97    22     240      7      3
      40        5    15        2      4     113    21     270      9      2
      41        5    16        2      4     125    21     270     10      2
      42        6    10        2      1     128    37     242     11      4
      43        6    10        2      1      37   112     118      2     10
      44        6    11        2      1     127    38     240     10      4
      45        6    11        2      1      50   105     101      4      9
      46        6    13        2      4     108    23     270      8      4
      47        6    13        2      4      36    90     115      1      9
      48        6    14        2      4     109    23     274      9      4
      49        6    14        2      4      46    92      86      3     10
      50        6    15        2      4     140    47     347     12      6
      51        7    10        2      1      36   127      91      2     11
      52        7    11        2      1      90   157       0      7     13
      53        7    13        2      4      35   105      90      1     10
      54        7    14        2      4      73   131       0      6     14
      55        7    14        2      4      90   147       0      8     15
      56        8    10        2      1      35   139      91      1     12
      57        8    13        2      4      35   117      90      2     11
      58       10    13        1      4      71    48      16      7      7
      59       10    13        1      4     160   138       0     13     12
      60       10    14        1      4      64    44      29      6      7
      61       10    14        1      4     105    87     332      9      9
      62       10    15        1      4      33    36      69      3      5
      63       10    16        1      4      21    35      89      1      3
      64       11    13        1      4      67    44      23      7      6
      65       11    14        1      4      62    41      34      6      6
      66       11    14        1      4     157   147       0     14     16
      67       11    15        1      4      33    35      90      3      4
      68       11    16        1      4      21    35      90      1      4

    TOTAL NUMBER OF CONFLICTS =   68
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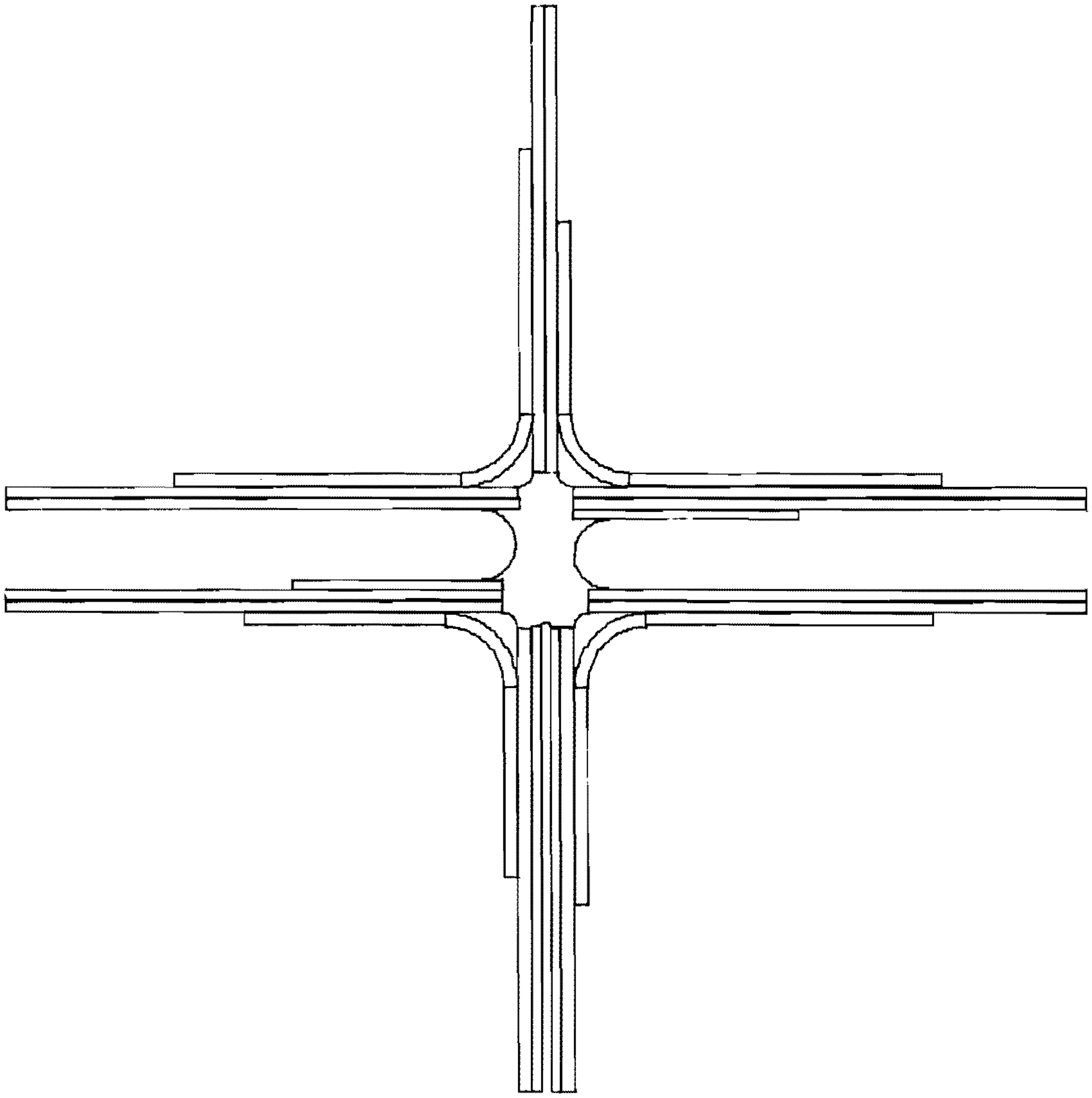
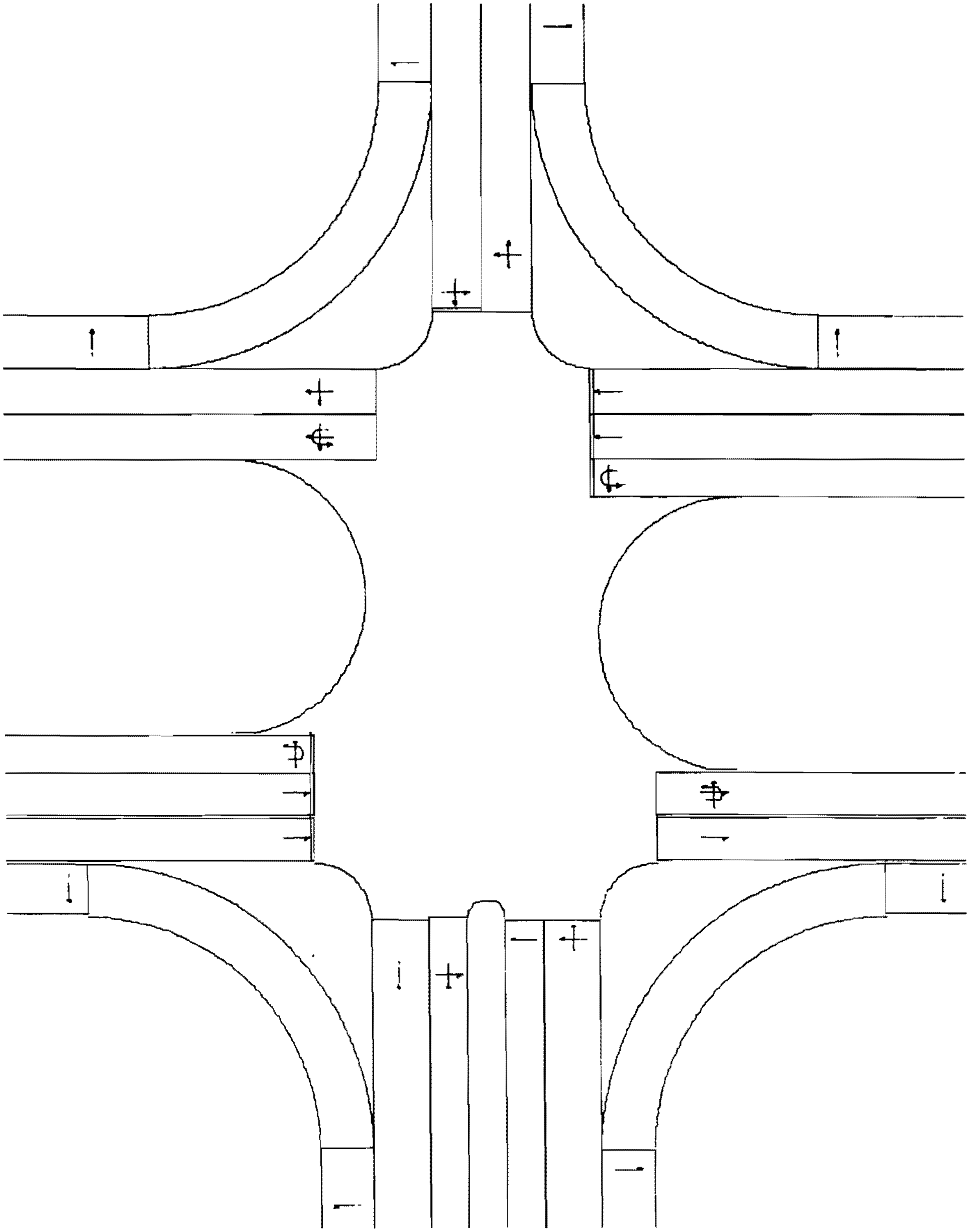
US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK



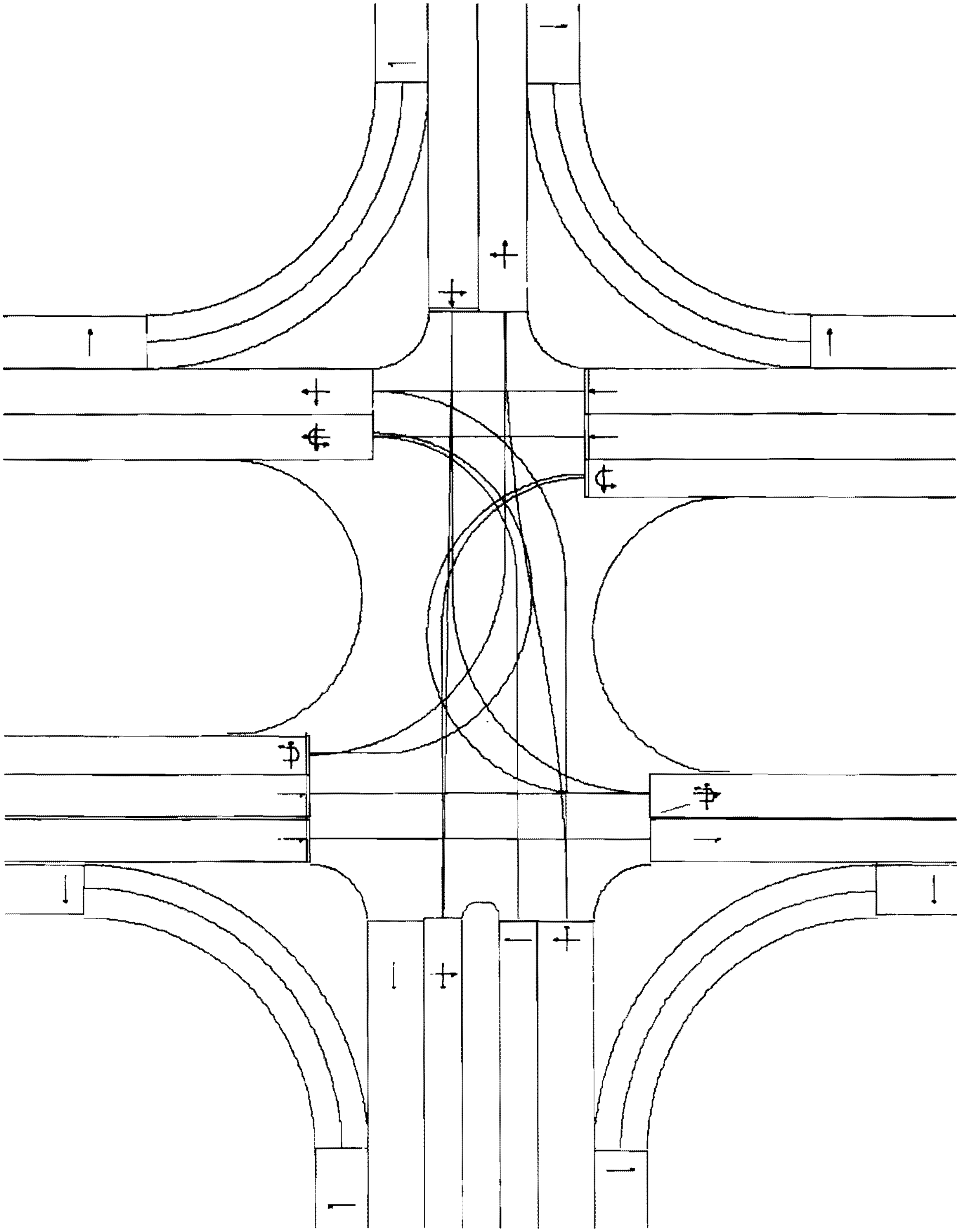
SCALE FACTOR IS 200.0 FEET PER INCH

US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK



SCALE FACTOR IS 40.0 FEET PER INCH

US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK



SCALE FACTOR IS 40.0 FEET PER INCH

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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE                                          PAGE  1
     US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK

TABLE  1  -  LISTING OF INBOUND APPROACH NUMBERS


              3
              2
              1
              4


    TOTAL NUMBER OF INBOUND APPROACHES =  4


TABLE  2  -  LISTING OF OUTBOUND APPROACH NUMBERS


              5
              6
              7
              8


    TOTAL NUMBER OF OUTBOUND APPROACHES =  4


    TOTAL NUMBER OF INBOUND AND OUTBOUND APPROACHES =  8


TABLE  3  -  DRIVER-VEHICLE PROCESSOR OPTIONS

    TIME FOR GENERATING VEHICLES (MIN) ----   12
    MINIMUM HEADWAY FOR VEHICLES (SEC) ----    1.0
    NUMBER OF VEHICLE CLASSES ------------   10
    NUMBER OF DRIVER CLASSES -------------    3
    PERCENT OF LEFT TURNS IN MEDIAN LANE --   90.
    PERCENT OF RIGHT TURNS IN CURB LANE ---   90.


TABLE  4  -  LISTING OF APPROACHES

    APPROACH NUMBER ----------------------    1
    APPROACH AZIMUTH ---------------------  180
    NUMBER OF LANES ----------------------    2
    NUMBER OF DEGREES FOR STRAIGHT --------   20
    HEADWAY DISTRIBUTION NAME ------------- NEGEXP
    EQUIVALENTLY HOURLY VOLUME (VPH) ------  150
    APPROACH MEAN SPEED (MPH) ------------   40.0
    APPROACH 85 PERCENTILE SPEED (MPH) ----   45.0
        OUTBOUND APPROACH NUMBER ---------    5     6     7     8
    PERCENT GOING TO OUTBOUND APPROACHES --    0  26.   49.   25.
    USER SUPPLIED PERCENT OF VEHICLES -----   YES
        VEHICLE CLASS NUMBER -------------    1     2     3     4     5     6     7     8     9    10
    USER SUPPLIED PERCENT OF VEHICLES -----  15.3  49.2  6.5  4.0  23.4   .8     0    .8     0     0
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  100. (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -    -0 (CURB LANE)
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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE                     PAGE  2

    US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK


   APPROACH NUMBER ----------------------     2
   APPROACH AZIMUTH ---------------------    90
   NUMBER OF LANES ----------------------     4
   NUMBER OF DEGREES FOR STRAIGHT --------   20
   HEADWAY DISTRIBUTION NAME ------------- LOGNRML   PARAMETER =     1.00
   EQUIVALENTLY HOURLY VOLUME (VPH) ------  383
   APPROACH MEAN SPEED (MPH) -------------   50.0
   APPROACH 85 PERCENTILE SPEED (MPH) ----   55.0
       OUTBOUND APPROACH NUMBER ----------   5    6    7    8
   PERCENT GOING TO OUTBOUND APPROACHES --   7.    0   8.  85.
   USER SUPPLIED PERCENT OF VEHICLES -----   YES
       VEHICLE CLASS NUMBER --------------   1    2    3    4    5    6    7    8    9   10
   USER SUPPLIED PERCENT OF VEHICLES -----   9.7 36.4 10.6  4.4 31.3  3.2  3.0   .7   .2   .5
   PERCENT OF TRAFFIC ENTERING ON LANE 1 -   -0 (MEDIAN LANE)
   PERCENT OF TRAFFIC ENTERING ON LANE 2 -   45.
   PERCENT OF TRAFFIC ENTERING ON LANE 3 -   55.
   PERCENT OF TRAFFIC ENTERING ON LANE 4 -   -0 (CURB LANE)


   APPROACH NUMBER ----------------------     3
   APPROACH AZIMUTH ---------------------     0
   NUMBER OF LANES ----------------------     3
   NUMBER OF DEGREES FOR STRAIGHT --------   20
   HEADWAY DISTRIBUTION NAME ------------- NEGEXP
   EQUIVALENTLY HOURLY VOLUME (VPH) ------  170
   APPROACH MEAN SPEED (MPH) -------------   40.0
   APPROACH 85 PERCENTILE SPEED (MPH) ----   45.0
       OUTBOUND APPROACH NUMBER ----------   5    6    7    8
   PERCENT GOING TO OUTBOUND APPROACHES --   26.  63.    0  11.
   USER SUPPLIED PERCENT OF VEHICLES -----   YES
       VEHICLE CLASS NUMBER --------------   1    2    3    4    5    6    7    8    9   10
   USER SUPPLIED PERCENT OF VEHICLES -----   9.1 59.4  9.8  7.0 13.3   .7    0   .7    0    0
   PERCENT OF TRAFFIC ENTERING ON LANE 1 -   51. (MEDIAN LANE)
   PERCENT OF TRAFFIC ENTERING ON LANE 2 -   49.
   PERCENT OF TRAFFIC ENTERING ON LANE 3 -   -0 (CURB LANE)


   APPROACH NUMBER ----------------------     4
   APPROACH AZIMUTH ---------------------   270
   NUMBER OF LANES ----------------------     4
   NUMBER OF DEGREES FOR STRAIGHT --------   20
   HEADWAY DISTRIBUTION NAME ------------- LOGNRML   PARAMETER =     1.00
   EQUIVALENTLY HOURLY VOLUME (VPH) ------  541
   APPROACH MEAN SPEED (MPH) -------------   50.0
   APPROACH 85 PERCENTILE SPEED (MPH) ----   55.0
       OUTBOUND APPROACH NUMBER ----------   5    6    7    8
   PERCENT GOING TO OUTBOUND APPROACHES --   20.  73.   7.    0
   USER SUPPLIED PERCENT OF VEHICLES -----   YES
       VEHICLE CLASS NUMBER --------------   1    2    3    4    5    6    7    8    9   10
   USER SUPPLIED PERCENT OF VEHICLES -----   8.8 37.9  9.3  3.0 34.2  2.7  2.7   .3   .3   .8
   PERCENT OF TRAFFIC ENTERING ON LANE 1 -   -0 (MEDIAN LANE)
   PERCENT OF TRAFFIC ENTERING ON LANE 2 -   51.
   PERCENT OF TRAFFIC ENTERING ON LANE 3 -   49.
   PERCENT OF TRAFFIC ENTERING ON LANE 4 -   -0 (CURB LANE)


   APPROACH NUMBER ----------------------     5
   APPROACH AZIMUTH ---------------------     0
   NUMBER OF LANES ----------------------     2


   APPROACH NUMBER ----------------------     6
   APPROACH AZIMUTH ---------------------   270
   NUMBER OF LANES ----------------------     3


   APPROACH NUMBER ----------------------     7
   APPROACH AZIMUTH ---------------------   180
   NUMBER OF LANES ----------------------     3
```

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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE                                      PAGE  3
    US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK

   APPROACH NUMBER ----------------------      8
   APPROACH AZIMUTH ---------------------     90
   NUMBER OF LANES ----------------------      3

   TOTAL NUMBER OF APPROACHES =  8


TABLE  5  -  DRIVER AND VEHICLE CLASS CHARACTERISTICS

   USER SUPPLIED DRIVER CLASS SPLIT ------    NO
   USER SUPPLIED VEHICLE CHARACTERISTICS -    NO
   USER SUPPLIED DRIVER CHARACTERISTICS --    NO
       VEHICLE CLASS NUMBER --------------     1     2     3     4     5     6     7     8     9    10
   VEHICLE LOGOUT SUMMARY REQUESTED ------    NO    NO    NO    NO    NO    NO    NO    NO    NO    NO
       DRIVER CLASS NUMBER ---------------     1     2     3
   DRIVER LOGOUT SUMMARY REQUESTED -------    NO    NO    NO

   DRIVER CLASS SPLIT          (PROGRAM SUPPLIED VALUES)

       DRIVER CLASS NUMBER ---------------     1     2     3

       VEHICLE CLASS NUMBER  1 -----------  30,0  40,0  30,0
       VEHICLE CLASS NUMBER  2 -----------  35,0  35,0  30,0
       VEHICLE CLASS NUMBER  3 -----------  20,0  40,0  40,0
       VEHICLE CLASS NUMBER  4 -----------  25,0  50,0  25,0
       VEHICLE CLASS NUMBER  5 -----------  40,0  30,0  30,0
       VEHICLE CLASS NUMBER  6 -----------  50,0  40,0  10,0
       VEHICLE CLASS NUMBER  7 -----------  50,0  40,0  10,0
       VEHICLE CLASS NUMBER  8 -----------  20,0  30,0  50,0
       VEHICLE CLASS NUMBER  9 -----------  25,0  50,0  25,0
       VEHICLE CLASS NUMBER 10 -----------  50,0  40,0  10,0

   VEHICLE CHARACTERISTICS     (PROGRAM SUPPLIED VALUES)

       VEHICLE CLASS NUMBER --------------     1     2     3     4     5     6     7     8     9    10

       LENGTH OF VEHICLES (FT) -----------    15    17    19    25    30    50    55    25    35    14
       VEHICLE OPERATIONAL FACTOR --------   100   110   110   100    85    80    75    90    85   115
       MAXIMUM DECELERATION (FT/SEC/SEC) -     8    11    11     8    11    11    11     8    11    12
       MAXIMUM ACCELERATION (FT/SEC/SEC) -     8     9    11     8     8     7     6     6     5    14
       MAXIMUM VELOCITY (FT/SEC) ---------   150   192   200   150   160   160   150   150   125   205
       MINIMUM TURNING RADIUS (FT) -------    20    22    24    28    42    40    45    28    28    20

   DRIVER CHARACTERISTICS      (PROGRAM SUPPLIED VALUES)

       DRIVER CLASS NUMBER ---------------     1     2     3

       DRIVER OPERATIONAL FACTOR ---------   110   100    85
       DRIVER REACTION TIME (SEC) --------    ,5   1,0   1,5


TABLE  6  -  GENERATION OF APPROACH HEADWAYS

   APPROACH  DISTRIBUTION    NUMBER     VOLUME     INPUT    PERCENT
    NUMBER       NAME      GENERATED  GENERATED   VOLUME  DIFFERENCE

      3        NEGEXP          40        200        170      17,65
      2        LOGNRML         76        380        383       -,78
      1        NEGEXP          28        140        150      -6,67
      4        LOGNRML        106        530        541      -2,03

    TOTAL                     250       1250       1244        ,48
```

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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE                                         PAGE  4

     US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK

TABLE  7  -  EXPLANATION OF SPECIAL CASES

    QTIME  VEHICLE DRIVER VELOCITY OUTBOUND  INBOUND  LANE  LOGOUT NOTE
            CLASS  CLASS    (FPS)  APPROACH  APPROACH  NO.  PRINT

   47.59                                         1                      1
  116.68                                         1                      1
  432.17                                         1                      1

    NOTE  EXPLANATION OF THE NOTE(S)

      1   HEADWAY LESS THAN 1.0 SECONDS FROM PREVIOUS VEHICLE FOR THIS APPROACH AND ITS LANE(S)
          GENERATED VEHICLE IGNORED


TABLE  8  -  FINAL APPROACH VOLUMES

                    SPECIAL  VEHICLES        GENERATED  VEHICLES       TOTAL  VEHICLES
                 ----------------------   ----------------------   ----------------------
    APPROACH     NUMBER FOR  VOLUME FOR   NUMBER FOR  VOLUME FOR   NUMBER FOR  VOLUME FOR     INPUT
     NUMBER      SIMULATION  SIMULATION   SIMULATION  SIMULATION   SIMULATION  SIMULATION     VOLUME

       3             0           0            40         200           40          200         170
       2             0           0            76         380           76          380         383
       1             0           0            25         125           25          125         150
       4             0           0           106         530          106          530         541

     TOTAL           0           0           247        1235          247         1235        1244

    THE INTERSECTION HAS A JAM DENSITY OF 193 VEHICLES PER MILE


TABLE  9  -  STATISTICS OF GENERATION

    APPROACH STATISTICS
    -------------------

    APPROACH NUMBER -----------------------     3
        OUTBOUND APPROACH NUMBER ----------     5    6    7    8
    PERCENT GOING TO OUTBOUND APPROACHES --  25.0 60.0    0 15.0
        VEHICLE CLASS NUMBER --------------     1    2    3    4    5    6    7    8    9   10
    GENERATION PERCENT OF VEHICLES --------  12.5 52.5  5.0  7.5 20.0    0    0  2.5    0    0
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -  42.5 (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  57.5
    PERCENT OF TRAFFIC ENTERING ON LANE 3 -     0 (CURB LANE)

    APPROACH NUMBER -----------------------     2
        OUTBOUND APPROACH NUMBER ----------     5    6    7    8
    PERCENT GOING TO OUTBOUND APPROACHES --  10.5    0  6.6 82.9
        VEHICLE CLASS NUMBER --------------     1    2    3    4    5    6    7    8    9   10
    GENERATION PERCENT OF VEHICLES --------  13.2 34.2 11.8  5.3 26.3  3.9  3.9    0  1.3    0
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -     0 (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -  36.8
    PERCENT OF TRAFFIC ENTERING ON LANE 3 -  63.2
    PERCENT OF TRAFFIC ENTERING ON LANE 4 -     0 (CURB LANE)

    APPROACH NUMBER -----------------------     1
        OUTBOUND APPROACH NUMBER ----------     5    6    7    8
    PERCENT GOING TO OUTBOUND APPROACHES --     0 16.0 60.0 24.0
        VEHICLE CLASS NUMBER --------------     1    2    3    4    5    6    7    8    9   10
    GENERATION PERCENT OF VEHICLES --------  12.0 56.0  4.0  4.0 20.0  4.0    0    0    0    0
    PERCENT OF TRAFFIC ENTERING ON LANE 1 - 100.0 (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -     0 (CURB LANE)
```

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DRIVER-VEHICLE PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE                                   PAGE  5

     US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK

    APPROACH NUMBER -----------------------      4
        OUTBOUND APPROACH NUMBER ----------      5    6    7    8
    PERCENT GOING TO OUTBOUND APPROACHES --   19.8 75.5  4.7    0
        VEHICLE CLASS NUMBER --------------      1    2    3    4    5    6    7    8    9   10
    GENERATION PERCENT OF VEHICLES --------    5.7 37.7  6.6  1.9 42.5  4.7   .9    0    0    0
    PERCENT OF TRAFFIC ENTERING ON LANE 1 -      0 (MEDIAN LANE)
    PERCENT OF TRAFFIC ENTERING ON LANE 2 -   53.8
    PERCENT OF TRAFFIC ENTERING ON LANE 3 -   46.2
    PERCENT OF TRAFFIC ENTERING ON LANE 4 -      0 (CURB LANE)


    DRIVER CLASS SPLIT STATISTICS
    -----------------------------

    DRIVER CLASS NUMBER -------------------        1      2      3

    VEHICLE CLASS NUMBER  1 (  24 VEH) -----    29.2   29.2   41.7
    VEHICLE CLASS NUMBER  2 ( 101 VEH) -----    37.6   30.7   31.7
    VEHICLE CLASS NUMBER  3 (  19 VEH) -----    26.3   52.6   21.1
    VEHICLE CLASS NUMBER  4 (  10 VEH) -----    30.0   60.0   10.0
    VEHICLE CLASS NUMBER  5 (  78 VEH) -----    48.7   30.8   20.5
    VEHICLE CLASS NUMBER  6 (   9 VEH) -----    44.4   44.4   11.1
    VEHICLE CLASS NUMBER  7 (   4 VEH) -----    75.0   25.0      0
    VEHICLE CLASS NUMBER  8 (   1 VEH) -----   100.0      0      0
    VEHICLE CLASS NUMBER  9 (   1 VEH) -----   100.0      0      0
    VEHICLE CLASS NUMBER 10 (   0 VEH) -----       0      0      0
```

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    *******  PRINT OF FILE CAMSTM   -  29 NOV 77  -  21.28.25.  -  PAGE   1  *******

             1         2         3         4         5         6         7         8
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
    ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
 1 <       US 183 AND CAMERON ROAD - SIX PHASE FULLY ACTUATED WITH DUAL LEFTS      >      1
 2 <2.00 10.00 1.00 10 30 2.800 0.800 4000 7 NO  YES NO  NO  1.50 2.50              >      2
 3 <5355535535555311111111111                                                       >      3
 4 <  36                                                                            >      4
 5 < 1   AP UNSAR AR AR UNSAR AR UNSAR AR AR UNS             PHASE 1                >      5
 6 < 1   AA                                                    CLEAR TO 2           >      6
 7 < 1                                                         CLEAR TO 3           >      7
 8 < 1                                                         CLEAR TO 4           >      8
 9 < 1                                                         CLEAR TO 5           >      9
10 < 1                                                         CLEAR TO 6           >     10
11 < 2   AR UNSAR AR AR UNSAP AP UNSAR AR AR UNS             PHASE 2                >     11
12 < 2                     AA                                  CLEAR TO 3           >     12
13 < 2                                                         CLEAR TO 4           >     13
14 < 2                                                         CLEAR TO 5           >     14
15 < 2                                                         CLEAR TO 6           >     15
16 < 2                                                         CLEAR TO 1           >     16
17 < 3   AR UNSAP AR AR UNSAR AR UNSAP AR AR UNS             PHASE 3                >     17
18 < 3         AA                                              CLEAR TO 4           >     18
19 < 3         AP                   AA                         CLEAR TO 5           >     19
20 < 3         AA                                              CLEAR TO 6           >     20
21 < 3                                                         CLEAR TO 1           >     21
22 < 3                                                         CLEAR TO 2           >     22
23 < 4   AR UNSAR AR AR UNSAR AR UNSAP AG AG UNS             PHASE 4                >     23
24 < 4                              AA                         CLEAR TO 6           >     24
25 < 4                                 AA AA                   CLEAR TO 1           >     25
26 < 4                                                         CLEAR TO 2           >     26
27 < 4                              AP                         CLEAR TO 3           >     27
28 < 4                              AA                         CLEAR TO 5           >     28
29 < 5   AR UNSAP AG AG UNSAR AR UNSAR AR AR UNS             PHASE 5                >     29
30 < 5         AA                                              CLEAR TO 6           >     30
31 < 5            AA AA                                        CLEAR TO 1           >     31
32 < 5                                                         CLEAR TO 2           >     32
33 < 5         AP                                              CLEAR TO 3           >     33
34 < 5         AA                                              CLEAR TO 4           >     34
35 < 6   AR UNSAR AG AG UNSAR AR UNSAR AG AG UNS             PHASE 6                >     35
36 < 6            AA AA                AA AA                   CLEAR TO 1           >     36
37 < 6                                                         CLEAR TO 2           >     37
38 < 6                                                         CLEAR TO 3           >     38
39 < 6                                 AG AG                   CLEAR TO 4           >     39
40 < 6            AG AG                AA AA                   CLEAR TO 5           >     40
41 <   6                                                                            >     41
42 < 1  2.0  3.0  4.0  0.0  18.0 ON  OFF NO  NO  OR    1   5 2 3 4 5 6              >     42
43 <   1                                                                            >     43
44 < 2  2.0  3.0  4.0  0.0  15.0 ON  OFF NO  NO  OR    2   5 3 4 5 6 1              >     44
    vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv
             1         2         3         4         5         6         7         8
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
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    *******  PRINT OF FILE CAMSIM   -  29 NOV 77  -  21.28.25.  -  PAGE   2  *******

             1         2         3         4         5         6         7         8
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
    ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
45 <   5   6                                                                        >    45
46 < 3  2.0  1.0  3.0  0.0  10.0 ON  OFF NO  YES AND   2   5 4 5 6 1 2              >    46
47 <   2   7                                                                        >    47
48 < 4  2.0  1.0  3.0  0.0  10.0 ON  OFF NO  NO  AND   2   5 6 1 2 3 5              >    48
49 <   7  -2                                                                        >    49
50 < 5  2.0  1.0  3.0  0.0  10.0 ON  OFF NO  NO  AND   2   5 6 1 2 3 4              >    50
51 <   2  -7                                                                        >    51
52 < 6  8.0  2.0  5.0  0.0  30.0 OFF OFF NO  NO  OR   10   5 1 2 3 4 5              >    52
53 <   3   4   8   9  10  11  12  13  14  15                                        >    53
54 <  15                                                                            >    54
55 < 1 PRESENCE  430 480   1   1   1                                                >    55
56 < 2 PRESENCE  470 520   2   1   1                                                >    56
57 < 3 PRESENCE  470 520   2   1   2                                                >    57
58 < 4 PRESENCE  470 520   2   1   3                                                >    58
59 < 5 PRESENCE  430 480   3   1   1                                                >    59
60 < 6 PRESENCE  430 480   3   1   2                                                >    60
61 < 7 PRESENCE  490 537   4   1   1                                                >    61
62 < 8 PRESENCE  490 537   4   1   2                                                >    62
63 < 9 PRESENCE  490 537   4   1   3                                                >    63
64 <10 PRESENCE  347 353   2   2   2   3         RIPPLE DETECTORS,APPROACH 2        >    64
65 <11 PRESENCE  197 203   2   2   2   3         RIPPLE DETECTORS                   >    65
66 <12 PRESENCE   47  53   2   2   2   3         RIPPLE DETECTORS                   >    66
67 <13 PRESENCE  367 373   4   2   2   3         RIPPLE DETECTORS,APPROACH 4        >    67
68 <14 PRESENCE  217 223   4   2   2   3         RIPPLE DETECTORS                   >    68
69 <15 PRESENCE   67  73   4   2   2   3         RIPPLE DETECTORS                   >    69
    vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv
             1         2         3         4         5         6         7         8
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
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ECHO-PRINT OF TITLE FROM GEOMETRY PROCESSOR
     US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK

ECHO-PRINT OF TITLE FROM DRIVER-VEHICLE PROCESSOR
     US 183 AND CAMERON ROAD - LEFT AND RIGHT TURN BAYS - SUBURBAN OFF-PEAK

ECHO-PRINT OF TITLE FROM SIMULATION PROCESSOR INPUT
       US 183 AND CAMERON ROAD - SIX PHASE FULLY ACTUATED WITH DUAL LEFTS


START-UP TIME (MINUTES) -------------------------- =      2.00
SIMULATION TIME (MINUTES) ------------------------ =     10.00
STEP INCREMENT FOR SIMULATION TIME (SECONDS) ------ =      1.00

SPEED FOR DELAY BELOW XX MPH (MPH) --------------- =     10.00

MAXIMUM CLEAR DISTANCE FOR BEING IN A QUEUE (FT) -- =     30.00

CAR FOLLOWING EQUATION LAMBDA -------------------- =      2.80000
CAR FOLLOWING EQUATION MU ------------------------ =       .80000
CAR FOLLOWING EQUATION ALPHA --------------------- =   4000.00000

SUMMARY STATISTICS PRINTED BY TURNING MOVEMENTS --- =    NO
SUMMARY STATISTICS PRINTED BY INBOUND APPROACH ---- =    YES

PUNCHED OUTPUT OF STATISTICS --------------------- =    NO

WRITE TAPE FOR POLLUTION DISPERSION MODEL --------- =    NO

LEAD TIME GAP FOR CONFLICT CHECKING (SECONDS) ----- =      1.50
LAG TIME GAP FOR CONFLICT CHECKING (SECONDS) ------ =      2.50

INTERSECTION TRAFFIC CONTROL --------------------- =      7  (FULL-ACTUATED)
```

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          SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

        US 183 AND CAMERON ROAD - SIX PHASE FULLY ACTUATED WITH DUAL LEFTS


LANE CONTROL FOR THE 24 LANES = 5 3 5 5 5 3 5 5 3 5 5 5 3 1 1 1 1 1 1 1 1 1 1 1

     WHERE  1 = OUTBOUND (OR BLOCKED INBOUND) LANE
            2 = UNCONTROLLED
            3 = YIELD SIGN
            4 = STOP SIGN
            5 = SIGNAL
            6 = SIGNAL WITH LEFT TURN ON RED
            7 = SIGNAL WITH RIGHT TURN ON RED


A TOTAL OF 36 CAM STACK ENTRIES

ENTRY  1 PHASE  1  AP   UNS  AR   AR   AR   UNS  AR   AR   UNS  AR   AR   AR   UNS
ENTRY  2 PHASE  1  AA
ENTRY  3 PHASE  1
ENTRY  4 PHASE  1
ENTRY  5 PHASE  1
ENTRY  6 PHASE  1
ENTRY  7 PHASE  2  AR   UNS  AR   AR   AR   UNS  AP   AP   UNS  AR   AR   AR   UNS
ENTRY  8 PHASE  2                                AA
ENTRY  9 PHASE  2
ENTRY 10 PHASE  2
ENTRY 11 PHASE  2
ENTRY 12 PHASE  2
ENTRY 13 PHASE  3  AR   UNS  AP   AR   AR   UNS  AR   AR   UNS  AP   AR   AR   UNS
ENTRY 14 PHASE  3            AA
ENTRY 15 PHASE  3            AP                                 AA
ENTRY 16 PHASE  3            AA
ENTRY 17 PHASE  3
ENTRY 18 PHASE  3
ENTRY 19 PHASE  4  AR   UNS  AR   AR   AR   UNS  AR   AR   UNS  AP   AG   AG   UNS
ENTRY 20 PHASE  4                                               AA
ENTRY 21 PHASE  4                                                    AA   AA
ENTRY 22 PHASE  4
ENTRY 23 PHASE  4                                               AP
ENTRY 24 PHASE  4                                               AA
ENTRY 25 PHASE  5  AR   UNS  AP   AG   AG   UNS  AR   AR   UNS  AR   AR   AR   UNS
ENTRY 26 PHASE  5            AA
ENTRY 27 PHASE  5                 AA   AA
ENTRY 28 PHASE  5
ENTRY 29 PHASE  5            AP
ENTRY 30 PHASE  5            AA
ENTRY 31 PHASE  6  AR   UNS  AR   AG   AG   UNS  AR   AR   UNS  AR   AG   AG   UNS
ENTRY 32 PHASE  6                 AA   AA                            AA   AA
ENTRY 33 PHASE  6
ENTRY 34 PHASE  6
ENTRY 35 PHASE  6                                                    AG   AG
ENTRY 36 PHASE  6                 AG   AG                            AA   AA
```

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          SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

        US 183 AND CAMERON ROAD - SIX PHASE FULLY ACTUATED WITH DUAL LEFTS

A TOTAL OF 6 SIGNAL PHASES

SIGNAL PHASE NUMBER ------------------------------- =   1
INITIAL INTERVAL (SECONDS) ------------------------ =   2.0
VEHICLE INTERVAL (SECONDS) ------------------------ =   3.0
AMBER CLEARANCE INTERVAL (SECONDS) ---------------- =   4.0
ALL-RED CLEARANCE INTERVAL (SECONDS) -------------- =     0
MAXIMUM EXTENSION AFTER DEMAND ON RED (SECONDS) --- =  18.0
SKIP-PHASE SWITCH (ON/OFF) ------------------------ =   ON
AUTO-RECALL SWITCH (ON/OFF) ----------------------- =   OFF
PARENT/MINOR MOVEMENT PHASE OPTION (YES/NO) ------- =   NO
DUAL LEFT OPTION (YES/NO) ------------------------- =   NO
DETECTOR CONNECTION TYPE (AND/OR) ----------------- =   OR
NUMBER OF DETECTORS CONNECTED TO PHASE ------------ =   1
NUMBER OF PHASES CLEARED TO ----------------------- =   5
LIST OF PHASES CLEARED TO ------------------------- =   2    3    4    5    6
LIST OF DETECTORS CONNECTED TO PHASE -------------- =   1

SIGNAL PHASE NUMBER ------------------------------- =   2
INITIAL INTERVAL (SECONDS) ------------------------ =   2.0
VEHICLE INTERVAL (SECONDS) ------------------------ =   3.0
AMBER CLEARANCE INTERVAL (SECONDS) ---------------- =   4.0
ALL-RED CLEARANCE INTERVAL (SECONDS) -------------- =     0
MAXIMUM EXTENSION AFTER DEMAND ON RED (SECONDS) --- =  15.0
SKIP-PHASE SWITCH (ON/OFF) ------------------------ =   ON
AUTO-RECALL SWITCH (ON/OFF) ----------------------- =   OFF
PARENT/MINOR MOVEMENT PHASE OPTION (YES/NO) ------- =   NO
DUAL LEFT OPTION (YES/NO) ------------------------- =   NO
DETECTOR CONNECTION TYPE (AND/OR) ----------------- =   OR
NUMBER OF DETECTORS CONNECTED TO PHASE ------------ =   2
NUMBER OF PHASES CLEARED TO ----------------------- =   5
LIST OF PHASES CLEARED TO ------------------------- =   3    4    5    6    1
LIST OF DETECTORS CONNECTED TO PHASE -------------- =   5    6

SIGNAL PHASE NUMBER ------------------------------- =   3
INITIAL INTERVAL (SECONDS) ------------------------ =   2.0
VEHICLE INTERVAL (SECONDS) ------------------------ =   1.0
AMBER CLEARANCE INTERVAL (SECONDS) ---------------- =   3.0
ALL-RED CLEARANCE INTERVAL (SECONDS) -------------- =     0
MAXIMUM EXTENSION AFTER DEMAND ON RED (SECONDS) --- =  10.0
SKIP-PHASE SWITCH (ON/OFF) ------------------------ =   ON
AUTO-RECALL SWITCH (ON/OFF) ----------------------- =   OFF
PARENT/MINOR MOVEMENT PHASE OPTION (YES/NO) ------- =   NO
DUAL LEFT OPTION (YES/NO) ------------------------- =   YES
DETECTOR CONNECTION TYPE (AND/OR) ----------------- =   AND
NUMBER OF DETECTORS CONNECTED TO PHASE ------------ =   2
NUMBER OF PHASES CLEARED TO ----------------------- =   5
LIST OF PHASES CLEARED TO ------------------------- =   4    5    6    1    2
LIST OF DETECTORS CONNECTED TO PHASE -------------- =   2    7

SIGNAL PHASE NUMBER ------------------------------- =   4
INITIAL INTERVAL (SECONDS) ------------------------ =   2.0
VEHICLE INTERVAL (SECONDS) ------------------------ =   1.0
AMBER CLEARANCE INTERVAL (SECONDS) ---------------- =   3.0
ALL-RED CLEARANCE INTERVAL (SECONDS) -------------- =     0
MAXIMUM EXTENSION AFTER DEMAND ON RED (SECONDS) --- =  10.0
SKIP-PHASE SWITCH (ON/OFF) ------------------------ =   ON
AUTO-RECALL SWITCH (ON/OFF) ----------------------- =   OFF
PARENT/MINOR MOVEMENT PHASE OPTION (YES/NO) ------- =   NO
DUAL LEFT OPTION (YES/NO) ------------------------- =   NO
DETECTOR CONNECTION TYPE (AND/OR) ----------------- =   AND
NUMBER OF DETECTORS CONNECTED TO PHASE ------------ =   2
NUMBER OF PHASES CLEARED TO ----------------------- =   5
LIST OF PHASES CLEARED TO ------------------------- =   6    1    2    3    5
LIST OF DETECTORS CONNECTED TO PHASE -------------- =   7   -2

SIGNAL PHASE NUMBER ------------------------------- =   5
INITIAL INTERVAL (SECONDS) ------------------------ =   2.0
VEHICLE INTERVAL (SECONDS) ------------------------ =   1.0
AMBER CLEARANCE INTERVAL (SECONDS) ---------------- =   3.0
ALL-RED CLEARANCE INTERVAL (SECONDS) -------------- =     0
MAXIMUM EXTENSION AFTER DEMAND ON RED (SECONDS) --- =  10.0
SKIP-PHASE SWITCH (ON/OFF) ------------------------ =   ON
AUTO-RECALL SWITCH (ON/OFF) ----------------------- =   OFF
PARENT/MINOR MOVEMENT PHASE OPTION (YES/NO) ------- =   NO
DUAL LEFT OPTION (YES/NO) ------------------------- =   NO
DETECTOR CONNECTION TYPE (AND/OR) ----------------- =   AND
NUMBER OF DETECTORS CONNECTED TO PHASE ------------ =   2
NUMBER OF PHASES CLEARED TO ----------------------- =   5
LIST OF PHASES CLEARED TO ------------------------- =   6    1    2    3    4
LIST OF DETECTORS CONNECTED TO PHASE -------------- =   2   -7

SIGNAL PHASE NUMBER ------------------------------- =   6
INITIAL INTERVAL (SECONDS) ------------------------ =   8.0
VEHICLE INTERVAL (SECONDS) ------------------------ =   2.0
AMBER CLEARANCE INTERVAL (SECONDS) ---------------- =   5.0
ALL-RED CLEARANCE INTERVAL (SECONDS) -------------- =     0
MAXIMUM EXTENSION AFTER DEMAND ON RED (SECONDS) --- =  30.0
SKIP-PHASE SWITCH (ON/OFF) ------------------------ =   OFF
AUTO-RECALL SWITCH (ON/OFF) ----------------------- =   OFF
PARENT/MINOR MOVEMENT PHASE OPTION (YES/NO) ------- =   NO
DUAL LEFT OPTION (YES/NO) ------------------------- =   NO
DETECTOR CONNECTION TYPE (AND/OR) ----------------- =   OR
NUMBER OF DETECTORS CONNECTED TO PHASE ------------ =  10
NUMBER OF PHASES CLEARED TO ----------------------- =   5
LIST OF PHASES CLEARED TO ------------------------- =   1    2    3    4    5
LIST OF DETECTORS CONNECTED TO PHASE -------------- =   3    4    8    9   10
                                                       11   12   13   14   15
```

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          SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

       US 183 AND CAMERON ROAD - SIX PHASE FULLY ACTUATED WITH DUAL LEFTS

A TOTAL OF 15 DETECTORS

DETECTOR NUMBER ------------ =    1
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =  430
STOPPING POSITION (FEET) --- =  480
APPROACH NUMBER ------------ =    1
NUMBER OF LANES ------------ =    1
LIST OF LANE NUMBERS ------- =    1

DETECTOR NUMBER ------------ =    2
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =  470
STOPPING POSITION (FEET) --- =  520
APPROACH NUMBER ------------ =    2
NUMBER OF LANES ------------ =    1
LIST OF LANE NUMBERS ------- =    1

DETECTOR NUMBER ------------ =    3
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =  470
STOPPING POSITION (FEET) --- =  520
APPROACH NUMBER ------------ =    2
NUMBER OF LANES ------------ =    1
LIST OF LANE NUMBERS ------- =    2

DETECTOR NUMBER ------------ =    4
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =  470
STOPPING POSITION (FEET) --- =  520
APPROACH NUMBER ------------ =    2
NUMBER OF LANES ------------ =    1
LIST OF LANE NUMBERS ------- =    3

DETECTOR NUMBER ------------ =    5
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =  430
STOPPING POSITION (FEET) --- =  480
APPROACH NUMBER ------------ =    3
NUMBER OF LANES ------------ =    1
LIST OF LANE NUMBERS ------- =    1

DETECTOR NUMBER ------------ =    6
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =  430
STOPPING POSITION (FEET) --- =  480
APPROACH NUMBER ------------ =    3
NUMBER OF LANES ------------ =    1
LIST OF LANE NUMBERS ------- =    2

DETECTOR NUMBER ------------ =    7
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =  490
STOPPING POSITION (FEET) --- =  537
APPROACH NUMBER ------------ =    4
NUMBER OF LANES ------------ =    1
LIST OF LANE NUMBERS ------- =    1
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DETECTOR NUMBER ------------ =    8
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =  490
STOPPING POSITION (FEET) --- =  537
APPROACH NUMBER ------------ =    4
NUMBER OF LANES ------------ =    1
LIST OF LANE NUMBERS ------- =    2

DETECTOR NUMBER ------------ =    9
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =  490
STOPPING POSITION (FEET) --- =  537
APPROACH NUMBER ------------ =    4
NUMBER OF LANES ------------ =    1
LIST OF LANE NUMBERS ------- =    3

DETECTOR NUMBER ------------ =   10
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =  347
STOPPING POSITION (FEET) --- =  353
APPROACH NUMBER ------------ =    2
NUMBER OF LANES ------------ =    2
LIST OF LANE NUMBERS ------- =    2     3

DETECTOR NUMBER ------------ =   11
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =  197
STOPPING POSITION (FEET) --- =  203
APPROACH NUMBER ------------ =    2
NUMBER OF LANES ------------ =    2
LIST OF LANE NUMBERS ------- =    2     3

DETECTOR NUMBER ------------ =   12
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =   47
STOPPING POSITION (FEET) --- =   53
APPROACH NUMBER ------------ =    2
NUMBER OF LANES ------------ =    2
LIST OF LANE NUMBERS ------- =    2     3

DETECTOR NUMBER ------------ =   13
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =  367
STOPPING POSITION (FEET) --- =  373
APPROACH NUMBER ------------ =    4
NUMBER OF LANES ------------ =    2
LIST OF LANE NUMBERS ------- =    2     3

DETECTOR NUMBER ------------ =   14
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =  217
STOPPING POSITION (FEET) --- =  223
APPROACH NUMBER ------------ =    4
NUMBER OF LANES ------------ =    2
LIST OF LANE NUMBERS ------- =    2     3

DETECTOR NUMBER ------------ =   15
DETECTOR TYPE -------------- = PRESENCE
STARTING POSITION (FEET) --- =   67
STOPPING POSITION (FEET) --- =   73
APPROACH NUMBER ------------ =    4
NUMBER OF LANES ------------ =    2
LIST OF LANE NUMBERS ------- =    2     3
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          SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

       US 183 AND CAMERON ROAD - SIX PHASE FULLY ACTUATED WITH DUAL LEFTS

SUMMARY STATISTICS FOR INBOUND APPROACH  3


TOTAL DELAY (VEHICLE-SECONDS) ---------------------- =    842.7
NUMBER OF VEHICLES INCURRING TOTAL DELAY ----------- =     33
PERCENT OF VEHICLES INCURRING TOTAL DELAY ---------- =    100.0
AVERAGE TOTAL DELAY (SECONDS) ---------------------- =     25.5
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ------------ =     54.4 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) ---------------------- =    638.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ----------- =     22
PERCENT OF VEHICLES INCURRING QUEUE DELAY ---------- =     66.7
AVERAGE QUEUE DELAY (SECONDS) ---------------------- =     29.0
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ------------ =     61.7 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) -------------------- =    602.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY --------- =     22
PERCENT OF VEHICLES INCURRING STOPPED DELAY -------- =     66.7
AVERAGE STOPPED DELAY (SECONDS) -------------------- =     27.4
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME ---------- =     58.2 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------- =    662.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH -- =     22
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH   =     66.7
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------- =     30.1
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =     64.1 PERCENT

VEHICLE-MILES OF TRAVEL ---------------------------- =      7.499
AVERAGE VEHICLE-MILES OF TRAVEL -------------------- =       .227
TRAVEL TIME (VEHICLE-SECONDS) -----------------------=   1550.3
AVERAGE TRAVEL TIME (SECONDS) ---------------------- =     47.0
NUMBER OF VEHICLES PROCESSED ----------------------- =     33
VOLUME PROCESSED (VEHICLES/HOUR) ------------------- =    198.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS   =     21.2
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =     17.4
AVERAGE DESIRED SPEED (MPH) ------------------------ =     38.6
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) ---------- =      4.9
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) ---------- =      4.9

OVERALL AVERAGE TOTAL DELAY (SECONDS) -------------- =     25.5
OVERALL AVERAGE QUEUE DELAY (SECONDS) -------------- =     19.3
OVERALL AVERAGE STOPPED DELAY (SECONDS) ------------ =     18.2
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ----- =     20.1

PERCENT OF VEHICLES MAKING A U-TURN OR A LEFT TURN   =     57.6
PERCENT OF VEHICLES GOING STRAIGHT ----------------- =     24.2
PERCENT OF VEHICLES MAKING A RIGHT TURN ------------ =     18.2

AVERAGE QUEUE LENGTH FOR LANE 1 -------------------- =        .4  MAX =  2
AVERAGE QUEUE LENGTH FOR LANE 2 -------------------- =        .6  MAX =  3

AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ----- =     99.8
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          SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

       US 183 AND CAMERON ROAD - SIX PHASE FULLY ACTUATED WITH DUAL LEFTS

SUMMARY STATISTICS FOR INBOUND APPROACH  2


TOTAL DELAY (VEHICLE-SECONDS) ---------------------- =    959.4
NUMBER OF VEHICLES INCURRING TOTAL DELAY ----------- =     41
PERCENT OF VEHICLES INCURRING TOTAL DELAY ---------- =     63.1
AVERAGE TOTAL DELAY (SECONDS) ---------------------- =     23.4
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ------------ =     73.3 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) ---------------------- =    730.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ----------- =     31
PERCENT OF VEHICLES INCURRING QUEUE DELAY ---------- =     47.7
AVERAGE QUEUE DELAY (SECONDS) ---------------------- =     23.5
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ------------ =     73.8 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) -------------------- =    681.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY --------- =     31
PERCENT OF VEHICLES INCURRING STOPPED DELAY -------- =     47.7
AVERAGE STOPPED DELAY (SECONDS) -------------------- =     22.0
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME ---------- =     68.8 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------- =    774.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH -- =     33
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH   =     50.8
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------- =     23.5
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =     73.5 PERCENT

VEHICLE-MILES OF TRAVEL ---------------------------- =     14.709
AVERAGE VEHICLE-MILES OF TRAVEL -------------------- =       .226
TRAVEL TIME (VEHICLE-SECONDS) -----------------------=   2075.1
AVERAGE TRAVEL TIME (SECONDS) ---------------------- =     31.9
NUMBER OF VEHICLES PROCESSED ----------------------- =     65
VOLUME PROCESSED (VEHICLES/HOUR) ------------------- =    390.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS   =     34.3
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =     25.5
AVERAGE DESIRED SPEED (MPH) ------------------------ =     47.4
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) ---------- =      3.2
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) ---------- =      4.1

OVERALL AVERAGE TOTAL DELAY (SECONDS) -------------- =     14.8
OVERALL AVERAGE QUEUE DELAY (SECONDS) -------------- =     11.2
OVERALL AVERAGE STOPPED DELAY (SECONDS) ------------ =     10.5
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ----- =     11.9

PERCENT OF VEHICLES MAKING A U-TURN OR A LEFT TURN   =     10.8
PERCENT OF VEHICLES GOING STRAIGHT ----------------- =     86.2
PERCENT OF VEHICLES MAKING A RIGHT TURN ------------ =      3.1

AVERAGE QUEUE LENGTH FOR LANE 1 -------------------- =        .6  MAX =  3
AVERAGE QUEUE LENGTH FOR LANE 2 -------------------- =        .2  MAX =  2
AVERAGE QUEUE LENGTH FOR LANE 3 -------------------- =        .4  MAX =  3

AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ----- =    100.0
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         SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

      US 183 AND CAMERON ROAD - SIX PHASE FULLY ACTUATED WITH DUAL LEFTS

SUMMARY STATISTICS FOR INBOUND APPROACH  1


TOTAL DELAY (VEHICLE-SECONDS) -------------------- =     519.8
NUMBER OF VEHICLES INCURRING TOTAL DELAY ---------- =     21
PERCENT OF VEHICLES INCURRING TOTAL DELAY --------- =     95.5
AVERAGE TOTAL DELAY (SECONDS) -------------------- =     24.8
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ----------- =     55.6 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) -------------------- =    425.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ---------- =     17
PERCENT OF VEHICLES INCURRING QUEUE DELAY --------- =     77.3
AVERAGE QUEUE DELAY (SECONDS) -------------------- =     25.0
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ----------- =     56.1 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) ------------------ =    389.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY -------- =     17
PERCENT OF VEHICLES INCURRING STOPPED DELAY ------- =     77.3
AVERAGE STOPPED DELAY (SECONDS) ------------------ =     22.9
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME --------- =     51.4 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------ =    437.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH - =     17
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH  =     77.3
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------ =     25.7
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =     57.7 PERCENT

VEHICLE-MILES OF TRAVEL -------------------------- =      4.902
AVERAGE VEHICLE-MILES OF TRAVEL ------------------ =       .223
TRAVEL TIME (VEHICLE-SECONDS) ---------------------=    980.1
AVERAGE TRAVEL TIME (SECONDS) -------------------- =     44.5
NUMBER OF VEHICLES PROCESSED --------------------- =     22
VOLUME PROCESSED (VEHICLES/HOUR) ----------------- =    132.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS  =     21.0
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =     18.0
AVERAGE DESIRED SPEED (MPH) ---------------------- =     38.9
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) --------- =      5.0
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) --------- =      5.2

OVERALL AVERAGE TOTAL DELAY (SECONDS) ------------- =     23.6
OVERALL AVERAGE QUEUE DELAY (SECONDS) ------------- =     19.3
OVERALL AVERAGE STOPPED DELAY (SECONDS) ----------- =     17.7
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ---- =     19.9

PERCENT OF VEHICLES MAKING A U-TURN OR A LEFT TURN  =     22.7
PERCENT OF VEHICLES GOING STRAIGHT --------------- =     59.1
PERCENT OF VEHICLES MAKING A RIGHT TURN ---------- =     18.2

AVERAGE QUEUE LENGTH FOR LANE 1 ------------------ =       .7  MAX =  4

AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ---- =     99.8
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         SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

      US 183 AND CAMERON ROAD - SIX PHASE FULLY ACTUATED WITH DUAL LEFTS

SUMMARY STATISTICS FOR INBOUND APPROACH  4


TOTAL DELAY (VEHICLE-SECONDS) -------------------- =     990.1
NUMBER OF VEHICLES INCURRING TOTAL DELAY ---------- =     68
PERCENT OF VEHICLES INCURRING TOTAL DELAY --------- =     76.4
AVERAGE TOTAL DELAY (SECONDS) -------------------- =     14.6
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ----------- =     50.8 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) -------------------- =    662.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ---------- =     34
PERCENT OF VEHICLES INCURRING QUEUE DELAY --------- =     38.2
AVERAGE QUEUE DELAY (SECONDS) -------------------- =     19.5
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ----------- =     67.9 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) ------------------ =    596.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY -------- =     34
PERCENT OF VEHICLES INCURRING STOPPED DELAY ------- =     38.2
AVERAGE STOPPED DELAY (SECONDS) ------------------ =     17.5
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME --------- =     61.2 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------ =    704.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH - =     39
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH  =     43.8
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------ =     18.1
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME -- =     63.0 PERCENT

VEHICLE-MILES OF TRAVEL -------------------------- =     19.734
AVERAGE VEHICLE-MILES OF TRAVEL ------------------ =       .222
TRAVEL TIME (VEHICLE-SECONDS) ---------------------=   2550.3
AVERAGE TRAVEL TIME (SECONDS) -------------------- =     28.7
NUMBER OF VEHICLES PROCESSED --------------------- =     89
VOLUME PROCESSED (VEHICLES/HOUR) ----------------- =    534.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS  =     33.5
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME =     27.9
AVERAGE DESIRED SPEED (MPH) ---------------------- =     46.2
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) --------- =      3.5
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) --------- =      4.2

OVERALL AVERAGE TOTAL DELAY (SECONDS) ------------- =     11.1
OVERALL AVERAGE QUEUE DELAY (SECONDS) ------------- =      7.4
OVERALL AVERAGE STOPPED DELAY (SECONDS) ----------- =      6.7
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ---- =      7.9

PERCENT OF VEHICLES MAKING A U-TURN OR A LEFT TURN  =      3.4
PERCENT OF VEHICLES GOING STRAIGHT --------------- =     75.3
PERCENT OF VEHICLES MAKING A RIGHT TURN ---------- =     21.3

AVERAGE QUEUE LENGTH FOR LANE 1 ------------------ =       .3  MAX =  2
AVERAGE QUEUE LENGTH FOR LANE 2 ------------------ =       .5  MAX =  4
AVERAGE QUEUE LENGTH FOR LANE 3 ------------------ =       .3  MAX =  2

AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ---- =    100.0
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             SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

          US 183 AND CAMERON ROAD - SIX PHASE FULLY ACTUATED WITH DUAL LEFTS

SUMMARY STATISTICS FOR ALL APPROACHES


TOTAL DELAY (VEHICLE-SECONDS) ----------------------- =   3311.9
NUMBER OF VEHICLES INCURRING TOTAL DELAY ----------- =    163
PERCENT OF VEHICLES INCURRING TOTAL DELAY ---------- =     78.0
AVERAGE TOTAL DELAY (SECONDS) ---------------------- =     20.3
AVERAGE TOTAL DELAY/AVERAGE TRAVEL TIME ------------ =     59.3 PERCENT

QUEUE DELAY (VEHICLE-SECONDS) ---------------------- =   2455.0
NUMBER OF VEHICLES INCURRING QUEUE DELAY ----------- =    104
PERCENT OF VEHICLES INCURRING QUEUE DELAY ---------- =     49.8
AVERAGE QUEUE DELAY (SECONDS) ---------------------- =     23.6
AVERAGE QUEUE DELAY/AVERAGE TRAVEL TIME ------------ =     68.9 PERCENT

STOPPED DELAY (VEHICLE-SECONDS) -------------------- =   2268.0
NUMBER OF VEHICLES INCURRING STOPPED DELAY --------- =    104
PERCENT OF VEHICLES INCURRING STOPPED DELAY -------- =     49.8
AVERAGE STOPPED DELAY (SECONDS) -------------------- =     21.8
AVERAGE STOPPED DELAY/AVERAGE TRAVEL TIME ---------- =     63.7 PERCENT

DELAY BELOW 10.0 MPH (VEHICLE-SECONDS) ------------- =   2577.0
NUMBER OF VEHICLES INCURRING DELAY BELOW 10.0 MPH -- =    111
PERCENT OF VEHICLES INCURRING DELAY BELOW 10.0 MPH   =     53.1
AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ------------- =     23.2
AVERAGE DELAY BELOW 10.0 MPH/AVERAGE TRAVEL TIME --- =     67.8 PERCENT

VEHICLE-MILES OF TRAVEL ---------------------------- =     46.844
AVERAGE VEHICLE-MILES OF TRAVEL -------------------- =       .224
TRAVEL TIME (VEHICLE-SECONDS) ---------------------- =   7155.8
AVERAGE TRAVEL TIME (SECONDS) ---------------------- =     34.2
NUMBER OF VEHICLES PROCESSED ----------------------- =    209
VOLUME PROCESSED (VEHICLES/HOUR) ------------------- =   1254.0
TIME MEAN SPEED (MPH) = MEAN OF ALL VEHICLE SPEEDS   =     30.5
SPACE MEAN SPEED (MPH) = TOT DIST / TOT TRAVEL TIME  =     23.6
AVERAGE DESIRED SPEED (MPH) ------------------------ =     44.6
AVERAGE MAXIMUM ACCELERATION (FT/SEC/SEC) ---------- =      3.8
AVERAGE MAXIMUM DECELERATION (FT/SEC/SEC) ---------- =      4.4

OVERALL AVERAGE TOTAL DELAY (SECONDS) -------------- =     15.8
OVERALL AVERAGE QUEUE DELAY (SECONDS) -------------- =     11.7
OVERALL AVERAGE STOPPED DELAY (SECONDS) ------------ =     10.9
OVERALL AVERAGE DELAY BELOW 10.0 MPH (SECONDS) ----- =     12.3

AVERAGE OF LOGIN SPEED/DESIRED SPEED (PERCENT) ----- =     99.9
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             SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

          US 183 AND CAMERON ROAD - SIX PHASE FULLY ACTUATED WITH DUAL LEFTS

SUMMARY STATISTICS FOR FULL-ACTUATED SIGNAL

SIGNAL PHASE NUMBER ------------------------------------ =    1
INITIAL INTERVAL (SECONDS) ----------------------------- =    2.0
VEHICLE INTERVAL (SECONDS) ----------------------------- =    3.0
AMBER CLEARANCE INTERVAL (SECONDS) --------------------- =    4.0
ALL-RED CLEARANCE INTERVAL (SECONDS) ------------------- =      0
MAXIMUM EXTENSION AFTER DEMAND ON RED (SECONDS) -------- =   10.0
SKIP-PHASE SWITCH (ON/OFF) ----------------------------- =    ON
AUTO-RECALL SWITCH (ON/OFF) ---------------------------- =    OFF
PARENT/MINOR MOVEMENT PHASE OPTION (YES/NO) ------------ =    NO
DUAL LEFT OPTION (YES/NO) ------------------------------ =    NO
DETECTOR CONNECTION TYPE (AND/OR) ---------------------- =    OR
NUMBER OF DETECTORS CONNECTED TO PHASE ----------------- =    1
NUMBER OF PHASES CLEARED TO ---------------------------- =    5
LIST OF PHASES CLEARED TO ------------------------------ =    2    3    4    5    6
LIST OF DETECTORS CONNECTED TO PHASE ------------------- =    1
NUMBER OF MAX-OUTS ------------------------------------- =    0
AVERAGE TIME INTO PHASE FOR MAX-OUT (SECONDS) ---------- =      0
NUMBER OF GAP-OUTS ------------------------------------- =    9
AVERAGE TIME INTO PHASE FOR GAP-OUT (SECONDS) ---------- =    7.6


SIGNAL PHASE NUMBER ------------------------------------ =    2
INITIAL INTERVAL (SECONDS) ----------------------------- =    2.0
VEHICLE INTERVAL (SECONDS) ----------------------------- =    3.0
AMBER CLEARANCE INTERVAL (SECONDS) --------------------- =    4.0
ALL-RED CLEARANCE INTERVAL (SECONDS) ------------------- =      0
MAXIMUM EXTENSION AFTER DEMAND ON RED (SECONDS) -------- =   15.0
SKIP-PHASE SWITCH (ON/OFF) ----------------------------- =    ON
AUTO-RECALL SWITCH (ON/OFF) ---------------------------- =    OFF
PARENT/MINOR MOVEMENT PHASE OPTION (YES/NO) ------------ =    NO
DUAL LEFT OPTION (YES/NO) ------------------------------ =    NO
DETECTOR CONNECTION TYPE (AND/OR) ---------------------- =    OR
NUMBER OF DETECTORS CONNECTED TO PHASE ----------------- =    2
NUMBER OF PHASES CLEARED TO ---------------------------- =    5
LIST OF PHASES CLEARED TO ------------------------------ =    3    4    5    6    1
LIST OF DETECTORS CONNECTED TO PHASE ------------------- =    5    6
NUMBER OF MAX-OUTS ------------------------------------- =    0
AVERAGE TIME INTO PHASE FOR MAX-OUT (SECONDS) ---------- =      0
NUMBER OF GAP-OUTS ------------------------------------- =    9
AVERAGE TIME INTO PHASE FOR GAP-OUT (SECONDS) ---------- =    8.0


SIGNAL PHASE NUMBER ------------------------------------ =    3
INITIAL INTERVAL (SECONDS) ----------------------------- =    2.0
VEHICLE INTERVAL (SECONDS) ----------------------------- =    1.0
AMBER CLEARANCE INTERVAL (SECONDS) --------------------- =    3.0
ALL-RED CLEARANCE INTERVAL (SECONDS) ------------------- =      0
MAXIMUM EXTENSION AFTER DEMAND ON RED (SECONDS) -------- =   10.0
SKIP-PHASE SWITCH (ON/OFF) ----------------------------- =    ON
AUTO-RECALL SWITCH (ON/OFF) ---------------------------- =    OFF
PARENT/MINOR MOVEMENT PHASE OPTION (YES/NO) ------------ =    NO
DUAL LEFT OPTION (YES/NO) ------------------------------ =    YES
DETECTOR CONNECTION TYPE (AND/OR) ---------------------- =    AND
NUMBER OF DETECTORS CONNECTED TO PHASE ----------------- =    2
NUMBER OF PHASES CLEARED TO ---------------------------- =    5
LIST OF PHASES CLEARED TO ------------------------------ =    4    5    6    1    2
LIST OF DETECTORS CONNECTED TO PHASE ------------------- =    2    7
NUMBER OF MAX-OUTS ------------------------------------- =    0
AVERAGE TIME INTO PHASE FOR MAX-OUT (SECONDS) ---------- =      0
NUMBER OF GAP-OUTS ------------------------------------- =    2
AVERAGE TIME INTO PHASE FOR GAP-OUT (SECONDS) ---------- =    3.5
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SIGNAL PHASE NUMBER ------------------------------- =   4
INITIAL INTERVAL (SECONDS) ------------------------ =   2.0
VEHICLE INTERVAL (SECONDS) ------------------------ =   1.0
AMBER CLEARANCE INTERVAL (SECONDS) ---------------- =   3.0
ALL-RED CLEARANCE INTERVAL (SECONDS) -------------- =     0
MAXIMUM EXTENSION AFTER DEMAND ON RED (SECONDS) --- =  10.0
SKIP-PHASE SWITCH (ON/OFF) ------------------------ =   ON
AUTO-RECALL SWITCH (ON/OFF) ----------------------- =   OFF
PARENT/MINOR MOVEMENT PHASE OPTION (YES/NO) ------- =   NO
DUAL LEFT OPTION (YES/NO) ------------------------- =   NO
DETECTOR CONNECTION TYPE (AND/OR) ----------------- =   AND
NUMBER OF DETECTORS CONNECTED TO PHASE ------------ =   2
NUMBER OF PHASES CLEARED TO ----------------------- =   5
LIST OF PHASES CLEARED TO ------------------------- =   6    1    2    3    5
LIST OF DETECTORS CONNECTED TO PHASE -------------- =   7   -2
NUMBER OF MAX-OUTS -------------------------------- =   0
AVERAGE TIME INTO PHASE FOR MAX-OUT (SECONDS) ----- =     0
NUMBER OF GAP-OUTS -------------------------------- =   1
AVERAGE TIME INTO PHASE FOR GAP-OUT (SECONDS) ----- =   8.0


SIGNAL PHASE NUMBER ------------------------------- =   5
INITIAL INTERVAL (SECONDS) ------------------------ =   2.0
VEHICLE INTERVAL (SECONDS) ------------------------ =   1.0
AMBER CLEARANCE INTERVAL (SECONDS) ---------------- =   3.0
ALL-RED CLEARANCE INTERVAL (SECONDS) -------------- =     0
MAXIMUM EXTENSION AFTER DEMAND ON RED (SECONDS) --- =  10.0
SKIP-PHASE SWITCH (ON/OFF) ------------------------ =   ON
AUTO-RECALL SWITCH (ON/OFF) ----------------------- =   OFF
PARENT/MINOR MOVEMENT PHASE OPTION (YES/NO) ------- =   NO
DUAL LEFT OPTION (YES/NO) ------------------------- =   NO
DETECTOR CONNECTION TYPE (AND/OR) ----------------- =   AND
NUMBER OF DETECTORS CONNECTED TO PHASE ------------ =   2
NUMBER OF PHASES CLEARED TO ----------------------- =   5
LIST OF PHASES CLEARED TO ------------------------- =   6    1    2    3    4
LIST OF DETECTORS CONNECTED TO PHASE -------------- =   2   -7
NUMBER OF MAX-OUTS -------------------------------- =   0
AVERAGE TIME INTO PHASE FOR MAX-OUT (SECONDS) ----- =     0
NUMBER OF GAP-OUTS -------------------------------- =   4
AVERAGE TIME INTO PHASE FOR GAP-OUT (SECONDS) ----- =   6.3


SIGNAL PHASE NUMBER ------------------------------- =   6
INITIAL INTERVAL (SECONDS) ------------------------ =   8.0
VEHICLE INTERVAL (SECONDS) ------------------------ =   2.0
AMBER CLEARANCE INTERVAL (SECONDS) ---------------- =   5.0
ALL-RED CLEARANCE INTERVAL (SECONDS) -------------- =     0
MAXIMUM EXTENSION AFTER DEMAND ON RED (SECONDS) --- =  30.0
SKIP-PHASE SWITCH (ON/OFF) ------------------------ =   OFF
AUTO-RECALL SWITCH (ON/OFF) ----------------------- =   OFF
PARENT/MINOR MOVEMENT PHASE OPTION (YES/NO) ------- =   NO
DUAL LEFT OPTION (YES/NO) ------------------------- =   NO
DETECTOR CONNECTION TYPE (AND/OR) ----------------- =   OR
NUMBER OF DETECTORS CONNECTED TO PHASE ------------ =  10
NUMBER OF PHASES CLEARED TO ----------------------- =   5
LIST OF PHASES CLEARED TO ------------------------- =   1    2    3    4    5
LIST OF DETECTORS CONNECTED TO PHASE -------------- =   3    4    8    9   10
                                                       11   12   13   14   15
NUMBER OF MAX-OUTS -------------------------------- =   8
AVERAGE TIME INTO PHASE FOR MAX-OUT (SECONDS) ----- =  31.5
NUMBER OF GAP-OUTS -------------------------------- =   2
AVERAGE TIME INTO PHASE FOR GAP-OUT (SECONDS) ----- =  17.0
```

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     SIMULATION PROCESSOR FOR THE TEXAS TRAFFIC SIMULATION PACKAGE

  US 183 AND CAMERON ROAD - SIX PHASE FULLY ACTUATED WITH DUAL LEFTS

START-UP TIME    =  120.000 SECONDS      NUMBER OF VEHICLES PROCESSED =   33

SIMULATION TIME =  600.000 SECONDS      NUMBER OF VEHICLES PROCESSED =  209

NUMBER OF VEHICLES IN THE SYSTEM AT SUMMARY =     5
AVERAGE NUMBER OF VEHICLES IN THE SYSTEM -- =   11.8  MAX =  21



INITIAL     TM TIME =      .965 SECONDS   COST = $   .06

START-UP    TM TIME =     3.186 SECONDS   COST = $   .20
            REAL/TM =    37.665

SIMULATION  TM TIME =    18.264 SECONDS   COST = $  1.17
            REAL/TM =    32.852

SUMMARY     TM TIME =      .536 SECONDS   COST = $   .03


TOTAL       TM TIME =    22.951 SECONDS   COST = $  1.47


VEHICLE-SECONDS OF SIMULATION PER TM TIME =  391.798

VEHICLE UPDATES PER TM TIME =  391.798
```