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16. Abstract

The TEXAS Model for Intersection Traffic has been revised and released as Version 3.2. The new Version 3.2 provides nine new features, including: separate diamond interchange u-turn lanes, exact percentages of generated driver-vehicle units, sight-distance checking options in the user interface, NEMA dual-ring traffic signal controllers, volume-density traffic signal controllers, user choice options for diamond interchange traffic phase numbering, output statistics in graphical form, generic plotter-driver output routines and interfaces, and automation of the replicate simulation run process.

The basic look and feel of earlier versions of the model has been retained to minimize needs for additional user training. The progress of each individually characterized vehicle moving through a simulated intersection or interchange is displayed in real-time or in stop-action on a microcomputer or workstation-driven graphics screen. This allows the user to study the overall traffic performance or to examine the behavior of any selected vehicle(s) in great detail. With Version 3.2 of the TEXAS Model that is described in this report, alternative intersection or diamond interchange designs and traffic-control schemes can be evaluated quickly and accurately in a timely and cost-effective manner.

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TEXAS MODEL FOR INTERSECTION TRAFFIC ADDITIONAL FEATURES

by

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Research Report Number 1258-1F

Texas Model for Intersection Traffic-Additional Features
Research Project 3-18-91-1258

conducted for

Texas Department of Transportation

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

by the

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The University of Texas at Austin

January 1993

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

PREFACE

Research Study Number 3-18-91-1258, "TEXAS Model for Intersection Traffic—Additional Features," was a two-year project with the objectives of adding nine new features to the TEXAS Traffic Simulation Package. These objectives have been accomplished through the addition of code enabling the following:

- Separate diamond interchange u-turn lanes,
- Generation of exact percentages of driver-vehicle units,
- Implementation of sight-distance checking in the user interface,
- Inclusion of NEMA dual-ring traffic signal controllers,
- Inclusion of volume-density traffic signal controllers,
- Providing user choice options for diamond interchange traffic phase numbering,
- Presentation of output statistics in graphical form,
- Development of generic plotter-driver output routines and interfaces, and,
- Automation of the process for producing replicate simulation observations.

This latest Version 3.2 of The TEXAS Model for Intersection Traffic package continues to be available for application on DOS based micro computers and Intergraph Workstations. The primary language continues to be FORTRAN 77.

The Traffic Engineering Section of the Division of Maintenance and Operations, D-18TE, of the Texas Department of Transportation has participated in all stages of the project work. Their timely and pertinent suggestions have been extremely helpful in adapting the simulation model to practical applications.

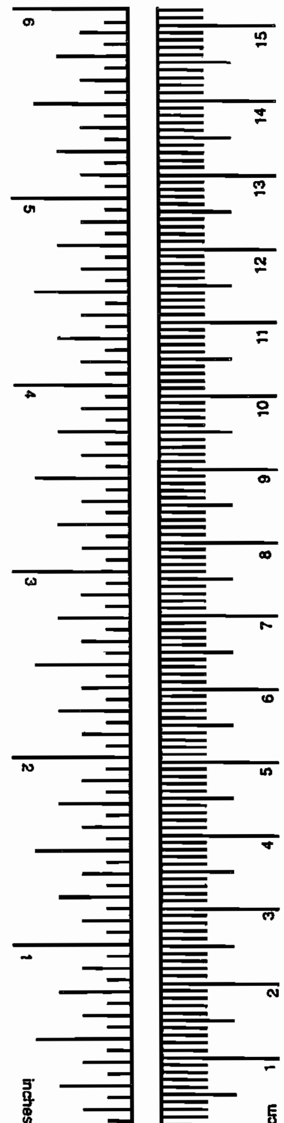
METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.0765	meters cubed	m^3

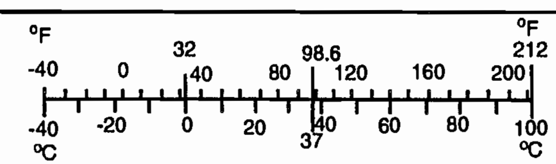
NOTE: Volumes greater than 1,000 L shall be shown in m^3.

Symbol	When You Know	Multiply by	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.20	square yards	yd^2
km^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1,000 kg)	1.103	short tons	T
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

ACKNOWLEDGMENTS

The conduct of this study was supported continually by study contact individuals in the Traffic Engineering Section of the Division of Maintenance and Operations, D-18TE, of the Texas Department of Transportation. Their judgment and timely suggestions guided the project development, particularly with respect to applications in practice. Comments and suggestions made by Federal Highway Administration study contact individuals also provided valuable direction.

Workstation computer resources made available to The University of Texas at Austin, College of Engineering, Department of Civil Engineering through Intergraph Corporation made many of the computer program developments possible. The assistance of Robert L. Gloyd, Manager of Computer Services, Department of Civil Engineering, in acquiring and maintaining microcomputer, as well as workstation resources in the Department of Civil Engineering, is greatly appreciated.

The modified and new computer code for the TEXAS Model, Version 3.2 was written by Dr. Thomas W. Rioux, principal author of the original TEXAS Model for Intersection Traffic and Robert F. Inman, author of the user interfaces first released in Version 3.0.

This report document was prepared by Wendy Giles and Candace Gloyd. Their skills, patience, persistence, and concentrated effort is sincerely appreciated.

ABSTRACT

The TEXAS (Traffic EXperimental Analytical Simulation) Model for Intersection Traffic has been revised and released as Version 3.2. The new Version 3.2 provides nine new features including: separate diamond interchange u-turn lanes, exact percentages of generated driver-vehicle units, sight-distance checking options in the user interface, NEMA dual-ring traffic signal controllers, volume-density traffic signal controllers, user choice options for diamond interchange traffic phase numbering, output statistics in graphical form, generic plotter-driver output routines and interfaces, and, automation of the replicate simulation run process.

The basic look and feel of earlier versions of the model have been retained to minimize needs for additional user training. The progress of each individually-characterized vehicle moving through a simulated intersection or interchange is displayed in real-time or in stop-action on a microcomputer or workstation driven graphics screen. This allows the user to study the overall traffic performance or to examine the behavior of any selected vehicle(s) in great detail. With Version 3.2 of the TEXAS Model that is described in this report, alternative intersection or diamond interchange designs and traffic-control schemes can be evaluated quickly and accurately in a timely and cost-effective manner.

SUMMARY

The TEXAS Model for Intersection Traffic has been developed at the Center for Transportation Research at the University of Texas at Austin in cooperation with the Texas Department of Transportation and the Federal Highway Administration. Continuing improvement of this powerful traffic simulation package has recently resulted in the addition of nine significant new features that are described in this report.

Version 3.2 of the TEXAS Model provides all functions of previous versions plus:

- Simulation of separate diamond interchange u-turn lanes,
- Generation of exact user-specified percentages of driver-vehicle units,
- Implementation of sight-distance checking in the user interface,
- Inclusion of NEMA dual-ring traffic signal controllers,
- Inclusion of volume-density traffic signal controllers,
- Providing user choice options for diamond interchange traffic phase numbering,
- Presentation of output statistics in graphical form,
- Development of generic plotter-driver output routines and interfaces, and
- Automation of the process for producing replicate simulation observations.

The interactive data-entry programs which greatly ease the task of preparing input data for the Geometry Processor (GEOPRO), the Driver-Vehicle Processor (DVPRO), and the Simulation Processor (SIMPRO), of the TEXAS Model, have been retained and improved in the new version of the package.

The unique graphics display feature, available in previous versions, has been retained and is available both on DOS-based microcomputers and Intergraph workstations. The speed, position, and time relationship between every simulated driver-vehicle unit and the intersection geometry is displayed in real-time, or in stop-action, on a screen driven by a microcomputer or a workstation. This animated display allows the user to study the overall performance of traffic and traffic control at an intersection or to examine the behavior of an individual driver-vehicle unit in great detail, if desired. Alternative solutions to intersection or diamond interchange problems can be evaluated quickly and economically by applyin the TEXAS Model.

IMPLEMENTATION

A TEXAS Model Version 3.2 has been developed, and it is recommended for implementation by the Texas Department of Transportation. With Version 3.2 of the TEXAS Model, significant new capabilities and flexibility have become available. Graphical animation of the simulated traffic can be displayed on a screen driven by a microcomputer or workstation for real-time observation.

A further recommendation is that the new version be implemented immediately in the continuing series of training sessions supported by TxDOT. The capabilities and flexibility of this powerful engineering tool have been enhanced considerably by the developments accomplished under this study.

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CHAPTER 1. INTRODUCTION

STUDY PROBLEM STATEMENT

The TEXAS Model for Intersection Traffic is a powerful engineering and planning tool which is now being used routinely to evaluate designs and traffic operations at intersections and at diamond interchanges through highly-detailed computer simulation and animated graphics. In a series of workshops, more than 120 TxDOT personnel have been trained in its use for solving complex design and traffic control problems. The model currently handles most common intersection situations very well, but users have requested that several additional features be developed.

BACKGROUND

Initial development of the Traffic EXperimental Analytical Simulation (TEXAS) Model for Intersection Traffic began in 1971 under Research Study 3-18-72-184, and four reports documenting this mainframe, batch-processing version of the microscopic computer model were published in 1977. Because of the cumbersome communication with the Model through hand-written coding forms, it was not utilized extensively other than by researchers. Research Study 3-18-84-361 produced a "User-Friendly" TEXAS Model (Report 361-F) which allows input to and running of the model on an IBM-compatible microcomputer as well as on main-frame machines. This version also features an animated-graphics display of intersection traffic activities on the screen of a microcomputer. The most recent model enhancement was accomplished under Research Study 3-18-84-443 entitled "TEXAS Diamond - A Microscopic Simulation Model for Diamond Interchanges." Study Report 443-1F "TEXAS Model, Version 3.0 (Diamond Interchanges)" was approved in March 1990 and was published in May 1990. Version 3.0 incorporates all the user-friendly features of the previous versions and also handles the simulation of geometry, traffic, and traffic control (including actuated controllers, see Appendix C) for most conventional diamond interchanges. In addition to running on IBM (and compatible) main-frame and micro computers, Version 3.0 has been adapted to run in the UNIX environment on Intergraph Corporation's Clipper workstations. A unique, high-quality animated-graphics screen display is available on this platform, also. It features simultaneous, synchronized viewing and manipulation of the animated-graphics from four runs of the TEXAS Model, Version 3.0. Engineers now have a practical, useful tool with which to evaluate the performance of single intersections and diamond interchanges under a wide range of geometry, traffic, and traffic-control conditions. A few additional functions are needed to make the TEXAS Model, Version 3.0 even more responsive to the needs of transportation engineers.

OBJECTIVE

The objective of this study is to add nine features to the TEXAS Model, Version 3.0. The following features will be incorporated:

1. Handle separate U-Turn lanes at diamond interchanges.
2. Generate exact percentage of desired driver-vehicle units.
3. Implement sight-distance checking in the user-friendly version.
4. Simulate NEMA dual-ring traffic signal controllers.
5. Simulate volume-density traffic signal controllers.
6. Provide user choice between "City of Dallas" and "TxDOT" numbering scheme for traffic phases at diamond interchanges.
7. Present output summary statistics in graphical form (spreadsheet-compatible output format).
8. Develop generic plotter-driver output routines and interface capabilities to selected types of plotters.
9. Automate the required number of replicate runs to achieve stability in selected measures of effectiveness.

In addition to the 9 objectives listed above, numerous errors have been corrected and several modifications suggested by TxDOT personnel have been implemented.

This report describes the development of the TEXAS Model for Intersection Traffic Version 3.2. It is based upon the existing TEXAS Model for Intersection Traffic Version 3.0 with interim releases for Version 3.10, Version 3.11, and Version 3.12. All the capabilities of prior versions of the TEXAS Model for Intersection Traffic are incorporated in Version 3.2.

The following sections of this chapter present a brief overview of the characteristics of the TEXAS Model for Intersection Traffic. The additions, changes, and enhancements made to the user-friendly interface are discussed in detail in Chapter 2 while the additions, changes, and enhancements made to the processors are discussed in detail in Chapter 3. Chapter 4 presents the summary, conclusions, and recommendations. Appendix A shows command line parameters, Appendix B lists code for spreadsheet macros, and Appendix C shows phase sequence diagrams for actuated diamond interchange traffic signal controllers.

TEXAS Model for Intersection Traffic - Overview

The TEXAS Model for Intersection Traffic [Ref 1] is a powerful computer simulation tool which allows the user to evaluate in detail the complex interaction among individually-characterized driver-vehicle units as they operate in a defined intersection environment under a specified type of traffic control. This model deals only with vehicular traffic at a single intersection or diamond interchange. In its current version, it includes a user-friendly data-entry process and an animated-graphics display of real-time movements of vehicles through the intersection or diamond interchange on a monitor screen driven by an IBM (or compatible) microcomputer [Ref 2] or by an Intergraph workstation. The following paragraphs summarize the principal characteristics of the model.

Structure of the TEXAS Model for Intersection Traffic

The TEXAS Model for Intersection Traffic includes nine main processors: DISFIT (Headway Distribution Fitting) a utility routine for fitting several traffic headway statistical distributions to user data, GEOPRO (Geometry Processor) for describing the geometric configurations, GEOPLOT (Geometry Plotting) for plotting the geometric configurations, DVPRO (Driver-Vehicle Processor) for describing the stochastically arriving traffic, SIMPRO (Simulation Processor) for determining the behavior of traffic in response to the applicable traffic controls, EMPRO (Emissions Processor) for calculating the emissions generated by the traffic, SIMSTA (Simulation Statistics) for computing the simulation statistics from replicate runs, and DISPRE (Display Pre-Processor) and DISPRO (Display Processor) for viewing the animation. The structural relationship among these data processors is shown in Fig 1.1.

DISFIT is a newly converted processor and is discussed in detail in Chapter 3.

GEOPRO defines the geometry of the intersection or interchange in the computer. It calculates vehicle paths along the lanes abutting the intersection and within the intersection. The number of intersection legs, together with their associated number of lanes and lane widths, define the intersection size and the location of any special lanes. The azimuth for each leg and the associated coordinates define the shape of the intersection. The allowed directional movements of traffic on the inbound lanes and the allowed movements on outbound lanes define the directional use of the intersection.

GEOPLOT is a new processor and is discussed in detail in Chapter 3.

DVPRO utilizes certain assigned characteristics for each class of driver and vehicle and generates attributes for each individual driver-vehicle unit; thus, each unit is characterized by inputs concerning driver class, vehicle class, desired speed, desired outbound intersection leg, and lateral inbound lane position. All these attributes are generated by a discrete probability distribution, except for the desired speed which is defined by a normal distribution. Each unit is sequentially ordered by queue-in time as defined by the input of a selected headway distribution. The total number of driver-vehicle units which

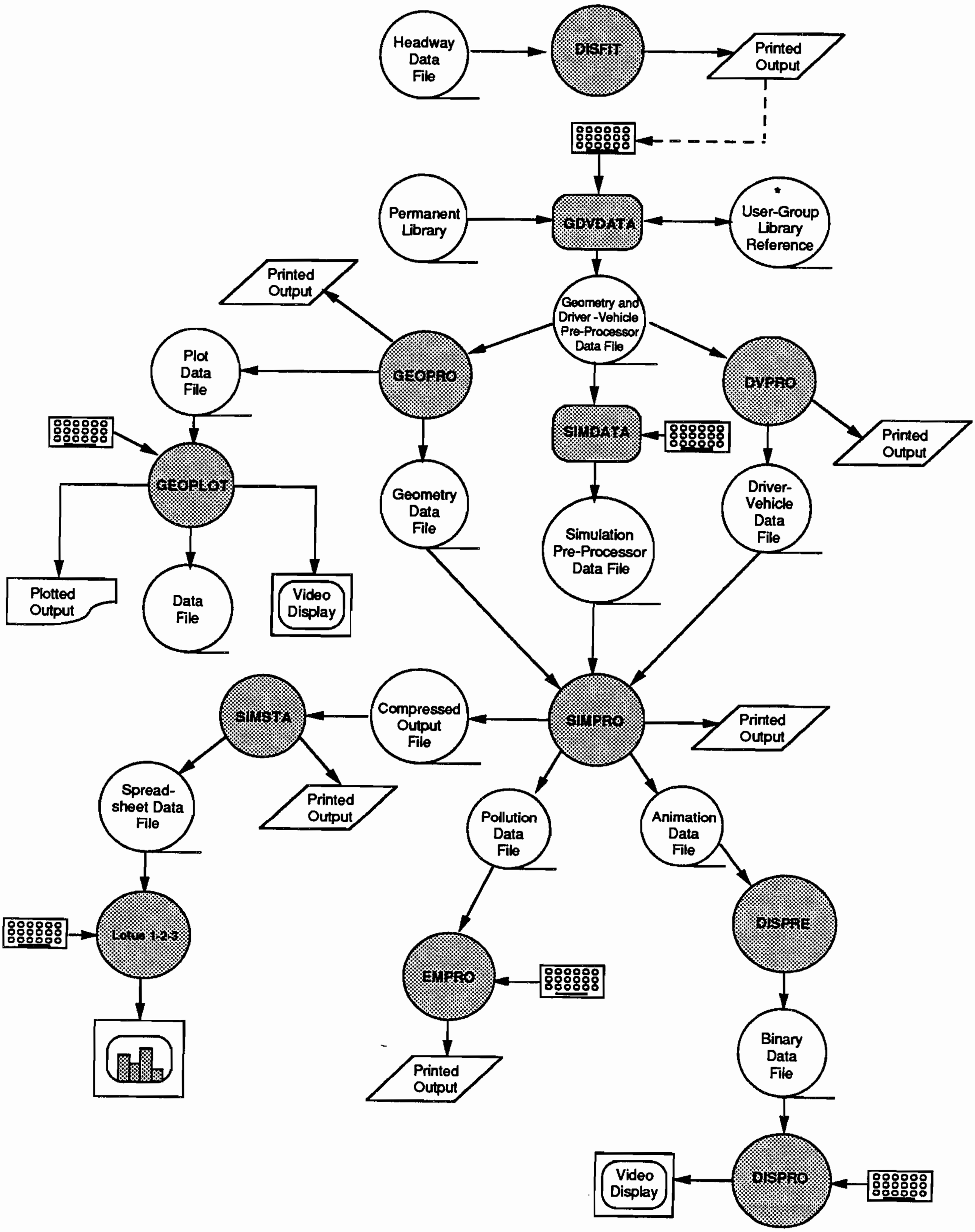


Figure 1.1 Relationship among TEXAS Model processors

must be generated by DVPRO is determined by the product of the input traffic volume, in vehicles per hour, and the minutes of time to be simulated.

SIMPRO simulates the traffic behavior of each unit according to the momentary surrounding conditions including any traffic control device indications which might be applicable. Upon entering the inbound approach lane, the entry velocity of each unit is set so that the vehicle will neither exceed a selected desired speed nor collide with the unit immediately ahead of it. If the unit ahead is accelerating, or is traveling at its desired speed, the entering unit will enter the approach at its own desired speed. If the unit ahead is decelerating, the speed of the entering unit is set to a value which is less than its own desired speed. If there is no leading unit on the inbound lane, the unit enters with its desired speed.

After entry, the unit is checked moment-by-moment within SIMPRO as to whether or not it is in a car-following situation. If it is not, the magnitude of required acceleration or deceleration which is applicable at any given instant is calculated and bound between the extreme values which are set for each vehicle class. Maximum required acceleration and deceleration occur at or near zero speed, and zero acceleration occurs at the maximum speed that each type of vehicle can attain. If the unit is in a car-following situation, the speed and acceleration of the unit interact with the speed and position of the unit ahead. Current and relative speeds and positions of all adjacent vehicles are thus utilized in determining the behavior of each driver-vehicle unit in the simulation model.

When car following or traffic control makes it necessary for a unit to accelerate or decelerate, the logic in SIMPRO provides for accelerating to the desired speed, accelerating to the speed of the unit ahead, decelerating to follow the unit ahead, or decelerating to the desired speed within the available distance.

As the unit proceeds along the inbound approach lane, the location and the status of traffic control devices are checked moment-by-moment. The indication of the traffic control devices will apply to the unit as soon as the unit comes into the device influence area .

If stop signs control the intersection, SIMPRO lists the units stopped before the sign according to their arrival times and then releases them in a first-arrived-first-served sequence. If there are simultaneous arrivals on adjacent intersection legs, the unit to the right gets priority for earliest release.

If pre-timed signals control, each unit responds to the signal indications, which appear in a defined sequence and are of a specified duration for each phase. Each unit will attempt to go on a green indication after checking for intersection conflicts. If the unit is in the leading position and has cleared conflicts, the unit will enter the intersection. If a leading unit has stopped before the unit being examined, or if the leading unit is decelerating, the unit being examined will begin to stop. When the signal indication is red, each arriving unit will stop; however, a right-turn-on-red option is provided.

If control is by an actuated signal controller, the sequence and duration of each indication is selected in response to the information received by the controller from the detectors. The logic for driver response to signal indications is, of course, the same as that described for the pre-timed signal. A detector actuation is defined by the time interval during which the front bumper of a unit has crossed the start of the detector but the rear bumper has not crossed the end of the detector. Actuations may cause the controller to continue the phase or allow the phase to change when a maximum time interval for that phase has elapsed, or a sufficiently large gap occurs.

A unit is allowed to change into an adjacent lane if less delay can be expected or the current lane does not have an intersection path to the unit's desired outbound leg. The geometric path of the lane-changing unit is a cosine curve. Each unit is processed incrementally in time from its entry onto the inbound lane to the end of the outbound lane. The length of each approach is specified. The instantaneous traffic behavior of each unit including speed, location, and time are written onto a file by the TEXAS Model for subsequent use in the animation processor (DISPRE and DISPRO) or in the emission processor (EMPRO). Statistics about delays and queue lengths are also gathered by the TEXAS Model for evaluating the performance of traffic at the intersection.

Delay statistics include the average of total delay and the average of stop delay incurred by each vehicle processed. Each delay is summarized by u-turn, left-turn, straight, right-turn, internal-then-left, and internal-then-right movements and by the total of these six permitted directional movements on each inbound approach (internal-then-left and internal-then-right are only applicable at diamond interchanges). Total delay is the difference between travel time for a vehicle through the system and the time it would have taken the vehicle to travel the same distance at its desired speed. Stop delay is the time spent by a vehicle which has a velocity less than 3 feet/second. Delay statistics show the overall influence of the intersection environment on traffic passing through the intersection. Comparison of the delays experienced by traffic making various directional movements indicates the interaction among traffic flows on the intersecting streets. Queue-length statistics include average queue length and maximum queue length for each inbound lane. Both are measured in units of vehicles, not feet.

EMPRO, the emissions processor, incorporates models to predict the instantaneous vehicle emissions of Carbon Monoxide (CO), Hydrocarbons (HC), Oxides of Nitrogen (NO_X), and fuel flow (FF) for both light-duty vehicles and heavy-duty vehicles. EMPRO utilizes information from SIMPRO about the instantaneous speed and acceleration of each vehicle to compute instantaneous vehicle emissions and fuel consumption at points along the vehicle path.

SIMSTA is a new processor and is discussed in detail in Chapter 3.

DISPRE reads the animation file produced by SIMPRO and prepares the data for DISPRO. DISPRO reads the file produced by DISPRE and allows the user to view the animation.

Data Entry to the User-Friendly TEXAS Model

As shown in Fig 1.1, data that are required for running the TEXAS Model are entered by the user through two computer data-entry programs called GDVDATA (Geometry and Driver-Vehicle Data) and SIMDATA (Simulation Data). These are features of the user-friendly version of the model which were not included in the original mainframe computer version. All geometric data are specified in terms of lengths and angles.

The data-entry program GDVDATA includes user aids for entering the geometric data needed by the geometry processor GEOPRO and the data to characterize the drivers and vehicles which make up the traffic stream passing through a simulated intersection needed by the driver-vehicle processor DVPRO. For efficiency, and for the convenience of the user, a permanent library (see Fig 1.1), which contains 20 typical intersection configurations along with an associated traffic pattern, has been created and stored within GDVDATA. Instructions for using and modifying data files copied from the permanent library are given through prompts on the screen and in Ref 2. A user-group library (see Fig 1.1) is also provided to allow users to develop, store, index, and retrieve conveniently their own data files for modification or for repeated use without modification.

Data that are needed by the simulation processor SIMPRO are entered through the data-entry program called SIMDATA (see Fig 1.1). This program pairs the entered data required by SIMPRO with data previously defined by using GDVDATA or with data contained in a permanent library file within GDVDATA. Use of SIMDATA is described in Ref 2 and through prompts and instructions on the screen.

Animated Graphics Display of TEXAS Model Output

Output from the TEXAS Model optionally includes the instantaneous acceleration, speed, location, and time relationship for every simulated vehicle. These data are optionally written into a file for use by the emissions processor EMPRO, by the animation processor DISPRE and DISPRO, or for other applications (see Fig 1.1). The User-Friendly TEXAS Model provides a feature whereby this information can be displayed graphically in real-time, or in stop action, on a screen driven by a DOS-based computer or by Intergraph workstations. Intersection geometry is extracted from the files created by GDVDATA and displayed on the screen; then, the position of each simulated vehicle is represented on the screen by an outline of the vehicle, scaled to size and color-coded according to performance capability, with respect to time. With this animated-graphics display, the user can study the overall traffic performance at an intersection or examine in great detail the behavior of an individual vehicle in the traffic stream. A wide range of conditions can be defined and evaluated visually on the screen as well as in the form of tabular listings that give summary statistics about traffic and traffic-signal-controller performance.

TEXAS MODEL, VERSION 3.0 (DIAMOND INTERCHANGES)

The TEXAS Model, Version 3.0 (Diamond Interchanges) is a computer simulation software package which allows the user to study in great detail the interaction among individually-characterized driver-vehicle units as they approach and pass through the two closely-spaced at-grade intersections of a conventional diamond interchange with one-way traffic on the ramps that form two opposite intersection legs. Traffic control at these intersections may range from the rules-of-the-road, to traffic signs, to complex traffic-signal controls. The model incorporates all the basic features of the TEXAS Model for Intersection Traffic [Refs 1 & 2] and modifies them as needed to handle vehicular traffic operating in the conventional diamond-interchange environment. The principal modifications and additions are:

- Geometry is defined for two adjacent intersections with connecting internal lanes.
- Linking is provided in the simulation processor, SIMPRO, for transferring each simulated driver-vehicle unit on an existing path within the first intersection to an appropriate internal lane. The internal lanes then function as inbound lanes to the second intersection.
- Drivers approaching an intersection look forward into and beyond the intersection and respond to other vehicles on, or adjacent to, their path and to traffic-control devices ahead when they are within the influence area of such a device.
- Drivers merging into an outbound lane from an intersection look back into the intersection and onto the outbound lane to check conflicts before entering the lane.
- A signal-controller module to simulate actuated diamond-interchange controllers is provided (see Appendix C).
- Summary statistics are collected for every vehicle (a) from log-in to the system until log-out from the system, and (b) from log-in to an internal lane until log-out from the system.
- An example of the geometry and traffic for a diamond interchange is included in the permanent library file of Version 3.0.

Each of these modifications and additions is discussed in some detail below. Most of the different operating features of the diamond-interchange version of the model are transparent to the user, but the user should be aware of their fundamental characteristics.

Geometry of the Diamond Interchange

In the TEXAS Model, Version 3.0 (Diamond Interchanges), the geometry of the interchange is configured as two adjacent, three-leg, at-grade intersections connected by a set of internal lanes (Fig 1.2). The intersections are designated as Left Intersection, L, and Right Intersection, R, with the centerline of the internal lanes oriented *perpendicular* to the zero-degree leg angle as shown in Fig 1.2. Legs 2 and 5 and the internal lanes can handle either one-way or two-way traffic, but Legs 1,3, 4, and 6 (the ramps) accommodate only one-way traffic. Each leg is made up of one or more parallel lanes and the legs *must* be numbered as shown in Fig 1.2. The numbering sequence for inbound and outbound lanes is the same as that used in the User-Friendly TEXAS Model for Intersection Traffic [Ref 2]. The numbering sequence for the internal lanes is indicated by the pattern shown in Fig 1.2, wherein the lanes inbound toward Intersection R are numbered first, beginning at the centerline of the internal lanes and continuing outward until all these lanes are numbered; then, the lanes inbound toward Intersection L are numbered with continuing serial numbers beginning at the centerline and continuing outward until all lanes are numbered. Curb returns *must* be numbered as shown in Fig 1.2. Entry of geometric data to GDVDATA (Fig 1.1) follows the format of the User-Friendly TEXAS Model for Intersection Traffic [Ref 2]. A series of screen prompts, including an on-screen representation of Fig 1.2, guide the user through the geometry data-entry process.

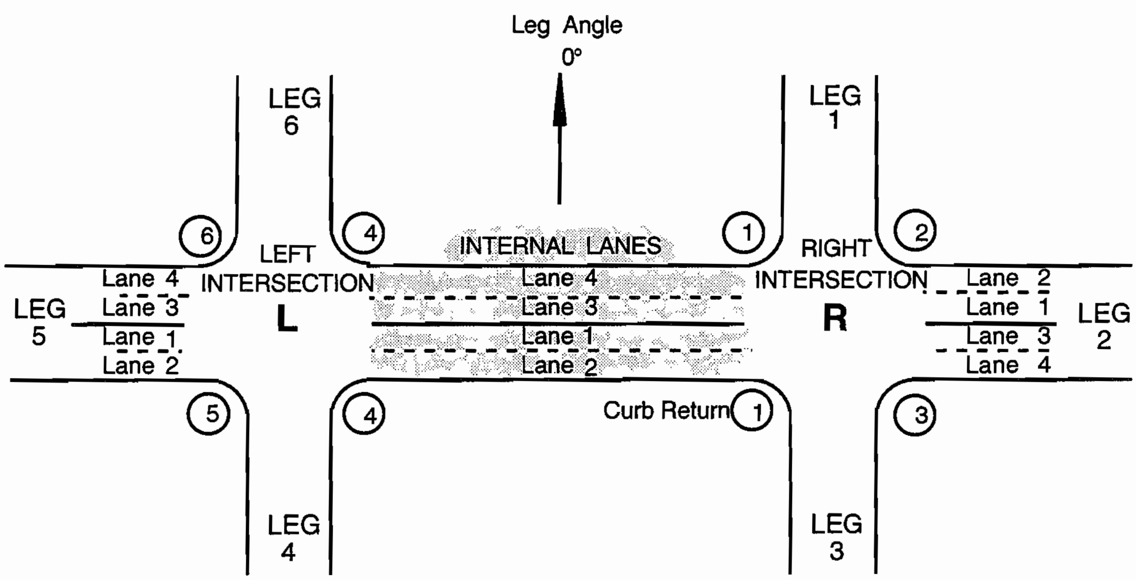


Figure 1.2 Geometry and nomenclature of traditional diamond interchange

Linking Lanes and Intersection Paths

Simulated driver-vehicle units moving through the diamond interchange may travel along inbound, internal, and outbound lanes as well as intersection paths generated by GEOPRO. Only the units which traverse both intersections utilize the internal lanes. Therefore, internal lanes accept traffic only from the first (upstream) intersection and then function as inbound lanes to the second (downstream) intersection in the simulation processor, SIMPRO.

Driver Look-Ahead Feature

In SIMPRO, each simulated driver is provided with information about the current traffic situation on their, and adjacent, lanes and paths, along with the indications of any applicable traffic control devices ahead. The influence area for a traffic control device is defined dynamically for each simulated driver, and may extend for several hundred feet. In a conventional diamond interchange with closely-spaced intersections, the influence area for a traffic control device located at the second (downstream) intersection can affect drivers approaching the first (upstream) intersection, those in the first intersection, and those on the internal lanes. The TEXAS Model, Version 3.0 (Diamond Interchanges) incorporates features which allow all these drivers to respond to the influence of other vehicles and traffic-control devices located at and beyond the first intersection at the time the simulated driver makes a decision.

Conflict Checking Before Merging into an Outbound Lane

Right-turning vehicles merge into the outbound lanes from an intersection path. The model allows the simulated drivers of such vehicles to check for potentially-conflicting vehicles in the intersection as well as on the outbound lane into which they propose to merge.

Signal-Controller Module for Diamond Interchanges

Traffic at diamond interchanges is frequently controlled by signals that are coordinated in an attempt to provide continuous movement of vehicles through both intersections. The signal controller for a diamond interchange can be either pre-timed or actuated. In addition to the signal controllers incorporated in the TEXAS Model for Intersection Traffic, a special signal-controller module for actuated signals at diamond interchanges (see Appendix C) is included in the TEXAS Model, Version 3.0 (Diamond Interchanges). The functioning and use of this signal-controller simulation module is described in Reference 15. Screen prompts for entry of required data for both pre-timed and actuated signal controllers are included in Version 3.0.

Summary Statistics for Diamond Interchange

In the TEXAS Model, Version 3.0 (Diamond Interchanges), statistics concerning the performance of each driver-vehicle unit, and of the signal controller if used, are gathered during simulation and presented in summary form at the end of each run. For certain purposes, data concerning the cumulative experience of a driver-vehicle unit as it traversed its entire path through the interchange are desired. These data are accumulated in the TEXAS Model, Version 3.0 (Diamond Interchanges) from initial log-in at the outer end of the inbound lane to the first intersection until final log-out at the outer end of the outbound lane when the vehicle leaves the simulated interchange system. Another set of statistical data is collected beginning with log-in to the outer end of an *internal lane* until final log-out at the outer end of the outbound lane when the vehicle leaves the simulated interchange system. The latter data set permits separate analysis of the performance of traffic on the internal lanes and the second (downstream) intersection of the interchange. Differences between the two data sets indicate the behavior of traffic at the first intersection traversed.

ADDITIONAL FEATURES - VERSION 3.2

In response to specific requests from users of the TEXAS Model, and to other perceived needs, nine new features have been added to the Model to produce Version 3.2. The general functions of these enhancements are described here, and details are presented in Chapters 2 and 3.

1. Simulate Separate U-Turn Lanes at Diamond Interchanges

At diamond interchanges which must handle large traffic volumes through the two closely-spaced, at-grade intersections, it is usually difficult to provide signal phasing and timing plans that will accommodate heavy U-turns between the diagonal ramps on the same side of the interchange along with the other straight, left-turn, and right-turn movements in the intersections. Normally, the U-turning vehicles represent a considerable part of the intersection traffic demand, and delay, as they must pass through both intersections, making left turns at each, in order to reverse direction. Considerable benefits can sometimes be realized by providing a separate, free U-turn lane in advance of the two intersections to handle these vehicles, thereby removing them from the traffic that passes through the intersections.

A feature has been added to the TEXAS Model, Version 3.2 to prompt the user through the process of creating or deleting the geometric configuration of a free U-turn lane and adjusting the location of any detectors on the ramp that might be affected. Simulation of the behavior of individual vehicles using the free U-turn lane is handled in the usual way, and summary statistics are gathered and reported for this lane. Provisions are made for the user to specify the percentage of U-turning vehicles which will attempt to use the free U-turn lane. Vehicles which are unable to access the separate lane will proceed to the intersection ahead and maneuver through the two intersections by making two left turns.

Application of this new feature allows the user to evaluate the probable performance of a diamond interchange with and without separate, free U-turn lane(s) under various geometry, traffic, and traffic control conditions. The screen prompts make it easy to add or delete the separate lane before simulation.

2. Generate Exact Percentage of Desired Driver-Vehicle Units

Previously, due to the computational procedure that was used to generate driver-vehicle units on each intersection approach and allocate specified percentages to each lane, the assigned percentage did not always match exactly the user-specified value. New algorithms which correct this problem have been incorporated into Version 3.2. The process is transparent to the user, but now, assigned percentages of vehicles exactly match requested values.

3. Implement Sight-Distance Checking in the User-Friendly Version

In the original version of the TEXAS Model which ran only on mainframe computers, provision was made for drivers approaching the intersection to look for vehicles approaching on potentially-coinciding paths and adjust their speed in order to avoid a conflict in the intersection. In effect, a sight-triangle was established past any obstructions in the area between adjacent intersection legs. This sight-distance checking capability was not implemented in the user-friendly version of the model; however, it has again been made accessible to the user in Version 3.2. The user enters data to locate up to eight sight-distance restriction points. The model takes into account the effect of the obstructions as driver-vehicle units move toward and through the intersection.

4. Simulate NEMA Dual-Ring Traffic Signal Controllers

Simulation of traffic signal controllers in previous versions of the TEXAS Model has been accomplished by emulating the functions of electro-mechanical timer/camstack hardware. In Version 3.2, provisions have been made to simulate NEMA single-ring or dual-ring controllers with 2 to 8 phases. The user selects the type of controller to be simulated and responds to prompts to enter the controller data needed for the simulation. On-screen diagrams are used to aid the user in data entry.

5. Simulate Volume-Density Traffic Signal Controllers

In earlier versions, the TEXAS Model handled pretimed and actuated traffic signal controllers. Code has now been added to allow the Model to simulate the behavior of volume-density type controllers. Screen prompts guide the user in entering the data needed to utilize the various features of volume-density controllers. Summary statistics concerning the response of the controller with its volume-density features activated are gathered and reported.

6. Optional Traffic Phase Numbering for Traffic Signal Controllers

Default values for numbering the traffic phases at 4-leg intersections and at diamond interchanges have been provided in Version 3.2. The user may use a text editor to change these values if desired. On-screen diagrams and prompts are presented to aid the user in rearranging the traffic phase numbers into a more familiar or convenient order.

7. Presentation of Output Summary Statistics in Graphical Form

Provisions have been made in Version 3.2 to write summary statistics from simulation runs of the Model to a file that is compatible with Lotus 1-2-3 spreadsheet format. A series of macro-programs has been written to facilitate the display and analysis of these data. Screen prompts and menus aid the user in handling the graphical displays.

8. Generic Plotter-Driver Outputs and Interfaces

The TEXAS Model includes capabilities for plotting a plan view of the intersection or diamond-interchange geometry and vehicle paths through the intersection or interchange. Version 3.2 has added plot subroutines which are compatible with the requirements of a wide range of hardcopy devices and graphics-processing programs. The user is able to interface TEXAS Model output directly with various data-presentation devices.

9. Automated Process for Replicate Runs to Achieve Stability in Selected Measures of Effectiveness

A simulation run of the TEXAS Model is like taking a brief view of real-world traffic moving through an intersection. In the simulation, driver-vehicle units enter the intersection approaches with randomly-varying headways and then respond on a moment-by-moment basis, in a pre-programmed manner, to their static and dynamic surroundings. Thus, in the simulation, as in the real-world, there is variability in the traffic behavior which occurs during different short periods of time. To assess the relative magnitude of this variability on traffic flow, replicate runs of the simulation model can be made, using a different seed-number in the random-number generator which creates the headway distribution for vehicles approaching the intersection on each leg for each run. Then, appropriate measures of effectiveness, or indicators of performance, can be selected and evaluated to define a number of replicate runs which indicates a desired level of stability, or consistency, in the flow of traffic through the intersection.

In Version 3.2, a new computer operating system program has been added to automate replicate-run processing. The user simply responds to screen prompts to enter the desired number of replicate runs (1 to 10). The program executes the requested number or replications, making an appropriate change in the random-number seed between runs. Another optional replication feature allows the user to have the program execute the required number of replicate runs (3 to 10) needed to bring the resulting mean value of Overall Average Total Delay for all executed runs, with 95% statistical confidence, to within a specified (say 10%) percentage difference from the population mean for this selected measure of effectiveness. Finally, another program reads all replicate-run output statistics files for the job, calculates and prints statistical parameters, and optionally writes the statistics to a spreadsheet-compatible file. This automated replicate-run feature makes it convenient for the user to utilize the TEXAS Model with confidence that statistical variability in the selected measure of effectiveness is within reasonable tolerances.

CHAPTER 2. ADDITIONS, CHANGES, AND ENHANCEMENTS TO DATA ENTRY

The data-entry programs GDVDATA and SIMDATA have been revised to provide for entry of data needed for features which have been added to the TEXAS Model. These features include the creation of a non-device-specific geometry plot file (Objective 8), entry of sight distance restriction point coordinates (Objective 3), simulation of separate u-turn lanes at diamond interchanges (Objective 1), creation of a pollution-dispersion model data input file, and implementation of the NEMA 8-phase dual-ring signal controller (Objective 4) with volume-density options (Objective 5). The first two items are now included in the GDVDATA entry sequence, the third item is seen in both GDVDATA and SIMDATA, and the final two are handled in SIMDATA.

An additional data line has been added to a system-setup file to provide various traffic phase sequence numbering arrangements to suit individual needs (Objective 6).

Spreadsheet macros for use with Lotus 1-2-3 have been developed to aid in the review and analysis of summary statistics (Objective 7).

Two new operating system programs (DOS batch files, UNIX shell scripts, or VMS command procedures) have been written to make replicate-run processing easy. REPRUN will process a specific number of replicates and REPTOL will make a minimum of 3 replicate runs and continue running replicates until there is a 95% probability that the mean of Overall Average Total Delay of the replicates is within a specified percent of the mean of Overall Average Total Delay for the population (Objective 9). A new Simulation Statistics Processor SIMSTA has been written to calculate statistics for the sets of data produced by the replicate run processors.

OBJECTIVE 1. HANDLE SEPARATE U-TURN LANES AT DIAMOND INTERCHANGES

Free U-Turn Lane Geometry

A new set of screen prompts for creating free (separate) u-turn lanes has been added to GDVDATA (Figure 2.1). The prompts are displayed only when modeling a diamond interchange. These prompts make it easy to add a new, or remove an existing, free u-turn lane. A free u-turn lane is added or removed based upon the value in Field 1: a value of 0 (zero) specifies that no free u-turn lane is to be created, or an existing free u-turn lane is to be removed; whereas, a value in the range of 8 to 15 (feet) specifies that a free u-turn lane of that width is to be created.

```
FREE U-TURN LANE DATA:
F(1) - WIDTH OF LANE (0 FOR NO FREE U TURN LANE).  <0, 8 TO 15> [0]
F(2) - SPACE BETWEEN OUTER INTERNAL LANE AND FREE U-TURN LANE.  <0 TO 25> [10]
F(3) - LENGTH OF ENTRANCE LANE.  <20 TO 250> [100]
F(4) - RADIUS AT ENTRANCE.  <5 TO 100> [20]
F(5) - LENGTH OF EXIT LANE.  <20 TO 250> [100]
F(6) - RADIUS AT EXIT.  <5 TO 100> [20]
F(7) - PERCENT OF U-TURNING TRAFFIC TO USE THE FREE U-TURN.  <0 TO 100> [80]
*** L(1) IS FOR FREE U-TURN FROM LEG 3 TO LEG 4
*** L(2) IS FOR FREE U-TURN FROM LEG 6 TO LEG 1

L(1):  0  10 100  20 100  20  80
 (2): 15  10 100  20 100  20  80
 FLD: \1 \2/ \3/ \4/ \5/ \6/ \7/
```

Figure 2.1 Free u-turn lane data for diamond interchange

The free u-turn geometry comprises 5 segments: (1) a single, exclusive, inbound lane of specified length on the median (left) side of the external inbound ramp leg on one side of the diamond interchange, (2) an exclusive, circular-arc, intersection path tangent to the centerline of segment 1, tangent to the centerline of segment 3, and changing direction by approximately 90 degrees, (3) a single, exclusive, internal lane of calculated length with traffic control at the end of this internal lane, (4) an exclusive, circular-arc, intersection path tangent to the centerline of segment 3, tangent to the centerline of segment 5, and changing direction by approximately 90 degrees, and (5) a single, exclusive, outbound lane of specified length on the median (left) side of the external outbound ramp leg on the other side of the diamond interchange. The width of the free u-turn lane is specified with the same value for segments 1, 3, and 5.

If a free u-turn lane is requested, for example (see Fig 2.1) from Leg 3 (right side of diamond interchange northbound) to Leg 4 (left side of diamond interchange southbound), it is created automatically as follows. The number of inbound lanes on Leg 3 is increased by 1. All the properties of the inbound lanes are transferred to the next higher-numbered lane. The properties of the previously high-numbered lane (right-hand lane) are transferred to the newly-added lane and so-on until the properties of the previous Lane 1 (median lane) are transferred to Lane 2. Lane 1 is then available to be used as the entrance to the free u-turn lane. Its length and width are assigned from the values in data Fields 1 and 3. It is located geometrically to the left of the lane that was previously Lane 1. It is assigned a turn code of "U" to indicate that it is for u-turns only. A similar process is applied to Leg 4 to add the exit segment of the free u-turn lane. Next, a pseudo leg is created. This new leg has only one lane, with lane width as specified in Field 1 and is located parallel to the internal lanes of the diamond interchange. Field 2 specifies the distance between this lane and the right-hand edge of the internal lanes that are inbound to the right intersection. Finally, this new leg is connected to the entrance and exit lanes by circular segments. The radii of the left edge of these circular segments (curb returns) are specified in Fields 4 and 6, respectively, and their width is taken from Field 1.

To remove an existing free u-turn lane, simply change the value in Field 1 to 0 (zero) and the above process will automatically be reversed. Free u-turn lane data cannot be added to a file that was created by a previous version of GDVDATA. When revising such a file, an informative message will be issued in place of the free u-turn data prompts.

Free U-Turn Processing in SIMDATA

The Simulation Data Processor SIMDATA is aware of the free u-turn data in the GDVDATA reference data file and will make adjustments, as needed, in lane-control data, signal-sequence data and detector data. This is illustrated in Figs 2.2, 2.3 and 2.4. In each figure, the SIMDATA data shown in Part (a) resulted from the use of a reference file that had no free u-turn lanes. The reference file was then revised to add a free u-turn lane from Leg 3 to Leg 4. The adjustments made by SIMDATA are shown in Part (b) of each figure.

```
 LEG: /-IR\ /-2-\ /-3-\ /-5-\ /-6-\ /-IL\
LANE:  1  2  1  2  1  2  1  2  1  2  1  2
DATA: SI SI SI RT SI RT SI RT SI RT SI SI
 FLD: \1 \2 \3 \4 \5 \6 \7 \8 \9 10 11 12
```

(a) - Without free u-turns

```
 LEG: /-IR\ /-2-\ /---3--\ /-5-\ /-6-\ /-IL\
LANE:  1  2  1  2  1  2  3  1  2  1  2  1  2
DATA: SI SI SI RT YI SI RT SI RT SI RT SI SI
 FLD: \1 \2 \3 \4 \5 \6 \7 \8 \9 10 11 12 13
```

(b) -.With free u-turn from Leg 3 to Leg 4

Figure 2.2 Lane control data

Figure 2.2(b) shows the free u-turn entrance lane (Lane 1) added to Leg 3 with the default lane control "YI" (yield sign control). It is important to note that the lane control for a free u-turn will be applied at the exit end of the free u-turn internal lane (pseudo leg). Only "YI" or "ST" (stop sign control) are appropriate for a free u-turn lane.

The addition of the free u-turn lane (the column of data in Field 5) is also seen in Fig 2.3(b). The data "UN" (unsignalized) is appropriate for a sign-controlled lane.

```
  LEG: /-IR\ /-2-\ /-3-\ /-5-\ /-6-\ /-IL\
 LANE:  1  2  1  2  1  2  1  2  1  2  1  2
   MC: LS S  S  SR LS SR S  SR LS SR LS S
   LC: SI SI SI RT SI RT SI RT SI RT SI SI
 P(1):             C  C              LC C
  (2):       C  C                    LC C
  (3): LC C                    C  C
  (4): LC C              C  C
       ------------ OVERLAPS ------------
  (A):
  (B):
  (C):
  (D):
  FLD: \1 \2 \3 \4 \5 \6 \7 \8 \9 10 11 12
```

(a) - Without free u-turns

```
  LEG: /-IR\ /-2-\ /---3--\ /-5-\ /-6-\ /-IL\
 LANE:  1  2  1  2  1  2  3  1  2  1  2  1  2
   MC: LS S  S  SR U  LS SR S  SR LS SR LS S
   LC: SI SI SI RT YI SI RT SI RT SI RT SI SI
 P(1):             UN C  C              LC C
  (2):       C  C  UN                   LC C
  (3): LC C        UN             C  C
  (4): LC C        UN       C  C
       ------------- OVERLAPS --------------
  (A):             UN
  (B):             UN
  (C):             UN
  (D):             UN
  FLD: \1 \2 \3 \4 \5 \6 \7 \8 \9 10 11 12 13
```

(b) - With free u-turn from Leg 3 to Leg 4

Figure 2.3 Signal sequence data

Detector data are also revised to conform to the new geometry. The data in Field 2 indicates the first lane to be covered by a detector. Detector number 1 is located on Leg 3 and it can be seen by comparing Fig 2.4(a) with 2.4(b) that the data in Field 2 has been revised to exclude the new free u-turn entrance lane but to still cover the other two lanes.

When entering detector lane coverage data, the user should always consider the absence or presence of free u-turn lanes in the reference data file that is being used at that time. It is inappropriate to place a detector to cover Lane 1 if that lane is indeed a free u-turn lane. SIMDATA will not specifically prohibit this. However, if at a later time the reference file were revised to remove the free u-turn lane that is covered by a detector, the results will be invalid detector data.

```
                          LEG: /IR /2\ /3\ /5\ /6\ /IL
                         LANE: 1 2 1 2 1 2 1 2 1 2 1 2
D(1):  3 1 2     0  60 PR              X X
 (2):  2 1 2     0  60 PR          X X
 (3):  6 1 2     0  60 PR                      X X
 (4):  5 1 2     0  60 PR                  X X
 FLD: \1 2 3 \.4./ \5/ \6
```

(a) - Without free u-turns

```
                          LEG: /IR /2\ /-3-\ /5\ /6\ /IL
                         LANE: 1 2 1 2 1 2 3 1 2 1 2 1 2
D(1):  3 2 2     0  60 PR                X X
 (2):  2 1 2     0  60 PR          X X
 (3):  6 1 2     0  60 PR                        X X
 (4):  5 1 2     0  60 PR                    X X
 FLD: \1 2 3 \.4./ \5/ \6
```

(b) - With free u-turn from Leg 3 to Leg 4

Figure 2.4 Detector data

OBJECTIVE 2. GENERATE EXACT PERCENTAGE OF DESIRED DRIVER-VEHICLE UNITS

No changes to the user interface were required to implement this objective.

OBJECTIVE 3. IMPLEMENT SIGHT-DISTANCE CHECKING IN THE USER-FRIENDLY VERSION

Sight Distance Restrictions

GDVDATA now has provision for defining up to 8 sight distance restriction points. The prompts for entering these data are shown in Fig 2.5. The position of a point is defined by specifying three data items: a reference leg, a setback from the intersection center along the centerline of the reference leg, and an offset from the reference leg's centerline. For a diamond interchange, the reference leg must be an external leg. Points cannot be referenced from the internal lanes. Specifying 0 (zero) for the reference leg causes the point to be inactive. Initially, all 8 points are inactive by default.

The reference legs are only used in locating the points. The effect of points on traffic operation will be determined later and is dependent on the geometric relationship between points and all traffic lanes.

Sight distance restriction data cannot be added to a file that was created by a previous version of GDVDATA. When revising such a file, an informative message will be issued in place of the sight distance restriction data prompts.

```
SIGHT DISTANCE RESTRICTION LOCATION DATA:
F(1) - REFERENCE LEG USED WHEN LOCATING RESTRICTION  |        |        X
       POINT. (USE 0 FOR INACTIVE) <0, 1 TO 6> [0]   |        |        ↑
F(2) - SETBACK FROM INTERSECTION CENTER,             |        |        |
       ALONG REF. LEG CENTERLINE. <0 TO 250> [0]     |        |       F(3)
F(3) - OFFSET FROM REF. LEG CENTERLINE.           ---|        |-------- | -----
       (+ IS TO RIGHT WHEN LOOKING IN DIRECTION          ------F(2)--->|
       OF INBOUND TRAFFIC)  <-250 TO 250> [0]     ---|        |----------------
                                                     |        |

SDR(1):  0   0    0 (INACTIVE)
   (2):  2  50   30
   (3):  0   0    0 (INACTIVE)
   (4):  0   0    0 (INACTIVE)
   (5):  0   0    0 (INACTIVE)
   (6):  0   0    0 (INACTIVE)
   (7):  0   0    0 (INACTIVE)
   (8):  0   0    0 (INACTIVE)
  FLD: \1 \2/ \.3/
```

Figure 2.5 Sight distance restriction points

OBJECTIVE 4. SIMULATE NEMA DUAL-RING TRAFFIC SIGNAL CONTROLLERS

NEMA Signal Controller

The Simulation Processor SIMPRO has been revised to model a NEMA 8-phase dual-ring controller, with volume-density options available on a per-phase basis. The desire to use this controller can be indicated in SIMDATA by entering "N" for Field 4 of the Simulation Parameter-Option Data prompts (Fig 2.6). Later, SIMDATA will prompt for the number of controller phases in the range of 2 through 8. Choosing 8 (phases) will select a dual-ring controller with two phase groups (barriers). A choice of less than 8 (phases) will select a single-ring controller. The controller will have four programmable overlaps unless 2 or 3 (phases) are requested. A 3-phase controller will have three overlaps and a 2-phase controller will have no overlaps.

```
SIMULATION PARAMETER-OPTION DATA:
F(1) - START-UP TIME IN MINUTES. (STATISTICS NOT GATHERED)  <2.0 TO 5.0> [5.0]
F(2) - SIMULATION TIME IN MINUTES.  <10.0 TO 60.0> [FROM G&D-V REF. FILE]
F(3) - TIME INCREMENT FOR SIMULATION, "DT". (SUGGEST 1.0 FOR SIGNAL,
       0.5 FOR NON-SIGNAL)  <0.50 TO 1.00> [0.50]
F(4) - TYPE OF INTERSECTION CONTROL: <"U", "Y", "ST", "A", "P", "SE", "F", "N">
       "U" - UNCONTROLLED.                "Y" - YIELD.
       "ST" - STOP, LESS THAN ALL WAY.    "A" - ALL-WAY STOP.
       "P" - PRETIMED SIGNAL.             "SE" - SEMI-ACTUATED SIGNAL.
       "F" - FULL-ACTUATED SIGNAL.        "N" - NEMA ACTUATED SIGNAL.
F(5) - STATISTICAL SUMMARY BY TURNING MOVEMENT ?  <"YES" OR "NO"> ["YES"]
F(6) - STATISTICAL SUMMARY BY INBOUND APPROACH ?  <"YES" OR "NO"> ["YES"]
F(7) - COMPRESSED OUTPUT OF STATISTICS ?  <"YES" OR "NO"> ["NO"]
F(8) - VEHICLE POSITION (DISPLAY/POLLUTION) DATA ?  <"YES", "NO", "POL">["YES"]
F(9) - VEHICLE POSITION DATA ENDING TIME IN MINUTES.  <0.0 TO 70.0> [5.0]
F(10) - PRINTED OUTPUT USES 132 COLUMNS ("NO" USES 80) ? <"YES" OR "NO">["YES"]
F(11) - LEFT TURNING VEHICLES PULL INTO INTERSECTION ?  <"YES" OR "NO"> ["NO"]

DATA: 5.00 15.00 0.50 NEMA 8   YES YES NO  YES  5.0 YES NO
 FLD: \.1/ \.2./ \.3/ \...4../ \5/ \6/ \7/ \8/ \.9/ \10 \11
```

Figure 2.6 Simulation parameter-option data

The method used by SIMDATA for prompting for further controller data will depend on the controller configuration (single-ring or dual-ring) and the intersection geometry (single intersection or diamond interchange, and number of legs). One or two types of data must be defined: 1) The relationship between controller phases (including overlaps) and traffic phases. This relationship will then be used to create the Signal Sequence Data. Signal Sequence Data is equivalent to a diagram showing the connections between controller load switches and traffic signal faces. The Signal Sequence Data will later be shown in prompts for review and possible revision. 2) For a dual-ring controller only, the method depends on the phase selection priority to be used in each ring when a barrier is crossed.

For a standard 4-leg intersection with left-turn bays on each leg, there is a one-to-one relationship between traffic phases and controller phases, so this case is handled automatically.

For other cases such as a diamond interchange or an intersection with other than four legs, the user will be prompted to keyin data to describe this relationship. The prompts for a diamond interchange and a 4-phase, 4-overlap controller are shown in Fig 2.7.

```
TRAFFIC PHASES:

        | LEG 6 |               | LEG 1 |
        |       |               |       |
        |   2   |               |       |
---------   |   -----------------       ---------
               -- 4   INTERNAL         -- 6
LEG 5          /- 3            5 -/          LEG 2
      1 --              LANES   8 --
---------       -----------------   |   ---------
        |       |               |   7   |
        |       |               |       |
        | LEG 4 |               | LEG 3 |

KEYIN THE TRAFFIC PHASES TO BE IN CONTROLLER PHASE 1. (OR "NONE")
1 TO 4 INTEGERS, SEPARATED BY COMMAS:
1
TRAFFIC PHASE 1 IS TO BE IN CONTROLLER PHASE 1. IS THIS OK ?
Y

KEYIN THE TRAFFIC PHASES TO BE IN CONTROLLER PHASE 2. (OR "NONE")
1 TO 4 INTEGERS, SEPARATED BY COMMAS:
2
TRAFFIC PHASE 2 IS TO BE IN CONTROLLER PHASE 2. IS THIS OK ?
Y

KEYIN THE TRAFFIC PHASES TO BE IN CONTROLLER PHASE 3. (OR "NONE")
1 TO 4 INTEGERS, SEPARATED BY COMMAS:
6
TRAFFIC PHASE 6 IS TO BE IN CONTROLLER PHASE 3. IS THIS OK ?
Y

KEYIN THE TRAFFIC PHASES TO BE IN CONTROLLER PHASE 4. (OR "NONE")
1 TO 4 INTEGERS, SEPARATED BY COMMAS:
7
TRAFFIC PHASE 7 IS TO BE IN CONTROLLER PHASE 4. IS THIS OK ?
Y

KEYIN THE TRAFFIC PHASES TO BE IN CONTROLLER OVERLAP A. (OR "NONE")
1 TO 4 INTEGERS, SEPARATED BY COMMAS:
8
TRAFFIC PHASE 8 IS TO BE IN CONTROLLER OVERLAP A. IS THIS OK ?
Y

KEYIN THE TRAFFIC PHASES TO BE IN CONTROLLER OVERLAP B. (OR "NONE")
1 TO 4 INTEGERS, SEPARATED BY COMMAS:
4
TRAFFIC PHASE 4 IS TO BE IN CONTROLLER OVERLAP B. IS THIS OK ?
Y

KEYIN THE TRAFFIC PHASES TO BE IN CONTROLLER OVERLAP C. (OR "NONE")
1 TO 4 INTEGERS, SEPARATED BY COMMAS:
5
TRAFFIC PHASE 5 IS TO BE IN CONTROLLER OVERLAP C. IS THIS OK ?
Y

KEYIN THE TRAFFIC PHASES TO BE IN CONTROLLER OVERLAP D. (OR "NONE")
1 TO 4 INTEGERS, SEPARATED BY COMMAS:
3
TRAFFIC PHASE 3 IS TO BE IN CONTROLLER OVERLAP D. IS THIS OK ?
Y
```

Figure 2.7 Associating traffic phases with controller phases

For the case of a standard 4-leg intersection with left-turn bays on each leg, the procedure for selecting the dual-ring phase sequencing is shown in Figs 2.8(a), 2.8(b) and 2.8(c). The procedure for other cases is very similar. Figure 2.8(a) shows the selection of leading left turns for the E-W street (Leg 2 and Leg 4). Figure 2.8(b) shows the selection of lagging left turns for the N-S street (Leg 1 and Leg 3). Figure 2.8(c) reports the result of these two choices. Note that the order of phases in the Ring-Group diagram have been rearranged from the usual to indicate the choices. In particular, phases in Group 2 have been reordered to indicate that Phases 4 and 8 (the straight movements) will have first priority to be served when the barrier is crossed.

```
THE CONTROLLER HAS 8 TIMED PHASES AND 4 PROGRAMMABLE OVERLAPS.

THE CONTROLLER HAS 2 RINGS AND 2 PHASE GROUPS.
THE PHASE GROUPS ARE SEPARATED BY BARRIERS.
         LEG 1

          4 7
          : \
                --2   LEG            GROUP  GROUP
LEG   1-/       /-5    2               1      2
 4    6--                            |------|------|
             \ :           RING 1    | _  _ |      |
             3 8                     |------|------|
                           RING 2    | _  _ |      |
           LEG 3                     |------|------|

SELECT PHASE SEQUENCING FOR GROUP 1 (PHASES 1, 2, 5 AND 6).
1 - LEFT TURN MOVEMENTS 1 AND 5 FIRST.
2 - LEAD-LAG LEFTS WITH MOVEMENTS 2 AND 5 FIRST.
3 - LEAD-LAG LEFTS WITH MOVEMENTS 1 AND 6 FIRST.
4 - STRAIGHT MOVEMENTS 2 AND 6 FIRST.
KEYIN THE NUMBER OF THE DESIRED PHASE SEQUENCE:

1
PHASE SEQUENCE NUMBER 1 IS SELECTED. IS THIS OK ?
Y
```

Figure 2.8(a) Selecting phase sequence for phases in Group (Barrier) 1

```
          LEG 1

           4 7
           : \
                 --2   LEG              GROUP  GROUP
LEG    1-/       /-5    2                 1      2
 4     6--                             |------|------|
             \ :              RING 1   | 1  2 | _  _ |
             3 8                       |------|------|
                              RING 2   | 5  6 | _  _ |
            LEG 3                      |------|------|

SELECT PHASE SEQUENCING FOR GROUP 2 (PHASES 3, 4, 7 AND 8).
1 - LEFT TURN MOVEMENTS 3 AND 7 FIRST.
2 - LEAD-LAG LEFTS WITH MOVEMENTS 4 AND 7 FIRST.
3 - LEAD-LAG LEFTS WITH MOVEMENTS 3 AND 8 FIRST.
4 - STRAIGHT MOVEMENTS 4 AND 8 FIRST.
KEYIN THE NUMBER OF THE DESIRED PHASE SEQUENCE:
4
PHASE SEQUENCE NUMBER 4 IS SELECTED. IS THIS OK ?
Y
```

Figure 2.8(b) Selecting phase sequence for phases in Group (Barrier) 2

```
          LEG 1

           4 7
           : \
                 --2   LEG              GROUP  GROUP
LEG    1-/       /-5    2                 1      2
 4     6--                             |------|------|
             \ :              RING 1   | 1  2 | 4  3 |
             3 8                       |------|------|
                              RING 2   | 5  6 | 8  7 |
            LEG 3                      |------|------|

PRESS THE <RETURN> KEY TO CONTINUE . . .
```

Figure 2.8(c) Selected sequence for phases in both groups (Barriers)

OBJECTIVE 5. SIMULATE VOLUME-DENSITY TRAFFIC SIGNAL CONTROLLERS

Volume-Density Option for NEMA Signal Controller

Prompting for phase timing data will result in a screen display as shown in Fig 2.9. Notice that Field 11 indicates the desire to use the controller's volume-density options. If "YES" appears in Field 11 for any phase, then the volume-density data prompts shown in Figure 2.7 will be presented. If Field 11 is "NO" for all phases, then the volume-density data prompt will be skipped.

```
NEMA ACTUATED CONTROLLER SIGNAL TIMING DATA:
F(1) - INITIAL INTERVAL.  <"DT" TO 99.0> [3.0]
F(2) - VEHICLE INTERVAL. <"DT" TO 99.0> [2.0]
F(3) - YELLOW-CHANGE INTERVAL.  <1.0 TO 9.0> [3.0]
F(4) - ALL RED-CLEARANCE INTERVAL.  <0.0 TO 9.0> [0.5]
F(5) - MAXIMUM EXTENSION. <0 TO 99>  [30]
F(6) - DUAL ENTRY PHASE. (0 = SINGLE ENTRY PERMITTED)  <0 TO 8> [0]
F(7) - PROVISION FOR STORING DEMAND ? <"YES" OR "NO"> [YES]
F(8) - ENABLE MAXIMUM RECALL ? <"YES" OR "NO"> [NO]
F(9) - ENABLE MINIMUM RECALL ? <"YES" OR "NO"> [NO]
F(10) - PLACE CALL ON MAX-OUT ? <"YES" OR "NO"> [YES]
F(11) - USE VOLUME DENSITY OPTIONS ?  <"YES" OR "NO"> [NO]
** DATA IN FIELDS 1 THROUGH 4 WILL BE AUTOMATICALLY ROUNDED TO THE NEAREST "DT".

P(1):  3.0  2.0 3.0 0.5 30  0 YES NO  NO  YES NO
 (2):  3.0  2.0 3.0 0.5 30  0 YES NO  NO  YES NO
 (3):  3.0  2.0 3.0 0.5 30  0 YES NO  NO  YES NO
 (4):  3.0  2.0 3.0 0.5 30  0 YES NO  NO  YES YES
 (5):  3.0  2.0 3.0 0.5 30  0 YES NO  NO  YES NO
 (6):  3.0  2.0 3.0 0.5 30  0 YES NO  NO  YES NO
 (7):  3.0  2.0 3.0 0.5 30  0 YES NO  NO  YES NO
 (8):  3.0  2.0 3.0 0.5 30  0 YES NO  NO  YES YES
 FLD: \.1/ \.2/ \3/ \4/ \5 \6 \7/ \8/ \9/ \10 \11

IS NEMA ACTUATED CONTROLLER SIGNAL TIMING DATA OK ?
```

Figure 2.9 NEMA actuated controller signal timing data

```
NEMA ACTUATED CONTROLLER VOLUME DENSITY DATA:
F(1) - USE VOLUME DENSITY OPTIONS FOR THIS PHASE ?  <"YES" OR "NO">
F(2) - ADDED INITIAL INTERVAL PER ACTUATION.  <0.000 TO 3.000> [0.125]
F(3) - MAXIMUM INITIAL INTERVAL.  <1 TO 60> [30]
F(4) - MINIMUM VEHICLE INTERVAL. <0.000 TO 7.750>  [2.000]
F(5) - TIME BEFORE STARTING TO REDUCE VEHICLE INTERVAL. <1 TO 60> [5]
F(6) - TIME PERIOD FOR REDUCING VEHICLE INTERVAL. <1 TO 60> [5]

P(1): NO  0.100 30 3.000  5  5
 (2): NO  0.100 30 3.000  5  5
 (3): NO  0.100 30 3.000  5  5
 (4): YES 0.100 30 3.000  5  5
 (5): NO  0.100 30 3.000  5  5
 (6): NO  0.100 30 3.000  5  5
 (7): NO  0.100 30 3.000  5  5
 (8): YES 0.100 30 3.000  5  5
 FLD: \1/ \.2./ \3 \.4./ \5 \6

IS NEMA ACTUATED CONTROLLER VOLUME DENSITY DATA OK ?
```

Figure 2.10 NEMA actuated controller volume density data

OBJECTIVE 6. PROVIDE USER CHOICE BETWEEN "CITY OF DALLAS" AND "TXDOT" NUMBERING SCHEME FOR TRAFFIC PHASES AT DIAMOND INTERCHANGES

Alternate Traffic Phase Numbering

An optional line has been added to the TEXAS Model configuration file. If this file has only seven lines (see Fig 2.11(a)), the default traffic phase numbering will be used. The defaults are shown in Fig 2.11(b) for a 4-leg intersection and in Fig 2.11(c) for a diamond interchange.

To use an alternate traffic phase numbering plan, use a text editor to add Line 8 to the configuration file. The first eight columns in this line are for specifying alternate traffic phase numbering for 4-leg intersections and the second eight columns are for diamond interchanges. To make changes for only one of the two types of intersections, supply exactly eight digits for that type intersection and leave the other eight columns blank. Only digits 1 through 8 are acceptable and there must be no duplication among the eight digits for either type of intersection. Figure 2.12(a) shows the configuration file with this optional line. The particular traffic phase numbering in Fig 2.12(a) is provided to show the relationship of the order of the digits in the configuration file and the traffic phase designations on the diagrams shown in Figs 2.12(b) and 2.12(c).

```
   6  21    6    2   -1    2    0    0    0    0    0    0    0    0    0    0    0    0    0    0
C:\TEXAS\SYS_DAT\                        C:\TEXAS\SYS_DAT\
C:\TEXAS\USER_DAT\GDDATA                 C:\TEXAS\USER_DAT\SIMDATA
C:\TEXAS\USER_DAT\                       C:\TEXAS\USER_DAT\
UG_LIB                                   17
CON                                      10
IBMPC                                     5
```

(a) - Configuration file (DOS version)

```
TRAFFIC PHASES:

              LEG 1

               4 7
               : \
                     --2    LEG
     LEG    1-/      /-5     2
      4     6--
                 \ :
                 3 8

                LEG 3
```

(b) - 4-Leg intersection

```
TRAFFIC PHASES:

        | LEG 6 |                | LEG 1 |
        |       |                |       |
        |   2   |                |       |
---------   |   -----------------       ---------
           -- 4   INTERNAL             -- 6
LEG 5      /- 3             5 -/           LEG 2
     1 --          LANES    8 --
---------       -----------------   |   ---------
        |       |                |  7    |
        |       |                |       |
        | LEG 4 |                | LEG 3 |
```

(c) - Diamond interchange

Figure 2.11 Default traffic phase designations

```
   6  21    6    2  -1    2    0    0    0    0    0    0    0    0    0    0    0    0    0    0
C:\TEXAS\SYS_DAT\                       C:\TEXAS\SYS_DAT\
C:\TEXAS\USER_DAT\GDDATA                C:\TEXAS\USER_DAT\SIMDATA
C:\TEXAS\USER_DAT\                      C:\TEXAS\USER_DAT\
UG_LIB                                  17
CON                                     10
IBMPC                                    5
1234567812345678
```

(a) - Configuration file (DOS version)

```
TRAFFIC PHASES:

              LEG 1

               1 5
               : \
                     --2   LEG
     LEG   8-/       /-6    2
      4    4--
                 \ :
                 7 3

                LEG 3
```

(b) - 4-leg intersection

```
TRAFFIC PHASES:

        | LEG 6 |                | LEG 1 |
        |       |                |       |
        |   6   |                |       |
---------   |   -----------------       ---------
           -- 4   INTERNAL         -- 1
LEG 5      /- 8              7 -/          LEG 2
      5 --          LANES    3 --
---------       -----------------   |   ---------
        |       |                |  2    |
        |       |                |       |
        | LEG 4 |                | LEG 3 |c
```

(c) - Diamond interchange

Figure 2.12 An alternate traffic phase designation plan

Be cautious when selecting alternate traffic phase numbers for 4-leg intersections that may be controlled by a NEMA 8-phase dual-ring controller. For this case, traffic phases will correspond exactly to controller phases. The selection must be compatible with the standard dual-ring phase-sequence diagram (Fig 2.13).

```
             GROUP  GROUP
               1      2
            |------|------|
   RING 1   | 1  2 | 3  4 |
            |------|------|
   RING 2   | 5  6 | 7  8 |
            |------|------|
```

Figure 2.13 NEMA dual-ring phase-sequence diagram

Information about the configuration file is shown in Fig 2.14. The TEXAS Model processors will search for the configuration file in the primary location and then in the secondary location. If the file is not found, the processor will end with an error.

OPERATING SYSTEM	FILE NAME	PRIMARY LOCATION	SECONDARY LOCATION
UNIX	GDVS00	default directory	/usr/texas/sys_dat
DOS	GDVS00	\TEXAS	\TEXAS\SYS_DAT
VMS	GDVS00.DAT	default directory	TEXAS_SYS_DAT:

Figure 2.14 TEXAS Model configuration file

This alternate traffic phase numbering feature is not applicable to the Texas Diamond Controller option as the phase locations for this controller are defined by the controller specification.

OBJECTIVE 7. PRESENT OUTPUT SUMMARY STATISTICS IN GRAPHICAL FORM (SPREADSHEET-COMPATIBLE OUTPUT FORMAT)

The Simulation Statistics Processor SIMSTA has an option to write summary statistics to a file that can be read by the spreadsheet program Lotus 1-2-3 Version 2.4 or newer using the DOS operating system. This option is activated by including the "SS" parameter on the command line when running SIMSTA. To import a summary statistics file into Lotus 1-2-3, set the spreadsheet cell pointer to A1 then activate the main menu by keying in `/` , then select `File` from the menu, then select `Import`, then `Numbers`, then enter the name of the spreadsheet compatible summary statistics file. To view the spreadsheet data, set column A width to 54, set column B through I width to 9, and Detach WYSIWYG if necessary.

A set of spreadsheet macros has been written to aid in the display and analysis of these data. The macros are in a Macro Library file named \TEXAS\SYS_DAT\TEXAS_M1.MLB. This command sequence may be used to attach the Add-In named MACROMGR (Macro Manager) and load the macro when in the \TEXAS sub-directory: `/ Add-In Attach MACROMGR.ADN No-Key Invoke MACROMGR Load SYS_DAT\ TEXAS_M1.MLB Quit`. In addition the Add-Ins ICONS and WYSIWYG must be attached. See the Lotus 1-2-3 manuals for complete instructions.

Once the summary statistics file has been imported into the spreadsheet and the macros installed, proceed as follows:

1) To start the macro, hold down the ALT key and press G. A screen with options will appear as shown in Fig 2.15.

2) To choose a measure of effectiveness, use the mouse to point and click on the appropriate label (U1 through U10) in the column on the right edge of the screen.

3) A menu as shown in Fig 2.16 will appear. To choose to examine one approach, several approaches or the entire intersection, press the first letter of the selection of your choice.

4) If you choose one approach, indicate your choice by using the left and right arrow keys to move the cursor at the top left of the screen to the approach number of your choice, then press the Return key. See Fig 2.17.

   If you choose several approaches, you will be prompted for the approaches that you wish to examine. See Fig 2.18. For each approach, keyin it's number and press the Return key. When your list is complete, press 9 and then press the Return key.
   The chosen graph will now appear.

5) When finished viewing the graph, press the Return key. The prompt shown in Fig 2.19 will appear. Choose the desired option.

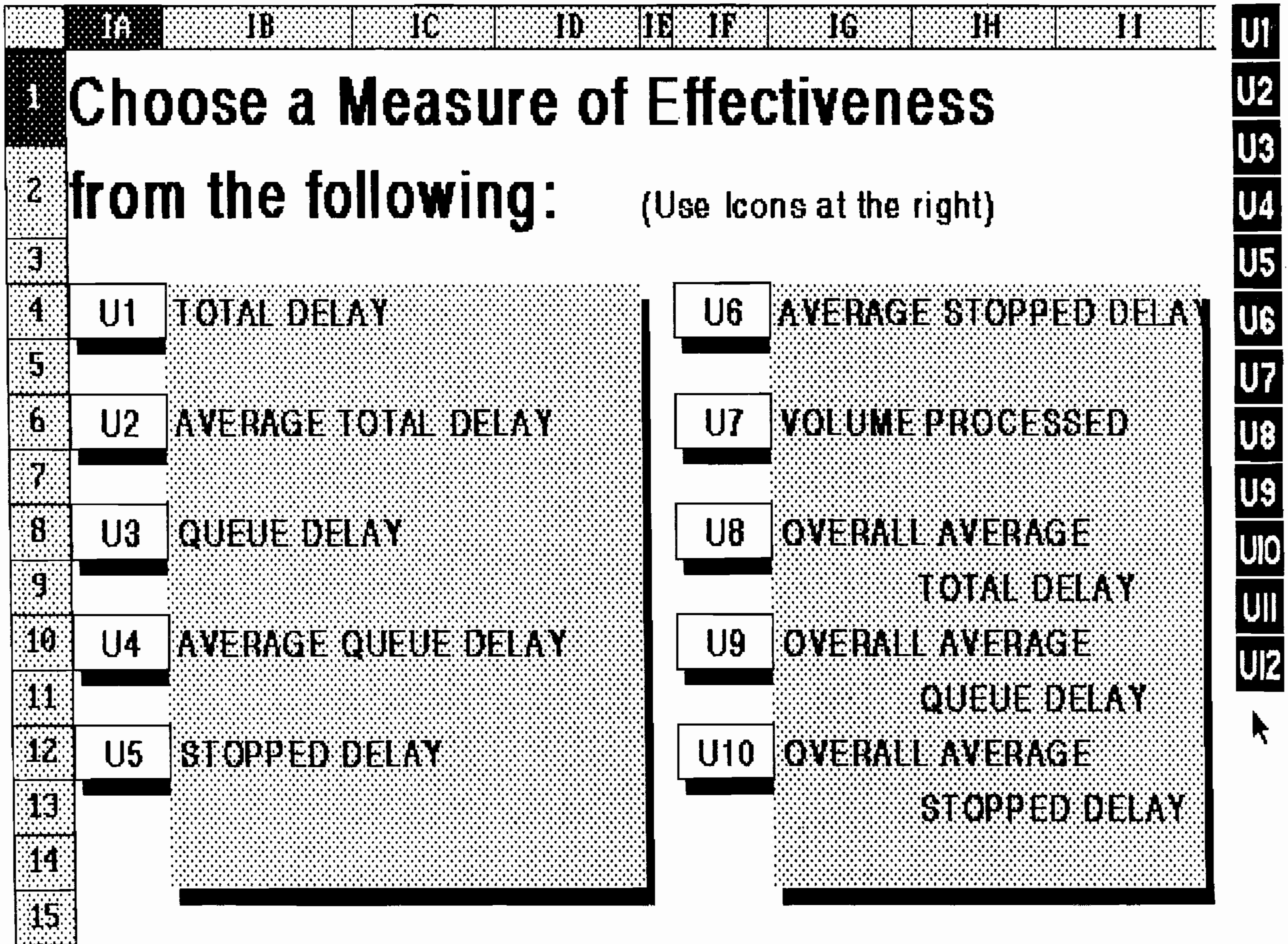


Figure 2.15 Spreadsheet Prompt Screen Image

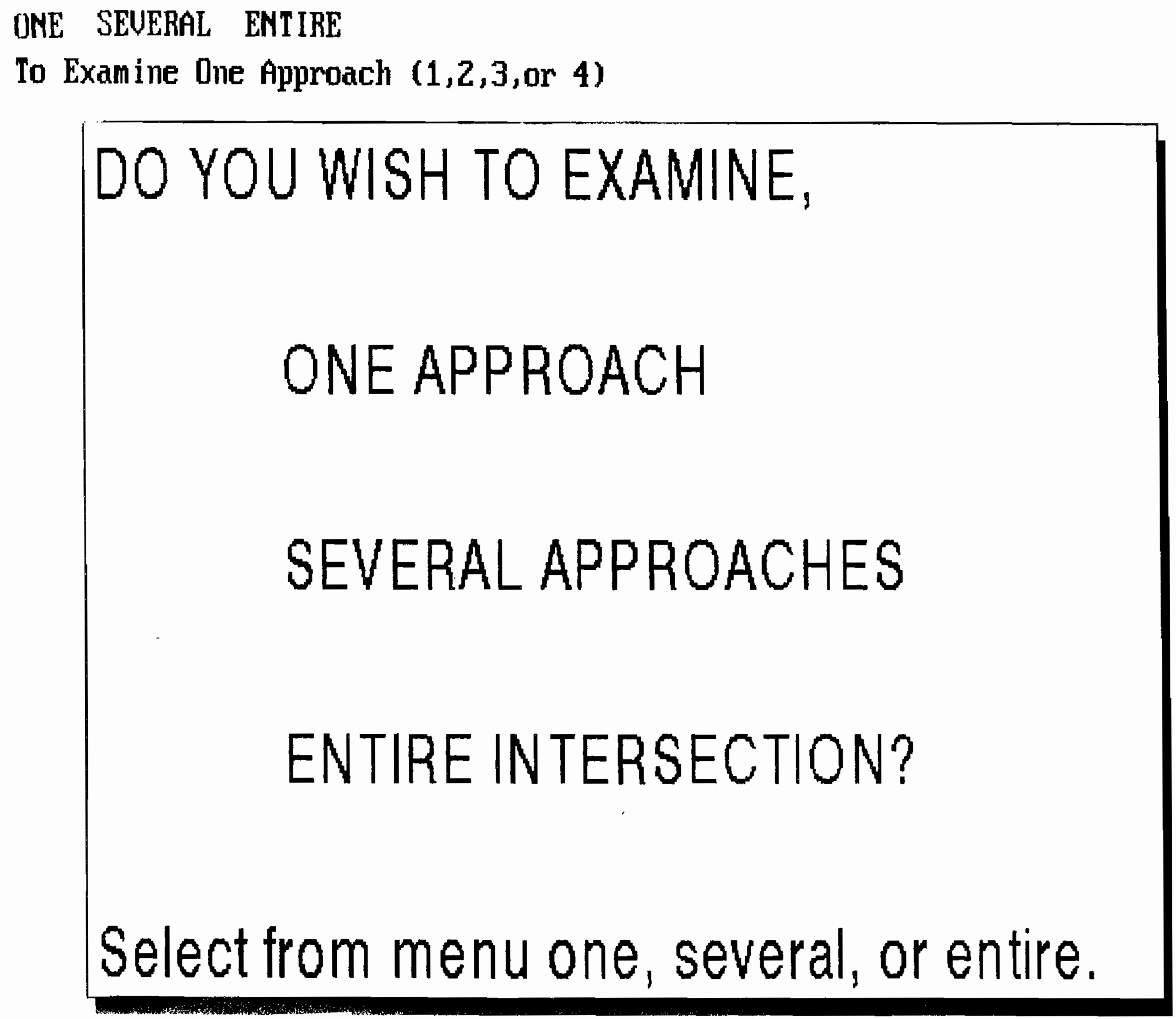


Figure 2.16 Spreadsheet Prompt Screen Image

1 2 3 4 5 6 7 8

APPROACH 2

Which approach you want to examine?

APPROACH 1	APPROACH 5
APPROACH 2	APPROACH 6
APPROACH 3	APPROACH 7
APPROACH 4	APPROACH 8

Figure 2.17 Spreadsheet Prompt Screen Image

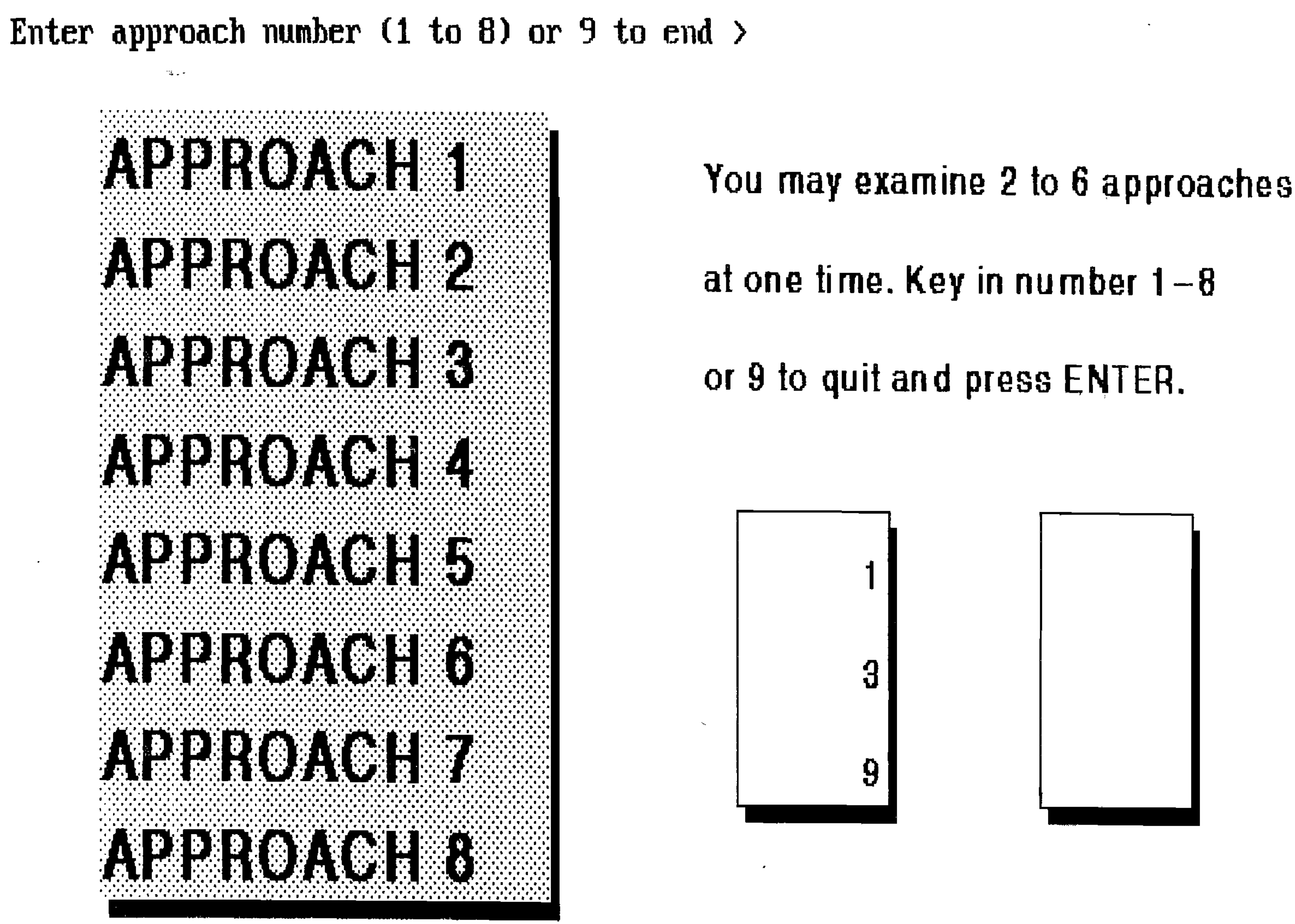


Figure 2.18 Spreadsheet Prompt Screen Image

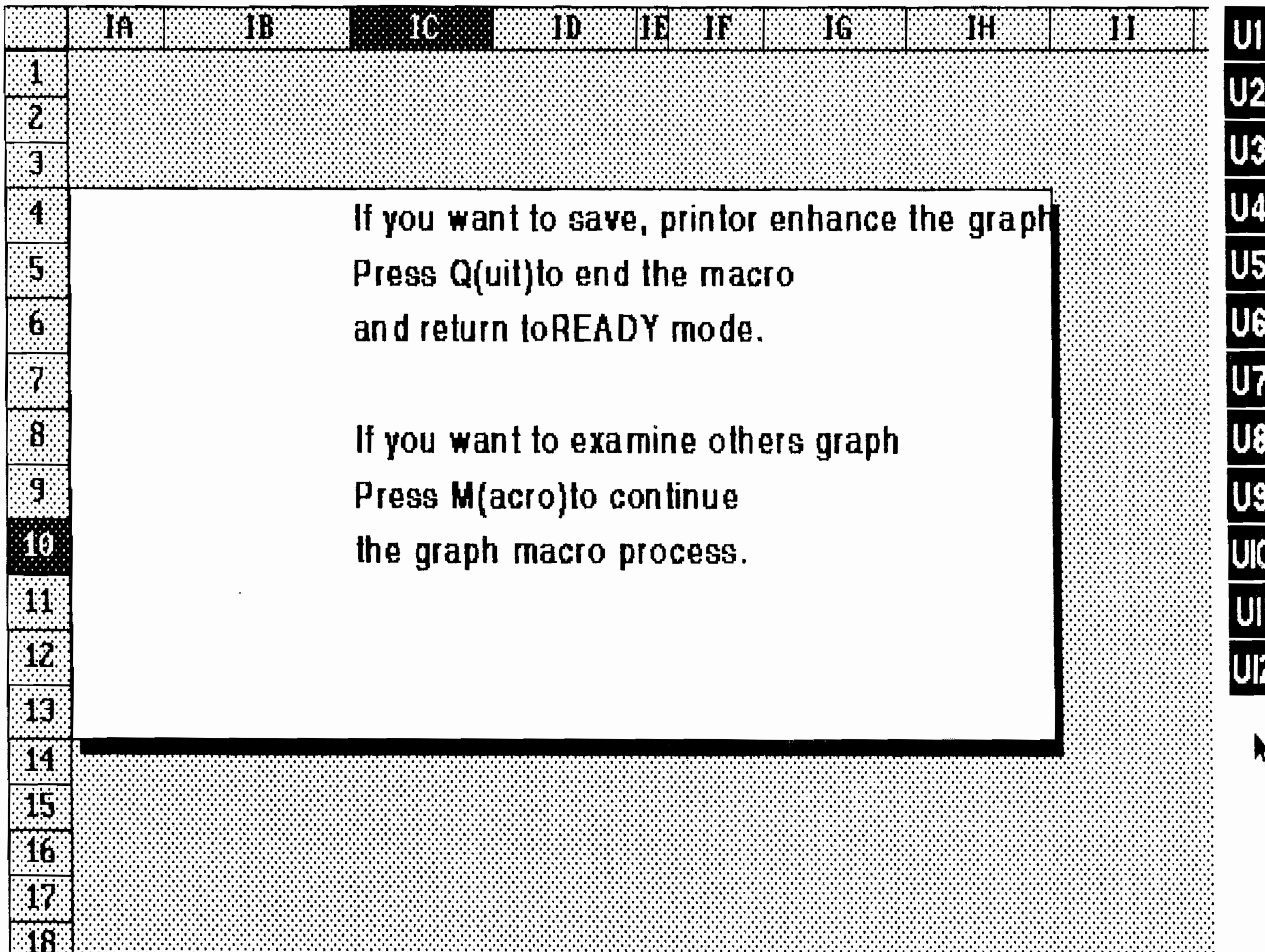


Figure 2.19 Spreadsheet Prompt Screen Image

OBJECTIVE 8. DEVELOP GENERIC PLOTTER-DRIVER OUTPUT ROUTINES AND INTERFACE CAPABILITIES TO SELECTED TYPES OF PLOTTERS

Geometry Plot

The Geometry Processor GEOPRO has provision to plot the intersection plan view. Several plot pages are produced. The first is an overall view and will show the entire length of all lanes. The next will be a close up view of the intersection and only a section of the lanes nearest the intersection will be shown. The third will be similar to the second, but all of the possible vehicle paths through the intersection will also be shown. Plot devices with color capability will show left-turn paths in red, straight paths in black (or white) and right turn paths in blue. For diamond interchanges, additional close-up views of each side of the diamond, with vehicle paths shown, will also be plotted.

Data to request creation of the geometry plot file are in the last two fields of the GDVDATA Parameter-Option data (Figure 2.20, data for diamond interchange is shown, but geometry plotting is valid for non-diamond interchanges also). The plot size entered in the last field specifies the dimensions of a square plotting surface, in inches. Please note that plotters usually cannot use the full paper width for plotting. The 7.5 default value will usually be satisfactory for plotters that use 8.5 inch wide paper. If the specified size exceeds the plotter's capacity, the result can be unpredictable, but usually the graphics that should appear beyond the plotters limit are simply not drawn and the plot appears as if part of it's right edge has been clipped off.

If requested, creation of the plot data file is done by GEOPRO. Plotting of the data is then done by the Geometry Plot Processor GEOPLOT.

```
PARAMETER-OPTION DATA FOR DIAMOND INTERCHANGE:
F(1) - TOTAL (STARTUP+SIMULATION) TIME IN MINUTES.  <1 TO 65> [20]
F(2) - MINIMUM HEADWAY IN SECONDS.  <1.0 TO 3.0> [1.0]
F(3) - NUMBER OF VEHICLE CLASSES.  <12> [12]
F(4) - NUMBER OF DRIVER CLASSES.  <3> [3]
F(5) - PERCENT OF LEFT TURNING VEHICLES TO ENTER IN MEDIAN LANE.<50 TO 100>[80]
F(6) - PERCENT OF RIGHT TURNING VEHICLES TO ENTER IN CURB LANE. <50 TO 100>[80]
F(7) - CREATE A GEOMETRY PLOT DATA FILE ? <"YES" OR "NO"> ["YES"]
F(8) - SIZE OF GEOMETRY PLOT (INCHES). <4.0 TO 34.0> [7.50]
EDIT EXAMPLE: "F(6)=75" CHANGES FIELD 6 TO "75", OTHER FIELDS REMAIN UNCHANGED
KEYIN "HELP" FOR ADDITIONAL ASSISTANCE

  DATA FIELDS:      20  1.0   12    3   80    80 YES  7.50
FIELD NUMBERS:    \.1/ \.2/ \.3/ \.4/ \.5/ \.6/ \7/ \.8./
```

Figure 2.20 Parameter option data for Diamond Interchange

OBJECTIVE 9. AUTOMATE THE REQUIRED NUMBER OF REPLICATE RUNS TO ACHIEVE STABILITY IN SELECTED MEASURES OF EFFECTIVENESS

Replicate Run Processor

A new computer operating system program (DOS batch file, UNIX shell script, or VMS command procedure) named REPRUN has been written to automate replicate run processing. The user is only required to supply the number of replicates (1 through 10), the name of the GDVDATA created file and the name of the SIMDATA created file. REPRUN will make the requested number of runs, with appropriate changes to the random number seeds between runs. Data files from each run will be identified by the suffix R*n* where *n* is the replicate run number. To make 5 replicate runs using testg.dat as the GDVDATA file and tests.dat as the SIMDATA file, the following command would be entered:

```
reprun 5 testg.dat tests.dat
```

To make the 6th replicate run using testg.dat as the GDVDATA file and tests.dat as the SIMDATA file, the following command would be entered:

```
reprun 6 testg.dat tests.dat 6
```

To make the 7th and 8th replicate run using testg.dat as the GDVDATA file and tests.dat as the SIMDATA file, the following command would be entered:

```
reprun 8 testg.dat tests.dat 7
```

The replicate run processor will delete the files listed below before beginning the simulation processing. The "*n* " in the file names represents the group of files in which "*n* " is the number of the first replicate run through 10.

GDV.REP	GPDATA.REP	GEOLIST.REP	DVDATA.REP
SIM.REP	SIMSTAT.REP	PARAMS.REP	DVLIST.R*n*
SIMPLST.R*n*	SIMERR.R*n*	SIMSTAT.R*n*	POSDAT.R*n*

Replicate Runs with Tolerance Checking

REPTOL is an additional replicate run processor. It does not make a specified number of runs, but runs replicate 1,2, and 3 first and then continues to make replicate runs until a certain statistical criteria is met or until a maximum of 10 replicate runs are processed. The criteria is that, with 95% confidence, the mean of Overall Average Total Delay for the replicate runs is within a specified percent of the Overall Average Total Delay for the population. REPTOL always makes at least 3 runs. As with REPRUN, the files specified above are deleted before the beginning of simulation. REPTOL is the suggested method for making replicate runs of the TEXAS Model. To make replicate runs using a tolerance value of 10%, testg.dat as the GDVDATA file, and tests.dat as the SIMDATA file, the following command would be entered: `reptol 10 testg.dat tests.dat`

Replicate Run Statistics Processor

A new Simulation Statistics processor is called SIMSTA. SIMSTA reads all replicate-run output statistics files for a given job, calculates statistics, prints statistics, optionally writes the statistics to a spreadsheet-compatible file, and optionally checks for a user-specified statistical tolerance being achieved (a feature used by the REPTOL processor).

ADDITIONAL ENHANCEMENTS

Changes to Simulation Parameter-Option Data 1

Vehicle Position Data for Emissions Processor. — Field 8 of SIMDATA Simulation Parameter-Option Data (Fig 2.6) now has provision for the option "POL". This option requests creation of a data file for input to the Emissions Processor EMPRO. As before, the "YES" options requests a data file for input to the Animation Preprocessor DISPRE. Collection of animation data will begin at time = 0.0 and will end at the time specified in Field 9. Collection of emission data will not begin until after the startup time, as specified in Field 1 and will continue until the end of simulation. A file created with the "YES" option can only be read by DISPRE and a file created with the "POL" option can only be read by EMPRO.

Printed Output — Field 10 permits the selection of wide or narrow printed output of the summary statistics. Narrow output will fit within 80 columns and prints a new page for each column of statistics (1 per turn code plus total). Wide output will use up to 132 columns , but all columns of related statistics are printed on a single page. For example, when printing statistics concerning approaches, a four-leg intersection using narrow output will generally use four pages for approach statistics. Wide output will use only one page but will require the ability to view 132 columns of data. Wide output will produce a more compact and readable file, so is the recommended choice. Virtually all dot matrix printers can be set for compressed printing to process 132 columns on 8.5 inch wide paper.

Left-Turning Vehicle Entering Intersection — Field 11 provides the option of permitting left-turning vehicles at signalized intersections to pull into the intersection while waiting for an acceptable gap. If "NO", left-turning vehicles will wait at the stop line. If "YES", the first vehicle may pull into the intersection to within 10 feet of the first point of potential intersection conflict and wait at that point. Additional vehicles may also cross the stop line and pull into the intersection as far as allowed by car-following algorithms. Any vehicles that have crossed the stop line more than 4 feet will proceed to complete the left-turn maneuver when the yellow-change signal indication is displayed.

Changes to Simulation Parameter-Option Data 2

SIMPRO was modified to add an intersection conflict avoidance procedure for all vehicles which have the right to enter the intersection. This procedure modifies the speed of the vehicle to maintain the safety zones before and after every other vehicle which has the right to enter the intersection. This modification allows lower values for the lead and lag zones in the intersection conflict checking procedure. Therefore, the default values for both Fields 6 and 7 have been changed to 0.8. It was found that by using these values, delay to left-turning vehicles determined by simulation more closely matched delays observed in the field. The prompt with these new values is shown in Fig 2.21.

```
SIMULATION PARAMETER-OPTION DATA 2:
F(1) - SPEED BELOW WHICH A SPECIAL DELAY STATISTIC IS COLLECTED. <0 TO 40> [10]
F(2) - MAXIMUM CLEAR DISTANCE FOR BEING IN A QUEUE.  <4 TO 40> [30]
F(3) - CAR FOLLOWING EQUATION PARAMETER LAMBDA.  <2.300 TO 4.000> [2.800]
F(4) - CAR FOLLOWING PARAMETER MU.  <0.600 TO 1.000> [0.800]
F(5) - CAR FOLLOWING PARAMETER ALPHA.  <0 TO 10000> [ 4000]
F(6) - TIME FOR LEAD ZONE USED IN CONFLICT CHECKING.  <0.50 TO 3.00> [0.80]
F(7) - TIME FOR LAG ZONE USED IN CONFLICT CHECKING.  <0.50 TO 3.00> [0.80]

DATA: 10  30 2.800 0.800  4000 0.80 0.80
 FLD: \1 \2/ \.3./ \.4./ \.5./ \.6/ \.7/
```

Figure 2.21 Simulation parameter-option data 2

CHAPTER 3. ADDITIONS, CHANGES, AND ENHANCEMENTS TO PROCESSORS

OBJECTIVE 1. HANDLE SEPARATE U-TURN LANES AT DIAMOND INTERCHANGES

Additions, Changes, and Enhancements to GEOPRO

A check was added that allows a u-turn at a diamond interchange to be made only from the median lane (Lane 1). Additionally, a procedure for correctly building u-turn paths through the diamond interchange was added.

Additions, Changes, and Enhancements to DVPRO

An option was provided for specifying the percentage of u-turning vehicles that will attempt to use a free u-turn lane as opposed to the long u-turn (through the diamond intersections). Additionally, appropriate logical limitations on free u-turn movements were added. A flag is set for each special driver-vehicle unit that will attempt to use a free u-turn lane at a diamond interchange. When a driver-vehicle unit is generated, if the approach that the unit enters and exits the system allows a free u-turn, DVPRO determines whether the unit will use the free u-turn lane by generating a random variate using the percentage of free u-turning vehicles from the external inbound approach. Finally, a flag is set for each driver-vehicle unit to define whether the unit will attempt a free u-turn.

Additions, Changes, and Enhancements to SIMPRO

The reading of the driver-vehicle unit information by SIMPRO was modified to include a flag for whether the unit would try to use the free u-turn path. If the flag is set, the desired external outbound let is specified as the negative value of the desired external outbound let that was read from the driver-vehicle processor.

The path-finder algorithm for a driver-vehicle unit was modified so that a negative desired external outbound let value sets an interim value as the free u-turn internal approach; otherwise, it sets the normal internal approach. Additionally, code was added so that if the unit is unable to use the free u-turn path, it tries the u-turn path through the intersections before using a forced intersection path and printing an informative message. Thus, a unit that cannot make the necessary lane changes to move into the median lane (Lane 1) to use the free u-turn intersection path tries to make two consecutive left turns to go to its desired external outbound leg.

OBJECTIVE 2. GENERATE EXACT PERCENTAGE OF DESIRED DRIVER-VEHICLE UNITS

Additions, Changes, and Enhancements to DVPRO

The random number generation routine was modified to generate and use a random number stream for each external inbound approach for the generation of entering headways and all driver-vehicle attributes. Additionally, the most recently used random number seed is saved, permitting the random number stream to be re-started at the same random number seed value.

A new algorithm was developed for generating headways for each approach. The low and best trial volumes are initialized to a large positive number and the high trial volume is initialized to a large negative number. For each trial, (1) the random number seed is set to the value for the approach before generating the headways and the random number generator is notified that there is a new seed value, (2) if the generated volume is exactly equal to the desired volume then the iterations are ended, and (3) the low, best, and high values are updated as necessary after generating the headways. For the first iteration, the trial volume is set to 90 percent of the desired volume and headways are generated. If this trial value produces an actual volume generated larger than the desired volume, then the trial volume is set to 90 percent of the trial volume and the process is repeated. For the second iteration, the trial volume is set to 110 percent of the desired volume and headways are generated. If this trial value produces an actual volume less than the desired volume then the trial volume is set to 110 percent of the trial volume and the process is repeated. For iterations 3 through 20, a trial volume is calculated as the linear interpolation between the current low and high values. If the process does not converge before the 21st iteration, the trial volume is set to the best value, the headways are generated, and the iterations are ended. This algorithm generally takes 3 to 4 iterations to converge, but occasionally it will take all 20 iterations. The random number stream is left intact after the generation of headways so that it may be used for generating the attributes for each driver-vehicle unit.

The generation of discrete random variates was modified to correct for inaccuracies in the randomness of the random number generator. The routine that generates discrete random variates uses an array of probabilities and the number of entries in the array to generate a number from 1 to the number of entries in the array. Thus if there are 100 vehicles to be generated, there are 3 lanes, and the probabilities for lane assignment are 30 percent for Lane 1, 40 percent for Lane 2, and 30 percent for Lane 3, a discrete random variate from 1 to 3 would be generated for each vehicle. After all 100 vehicles are generated, there should be 30 vehicles assigned to Lane 1, 40 to Lane 2, and 30 to Lane 3. In the standard process, this rarely happens. DVPRO has knowledge of the number of items to be generated because it first generates the headways for each approach and thus knows the number of driver-vehicle units for each approach. The modification involved keeping a count of the number of discrete random variates generated for each entry in the array of probabilities and creating a temporary array of probabilities each time a discrete random variate was to be generated. To create the temporary array of probabilities, (1) set the temporary array to the desired array and return, if there was only one entry; (2) sum the count of the number of discrete random variates generated for each entry in the array; (3) set the temporary array to the desired array and return, if the sum is less then the number of entries; (4) set the number of items to be generated to the desired value if the sum is less than the desired value, otherwise set the number of items to be generated to the sum plus one; (5) set the temporary array to the desired array and return, if sum is less than 10 percent of the number of items to be generated; (6) set each entry in the temporary array to the desired probability times the number of items to be generated minus the count of the number of discrete random variates generated times 100; (7) sum the entries in the temporary array; (8) divide each entry in the temporary array by the sum; and (9) return. Thus, the temporary array contains the probabilities needed to generate the remaining number of items in a manner that makes the generated distribution exactly match the desired distribution.

OBJECTIVE 3. IMPLEMENT SIGHT-DISTANCE CHECKING IN THE USER-FRIENDLY VERSION

No changes required in GEOPRO, DVPRO, or SIMPRO.

OBJECTIVE 4. SIMULATE NEMA DUAL-RING TRAFFIC SIGNAL CONTROLLERS

Additions, Changes, and Enhancements to SIMPRO

Input for a NEMA signal controller was added. The added intersection control option appears as:

```
16 = NEMA SIGNAL
```

The new NEMA signal controller functions according to the document "NEMA Traffic Control Systems, Standards Publication Number TS-1-1989" [Ref 3]. The controller allows 1 to 4 rings with 1 to 3 moveable barriers.

OBJECTIVE 5. SIMULATE VOLUME-DENSITY TRAFFIC SIGNAL CONTROLLERS

Additions, Changes, and Enhancements to SIMPRO

Input for a NEMA signal controller with optional volume-density operation was added. The added intersection control option appears as:

```
17 = NEMA VOLUME DENSITY SIGNAL
```

The new NEMA signal controller with optional volume-density operation functions according to the document "NEMA Traffic Control Systems, Standards Publication Number TS-1-1989" [Ref 3]. The controller allows 1 to 4 rings with 1 to 3 moveable barriers.

The statistics gathered and reported for the volume-density feature of the NEMA Signal Controller include (1) the number and percentage of times when added initial was set to the minimum value, (2) the number, percentage of times, and average value when the added initial was set to a value that was not the minimum or the maximum value, (3) the number and percentage of times when the added initial was set to the maximum value, (4) the number and percentage of times when the gap-timer was set to the minimum value for a gap-out, (5) the number, percent of times, and the average gap timer value when the gap timer was last set to a value that was not the minimum or the maximum value for a gap-out, and (6) the number and percentage of times when the gap timer was set to the maximum value for a gap-out.

For the volume-density feature of the NEMA Signal Controller, the number of vehicle actuations during the yellow and red intervals of a phase are counted. A count occurs for a detector when a vehicle's front bumper crosses the beginning of the detector in either pulse or presence mode and the detector is not tripped by another vehicle in any lane covered by the detector. The detector is assumed to reset each time step increment thus, at most, one vehicle can be counted by any one detector each time-step increment.

OBJECTIVE 6. PROVIDE USER CHOICE BETWEEN "CITY OF DALLAS" AND 'TXDOT" NUMBERING SCHEME FOR TRAFFIC PHASES AT DIAMOND INTERCHANGES

Additions, Changes, and Enhancements to SIMPRO

The Dallas Diamond Signal Controller phase numbering for the Texas Diamond Signal Controller Figure 3, Figure 4, Figure 6, and Figure 7 (see Appendix C) was added as an option. The phase sequencing is the same in the Texas Diamond Signal Controller and the Dallas Diamond Signal Controller; only the names of the phases have been changed.

Modified/added intersection control options:

```
08 = TEXAS DIAMOND FIG 3 SIGNAL
09 = TEXAS DIAMOND FIG 4 SIGNAL
10 = TEXAS DIAMOND FIG 6 SIGNAL
11 = TEXAS DIAMOND FIG 7 SIGNAL
12 = DALLAS DIAMOND FIG 3 SIGNAL
13 = DALLAS DIAMOND FIG 4 SIGNAL
14 = DALLAS DIAMOND FIG 6 SIGNAL
15 = DALLAS DIAMOND FIG 7 SIGNAL
```

Added the Dallas Diamond Signal Controller special timers:

```
01 = PHASES 1-5 CLEARANCE GREEN ------4-6-7
02 = PHASES 2-8 ADVANCE GREEN ------3-4-6-7
03 = PHASES 4-6 ADVANCE GREEN ------3-4-6-7
04 = PHASE   4  TRANSFER GAP ---------4-6-7
05 = PHASE   8  TRANSFER GAP ---------4-6-7
06 = PHASES 2-6 ADVANCE GREEN MIN ------6--
07 = PHASES 2-6 ADVANCE GREEN MAX ------6--
08 = PHASES 4-8 ADVANCE GREEN ----------6--
09 = PHASES 2-6 ADVANCE GREEN MIN --------7
10 = PHASES 2-6 ADVANCE GREEN MAX --------7
11 = PHASES 4-8 ADVANCE GREEN ------------7
12 = PHASES 1-5 CLEARANCE GREEN ----3------
13 = PHASES 3-5 CLEARANCE GREEN ------4-6-7
```

Added the Dallas Diamond Signal Controller options:

```
01 = ENABLE D1  DURING PHASES 1-8 ---------
02 = ENABLE D12 DURING PHASES 1-8 ---------
03 = ENABLE D5  DURING PHASES 4-5 ---------
04 = ENABLE D56 DURING PHASES 4-5 ---------
05 = TERMINATE LOGIC FOR PHASES 4-8 -------
06 = TERMINATE LOGIC FOR PHASES 4-8 -------
07 = FIGURE 6 OPTION A (2-6 TIMING) -------
08 = FIGURE 6 OPTION B (4-8 TIMING) -------
09 = FIGURE 6 OPTION C (PHASE 6 SKIPPING) -
10 = FIGURE 7 OPTION A (2-6 TIMING) -------
11 = FIGURE 7 OPTION B (4-8 TIMING) -------
12 = FIGURE 7 OPTION C (PHASE 2 SKIPPING) -
13 = ENABLE D3  DURING PHASES 3-7 ---------
```

OBJECTIVE 7. PRESENT OUTPUT SUMMARY STATISTICS IN GRAPHICAL FORM (SPREADSHEET-COMPATIBLE OUTPUT FORMAT)

Additions, Changes, and Enhancements to SIMPRO

An existing option, called punched statistics, was modified to produce a compressed summary statistics output file in a fixed row-column format that can be easily input to a spreadsheet program and used by the SIMSTA program.

Development of SIMSTA

A new processor called SIMSTA (Simulation Statistics) reads all replicate run output statistics files for a given job, calculates and prints statistics, optionally writes the statistics to a spreadsheet-compatible file, and optionally checks for a user-specified statistical tolerance being achieved (a feature used by the REPTOL processor).

SIMSTA parameters are (1) "TOL" to specify the statistical tolerance ("TOL" uses "10" percent while "TOL=n" uses "n" percent, where "n" must be in the range from 1 to 50), where no parameter is given, a check is not performed; (2) "STA" to specify the replicate run output statistics file name without extension ("STA" or no parameter uses "SIMSTAT" while "STA=file" uses "file"), (3) "L" to specify the printed output statistics file name ("L" or no parameter uses "SIMSLST" or "SIMSLST.LST" depending on the platform, while "L=file" uses "file"); (4) "SS" to specify the spreadsheet-compatible file ("SS" uses "SPRDSHT.DAT" while "SS=file" uses "file," where no parameter is given, SIMSTA does not produce the spreadsheet-compatible file); and (5) "GDVS00" to specify the GDVS00 file.

SIMSTA opens, and reads data from, files named "file.R*n*" ("file" is the value for the "STA" parameter and "*n* " ranges from "1" to "10"), adds the data to the statistics, and stops when the first data file cannot be opened. If the number of replicate runs processed is greater than or equal to 1, SIMSTA calculates the statistics, writes the statistics to the file specified by the "L" parameter, and optionally writes the spreadsheet-compatible file if the "SS" parameter is specified.

The statistics calculated for almost all parameters are the number of data values used in the calculation, the minimum value, the mean value, the maximum value, the variance, the standard deviation, and the standard deviation divided by the mean. The following equations are used to calculate most of the statistics:

XVAL = TVAL/KVAL

VVAL = (SVAL-KVAL*(XVAL**2))/(KVAL-1.0)

DVAL = SQRT(VVAL)

CVAL = DVAL/XVAL

where CVAL is the standard deviation divided by the mean where DVAL is the standard deviation

where KVAL is the number of data values

where SVAL is the sum of the square of the data values

where TVAL is the sum of the data values

where VVAL is the variance

where XVAL is the mean

The Student's T Distribution for the 95 percent confidence level is used to calculate the value of "xx.x" for the statement "there is a 95% probability that the population mean for aaa is within +/- xx.x % of yy.y sec/veh" where "aaa" is "overall average total delay", "overall average queue delay", "overall average stopped delay", or "overall average delay below zz.z mph"; "yy.y" is the mean value for "aaa" and "zz.z" is the user specified value for the Simulation Processor. The following equations are used to calculate these statistics:

PROBTD = T95(NUMREP-1)*COATD/SQRT(FLOAT(NUMREP))

PROBQD = T95(NUMREP-1)*COAQD/SQRT(FLOAT(NUMREP))

PROBSD = T95(NUMREP-1)*COASD/SQRT(FLOAT(NUMREP))

PROBDM = T95(NUMREP-1)*COADM/SQRT(FLOAT(NUMREP))

where NUMREP is the number of replicate runs

where COATD is the standard deviation divided by the mean for overall average total delay

where COAQD is the standard deviation divided by the mean for overall average queue delay

where COASD is the standard deviation divided by the mean for overall average stopped delay

where COADM is the standard deviation divided by the mean for overall average delay below zz.z mph

where T95(1) is 12.706

where T95(2) is 4.303

where T95(3) is 3.182

where T95(4) is 2.776

where T95(5) is 2.571

where T95(6) is 2.447

where T95(7) is 2.365

where T95(8) is 2.306

where T95(9) is 2.262

All versions of a file named "STOP.REP" are deleted from the current directory. If statistical tolerance checking is requested by the user by specifying the "TOL" parameter, and the number of replicate runs processed is greater than or equal to 3, and the calculated value of "xx.x" from above for overall average total delay is less than or equal to the specified tolerance value, a file named "STOP.REP" is created in the current directory. This file contains the calculated value of "xx.x" from above for overall average total delay along with the specified tolerance value.

If a spreadsheet-compatible file is requested by the user by specifying the "SS" parameter, a fixed 581 row and maximum 9-column file is written in the following general format:

row 001	Geometry	Processor Title from replicate run 1
row 002	Driver-Vehicle	Processor Title from replicate run 1
row 003	Simulation	Processor Title from replicate run 1
row 004-058	Summary Statistics for Approach 1	
row 059-113	Summary Statistics for Approach 2	
row 114-168	Summary Statistics for Approach 3	
row 169-223	Summary Statistics for Approach 4	
row 224-278	Summary Statistics for Approach 5	
row 279-333	Summary Statistics for Approach 6	
row 334-388	Summary Statistics for Approach 7	
row 389-443	Summary Statistics for Approach 8	
row 444-498	Summary Statistics for All Non-Internal Approaches	
row 499-553	Summary Statistics for All Internal Approaches	
row 554	Number of replicate runs	
row 555	Start-up time (minutes)	
row 556	Simulation time (minutes)	
row 557	Step increment for simulation time (seconds)	
row 558	Speed for delay below xx mph (mph)	
row 559	Maximum clear distance for being in a queue (ft)	
row 550	Car following equation lambda	
row 561	Car following equation mu	
row 562	Car following equation alpha	
row 563	Lead time gap for conflict checking (seconds)	
row 564	Lag time gap for conflict checking (seconds)	
row 565	Intersection traffic control	
row 566	Maximum number of vehicles in system	
row 567	Minimum hesitation for vehicle at stop sign (sec)	
row 568	Intersection is a diamond interchange	
row 569	Number of inbound approaches	

row 570	List of inbound approaches
row 571	Start-up time (minutes)
row 572	Number of vehicles processed during start-up time
row 573	Simulation time (minutes)
row 574	Number of vehicles processed during simulation time
row 575	Number of vehicles in the system at summary
row 576	Average number of vehicles in the system
row 577	Maximum number of vehicles in the system
row 578	95% prob mean overall average total delay
row 579	95% prob mean overall average queue delay
row 570	95% prob mean overall average stopped delay
row 581	95% prob mean overall average delay below zz.z mph

Rows 001-003 have an 80-character title in the first spreadsheet field. Rows 004-553 have a 53-character label in the first field and seven 8-character fields containing the values for u-turns, lefts, straights, rights, internal lefts, internal rights, and the total for all turn movements. Rows 554-577 have two fields containing a 53-character label and one to eight-character values. The value fields in row 570 contains the inbound approach numbers. Rows 578-581 have a 53-character label, an 8-character number, a 4- character label, an 8-character number, and a 7-character label. This file is an ASCII text file that may be edited or printed and is capable of being imported by Lotus 1-2-3.

Development of Spreadsheet Macros

Spreadsheet macros were developed to create bar charts showing volume and delay statistics for one approach, several approaches, or the entire intersection. The spreadsheet data file created by SIMSTA is used, and no additional statistics are calculated. Appendix B contains a listing of the spreadsheet macros, which will work with Lotus 1-2-3 Version 2.4 or greater.

OBJECTIVE 8. DEVELOP GENERIC PLOTTER-DRIVER OUTPUT ROUTINES AND INTERFACE CAPABILITIES TO SELECTED TYPES OF PLOTTERS

The plot capabilities of the existing Geometry Processor GEOPRO were changed and a new Geometry Plot Processor called GEOPLOT was created to implement a non-device-specific plot file format.

Additions, Changes, and Enhancements to GEOPRO

A major revision to GEOPRO comprises a new set of plot subroutines that are compatible with the calling conventions of "Calcomp Plot Subroutines." To accommodate a wide range of plot devices that include dot matrix printers, desktop pen plotters, laser printers, and CRT's with graphics capability, GEOPRO is linked with a newly-written set of Plot Subroutines. GEOPRO uses these new subroutines to create a plot data file that contains all the information needed to produce a plot, but this file in a form that is not specific to any individual plot device.

The format of the entries in this file is shown by sections of FORTRAN 77 code that has been extracted from the Plot Subroutines. Refer to any FORTRAN 77 Compiler Reference Manual if needed.

Figure 3.1 illustrates the form of a "PLOTS" entry. It is used to initialize a new plot file.

```
      SUBROUTINE PLOTS(I,XDUM,PLFILE)
C
C I - UNIT TO OPEN FOR OUTPUT
C XDUM - MAXIMUM DIMENSION (HEIGHT OR WIDTH) OF PLOT
C PLFILE(1) - NAME OF FILE TO OPEN FOR OUTPUT
C PLFILE(2) - OTHER DESCRIPTIVE DATA TO BE PUT INTO PLOT FILE
      CHARACTER*(*)PLFILE(2)
      WRITE(IUNIT,'(A10,I10,1PE15.8)')'PLOTS     ',0,XDUM
      WRITE(IUNIT,'(A)')PLFILE(2)
```

Figure 3.1 FORTRAN 77 code for writing the PLOTS entry

Figure 3.2 illustrates the form of a "PLOT" entry. It is used to define the plotter origin, raise or lower the plot pen, move the plot pen ,and set the end of a plot page or a plot file.

```
      SUBROUTINE PLOT(X,Y,IPEN)
      WRITE(IUNIT,'(A10,1P2E15.8,I10)')'PLOT      ',X,Y,IPEN
```

Figure 3.2 - FORTRAN 77 code for writing the PLOT entry

Figure 3.3 illustrates the form of a "SYMBOL" entry. It is used to draw text (NC is positive) with a specified number of characters (NC) or a single-centered symbol (NC is negative). The object is drawn at a specified coordinate (X,Y), height (H0), and angle (ANG).

```
      SUBROUTINE SYMBOL(X,Y,H0,TEXT,ANG,NC)
      CHARACTER TEXT*(*)
      IF(NC.GT.0)THEN
        WRITE(IUNIT,'(A10,1P4E15.8,I10/A)')'SYMBOL    ',X,Y,H0,ANG,NC,
     1                                     TEXT
      ELSE
        CALL IYAD(TEXT,IT)
        WRITE(IUNIT,'(A10,1P4E15.8,I10/I10)')'SYMBOL    ',X,Y,H0,ANG,NC,
     1                                       IT
      END IF
```

Figure 3.3 - FORTRAN 77 code for writing the SYMBOL entry

Figure 3.4 illustrates the form of a "NUMBER" entry. It is used to draw numbers with a specified number of digits (NDEC) to the right of the decimal point. The object is drawn at a specified coordinate (X,Y), height (H0), and angle (ANG).

```
      SUBROUTINE NUMBER(X,Y,H0,FPN,ANG,NDEC)
      WRITE(IUNIT,'(A10,1P5E15.8,I10)')'NUMBER    ',X,Y,H0,FPN,ANG,NDEC
```

Figure 3.4 - FORTRAN 77 code for writing the NUMBER entry

Figure 3.5 illustrates the form of a "NEWPEN" entry. It is used to change the line width or plotting color, depending on the plotting device.

```
      SUBROUTINE NEWPEN(IPEN)
      WRITE(IUNIT,'(A10,I10)')'NEWPEN    ',IPEN
```

Figure 3.5 - FORTRAN 77 code for writing the NEWPEN entry

As an additional enhancement, GEOPRO was modified to assign colors to the turn-movement arrows and vehicle paths to indicate the type of movement being represented. Left-turn movements are red, straight and u-turn movements are black (or white), and right-turn movements are blue.

Development of GEOPLOT

A new processor, GEOPLOT, has the ability to read the plot-data file created by GEOPRO and translate it into different formats. The specific format is user-selectable with command-line parameters, and it may be used to interface with hardcopy devices or graphics-processing programs (CAD). GEOPLOT can also display the contents of the plot-data file on the computer's graphics CRT.

The GKS plot scheme is one option available in GEOPLOT. For the DOS implementation of this option, a license for incorporation of proprietary software into GEOPLOT is required. One term of this license requires that the software be delivered only to end-users who have purchased additional device drivers from the GKS vendor. As it was not the intent of this research project to produce software that cannot be freely distributed in the public domain without restriction, two versions of GEOPLOT exist. The version that is normally included on the distribution disk has the GKS option disabled and does not include the proprietary GKS code. For end-users who wish to use the GKS option and own, or are purchasing the device drivers, there is a version of GEOPLOT that has the GKS option active.

OBJECTIVE 9. AUTOMATE THE REQUIRED NUMBER OF REPLICATE RUNS TO ACHIEVE STABILITY IN SELECTED MEASURES OF EFFECTIVENESS

Development of REPRUN

A batch file for DOS, a shell script for Unix, and a command procedure for VMS were developed to automate the processing of replicate runs. REPRUN (1) checks all parameters for errors, (2) removes files named: PARAMS.REP, GDV.REP, GPDATA.REP, GEOLIST.REP, DVDATA.REP, and SIM.REP; (3) for <n> equal to <opt_begin_rep> to 10, removes DVLIST.R<n>, SIMPLST.R<n>, SIMERR.R<n>, SIMSTAT.R<n>, and POSDAT.R<n>; (4) creates PARAMS.REP containing the parameters for the replicate run; (5) sets the TEXAS mode for replicate run processing; (6) runs GDVCONV using <gdv_pre_file> and creating GDV.REP; (7) runs GEOPRO using GDV.REP and creating GPDATA.REP and GEOLIST.REP; (8) runs SIMCONV using <sim_pre_file> and creating SIM.REP; (9) for <n> equal to <opt_begin_rep> to <end_rep>, (a) runs DVPRO using GDV.REP and REP=<n> and creating DVDATA.REP and DVLIST.R<n> and (b) runs SIMPRO using SIM.REP, GPDATA.REP, DVDATA.REP, and REP=<n> and creating SIMPLST.R<n>, SIMERR.R<n>, SIMSTAT.R<n>, and POSDAT.R<n>; (10) deletes STOP.REP, runs SIMSTA using STA=SIMSTAT and creating SIMSTAT.REP, and deletes STOP.REP; and (11) writes the starting and ending times on the terminal.

Development of REPTOL

A batch file for DOS, a shell script for Unix, and a command procedure for VMS were developed which automate the processing of replicate runs with tolerance checking. REPTOL (1) checks all parameters for errors, (2) removes files named: PARAMS.REP, GDV.REP, GPDATA.REP, GEOLIST.REP, DVDATA.REP, SIM.REP, and SIMSTAT.REP; (3) for <n> equal to 1 to 10, removes DVLIST.R<n>, SIMPLST.R<n>, SIMERR.R<n>, SIMSTAT.R<n>, and POSDAT.R<n>; (4) creates PARAMS.REP containing the parameters for the replicate run; (5) sets the TEXAS mode for replicate run processing; (6) runs GDVCONV using <gdv_pre_file> and creating GDV.REP; (7) runs GEOPRO using GDV.REP and creating GPDATA.REP and GEOLIST.REP; (8) runs SIMCONV using <sim_pre_file> and creating SIM.REP; (9) for <n> equal to 1 to 10, (a) runs DVPRO using GDV.REP and REP=<n> and creating DVDATA.REP and DVLIST.R<n>, (b) runs SIMPRO using SIM.REP, GPDATA.REP, DVDATA.REP, and REP=<n> and creating SIMPLST.R<n>, SIMERR.R<n>, SIMSTAT.R<n>, and POSDAT.R<n>, and (c) when <n> is greater than or equal to 3, deletes STOP.REP, runs SIMSTA using TOL=<tol_val> and STA=SIMSTAT and creating SIMSTAT.REP, stops replicate run processing if STOP.REP is created by SIMSTA, and deletes STOP.REP; and (10) prints whether or not the specified tolerance was reached and writes the starting and ending times on the terminal.

Additions, Changes, and Enhancements to DVPRO

A parameter was added to the command line which executes DVPRO to define the replicate run numbers (REP=n, where n is 1 through 10) to be processed. The default replicate run number is set to 1. If the replicate run number is specified, columns 56 through 59 of the DVPRO title are replaced with " Rnn". The random number seed to be used by DVPRO is either the user-specified or default value plus 10000 times the replicate run number minus one. As the user-specified and the default random number seed is a 5-digit number while the internal value can be an 11-digit number, this action makes the random number a 7-digit number, with the random number seed for replicate 1 being unchanged. This procedure allows DVPRO to generate the replicate run in a predictable manner, based upon either the user-specified value or the default value, without requiring the user to change any value in a data file.

Additions, Changes, and Enhancements to SIMPRO

A parameter was added to the command line which executes SIMPRO to define the replicate run number (REP=n, where n is 1 through 10) to be processed. If a replicate run number is specified, columns 56 through 59 of the SIMPRO title are replaced with " Rnn" and the compressed summary statistics option is forced "YES".

An existing option called punched statistics was modified to produce a compressed summary statistics output file in a fixed row-column format that can be easily input to a spreadsheet program and used by the SIMSTA program.

Development of SIMSTA

The development of SIMSTA is described under Objective 7, which describes the development of features needed to present output summary statistics in graphical form.

OBJECTIVE 10. OTHER ITEMS

Conversion of DISFIT

The Headway Distribution Fitting Processor called DISFIT, which was originally developed circa 1975 as part of the TEXAS Model for Intersection Traffic, was converted to FORTRAN 77 so that it can run on modern computers. The purpose of DISFIT is to aid the user in selecting an appropriate mathematical description of an observed headway frequency distribution. For a more detailed discussion of DISFIT, refer to Chapter 7.6 "The Headway Distribution Fitting Processor", Chapter 4.3.3.1 "Generation of Erlang Random Variates", Chapter 4.3.3.2 "Generation of Gamma Random Variates", Chapter 4.3.3.3 "Generation of Lognormal Random Variates", Chapter 4.3.3.4 "Generation of Negative Exponential Random Variates", Chapter 4.3.3.5 "Generation of Shifted Negative Exponential Random Variates", Chapter 4.3.3.6 "Generation of Uniform Random Variates", and Chapter 4.3.6.2 "Generation of Normal Random Variates" contained in the report entitled "The TEXAS Model for Intersection Traffic - Development" by Clyde E. Lee, Thomas W. Rioux, and Charlie R. Copeland, Research Report 184-1, Project 3-18-72-184, Center for Transportation Research, Bureau of Engineering Research, The University of Texas at Austin, December, 1977 [Ref 1].

DISFIT (1) reads headway data, (2) computes the location and dispersion parameters for the data using a 1-second time interval size, (3) fits selected mathematical distributions to the empirical headway data based on the best-fit parameters calculated from the mean and variance of the data, (4) calculates Chi-Squared, alpha, and the confidence level for the Chi-Squared goodness-of-fit test, (5) determines the maximum cumulative difference for the Kolmogorov-Smirnov one-sample test, and (6) plots a histogram of the input headway data and of each distribution fitted.

The input to DISFIT is (1) an 80-character title on line 1, (2) a 4 to 80-character FORTRAN format on line 2 for reading the headway data one value per line (must begin with a "(" and must end with a ")"), and (3) headway data in seconds with one value per line.

The statistics computed for the headway data are (1) the number of headways read, (2) the number and percent of headways less than or equal to 0.0, (3) the number and percent of headways greater than or equal to 50.5, (4) the summation of all headways in hours, (5) the volume of traffic in vehicles per hour, (6) the minimum headway in seconds per vehicle, (7) the maximum headway in seconds per vehicle, (8) the range of headways in seconds per vehicle, (9) the mean of the headways in seconds per vehicle, (10) the variance of the headways in seconds squared, and (11) the standard deviation of the headways in seconds per vehicle. The following equations are used to calculate the location and dispersion parameters for the headway data:

```
TIME = SUMX/3600.0D+00
VOLUME = N/TIME
RANGE = HMAX - HMIN
XMEAN = SUMX/N
VAR = (SUMXX - N*(XMEAN**2))/(N-1.0D+00)
SD = DSQRT(VAR)
```

where	TIME	is the sum of the headways in hours
where	SUMX	is the sum of the headways in seconds
where	VOLUME	is volume of traffic in vehicles per hour
where	N	is the number of headways read
where	RANGE	is range of headways in seconds per vehicle
where	HMAX	is the maximum headway in seconds per vehicle
where	HMIN	is the minimum headway in seconds per vehicle
where	XMEAN	is the mean of the headways in seconds per vehicle
where	VAR	is variance of the headways in seconds squared
where	SUMXX	is the sum of the square of the headways in seconds squared
where	SD	is standard deviation of the headways in seconds per vehicle

The headway frequency distributions fitted are (1) Erlang (rounded down to the nearest integer value of K), (2) Erlang (rounded up to the nearest integer value of K), (3) gamma, (4) lognormal, (5) negative exponential, (6) shifted negative exponential, (7) uniform, and (8) normal. For each distribution fitted, the parameter required as input by SIMPRO is listed along with the Chi-Squared value, the number of degrees of freedom, the alpha value, the confidence value, and the maximum cumulative difference.

For the Erlang distribution, the parameter required by SIMPRO is the K value and the ALPHA and K parameters are computed using the following equations:

```
ALPHA = XMEAN/VAR
K = XMEAN**2/VAR + ROUND
```

where ROUND is 0.0 for rounded down and 1.0 for rounded up

For the gamma distribution, the parameter required by SIMPRO is the A value and the ALPHA and A parameters are computed using the following equations:

ALPHA = XMEAN/VAR

A = XMEAN**2/VAR

The algorithm for calculating the lognormal distribution came from "Probability and Statistics for Engineers" by Irwin Miller and John E. Freund, page 76-78. For the lognormal distribution, the parameter required by SIMPRO is the standard deviation and the mean and variance parameters are computed using the following equations:

MEANY = DLOG(XMEAN) - 0.5D+00*DLOG((VAR/(XMEAN**2))+1.0D+00)

SDY = DSORT(DLOG((VAR/(XMEAN**2))+1.0D+00))

For the negative exponential distribution, there is no parameter required by SIMPRO and the TBAR parameter is computed using the following equation:

TBAR = XMEAN

For the shifted negative exponential distribution, the parameter required by SIMPRO is the shift TAU and the TBAR and TAU parameters are computed using the following equations:

TBAR = XMEAN

TAU = XMEAN - SD

For the uniform distribution, the parameter required by SIMPRO is the standard deviation and the A and B parameters are computed using the following equations:

A = XMEAN - SD*SQRT(3.0D+00)

B = XMEAN + SD*SQRT(3.0D+00)

The algorithm for calculating the normal distribution came from "Statistical Principles in Experimental Design", Second Edition by B. J. Winer, Page 822.

The algorithm for calculating the Chi-Squared value came from page 825 of "Statistical Principles in Experimental Design" by B. J. Winer.

The algorithm for calculating the Gamma Function value came from Algorithm 221 from "Collected Algorithms from CACM" by Walter Gautschi, 10-Aug-1963, and adapted from Chebyshev Approximations to the Gamma Function by Helmut Werner and Robert Collinge, "Mathematics of Computation", Volume 15, 1965, page 195-197, with coefficients for maximum error of 0.96E-14.

In plotting the histogram of the input headway data and of each distribution fitted for each 1-second interval, the following procedures are used: (1) the 120 character line is set to all blanks, (2) a "+" character is added from the origin on the left toward the right to the observed probability unless the observed probability is less than 0.00125, (3) a ")" character is placed in the right-most position if the observed probability is greater than or equal to 0.3, (4) if the expected probability is less than 0.00125 then nothing additional is placed else if the expected probability is less than or equal to the observed probability then an "=" character is placed at the expected probability else if the expected probability is greater than the observed probability then an "*" character is placed at the expected probability, (5) if the expected probability is greater than or equal to 0.3 then a ")" character is placed in the right-most position, and (6) the line is printed.

DISPRO

DISPRO was modified for Intergraph Workstations to determine the screen size upon initialization and make the animation use the full screen size. This change allows DISPRO to be used effectively on both the one million and two million pixel monitors.

Input to DVPRO

Columns 60-80 of the DVPRO title have been replaced with "DD-MMM-YYYY HH:MM:SS" which is the current day, month, year, hours, minutes, and seconds when DUPRO runs.

Input to GEOPRO

Columns 60-80 of the GEOPRO title have been replaced with "DD-MMM-YYYY HH:MM:SS" which is the current day, month, year, hours, minutes, and seconds when GEOPRO runs.

Calculating Points of Intersection Conflict in GEOPRO

The arc-to-arc checking routine was modified for the case in which both arcs on an intersection path have the same center coordinates and the same radius. The beginning and ending azimuths for each arc are bound to the range 0 to 359 degrees. The beginning azimuth for the first arc is added to a list if the azimuth lies on the second arc; the ending azimuth for the first arc is added to a list if the azimuth lies on the second arc; the beginning azimuth for the second arc is added to a list if the azimuth lies on the first arc; and the ending azimuth for the second arc is added to a list if the azimuth lies on the first arc. A check is made to assure that azimuths are not added more than once to the list. Finally, an intersection conflict point is added for each azimuth on the list. There may be no points on the list if the two arcs do not touch or overlap, there may be one point when the two arcs only touch, or there may be two points when the two arcs overlap. Previously, this situation was treated as an error.

Calculating Vehicle Intersection Paths in GEOPRO

The bounds for the maximum path radius were changed to a minimum value of 100.0 feet and a maximum value of 9999.0 feet. Conditions for replacing an intersection path containing one or more arcs with a straight line connecting the center of the inbound lane to the center of the outbound lane were modified. A straight line is substituted when the center x coordinate or the center y coordinate of either of the arcs is less than -999.0 feet or greater than 9999.0 feet. This replacement was previously performed only when the radius of either arc was greater than the maximum path radius. This modification allows larger values of maximum path radius while ensuring that a coordinate can be formatted into a maximum of four characters.

Plotting in GEOPRO

The draw-arc routine has been modified to draw large radius arcs with small sweep angles more accurately. The draw-intersection routine adds "LEFT SIDE OF DIAMOND" or "RIGHT SIDE OF DIAMOND" annotation centered below the scale factor when plotting the enlargement of the left side and the right side of a diamond interchange.

Input to SIMPRO

The previous input data checking routine incorrectly reported an error concerning the number of phases to clear-to for the Texas diamond signal controller options and halted processing. This fault has been corrected.

Columns 60-80 of the SIMPRO title have been replaced with " DD-MMM-YYYY HH:MM:SS" which is the current day, month, year, hours, minutes, and seconds when SIMPRO runs.

An added input option defines the desired width of the printed output. The values are "N" for narrow (80-column) and "W" for wide (132-column). The wide output option allows statistics for each turning movement and the total for the approach to be printed on one page; whereas, the narrow output option uses one page per turning movement and one page for the total for the approach. SIMDATA processes this new option. This option is on SIMPRO input card 2 column 41.

An input option now allows left-turning vehicles on signalized lanes to advance into the intersection on the green signal indication to within 10 feet of the first potential intersection conflict point. This option is referred to as the "left-turn pull-out option." The values are "Y" for yes and "N" for no. This option is on SIMPRO input card 2 column 45.

The input option that defines the animation/pollution tape option on SIMPRO input card 2 columns 54-56 has been changed from "YES" or "NO" to "ANI", "POL", or "NO". The old value "YES" is changed to "ANI." "ANI" designates an animation tape, and "POL" designates a pollution tape.

An added input option defines the time into the simulation at which to end the writing of the animation/pollution data. The values begin at 0 (zero) and go to the start-up time plus the simulation time, in minutes. This option is on SIMPRO input card 2 columns 67-70.

An input option was added to define the hesitation factor (HESFAC). This option is on SIMPRO input card 2 columns 81-84. The hesitation factor was changed to be a minimum queue delay value at unsignalized lanes and the default value was changed to 2 seconds.

The default values for the time for the lead (TLEAD) and lag (TLAG) safety zones for intersection conflict checking were both set to 0.8 seconds. SIMDATA uses these defaults.

A check has been added for each inbound lane and intersection path which has a "straight" turn code to insure that the time increment is small enough so that vehicles traveling at the speed limit of the lane or intersection path will be processed during at least one time increment while on the lane or intersection path.

Output From SIMPRO

The times when animation/pollution data are written to tape are controlled. For the animation tape, data collection starts at the beginning of start-up time and ends at the user-specified time or at the default time of 5 minutes. For the pollution tape, data collection starts at the end of start-up time (the beginning of simulation time) and ends at the end of simulation time. Additionally, vehicle position, velocity, and acceleration are written after each time step increment for each vehicle when pollution data are requested.

Summary statistics are written in narrow or wide printed output. The wide output option allows statistics for each turning movement and the total for the approach to be printed on one page; whereas, the narrow output option uses one page per turning movement and one page for the total for this approach.

Blocked Lanes in SIMPRO

The blocked-lane treatment in SIMPRO was modified to accommodate short blocked-lane sections. If the lane is blocked for a vehicle, then SIMPRO (1) sets a flag to discontinue any calculated deceleration to a stop, (2) sets the distance for a lane change (DISLCH) equal to the minimum of 2 car lengths, 50 feet, and one-half the length of the blocked lane (ENDLN), (3) sets the distance from the end of the blocked lane (DISEND) equal to one-half the remaining distance to the end of the blocked lane with a minimum of the distance for a lane-change and a maximum of one-half the length of the blocked lane, and (4) sets the position of the previous vehicle (where the current vehicle should stop) equal to the maximum of the length of the blocked lane (ENDLN) minus the distance from the end of the blocked lane (DISEND) and the position of the current vehicle. The effect of these changes is to increase the likelihood that a vehicle can change lanes out of a short blocked-lane section without stopping or without traveling all the way to the end of the short blocked-lane section before stopping.

Intersection Conflict Checking in SIMPRO

An intersection conflict-avoidance routine allows vehicles that have gained the right to enter the intersection to adjust their velocity to avoid conflicts with other vehicles that have gained the right to enter the intersection. Under this feature, smaller values for the lead and lag safety zones for intersection conflict checking are permitted; thus, a higher volume of left-turning traffic can be processed. The default time values for lead (TLEAD) and lag (TLAG) safety zones for intersection conflict checking have both been changed to 0.8 seconds.

Intersection conflict-avoidance logic has been improved to increase safety when two vehicles are merging at the point of intersection conflict into the same outbound lane. The lead or lag safety zone is maximized with the sum of the time required for the vehicle to pass through the intersection conflict, plus the time required for the vehicle to pass the car-following distance, plus the error in judgment. The effect of this modification is that right-turn-on-red and left-turn-on-red vehicles have a larger factor of safety. Additionally, the vehicle to arrive last in time at the merge point is made to car-follow or stop behind the vehicle that arrives first in time at the merge point.

The intersection conflict-avoidance algorithm has been modified so that a vehicle who's signal indication just changed from red to green would give an advantage to vehicles already within the intersection. This change attempts to give the right-of-way to vehicles which have not cleared the intersection during the yellow-change or red-clearance signal interval.

Car Following and Lane Changing in SIMPRO

In the TEXAS Model, lane-change behavior is affected by vehicle length, driver operational factor, and vehicle operational factor. Driver and vehicle operational factors range typically from about 1.15 for aggressive drivers, to 1.0 for normal drivers, about 0.85 for less-aggressive drivers. When these factors are applied in lane-changing calculations, aggressive drivers accept smaller gaps and use higher jerk rates to avoid collisions. Default values for these factors can be adjusted by the user. The lane-change logic was modified to try to equalize the usage of multiple left-turn or right-turn lanes, when present. The path-finder and check-my-lane routines were improved so that a vehicle in a currently blocked lane will lane-change into an appropriate lane to the right or the left in order to proceed to the desired outbound leg most expeditiously. Consideration is given to the availability, continuity, and length of the adjacent lane(s) ahead into which the vehicle may change.

The check-my-lane routine was modified when the vehicle's current lane is blocked and there is a lane to the left or right then set the direction for a lane change by the following criteria: (1) if lanes to the left and right are continuously available then u-turns and lefts change lanes to the left while straights and rights change lanes to the right, (2) if there is a lane to the left that is continuously available and there is a lane to the right that is not continuously available then change lanes to the left, (3) if there is a lane to the right that is continuously available and there is a lane to the left that is not continuously available then change lanes to the right, (4) if lanes to the left and right are not continuously available and both are longer than the current lane then set the direction for a lane change toward the longest lane, (5) if lanes to the left and right are not continuously available and the lane to the left is longer than the current lane then change lanes to the left, (6) if lanes to the left and right are not continuously available and the lane to the right is longer than the current lane then change lanes to the right, (7) if there is a lane to the left and none to the right then change lanes to the left, and (8) if there is a lane to the right and none to the left then change lanes to the right.

Logic was added for a vehicle on an inbound or internal lane to check the vehicle ahead and calculate the jerk rate required to car-follow or stop behind the vehicle ahead when the vehicle's lane is not blocked, the vehicle is logically first in the lane, and the vehicle may not proceed into the intersection. This ensures that a vehicle that made the first yellow-stop decision for a lane will not run over a vehicle ahead on the same inbound lane that made an yellow-go decision but is delayed from entering the intersection.

The acceleration/deceleration logic for intersection conflict avoidance was modified to apply the most critical jerk rate calculated for lane-changing, intersection blockage avoidance or car-following. The deceleration-to-a-stop logic was modified to calculate a new jerk rate value each time-step increment, based upon the remaining stopping distance, current velocity, and acceleration for the vehicle being examined.

The car-following logic was modified to check whether the vehicle ahead is stopping, and if so, predict where it would stop. The jerk rate required to stop safely behind the vehicle ahead is calculated and used if it is more critical than the value derived from the generalized car-following equations.

The lane-changing algorithms were modified to count the equivalent number of 20-foot vehicles ahead of the current vehicle instead of the actual number of vehicles ahead of the current vehicle. The effect of this change was to model driver queuing behavior more appropriately. Lane-changing algorithms for the diamond interchange were modified to correct an error when a vehicle on the inbound lane was trying to make a left or right turn from the internal lane when there was more than one lane available. The error caused the vehicle to oscillate between inbound lanes.

The look-ahead algorithms were modified so that a vehicle entering the intersection now affects a following vehicle that may enter the intersection (1) until the rear of the vehicle ahead enters the intersection and (2) until the rear of this vehicle has traversed the shorter length of the first tangent portion of the two intersection paths for the respective vehicles.

A vehicle changing lanes now affects a following vehicle in the old lane until the vehicle ahead completes 60 percent of the lane-change maneuver.

If a left turn is permitted only from a left-turn bay, then a left-turning vehicle trying to change lanes into the left-turn bay will additionally car-follow the last vehicle in the lane adjacent to the left-turn bay. This insures that the left-turning vehicle trying to change lanes will not pass the last vehicle in the lane adjacent to the left-turn bay. If the left-turn bay becomes full, this causes the left-turning vehicle trying to change lanes to come to a complete stop in the current lane behind the last vehicle in the lane adjacent to the left-turn bay.

Look-ahead Processing in SIMPRO

Logic was added for a vehicle on an inbound or internal lane to check whether its entry into the intersection would block the intersection when its lane is not blocked, no vehicles ahead on this lane have determined that they would block the intersection, the vehicle may proceed into the intersection, and the vehicle is not beyond 2*XRELMI feet (currently 6 feet) past the end of the lane. The vehicle is not allowed to enter the intersection if its entry into the intersection will block the intersection.

An anti-gridlock mechanism was added whereby a vehicle on an inbound lane that has the right to enter the intersection would determine whether his entry into the intersection would block the intersection. If so, then the vehicle begins a deceleration-to-a-stop at the stop line. The routine checks the speed, position, and length of vehicles on the path ahead and calculates whether entry of the approaching vehicle will block the intersection. If the vehicle should not enter the intersection, a jerk rate needed to stop the vehicle at the stop line of the current lane is computed.

The look-ahead algorithms were modified for the diamond interchange to cause the first vehicle in an external approach lane to react properly to the internal-lane signal indication ahead. When the external inbound lane signal indication is green, no vehicles are on the first intersection path or in the internal lane ahead, and the internal lane signal indicates red, the vehicle checks for deceleration-to-a-stop at the stop line on the internal lane. When the external lane signal indication is green and the internal lane signal indication is green, the vehicle looks ahead as far as possible and car-follows any vehicle ahead; else, the vehicle accelerates according to its desired speed. Additionally, any calculated deceleration-to-a-stop is canceled, and the vehicle is instructed to check for a new deceleration-to-a-stop whenever a vehicle changes links.

Signal Control in SIMPRO

The signal-response logic was modified for the time when the signal indication changes from green to yellow. If the lane ahead is not currently blocked, an intersection path has been chosen, the vehicle's position is 2.0 times the minimum relative distance (currently 3.0 feet) beyond the stop line, and entry into the intersection will not block the intersection; the vehicle may proceed into the intersection after its intersection conflicts clear. This response logic was also modified for the condition when the signal indication changes from yellow to red. If the lane ahead is not currently blocked, the vehicle has chosen an intersection path, the vehicle's position is 4.0 times the minimum relative distance (currently 3.0 feet) beyond the stop line, and entry into the intersection will not block the intersection; the vehicle may proceed into the intersection without checking for intersection conflicts. These additions potentially allow an increased volume of left-turn traffic. For a typical 4-leg intersection with passenger-type vehicles, 2 left-turning vehicles generally pull out into the intersection during the green and complete the turn during the yellow-change interval.

The detector logic was modified to implement a loop detector (1) in presence mode where a vehicle is detected from the time its front bumper crosses the start of the detector until its rear bumper crosses the end of the detector and (2) in pulse mode where a vehicle is detected once when its front bumper crosses the start of the detector, only one vehicle may be detected per time step increment, and the detector can detect a different vehicle the next time step increment.

All signal controllers were modified so that if the time remaining in the phase is decremented to a value less than 0.5 times the time step increment, then the time remaining in the phase is set to 0.0. This change rounds the time remaining in the phase to the nearest multiple of the time step increment instead of rounding to the next higher multiple of the time step increment.

Vehicle Logout in SIMPRO

A potential division by zero error was corrected in the vehicle logout routine.

SIMPRO Constants, Variables, and Dimensions

The maximum jerk rate (rate of change of acceleration) for a vehicle was changed from a constant to a variable (SLPMAX) and the value was changed from 4 to 6 feet/sec/sec/sec. This change made the drivers behave more aggressively without changing the maximum acceleration or deceleration rate that the driver would use or the driver's desired velocity.

The minimum distance between vehicles when stopped was changed from a constant to a variable (XRELMI) and the value was changed from 4 to 3 feet. This change made the drivers behave more aggressively.

The minimum relative distance between vehicles when stopped that would cause a following vehicle to initiate a move-up maneuver was changed from a constant to a variable (XRELMX) and the value remained at 10 feet. A vehicle would normally use the 10-foot value except that it is decreased to 3 feet (XRELMI) when the vehicle ahead is accelerating. This change allows vehicles to respond more aggressively when a signal turns green or when the vehicle ahead starts pulling away from the vehicle being processed.

The maximum number of loop detectors per lane was increased from 3 to 6. Additionally, the total number of detectors was increased to 30.

When a vehicle is required to accelerate according to the lead vehicle's speed, the distance used to transition current desired speed from the lead vehicle's speed to the desired speed of the vehicle was decreased from 100 to 50 feet. This change allows vehicles to respond more aggressively when the vehicle ahead is pulling away from the vehicle being processed.

A variable was added for each vehicle defining whether the vehicle has been updated for the current time increment. A subroutine was added to predict the vehicle's position, velocity, and acceleration/deceleration one time-step increment into the future if the vehicle had not been updated for the current time increment and one time-step increment into the past if the vehicle had been updated for the current time increment.

A variable was added for each vehicle defining whether the vehicle doubled its desired speed while on an intersection path.

Vehicle Delay for Unsignalized Lanes in SIMPRO

The model now determines (1) the number of inbound lanes available for traffic at the intersection, (2) the number of 50-foot sections within 200 feet of the intersection-end of each inbound lane, and (3) for each time increment for each inbound lane, (a) the number of vehicles within 200 feet of the intersection-end of each inbound lane and (b) whether there is at least one vehicle within 50 feet of the intersection-end of each inbound lane.

The algorithm for determining the amount of time that a vehicle waits at the stop line for unsignalized lanes has been modified. A factor (FHES) is calculated expressing the pressure of vehicles at or near the stop line of other lanes at the intersection. The range of FHES is from 0.0 when there is at least one vehicle to 1.0 when there are no vehicles within 50 feet of the intersection end of all other inbound lanes and FHES is proportional for other cases. A factor (GHES) is calculated expressing the pressure of vehicles in the vehicle's lane. The range of GHES is from 0.0 when there is at least one vehicle per 50-foot section to 1.0 when there are no other vehicles within 200 feet of the intersection end of the lane and GHES is proportional for other cases. A combined factor (HHES) is calculated by adding FHES and GHES based upon the percentage of GHES as expressed by HHES=(GHES*FHES + (1.0-GHES)*GHES). Therefore, (a) when there are many vehicles behind the current vehicle, the current vehicle ignores the pressure of the vehicles at the other stop lines while (b) when there are no vehicles behind the current vehicle, the current vehicle relies solely on the pressure of the vehicles at the other stop lines and (c) the current vehicle uses proportions for other cases. Next, the hesitation (THES) is calculated by multiplying HHES by 4 times the PIJR time for the driver class for the current vehicle. Finally, if the queue delay time plus THES for the current vehicle is less than the hesitation factor (HESFAC) from input, then THES is set so that the current vehicle will incur the hesitation factor minimum time. Because this algorithm may produce a THES value of 0, modifications were made to allow a vehicle to enter the intersection during the same time-step increment that the vehicle stopped at the stop line.

Consistent Parameters in GEOPRO, DVPRO, and SIMPRO

The parameters file for GEOPRO, DVPRO, and SIMPRO were merged to create a single, common parameters file containing the maximum values for various entities. The following parameters are in effect:

```
MTABR   58 NUMBER OF ROWS IN SUMMARY STATISTICS TABLE
NAL      6 NUMBER OF LANES PER APPROACH
NAR     20 NUMBER OF ARCS
NAS      4 NUMBER OF SIGHT DISTANCE RESTRICTIONS PER APPROACH
NCM     72 NUMBER OF CAM STACK ENTRIES
NCO    125 NUMBER OF INTERSECTION CONFLICTS
NCP     20 NUMBER OF INTERSECTION CONFLICTS PER INTERSECTION PATH
NDC      3 NUMBER OF DRIVER CLASSES
NGR      4 NUMBER OF GROUPS IN NEMA ACTUATED SIGNAL
NIA      8 NUMBER OF INBOUND APPROACHES
NIL     25 NUMBER OF INBOUND LANES
NLG      6 NUMBER OF LEGS
NLI     20 NUMBER OF LINES
NLO      6 NUMBER OF LOOP DETECTORS PER LANE
NLP      4 NUMBER OF INTERSECTION PATHS PER LANE
NLS     30 NUMBER OF LOOP DETECTORS
NOA      8 NUMBER OF OUTBOUND APPROACHES
NOL     25 NUMBER OF OUTBOUND LANES
NOP     12 NUMBER OF OPTIONS FOR TEXAS/DALLAS DIAMOND SIGNAL
NOV      4 NUMBER OF OVERLAPS FOR DIAMOND/NEMA SIGNAL
NPA     45 NUMBER OF INTERSECTION PATHS
NPC      9 NUMBER OF PHASE COMBINATIONS FOR DIAMOND/NEMA SIGNAL
NPH      8 NUMBER OF PHASES FOR SIGNAL
NPL     10 NUMBER OF LOOP DETECTORS PER SIGNAL PHASE
NRG      4 NUMBER OF RINGS FOR DIAMOND/NEMA SIGNAL
NSR     10 NUMBER OF SIGHT DISTANCE RESTRICTION POINTS
NSS     40 NUMBER OF 25FT SECTIONS FOR SIGHT DISTANCE RESTRICTION
NTC      6 NUMBER OF TURN CODES
NTM     12 NUMBER OF TIMERS FOR TEXAS/DALLAS DIAMOND SIGNAL
NVC     12 NUMBER OF VEHICLE CLASSES
NVE    500 NUMBER OF VEHICLES IN THE SYSTEM AT ONE TIME
NVP   6000 NUMBER OF VEHICLES GENERATED PER APPROACH
NAP     16 NUMBER OF APPROACHES                (NAP=NIA+NOA)
NIS     10 NUMBER OF APPROACHES FOR STATISTICS (NIS=NIA+2)
NLA     50 NUMBER OF LANES                     (NLA=NIL+NOL)
NTS      7 NUMBER OF TURN CODES FOR STATISTICS (NTS=NTC+1)
```

CHAPTER 4. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The TEXAS Model for Intersection Traffic has been developed at the Center for Transportation Research at The University of Texas at Austin in cooperation with the Texas Department of Transportation and the Federal Highway Administration. Continuing improvement of this powerful traffic simulation package has recently added several user-requested features which bring the model once again to the leading edge of technology.

Version 3.2 of the TEXAS Model, which is described in this report, provides all functions of previous versions plus free u-turn lanes at diamond interchanges, NEMA dual-ring traffic signal controller simulation with optional volume-density operation, spreadsheet graphical output of summary statistics, geometry plotting capabilities, simulation statistics calculations from replicate model runs, and automated procedures for performing replicate model runs. In addition to meeting all the original objectives of the project, several other additions, corrections, and enhancements were implemented at the request of TxDOT personnel.

The following topics are recommended research applications of the TEXAS Model for Intersection Traffic:

1. Develop warrants for construction and use of free u-turns at a diamond interchanges.
2. Develop warrants for volume-density operation of NEMA signal controllers based upon delay for various traffic conditions and geometric configurations.

The following topics are recommended for future additions and enhancements to the TEXAS Model for Intersection Traffic:

1. Develop a program which reads the SIMSTA output file of summary statistics from two different sets of replicate runs and determines whether there is a statistically significant difference between the sets of replicate runs.
2. Modify path choice logic to check intersection path radius and vehicle turning radius compatibility.
3. Add a method of assessing the effects of truck encroachment on adjacent lanes.
4. Allow different traffic volumes to be specified for specified time periods in a simulation.
5. Provide for intermediate statistics in the user-friendly version.
6. Add bus stop-and-dwell capabilities.
7. Modify user-friendly interface to use full-screen data entry.
8. Increase the number of inbound and outbound lanes from 25 to 30 or more.
9. Increase the length of lanes from 1000 feet to 2000 feet.

10. Develop X Windows animation for workstations.

11. Develop Microsoft Windows animation for PCs.

REFERENCES

1. Lee, Clyde E., Thomas W. Rioux, and Charlie R. Copeland, "The TEXAS Model for Intersection Traffic – Development," Center for Transportation Research Report 184-1, Center for Transportation Research, The University of Texas at Austin, Austin, Texas, December 1977.

2. Lee, Clyde E., Randy B. Machemehl, Robert F. Inman, Charlie R. Copeland, Jr., and Wiley M. Sanders, "User-Friendly TEXAS Model – Guide to Data Entry," Center for Transportation Research Report 361-1F, Center for Transportation Research, The University of Texas at Austin, Austin, Texas, November 1985.

3. Pinnell, C. & Capelle, D.G., "Operational Study of Signalized Diamond Interchanges," Highway Research Board Record No 324, July 1962, pp. 38-72.

4. Capelle & Pinnell, "Capacity Study of Signalized Diamond Interchanges," Highway Research Board Record No. 291, 1961.

5. Pinnell, C. & Tutt, P.R., "Evaluation of Frontage Roads as an Urban Freeway Design Element," Highway Research Board Record No.9, 1963.

6. Torres, J.F, Nemeczky, J.A., Munjal, P.K., and Widdice, B.J., "Before-and-After Simulation and Field Studies of Diamond Interchange Operations," System Development Corporation, Santa Monica, California, (PB 218138), May 1973.

7. Torres, J.F., "Diamond Interchange Traffic Control Vol. 9: Test and Evaluation of Traffic Signal Control System," System Development Corporation, Santa Monica, California, (PB 224160), July 1973.

8. Spitz, Salem, "Signalization of Diamond Interchanges," Traffic Engineering, Vol. 34, No. 7, April 1964, pp. 15-17.

9. Munjal, P.K., et al., "Design Manual for Traffic Signal Control of Diamond Interchange Complexes," System Development Corporation, Santa Monica, California, (PB 217518), June 1972.

10. Crouse-Hinds Corporation, "Diamond Interchange Controller Manual," Unpublished Equipment Manual, 1980.

11. Messer, C.J. and Chang, M-S, "Traffic Operations of Basic Actuated Traffic Control Systems at Diamond Interchanges," Texas Transportation Institute, Research Report 344-2F, August 1985.

12. Van Horn, R. L. , "Validation of Simulation Results," Management Science, 17, pp. 247-258, 1971.

13. Lin, Han-Jei, "A Simulation Study of Left-Turn Operations at Signalized Intersections," Ph.D Dissertation, The University of Texas at Austin, December 1982.

14. "Diamond Operation Notes," Plan Sheets, Texas State Department of Highways and Public Transportation, LFile D-18, Safety and Maintenance Operations Division, Austin, Texas.

15. Lee, Clyde E., Randy B. Machemehl, and Wiley Sanders, "TEXAS Model Version 3.0 (Diamond Interchanges)," Center for Transportation Research Report 443-1F, Center for Transportation Research, The University of Texas at Austin, Austin, Texas, January 1989.

APPENDIX A

COMMAND LINE PARAMETERS

Table of Contents

Section 1

USAGE

Command line parameters are for passing file names or instructions to the TEXAS Model processors. Each parameter may be presented to a processor as keyword parameter or as positional parameter.

Each keyword parameter requires a keyword, a separator and a file name. Keywords are listed below. The separator is an equal sign (=) on all but DOS implementations. The separator must be a plus sign (+) for the DOS implementation. Keyword parameters may appear in any order on the command line.

Positional parameters are distinguished by the order in which they appear on the command line. Keyword parameters are not considered when determining ordering on the command line. There is no provision for skipping positional parameters. If it is desired to skip one or more parameters and therefore use defaults for these, entry of any parameter(s) that follow must use the keyword form.

Parameters are listed below in positional parameter order for each processor. Defaults as shown below in square brackets ([ ]) will be used for all items that are not redefined from the command line.

The examples below assume that you wish to specify *file1* for the PVA parameter, *file2* for the DIS parameter and *file3* for the PAR parameter to the TEXAS Model processor DISPRE. If any of the parameters are not specified, it is assumed that the default is desired for that parameter.

valid

DISPRE PVA+*file1* DIS+*file2* PAR+*file3*
DISPRE *file1* *file2* *file3*
DISPRE *file1* PAR+*file3*
(use default file for DIS)
DISPRE PAR+file3 DIS+*file2* *file1*
(*file1* is the first positional parameter)

not valid

DISPRE *file1* *file3*	(*file3* is second positional parameter, will be used for DIS)
DISPRE PVA+*file1* DIS+*file2* *file3*	(*file3* is first positional parameter, will be used for PVA)
DISPRE *file2*	(*file2* is first positional parameter, will be used for PVA)

Section 2

DEFINITIONS FOR EACH PREPROCESSOR AND PROCESSOR

GDVDATA - Geometry & Driver-Vehicle preprocessor data entry

L - Listing of input data.
    [GDVLIST]

GDVCONV - Convert Geometry & Driver-Vehicle preprocessor data

PRE - Input data in preprocessor format.
    [GDVDATA]
C - Output data in converted format. For input to Simulation Processor.
    [GDV]

GDVPRO - Geometry & Driver-Vehicle Processors

I - Input data in converted format.
    [GDV]
T8 - Geometry Processor output data, for input to SIMPRO.
    [FORT8] (DOS)
    [fort.8] (UNIX)
T9 - Driver-Vehicle Processor output data, for input to SIMPRO. [fort.8] (UNIX)
    [FORT9] (DOS)
    [fort.9] (UNIX)
PLOT - Geometry Processor output data, for input to GEOPLOT. [fort.9] (UNIX)
    [GEOPLOT]
PRE - Input data in preprocessor format. Will be converted and used by GEOPRO and written to file defined by C, below.
    [GDDATA]
C - Output data in converted format. For input to DVPRO.
    [GDV]
LGEO - Listing of Geometry Processor input data.
    [GEOLIST]
LDV - Listing of Driver-Vehicle Processor input data.
    [DVLIST]

GEOPRO - Geometry Processor

I - Input data in converted format.
    [GDV]
L - Listing of input data.
    [GEOLIST]
T8 - Output data, for input to SIMPRO.
    [FORT8] (DOS)
    [fort.8] (UNIX)
PLOT - Output data, for input to GEOPLOT.
    [GEOPLOT]
PRE - Input data in preprocessor format. Will be converted and used by GEOPRO and written to file defined by C, below.
    [GDDATA]

C - Output data in converted format.
[GDV]
LGEO - Same as L, for compatibility with GDVPRO.
[GEOLIST]

GEOPLOT - Plot geometry and path data. (DOS)

PLOT - Plot file for input. This file is from GEOPRO. If this is the first parameter, the file name may be specified without the keyword and plus sign.
[GEOPLOT] TEXT
GKS - The GKS interface will be used. This requires that a GKS Device Driver be available for the desired plotting device. For the PC, DISPLAY or PRINTER or PLOTTER may be chosen. When DISPLAY is used and the GEOPLOT program does not end normally (crash, CNTRL-BREAK, etc.), the DOS mode may not be set correctly. If this happens, use the DOS MODE command (MODE CO80 or MODE MONO) to set the proper DOS mode. Please see the manual for the specific GKS Device Driver for more information about its installation, setup and use.
[DISPLAY]
HPGL - HPGL compatible plotter. This has been tested on Hewlett-Packard desktop plotters.
[COM1] TEXT
DXF - Standard AutoCad external file format. This file can be imported by many CAD packages.
[GEOPLOT.DXF] TEXT
DXF_HDR - File that contains text to be included in DXF header section. The DXF header section contains settings of variables associated with the drawing. If this command line parameter is absent, or the specified file is not found, a search proceeds as follows. First, the current directory is searched. Next, the TEXAS Model system data directory is searched. If a file name and/or path is included on the command line, it is used for the search. A standard file is installed in the TEXAS Model system data directory. This standard file should be adequate for most cases. Including the DXF_HDR parameter implies that the DXF file format is desired.
[GDVDXF] TEXT
PROPRINT - IBM Proprinters and Proprinter XLs. Plotting area is 8.0 x 10.0 inches. Plotting of text is currently not implemented. If data is placed into a file, use the DOS copy command to plot. The /B parameter must be used.
Example: COPY GEOPLOT.PPR /B LPT1
[PRN] BINARY
EPSON - Epson FX and LQ printers. Plotting area is 8.0 x 10.0 inches. Plotting of text is currently not implemented. If data is placed into a file, use the DOS copy command to plot. The /B parameter must be used.
Example: COPY GEOPLOT.EP /B LPT1
[PRN] BINARY
GKS_FIT - Similar to GKS, but the plot will be scaled to fit the available plotting surface. This scaling is done automatically for GKS if the selected device doesn't have a specific, fixed size. A CRT display is one such device.
CONSOLE - PC graphics screen. This is the GEOPLOT default output device. The PC hardware will be inspected and the most advanced graphics mode will be used. For PC's with more than one monitor, the user must first switch to the monitor that will be used. Supports standard IBM CGA, EGA and VGA adapters, plus Hercules mono.
POSTSCRIPT - Data file that can be plotted on a PostScript compatible device.
[GEOPLOT.PS] TEXT

DVPRO - Driver-Vehicle Processor

I - Input data in converted format.
[GDV]
L - Listing of input data.
[DVLIST]
T9 - Output data, for input to SIMPRO.
[FORT9] (DOS)
[fort.9] (UNIX)
PRE - Input data in preprocessor format. Will be converted and used by DVPRO and written to file defined by C, below. [fort.9] (UNIX)
[GDDATA]
C - Output data in converted format.
[GDV]
LDV - Same as L, for compatibility with GDVPRO.
[DVLIST]

SIMDATA - Simulation preprocessor data entry

L - Listing of input data.
[SIMDLST]

SIMCONV - Convert Simulation preprocessor data

PRE - Input data in preprocessor format.
[SIMDATA]
C - Output data in converted format. For input to Simulation Processor.
[SIM]

SIMPRO - Simulation processor

I - Input data in converted format.
[SIM]
L- Listing of input data and summary statistics.
[SIMDLST]
STA - Output of summary statistics in compact format
[SIMSTAT]
T8 - Data from Geometry processor.
[FORT8] (DOS)
[fort.8] (UNIX)
T9 - Data from Driver-Vehicle Processor.
[FORT9] (DOS)
[fort.9] (UNIX)
PVA - Output of vehicle position and velocity data. For input to Animation Preprocessor.
[POSDAT] (DOS) (UNIX)
ERR - Listing of detected errors.
[SIMERR]
PRE - Input data in preprocessor format (VAX VMS).
[SIMDATA.DAT]
C - Output data in converted format. For input to Simulation Processor (VAX VMS).
[SIM.DAT]
REP - Replicate run number, 1 through 10. If present, "R*n*" is put in columns 56 through 59 of the title and the compressed summary statistics option is forced "YES".

DISPRE - Animation Preprocessor (DOS and UNIX)

PVA - Input data with vehicle position and velocity data from Simulation Processor.
[POSDAT]
DIS - Output data with animation data for use by Animation Processor .
[DISDAT]
PAR - Input, animation setup data.
[DISPAR]

DISPRO - Animation Processor (DOS)

DIS - Input of animation data from Animation Preprocessor.
[DISDAT]

DISPRO - Animation Processor (UNIX)
One, two, three or four positional parameters. Each is a file with input of animation data from animation preprocessor.
[DISDAT]

REPRUN - Replicate Run Processor
All parameters are positional parameters. The first three are required. The fourth is optional. All must be in the order shown below.

first - Number of replicate runs to be processed.
second - Name of Geometry & Driver-Vehicle preprocessor data file. This is the file created in GDVDATA.
third - Name of Simulation preprocessor data file. This is the file created in SIMDATA.
fourth (optional) - Sequence number of first replicate run to be processed. If this parameter is present, the first parameter becomes the sequence number of the last replicate run to be processed.

REPTOL - Replicate Run Processor with Tolerance Checking
All parameters are positional parameters. All are required. All must be in the order shown below.

first - Percentage for tolerance check.
second - Name of Geometry & Driver-Vehicle preprocessor data file. This is the file created in GDVDATA.
third - Name of Simulation preprocessor data file. This is the file created in SIMDATA.

SIMSTA - Simulation Statistics Processor

TOL - Percentage for the optional tolerance check. Must be 1 to 50. TOL uses 10 while TOL=n uses n. If not present, the tolerance check is not performed.
STA - Name of summary statistics file from SIMPRO. The file extension(DOS, VMS) or suffix (UNIX) ".R*n* " will be added before opening and reading the data from the files.
[SIMSTAT]
L - Name of listing of summary statistics file.
[SIMSLST] (DOS)
[SIMSLST.LST] (VMS) (UNIX)
SS - Name of the optional spread sheet compatible data file. If not present, the spread sheet compatible data file is not created.
[SPRDSHT.DAT]

APPENDIX B
SPREADSHEET MACRO LISTING

```
APPBOX: {WINDOWSOFF}{PANELOFF}
        :FRIA1..IK20~/REIA1..IK20~
        {FRAMEOFF}
        {GOTO}IB2~Which approach
         you want to examine?~
        {D 2}APPROACH  1~
        {D 2}APPROACH  2~
        {D 2}APPROACH  3~
        {D 2}APPROACH  4~
        {GOTO}IF4~APPROACH  5~
        {D 2}APPROACH  6~
        {D 2}APPROACH  7~
        {D 2}APPROACH  8~
        :FF3IB2..IF10~:FLOIA1..II10~
        :FLSSIA1..II10~:FCTRIB2~
        {WINDOWSON}
        {MENUCALL ONE}


  \G:   {WINDOWSOFF}{PANELOFF}{FRAMEOFF}
        /REIA1..IJ20~:FRHZ1..IJ20~
        {GOTO}IA1~/WCS6~{GOTO}IB1~/WCS12~
        {GOTO}IE1~/WCS2~{GOTO}IF1~/WCS6~
        {GOTO}IA1~Choose a Measure of
        Effectiveness~{D}from the following:~
        {GOTO}IE2~'(Use Icons at the right)~
        {GOTO}IB4~TOTAL DELAY~{D 2}
        AVERAGE TOTAL DELAY~{D 2}
        QUEUE DELAY~{D 2}
        AVERAGE QUEUE DELAY~{D 2}
        STOPPED DELAY~{GOTO}IG4~
        AVERAGE STOPPED DELAY~
        {D 2}VOLUME PROCESSED~
        {D 2}OVERALL AVERAGE~
        {D 2}OVERALL AVERAGE~
        {D 2}OVERALL AVERAGE~
        {GOTO}IH9~TOTAL DELAY~
        {D 2}QUEUE DELAY~{D 2}
        STOPPED DELAY~{GOTO}IA4~
        ^U1~:FLO~:FLSS~{D 2}
        ^U2~:FLO~:FLSS~{D 2}
        ^U3~:FLO~:FLSS~{D 2}
        ^U4~:FLO~:FLSS~{D 2}
        ^U5~:FLO~:FLSS~{GOTO}IF4~
        ^U6~:FLO~:FLSS~{D 2}
        ^U7~:FLO~:FLSS~{D 2}
        ^U8~:FLO~:FLSS~{D 2}
        ^U9~:FLO~:FLSS~{D 2}
        ^U10~:FLO~:FLSS~
        :FF3IA1..IA2~:FF2IE2~
        :FF2IA4..IH15~:FBSIA1..IH15~
        :FLSSIB4..ID14~:FLSSIG4..II14~
        :FCBCIB4..ID14~:FCBCIG4..II14~
        :FCTDIB4..ID14~:FCTDIG4..II14~
        :FCTRIA1..IA2~{GOTO}IA1~
        {WINDOWSON}
```

```
OSEBOX: {WINDOWSOFF}
        {PANELOFF}/REIA1..IJ20~:FRIA1..IJ20~
        {FRAMEOFF}{GOTO}IA1~
        {GOTO}IB2~DO YOU WISH
         TO EXAMINE,~{D 2}{R}
        ONE APPROACH~{D 2}
        SEVERAL APPROACHES~{D 2}
        ENTIRE INTERSECTION?~{D 2}
        {L}Select from menu one,
         several, or entire.~
        :FF3IB2..IH10~:FLOIB2..II10~
        :FLSSIB2..II10~
        {WINDOWSON}{MENUCALL OSEMENU}


SEVBOX: {WINDOWSOFF}
        /REIA1..IJ20~:FRIA1..IJ20~
        {FRAMEOFF}{GOTO}IA1~
        APPROACH 1~{D}
        APPROACH 2~{D}
        APPROACH 3~{D}
        APPROACH 4~{D}
        APPROACH 5~{D}
        APPROACH 6~{D}
        APPROACH 7~{D}
        APPROACH 8~
        :FF3IA1..IA8~:FBSIA1..II8~
        :FCTMIA1..IA8~:FCBCIA1..IC8~
        :FLSSIA1..IC8~{GOTO}IE1~
        You may examine 2 to 6 approaches~
        {D}'at one time. Key in number 1-8~
        {D}'or 9 to quit and press ENTER.~{GOTO}IF4~
        /WCS9~:FF2IE1..IH8~:FLOIF5..IF7~
        :FLSSIF5..IF7~:FLOIH5..IH7~
        :FLSSIH5..IH7~{WINDOWSON}
        {GETNUMBER "Enter approach number (1 to 8) or 9 to end >",IF5}
        {GOTO}IF5~{IF IF5=9}{BRANCH COND1}
        {GETNUMBER "Enter approach number (1 to 8) or 9 to end >",IF6}
        {GOTO}IF6~{IF IF6=9}{BRANCH COND1}
        {GETNUMBER "Enter approach number (1 to 8) or 9 to end >",IF7}
        {GOTO}IF7~{IF IF7=9}{BRANCH COND1}
        {GETNUMBER "Enter approach number (1 to 8) or 9 to end >",IF5}
        {GOTO}IH5~{IF IH5=9}{BRANCH COND1}
        {GETNUMBER "Enter approach number (1 to 8) or 9 to end >",IF6}
        {GOTO}IH6~{IF IH6=9}{BRANCH COND1}
        {GETNUMBER "Enter approach number (1 to 8) or 9 to end >"'IF7}
        {GOTO}IH7~{IF IH7=9}{BRANCH COND1}
        {BRANCH COND1}
```

```
TOTAL-DELAY:    {WINDOWSOFF}{PANELOFF}
*(U1)           /GRROQTF3YQTBXK1..N1~
                AK2..N2~
                OLATotal-Delays~
                TFTOTAL DELAY~
                TYVehicles-Seconds~
                GHCDAK2..N2~CQQQ
                {GOTO}I21~1~{WINDOWSOFF}
                {BRANCH OSEBOX}


AVERAGE         {WINDOWSOFF}{PANELOFF}
TOTAL-DELAY:    /GRROQTF3YQ
*(U2)           TBXK1..N1~
                AK3..N3~
                OLAAverage
                Total-Delay~
                TFAVERAGE~
                TSTOTAL DELAY~
                TYSeconds~
                GHCDAK3..N3~CQQQ
                {GOTO}I21~2~
                {BRANCH OSEBOX}


QUEUE-DELAY:    {WINDOWSOFF}{PANELOFF}
*(U3)           /GRROQTF3YQ
                TBXK1..N1~
                AK4..N4~
                OLAQueue-Delays~
                TFQUEUE DELAY~
                TYVehicles-Seconds~
                GHCDAK4..N4~CQQQ
                {GOTO}I21~3~
                {BRANCH OSEBOX}


AVERAGE         {WINDOWSOFF}{PANELOFF}
QUEUE-DELAY:    /GRROQTF3YQ
*(U4)           TBXK1..N1~
                AK5..N5~
                OLAAverage
                Queue-Delay~
                TFAVERAGE~
                TSQUEUE DELAY~
                TYSeconds~
                GHCDAK5..N5~CQQQ
                {GOTO}I21~4~
                {BRANCH OSEBOX}


STOPPED-DELAY:  {WINDOWSOFF}{PANELOFF}
*(U5)           /GRROQTF3YQ
                TBXK1..N1~
                AK6..N6~
                OLAStopped-Delays~
                TFSTOPPED DELAY~
                TYVehicles-Seconds~
                GHCDAK6..N6~CQQQ
                {GOTO}I21~5~
                {BRANCH OSEBOX}
```

```
AVERAGE          {WINDOWSOFF}{PANELOFF}
STOPPED-DELAY:   /GRROQTF3YQ
*(U6)            TBXK1..N1~
                 AK7..N7~
                 OLAAvg.
                  Stopped-Delay~
                 TFAVERAGE~
                 TSSTOPPED DELAY~
                 TYSeconds~
                 GHCDAK7..N7~CQQQ
                 {GOTO}I21~6~
                 {BRANCH OSEBOX}


    VOLUME       {WINDOWSOFF}{PANELOFF}
  PROCESSED:     /GRROQTF3YQ
*(U7)            TBXK1..N1~
                 AK8..N8~
                 OLAVolume Processed~
                 TFVOLUME PROCESSED~
                 TYVehicles/Hour~
                 GHCDAK8..N8~CQQQ
                 {GOTO}I21~7~
                 {BRANCH OSEBOX}


OVERALL          {WINDOWSOFF}{PANELOFF}
AVERAGE          /GRROQTF3YQ
TOTAL-DELAY:     TBXK1..N1~
*(8)             AK9..N9~
                 OLAOverall
                  Average~
                 TFOVERALL AVERAGE~
                 TSTOTAL DELAY~
                 TYSeconds~
                 GHCDAK9..N9~CQQQ
                 {GOTO}I21~8~
                 {BRANCH OSEBOX}


OVERALL          {WINDOWSOFF}{PANELOFF}
AVERAGE          /GRROQTF3YQ
QUEUE-DELAY:     TBXK1..N1~
*(9)             AK10..N10~
                 OLAOverall
                  Average~
                 TFOVERALL AVERAGE~
                 TSQUEUE DELAY~
                 TYSeconds~
                 GHCDAK10..N10~CQQQ
                 {GOTO}I21~9~
                 {BRANCH OSEBOX}
```

```
OVERALL         {WINDOWSOFF}{PANELOFF}
AVERAGE         /GRROQTF3YQ
STOPPED-DELAY:  TBXK1..N1~
*(10)           AK11..N11~
                OLAOverall
                 Average~
                TFOVERALL AVERAGE~
                TSSTOPPED DELAY~
                TYSeconds~
                GHCDAK11..N11~CQQQ
                {GOTO}I21~10~
                {BRANCH OSEBOX}


APPROACH1: {WINDOWSOFF}{PANELOFF}
           /REI1..N13~{GOTO}I1~{FRAMEOFF
           APPROACH 1~{TABLE1}
           /CC5..E5~K2~/CH5~N2~
           /CC8..E8~K3~/CH8~N3~
           /CC10..E10~K4~/CH10~N4~
           /CC13..E13~K5~/CH13~N5~
           /CC15..E15~K6~/CH15~N6~
           /CC18..E18~K7~/CH18~N7~
           /CC30..E30~K8~/CH30~N8~
           /CC36..E36~K9~/CH36~N9~
           /CC37..E37~K10~/CH37~N10~
           /CC38..E38~K11~/CH38~N11~
           /GOTXAPPROACH 1~
           QQ{GRAPH}{ENDBOX}


APPROACH2: {WINDOWSOFF}{PANELOFF}
           {GOTO}I1~/REI1..N13~{FRAMEOFF
           APPROACH 2~{TABLE1}
           /CC60..E60~K2~/CH60~N2~
           /CC63..E63~K3~/CH63~N3~
           /CC65..E65~K4~/CH65~N4~
           /CC68..E68~K5~/CH68~N5~
           /CC70..E70~K6~/CH70~N6~
           /CC73..E73~K7~/CH73~N7~
           /CC85..E85~K8~/CH85~N8~
           /CC91..E91~K9~/CH91~N9~
           /CC92..E92~K10~/CH92~N10~
           /CC93..E93~K11~/CH93~N11~
           /GOTXAPPROACH 2~
           QQ{GRAPH}{ENDBOX}


APPROACH3: {WINDOWSOFF}{PANELOFF}
           {GOTO}I1~/REI1..N13~{FRAMEOFF
           APPROACH 3~{TABLE1}
           /CC115..E115~K2~/CH115~N2~
           /CC118..E118~K3~/CH118~N3~
           /CC120..E120~K4~/CH120~N4~
           /CC123..E123~K5~/CH123~N5~
           /CC125..E125~K6~/CH125~N6~
           /CC128..E128~K7~/CH128~N7~
           /CC140..E140~K8~/CH140~N8~
           /CC146..E146~K9~/CH146~N9~
           /CC147..E147~K10~/CH147~N10~
           /CC148..E148~K11~/CH148~N11~
           /GOTXAPPROACH 3~
           QQ{GRAPH}{ENDBOX}
```

```
APPROACH4: {WINDOWSOFF}{PANELOFF}
           {GOTO}I1~/REI1..N13~{FRAMEOFF
           APPROACH 4~{TABLE1}
           /CC170..E170~K2~/CH170~N2~
           /CC173..E173~K3~/CH173~N3~
           /CC175..E175~K4~/CH175~N4~
           /CC178..E178~K5~/CH178~N5~
           /CC180..E180~K6~/CH180~N6~
           /CC183..E183~K7~/CH183~N7~
           /CC195..E195~K8~/CH195~N8~
           /CC201..E201~K9~/CH201~N9~
           /CC202..E202~K10~/CH202~N10~
           /CC203..E203~K11~/CH203~N11~
           /GOTXAPPROACH 4~
           QQ{GRAPH}{ENDBOX}

APPROACH5: {WINDOWSOFF}{PANELOFF}
           {GOTO}I1~/REI1..N13~{FRAMEOFF
           APPROACH 5~{TABLE1}
           /CC225..E225~K2~/CH225~N2~
           /CC228..E228~K3~/CH228~N3~
           /CC230..E230~K4~/CH230~N4~
           /CC233..E233~K5~/CH233~N5~
           /CC235..E235~K6~/CH235~N6~
           /CC238..E238~K7~/CH238~N7~
           /CC250..E250~K8~/CH250~N8~
           /CC256..E256~K9~/CH256~N9~
           /CC257..E257~K10~/CH257~N10~
           /CC258..E258~K11~/CH258~N11~
           /GOTXAPPROACH 5~
           QQ{GRAPH}{ENDBOX}

APPROACH6: {WINDOWSOFF}{PANELOFF}
           {GOTO}I1~/REI1..N13~{FRAMEOFF
           APPROACH 6~{TABLE1}
           /CC280..E280~K2~/CH280~N2~
           /CC283..E283~K3~/CH283~N3~
           /CC285..E285~K4~/CH285~N4~
           /CC288..E288~K5~/CH288~N5~
           /CC290..E290~K6~/CH290~N6~
           /CC293..E293~K7~/CH293~N7~
           /CC305..E305~K8~/CH305~N8~
           /CC311..E311~K9~/CH311~N9~
           /CC312..E312~K10~/CH312~N10~
           /CC313..E313~K11~/CH313~N11~
           /GOTXAPPROACH 6~
           QQ{GRAPH}{ENDBOX}
```

```
APPROACH7: {WINDOWSOFF}{PANELOFF}
           {GOTO}I1~/REI1..N13~{FRAMEOFF
           APPROACH 7~{TABLE1}
           /CC335..E335~K2~/CH335~N2~
           /CC338..E338~K3~/CH338~N3~
           /CC340..E340~K4~/CH340~N4~
           /CC343..E343~K5~/CH343~N5~
           /CC345..E345~K6~/CH345~N6~
           /CC348..E348~K7~/CH348~N7~
           /CC360..E360~K8~/CH360~N8~
           /CC366..E366~K9~/CH366~N9~
           /CC367..E367~K10~/CH367~N10~
           /CC368..E368~K11~/CH368~N11~
           /GOTXAPPROACH 7~
           QQ{GRAPH}{ENDBOX}

APPROACH8: {WINDOWSOFF}{PANELOFF}
           {GOTO}I1~/REI1..N13~{FRAMEOFF
           APPROACH 8~{TABLE1}
           /CC390..E390~K2~/CH390~N2~
           /CC393..E393~K3~/CH393~N3~
           /CC395..E395~K4~/CH395~N4~
           /CC398..E398~K5~/CH398~N5~
           /CC400..E400~K6~/CH400~N6~
           /CC403..E403~K7~/CH403~N7~
           /CC415..E415~K8~/CH415~N8~
           /CC421..E421~K9~/CH421~N9~
           /CC422..E422~K10~/CH422~N10~
           /CC423..E423~K11~/CH423~N11~
           /GOTXAPPROACH 8~
           QQ{GRAPH}{ENDBOX}

COND1:     {WINDOWSOFF}{PANELOFF}
           {IF I21=1}{BRANCH SEV-TD}
           {IF I21=2}{BRANCH SEV-ATD}
           {IF I21=3}{BRANCH SEV-QD}
           {IF I21=4}{BRANCH SEV-AQD}
           {IF I21=5}{BRANCH SEV-SD}
           {IF I21=6}{BRANCH SEV-ASD}
           {IF I21=7}{BRANCH SEV-VP}
           {IF I21=8}{BRANCH SEV-OATD}
           {IF I21=9}{BRANCH SEV-OAQD}
           {IF I21=10}{BRANCH SEV-OASD}

SEV-TD:    {WINDOWSOFF}{PANELOFF}
           {FRAMEOFF}/REI21..M30~
           /CC4..E4~J21~/CH4~M21~
           {GOTO}I21~^TOTAL DELAY~
           /DFI22..I29~1~1~8~
           /CC5..E5~J22~/CH5~M22~
           /CC60..E60~J23~/CH60~M23~
           /CC115..E115~J24~/CH115~M24~
           /CC170..E170~J25~/CH170~M25~
           /CC225..E225~J26~/CH225~M26~
           /CC280..E280~J27~/CH280~M27~
           /CC335..E335~J28~/CH335~M28~
           /CC390..E390~J29~/CH390~M29~
           /GRROQXJ21..M21~OTFTOTAL DELAY~
           TYVehicles-Seconds~GHCQQ
           {\A}{ENDBOX}
```

```
SEV-ATD:  {WINDOWSOFF}{PANELOFF}
          {FRAMEOFF}/REI21..M30~
          /CC4..E4~J21~/CH4~M21~
          {GOTO}I21~^AVG. TOTAL DELAY~
          /DFI22..I29~1~1~8~
          /CC8..E8~J22~/CH8~M22~
          /CC63..E63~J23~/CH63~M23~
          /CC118..E118~J24~/CH118~M24~
          /CC173..E173~J25~/CH173~M25~
          /CC228..E228~J26~/CH228~M26~
          /CC283..E283~J27~/CH283~M27~
          /CC338..E338~J28~/CH338~M28~
          /CC393..E393~J29~/CH393~M29~
          /GRROQXJ21..M21~
          OTFAVERAGE~TSTOTAL DELAY~
          TYSeconds~
          GHCQQ{\A}{ENDBOX}
```

```
SEV-QD:   {WINDOWSOFF}{PANELOFF}
          {FRAMEOFF}/REI21..M30~
          /CC4..E4~J21~/CH4~M21~
          {GOTO}I21~^QUEUE DELAY~
          /DFI22..I29~1~1~8~
          /CC10..E10~J22~/CH10~M22~
          /CC65..E65~J23~/CH65~M23~
          /CC120..E120~J24~/CH120~M24~
          /CC175..E175~J25~/CH175~M25~
          /CC230..E230~J26~/CH230~M26~
          /CC285..E285~J27~/CH285~M27~
          /CC340..E340~J28~/CH340~M28~
          /CC395..E395~J29~/CH395~M29~
          /GRROQXJ21..M21~OTFQUEUE DELAY~
          TYVehicles-Seconds~GHCQQ
          {\A}{ENDBOX}
```

```
SEV-AQD:  {WINDOWSOFF}{PANELOFF}
          {FRAMEOFF}/REI21..M30~
          /CC4..E4~J21~/CH4~M21~
          {GOTO}I21~^AVG. QUEUE DELAY~
          /DFI22..I29~1~1~8~
          /CC13..E13~J22~/CH13~M22~
          /CC68..E68~J23~/CH68~M23~
          /CC123..E123~J24~/CH123~M24~
          /CC178..E178~J25~/CH178~M25~
          /CC233..E233~J26~/CH233~M26~
          /CC288..E288~J27~/CH288~M27~
          /CC343..E343~J28~/CH343~M28~
          /CC398..E398~J29~/CH398~M29~
          /GRROQXJ21..M21~
          OTFAVERAGE~TSQUEUE DELAY~
          TYSeconds~
          GHCQQ{\A}{ENDBOX}
```

```
SEV-SD:   {WINDOWSOFF}{PANELOFF}
          {FRAMEOFF}/REI21..M30~
          /CC4..E4~J21~/CH4~M21~
          {GOTO}I21~^STOPPED DELAY~
          /DFI22..I29~1~1~8~
          /CC15..E15~J22~/CH15~M22~
          /CC70..E70~J23~/CH70~M23~
          /CC125..E125~J24~/CH125~M24~
          /CC180..E180~J25~/CH180~M25~
          /CC235..E235~J26~/CH235~M26~
          /CC290..E290~J27~/CH290~M27~
          /CC345..E345~J28~/CH345~M28~
          /CC400..E400~J29~/CH400~M29~
          /GRROQXJ21..M21~OTFSTOPPED DELAY~
          TYVehicles-Seconds~GHCQQ
          {\A}{ENDBOX}

SEV-ASD:  {WINDOWSOFF}{PANELOFF}
          {FRAMEOFF}/REI21..M30~
          /CC4..E4~J21~/CH4~M21~
          {GOTO}I21~^AVG. STOPPED DELAY~
          /DFI22..I29~1~1~8~
          /CC18..E18~J22~/CH18~M22~
          /CC73..E73~J23~/CH73~M23~
          /CC128..E128~J24~/CH128~M24~
          /CC183..E183~J25~/CH183~M25~
          /CC238..E238~J26~/CH238~M26~
          /CC293..E293~J27~/CH293~M27~
          /CC348..E348~J28~/CH348~M28~
          /CC403..E403~J29~/CH403~M29~
          /GRROQXJ21..M21~
          OTFAVERAGE~TSSTOPPED DELAY~
          TYSeconds~
          GHCQQ{\A}{ENDBOX}

SEV-OATD: {WINDOWSOFF}{PANELOFF}
          {FRAMEOFF}/REI21..M30~
          /CC4..E4~J21~/CH4~M21~
          {GOTO}I21~^OVERALL ATD~
          /DFI22..I29~1~1~8~
          /CC36..E36~J22~/CH36~M22~
          /CC91..E91~J23~/CH91~M23~
          /CC146..E146~J24~/CH146~M24~
          /CC201..E201~J25~/CH201~M25~
          /CC256..E256~J26~/CH256~M26~
          /CC311..E311~J27~/CH311~M27~
          /CC366..E366~J28~/CH366~M28~
          /CC421..E421~J29~/CH421~M29~
          /GRROQXJ21..M21~
          OTFOVERALL AVERAGE~TSTOTAL DELAY~
          TYSeconds~
          GHCQQ{\A}{ENDBOX}
```

```
SEV-OAQD: {WINDOWSOFF}{PANELOFF}
          {FRAMEOFF}/REI21..M30~
          /CC4..E4~J21~/CH4~M21~
          {GOTO}I21~^OVERALL AQD~
          /DFI22..I29~1~1~8~
          /CC37..E37~J22~/CH37~M22~
          /CC92..E92~J23~/CH92~M23~
          /CC147..E147~J24~/CH147~M24~
          /CC202..E202~J25~/CH202~M25~
          /CC257..E257~J26~/CH257~M26~
          /CC312..E312~J27~/CH312~M27~
          /CC367..E367~J28~/CH367~M28~
          /CC422..E422~J29~/CH422~M29~
          /GRROQXJ21..M21~
          OTFOVERALL AVERAGE~TSQUEUE DELAY~
          TYSeconds~
          GHCQQ{\A}{ENDBOX}

SEV-OASD: {WINDOWSOFF}{PANELOFF}
          {FRAMEOFF}/REI21..M30~
          /CC4..E4~J21~/CH4~M21~
          {GOTO}I21~^OVERALL ASD~
          /DFI22..I29~1~1~8~
          /CC38..E38~J22~/CH38~M22~
          /CC93..E93~J23~/CH93~M23~
          /CC148..E148~J24~/CH148~M24~
          /CC203..E203~J25~/CH203~M25~
          /CC258..E258~J26~/CH258~M26~
          /CC313..E313~J27~/CH313~M27~
          /CC368..E368~J28~/CH368~M28~
          /CC423..E423~J29~/CH423~M29~
          /GRROQXJ21..M21~
          OTFOVERALL AVERAGE~TSSTOPPED DELAY~
          TYSeconds~
          GHCQQ{\A}{ENDBOX}
```

```
SEV-VP:  {WINDOWSOFF}{PANELOFF}
         {FRAMEOFF}/REI21..M30~
         /CC4..E4~J21~/CH4~M21~
         {GOTO}I21~^VOL-PROCESSED~
         /DFI22..I29~1~1~8~
         /CC30..E30~J22~/CH30~M22~
         /CC85..E85~J23~/CH85~M23~
         /CC140..E140~J24~/CH140~M24~
         /CC195..E195~J25~/CH195~M25~
         /CC250..E250~J26~/CH250~M26~
         /CC305..E305~J27~/CH305~M27~
         /CC360..E360~J28~/CH360~M28~
         /CC415..E415~J29~/CH415~M29~
         /GRROQXJ21..M21~
         OTFVOLUME PROCESSED~
         TYVehicles/Hour~
         GHCQQ{\A}{ENDBOX}

\A:    {IF IF5=1}/GAJ22..M22~OLAAPPROACH 1~QQ{BRANCH \B}
       {IF IF5=2}/GAJ23..M23~OLAAPPROACH 2~QQ{BRANCH \B}
       {IF IF5=3}/GAJ24..M24~OLAAPPROACH 3~QQ{BRANCH \B}
       {IF IF5=4}/GAJ25..M25~OLAAPPROACH 4~QQ{BRANCH \B}
       {IF IF5=5}/GAJ26..M26~OLAAPPROACH 5~QQ{BRANCH \B}
       {IF IF5=6}/GAJ27..M27~OLAAPPROACH 6~QQ{BRANCH \B}
       {IF IF5=7}/GAJ28..M28~OLAAPPROACH 7~QQ{BRANCH \B}
       {IF IF5=8}/GAJ29..M29~OLAAPPROACH 8~QQ{BRANCH \B}
       {IF IF5=9}{GRAPH}

\B:    {IF IF6=1}/GBJ22..M22~OLBAPPROACH 1~QQ{BRANCH \C}
       {IF IF6=2}/GBJ23..M23~OLBAPPROACH 2~QQ{BRANCH \C}
       {IF IF6=3}/GBJ24..M24~OLBAPPROACH 3~QQ{BRANCH \C}
       {IF IF6=4}/GBJ25..M25~OLBAPPROACH 4~QQ{BRANCH \C}
       {IF IF6=5}/GBJ26..M26~OLBAPPROACH 5~QQ{BRANCH \C}
       {IF IF6=6}/GBJ27..M27~OLBAPPROACH 6~QQ{BRANCH \C}
       {IF IF6=7}/GBJ28..M28~OLBAPPROACH 7~QQ{BRANCH \C}
       {IF IF6=8}/GBJ29..M29~OLBAPPROACH 8~QQ{BRANCH \C}
       {IF IF6=9}{GRAPH}

\C:    {IF IF7=1}/GCJ22..M22~OLCAPPROACH 1~QQ{BRANCH \D}
       {IF IF7=2}/GCJ23..M23~OLCAPPROACH 2~QQ{BRANCH \D}
       {IF IF7=3}/GCJ24..M24~OLCAPPROACH 3~QQ{BRANCH \D}
       {IF IF7=4}/GCJ25..M25~OLCAPPROACH 4~QQ{BRANCH \D}
       {IF IF7=5}/GCJ26..M26~OLCAPPROACH 5~QQ{BRANCH \D}
       {IF IF7=6}/GCJ27..M27~OLCAPPROACH 6~QQ{BRANCH \D}
       {IF IF7=7}/GCJ28..M28~OLCAPPROACH 7~QQ{BRANCH \D}
       {IF IF7=8}/GCJ29..M29~OLCAPPROACH 8~QQ{BRANCH \D}
       {IF IF7=9}{GRAPH}

\D:    {IF IH5=1}/GDJ22..M22~OLDAPPROACH 1~QQ{BRANCH \E}
       {IF IH5=2}/GDJ23..M23~OLDAPPROACH 2~QQ{BRANCH \E}
       {IF IH5=3}/GDJ24..M24~OLDAPPROACH 3~QQ{BRANCH \E}
       {IF IH5=4}/GDJ25..M25~OLDAPPROACH 4~QQ{BRANCH \E}
       {IF IH5=5}/GDJ26..M26~OLDAPPROACH 5~QQ{BRANCH \E}
       {IF IH5=6}/GDJ27..M27~OLDAPPROACH 6~QQ{BRANCH \E}
       {IF IH5=7}/GDJ28..M28~OLDAPPROACH 7~QQ{BRANCH \E}
       {IF IH5=8}/GDJ29..M29~OLDAPPROACH 8~QQ{BRANCH \E}
       {IF IH5=9}{GRAPH}
```

```
\E:    {IF IH6=1}/GEJ22..M22~OLEAPPROACH 1~QQ{BRANCH \F}
       {IF IH6=2}/GEJ23..M23~OLEAPPROACH 2~QQ{BRANCH\F}
       {IF IH6=3}/GEJ24..M24~OLEAPPROACH 3~QQ{BRANCH \F}
       {IF IH6=4}/GEJ25..M25~OLEAPPROACH 4~QQ{BRANCH \F}
       {IF IH6=5}/GEJ26..M26~OLEAPPROACH 5~QQ{BRANCH \F}
       {IF IH6=6}/GEJ27..M27~OLEAPPROACH 6~QQ{BRANCH \F}
       {IF IH6=7}/GEJ28..M28~OLEAPPROACH 7~QQ{BRANCH \F}
       {IF IH6=8}/GEJ29..M29~OLEAPPROACH 8~QQ{BRANCH \F}
       {IF IH6=9}{GRAPH}

\F:    {IF IH7=1}/GFJ22..M22~OLFAPPROACH 1~QQ{GRAPH}
       {IF IH7=2}/GFJ23..M23~OLFAPPROACH 2~QQ{GRAPH}
       {IF IH7=3}/GFJ24..M24~OLFAPPROACH 3~QQ{GRAPH}
       {IF IH7=4}/GFJ25..M25~OLFAPPROACH 4~QQ{GRAPH}
       {IF IH7=5}/GFJ26..M26~OLFAPPROACH 5~QQ{GRAPH}
       {IF IH7=6}/GFJ27..M27~OLFAPPROACH 6~QQ{GRAPH}
       {IF IH7=7}/GFJ28..M28~OLFAPPROACH 7~QQ{GRAPH}
       {IF IH7=8}/GFJ29..M29~OLFAPPROACH 8~QQ{GRAPH}
       {IF IH7=9}{GRAPH}

COND2:    {WINDOWSOFF}{PANELOFF}
          {IF I21=1}{BRANCH E-TD}
          {IF I21=2}{BRANCH E-ATD}
          {IF I21=3}{BRANCH E-QD}
          {IF I21=4}{BRANCH E-AQD}
          {IF I21=5}{BRANCH E-SD}
          {IF I21=6}{BRANCH E-ASD}
          {IF I21=7}{BRANCH E-VP}
          {IF I21=8}{BRANCH E-OATD}
          {IF I21=9}{BRANCH E-OAQD}
          {IF I21=10}{BRANCH E-OASD}
```

```
E-TD:    {WINDOWSOFF}{PANELOFF}
         {FRAMEOFF}/REI21..M30~
         /CC4..E4~J21~/CH4~M21~
         {GOTO}I21~^TOTAL DELAY~
         /DFI22..I29~1~1~4~
         /CC5..E5~J22~/CH5~M22~
         /CC60..E60~J23~/CH60~M23~
         /CC115..E115~J24~/CH115~M24~
         /CC170..E170~J25~/CH170~M25~
         /GRROQOTFTOTAL DELAY~
         TYVehicles-Seconds~QQ
         {ENTIREGRAPH}

E-ATD:   {WINDOWSOFF}{PANELOFF}
         {FRAMEOFF}/REI21..M30~
         /CC4..E4~J21~/CH4~M21~
         {GOTO}I21~^AVG. TOTAL DELAY~
         /DFI22..I29~1~1~4~
         /CC8..E8~J22~/CH8~M22~
         /CC63..E63~J23~/CH63~M23~
         /CC118..E118~J24~/CH118~M24~
         /CC173..E173~J25~/CH173~M25~
         /GRROQ
         OTFAVERAGE~TSTOTAL DELAY~
         TYSeconds~QQ{ENTIREGRAPH}

E-QD:    {WINDOWSOFF}{PANELOFF}
         {FRAMEOFF}/REI21..M30~
         /CC4..E4~J21~/CH4~M21~
         {GOTO}I21~^QUEUE DELAY~
         /DFI22..I29~1~1~4~
         /CC10..E10~J22~/CH10~M22~
         /CC65..E65~J23~/CH65~M23~
         /CC120..E120~J24~/CH120~M24~
         /CC175..E175~J25~/CH175~M25~
         /GRROQOTFQUEUE DELAY~
         TYVehicles-Seconds~QQ
         {ENTIREGRAPH}

E-AQD:   {WINDOWSOFF}{PANELOFF}
         {FRAMEOFF}/REI21..M30~
         /CC4..E4~J21~/CH4~M21~
         {GOTO}I21~^AVG. QUEUE DELAY~
         /DFI22..I29~1~1~4~
         /CC13..E13~J22~/CH13~M22~
         /CC68..E68~J23~/CH68~M23~
         /CC123..E123~J24~/CH123~M24~
         /CC178..E178~J25~/CH178~M25~
         /GRROQ
         OTFAVERAGE~TSQUEUE DELAY~
         TYSeconds~QQ{ENTIREGRAPH}
```

```
E-SD:   {WINDOWSOFF}{PANELOFF}
        {FRAMEOFF}/REI21..M30~
        /CC4..E4~J21~/CH4~M21~
        {GOTO}I21~^STOPPED DELAY~
        /DFI22..I29~1~1~4~
        /CC15..E15~J22~/CH15~M22~
        /CC70..E70~J23~/CH70~M23~
        /CC125..E125~J24~/CH125~M24~
        /CC180..E180~J25~/CH180~M25~
        /GRROQOTFSTOPPED DELAY~
        TYVehicles-Seconds~QQ
        {ENTIREGRAPH}

E-ASD:  {WINDOWSOFF}{PANELOFF}
        {FRAMEOFF}/REI21..M30~
        /CC4..E4~J21~/CH4~M21~
        {GOTO}I21~^AVG. STOPPED DELAY~
        /DFI22..I29~1~1~4~
        /CC18..E18~J22~/CH18~M22~
        /CC73..E73~J23~/CH73~M23~
        /CC128..E128~J24~/CH128~M24~
        /CC183..E183~J25~/CH183~M25~
        /GRROQ
        OTFAVERAGE~TSSTOPPED DELAY~
        TYSeconds~QQ{ENTIREGRAPH}

E-OATD: {WINDOWSOFF}{PANELOFF}
        {FRAMEOFF}/REI21..M30~
        /CC4..E4~J21~/CH4~M21~
        {GOTO}I21~^OVERALL ATD~
        /DFI22..I29~1~1~4~
        /CC36..E36~J22~/CH36~M22~
        /CC91..E91~J23~/CH91~M23~
        /CC146..E146~J24~/CH146~M24~
        /CC201..E201~J25~/CH201~M25~
        /GRROQOTFOVERALL AVERAGE~
        TSTOTAL DELAY~
        TYSeconds~QQ{ENTIREGRAPH}

E-OAQD: {WINDOWSOFF}{PANELOFF}
        {FRAMEOFF}/REI21..M30~
        /CC4..E4~J21~/CH4~M21~
        {GOTO}I21~^OVERALL AQD~
        /DFI22..I29~1~1~4~
        /CC37..E37~J22~/CH37~M22~
        /CC92..E92~J23~/CH92~M23~
        /CC147..E147~J24~/CH147~M24~
        /CC202..E202~J25~/CH202~M25~
        /CC257..E257~J26~/CH257~M26~
        /CC312..E312~J27~/CH312~M27~
        /CC367..E367~J28~/CH367~M28~
        /CC422..E422~J29~/CH422~M29~
        /GRROQ
        OTFOVERALL AVERAGE~TSQUEUE DELAY
        TYSeconds~QQ{ENTIREGRAPH}
```

```
   E-OASD:  {WINDOWSOFF}{PANELOFF}
            {FRAMEOFF}/REI21..M30~
            /CC4..E4~J21~/CH4~M21~
            {GOTO}I21~^OVERALL ASD~
            /DFI22..I29~1~1~4~
            /CC38..E38~J22~/CH38~M22~
            /CC93..E93~J23~/CH93~M23~
            /CC148..E148~J24~/CH148~M24~
            /CC203..E203~J25~/CH203~M25~
            /GRROQOTFOVERALL AVERAGE~
            TSSTOPPED DELAY~
            TYSeconds~QQ{ENTIREGRAPH}


    E-VP:   {WINDOWSOFF}{PANELOFF}
            {FRAMEOFF}/REI21..M30~
            /CC4..E4~J21~/CH4~M21~
            {GOTO}I21~^VOL-PROCESSED~
            /DFI22..I29~1~1~4~
            /CC30..E30~J22~/CH30~M22~
            /CC85..E85~J23~/CH85~M23~
            /CC140..E140~J24~/CH140~M24~
            /CC195..E195~J25~/CH195~M25~
            /GRROQ
            OTFVOLUME PROCESSED~
            TYVehicles/Hour~QQ
            {ENTIREGRAPH}


  ENDBOX:   {WINDOWSOFF}{PANELOFF}
            {FRAMEOFF}{GOTO}IA1~
            /REIA1..IJ20~:FRIA1..IJ20~
            {GOTO}IC4~If you want to save, p
            or enhance the graph~{D}Press Q(
            to end the macro~{D}and return t
            READY mode.~{D 2}If you want to
            examine others graph~{D}Press M(
            to continue~{D}the graph macro
            process.~
            :FCBCHZ1..IJ20~:FCBNIA4..IH13~
            :FCTRIC5~:FCTRIC10~
            :FLOIA4..IH13~:FLSSIA4..IH13~
            :FF2IC4..IC13~:FBSIC4..IC13~
            :GAM{R}~IB4~AM{R}~IB9~Q
            {WINDOWSON}{MENUCALL ENDMENU}
            :GRIB4..IB12~Q

ENTIREGRAPH:/GGJ21..M25~R
             OLAAPPROACH 1~
             LBAPPROACH 2~
             LCAPPROACH 3~
             LDAPPROACH 4~
             GHCQQ{GRAPH}
             {ENDBOX}
```

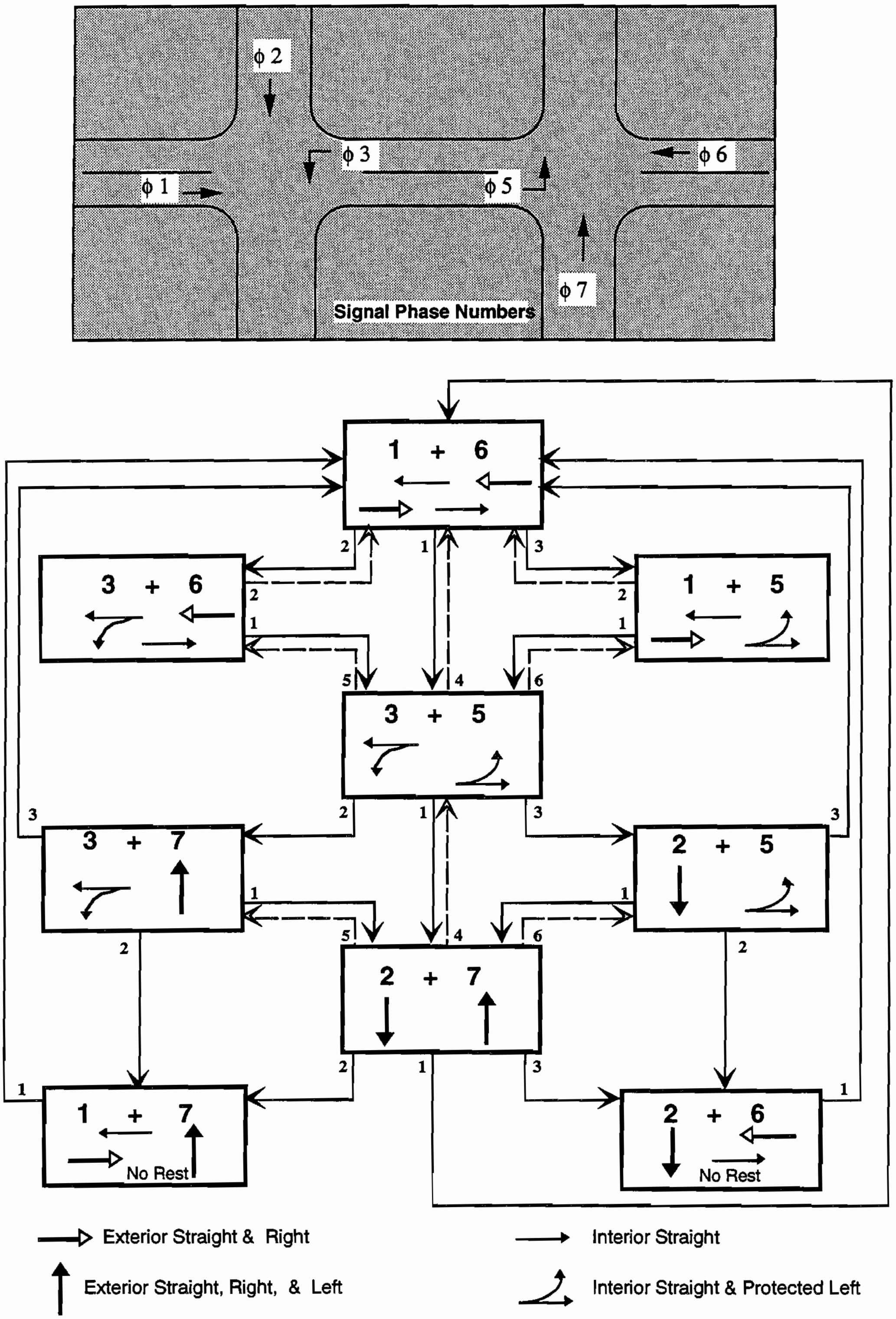
```
OSEMENU:              ONE                                            SEVERAL                      ENTIRE
         To Examine One Approach (1,2,3,or 4)  To Examine Several Approaches           To Examine Approach 1 to 4
         {APPBOX}                              {SEVBOX}                       {COND2}

  ONE:                1                         2          3           4           5           6           7           8
         APPROACH 1           APPROACH 2                APPROACH 3  APPROACH 4  APPROACH 5  APPROACH 6  APPROACH 7  APPROACH 8
         {APPROACH1}          {APPROACH2}               {APPROACH3} {APPROACH4} {APPROACH5} {APPROACH6} {APPROACH7} {APPROACH8}

ENDMENU: Macro                                 Quit
         To continue the macro                 To end the macro
         {\G}                                  :GRIB4..IB11~Q/REIA1..IJ20~:FRIA1..IJ20~{QUIT}

    TABLE1: {WINDOWSOFF}{PANELOFF}
            {FRAMEOFF}{GOTO}K1~
            ^LEFT~{R}^STRAIGHT~
            {R}^RIGHT~
            {R}^ALL TRAFFIC~
            {GOTO}I2~/WCS21~
            TOTAL DELAY~{D}
            AVERAGE TOTAL
            DELAY~{D}
            QUEUE DELAY~{D}
            AVERAGE QUEUE
            DELAY~{D}
            STOPPED DELAY~{D}
            AVERAGE STOPPED
            DELAY~{D}
            VOLUME PROCESSED~
            {D}OVERALL AVERAGE
             TOTAL DELAY~{D}
            OVERALL AVERAGE
             QUEUE DELAY~{D}
            OVERALL AVERAGE
             STOPPED DELAY~
```

APPENDIX C

PHASE SEQUENCE PATTERNS
for
ACTUATED TRAFFIC SIGNAL CONTROLLERS
at
DIAMOND INTERCHANGES

(After Texas Department of Transportation, Traffic Engineering Section of the Division of Maintenance and Operations, D-18TE, "Diamond Operation Notes," Plan Sheets)

Figure 3	LAG-LAG Interior left-turn at Left intersection lags opposing arterial phase Interior left-turn at Right intersection lags opposing arterial phase
Figure 4	LEAD-LEAD Interior left-turn at Left intersection leads opposing arterial phase Interior left-turn at Right intersection leads opposing arterial phase
Figure 6	LEAD-LAG Interior left-turn at Left intersection leads opposing arterial phase Interior left-turn at Right intersection lags opposing arterial phase
Figure 7	LAG-LEAD Interior left-turn at Left intersection lags opposing arterial phase Interior left-turn at Right intersection leads opposing arterial phase



Rest allowed in all phases except 1+7 and 2+6 (call phase on Exit Path Priority 1)

Figure C-1 Operation of the "Figure 3" Signal Controller Pattern

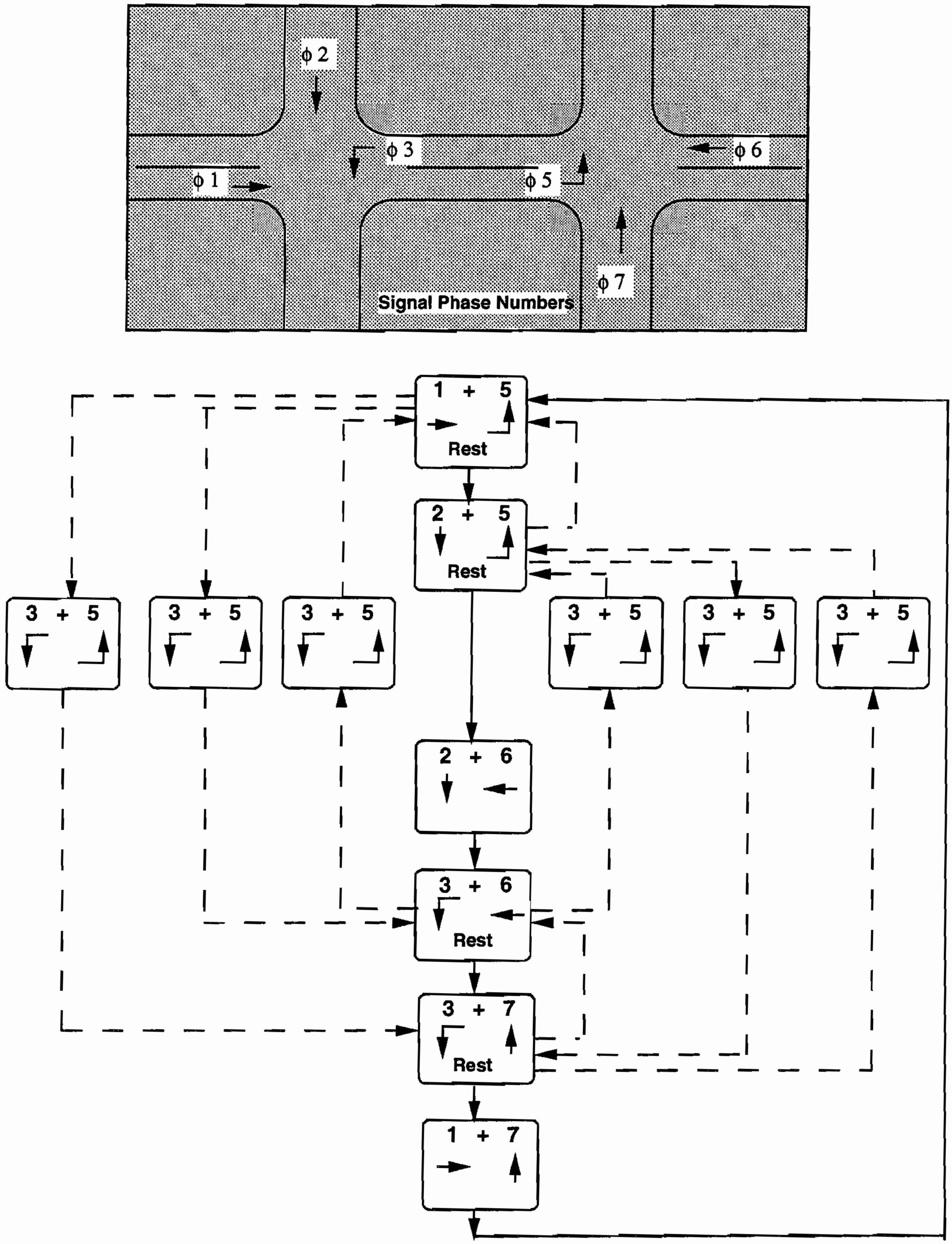


Figure C-2 Operation of the "Figure 4" Signal Controller Pattern

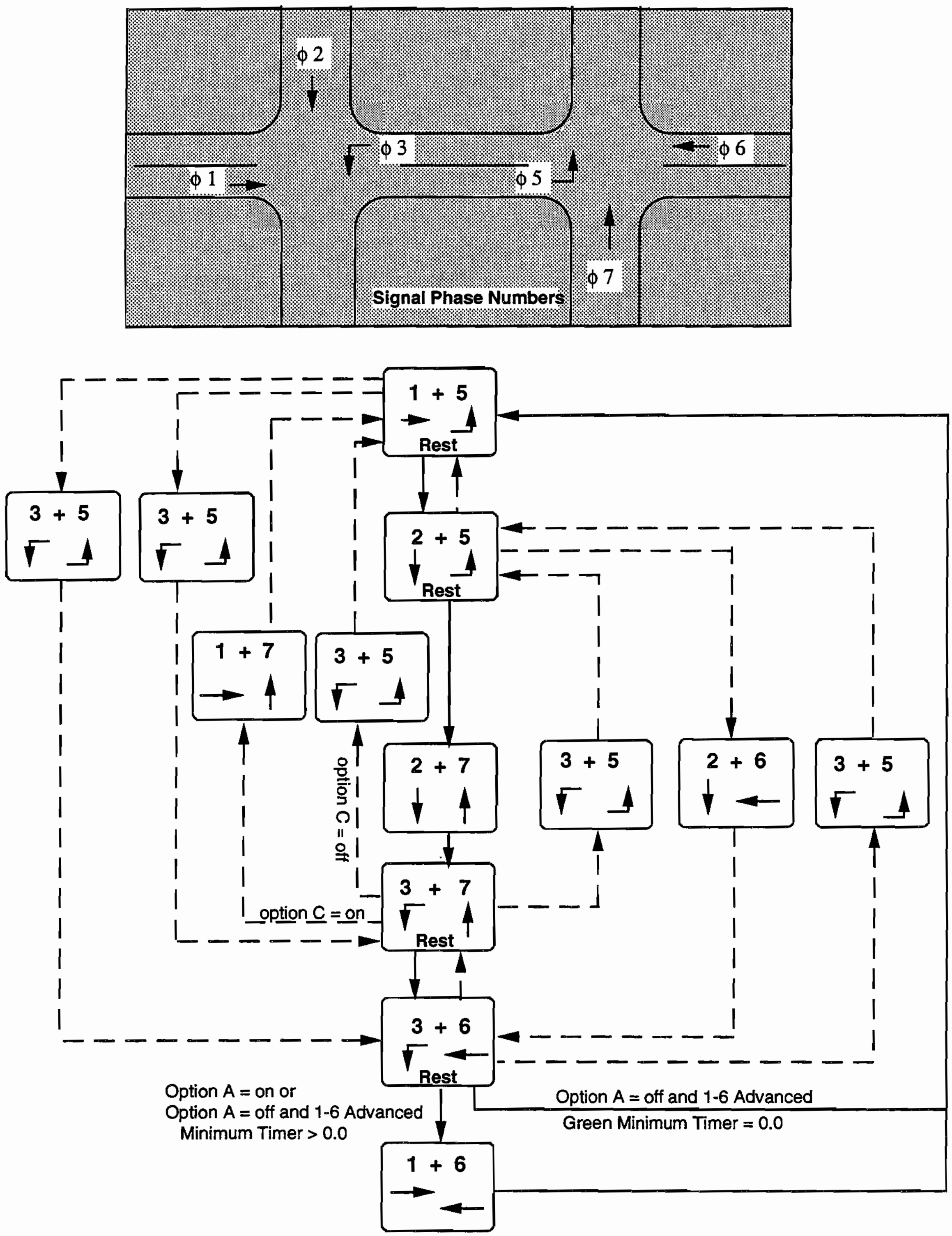
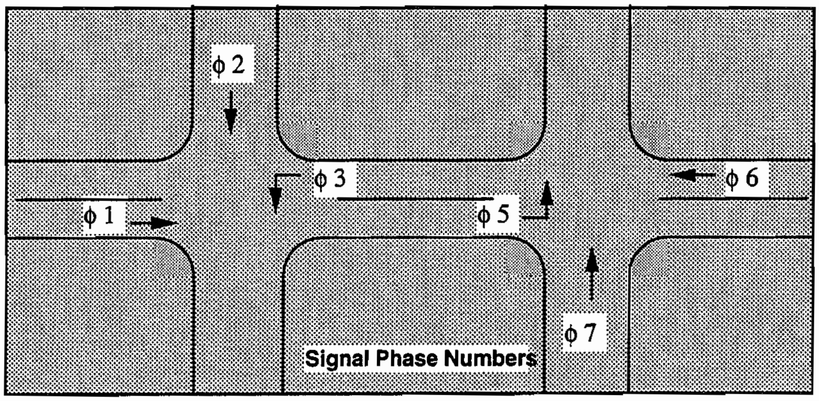


Figure C-3 Operation of the "Figure 6" signal controller pattern



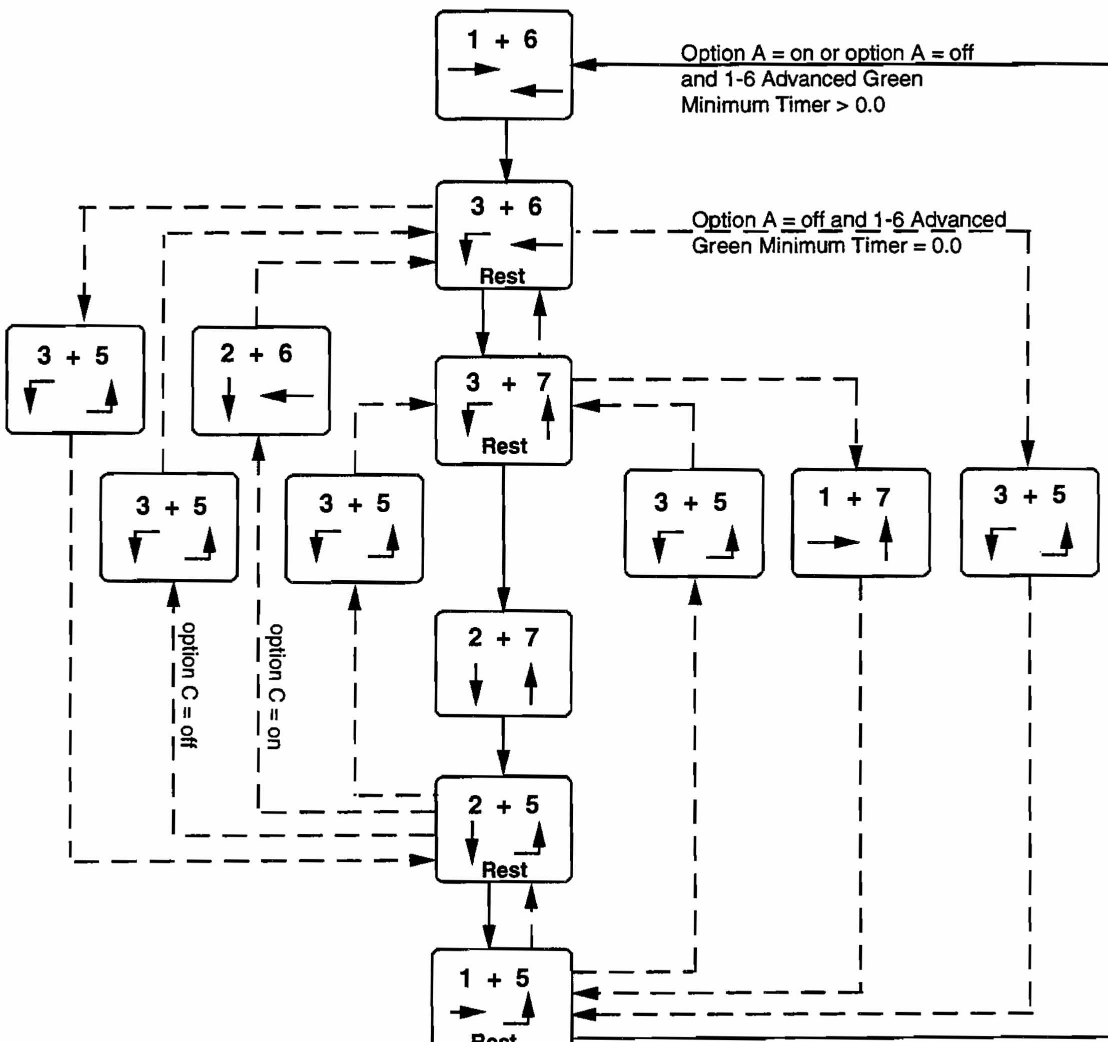


Figure C-4 Operation of the "Figure 7" signal controller pattern