The TEXAS Model for Intersection Traffic—A User-Friendly Microcomputer Version with Animated Graphics Screen Display

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Two interactive data-entry programs have been incorporated into the TEXAS Model for Intersection Traffic to produce the user-friendly TEXAS model. With these programs, a user, by working through an alphanumeric terminal connected in an interactive time-sharing mode to a mainframe computer or through the keyboard of a microcomputer, can respond to screen-displayed prompts and instructions and enter all the data needed for a simulation run in about one-tenth the time previously required. The actual simulation can then be executed either on a mainframe computer or on an IBM personal computer. During simulation, the progress of each individually characterized vehicle moving through a simulated intersection is recorded and subsequently displayed in real time or in stop action on a microcomputer-driven graphics screen. This animated graphics display allows the user to study the overall traffic performance at an intersection or to examine the behavior of any selected vehicle or vehicles in great detail. It also offers an effective way of describing alternative intersection traffic flow conditions at public meetings and technical work sessions. Tabular summary statistics may be produced for each simulation run if requested by the user. With the user-friendly version of the TEXAS model, alternative intersection designs and traffic-control schemes can be evaluated quickly and accurately in a timely and cost-effective manner.

The Traffic EXperimental, Analytical, Simulation (TEXAS) Model for Intersection Traffic *(1–3)* is a powerful computer simulation tool that 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. In the original version of the model, the user was required to input an extensive amount of highly detailed descriptive data in order to characterize a simulated geometric, traffic, and traffic-control situation. A series of data-coding forms was developed to aid the user in the tedious data-input process, but use of the forms proved to be cumbersome at best and coding errors occurred rather frequently. Some potential users of the TEXAS model were discouraged by the amount of effort needed for data entry. Several hours of work were frequently required in preparation for a single run of the model.

Output from the model, which includes several pages of tabular data concerning the behavior of traffic and traffic-control devices during the simulated time period, also lacked user appeal. These data summarize exactly many different measures of intersection performance, but they are rather difficult to interpret, even for an experienced traffic engineer. The need for a more efficient means of communication between the user and the TEXAS model became evident.

The results of a major effort to make the TEXAS model more user-friendly and more accessible are described. In the new version of the model, the user builds compatible data files through alphanumeric terminals networked to the mainframe computer in an interactive time-sharing mode or through microcomputers, which may stand alone or be networked to the mainframe. Two interactive data-entry programs guide the user in entering data via a series of prompts (questions and instructions) displayed on the screen of the terminal or the microcomputer. The results of data entry can be echoed on the screen and also printed on a hard-copy device. The TEXAS model can then utilize these data files when running either on the mainframe or on an IBM personal computer. Running time on the microcomputer is considerably longer than that on the mainframe, but is quite practical in view of the relative availability of time on the two classes of computers. Output data files, which include the instantaneous speed, location, and time relationship for every simulated vehicle, provide the basis for an animated graphics display on a screen driven by the microcomputer. With this display the user can study the overall traffic performance at a particular intersection or examine in great detail the behavior of an individual vehicle in the traffic stream. The tabular summary data from the model are also available for quantitative analysis.

STRUCTURE OF THE TEXAS MODEL FOR INTERSECTION TRAFFIC

The TEXAS Model for Intersection Traffic includes four data processors—GEOPRO (geometry), DVPRO (driver-vehicle), SIMPRO (simulation), and EMPRO (emissions)—for describing, respectively, the geometric configurations, the arriving traffic, the behavior of traffic in response to the applicable traffic controls, and the emissions generated by the traffic. The structural relationship among these data processors is shown in Figure 1.

GEOPRO defines the geometric intersection characteristics needed for simulation. The user specifies the lengths of inbound and outbound lanes on the approaches, and GEOPRO calculates vehicle paths along the approaches 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 azimuths of the legs define the intersection shape. The

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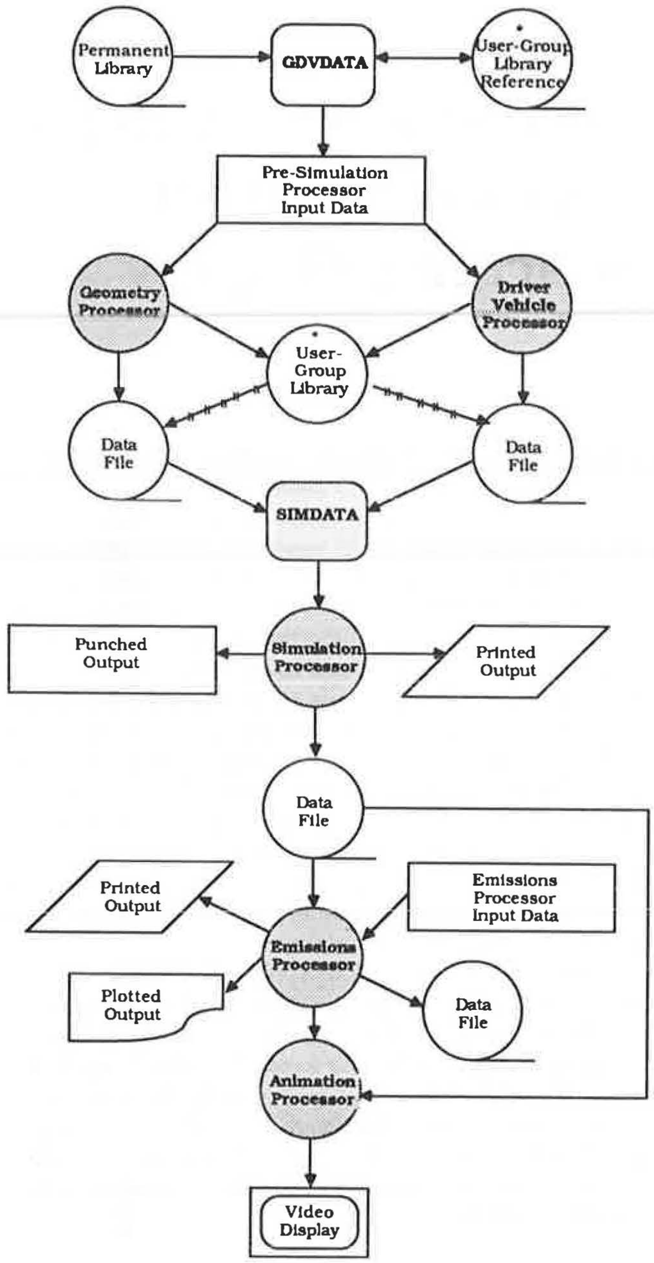

FIGURE 1 Flowchart of structure of user-friendly TEXAS model.

allowed directional movements of traffic on the inbound lanes and the allowed movements on outbound lanes define the directional use of the intersection.

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 uniform probability distribution, except for the desired speed, which is defined by a normal distribution. Units are sequentially ordered by log-in time (the time of entry into an inbound lane) as defined by the input of a selected headway distribution. The total number of driver-vehicle units that must be generated by DVPRO is determined by the product of the input traffic volume and the time to be simulated.

SIMPRO simulates the traffic behavior of each unit according to the surrounding conditions of the moment, including any traffic-control device indications that might be applicable. When the unit enters the inbound approach lane, its entry velocity 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 that 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 from moment to moment within SIMPRO to see whether it is in a car-following situation. If it is not, the magnitude of required acceleration or deceleration applicable at any given instant is calculated by linear interpolation between extreme values set for each vehicle class with respect to the desired speed and to zero speed. 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. A unit is allowed to change into an adjacent lane and follow a path described by a cosine curve if less delay can be expected. 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 it comes into the influence area of the device.

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 pretimed 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, it 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 are 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 pretimed 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.

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 left-turn, right-turn, and straight movements and by the total of these three permitted directional movements on each inbound approach. Total delay is the difference between travel time for a vehicle through the system and the time it would have taken the vehicle at its desired speed. Stop delay is the time spent by a vehicle that has a velocity less than 3 ft/sec. Delay statistics show the overall influence of the intersection environment on traffic passing through the intersection. Comparison of the delays expected 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. Both are measured in units of vehicles, not feet. Average queue length and maximum queue length are taken for each inbound lane over any selected time interval.

EMPRO, the emissions processor, incorporates models to predict the instantaneous vehicle emissions of carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NOx), and fuel flow (FF) for both light-duty and heavy-duty vehicles. EMPRO utilizes information from SIMPRO about the instantaneous location, speed, and acceleration of each vehicle to compute instantaneous vehicle emissions and fuel consumption at points along the vehicle path.

USER-FRIENDLY TEXAS MODEL

Data Entry

As shown in Figure 1, data that are required for running the TEXAS model are entered by the user through two computer data-entry programs called GDVDATA (geometry, driver, vehicle) and SIMDATA (simulation). These are unique features of the user-friendly version of the model.

A new technique is incorporated into GDVDATA for entering the data needed for defining the geometric features of the intersection area in terms that are acceptable to the geometry processor (GEOPRO) of the TEXAS model. Previously the coordinates of all lines and circular arcs had to be calculated and coded individually, but the new technique uses a modular construction concept to build the intersection geometry from sets of properly configured and oriented lanes, legs, and curb returns. Now all geometric features are specified by lengths and angles, which can be more easily defined by the user. The nomenclature and arrangement of various geometric intersection features are shown in Figure 2.

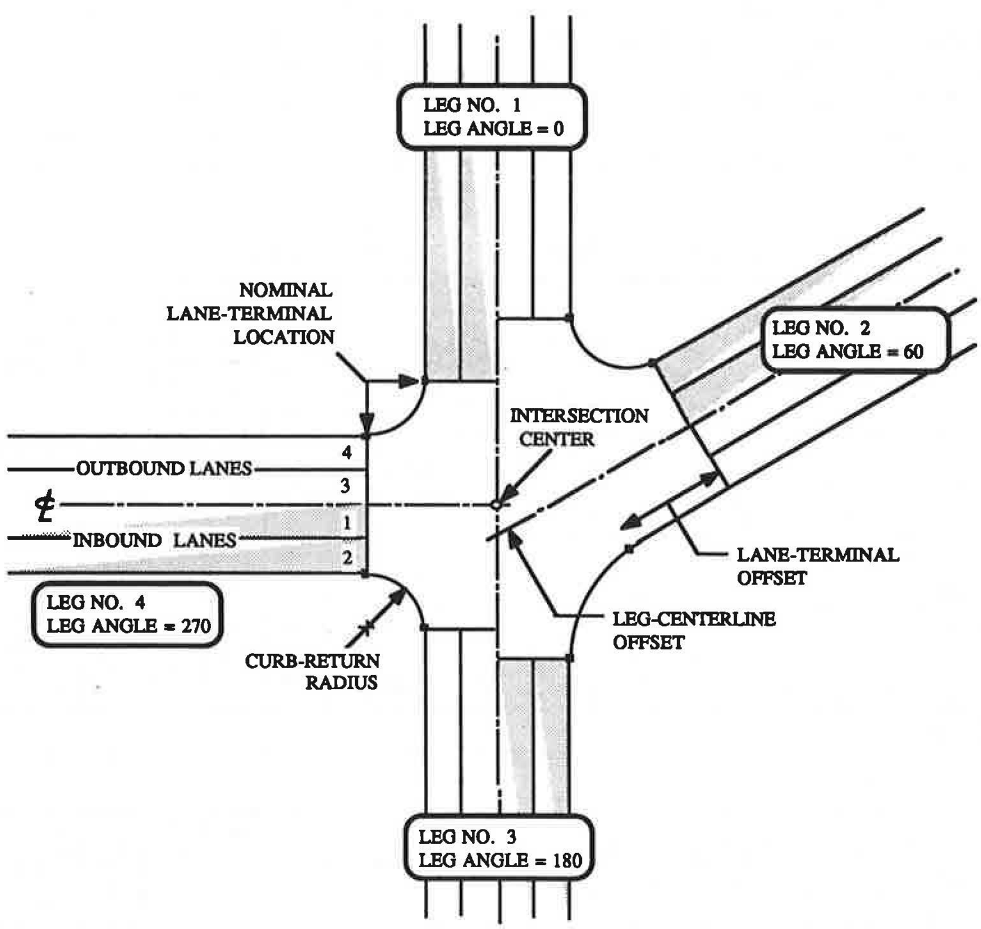

FIGURE 2 Nomenclature and arrangement of intersection geometric features.

In addition to the geometric data needed by the model, the user must enter data to characterize the drivers and vehicles that make up the traffic stream passing through a simulated intersection. GDVDATA includes user aids for entering the data needed by the driver-vehicle processor (DVPRO), which then arranges all data that are needed by the model to characterize driver and vehicle behavior into a format that is suitable for use in the actual simulation process. The driver-vehicle data items that can be defined by the user through GDVDATA are listed in Table 1 along with the default values that will be supplied automatically by the program unless the user requests otherwise.

For efficiency and for the convenience of the user, a series of 20 typical geometric arrangements and traffic patterns have been configured and stored in GDVDATA. These files, which can serve as the basis for many practical cases of interest to the user, are called the "permanent library." Each file in the permanent library contains all the geometric and traffic data that are needed for running the model. The contents of each permanent library file, including a simplified diagram that can be displayed on the screen of an alphanumeric terminal, are described elsewhere *(4)*. The user can study the permanent library files to determine whether one of them contains data that define an intersection situation of interest. If one of the files describes the situation exactly and the user wants to utilize the data contained in the permanent library file without modification, data entry proceeds directly to SIMDATA.

A user-group library is also provided through GDVDATA to allow users to develop, store, index, and retrieve their own data files conveniently for modification or for repeated use without modification. This feature is particularly efficient when the same intersection geometry and traffic are to be used repeatedly in several simulation runs, because it will not be necessary to rerun the geometry and driver-vehicle processors each time. The user-group library consists of the names of up to 16 data files that have been (a) saved on a permanent file and (b) entered into the user-group library. This library serves as a cross reference, or an index, to data files that have been previously prepared and saved by users on the same computer system.

Data that are needed by the simulation processor, SIMPRO, are entered through the data-entry program called SIMDATA. 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. A series of prompts and instructions is utilized in SIMDATA, as in GDVDATA, to guide the user through this part of the data-entry process.

Animated Graphics Display

Output from the TEXAS model includes the instantaneous speed, location, and time relationship for every simulated vehicle. These data are routinely written onto an external file for use by the emissions processor, EMPRO, or for other applications. 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 an IBM PC. Intersection geometry is extracted from the files created by GDVDATA and displayed on the screen first. Then the position of each simulated vehicle with respect to time is represented on the screen by an outline of the vehicle, scaled to size and color coded according to performance capability.

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. This is a unique capability that permits the user to

TABLE 1 PROGRAM SUPPLIED (DEFAULT) VALUES FOR DRIVER AND VEHICLE CLASS DATA

VEHICLE CHARACTERISTIC \ VEHICLE TYPE	PASSENGER CARS				TRUCKS							
					Single-Unit				Tractor Semi-Trailer			
					Gasoline		Diesel		Gasoline		Diesel	
	Sports	Compact	Medium	Large	PL*	FL#	PL	FL	PL	FL	PL	FL
Class	1	2	3	4	5	6	7	8	9	10	11	12
Operating Characteristics Factor	115	90	100	110	85	80	80	75	70	65	75	70
Maximum Deceleration, ft/sec/sec	14	13	13	8	7	5	7	5	6	4	6	4
Maximum Acceleration, ft/sec/sec	14	8	9	11	7	6	6	5	4	3	5	4
Maximum Velocity, ft/sec	205	120	135	150	100	85	100	85	95	75	100	80
Minimum Turning Radius, ft	20	20	22	24	42	42	42	42	45	45	45	45
Length, ft	14	15	16	18	32	32	32	32	60	60	60	60
Percentage in Traffic Stream, %	1.5	22.5	23.3	44.7	2.6	2.6	0.2	0.2	0.2	0.2	1.0	1.0

DRIVER				PERCENTAGE OF DRIVER CLASS IN EACH VEHICLE TYPE											
Type	Class	P-R Time	Factor	Sports	Compact	Medium	Large	SU Gas PL	SU Gas FL	SU Diesel PL	SU Diesel FL	TST Gas PL	TST Gas FL	TST Diesel PL	TST Diesel FL
Aggressive	1	0.5	110	50	30	35	25	40	40	40	40	40	40	40	40
Average	2	1.0	100	40	40	35	45	40	40	40	40	40	40	40	40
Slow	3	1.5	85	10	30	30	30	20	20	20	20	20	20	20	20

* Partially-Loaded Truck # Fully-Loaded Truck

examine easily several alternative solutions to a problem by simulation without the time and expense of cut-and-try experimentation in the field. A wide range of conditions can be defined and evaluated visually on the screen as well as in the form of tabular summaries of statistics about traffic and signal-control performance.

Microcomputer Requirements

Development of the microcomputer version of the TEXAS model was significantly aided by grants of hardware and software from IBM through the QUEST Project at the University of Texas. The current microcomputer version of the model is configured to run on IBM PC-XT's or PC-AT's with at least 512K of random-access memory (RAM), a math coprocessor, a color graphics adapter and color graphics monitor, or an enhanced graphics adapter and monochrome, color, or enhanced graphics monitor. DOS 3.1 or the equivalent and a printer are also required by the current configuration.

Because the basic processors are written totally in ANSI Standard FORTRAN 77, implementation on other machines will only require modification of the language used by other operating systems to access and store files. The animation processor contains assembly language routines that enable faster execution of the graphics display. Implementation of these routines on other machines would obviously require additional modification. All other processors, however, can be quite readily implemented on other machines, essentially without modification.

Execution time for a normal intersection simulation run on an IBM PC-XT is slightly longer than the real time that is simulated. This includes writing the data file that is required for the subsequent animated graphics display of intersection geometry, traffic signal indications, and vehicles. The same simulation run requires somewhat less than real time for execution on the University of Texas at Austin's CYBER time-shared mainframe.

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