1. Report No. TX-92/1375-1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle SUMMARY DOCUMENTATION FOR THE TEXAS TRAVEL DEMAND PACKAGE		5. Report Date December 1992
		6. Performing Organization Code
7. Author(s) Tom A. Williams and George B. Dresser		8. Performing Organization Report No. Research Report 1375-1
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, TX 77843-3135		10. Work Unit No.
		11. Contract or Grant No. Study No. 2-10-92-1375
12. Sponsoring Agency Name and Address Texas Department of Transportation Division of Transportation Planning P.O. Box 5051 Austin, TX 78763		13. Type of Report and Period Covered Interim: April 1992 to August 1993
		14. Sponsoring Agency Code

15. Supplementary Notes
Research performed in cooperation with the Texas Department of Transportation. Research Study Title: Develop Air Quality Data for Federal Submission

16. Abstract
The statewide practice of urban travel forecasting in Texas is described. An overview of methods practiced and theoretical basis for travel modeling is presented in brief format. Each of the four steps used in the Texas Package travel modeling process is described. TRIPCAL5, the Texas Package trip generation method, is summarized. Trip distribution practice using the Texas Package ATOM model is included. Finally, the Texas Package methodology using the iterative traffic assignment process is described.

17. Key Words Travel Forecasting, Transportation Modeling, Texas Travel Demand Package.	18. Distribution Statement No restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 53	22. Price

Form DOT F 1700.7 (8-69)

SUMMARY DOCUMENTATION FOR THE

TEXAS TRAVEL DEMAND PACKAGE

by

Tom A. Williams
Assistant Research Scientist

and

George B. Dresser
Research Scientist

Research Report 1375-1
Research Study Number 2-10-92-1375

Sponsored by

Texas Department of Transportation

Texas Transportation Institute
The Texas A&M University System
College Station, Texas

December 1992

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					**LENGTH**		
in	inches	2.54	centimeters	cm	mm	millimeters	0.039	inches	in
ft	feet	0.3048	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	yd	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					**AREA**		
in^2	square inches	6.452	centimeters squared	cm^2	mm^2	millimeters squared	0.0016	square inches	in^2
ft^2	square feet	0.0929	meters squared	m^2	m^2	meters squared	10.764	square feet	ft^2
yd^2	square yards	0.836	meters squared	m^2	yd^2	kilometers squared	0.39	square miles	mi^2
mi^2	square miles	2.59	kilometers squared	km^2	ha	hectares (10,000 m^2)	2.53	acres	ac
ac	acres	0.395	hectares	ha					
		MASS (weight)					**MASS (weight)**		
oz	ounces	28.35	grams	g	g	grams	0.0353	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000 lb)	0.907	megagrams	Mg	Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME					**VOLUME**		
fl oz	fluid ounces	29.57	millimeters	mL	mL	millimeters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.264	gallons	gal
ft^3	cubic feet	0.0328	meters cubed	m^3	m^3	meters cubed	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	meters cubed	m^3	m^3	meters cubed	1.308	cubic yards	yd^3

Note: Volumes greater than 1000 L shall be shown in m^3.

		TEMPERATURE (exact)					**TEMPERATURE (exact)**		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C	°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
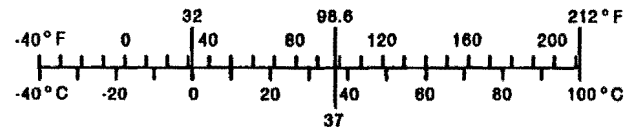
ABSTRACT

The statewide practice of urban travel forecasting in Texas is described. An overview of methods practiced and theoretical basis for travel modeling is presented in a brief format. Each of the four steps used in the Texas Package travel modeling process is described. TRIPCAL5, the Texas Package trip generation method, is summarized. Trip distribution practice using the Texas Package ATOM model is included. Finally, the Texas Package methodology using the iterative traffic assignment process is described.

DISCLAIMER

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

more trips than a zone with a smaller number.

Measures of the amount of activity usually are not enough to develop a good relationship between activities and travel. The character of activities is important, too. For residential land uses, character is described in terms of socioeconomic variables such as household size and income. Generally, large or high income households generate more trips than small or low income households. For non-residential activities, trip generation character reflects the type of activity (for example, retail and industrial). A major shopping center generates more trips than a warehouse of the same size.

In trip generation analyses, the number of trip ends in each traffic serial zone are estimated for each of a number of trip purposes. Usually, trip purposes include home-based work trips, home-based non-work trips, and non-home based trips. Other trip purposes which must be estimated are truck and taxi trips and trips with origins or destinations outside of the study area. The output of trip generation analysis is a table of trip ends that are produced from and attracted to each traffic serial zone categorized by trip purpose.

Trip Distribution

Trip distribution is the process by which the transportation planner links the production and attraction trip ends to form complete trips, thereby transforming trip ends into origin/destination pairs. Each zone's trip productions are connected to all zones to which they are attracted.

The most widely used trip distribution technique is the gravity model. The gravity model gets its name from the fact that it is conceptually based on Newton's law of gravitation, which states that the force of attraction between bodies is directly proportional to the product of the masses of the two bodies and inversely proportional to the square of the distance between them.

Similarly, in the gravity model, the interchange of trips between two areas is directly related to activities in those areas and inversely related to the separation between the areas, represented as a function of travel time. Consequently, areas with large amounts of activity tend to exchange more trips, and areas farther from each other tend to exchange fewer trips. Thus, the distribution model calculates the trip interchange volume based on the travel time

2

I. TRAVEL MODELING IN TEXAS

THE FOUR-STEP TRANSPORTATION MODELING PROCESS

Travel demand forecasting attempts to quantify the existing and future interaction between the supply of and the demand for the transportation system. The supply of transportation is represented by the characteristics of the highway and transit networks. The demand for transportation is created by the separation and intensity of urban activities. Land use forecasts provide estimates of where people will live and where businesses will locate in the future. These forecasts include the intensity of activity in an area, such as the number of households, employees, and demographic data concerning income levels and household size. These forecasts are prepared for small geographic areas called traffic serial zones (TSZ). Descriptions of the service characteristics of the highway and transit networks and the land use forecasts are direct inputs to the travel demand forecasting model.

The traditional travel demand forecasting process has four principal components: Trip generation, trip distribution, mode choice, and trip assignment. Much of the following discussion is excerpted from An Introduction to Urban Travel Demand Forecasting, A Self-Instructional Text, distributed by the U.S. Department of Transportation, 1977.

Trip Generation

Trip generation is the process by which the transportation planner translates the land use forecast into the number of trips in the study area's traffic serial zone for a typical day of the target year. Trip generation results in the total number of "trip ends" in the study area. A trip end is defined as the beginning or end of a trip. For example, a one-way trip from home to work has two trip ends. Trip generation models estimate total trip ends by applying trip generation rates to the land use forecast data.

A trip generation rate is obtained by dividing the number of trips made by a given activity by the amount of the activity. For example, common trip generation rates are trips per household and trips per employee. Trip generation rates are based on relationships between the amount or character of urban activity, and the amount of trips generated. All else being equal, a zone with a larger number of households or employees will generate

1

to reach the potential destination and the attractiveness of that destination. Originating trips from any one zone are allocated to competing destinations based on this combination of relative trip lengths and relative attractiveness.

In practice, a separate gravity model is developed for each trip purpose, because different trip purposes have different distribution characteristics with respect to trip length. For example, a person who travels from one side of the city to the other for work will not travel as far to buy groceries.

The output of trip distribution is a set of tables for each trip purpose; the tables contain the travel flow between each pair of zones. The output is a representation of expected travel patterns; the origin and destination of every trip is modeled.

Mode Choice

The third step of the travel demand forecasting process is mode choice. Mode choice analysis is the process by which the transportation planner determines the amount of travel that will be made between each set of zones using each available mode of transportation. The specific modes that are analyzed typically include single-driver auto, various carpool categories, local and express bus, and fixed guideway transit.

Many factors affect mode choice. Two important factors are relative costs and travel times of the available modes. A fast or inexpensive mode is more attractive to travelers than a slower or more expensive mode. In addition to these transportation system characteristics, the transportation planner considers characteristics of the traveler and characteristics of the trip. Studies have demonstrated that traveler characteristics, such as income and number of available autos, are correlated to mode choice. Generally, people with high incomes and greater number of available autos are less likely to ride transit. Similarly, mode choice can be affected by trip characteristics, such as trip purpose. For example, a person who rides a bus to work every day might not want to take a bus to see a movie on Friday night.

The output of mode choice analysis is tables representing the (1) number of vehicle trips between each pair of traffic serial zones utilizing the highway network and (2) the number of transit trips between each pair of zones which utilize the transit network.

3

Traffic Assignment

The fourth step in the travel demand forecasting process, traffic assignment, is the procedure by which the transportation planner estimates the volume of travel on each individual component of the transportation system. This involves "loading" the transit network with transit person trips by mode and the highway network with vehicle trips. Several techniques are available to determine which paths through the network are to be utilized by the transit and vehicle trips between zones. The most common type of trip assignment technique is the minimum path. Minimum path techniques are based on the assumption that travelers want to use the route of minimum impedance between two points. Impedance is usually measured in terms of time (for example, walking, waiting, and riding) and/or cost (for example, fares, operating costs, tolls, and parking costs). Minimum path techniques are generally used for transit assignment.

For highway assignment, minimum path algorithms can be refined by including capacity restraint techniques. Capacity restraint techniques reflect the finding that as the volume of traffic increases, the speed of traffic decreases. Capacity restraint attempts to balance the assigned volume, the capacity of the facility, and the resultant speed.

The output from the assignment step is an estimate of the total number of vehicle and transit trips for each segment of the highway and transit networks. The transportation planner's job does not end with trip assignment. The results of the trip assignment process, like all other steps of the travel demand forecasting process, must be evaluated. For example, the transportation planner checks individual links, smooths individual link values along a facility or within a corridor, and summarizes vehicle miles of travel (VMT) to assess the reliability of the assignment. As the desire for accuracy increases, the transportation planner must complete additional analysis and reliability checks.

THE TEXAS TRAVEL DEMAND PACKAGE

The Texas Travel Demand Package (Texas Package) is a set of mainframe computer programs used to forecast travel in urbanized areas in Texas. The Texas Package is operated by the Planning Division (Division 10) of the Texas Department of Transportation and has been developed and updated since the 1960s by TxDOT and the Texas Transportation Institute (TTI) of The Texas A&M University System. The models used in the Texas Package follow the widely accepted four-step urban transportation modeling process. The Texas Package contains three of the models: trip generation, trip distribution, and traffic assignment (see Figure 1). Many of the urbanized areas in Texas have only modest public transportation systems; therefore, the Texas Package does not contain a mode choice model. However, some urbanized areas in Texas, such as Houston, have developed mode choice and HOV models to complement the Texas Package.

This paper provides only summary documentation of the Texas Package. More detailed descriptions of model development, surveys, and computer program user manuals are available for each of the specific models.
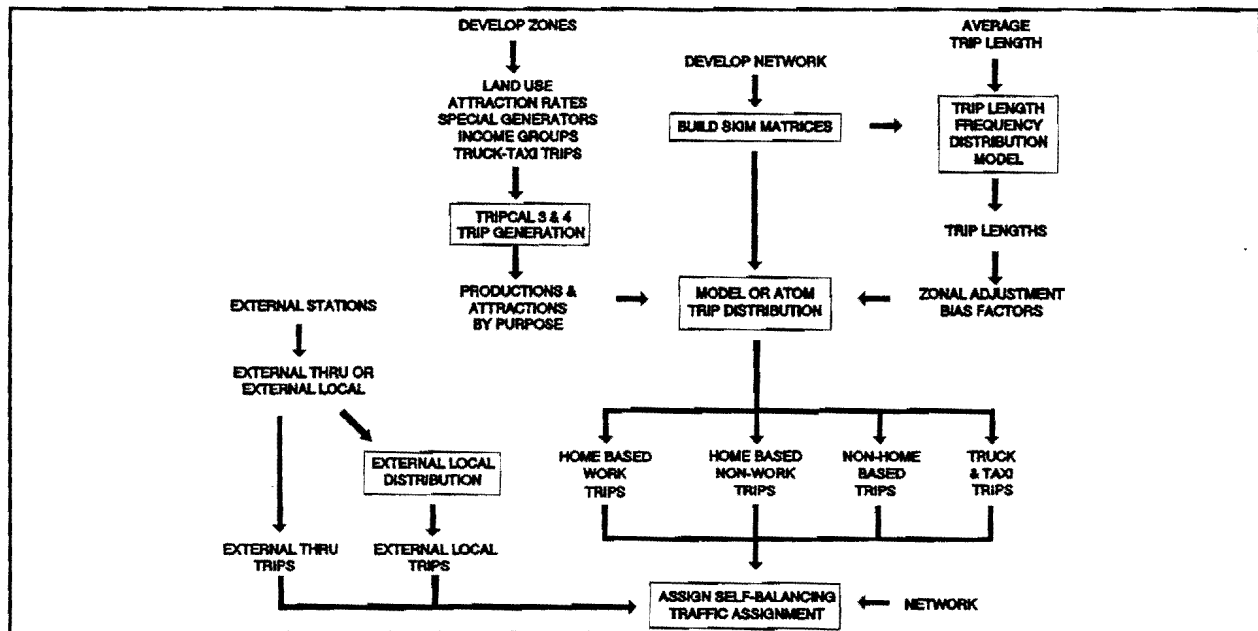
FIGURE 1. Texas Travel Demand Package Process

5

TEXAS FORECASTING ORGANIZATION

There are currently 25 Metropolitan Planning Organization (MPO) areas in Texas, four of which are classified as non-attainment areas under the Clean Air Act Amendments of 1990 (see Figure 2). The Texas Package is used for travel forecasting in all areas with the exception of Dallas-Fort Worth. The Dallas-Fort Worth area is covered by the Dallas-Fort Worth Travel Model, a four-step travel model developed and maintained by the North Central Texas Council of Governments in cooperation with TxDOT.
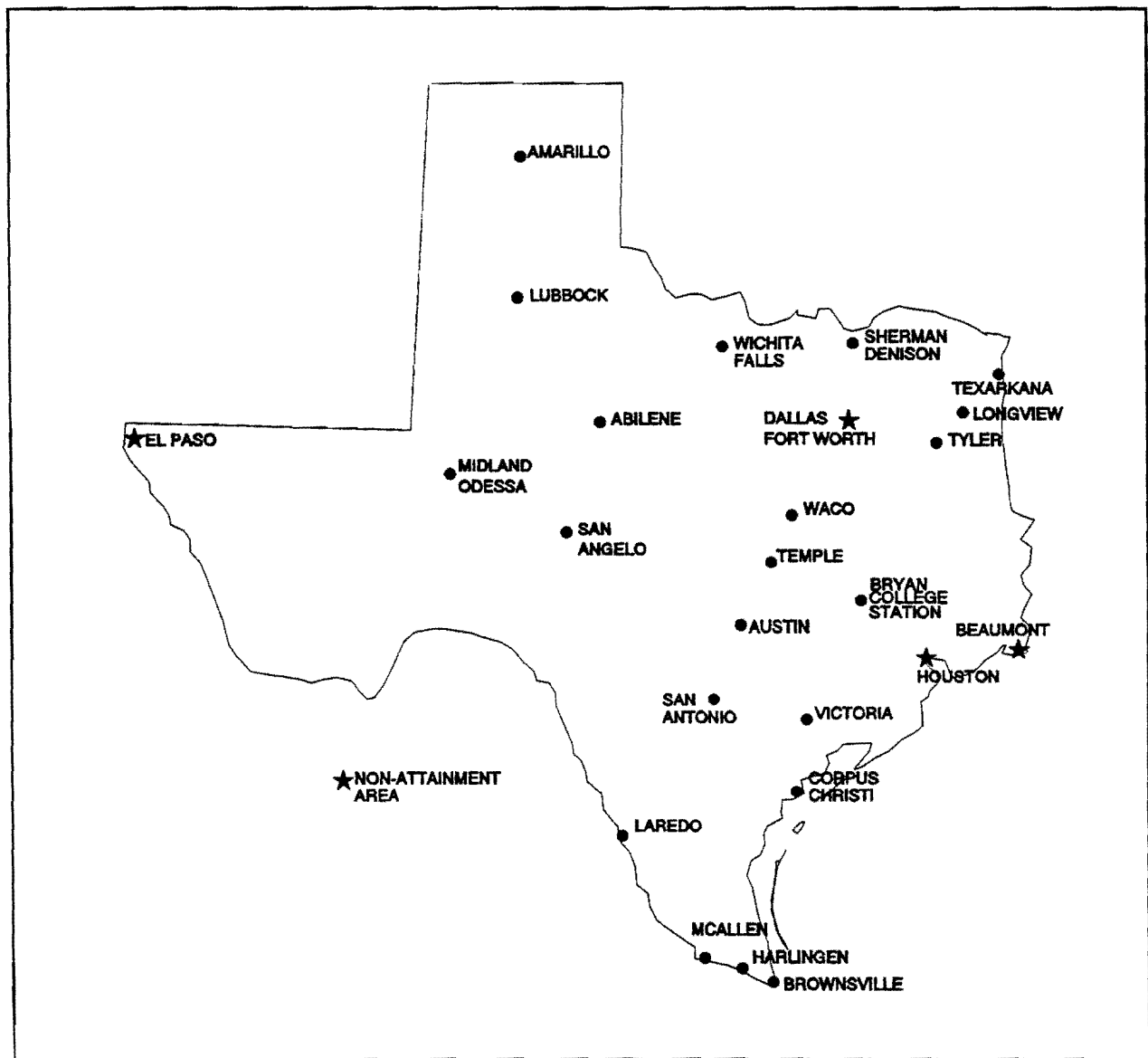
FIGURE 2. Texas MPO Areas Covered by the Texas Travel Demand Package (with the exception of Dallas-Fort Worth).

II. DEMOGRAPHICS

HOUSEHOLDS

Census data are used for developing initial estimates of the number of households, population, and household sizes for an urban area. This information is aggregated to census tracts or traffic serial zones within an urban area. When the base year does not fall on a census year, the current census data are updated with building permits, subdivision plats, and other local data or locally acceptable judgment process. Aerial photography is used in some areas to update zonal land use information. Projections of population and number of households for census tracts and/or zones within the urban area are usually accomplished through a step-down procedure, allocating regional control totals to specific census tracts or zones.

Forecasted households are developed locally or may be obtained from another source (e.g., Texas Department of Water Resources) for the urban area. The forecasted control totals are developed cooperatively but are driven by the county forecasts from the Texas State Data Center. TxDOT is currently required to work within the high and low range population forecasts set by the Texas State Data Center.

Population forecasts are usually developed at large aggregations (sometimes the whole region) and are used as control totals for distribution to smaller zones. The distribution to subareas within the region is accomplished through the use of a heuristic model, a simulation model, an activity distribution model, professional judgment tempered with knowledge of local development patterns (Delphi), or other methods which are considered credible by local decision makers. This distribution may be done in one or several steps (e.g., population distributed to districts and then to zones within each district).

Population forecasts at the census tract or zone level are usually the basis for estimating the number of households. This may be accomplished through the use of an average household size for the urban area or the census tract (from census data), or by other procedures developed locally. The forecasts at the tract or zone level are constrained to agree with regional totals.

The number of households of different sizes at the tract or zone level are usually

obtained by applying disaggregation curves. These curves are developed from census data at the census tract level. The percentage of households of each size (within the census tract) is plotted versus the average household size for the census tract. The curves are plotted in such a way that the percentages of each household size will add up to 100 percent. For example, a tract is determined to have an average household size of 1.4. Using the disaggregation curves, the percentage of households falling in each household size (one person, two persons, etc.) can be looked up (see Figure 3). These values are applied to the total number of households in the tract to determine the number of households falling into each household size category.
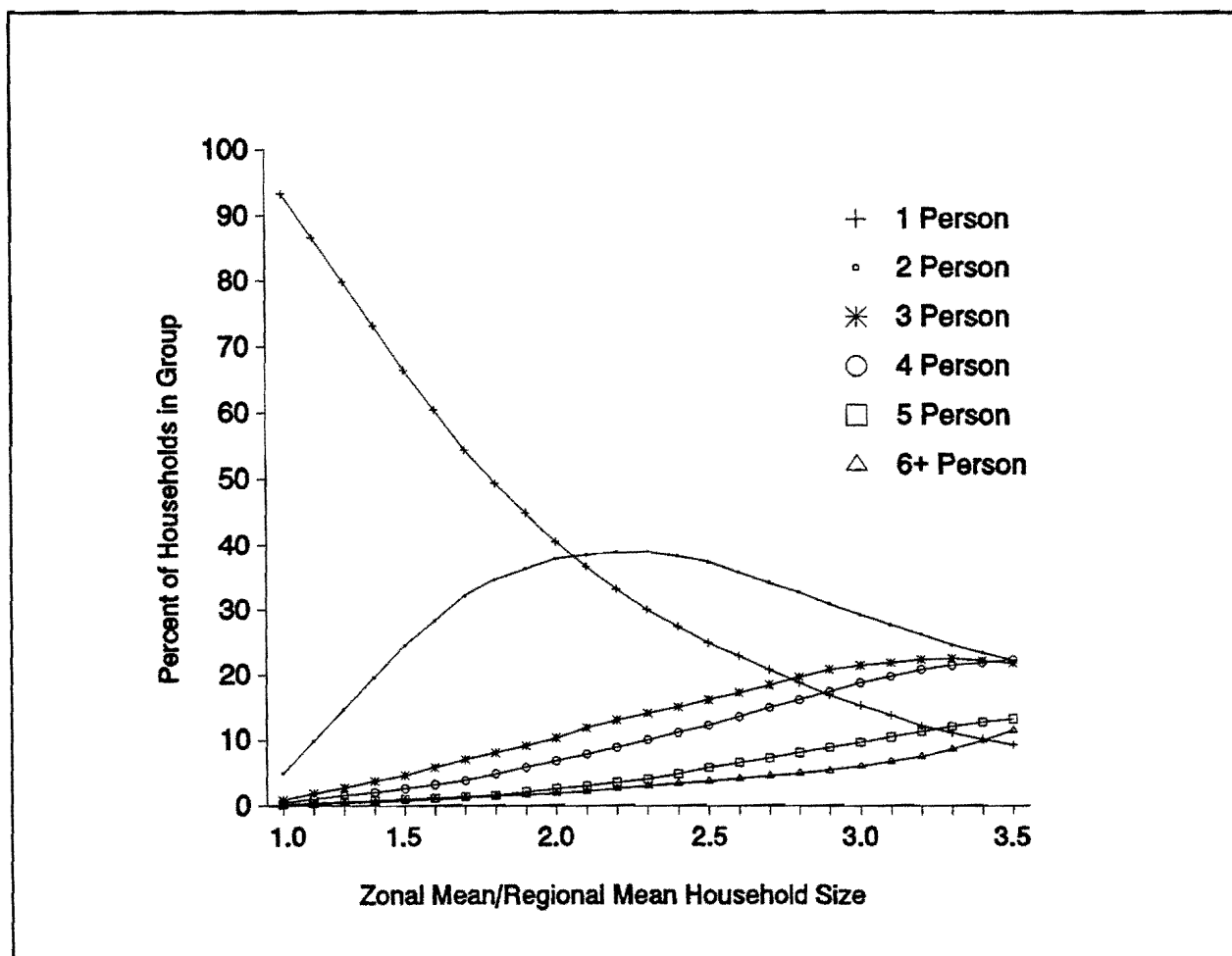
FIGURE 3. Sample Disaggregation Curves for Household Sizes.

INCOME

Several techniques are used to estimate and forecast household income. In some cases income is assumed to remain constant over time implying that no real growth in income or purchasing power will occur. The basic data requirement of the Texas Package trip generation model is an estimate of the number of households within each income range. The method normally employed is a disaggregation method similar to the household size disaggregation process (see Figure 4).
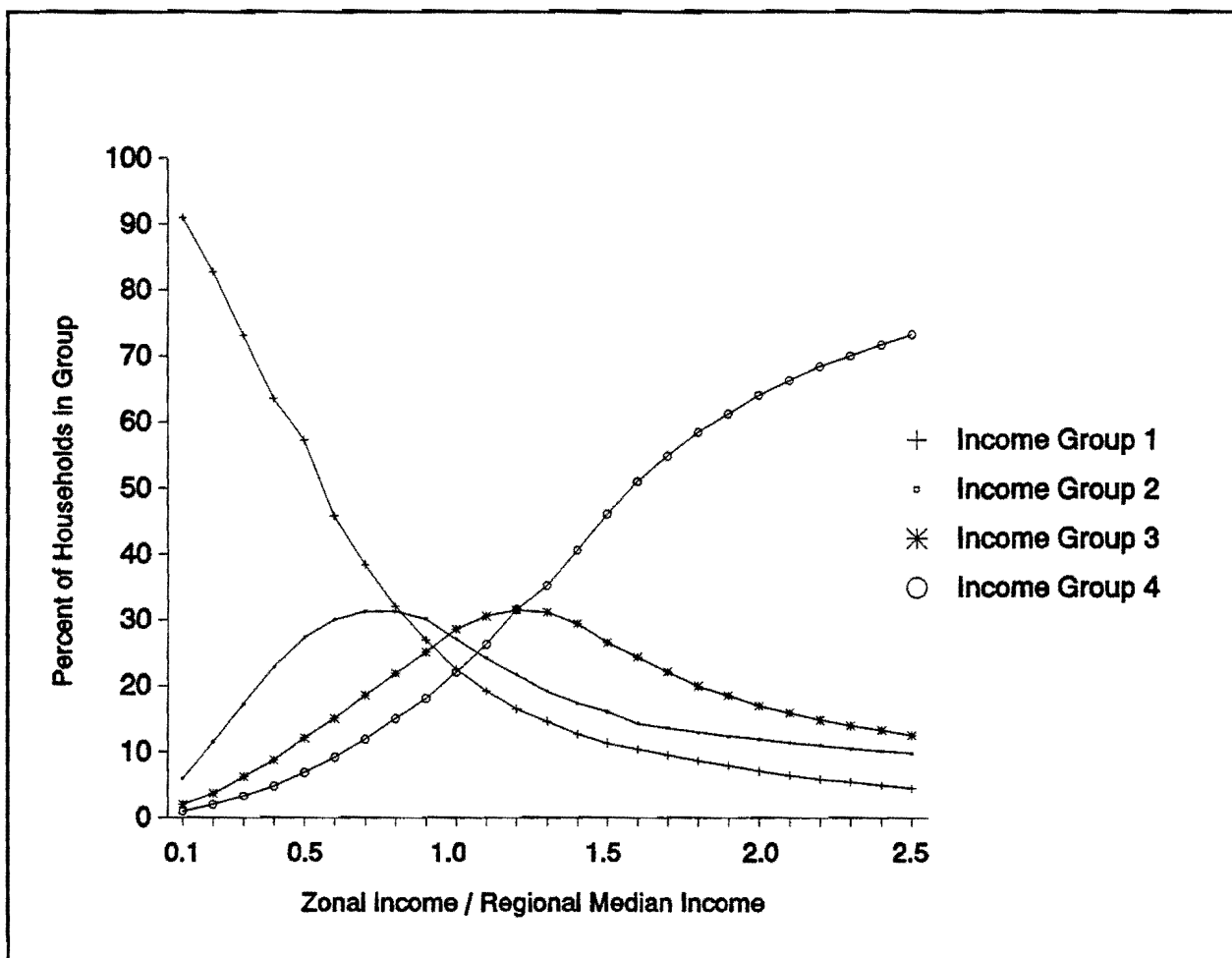
FIGURE 4. Sample Disaggregation Curves for Income Groups.

Methods for estimating median or mean income at the zone or tract level vary among urban areas. Some of the methods employed are:

- No growth
- A constant rate of growth, or compounded rate

- Income growth applied to new development only
- Historical trends
- Regional growth forecasts from outside agencies, such as the Bureau of Economic Analysis
- Other mathematical techniques

AUTO OWNERSHIP

Auto ownership is used in some areas in lieu of income for trip generation models. The methods of estimating auto ownership usually involve income as an independent variable. The Texas Package method uses a zonal median income as input to disaggregation curves showing the number of households with 0, 1, 2, and 3+ autos.

EMPLOYMENT

Employment forecasts are integral to the analysis of future roadway needs. Usually, employment is forecasted on a regional basis, which is disaggregated later in the process (control total). Several sources for control total employment forecasts are often used in an urban area, and are selected based on local judgment and political processes. A common source for base year regional employment estimates is the Texas Employment Commission. Forecasted employment is derived from various locally-accepted sources and methodologies.

Employment is generally separated into three categories: Basic Employment, comprising industries which are part of an economy larger than the region, such as manufacturing; Retail Employment, reflecting jobs generated by local shopping; and Service Employment, which is made up of office and institutional type jobs.

Allocation of employment is performed by local judgment and heuristic models. Forecasted central business district employment is most often estimated from various sources at the local level. Several urban areas use allocation models which distribute employment on the basis of the location of other activities in traffic serial zones and the effect of distances between zones. Examples of these types of model include the Lowry Model and the Dram/Empal Model.

III. NETWORKS AND ZONES

NETWORKS

Computerized representations of regional roadway systems are developed by TxDOT with assistance from MPOs, municipalities, and other agencies. Networks are built around detailed analysis zone structures, commonly called Traffic Serial Zones. Special connector links referred to as centroid connectors represent access to the regional roadway network from zone centroids. Centroid connectors represent local roadway access between the centroid of zonal activity and the regional network. The operational characteristics of centroid connectors reflect zone size, proximity of land development to the regional roadway network and local street speeds and capacities. Figure 5 shows a typical centroid connector.

The physical and operational attributes of roadways, such as number of lanes, speed limit, one-way or two-way facility, and divided or undivided facility, and 24-hour non-directional weekday count are obtained from roadway inventories. Additional traffic count data are obtained from saturation counts performed by TxDOT. These traffic counts are coded into the base year roadway network and are utilized in the validation of the process.

Area Types

Areas of differing density levels, called "area types," are developed to represent the fact that the duration and amount of traffic congestion, which influence roadway capacity, vary throughout a region. Area type categories help to quantify differences in traffic signal spacing, maximum permissible speeds, and other factors which ultimately relate to differences in population and employment densities. The area types normally used are CBD, Urban, Suburban, Fringe Suburban and Rural.

Area types are used to assign network speeds and capacities to individual links. Coded network speeds and capacities within a given roadway functional classification vary by area type.

The methodology used for calculating the area type is a classification of each traffic serial zone based on a function of population and employment density. The equation is:
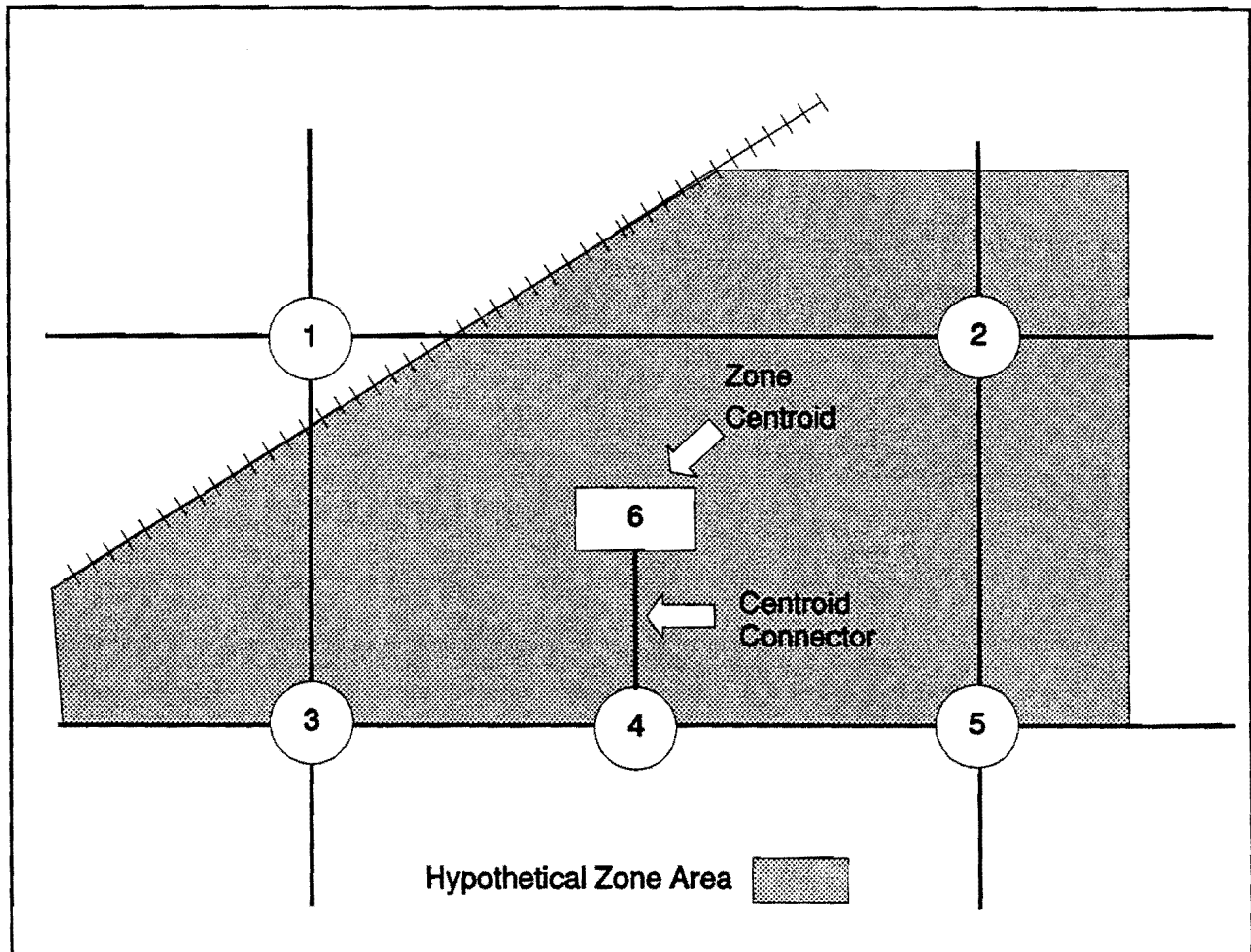
FIGURE 5. Centroid Connector Example.

$$TSZ \text{ factor} = TSZ \text{ population density} + B * (TSZ \text{ employment density})$$

Where: B = study area population/employment ratio

TSZ population density = TSZ population/acres

TSZ employment density = TSZ employment/acres

The constant "B" in this equation is the population/employment ratio for the entire study area. Density values are in persons per acre. The results are placed into five or six ranges of values which define the area types (five are presented in Table 1); thus, each traffic serial zone receives an area type classification. When using six area type classifications, the typical classes are CBD, CBD Fringe, Urban, Suburban, Suburban Fringe, and Rural.

12

Table 1
Typical Factor Ranges for Area Type Classification

Area Type	Density Range
CBD	$x > 50$
Urban	$50 > x > 15$
Urban Fringe	$15 > x > 10$
Suburban	$10 > x > 1$
Rural	$x < 1$

Functional Classification

The second predominant characteristic used to determine capacity and speed of a facility is the functional classification. Two typical Texas Package functional classification schemes are presented in Table 2.

Functional classification is used to assign speeds and capacities to the network. Functional classification is subdivided into facility types to further identify the characteristic of the specific segment. For instance, divided principal arterials may be subdivided into facility types reflecting continuous left-turn lanes or left-turn bays. Toll facilities are separately identified to reflect the operational policies of these facilities.

Capacity

Link capacity is used during the assignment process for capacity restraint assignments. Capacity restraint assignment techniques are based on the finding that as traffic congestion increases, the speed of traffic decreases. The assignment process assigns trips according to impedances coded for each network link, usually travel time. There is a direct relationship between travel time (or speed) and the volume on a transportation facility. Capacity restraint attempts to bring the assigned volume, the capacity of a facility, and the related speed into balance. Capacities are cross-classified by functional classification (or facility type) and area type. The capacities typically used are based on a service volume at level of service C and are derived from the Transportation Research Board Highway Capacity Manual. However, in some instances other levels of service may be used depending on the

characteristics of the urban area. Table 3 shows a typical speed/capacity reference table used in the Texas Package.

Table 2
Texas Functional Classification

TXDOT FUNCTIONAL CLASS CODE	TYPICAL FACILITY DESCRIPTION (BEAUMONT)	ALTERNATE FACILITY DESCRIPTION (BRYAN-COLLEGE STATION)
0	Centroid Connector	Interstate
1	Interstate, Expressway, or Freeway	Major Arterial, 4 Lanes Divided
2	Multi-Lane Highway or Rural Highway	Major Arterial, 4 Lanes Un-divided
3	Divided Principal Arterial	Major Arterial, 2 Lanes
4	Undivided Principal Arterial	Minor Arterial, 6 Lanes Divided
5	Divided Minor Arterial	Minor Arterial, 4 Lanes Divided
6	Undivided Minor Arterial	Minor Arterial, 4 Lanes Un-Divided
7	Collector	Minor Arterial, 2 Lanes Un-divided
8	Frontage Road	Collector, 2 Lanes
9	Ramp	Local
A	None	Frontage Road
B	None	Ramp
C	None	Centroid Connector

Several factors influence the determination of capacity. The characteristics of a facility which must be taken into account include the percent of daily traffic occurring during the peak hour (K-factor), the maximum flow rate factor (peak hour factor), the directional split, the percentage of trucks, and the ratio of green time to total traffic light cycle length. The threshold for capacity determination in rural, less congested urban areas is level of service A or B. In contrast, the threshold for determining capacity in more congested urban areas is level of service C or D.

Table 3

Table 3
Typical Speed/Capacity Look-up Table
Bryan-College Station Urban Transportation Study

DESCRIPTION	LANES	FUNC. CLASS	AREA TYPE					
			CBD	CBD FRINGE	URBAN	SUBURBAN	SUBURBAN FRINGE	RURAL
Interstate	4D	0	45	45	50	55	55	60
			103500	87200	75000	49700	28400	23600
Major Arterial	4D	1	40	40	45	50	50	55
			N/A	N/A	N/A	25600	25600	28400
	4U	2	40	40	45	50	50	55
			N/A	N/A	N/A	22800	22800	27000
	2U	3	40	40	45	50	50	55
			N/A	N/A	N/A	10600	5800	5200
Minor Arterial	6D	4	37	37	42	47	47	52
			64200	53000	44700	28300	17700	N/A
	4D	5	36	36	41	46	46	51
			42800	35300	29800	18900	11800	N/A
	4U	6	33	33	38	43	43	48
			38000	31400	26500	16800	10300	N/A
	2U	7	30	30	35	40	40	45
			15800	13100	11000	6900	4200	N/A
Collector	2U	8	25	25	30	35	35	40
			14100	11600	9700	5900	3500	2300
Local	2U	9	20	20	25	30	30	35
			14100	11600	9700	5900	3500	2300
Frontage	2U	A	35	35	40	45	45	50
			16900	14200	12100	10600	5800	5200
Ramps	2U	B	35	35	40	45	45	50
			16900	14200	12100	10600	5800	5200
Centroid Connector		C	15	15	20	25	25	30

Speed

Link distance divided by the link speed produces an estimate of link travel time. Link travel times, or network impedances, are the basis for the development of minimum path routes from each zone to every other zone in the network. The speeds assigned to each link in the Texas Package are derived from two sources: speed surveys, where actual observed traveling speeds are measured and coded to each link, and more commonly, the

Highway Capacity Manual produced by the Transportation Research Board. The Highway Capacity Manual identifies a range of speeds suitable to meet a level of service C for each functional classification.

Distance

Link lengths, or distances, are critical in determining link travel times. Distances are calculated during the process of digitizing the network. The base maps typically used for digitizing the network are county roadway maps originally drawn from a U.S.G.S. survey map base. Networks are digitized using the Intergraph computer design system. Roads are drawn as curvilinear features and the distance on each link, including curves, is calculated by the computer system, which is later transferred to the Texas Package.

ZONES

Detailed zones used in the Texas Package are referred to as "traffic serial zones" and are developed as the basis for estimation of travel. The area covered by a given traffic serial zone is determined by aggregating homogeneous land uses. Serial zones are bounded by the roadway network or other physical characteristics, such as a railroad line or stream.

Zones in the Texas Package vary in size. Serial zones are generally sized by the detail of the network. Traffic serial zones are aggregated into larger geographic areas called districts and sectors. Districts and sectors are used for summary information and some aggregate modeling statistics. Aggregated zones are also used for mode choice modeling in urban areas where this step is performed. Traffic assignments and trip distribution are performed at the traffic serial zone level.

IV. TRIP GENERATION

THE TRIP GENERATION PROCESS

Trip generation is the process used to estimate trip-making activity. Measuring travel demand in terms of trip productions and attractions is normal practice. The units for which these estimates are derived are subareas within an urban area referred to as zones. Trip generation is defined as the procedure by which estimates of the number of trips produced and attracted by the zone within an urban area are developed. Thus it plays an important role in the overall process of urban traffic forecasting. The Texas Package trip generation models include TRIPCAL3, TRIPCAL4, and more recently, TRIPCAL5.

TRIPCAL3 AND TRIPCAL4

Current trip generation practice involves two programs: TRIPCAL3 and TRIPCAL4. TRIPCAL3 computes the number of attractions for each traffic serial zone. Trip attractions are estimated for four different trip purposes: home based work, home based non-work, non-home based, and truck-taxi trips. The program allows the user the flexibility to input land use in terms of acres or employment or a combination of both, i.e., acres for some zones and employment for others. The ability to input trip productions and attractions for special generators is also provided. Trip rates are input for each trip purpose and cross-classified by area type and households, employment, or acres of land. It is not a true cross-classification model because the trip rates are applied in an aggregate manner which is similar to the way a regression model operates. The output from TRIPCAL3 is input to TRIPCAL4.

TRIPCAL4 computes the trip productions for each serial zone. Trip productions are estimated for each zone using a cross-classification model. Trip rates (either person trips per household or auto-driver trips per household) are input to the program and cross-classified by income and auto ownership. Five income categories are normally used with the percentage of households with 0, 1, 2 and 3+ autos being input to the program for each income category. The percentage of trips by trip purpose for each income category is also input for home based work, home based non-work, and non-home based trips. Truck-taxi

17

productions are set equal to the truck-taxi attractions after the attractions have been scaled to sum to the control total truck-taxi trips input to the program.

Truck and taxi trips are estimated prior to running TRIPCAL3 and TRIPCAL4. Generally, truck and taxi trips are estimated to be about 10 percent of the total trips in a given urban area. For forecast years, a lesser percentage is used to reflect a slower growth rate than other trip purposes. Information relating to the percentage of truck and taxi trips is derived from observed counts.

Trips originating external to the urban area are estimated from traffic counting at external stations around the periphery of the region. Using a manual process, the external trips are divided into external-through trips and external-local trips. Typically, the trip purposes used with TRIPCAL3 and TRIPCAL4 include:

- Home Based Work
- Home Based Non-Work
- Non-Home Based
- Truck-Taxi
- External-Local
- External-Through

TRIPCAL5

A recently developed trip generation package used with the Texas Package is TRIPCAL5. TRIPCAL5 is designed to be flexible and allow the user different options in developing estimates of travel demand. This allows the trip generation process to be designed to use available data and improve the overall travel demand estimates. The different options include trip production models, trip attraction models, disaggregation models, multiple trip purposes, and user-selected data inputs.

Trip Purposes

Up to 10 trip purposes may be used in TRIPCAL5 with specific trip rates or models for each. The only limitation is that the same type of cross-classification model must be

used for each run where those trip purposes are being estimated using a cross-classification model. Typical trip purposes which might be used are:

- Home Based Work
- Home Based School (Non-College)
- Home Based School (College/Post-High School)
- Home Based Shopping
- Home Based Other
- Non-Home Based Work
- Non-Home Based Other
- Truck-Taxi
- External-Local

Trip productions and attractions may be estimated for up to 9,999 zones.

Estimation of Trip Productions

Three trip production models are included in TRIPCAL5:

- A Two-Way Cross-Classification Model which allows trip rates to be stratified for up to six categories for each independent variable
- A Three-Way Cross-Classification Model which allows trip rates to be stratified for up to six categories for two of the independent variables and up to four categories for the third independent variable
- A Linear Regression Model with up to six independent variables

The recommended trip production model is a Two-Way Cross-Classification Model with person trips (or auto-driver trips) per household cross-classified by up to six row categories and up to six column categories. While the program was developed to allow the user to input any independent variables for the cross-classification model, the recommended independent variables are median household income and household size.

Estimation of Trip Attractions

Five trip attraction models may be used to estimate trip attractions:

- A Two-Way Cross-Classification Model may be selected and attraction

19

trip rates stratified for up to six categories for each independent variable

- A Three-Way Cross-Classification Model with trip rates stratified for up to six categories for two of the independent variables and up to four categories for the third independent variable

- A Cross-Classification/Regression Model with trip rates stratified for up to 24 generation areas by households and employment type

- A Linear Regression Model with up to six independent variables

- A Two-Tier Regression Model with six independent variables

The recommended trip attraction model is a regression type cross-classification model for each trip purpose stratified for up to 24 generation areas. While referred to as a regression type model, it would be developed in a similar manner as a cross-classification model using trip rates per employee and per household stratified by area type for up to 24 generation areas. It is referred to as a regression type model because the trip rates are applied to the independent variables (employment and households) in the same manner as the coefficients in a linear regression equation. The trip rates are normally developed from data from a workplace survey and not developed using statistical regression techniques.

Since many areas do not have data available to develop cross-classification attraction models, regression type models are widely used. Many areas, due to data limitations, must develop regression relationships using zones aggregated to district levels with additional models used to allocate district level attractions to the zones within the district. For this reason, an option is included which allows these "two-tier" regression models to be input.

Disaggregation Models

The disaggregation models provided in TRIPCAL5 are for three production model variables: households by household size, households by household income, and households by auto ownership. For any one of these three variables, the user may choose to input the marginal distribution for each zone, input a disaggregation curve for the urban area which is used to develop a marginal distribution for each zone, let the default model in the program compute the marginal distribution for each zone, or use a combination of those

20

three methods. While TRIPCAL5 is oriented to those three variables, the user may select and use any other variable desired as long as the marginal distribution is input for each zone.

Special Generators

The trip production and attraction models are developed for average conditions and land development types in an urban area. Land use activities considered unique within an urban area are handled as a special generator. The estimation of trip productions and attractions is estimated on an individual basis independent from TRIPCAL5, and the resulting productions and attractions are directly added to the zone.

Trip Balancing

It is intuitive that all trips produced in an urban area must be satisfied with a complimentary trip attraction since all externally related trips are accounted for in the process. Since they are developed independently, trip productions and attractions may not equal each other at the regional level after estimation is performed across all zones.

An option is included in TRIPCAL5 which allows regional control of total trip productions and/or trip attractions to be input directly for each trip purpose. The trips are then scaled to the control total by proportionally weighting the number of trips in each zone.

Another option is to balance productions to attractions, or attractions to productions, depending on the methodology used in estimation and whether the productions or the attractions are considered more reliable. Generally, home based work trips are balanced to attractions when a workplace survey is used as a basis for calculating the attraction rates. Since production models are generally more reliable than the attraction models, other trip purposes use productions as control totals. The model will be structured to set the zonal productions equal to the zonal attractions for non-home based trips and truck-taxi trips after all scaling and balancing has been done.

21

V. TRIP DISTRIBUTION

THE TEXAS TRIP DISTRIBUTION PACKAGE

Trip distribution is the process by which the trip interchange volumes between zones are estimated. Thus, the expected urban travel pattern is described. Over time, a number of methods have been employed, ranging from the uniform factor method and the Fratar method of successive approximations (both of which used observed data to project into the future) to a variety of mathematical models. These latter models are often referred to as synthetic distribution techniques. The model used in the Texas Package is the gravity model.

The Texas Travel Demand Package provides the analyst with the option to select either of two synthetic, mathematical, distribution techniques. The alternatives are MODEL and ATOM. Trip Length Frequency Distribution (TLFD) is an input to both MODEL and ATOM.

THE TRIP LENGTH FREQUENCY DISTRIBUTION (TLFD) MODEL

During the era of origin-destination (O-D) surveys, trip length frequency distribution was determined manually by the analyst. Points were plotted on a graph with trips on the vertical axis and separations on the horizontal axis. From these points, a "smoothed" curve was drawn. This curve would be an input to MODEL and ATOM. With the discontinuation of O-D surveys, the need for an alternative method of determining the TLFD curve became apparent. A TLFD model was developed and put into use in 1974. Theoretical revisions were made and an improved TLFD model was made available in late 1979. These revisions overcame the tendency of the original model to underestimate trips at the very short separations.

To use the TLFD model, the analyst must estimate the mean desired trip length for each trip purpose. Next, the maximum separation at which trips can occur is either estimated by the analyst using a network program, or the default set of estimation models in the TLFD model calculate the values. To control the underestimation of trips at the longer separations, the analyst may impose a limit to control the minimum percentage of

23

trips at the maximum separations.

The principal benefit of an accurate trip length frequency estimation procedure is that it has allowed for a reduction in the amount of data required from urban travel surveys. Previous research has shown that a home interview survey of approximately 600 dwelling units will provide a reliable estimate of the mean trip length but a poor estimate of the frequency distribution. Given the mean trip length, the procedure can be used to estimate the frequency distribution. The trip length frequency distribution is, of course, of great importance since it is used as an objective function in the trip distribution process for both MODEL and ATOM.

The Texas Package method uses two inputs to estimate a synthetic trip length frequency distribution: the mean trip length and the maximum trip length. Since a trip length frequency distribution is generally presented as the percentage of trips occurring at each separation, the distribution may be thought of as a probability distribution. The gamma distribution approximates a trip length frequency distribution in form (see Figure 6). The statistical method of Maximum Likelihood is used to estimate the shape and scale parameters of the gamma distribution, using the mean trip length and the maximum trip length. The form of the model is:

$$f_t = \frac{\beta^\alpha}{\Gamma_\alpha} \, t^{\alpha-1} \, e^{-\beta t}$$

Where:
t	=	time
f_t	=	relative density of occurrence of trips
α	=	shape parameter
β	=	scale parameter
e	=	2.71828...
Γ_α	=	$(\alpha-1)!$

The two-parameter gamma model was found to decay excessively at the right-hand tail of the estimate of the trip length frequency distribution; i.e., longer trips were

24
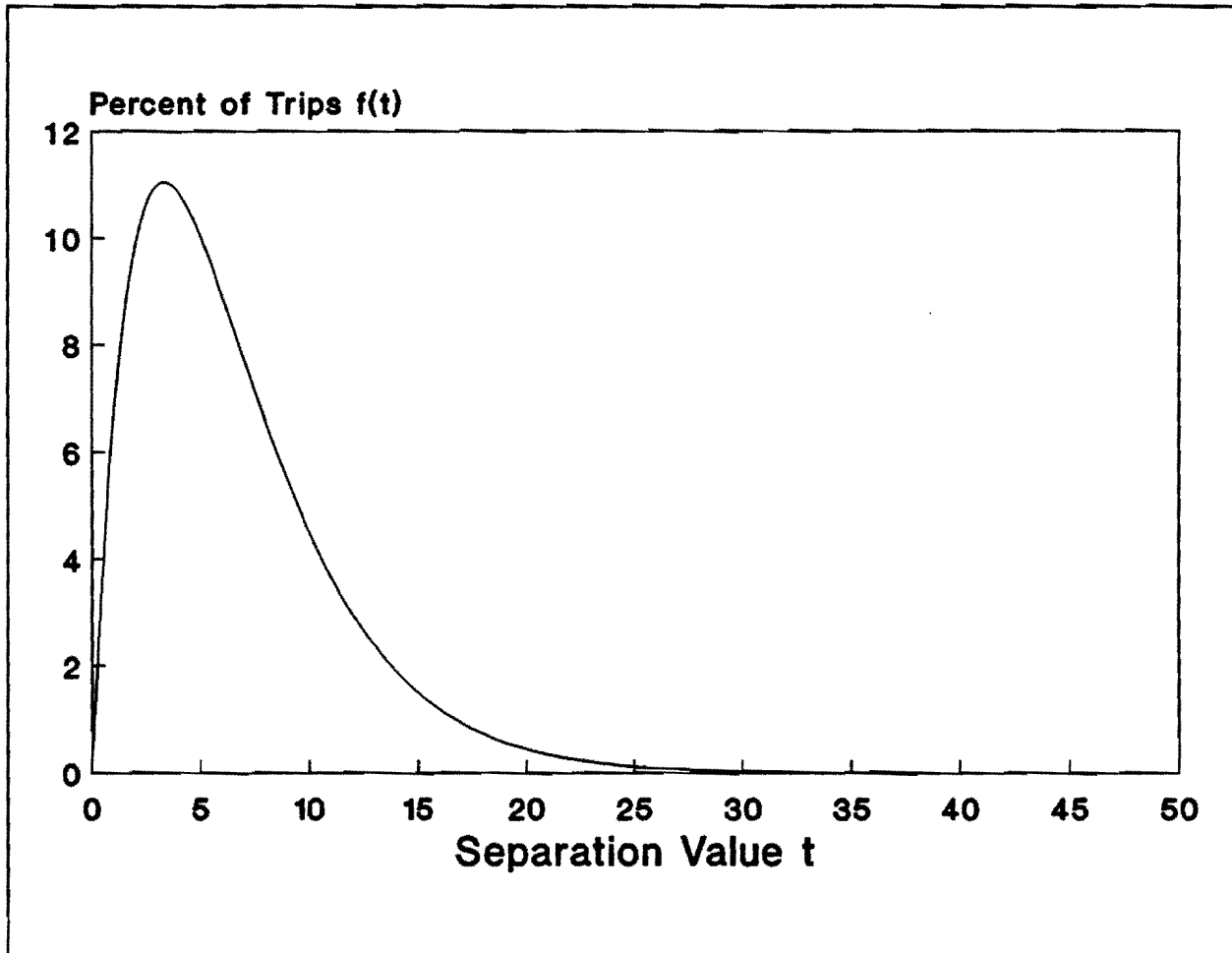
FIGURE 6. Gamma Function Approximation to Trip Length Frequency Distribution, holding $\beta = 0.3$ and $\alpha = 2$.

underestimated. As a result, an option has been provided for the analyst to impose a constraint which specifies the minimum value which the right-hand tail should asymptomatically approach.

GRAVITY MODEL

Trip distribution is the conversion of trip ends (the product of trip generation) to interacting "trips." In other words, trip ends are joined to produce completed trips. To date, the most widely used trip distribution model is the "gravity model" which essentially describes trip interchange between zones as directly proportional to the relative attraction of each of the zones and inversely proportional to some function of the spatial separation between zones, usually time or distance. Because experience demonstrates that the

exponent of travel time is not constant for all intervals of time, the basic gravity model is revised to express the effect of spatial separation on zonal trip interchange, rather than the traditional inverse exponential function of time.

The Texas Package trip distribution model is a modified gravity model. It is self-calibrating (described later) and normally runs five iterations. It constrains the resulting trip matrix directly to desired productions and indirectly to desired attractions and desired trip length frequency. The model also accepts directional bias factors between sectors. All bias factors which are not entered will be set to 1.0. The Texas Package gravity model is as follows:

$$
T_{i,j} = \frac{P_i \, A_j \, F_{t_{i,j}} \, K_{s_i s_j} \, E_{i,j}}{\sum_{x=1}^{n} A_x \, F_{t_{i,x}} \, K_{s_i s_x} \, E_{i,x}}
$$

Where:

$T_{i,j}$ = the trips produced in zone i and attracted to zone j (analogous to gravitational force)

P_i = the trips produced in zone i (analogous to mass of body i)

A_j = the trips attracted to zone j (analogous to mass of body j)

$t(i,j)$ = the travel time in minutes between zone i and zone j (analogous to separation between bodies i and j)

$F_{t(i,j)}$ = empirically derived travel time factor that expresses the average area-wide effect of spatial separation on trip interchange between zones that are $t(i,j)$ apart

$K_{s(i),s(j)}$ = specific zone-to-zone adjustment factor bias to allow for the incorporation of the effect on travel patterns of defined social and economic linkages not otherwise

26

$$E_{i,j} \quad = \quad$$ accounted for in the gravity model formulation

the interaction eliminator function which has a value of 1 if the interaction from zone i to zone j is used or a value of 0 if the interaction from zone i to zone j is eliminated

External Trip Distribution

External through trips are assigned a distribution pattern based on individual judgment or on a cordon survey, if available. Forecasted external through trips are distributed with the use of a Fratar Model. External to local trip patterns are obtained by assuming that external trips will pattern the non-home based trips. Non-home based trip attractions are used to rank the external to local trips; and an external-local trip distribution model is run, including zonal adjustment factors, if needed.

MODEL and ATOM

MODEL and ATOM perform the same task: trip distribution. But they vary in fundamental methodology. Nevertheless, the inputs are similar, and the outputs are similar. Accordingly, a brief discussion of the two processes will follow.

MODEL

MODEL is the original synthetic mathematical distribution model in the Texas Package. This trip distribution model, sometimes referred to as a constrained interactance model, loosely parallels the gravitational law introduced by Isaac Newton in 1686. MODEL includes an interaction constraint option which limits the number of attraction zones eligible to receive productions from a given zone. This will provide a more rational mix of interactions for the smaller production zones. The interaction constraint applies to all zones in the study area. Its use is optional at the discretion of the analyst. If, whether or not the interaction constraint is in effect, there appears to be a sector to sector distribution problem, adjustments can be used to modify interactions between specified sectors. An important

feature of MODEL is the direct use of the desired trip length frequency distribution as an objective in the iterative process. Under this approach, the traditional friction factors of the gravity model (the relative measures of the impedance to travel due to spatial separation) are treated as simple iteration variables. Probably the most significant feature of this model is its ability to balance attractions and trip lengths.

Interaction Constraint

The model also accepts a production interaction curve and selects eligible interactions based on the larger values of the desired attraction values divided by the separation between the zone pairs. This limits the number of attraction zones eligible to receive productions from a given zone. The interaction constraint is applied due to problems often encountered in dealing with a large number of small zones. A pre-processor routine is employed to preselect the eligible interactions based on a user-defined production-interaction curve which describes the maximum likely interactions for a given zonal production volume.

ATOM

For simplicity, the term ATOM is used for the Texas Package trip distribution model when, in fact, it is more proper to refer to it as the "atomistic model." It is also known as a spatially disaggregate trip distribution modeling technique.

The following terms and their definitions from Webster's dictionary form the basis for the nomenclature adopted to describe the ATOM model:

atomism, n.   -   Doctrine that the universe is composed of simple, indivisible, and minute particles (atoms).

atomize, v.t.   -   To view or treat as made up of discrete or atomistic units.

atom, n.   -   One of the minute particles postulated in atomism.

Using this nomenclature, the disaggregate (or atomistic) approach can be described as follows: The basic premise of the atomistic approach is that travel occurs between small parcels of land (i.e., atoms) rather than between zones. In other words, the traditional zones may be viewed as aggregations of atoms between which travel occurs. A gravity model

analogy can be applied to atom pairs that form a zone pair to estimate the expected atom interchange volumes. These atom interchange volumes are essentially accumulated to form the zonal interchange volumes needed for traffic assignment.

ATOM had its genesis in the need to overcome the differences which result from the use of a common trip length frequency objective when modeling at two significantly different levels of detail. An example would be the 515-zone sketch planning structure for the City of Houston as compared to 2,600-zone structure for the traditional detailed planning study. Research has shown that where sketch planning zones are from two to 10 times the size of small zones used in the detail study, the difference in the results when the small zone results are aggregated to large zone equivalents are of sufficient magnitude to dictate the use of different trip length frequency distributions for the calibration of trip distribution models at the two levels of detail. It is apparent that there is a strong basis for a credibility gap if differing trip length frequency distributions are used. Similar problems are observed in the estimation of intrazonal trips at two levels of planning detail.

Having established the problem of using a trip distribution tool such as MODEL at two levels of detail, a solution, ATOM, was developed. ATOM uses, as does MODEL, a gravity analogy in its basic formulation. ATOM is unique, however, in that it provides for the assignment of spatial attributes to zonal activities. In other words, a range of separation intervals is accepted by the models. This is a significant departure from the logic of MODEL where all zonal activity is concentrated at the zonal centroid, an assumed point in the zone which represents the center of gravity of trip ends.

In the logic of ATOM, a square space consisting of 400 equal-sized "atoms" is centered on the zonal centroid. This space encompasses the activity within the zone and is called the centroid area. The only additional datum required to use ATOM is a zonal parameter, called RADIUS, which describes the desired size of the centroid area for each zone. In effect, this parameter measures the distance in minutes of travel time from the center point of the zonal centroid to the nearest point on the perimeter of the zone. This nearest point must be on a segment of the street and highway network. Care must be exercised to avoid mistaking a geographical barrier (e.g., river) or a man-made barrier (e.g., railroad, canal) for a segment of the network. There are situations where a river or a

29

railroad form a part of the zone boundary. With the spatial dimension of each zone established, ATOM then functions essentially as MODEL in the distribution of trips, not only between zone pairs but within the zones, thus producing calculated intrazonal trips.

ZONE-TO-ZONE BIAS FACTORS (K-FACTORS)

There may be factors specific to an urban area, other than those related to travel time, which affect patterns of travel. Various social and economic conditions may also affect travel patterns.

The decennial Census transportation package includes data for each census tract of residence and employment; i.e., the trip ends for the Home Based Work (HBW) trip purpose. These data represent the actual surveyed origins of the HBW trip. The coverage of the Census is generally every 1 out of 6 households and therefore provides a good basis for calibrating the modeled HBW trip matrix.

Generally, the amount of adjustment that is required would be dependent on the ratio of the origin/destination survey results to the unadjusted gravity model results for a particular movement. However, it is also dependent to a more limited extent on the proportion of trips produced in any zone which are to be adjusted. The following formula has been used to express the relationship between the adjustment factor for any zone movement and these two factors:

$$K_{i,j} = \frac{R_{i,j}\,(1 - X_i)}{1 - (X_i\,R_{i,j})}$$

Where: $K_{i,j}$ = adjustment factor to be applied to movements between zone i and zone j

 $R_{i,j}$ = ratio of O-D survey results to the gravity model results for the movement between zone i and zone j

 X_i = ratio of O-D trips from zone i to zone j to total O-D trips leaving zone i

30

The trip distribution model applications require the zonal trip productions and attractions by purpose produced in the trip generation process and the zone-to-zone travel times for the minimum time paths estimated using the highway network with 24-hour speeds. In addition, the models require estimates of the zonal radii values, estimates of the trip length frequency distributions by purpose, and any needed bias factors (also referred to as K-factors) by trip purpose.

VI. MODE CHOICE AND HOV MODELING

The Texas Package does not contain a mode choice model. The Texas Package trip generation model estimates vehicle-driver trips or person trips. Houston, San Antonio, and Austin have developed separate mode choice models to complement the Texas Package for transit forecasting. The Texas Package does contain, however, a model for predicting vehicle usage of HOV lanes.

This section summarizes the models used by the Metropolitan Transit Authority to perform mode choice modeling (Source: "Metropolitan Authority of Harris County, Texas - Priority Corridor Alternatives Analysis - Methods Report No. 3: Travel Demand Forecasting," September, 1990).

Mode choice modeling in Houston is accomplished through the use of multinomial logic equations for each trip purpose. The Houston trip generation model estimates person trips, which are separated into transit and auto vehicle trips in the mode choice model.

The models used by METRO to perform mode choice modeling are multinomial mode choice models originally developed and calibrated for the Houston-Galveston region by Texas Transportation Institute (TTI) and Barton-Aschmann Associates (BAA). Three separate models are used, one each for Home Based Work (HBW), Home Based Other (HBO), and Non-Home Based (NHB). The HBO model sums the Home Based School, Home Based Shop, and Home Based Other trips purposes used by HGAC in the other modeling phases.

Each model is a six-dimension multinomial logic model. The modes used for the HBW mode split are: transit, drive alone, two person auto, three person auto, four plus person auto, and van. "Van" represents vanpooling and assumes an 8.9 person average van occupancy. The modes used for Home Based Other and Non-Home Based mode split are transit, drive alone, two person auto, three person auto, four person auto, and five plus person auto. In all three models, transit is separated into walk-access and auto-access opportunities, and mode split is conducted for each.

33

PREPARING VEHICLE TRIP TABLES FOR ASSIGNMENT

The trip generation and trip distribution models are applied at the detailed traffic serial zone level. In Houston, the person trip tables are then collapsed to 784 transit analysis zones for application of the mode choice models. The subsequent post-mode choice highway analyses are performed at the traffic serial zone level. The Texas Mezzo-level HOV Carpool Model in Houston provides an important "bridge" between the 784 transit zones and the 2,598 highway zones. Since the mode choice model does not have an HOV carpool component, the Texas Mezzo-level HOV Carpool model is also used as the model for forecasting Home Based Work HOV carpool vehicle trips.

HOV CARPOOL MODEL

The Texas HOV model is essentially a "mezzo-level" adaptation and extension of the Atlanta HOV carpool model developed by Barton-Aschmann Associates, Inc., for the Atlanta Regional Commission. One of the salient features of the model is its use and adaptations of three models originally developed for use in the Washington D.C. region (i.e., (1) the travel time ratio model developed by JHK and Associates for use in estimating HOV carpools in the Shirley Highway and IH-66 corridor inside the beltway; (2) the logic model developed by BAA for use in estimating HOV carpools in the Bolling/Anacostia corridor; and, (3) the travel time savings model developed by the Metropolitan Washington Council of Governments for estimating HOV carpools for long-range planning. The three models are used as "shift" models, with the region's travel demand model data used as the basis for the shift. The final model results are obtained by computing a weighted average of the results from the three individual models.

A key difference between the Texas model and the Atlanta model is the level of detail at which the mode choice and auto occupancy data are input. The Texas model provides for the input of the expected percent transit and the average auto occupancy at the sector interchange level rather than the zonal interchange level; provides an option for inputting the auto occupancy estimates by separation; and provides an option for inputting the expected percent trips by school bus (since these school bus trips are not carried by the public transit system, this is an important option for converting Home Based School person

34

trips to vehicle trips). This "mezzo-level" approach for inputting the percent transit and expected auto occupancy provides the needed bridge between the two different levels of zonal detail used in the transit and highway modeling (Source: "Implementation of a Mezzo-level HOV Carpool Model for Texas," Texas Transportation Institute Research Report 1103-2F, November, 1989).

VII. TRAFFIC ASSIGNMENT

THE TRAFFIC ASSIGNMENT PROCESS

Following the creation of production/attraction trip tables during trip distribution, the vehicle trip tables are summed and converted to O-D format and assigned to the appropriate network (base year for base year trip table and forecast year for forecast year trip table). This 24-hour capacity restraint assignment is usually performed at the detailed traffic serial zone level using the ASSIGN SELF-BALANCING program in the Texas Large Network Package. Several iterations of the capacity restraint model are used before the computation of the final assignment results. Between each iteration, the capacity restraint model adjusts the link impedances based on the link's volume to capacity (V/C) ratio (regardless of whether or not the link volume is over-or-under capacity). The V/C ratio is calculated using a weighted average of the assigned volumes from the preceding iterations.

IMPEDANCE ADJUSTMENT FUNCTION

The impedance adjustment function used in the capacity restraint model is based on the Federal Highway Administration (FHWA) impedance adjustment function. The impedances used in the Texas Package are usually travel times, although a composite cost based on a combination of distance and travel time (or other variables) is possible. The FHWA function assumes the impedance is based on a "zero volume" link speed. Since Texas highway networks have been traditionally coded using a 24-hour speed rather than a zero volume speed, a modified version of the FHWA impedance adjustment function was implemented. The formula for the Texas impedance adjustment function is:

$$I_{n+1} = [\ 0.92\ +\ 0.15\ (\frac{V_n}{C})^4\ ]\ I_1$$

Subject to: $I_{n+1} <=$ $(n+1)I_1$

and Where: V_n =   a weighted average of the volumes assigned on all preceding iterations

            C =   level of service link capacity

            I_1 =   level of service link impedance

37

$$I_{n+1} \quad = \quad \text{adjusted link impedance}$$

The Texas impedance adjustment function increases impedance when the V/C ratio exceeds 0.85 for all links on every iteration. Again, the FHWA function (sometimes called the BPR function) from which the Texas function was derived is based on input free flow travel times. The input speeds for the Texas model are observed speeds. Therefore, the assumed beginning V/C ratio is 0.85. For links exhibiting a V/C ratio less than 0.85 after a single iteration, the impedance is lowered.

The constraint is imposed in order to limit the magnitude of the impedance adjustment. The maximum impedance adjustment varies by iteration. Following the initial assignment, the maximum impedance adjustment factor is 2 (i.e., essentially reducing the 24-hour speed by one-half). The maximum impedance adjustment factor is increased by 1 for each of the succeeding iterations.

Following the iterations (usually five), the model computes the final assignment results by using a weighted average of the link volumes from each of the preceding iterations. The weighting of the iterations is a user-specified input, although a multiple regression technique is possible but not recommended. The iteration weights used in the 1985 base year assignment for the Houston-Galveston region are: 10, 10, 20, 20, 20, 20 percent. Satisfactory results have been obtained in other areas using the following weighting percentages: 15, 15, 20, 20, 30.

THE TEXAS LARGE NETWORK PACKAGE

The assignment tool of the Texas Travel Demand Package is the Texas Large Network Package (LARGENET). The Texas Large Network Package can accommodate a study area consisting of up to 4,800 zones, 16,000 nodes, and 20,000 link data cards, and a maximum link impedance of 10.23 minutes. The package provides the user with several choices as to the procedure by which trips between zones are assigned to the network.

ASSIGN SELF-BALANCING

The ASSIGN model is a straightforward, single iteration, all-or-nothing process. In the Texas Large Network Package, this is accomplished using the routines BUILD TREES and LOAD NETWORK. Where unacceptable anomalies appear, the analyst must make adjustments and run ASSIGN again.

To overcome this handicap, ASSIGN SELF-BALANCING was developed. This model provides an iterative or repetitive cycle of assignments, with internal capability to adjust link impedances between iterations. The adjustment of link impedances is accomplished by comparing the number of trips assigned to a link in the preceding iteration with the capacity of the link. Where the link is over- or under-assigned, an algorithm is used by which the original link impedance is adjusted so as to discourage so many trips or so as to attract more trips. Thus, over the usual three to six iterations, the model "self-balances" each link assignment.

The Texas Large Network Package needs a network in the form of link data, and a trip matrix which is a product of the Texas Trip Distribution Package. If ASSIGN is to run, there is little else necessary, because this is a single iteration of the classic all-or-nothing assignment. If, however, the analyst chooses ASSIGN SELF-BALANCING with the capacity restraint option, some choices exist and some possible added inputs must be considered.

First, there are two options in capacity restraint. This has to do with how the results of the several (three to five) iterations are combined. One option allows the program to exercise a default option by which a multiple regression is performed. When the multiple regression option is selected, it is quite possible that the results of the first and/or the second iterations will not be used in the final calculation. Intuitively, this situation cannot be justified. The other option allows the analyst to specify a percentage weight for each iteration. Then the specified portion of each iteration is summed, and the result is shown as the last iteration. If five iterations are specified, the composite of these five iterations is shown as iteration six. Either process provides a degree of multiple routing which is not possible with a single all-or-nothing assignment. Both options use the same capacity restraint algorithm or formula. The second option was developed to insure that a part of

39

each iteration went into the final results.

Where limited access, high-capacity facilities play an important part in the study area network, it may be necessary to take steps to prevent the tree builder from assigning relatively short trips on and off the freeway. This can be accomplished by introducing a turn penalty at all, or specified, on and off ramps. Turn penalty values ranging from .25 minutes to .75 minutes have been used, but a penalty of .5 appears to be most reasonable.

There are several special-purpose tools available in the assignment process, such as SUB-AREA FOCUSING, ASSIGNED SELECTED LINKS, and POST ASSIGN SELECTED LINKS.

VIII. THE TRAVEL MODELING PROCESS

TRAVEL SURVEYS

Typical travel surveys in Texas may contain several elements: A home interview survey to gather data on household travel patterns, a workplace survey to collect both employee and non-employee trip data at the workplace, and occasionally an on-board transit origin-destination survey to provide information on transit users. Also, other aspects of urban area travel may be surveyed, such as truck and commercial vehicle travel and "special generators." Special generators are urban activities which are unusual in their traffic generating characteristics, such as theme parks, stadiums, and large shopping malls. In addition to travel surveys, the Journey-to-Work section of the Decennial Census is used to collect information on work trip characteristics.

The travel surveys and the journey-to-work surveys provide information used to develop trip production and attraction rates (vehicle and person) by purpose, household characteristic disaggregation curves, trip length frequency distributions by purpose, mean trip lengths by trip purpose, and temporal travel distributions. Trips per employee, auto occupancy, autos per household, mode of travel, and special generator trip rates are also calculated from the surveys.

The survey information is used as input to the trip generation models. Trip rates are compared to other urbanized areas to check for reasonableness. Other measures, such as person (or vehicle) trips per household are compared, and trip production/attraction balancing factors are checked. The trip length frequency distribution is used as input to trip distribution, or a synthetic trip length frequency is derived from the survey data.

Roadway Inventories and Traffic Counts

Roadway inventories are performed periodically in urban areas in Texas. Inventories are performed by driving the network, and are, therefore, sometimes referred to as "windshield" surveys. Typical data of greatest importance to planning models collected by windshield surveys include:

41

- Roadway speed - estimated speed on each class of roadway
- Capacity - number of lanes, whether the road is divided or undivided, and parking prohibitions

Texas maintains an extensive system of observed traffic counts. TxDOT has a large system of permanent traffic recording stations in urbanized areas which continuously collect traffic counts. TxDOT also collects traffic counts at other permanent sites and for specific studies. An additional system of traffic counts is maintained by other agencies within urban areas.

CALIBRATION AND VALIDATION

Calibration and validation are the development of a series of mathematical, computer models which can replicate existing traffic volumes and conditions within an acceptable associated error. The basis for travel models is usually a set of travel surveys.

Calibration

Calibration refers to the process of estimating model variables such as trip rates, friction factors, mean trip lengths, and trip length frequency distributions. All variables are based on surveyed or observed data. A model is calibrated for the year in which the field data is collected. A calibrated model needs to be tested and validated for a year other than the calibration year to verify the predictive ability of the model.

Validation

Validation is the process of using a previously calibrated model to predict traffic volumes, and comparing the predicted volumes with observed volumes for a year other than the calibration year. Extensive traffic counts must be made in order to validate a model. If trip rates, friction factors, and mean trip lengths are borrowed from another urban area, or default values are used, the model can still be validated for its predictive ability to replicate observed traffic counts.

Calibration Methodology

There are several steps used in the calibration process. Adjustments are made to each model run, and new parameters are estimated. The first step in the process is to run the model, region-wide, using default variables from previously calibrated models or another, similar urban area. Based on the initial results, region-wide values are developed for trips per person, vehicle-miles-travelled (VMT) per person, and the labor force participation ratio (population to employment ratio).

These values can be compared with surveyed values or typical values for urban areas. The model is then used to predict traffic volumes on links. The links can be aggregated to form screen-lines and cut-lines, imaginary lines partially or wholly crossing the urban area. Totals of observed traffic volume and predicted traffic volume are compared cross screen-lines and cut-lines.

Depending on the magnitude of the error in the model's predictive ability, model parameters are adjusted. Values which may be changed include:

- Socioeconomic Data
- Trip Rates by Trip Purpose and Auto Occupancy
- Centroid Connectors
- Intrazonal Travel Times
- Network Speeds and Capacities (Assumed LOS threshold)
- Trip Distribution Bias Factors

Validation Methodology

After the model is calibrated to within a specified margin of error, a validation is performed for a year other than the calibration year. This process is performed periodically as demographic estimates and comprehensive traffic counts become available for a given validation year.

In the validation process, the calibrated model parameters are assumed to be correct since they were used to "validate" against the calibration year traffic. Traffic assignment results for the validation year are compared to traffic counts collected during the same year. A percent error is calculated and aggregated according to the following categories:

- Region-wide
- Functional Classification
- Area Type
- District or subarea

Screenlines are developed and a comparison of total counted volume versus total assigned volume crossing the screenline is made. Where deficiencies occur, the trip table is adjusted with bias factors to account for the difference in assigned volume.

In urban areas where estimates of vehicle miles of travel (VMT) are prepared using statistical methods, the total VMT from a traffic assignment can be compared. VMT can be estimated using traffic counts and a roadway inventory. Annual increase in VMT for a given urban area is generally at a steady rate. The predictive ability of the model can be used to estimate VMT for a given year and then compared to the expected VMT region-wide, by functional classification, and area type.

Once a calibrated and validated model is developed for an urban area, the model can be used to forecast the impacts of future activity on the planned transportation system for a given forecast year. Also, the models can be used to test alternatives in planned transportation systems and the effectiveness of the modified plans.