TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-91/1235-2		

4. Title and Subtitle	5. Report Date
TRIPCAL5 - Program Specifications Informational Report #6	Jan. 1991 (Aug. 1991/Rev.) 6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
David Pearson and George B. Dresser	Research Report 1235-2
9. Performing Organization Name and Address	10. Work Unit No.
Texas Transportation Institute The Texas A&M University System College Station, TX 77843-3135	11. Contract or Grant No. 2-10-90-1235
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas Department of Transportation P. O. Box 5051 Austin, TX 78763	Interim - September 1989 - August 1990 14. Sponsoring Agency Code

15. Supplementary Notes

Study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration. Research Study Title: Improving Transportation Planning Techniques.

16. Abstract

This report documents the research and analysis undertaken to develop a state-of-the-art trip generation model for use by the Texas Department of Transportation (TxDOT). This work was undertaken as a part of an overall effort to improve the transportation planning techniques utilized by the TxDOT. Trip generation has been accomplished by the TxDOT since the early seventies using two computer programs, TRIPCAL3 and TRIPCAL4. The methods and models employed by those programs were considered to be outdated and no longer state of the practice in terms of trip generation. The work documented in this report includes a review of the input data for trip generation, a review of the trip generation rates developed as a result of recent travel surveys, a review of the current trip generation practice in urban areas outside Texas, and a review of the trip generation practice in Texas. Based on those reviews and analyses, specifications and recommendations were developed for a new trip generation program for use by the TxDOT as a part of their mainframe travel demand modeling package. The new program is called TRIPCAL5. The implementation of TRIPCAL5 is anticipated to provide a quantum improvement in the trip generation capabilities of the TxDOT.

17. Key Words	18. Distribution Statement
Transportation Planning, Trip Generation, Productions, Attractions, Dissagregation, Independent Variable, Cross-Classification Model, Regression Model	No restrictions. This document is available to the public through the National Technical Information Service Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	167	

Form DOT F 1700.7 (8-69)

TRIPCAL5 - PROGRAM SPECIFICATIONS
Informational Report #6

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Improving Transportation Planing Techniques
Research Study Number 2-10-90-1235

Sponsored by
Texas Department of Transportation

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

Texas Transportation Institute
The Texas A&M University System

January 1991
August 1991/Revised

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	2.54	centimetres	cm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in^2	square inches	645.2	centimetres squared	cm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
MASS (weight)				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

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

TEMPERATURE (exact)

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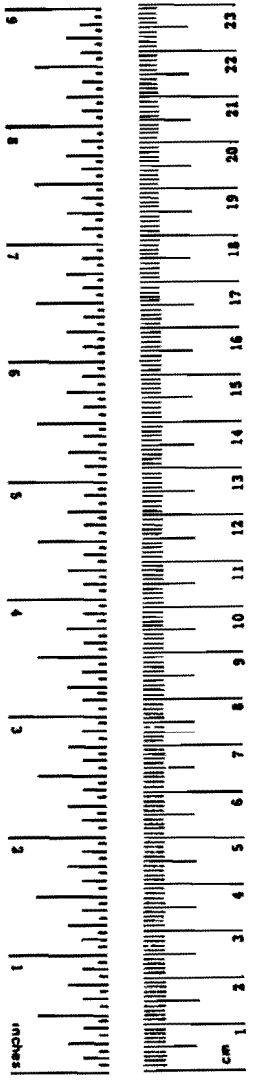

APPROXIMATE CONVERSIONS TO SI UNITS

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LENGTH				
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m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
MASS (weight)				
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3

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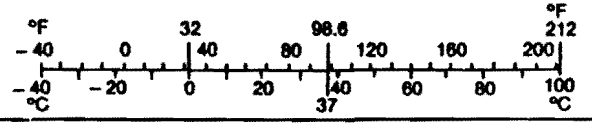


These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

ABSTRACT

In 1989, the State Department of Highways and Transportation, through the Texas Transportation Institute, began an overall effort to evaluate and update the practice of transportation planning in the state to equal or exceed current state-of-the-art practice in transportation planning. A new trip generation program, TRIPCAL5, was subsequently developed to replace the trip generation programs TRIPCAL3 and TRIPCAL4 developed in the early seventies.

TRIPCAL5 is a multi-functional, flexible trip generation program which allows a user to estimate trip productions and attractions for multiple trip purposes using different user-specified models.

This manual provides the information necessary to set up and operate the TRIPCAL5 program. Example setups are included with copies of actual program setups with test data sets and a cross reference of the control/input records necessary for accomplishing specified objectives. One of the features of the program is the ability to use available data for disaggregating zonal data or utilize built-in default models for disaggregating households at the zonal level by household size, household income, and/or auto ownership.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. EXECUTIVE SUMMARY

INTRODUCTION

Trip generation is the process by which estimates of the number of trips being made are developed. This project undertook the task of reviewing trip generation procedures currently employed in the state of Texas and other selected urban areas outside of Texas. The purpose of this review was to determine if a need existed to revise or update the trip generation procedure used in Texas.

OVERVIEW

Trip generation models generally fall into two categories: linear regression models and cross-classification models. Some areas use both depending upon the data available for calibration of the models and whether trip productions or attractions are being estimated.

Linear regression models have been used in trip generation modeling for many years. Models have been developed which relate the number of trips (either productions or attractions) by purpose to a wide range of independent variables. Trip productions are usually related to socioeconomic characteristics of the household such as household size, number of autos owned, household income, age of head of household, number of licensed drivers, etc. Trip attractions are usually related to the characteristics of the land-use activity or to intensity measures such as employment, acres of development, amount of parking, square feet of leasable area, etc.

Cross-classification, also referred to as category analysis, is a disaggregate approach to estimating trips. Using data from home interviews conducted in the 1960's (many of which are now being updated), trip rates (e.g., person or auto-driver trips per household) were cross-classified by certain socioeconomic characteristics found to significantly influence the number, type, and purpose of trips made at the household level. For example, trip rates could be cross-classified by income range and auto ownership. This would provide an estimate of the number of trips per household for households that fall into a certain income range and own a certain number of autos. Cross-classification tables of trip rates are generally developed for each trip purpose being projected and, until recently, were used

primarily for estimating trip productions. With the update of travel data from new travel surveys, new approaches are being developed using cross-classification models for estimating trip attractions. Cross-classification models are considered to be the state of the art relative to models used in trip generation.

CURRENT PRACTICE

Current trip generation practice by the Texas Department of Transportation (TxDOT) involves two programs, TRIPCAL3 and TRIPCAL4 (1). TRIPCAL3 computes the number of attractions for each serial zone. Trip attractions are estimated for four different trip purposes: home based work, home based non-work, non-home based, and truck-taxi. 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 estimates of trip productions and attractions for select activity centers within zones, i.e., "special generators," is also provided in this program. The attraction trip model used in the program is a cross-classification type model. Trip rates are input for each trip purpose and cross-classified by area type and households/employment or acres of land use. It is not a true cross-classification type model because the trip rates are applied in an aggregated manner which is similar to the way a regression model operates. The output from the program is input to the next program, 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, or 3+ autos being input to the program for each income category. For each income category, the percentage of trips by trip purpose is also input for home based work, home based non-work, and non-home based trips. Truck-taxi 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.

Within the last seven years, two urban areas in Texas, Dallas-Fort Worth and Houston-Galveston, undertook major efforts to update their travel demand models by conducting extensive travel surveys (2,3,4). As a result, these areas developed new trip generation models for use in their areas.

The trip generation process in Dallas-Fort Worth consists of three models: an area type model, a trip production model, and a trip attraction model (5). The area type model computes an activity density for each zone based on the zone's population and employment density. This activity measure is used to categorize each zone into one of five different area types: central business district, outer business district, urban residential, suburban residential, and rural. Both the trip production and attraction models are cross-classification type models which use trip rates cross-classified by different independent variables depending upon which trip purpose is being estimated. Productions and attractions are estimated for each of four trip purposes using different trip rates (i.e., cross-classification models). The models also disaggregate households and employment types within each zone by each of the classifications used in the cross-classification models. Thus the trip rate for a one person household in Income Quartile One would be applied to the estimated number of one person households in Income Quartile One in each zone.

The trip generation process in Houston-Galveston consists of two primary models, a trip production model and a trip attraction model. The trip production model is a cross-classification model (6). Trip rates are cross-classified by income and household size for each of five trip purposes. Households are disaggregated by income and household size in each zone prior to applying the trip rates. The trip attraction model is a two-stage (i.e., two-tier) regression model (6). The first regression, done at a district level, computes the trip attractions for the district by each trip purpose. The second regression is done at the zone level with the trip attractions (by purpose) for the zones within each district being scaled to total the computed trip attractions for the district.

A review was also conducted of the trip generation models being used in Florida and ten urban areas outside Texas. Florida was selected because they have centralized their trip generation modeling procedures and made them applicable for all urban areas within Florida. The other areas were selected because they had conducted travel surveys to update

previous origin-destination surveys. They were not the only areas which could have been selected but time limited the number which could be reviewed. The findings of this review were that most of the areas were using cross-classification models for estimating trip productions and regression models for estimating trip attractions. There was considerable diversity in the independent variables used in both modeling procedures, and the models used were highly dependent on the data available for calibration and forecasting.

PROPOSED TRIP GENERATION PROCEDURE

Based on the reviews and observations of the various trip generation models, the basic recommendation for the TxDOT is that a new trip generation program be developed that will provide the capability to use cross-classification models for estimating trip productions and trip attractions. It is also recommended that the program include the ability to disaggregate households at the zonal level for use in estimating trip productions. This ability should also be included for estimating trip attractions. At this time, no changes are being recommended relative to the way special generators are handled; but this may be an area where additional capabilities may be added and included in the program. The recommended program will provide a quantum improvement in the capabilities of the TxDOT in estimating travel within Texas' urban areas. The program is referred to as TRIPCAL5 and is briefly described in the following section.

TRIPCAL5 - AN OVERVIEW

TRIPCAL5 is a highly flexible trip generation program which computes estimates of trip productions and attractions for each zone utilizing a number of optional models which are specified by the user. The input data requirements include the basic input normally used in trip generation modeling, and the capability is included to allow the user to input additional data and information for zones felt to be unusual and that require more accuracy relative to disaggregation estimates.

There are several options available relative to the type of model desired. Trip productions may be estimated by specifying a regression model, two-way cross-classification model, or a three-way cross-classification model. The recommended model is a two-way

cross-classification model using household size and household income as the independent variables. Trip attractions may be estimated by specifying a regression type cross-classification model, a regression model, a two-way cross-classification model, a three-way cross-classification model, or a two-tier regression model. The recommended model is a regression type cross-classification model with trip rates stratified by area type and employment type/households. The difference between this type model and a regular two-way cross-classification model is that no disaggregation of independent variables is done at the zone level. As a result, even though the trip rates are cross-classified, they are applied in the same manner as a regression model.

If a cross-classification model is selected, a method for disaggregating the base for the trip rates being used is needed. This is provided in the program by allowing the user to input the disaggregation for each zone, input disaggregation curves (for selected variables), or use a default model included in the program (for selected variables). Default models are included for disaggregating households at the zone level by household size, household income, and auto ownership. Other variables selected for use must have the marginal distribution input for each zone. One other default model, a model to estimate the total truck trips for the area for use in lieu of having a control total input is included. For zones where additional information may be available, the marginal distribution may be input and the default models used for the other zones.

TRIPCAL5 is intended to offer sufficient flexibility for the user to adapt the trip generation model to the area under study to the detail and complexity of data available. It also allows the model to be upgraded as additional data become available.

II. TRIP GENERATION

INTRODUCTION

Within the context of the development of transportation plans to meet both short- and long-term objectives, trip generation comprises one of the major steps in the development of travel demand estimates which are subsequently used for project planning and programming. Project 2-10-90-1235, titled Improving Transportation Planning Techniques, was initiated as a joint effort of the TxDOT and the Texas Transportation Institute (TTI) of The Texas A&M University System to achieve a quantum improvement in the quality of the state's transportation planning data, planning techniques, and timeliness of traffic forecasts. As a part of this major undertaking, a need was identified early in the project to upgrade the TxDOT's mainframe trip generation models, TRIPCAL3 and TRIPCAL4. Both models had been developed in the 1970's and were no longer considered state of the practice.

The process of trip generation comprises those steps by which estimates of travel demand are developed. Normal practice is to measure travel demand in terms of trip productions and attractions. The units for which these estimates are derived are usually subareas within an urban area referred to as zones. Trip generation may be defined as the procedure by which estimates of the number of trips produced and attracted by each zone within an urban area are developed. Thus, it plays an important role in the overall process of urban traffic forecasting.

This report documents the research and analysis undertaken to develop a state-of-the-art trip generation model for use by the TxDOT as a part of the Texas Travel Demand Package. The objectives of this effort were to review the input data requirements for trip generation, review the trip generation rates that had been developed from recent travel surveys, review the current trip generation practice in other urban areas, and review the current trip generation practice in Texas. Based on these reviews, specifications would be developed for a new trip generation program for use by the TxDOT as a part of their mainframe travel demand modeling package. Subsequent to these specifications was the actual development, testing, and evaluation of the trip generation modeling program

including program documentation and development of the user's manual. This report documents the results and findings of this effort.

INPUT DATA REQUIREMENTS

To develop estimates of the number of trips being produced and attracted for zones within an urban area, certain data elements are required. The minimum area requirements for these data is usually the zone. The data items that are required by the trip generation model being used must be developed and forecasted at the zone level in order to estimate the trips being produced and attracted by each zone. It must be noted that regardless of the sophistication or known accuracy of the trip generation model being applied, the accuracy of its output will be dependent on the accuracy of the data input to the model.

Input data for trip generation models vary somewhat depending on the particular model being used. There are, however, fairly standard data which are used in a majority of the trip generation models. The purpose of this section is to discuss these data relative to their development for use in trip generation. It is not intended to be a comprehensive listing or discussion of all the data used (or potentially useable). It does include the most relevant data in use in most areas to date. These typical data include estimates of the number of households by household size, the number of households by income groups, the number of households by auto ownership, employment by type of employment and income, and zonal characteristics such as size and area type.

Households

Census data are normally used for developing initial estimates of the number of households, population and household size for an urban area, and the census tracts within the area. If the base year used is different from a census year, the census data are updated through the use of building permits, subdivision plats, and other local data or judgment. Aerial photography is also 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. Projections are developed locally or may be obtained from another source (e.g., Texas Department of Water

Resources) for the urban area/region. These are then distributed to subareas within the area through use of a heuristic type model, a simulation model, activity distribution model, professional judgment tempered with knowledge of local development patterns, or other method(s) 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 estimates at the census tract/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 subarea estimates derived from local sources. The estimates at the census tract/zone level will normally be constrained to agree with an estimate for the region as a whole.

The estimates of the number of households by different household size at the census tract/zone level are usually obtained through the application of disaggregation curves. These curves are developed from census data at the census tract level. They represent plots of the percentage of households of each household size (within the census tract) versus the average household size for the census tract. The curves have been hand fitted and smoothed to where for each average household size, the percentages will add to 100 percent. For example, if a census tract/zone was estimated to have an average household size of 1.4 (result of dividing a population estimate of 1,400 by a household estimate of 1,000), this value, using the curves, would yield estimates of the percentage of households of size one, size two, etc., up to size six or more.

Income

The techniques and methods by which household income is projected vary considerably. In some cases, it is simply assumed to remain constant over time implying that no real growth in income or purchasing power will occur. Since trip generation models which use income as a primary variable are usually disaggregate models, the basic data requirement is an estimate of the number of households within each income range being used in the model. It is a two-fold problem: one, to forecast household income at the zone/census tract level and two, to disaggregate the households within the zone/census tract

into the number within each income range being used. The following are some (not comprehensive) of the techniques used in forecasting income.

No Growth - This simply assumes that no real income growth will occur through the forecast year. Since constant dollars are used in travel demand models, the base year estimates of median or mean household income are used for the forecast year as well.

Constant Rate of Growth - This method uses the historical growth in the area's income (in constant dollars) and applies it to the base year zonal estimates to generate an estimate of the median or mean income for the forecast year. Certain zones or areas may be manually adjusted to account for perceived local conditions which are not felt to represent the same trend as the area. The rate of growth may be an average compound annual growth or simply a certain percent growth each year multiplied by the number of years and applied to the base year estimates.

New Growth Only - This method assumes that the income for existing development will remain constant through the forecast year and that the only change in a zone's income will occur through new development (i.e., population and household growth). The income for the new growth is assumed based on the local analyst's knowledge of development patterns and new housing costs.

Historical Trend - This method assumes that the historical growth in real income at the census tract level will continue through the forecast year. It requires the analysis of income changes over two or more census at the census tract level. Forecasts are based on extrapolation of historical trends for each census tract. If the zones are smaller than the census tracts, the growth for the zones within the census tract are assumed to be the same as the census tract.

Regional Growth Forecasts - In some cases, regional growth in income is forecast by agencies or firms outside the local area. An example is the Bureau of Economic Analysis which regularly produces forecasts of income for different areas and subareas around the nation. Some areas will "borrow" these forecasts and use them as they are or adjust them. In such cases, the growth in income may be applied to

the base year estimates for all zones or may be applied in a professional judgment manner to take into account development patterns and other local knowledge.

Mathematical Techniques - This method is a combination of historical trend forecasting with the application of a mathematical estimate of the distribution of households by income. Historical trends are used to project the mean household income for the area, and that is used with a calibrated income distribution model to develop a distribution of households by income for the forecast year. The distribution of households by income is used to develop growth factors for zones with the growth factor dependent on the zone's income in the base year. Initial forecasts of mean income are developed for each zone using the growth factors and then a distribution of households by income estimated for each zone. These are adjusted using an iterative procedure until the cumulative distribution matches the forecast distribution for the entire area.

The use of the above methods/techniques will provide an estimate of the median or mean household income for each zone/census tract. There is more consistency in the method used for estimating the number of households within established income ranges than there is for estimating median or mean household income for each zone. The method is similar to the one for estimating households by household size at the zone level. Disaggregation curves are developed from census tract data which reflect the percentage of households within each income range being used at each value of the computed ratio of the census tract median income to the regional median income. These curves are hand fitted and smoothed to insure that the percentage of households at each ratio add to 100 percent. Given the estimated median income for a zone and dividing it by the regional median income gives a value which, using the developed curves, allows the analyst to estimate the percentage of households within each income range being used.

Auto Ownership

Auto ownership is also used in some areas in lieu of income for trip generation models. The method for estimating auto ownership normally involves income as one (if not the only one) of the independent variables. The method currently used by the TxDOT in

their trip generation models consists of inputting a zone's median income into a plot which relates the percentage of households with 0, 1, 2, and 3+ autos versus income (1). Other methods found to estimate auto ownership usually involved the use of disaggregate data with linear regression models to estimate average autos per household. The input data requirements for some of those models was quite extensive. In general, relationships involving household income and other characteristics are used to develop estimates of the number of households by auto ownership at the zone level. The method used by the TxDOT was originally developed based on origin-destination survey data and updated with census data.

Employment

Employment is another data element which has considerable variation in the types of employment forecast and the method used for the forecast. Employment is generally the variable used in trip attraction models, both regression and cross-classification. The TxDOT typically uses three types of employment for estimating trip attractions: commercial, industrial, and other. Some other areas use three types referred to as basic, service, and retail. Some areas will also include manufacturing employment, school employment, and other highly specific categories of employment. The criteria for what is used is dependent upon the trip purposes and models which have been calibrated for the area. The discussion in this section will be limited to those methods and techniques which are generally used for forecasting employment at the zone/census tract level.

It appears that most areas use outside sources for obtaining existing and historical trends in employment at the regional level. Such sources include the Texas Employment Commission, Dunn and Bradstreet, Bureau of Economic Analysis, and others. In some cases, forecasts of employment at a regional level are also obtained from an outside source. The technique used to develop the regional forecasts may range from the use of econometric models applied at the national and regional levels to simple trend line analysis extrapolated through the forecast year. These regional forecasts are allocated to subareas (districts, census tracts, zones, etc.) through a variety of methods. These methods usually use census data in combination with known local conditions to determine the base year

allocations which becomes the starting point for allocation of the forecasts. The level of sophistication ranges from use of a land-use/transportation system allocation model to use of hand allocation methods based on professional judgment. Some areas use variations of technical methods in combination with the Delphi technique (7). Generally, the larger the urban area, the more sophisticated the method of forecasting and allocating employment. An example of this is the method employed in the Dallas-Fort Worth area (8). Regional forecasts are obtained from an outside source and are initially allocated in a step-down fashion using a land-use/transportation system model called EMPAL. Final allocations are made based on a Delphi technique which involves local area officials and professionals.

Zonal Characteristics

Zonal characteristics for the purposes of this discussion are limited to zone size and area type. Zone sizes vary among urban areas and, to a large extent, are dependent upon the size of the urban area, the limitations of the modeling system being used, and the level of analysis intended. Zone size is usually determined by actual measurement or the use of software programs when the zones have been digitized into a computer readable form.

Area type is a new and an old concept relative to trip generation. It has been recognized for many years that trip generation rates varied between zones, and this variation was related to the intensity of development within the zone. Trip generation models used by the TxDOT included the capability to use different rates for different areas within an urban area (1). The selection and determination of these areas has been dependent upon the judgment and capabilities of the analyst using the program. In recent years, a more rigorous method has been developed which groups zones into five area types based on a mathematical formula. This formula uses population and employment density as the input variables, and zones are grouped according to their computed value. This method will provide more consistent and, hopefully, more accurate results; but it still must be reviewed with necessary adjustments based on local knowledge. This method is discussed in more detail in subsequent sections of this document concerning the trip generation procedures used in the Dallas-Fort Worth area.

SUMMARY

Due to the general nature of the preceding discussions, it is difficult to draw conclusions. A more complete and rigorous discussion will be included in a subsequent research report on traffic data collection and analysis. A specific chapter in that report will be dedicated to urban travel demand modeling data. Initial results in that study, as well as the above discussions, indicate that a large variety of methods are employed in the development and projection of the input data for the trip generation phase of travel demand modeling. While some variation would be expected due to differences in sizes of urban areas, it was still concluded that procedures for development and projection of the data required for trip generation should be more consistent with the use of standard methods and techniques.

III. TRIP GENERATION RATES

The basic information used for travel demand forecasting initially came from extensive origin-destination surveys conducted during the 1960's and early 1970's. These surveys were the source of information for the development and calibration of trip generation models used in transportation planning in many urban areas. Efforts to conduct travel surveys in many urban areas with the intention of updating trip generation models and procedures began in the late seventies and are continuing. The discussions in preceding sections were based on the results of some of those efforts. This section will present and discuss briefly some of the findings of those surveys in terms of the observed trip rates. For the most part, these trip rates are not comparable due to the different stratifications used. They are presented and discussed to give an indication of the magnitude and range of values observed in the surveys. For comparison purposes only, the trip rates used in the trip generation models are also presented to demonstrate the adjustments found necessary to produce reasonable results.

PRODUCTIONS

Trip production rates varied somewhat between urban areas. To review them in any relative comparative form, the trip rates are presented stratified by trip purpose. Three purposes were considered for this review: home based work (HBW), home based non-work (HBNW), and non-home based (NHB).

Home Based Work

Home based work trip rates varied from an observed low of 0.182 trips per household to a high of 4.222 trips per household. The extent of the range of values depended upon the stratification used in the urban area where the survey was conducted. The low and high values were observed in the Minneapolis-St. Paul survey (9) with the trip rates stratified by household size (1, 2, 3, 4, 5, and 6+) and vehicle availability (0, 1, 2, and 3+). When stratified by household size and income quartiles (same area), the trip rates ranged from a low of 0.258 HBW trips per household to a high of 3.323 HBW trips per household.

HBW trip production rates for Atlanta, Georgia, (10) ranged from a low of 0.4 trips per household to a high of 3.3 trips per household with the rates stratified by household size (1 through 6+) and income group (4). Table 1 shows the HBW production person trip rates as reported in the 1980 travel survey done in Atlanta. The trip rates are fairly logical in terms of increasing as household size increases and increasing as income increases. Table 2 shows the HBW trip rates used in Atlanta's trip generation model. The differences from the survey data and the rates used in the model resulted from combining the survey results from 1980 with that from a 1972 survey and an analysis of statistical difference between the trip rates in adjoining cells.

Table 1
Home Based Work
Person Trips Per Household
Atlanta, Georgia
1980 Travel Survey

Household Size	1	2	3	4	5	6+
Inc Group 1	0.400	0.946	1.273	0.875	3.000	4.000
Inc Group 2	1.297	1.770	2.371	2.321	1.889	3.143
Inc Group 3	1.306	1.879	2.307	2.116	2.643	1.900
Inc Group 4	1.500	1.888	2.044	2.132	2.383	3.304

Source: Adapted from (10)

Table 2
Home Based Work
Person Trips Per Household
Trip Production Model
Atlanta, Georgia

Household Size	1	2	3	4	5	6+
Inc Group 1	0.297	0.750	0.923	0.923	1.655	1.655
Inc Group 2	1.165	1.660	2.231	2.231	2.373	2.373
Inc Group 3	1.339	1.959	2.309	2.309	2.438	2.438
Inc Group 4	1.238	2.378	2.378	2.378	2.904	2.904

Source: Adapted from (10)

For comparison, the HBW production trip rates from the Denver trip generation model (11), from the Minneapolis-St. Paul travel survey (9), from the Houston travel survey (12), and from the Dallas-Fort Worth (12) travel survey are presented in the following tables. Note that these are not directly comparable due to different stratifications.

Table 3
Home Based Work
Person Trips Per Household
Trip Generation Model
Denver, Colorado
1985

Household Size	1	2	3	4	5+
Inc Low < 10K	0.3	1.0	1.6	1.6	1.9
Inc Med 10K to 35K	1.0	1.7	2.3	2.3	2.6
Inc High > 35K	1.6	2.3	3.0	3.0	3.3

Source: Adapted from (11)

Table 4
Home Based Work
Person Trips Per Household
Travel Survey
Minneapolis-St. Paul, Minnesota
1982

Household Size	1	2	3	4	5	6+
Inc Quartile I	0.258	0.495	1.049	1.362	1.667	2.085
Inc Quartile II	0.968	1.404	2.062	1.974	2.165	1.906
Inc Quartile III	1.160	1.940	2.151	2.201	2.303	2.637
Inc Quartile IV	0.976	1.933	2.370	2.371	2.399	3.323

Source: Adapted from (9)

Table 5
Home Based Work
Person Trips Per Household
Travel Survey
Minneapolis-St. Paul, Minnesota
1982

Household Size	1	2	3	4	5	6+
0 Autos Avail	0.182	0.533	0.556	1.500	2.500	2.000
1 Auto Avail	0.723	0.968	1.375	1.587	2.565	0.833
2 Autos Avail	1.111	1.789	2.053	2.104	1.746	2.033
3+ Autos Avail	1.000	1.818	2.841	3.230	3.481	4.222

Source: Adapted from (9)

The survey data in Minneapolis were also analyzed to determine if the difference in trip rates between adjoining cells was statistically significant (9). The final trip rates used in the trip generation model were subsequently modified and are shown in the following table.

Table 6
Home Based Work
Person Trips Per Household
Trip Generation Model
Minneapolis-St. Paul, Minnesota

Household Size	1	2	3	4	5	6+
0 Autos Avail	0.182	0.533	0.933	0.933	2.000	2.000
1 Auto Avail	0.723	0.968	1.474	1.474	2.000	2.000
2 Autos Avail	1.100	1.791	2.339	2.339	2.267	3.227
3+ Autos Avail	1.100	1.791	2.339	2.339	2.267	3.227

Source: Adapted from (9)

Table 7
Home Based Work
Person Trips Per Household
Travel Survey
Houston, Texas
1984

Household Size	1	2	3	4+
Inc < 10K	0.31	0.37	1.60	1.44
Inc 10K - 20K	0.84	0.92	1.62	2.05
Inc 20K - 30K	1.11	1.36	1.55	1.66
Inc 30K - 40K	1.23	1.94	2.22	2.76
Inc > 40K	1.50	2.13	2.28	2.43

Source: Adapted from (12)

Table 8
Home Based Work
Person Trips Per Household
Travel Survey
Houston, Texas
1984

Household Size	1	2	3	4+
0 Autos Avail	1.05	1.05	1.05	1.05
1 Auto Avail	1.01	1.09	1.08	1.92
2 Autos Avail	1.04	1.73	2.00	2.03
3+ Autos Avail	0.86	2.28	2.50	2.86

Source: Adapted from (12)

Table 9
Home Based Work
Person Trips Per Household
Travel Survey
Dallas-Fort Worth, Texas
1984

Household Size	1	2	3	4+
Inc < $10K	0.23	0.36	1.53	1.42
Inc $10K - $20K	0.85	1.20	2.25	2.40
Inc $20K - $30K	1.11	2.17	1.98	2.61
Inc $30K - $40K	1.45	2.01	2.26	2.91
Inc > $40K	0.85	2.51	2.45	2.92

Source: Adapted from (12)

Table 10
Home Based Work
Person Trips Per Household
Travel Survey
Dallas-Fort Worth, Texas
1984

Household Size	1	2	3	4+
0 Autos Avail	0.26	0.70	2.18	2.00
1 Auto Avail	0.91	1.04	1.83	1.69
2 Autos Avail	0.86	2.13	2.03	2.25
3+ Autos Avail	2.00	2.19	2.61	3.42

Source: Adapted from (12)

Table 11
Home Based Work
Person Trips Per Household
Trip Generation Model
Portland, Oregon
1985

	Household Size			
Workers in Household	1	2	3	4+
1	1.418	1.413	1.550	1.655
2	-	2.855	2.661	2.693
3+	-	-	3.891	4.154

Source: Adapted from (24)

The above tables illustrate somewhat the variability of ways by which trip rates can and are being stratified in the development of trip generation models. They do have one common variable, that being household size. The following tables contain some HBW trip production models (i.e., trip rates) for other areas.

Table 12
Home Based Work
Person Trips Per Household
Trip Generation Model
Hartford, Connecticut
1979

Auto Ownership

Income	0	1	2+
< $6,000	0.400	0.600	1.000
$6,000 - $7,999	0.556	0.831	1.300
$8,000 - $9,999	0.800	0.980	1.469
$10,000 - $11,999	1.000	1.155	1.655
$12,000 - $14,999	1.000	1.418	1.871
$15,000 - $24,999	1.000	1.438	2.295
$25,000 - $50,000	1.000	1.438	2.376
> $50,000	1.000	1.438	2.376

Source: Adapted from (15)

Table 13
Home Based Work
Person Trips Per Household
Trip Generation Model
San Diego, California
1986

Household Income	Trips Per Household
< $20,000	1.096
$20,000 - $40,000	1.719
> $40,000	2.316

Source: Adapted from (16)

A 1986 travel survey in New Jersey (13) resulted in HBW trip rates from 0.75 trips per household (for one person households) to 3.79 trips per household (for 6+ person households). That same survey, when stratifying HBW trips by employed residents per household, had trip rates which ranged from 1.79 HBW trips per household (one employed resident) to 7.07 HBW trips per household (four employed residents). The rate for households with three employed residents was 5.27 HBW trips per household. These rates appear higher than those shown for Portland, Oregon, previously. An interesting note is that when HBW trip rates per employed person for New Jersey are computed, it ranges from 1.76 to 1.79 which compares favorably with the rate used in Detroit of 1.7 HBW trips per worker in the household (14). The rates per worker in Portland were significantly lower.

Home Based Non-Work

Since several areas reviewed in this project had multiple trip purposes under the general category of HBNW (e.g., home based shopping, home based school, etc.) the trip rates for the individual trip purposes were combined to reflect a total trip rate for home based non-work. This was done for discussion purposes only since, as will be noted, the rates are not directly comparable due to different stratifications. HBNW trip production rates in Atlanta, Georgia, are presented both as reported in the 1980 travel survey and as finally used in their trip generation model.

Table 14
Home Based Non-Work
Person Trips Per Household
Travel Survey
Atlanta, Georgia
1980

Household Size

	1	2	3	4	5	6+
Inc Group 1	1.325	3.001	3.454	2.000	4.000	4.000
Inc Group 2	1.433	2.459	3.457	4.250	6.000	10.857
Inc Group 3	1.445	2.517	4.280	5.918	7.762	9.900
Inc Group 4	1.000	2.689	4.442	6.781	9.575	9.740

Source: Based on data from (10)

Table 15
Home Based Non-Work
Person Trips Per Household
Trip Generation Model
Atlanta, Georgia

Household Size

	1	2	3	4	5	6+
Inc Group 1	1.370	2.993	3.673	4.268	5.879	6.897
Inc Group 2	1.512	2.849	3.828	4.814	7.243	8.615
Inc Group 3	1.546	2.860	4.199	5.960	8.334	11.278
Inc Group 4	1.457	2.951	4.413	7.059	9.802	11.655

Source: Based on data from (10)

For comparison, the HBNW production trip rates from the Denver trip generation model, the Minneapolis-St.Paul travel survey, the Houston travel survey, and the Dallas-Fort Worth travel survey are presented in the following tables. Note that these are not directly comparable due to different stratifications.

Table 16
Home Based Non-Work
Person Trips Per Household
Trip Generation Model
Denver, Colorado

Household Size

Income Group	1	2	3	4	5+
Low < 10K	1.3	2.8	3.7	5.4	7.1
Med 10K - < 35K	1.3	2.8	3.7	5.4	7.1
High 35K+	1.0	2.5	4.3	5.5	7.9

Source: Adapted from (11)

Note: Above rates were increased by 10 percent in final model.

Table 17
Home Based Non-Work
Person Trips Per Household
Travel Survey
Minneapolis-St. Paul, Minnesota
1982

Household Size

Vehicle Avail	1	2	3	4	5	6+
0	0.793	1.267	2.889	1.500	7.000	3.000
1	1.717	3.453	4.769	6.337	7.565	11.750
2	2.167	3.306	5.244	7.582	10.516	12.133
3+	1.000	2.773	5.183	8.332	11.630	13.694

Source: Adapted from (9)

Table 18
Home Based Non-Work
Person Trips Per Household
Travel Survey
Minneapolis-St. Paul, Minnesota
1982

Household Size

Inc Quartile	1	2	3	4	5	6+
I	1.467	3.346	4.405	6.344	12.192	8.263
II	1.693	3.274	5.162	6.630	9.628	10.882
III	1.550	3.562	5.224	7.634	10.596	13.315
IV	1.584	3.208	5.529	8.510	10.977	13.824

Source: Adapted from (9)

The trip rates from the survey were adjusted in the development of the final trip generation model. The rates used in the model are presented in the following table.

Table 19
Home Based Non-Work
Person Trips Per Household
Trip Generation Model
Minneapolis-St. Paul, Minnesota

Household Size

Vehicle Avail	1	2	3	4	5	6+
0	1.012	1.012	1.012	1.012	1.012	1.012
1	1.717	3.353	4.769	6.337	7.565	11.750
2	2.050	3.353	5.227	7.772	10.850	12.985
3+	2.050	3.353	5.227	7.772	10.850	12.985

Source: Adapted from (9)

Table 20
Home Based Non-Work
Person Trips Per Household
Travel Survey
Houston, Texas
1984

Income Group	Household Size 1	2	3	4+
< 10K	1.95	2.74	4.70	7.75
10K - 20K	1.60	3.49	4.88	7.19
20K - 30K	1.97	3.34	5.27	7.45
30K - 40K	1.73	3.17	4.49	7.66
> 40K	1.89	3.13	5.61	8.77

Source: Adapted from (12)

Table 21
Home Based Non-Work
Person Trips Per Household
Travel Survey
Houston, Texas
1984

Auto Avail	Household Size 1	2	3	4+
0	1.37	1.37	1.37	1.37
1	1.80	3.46	4.76	7.63
2	2.04	3.28	5.07	8.22
3+	2.14	2.79	5.50	8.35

Source: Adapted from (12)

Table 22
Home Based Non-Work
Person Trips Per Household
Travel Survey
Dallas-Fort Worth, Texas
1984

	Household Size			
Income Group	1	2	3	4+
< 10K	1.13	1.94	2.33	5.74
10K - 20K	1.62	2.61	4.32	6.04
20K - 30K	1.44	2.83	4.22	7.17
30K - 40K	1.61	2.68	4.59	8.22
> 40K	2.08	3.14	4.72	8.37

Source: Adapted from (12)

Table 23
Home Based Non-Work
Person Trips Per Household
Travel Survey
Dallas-Fort Worth
1984

	Household Size			
Auto Avail	1	2	3	4+
0	0.62	1.30	1.45	4.00
1	1.52	2.47	4.28	6.21
2	2.36	2.93	4.26	7.59
3+	3.00	2.68	4.93	8.37

Source: Adapted from (12)

The HBNW trip rates used in Hartford, Connecticut, and San Diego, California, were stratified by single, independent variables. Hartford used auto ownership with a trip rate

(i.e., HBNW trips per household) of 1.856 for households with no autos, 2.978 for households with one auto, and 4.405 for households with two or more autos (15). San Diego used income with a trip rate of 5.306 for households with less than $20,000 income, 6.372 for households with $20,000 to $40,000 income, and 6.799 for households with more than $40,000 income (16).

Non-Home Based

Non-home based (NHB) trips are those trips where the origin and the destination of the trip does not fall in the same zone as the home. Once again, the trip rates presented in the following tables are not comparable for the most part. They are presented to give an indication as to the range and variability of the rates. In certain cases, the rates are shown for both the actual survey and the rates as finally used in the trip production model. This is the case for Atlanta where the 1980 survey trip rates were combined with a 1972 survey. An analysis was conducted to statistically determine the cell rates that were different in order to develop the final rates as used in the model.

Table 24
Non-Home Based
Person Trips Per Household
Travel Survey
Atlanta, Georgia
1980

Household Size

	1	2	3	4	5	6+
Inc Group 1	0.525	0.973	1.545	0.875	0.000	0.333
Inc Group 2	0.784	0.656	1.886	2.250	2.111	2.714
Inc Group 3	1.056	1.637	1.907	1.942	2.952	2.700
Inc Group 4	0.000	1.778	2.481	2.396	3.574	3.304

Source: Adapted from (10)

Table 25
Non-Home Based
Person Trips Per Household
Trip Generation Model
Atlanta, Georgia

	Household Size					
	1	2	3	4	5	6+
Inc Group 1	0.594	0.981	1.198	1.198	1.198	1.198
Inc Group 2	0.835	0.981	1.527	1.527	1.527	1.527
Inc Group 3	1.107	1.698	1.837	1.837	1.837	1.837
Inc Group 4	1.524	1.738	2.296	2.296	3.543	3.543

Source: Adapted from (10)

It will be noted that several cells above have the same rate. This occurs because the analysis indicated there was no statistical difference between the values (using combined data from 1972 and 1980).

For comparison, the non-home based trip rates from the Denver trip generation model, the Minneapolis-St. Paul travel survey, the Houston travel survey, and the Dallas-Fort Worth travel survey are presented in the following tables. These are not directly comparable due to different stratifications.

Table 26
Non-Home Based
Person Trips Per Households
Trip Generation Model
Denver, Colorado

Income Group	Household Size 1	2	3	4	5+
Low < 10K	0.3	0.9	0.9	1.3	1.3
Medium 10K - < 35K	1.2	1.9	1.9	2.4	2.4
High 35K+	1.8	2.6	2.6	3.1	3.1

Source: Adapted from (11)

Note: Above rates were increased by 15 percent in final model.

Table 27
Non-Home Based
Person Trips Per Household
Travel Survey
Minneapolis-St. Paul, Minnesota
1982

Vehicle Avail.	Household Size 1	2	3	4	5	6+
0	0.283	0.567	1.000	0.667	0.000	0.000
1	1.326	1.839	2.096	2.880	1.783	4.750
2	2.778	2.436	3.062	3.789	3.468	3.700
3+	0.500	3.045	3.110	4.529	5.185	6.167

Source: Adapted from (9)

Table 28
Non-Home Based
Person Trips Per Household
Travel Survey
Minneapolis-St. Paul, Minnesota
1982

Household Size

Inc Quartile	1	2	3	4	5	6+
I	0.65	1.72	1.54	2.46	2.27	0.00
II	1.39	2.03	2.71	3.00	3.29	3.43
III	2.18	2.26	3.17	3.48	3.88	5.27
IV	2.44	2.78	3.35	4.95	4.78	7.19

Source: Adapted from (9)

Table 29
Non-Home Based
Person Trips Per Household
Final Trip Generation Model Rates
Minneapolis-St. Paul, Minnesota

Household Size

Vehicle Avail.	1	2	3	4	5	6+
0	0.283	0.553	0.553	2.000	2.000	2.000
1	1.326	1.839	2.096	2.858	2.858	2.858
2	2.451	2.451	3.062	3.683	3.683	3.683
3+	2.833	2.833	3.110	5.062	5.062	5.062

Source: Adapted from (9)

Note: The selection of auto availability in the final model was a policy decision.

Table 30
Non-Home Based
Person Trips Per Household
Travel Survey
Houston, Texas
1984

Household Size

Income Group	1	2	3	4+
< 10K	1.38	2.11	4.20	2.44
10K - 20K	1.68	2.41	3.54	2.33
20K - 30K	1.67	2.09	2.59	3.21
30K - 40K	2.08	3.09	3.74	3.87
> 40K	2.33	3.03	4.43	3.93

Source: Adapted from (12)

Table 31
Non-Home Based
Person Trips Per Household
Travel Survey
Houston, Texas
1984

Household Size

Auto Avail.	1	2	3	4+
0	1.11	1.11	1.11	1.11
1	1.72	2.20	2.97	1.84
2	2.35	2.77	3.54	3.67
3+	3.57	3.25	4.64	4.13

Source: Adapted from (12)

Table 32
Non-Home Based
Person Trips Per Household
Travel Survey
Dallas-Fort Worth, Texas
1984

	Household Size			
Income Group	1	2	3	4+
< 10K	0.41	0.60	0.33	1.05
10K - 20K	1.11	1.51	2.82	2.46
20K - 30K	1.85	2.14	2.73	3.11
30K - 40K	1.71	2.22	2.94	4.23
> 40K	2.46	3.33	3.47	4.46

Source: Adapted from (12)

Table 33
Non-Home Based
Person Trips Per Household
Travel Survey
Dallas-Fort Worth, Texas
1984

	Household Size			
Auto Avail.	1	2	3	4+
0	0.17	0.35	1.00	0.00
1	1.23	1.39	2.49	2.69
2	2.47	2.11	2.81	3.74
3+	1.00	3.48	3.43	4.23

Source: Adapted from (12)

The following two tables give the NHB trip production rates for Hartford, Connecticut, and San Diego, California. They are not directly comparable but are presented here for purposes of illustrating the range of values.

Table 34
Non-Home Based
Person Trips Per Household
Travel Survey
Hartford, Connecticut
1976-77

Auto Ownership

Income Group	0	1	2 +
< 6,000	0.20	0.70	1.00
6,000 - < 8,000	0.23	0.90	1.30
8,000 - < 10,000	0.24	1.00	1.40
10,000 - < 12,000	0.24	1.10	1.50
12,000 - < 15,000	0.25	1.25	1.65
15,000 - < 25,000	0.25	1.50	1.80
25,000 - 50,000	0.25	1.75	2.25
> 50,000	0.25	1.75	2.25

Source: Adapted from (15)

Table 35
Non-Home Based
Person Trips Per Household
Trip Generation Model
San Diego, California
1986

Household Income	Trips Per Household
< $20,000	2.338
$20,000 - $40,000	3.581
> $40,000	4.756

Source: Adapted from (16)

Note: These rates were used to calculate control total NHB trips only.

Table 36
Non-Home Based
Person Trips Per Zone
Trip Generation Model
San Diego, California
1986

Trip Rate Unit	Center City	Suburban
Households	0.568	1.657
Retail Employment	2.889	3.179
Service Employment	1.500	1.633
Government Employment	1.000	1.598
Other Employment	0.240	0.387

Source: Adapted from (16)

Note: Results from these rates were adjusted to equal the control total estimate.

In summary, the trip rates used in trip production models vary depending upon the model being developed and the stratification used for the model.

ATTRACTIONS

Attraction models were, for the most part, regression equations with different independent variables being used in different areas. This was further complicated by the fact that different trip purposes were used in different urban areas. With trip production rates, the problem of different trip purposes could be overcome by simply adding the trip rates as long as the unit of the trip rate (e.g., households) was the same. The same procedure could not be applied with regression equations where more than one independent variable was used, and the variables changed for different trip purposes. In some cases, different equations were used for different area types. To the extent possible, the following tables present the equations and coefficients used for the trip attraction models used in

different urban areas. The areas presented are not intended to be comprehensive but do cover different areas of the nation as well as different size urban areas.

Table 37
Attraction Models
Atlanta, Georgia

Trip Purpose

Independent Variables	HB Work	HB Shopping	HB Other	HB Grade Sch	HB University	Non HB	Truck
Population		0.2814	0.3105	0.8796		0.2231	0.1028
Households				-1.7728			
Total Employment	1.6813						
Retail Employment		5.8735	9.0274			5.996	0.2656
Commercial + Govt Employment		-0.9724	-1.1917			-0.7044	0.101
Other Employment		-0.6476	0.3561			0.0213	0.2924
Industrial Employment							0.2924
Construction Employment							1.6977
School Enrollment					1.3133		

Source: Adapted from (10)

Note: Blank cells indicate variable was not used for that trip purpose.

Table 38
Attraction Models
Minneapolis-St Paul, Minnesota

Independent Variables

Trip Purpose	Population	Total Employment	Retail Employment
Home Based Work Non-CBD		1.2297	
Home Based Work CBD		0.9397	
Home Based Other Non-CBD	1.3553	0.4364	3.5263
Home Based Other CBD	1.0045	0.3236	2.6136
Non-Home Based Non-CBD	0.6382		5.2699
Non-Home Based CBD	0.6009		4.9625
Truck Non-CBD	0.0317	0.0708	-0.2338
Truck CBD	0.0209	0.0466	-0.1539

Source: Adapted from (9)

Note: Blank cells indicate variable was not used in model. Truck models were those proposed and may not have been used in final model.

Table 39
Attraction Models
San Diego, California

		Trip Purpose				
Area	Independent Variable	Home Based Work	Home Based Shopping	Home Based Other	Non-Home Based Work	Non-Home Based Other
Center City	Households			0.143		0.143
	Total Employment	1.116			0.983	
	Retail Employment		1.778	0.222		1.222
	Service Employment			0.571		1.143
	Government Employment			1.333		0.833
	Other Employment			0.400		0.120
Suburban	Households			0.478		0.374
	Total Employment	1.280			0.779	
	Retail Employment		8.179	1.840		3.765
	Service Employment			2.252		1.933
	Government Employment			8.303		2.136
	Other Employment			0.413		0.438

Source: Adapted from (16)

Note: Blank cells indicate variable was not used in model.

Table 40
Attraction Models
Hartford, Connecticut

	Trip Purpose			
Independent Variable	Home Based Work	Home Based Other	Non-Home Based	External-Local
Population		0.743	0.286	0.175
Total Employment	1.160			
Retail Employment		2.327	0.833	0.671
Non-retail Employment		0.322	0.293	0.386
Shopping Center Area (000's Sq Ft)		13.096	2.766	0.994
Constant			-306.44	

Source: Adapted from (15)

Note: Blank cells indicate variable was not used in model. Non-home based trips were also factored to account for trips made by persons living outside area.

Table 41
Attraction Models
Detroit, Michigan

Trip Purpose

Var. No.	Independent Variable(s)	Home Based Work	Home Based Shop	Home Based Other	Home Based School	Non-Home Based	Truck Trips
1	Population		0.10	0.38		0.19	0.10
2	Total Employment	1.83					
3	Basic Employment						0.30
4	Non-Basic Employment			2.21			
5	Wholesale + Retail Employment		5.02			4.61	0.74
6	Variable 2 - Variable 5		0.04			0.07	
7	Variable 4 - Variable 5						0.03
8	Secondary School Enrollment				0.48		
9	College Enrollment				0.66		
10	Primary School Enrollment				0.35		
11	Constant	6.08	41.96	195.14		161.41	187.03

Source: Adapted from (14)

Note: Blank cells indicate variable was not used in model for that trip purpose.

Table 42
Attraction Models
Portland, Oregon

Independent Variables

Trip Purpose	Households	Total Employment	Retail Employment	School Employment	Students
Home Based Work (Oregon Zones)		1.33			
Home Based Work (Clark County)		1.64			
Home Based Other (Oregon Zones)	1.838		5.309		
Home Based Other (Clark County)	2.325		6.716		
Non-Home Based Work (Oregon Zones)			2.093		
Non-Home Based Work (Clark County)			1.92		
Non-Home Based Other	0.822		3.073		
Home Based College (4 Year)				-1.33	2.78
Home Based College (2 Year)				9.55	

Source: Adapted from (24)

Note: Blank cells indicate variable was not used in model for that trip purpose. Home based school trips were estimated using production model only.

Table 43
Attraction Models
Houston-Galveston, Texas

Independent Variables

Trip Purpose & Application Area	Hseholds	Total Emp	Retail Emp	Hseholds > 1 Person	Non-Univ Ed Emp	Univ Enroll	Office + Other Emp	Indust Emp	Office + Indust Emp	Other Emp
Home Based Work - Sectors/Zones		1.24								
Home Based Shop - Sectors 2-47	0.714		1.278							
Home Based Shop - Zones in Sectors 2-47			3.517							
Home Based Shop - Sector 1			0.299							
Home Based Shop - Zones in Sector 1			0.299							
Home Based School (Elementary)-Sectors				1.332						
Home Based School (Elementary) - Zones					11.661					
Home Based School (Univ) - Sectors & Zones						0.744				
Home Based Other - Sectors	1.959						0.637	0.3		
Home Based Other - Zones	0.9						2.172	0.3		
Non-Home Based - Sector 1 & Zones in Sector 1	0.524	2.593							0.212	2.454
Non-Home Based - Sectors & Zones for Sectors 2-47	0.740	3.659							0.3	3.464

Source: Adapted from (26)

Note: Blank cells indicate variable was not used in model. Also, two-tiered models were used, i.e., one model for sectors and one for zones within the sector to distribute sector attractions.

The following tables contain trip rates used in attraction cross-classification models in Dallas-Fort Worth, Texas, and Denver, Colorado.

Table 44
Home Based Work
Attraction Trip Rates
Denver/Boulder, Colorado

	Trip Rate Per			
Income Group	Low Income Employee	Med Income Employee	High Income Employee	Total Households
Low	0.7	---	---	0.01
Medium	---	1.2	---	0.04
High	---	---	1.6	0.04

Source: Adapted from (11)

Table 45
Home Based Non-Work
Attraction Trip Rates
Denver, Colorado

	Trip Rate Per			
Area Type	Household	Prod/Dist Employee	Retail Employee	Service Employee
CBD	0.2	0.1	1.1	0.9
Fringe	0.2	0.1	2.3	0.9
Urban	0.4	0.2	4.1	1.8
Suburban	0.5	0.4	7.8	3.9
Rural	0.5	0.4	7.8	3.9

Source: Adapted from (11)

Table 46
Home Based Non-Work
Attraction Trip Rates
Boulder, Colorado

	Trip Rate Per			
Area Type	Household	Prod/Dist Employee	Retail Employee	Service Employee
CBD	---	---	---	---
Fringe	0.2	0.1	3.4	0.5
Urban	0.3	0.2	5.7	3.7
Suburban	0.5	0.4	7.8	3.9
Rural	0.5	0.4	7.8	3.9

Source: Adapted from (11)

Table 47
Non-Home Based
Attraction Trip Rates
Denver, Colorado

	Trip Rate Per			
Area Type	Household	Prod/Dist Employee	Retail Employee	Service Employee
CBD	0.1	0.1	0.9	0.6
Fringe	0.1	0.3	2.0	0.7
Urban	0.3	0.3	2.4	0.9
Suburban	0.3	0.5	4.4	1.7
Rural	0.3	0.5	4.4	1.7

Source: Adapted from (11)

Table 48
Non-Home Based
Attraction Trip Rates
Boulder, Colorado

Area Type	Trip Rate Per Household	Prod/Dist Employee	Retail Employee	Service Employee
CBD	---	---	---	---
Fringe	0.1	0.3	3.9	0.4
Urban	0.2	0.3	3.4	1.7
Suburban	0.3	0.5	4.4	1.7
Rural	0.3	0.5	4.4	1.7

Source: Adapted from (11)

Table 49
Home Based Work
Attraction Trip Rates Per Employee
Dallas-Fort Worth, Texas

Employment Type	Income Quartile	Area Type: CBD	Outer Business District	Urban Residential	Suburban Residential	Rural
Basic	One	1.677	1.384	1.413	1.312	1.389
	Two	1.695	1.454	1.300	1.277	1.464
	Three	1.545	1.421	1.300	1.260	1.530
	Four	1.378	1.296	1.300	1.388	1.521
Retail	One	1.500	1.486	1.643	1.400	1.455
	Two	1.500	1.363	1.400	1.400	1.400
	Three	1.467	1.435	1.736	1.634	1.400
	Four	1.500	1.300	1.344	1.358	1.286
Service	One	1.732	1.296	1.424	1.402	1.422
	Two	1.700	1.322	1.430	1.295	1.338
	Three	1.700	1.341	1.365	1.456	1.566
	Four	1.704	1.258	1.265	1.323	1.244

Source: Adapted from (5)

Table 50
Home Based Non-Work
Attraction Trip Rates
Dallas-Fort Worth, Texas

Area Type

Trips Per	CBD	Outer Business District	Urban Residential	Suburban Residential	Rural
Basic Employee	0.453	0.442	0.300	0.200	0.139
Retail Employee	0.811	1.144	8.796	8.060	6.164
Service Employee	1.574	1.005	1.000	1.059	1.812
Household	0.442	0.500	0.511	0.627	0.682

Source: Adapted from (5)

Table 51
Non-Home Based
Attraction Trip Rates
Dallas-Fort Worth, Texas

Area Type

Trips Per	CBD	Outer Business District	Urban Residential	Suburban Residential	Rural
Basic Employee	0.500	0.655	0.858	0.589	0.500
Retail Employee	1.100	1.462	4.272	3.717	2.978
Service Employee	0.600	0.877	1.167	1.243	1.095
Household	0.100	0.104	0.216	0.261	0.235

Source: Adapted from (5)

SUMMARY

In summary, it is very difficult to compare trip rates between different areas. This difficulty stems from the use of different trip generation models which have different stratifications and/or independent variables, etc. Even the comparison of overall trip rates (e.g., average trips per household for an entire area) is sometimes questionable due to the inability to distinguish the basis for computing the average, that is, whether the average was based on a weighted expansion or simply the sample households. It appears that trip rates

are dependent on the type of trip generation model being used, the data on which the rates are based, and the stratification/independent variables selected.

IV. TRIP GENERATION PRACTICE

INTRODUCTION

Trip generation is the process by which estimates of the number of trips being made are developed. This process is accomplished by trip generation models which estimate existing or future trip ends generated by a zone, usually on a daily or peak-period basis, and by trip purpose. A trip end is a trip which either begins or ends in a zone. Two classes of trip ends are estimated, productions and attractions, which are subdivided into two general categories of trips: 1) home based trips for which the origin or destination of the trip is the home and 2) non-home based trips which include all other trips. A production is defined as the home end of a home based trip or the origin of a non-home based trip. An attraction is defined as the non-home end of a home based trip or the destination of a non-home based trip. Defining productions and attractions in this manner allows trip generation models to be structured in such a way that the trip ends can logically be related to the socioeconomic and land-use characteristics of the area. There may also be several different trip purposes for which trip productions and attractions are being estimated. Since each trip has a production zone and an attraction zone, the total productions must equal the total attractions for an urban area.

Trip generation models generally fall into two classes, linear regression models and cross-classification models. Some areas use both depending upon the data available for calibration of the models and whether trip productions or attractions are being estimated. The following sections generally discuss these two classes of models.

LINEAR REGRESSION

Linear regression models have been used in trip generation modeling in different forms and fashions for over 30 years. Models have been developed which relate the number of trips (either productions or attractions) by purpose to a wide range of independent variables. Trip productions are usually related to socioeconomic characteristics of the household such as household size, number of autos owned, household income, age of head of household, number of licensed drivers, etc. Trip attractions are usually related to the

characteristics of the land-use activity or intensity measures such as employment, acres of development, amount of parking, square feet of leasable area, etc. Typically the measures were aggregated by subareas (i.e., zones) and the trips related to the aggregated measures. Statistical methods are used to develop the relationships which produce the "best" results statistically. Up until the mid- to late sixties, regression analysis was widely used. It was during this period that researchers began to question the use of regression relationships in predicting travel behavior. The basis for these questions came from the technique that was employed in fitting the regression equations to the existing data. Typically this was done using data that were aggregated at the zonal level. While this produced what appeared to be statistically good results, research (17,18,19) demonstrated that these results were, in fact, misleading with regard to the prediction of trips at the home end. The general conclusion was that disaggregate household data were a better basis for estimating trips at the home end than aggregate zonal or district data. This eventually led to the most commonly applied modeling procedure used today, and that is cross-classification in estimating trips at the home end. Regression models are still widely used in estimating trips at the non-home end (i.e., attractions).

CROSS-CLASSIFICATION

Cross-classification, also referred to as category analysis, is a disaggregate approach to estimating trips. Using data from home interviews conducted in the 1960's (many of which are now being updated), trip rates (i.e., person or auto-driver trips per household) were cross-classified by certain socioeconomic characteristics found to significantly influence the number, type, and purpose of trips made at the household level. For example, trip rates could be cross-classified by income range and auto ownership. This would provide an estimate of the number of trips per household for households that fell into a certain income range and owned a certain number of autos. Cross-classification tables of trip rates are generally developed for each trip purpose being projected and, until recently, were used primarily for estimating trip productions. With the update of travel data from new travel surveys, new approaches are being developed using cross-classification models for estimating

trip attractions. Some of the reported (20) advantages of this method of estimating trip productions are:

Data are easy to understand
Data can be used efficiently
Trip productions are easily monitored and updated
Process is valid in forecasting as well as base year
Process can be made policy sensitive
Process is applicable at different study levels
Trip rates are more easily transferred between areas
Census data are more readily useable

STATE OF THE PRACTICE

When asked to identify the state of the art in trip generation, it becomes more a matter of distinguishing how trip generation is being accomplished than a matter of determining the state of the art relative to what is or is not "best." The reason for this is simply that urban areas have developed, modified, created, or borrowed trip generation models or procedures that have given them reasonable estimates which are sensitive to the policy issues relevant to their area. The following sections give a general overview and summary of the trip generation models being applied in different areas.

ATLANTA, GEORGIA (10)

The trip generation models in Atlanta, Georgia, were developed using data from a small home interview survey conducted in 1972 and an auto-use survey conducted in 1980. These data were used to develop trip production and trip attraction models for seven trip purposes. The trip purposes were home based work, home based shopping, home based grade school, home based university school, home based other, non-home based, and truck trips. Trip production models were actually developed for all trip purposes except truck which was estimated using an attraction model.

Trip Production Models

The trip production models were developed by relating trips per household to the income of the household and the number of persons residing in the household. The basic model structure was that of a cross-classification model with the trip rates (i.e., trips per household) cross-classified by household income and household size. Four categories of income were used and referred to as groups. Group One was the 20 percent of the households with the lowest income level, Group Two was the next 20 percent of the households by income, Group Three was the next 30 percent by income, and Group Four was the 30 percent of the households with the highest income level. The 1970 and 1980 census data were used to establish the income level for these groupings. The household size groups used were one person, two persons, three persons, etc., up to six or more persons per household. Initially the trip rates were developed separately for each survey. The rates were then compared statistically to determine if there was any significant difference between the rates. In addition, the rates were compared overall with trip rates from other metropolitan areas to determine any major differences. Overall, the trip rates were comparable with other areas. Since there were no significant differences found between rates from the two surveys, the data were combined, and trip rates were developed from the combined data. Additional statistical tests were performed to determine if there were significant differences in the trip rates between cells. The objective was to identify any groupings possible; e.g., instead of using three person and four person households, perhaps they should be combined since the trip rates for each were statistically the same. Some grouping of the data was possible, and the same trip rate was used in those cases.

Trip Attraction Models

The trip attraction models were developed for all seven trip purposes using the data from the 1972 survey. The trip data from the 1972 home interview data were expanded to represent the average day of travel and were aggregated at a district level (instead of zones). Regression analysis was performed on the aggregated data at the district level to develop attraction models which related the district attractions to the land use within the district. The use of linear regression analysis in the development of the models generated a bias

coefficient which was modified prior to applying the model to the zone level. This modification consisted of allocating the bias coefficient effects to the other coefficients in the model.

The attraction model for home based work trips used total employment as the only independent variable. Based on the documentation of the model development, the model was applied at both the district and zonal levels. The home based shopping attraction model used population, retail employment, commercial and government employment, and other employment as independent variables for estimating the total shopping attractions at the district level. These were then allocated to the zones within the district based on the amount of retail employment in each zone; i.e., if a zone contained 10 percent of the districts retail employment, it was allocated 10 percent of the district's shopping attractions. The home based other attraction model used population, retail employment, commercial and government employment, and other employment as independent variables to estimate home based other attractions. The same independent variables were used in the attraction model for estimating non-home based attractions. The non-home based attraction model was the basis for estimating both productions and attractions at the district level with the total being forced to equal the total non-home based production generated from the non-home based production model. The home based grade school attraction model used population and households as independent variables while the home based university school attraction model used university enrollment as the independent variable. The truck attraction model used population, retail employment, commercial and government employment, industrial employment, construction employment, and other employment as independent variables. The truck attraction model was also used for estimating the truck productions. After modifying the bias coefficient, the attraction models were felt to yield reasonable results for forecasting at the zonal level with the exception of the home based shopping model. The home based shopping model was applied at the district level and the district attractions allocated to the zones in the district based on retail employment. While the models gave statistically adequate estimates of attractions at the district level, it should be noted that in several of the models the coefficient for certain independent variables was opposite in terms of sign relative to what one would have expected. For example, the home

based grade school model coefficients were positive for population and negative for households. The non-home based model coefficients were positive for population, positive for retail employment, negative for commercial and government employment, and positive for other employment. This could raise questions concerning possible linear relationships between independent variables in some of the models even though explanations were given for these apparent illogical results.

Balancing

The models as applied in Atlanta had a somewhat different basis for balancing the total productions and attractions. Historically, most travel demand modeling trip generation models have used productions as the controlling estimate in terms of total trips within the study area. This was the case in Atlanta for home based shopping, home based other, home based grade school, and non-home based trips. The total attractions were forced to equal the total productions for those trip purposes. This was not the case for home based work and home based university trips. For those two trip purposes, the productions were forced to equal the total attractions. This was felt to be applicable based on the appropriateness of the models.

HARTFORD, CONNECTICUT (15)

Travel forecasting in Hartford is accomplished by the Capitol Region Council of Governments. The following descriptions of the trip generation models were based on the documentation of the development of the models using the results of a statewide travel household travel survey conducted in 1975-76.

Productions

Trip production models were developed for three trip purposes but actual estimates of trip productions and attractions were done for six types of trips. The trip purposes were home based work (HBW), home based other (HBO), and non-home based (NHB). Productions and attractions were also estimated for truck trips, internal-external trips and external-external (through) trips even though no formal model was developed. The basic

trip production model used in Hartford was a cross-classification model. Trip rates (person trips per household) were cross-classified by auto ownership and income. Three categories of auto ownership were used; 0 cars, 1 car, and 2 or more cars. Eight categories of income were used: < $6,000, $6,000 to $7,999, $8,000 to $9,999, $10,000 to $11,999, $12,000 to $14,999, $15,000 to $24,999, $25,000 to $50,000, and > $50,000. Production trip rates were developed using data from the 1975-76 statewide household travel survey done in Connecticut. Trip rates were plotted and a series of curves developed relating person trips per household for each car ownership group to household income. Trip rates stratified by car ownership and income were taken from the plotted relationships. It was found in the analysis that no distinction could be made between trip rates and income for HBO trips. The trip rates for HBO trips were stratified only by auto ownership as a result. The survey results for this category of trips were felt to be significantly under-reported. An adjustment for the HBO trip rates was subsequently developed using national trip rates to estimate the regional total of internal trips. The difference between that estimate and the one obtained from applying the survey trip rates (for all trip purposes) was assumed to be due to the under-reporting of HBO trips. The difference was added to the estimated HBO trips obtained from applying the survey trip rates and an adjustment factor computed to apply to the survey trip rates. The adjustment factor was 1.19.

In order to apply the cross-classification models it was necessary to develop a method of estimating the households within each category of the cross-classification matrix. The projected income distribution was derived by expanding the 1970 income distribution by the ratio of projected households to 1970 households. These were then adjusted to reflect real income growth, and a mean income was calculated for each of the eight groups used in the model. Relationships had previously been developed which plotted the percentage of households with 0 cars, 1 car, and 2 or more cars by income. These were then used to estimate the percentage of households within each zone with 0 cars, 1 car, and 2 or more cars based on the income of the households within the zone. It was not clear as to whether the households in the zone had been previously estimated for each income group or if the average income for households within the zone was used for estimating households by auto ownership.

Attractions

Linear regression was the method chosen for the development of the attraction models. Reasonable models were subsequently developed for home based other (HBO) and non-home based (NHB) trips which related the trip attractions to four independent variables: population, retail employment, non-retail employment, and shopping center area in thousands of square feet. No constant was used in the equation for HBO trips but a constant was used in the equation for NHB trips. While an attempt was made to develop regression equations for home based work (HBW) and for truck trips, the results were not felt to be acceptable. A trip rate for HBW attractions was developed by dividing the regional HBW attractions by the regional employment (yielded a rate of 1.16) which was felt to be reasonable when compared to the 1970 census data on journey to work. Truck productions and attractions were developed from the Connecticut Interregional Planning survey. External-internal attractions were also estimated using a regression equation with four independent variables: population, retail employment, non-retail employment, and shopping center area in thousands of square feet (no constant). Productions for external-internal trips were estimated using 1975 traffic counts on the study area cordon line. The counts on the expressways and other facilities crossing the cordon line were reduced by 12 percent and 5 percent respectively to account for truck travel. A carpool factor of 1.55 was applied to convert vehicle trips to person trips. Future projections were based on growth factors estimated from projections of population for areas outside the study area. Through trips (external-external) were estimated from a 1975 roadside origin-destination survey conducted by the Connecticut Department of Transportation. Future through trips were estimated using growth factors developed by extrapolating average daily trends.

SAN FRANCISCO, CALIFORNIA (21,22,23)

Travel demand forecasting in San Francisco is accomplished by the Metropolitan Transportation Commission. The following descriptions of their trip generation models are based on documentation of the update of their models using the results of a travel survey conducted in 1980-81.

Productions

Trip production models were developed and applied for four trip purposes: home based work, home based shopping, home based social recreation, and non-home based. Some of these trip purposes had additional stratifications with individual models for each stratification. The home based work (HBW) trip production model was stratified into two models, one for the primary worker in the household and one for the secondary worker in the household. Both models were linear regression models which were calibrated using disaggregated data from the travel survey. HBW trips for the primary worker were estimated based on the household income, household size, and total employment density (employees per acre for zone). HBW trips for the secondary worker were estimated based on the household income and household size. The constants for both equations were not constrained to zero.

Home based shopping (HBS) trips were defined to include trips for personal business, medical, dental, shopping, serve passenger, change travel mode, and other. The trip production models for this trip purpose were stratified into four distinct relationships: one for non-working households with residence in San Francisco, one for working households with residence in San Francisco, one for non-working households with residence outside of San Francisco, and one for working households with residence outside of San Francisco. All four models (i.e., equations) were linear regressions with the same independent variables: dummy variable representing 0 auto ownership, household income (1979 dollars), and household size. The dependent variable was HBS trips per household. The only model without a constant was that for working households with residence outside of San Francisco. The models were calibrated using disaggregated data from the travel survey.

Home based social-recreation (HBSR) trips included trips to visit, eat meals, and for recreation. Only one model was developed for this trip purpose. It was a linear regression with HBSR trips per household as the dependent variable and household size, income (1979 dollars), service employment density at zone of residence (service employment/total acres), and a dummy variable representing 0 auto ownership as independent variables. The model was calibrated using disaggregated data from the travel survey.

Non-home based (NHB) trips were defined as trips that did not begin or end in the zone of residence. The NHB trip production model was stratified into two models, both with a linear regression form. One model was developed for zones which fell within an area referred to as Super District 1 and one was developed for zones outside the Super District 1. Both models estimate the zonal number of non-home based person trip productions (dependent variable). The model for zones within the Super District 1 used other employment, retail trade employment, service employment, and total number of households as the independent variables. The model for zones outside Super District 1 used the same independent variables and included manufacturing employment as an additional independent variable. The models were calibrated using aggregated zonal data.

Attractions

Trip attraction models were developed and applied for the same four trip purposes as the trip production models. HBW trip attraction models were developed for the primary worker and the secondary worker in a household. While both linear regression and trip rate models were analyzed using aggregate zonal data, the final models selected were trip rate models which simply used an average HBW attraction rate per job to estimate the HBW attractions. Different rates were used for the primary worker and the secondary worker. The trip rates were developed at the Super District level using expanded data from the travel survey.

The HBS trip attraction model was developed using aggregate zonal data with the zonal attractions being estimated from expanding the travel survey data. Only one model was developed for HBS attractions. It was a linear regression model with the dependent variable being the aggregate zonal trip attractions and the independent variable those employment sectors which had the closest association with shopping attractions, i.e., retail employment and service employment. The HBS trip attraction model was stratified into two models, one for zones within the area referred to as Super District 1 and one for zones outside that area. Both had the same form but different values for the coefficients. The constants were constrained to zero.

The HBSR trip attraction model was developed using aggregate zonal data with the zonal attractions being estimated from expanding the travel survey data. Only one model was developed for HBSR attractions. It was a linear regression model with the dependent variable being the aggregate zonal trip attractions; and the independent variables were retail employment, service employment, total population, and zonal vacant acres. The model was stratified into two models, one for those zones within San Francisco County and one for those outside of San Francisco County. Both models (i.e., equations) had the same form but different values for the coefficients. The constants were constrained to zero in both models.

The NHB trip attraction model was developed using aggregate zonal data with the zonal attractions being estimated from expanding the travel survey data. The NHB trip attraction model was stratified into two models, one for zones within Super District 1 and one for zones outside that area. The models were linear regression models with the dependent variable in both cases being the zonal NHB person trip attractions. The independent variables for the model for zones within Super District 1 were other employment, retail employment, service employment, and total zonal households. The independent variables for the model for zones outside Super District 1 were the same except manufacturing employment was included as an additional independent variable.

PORTLAND, OREGON (24)

Travel demand modeling in Portland, Oregon, is accomplished by the Metropolitan Service District. The trip generation models were developed and calibrated using the results of a travel survey conducted in 1985. Trip productions and attractions are estimated for six trip purposes: home-work, home-school, home-college (any post-high school training), home-other, non-home with a work trip end, and non-home with no work trip end. The zonal input data for the trip generation models consist of households cross-classified by size (1, 2, 3, 4 or more), income (less than $15K, $15K to $25K, $25K to $35K, and more than $35K), and age of head of household (under 25, 25 to 55, 55 to 65, and over 65). These data are input into a workers per household model, a cars per household model (this model also uses the total employment within 30 minutes travel time by transit), and a children per

household model. These provide some of the input to the trip generation models described in the following paragraphs.

Productions

Trip production models were developed for each of the trip purposes listed in the preceding paragraph. The type of model and variables used in the model varied. The home based work trip production cross-classification model stratified person trips per household by household size (1, 2, 3, 4, or more) and workers per household (1, 2, 3, or more). The home based school (non-college) trip production model was a cross-classification model stratified person trips per household by children per household and household size. The home based college trip production model was also a cross-classification model. It cross-classified person trips per household by age of head of household and household size. Home based other (non-school) trip productions were estimated using a model which cross-classified person trips per household by workers per household and household size for four distinct stratifications: 0 car households, households with fewer cars than workers, households with cars equal to workers, and households with more cars than workers. The non-home based with a work end trip production model was an aggregate multiple linear regression model calibrated on aggregated data for 25 districts. The independent variable for the model was total zonal employment. The non-home based with no work trip end trip production model was also an aggregate multiple linear regression model calibrated on aggregated data for 25 districts. The independent variables were retail employment and households.

Attractions

Trip attraction models were also developed for each of the six trip purposes. The home based work trip attraction model was a linear regression model with total employment as the only independent variable. It was calibrated with aggregated data from 25 districts. Different coefficients were calibrated for use for Oregon zones versus Clark County zones. There was not a distinct model for estimating home based school attractions. The attractions were set equal to the productions as output from the home based school

production model with the destination choice calibrated to trip length. Attractions for home based college trips were estimated using trip rates derived from Institute of Transportation Engineering trip rates. These rates were modified by allowing for the home based work (employee based) attractions and an assumed auto occupancy. Attractions for four-year institutions were estimated base on the number of students and number of employees while attractions for two-year institutions were estimated based on employees. Home based other (non-school) attractions were estimated using a regression model with retail employment and number of households as independent variables. Different coefficients were calculated for zones within Oregon versus zones within Clark County. Non-home based with work end trip attractions were based on an aggregate multiple linear regression model calibrated at the 25 district levels. The independent variable was retail employment with different coefficients for Oregon versus Clark County. There was not a distinct attraction model for non-home based with no work end trips. These were set equal to the productions from the non-home based with no work trip production model.

Balancing

In all cases, the total trip attractions for each trip purpose were set equal to the total trip productions.

SAN DIEGO, CALIFORNIA (16)

Travel demand forecasting in San Diego is done by the San Diego Association of Governments. The following descriptions of their trip generation models is based on documentation of the update of their models using the results of a 1986 travel survey.

Productions

Trip production models were developed and applied for five trip purposes: home based work (referred to as home work), home based shop, home based other, other work, and other-other. Based on the definitions, other work and other-other trips are the same as non-home based work and non-home based other trip purposes. The production models also estimate trip productions for visitors and tourists. The trip production model is a cross-

classification model which has person trips per household rates stratified by household income for each trip purpose. Productions are estimated for visitors using trips per hotel employee for each trip purpose. The trip rates used in the model are for linked trips. The productions for work other and other-other (typically called non-home based) are estimated by applying the production person trip rates to households stratified by income. These are used to develop control totals for the region, not zonal estimates. The model uses three income ranges: under $20,000, $20,000 to $40,000, and $40,000 and over. Households are stratified by these three income groups at the zone level and input to the model with the other zonal data. The allocation of the non-home based productions is done by estimating non-home based productions using non-home based person trip rates for households, retail employment, service employment, government employment, and other employment with the rates being stratified by area. Two areas are defined: center city and suburban. These zonal estimates are factored to force the total to equal the total estimated for the region.

Attractions

Trip attraction models were developed and applied for the same trip purposes as the production models. Attractions are estimated by applying trip rates to select independent variables based on the trip purpose and area in which the zone is located. While not defined as regression type models, the function of the models is the same with different rates used for each of the two defined areas, center city and suburban. Home to work attractions were estimated based on total employment within the zone. For example, the home to work trip rate for the center city was 1.116 while that for the suburban was 1.28. Home to shop attractions were estimated based on retail employment in the zone. Home to other attractions used households, retail employment, service employment, government employment, and other employment as independent variables with distinct trip rates for each (rates were different for each area, also). Other to work attractions used total employment as the independent variable while other to other attractions used households, retail employment, service employment, government employment, and other employment as independent variables.

Unique Generators

Some zones were designated unique generators because they contain land uses which generated trips atypically from the rest of the region. Trip productions and attractions were input directly for these zones. Estimates were based on data obtained from traffic and auto occupancy counts. The file containing the unique generators also contains the external to internal and external to external auto and transit productions and attractions (in person trips) for the purpose of balancing productions and attractions.

Balancing

The trip productions are used as the control in the balancing of productions and attractions. The total attractions are forced to equal the total productions for each trip purpose. The productions and attractions for the unique generators and the zones within the central business district are removed from the totals prior to calculating the adjustment factors and adjusting the attractions for each zone. These are added in after the zonal attractions are factored.

DENVER, COLORADO (11)

Travel demand forecasting in Denver is conducted by the Denver Regional Council of Governments. The following descriptions of their trip generation models are based on documentation of their model updates using the results of a 1985 travel survey.

Productions

Trip production models were developed for three trip purposes: home based work, home based non-work, and non-home based. Trip productions were also estimated for truck trips and internal-external trips. Truck productions were set equal to truck attractions at the zonal level and, therefore, estimated by the attraction model. Internal-external trips are estimated by another agency exogenously to the trip generation modeling process. The basic model used is a cross-classification model with person trips per household stratified by income (low, medium, and high) and household size (1, 2, 3, 4, and 5 or more). The income groups were set such that 15 percent of the households with the lowest income would fall

in the low group, the next 45 percent of the households would comprise the medium group, and the last 40 percent of the households with the highest incomes would comprise the high income group. These groups were selected based on an analysis of the trip rates from the 1985 travel survey with regard to statistically significant differences in the trip rates. That decision was constrained by an early decision to use only three income groups. They did, however, attempt to determine the points at which the trip rates changed between income groups. After developing the trip rates stratified by income group and household size, an analysis was performed to determine if there was any statistically significant difference between trip rates within adjoining cells (both row and column) for each trip purpose. That analysis indicated no difference between three- and four-person households for home based work trips; no difference between low and medium income for home based non-work trips; and, for non-home based trips, no difference was found between two- and three-person households and between four- and five-plus-person households. Where no difference was found, the trip rates were set equal. An analysis of variance of household trip rates was also done to determine the significance of the interaction effects between income group and household size. The interaction effect was significant for home based non-work trips and not significant for home based work and non-home based trips. Subsequently, the home based work and non-home based models were calibrated with regression by dummy variables without interaction variables. Home based non-work was calibrated using simple cross-classification. Regional validation results using vehicle miles traveled required that the trip rates for home based non-work be increased by 10 percent and the trip rates for non-home based trips be increased by 15 percent. The observation was also made in the course of evaluating the modeled versus the observed that a "pseudo-life cycle" variable would improve the model results for home based work trips, but it was not included in the model due to the difficulty to project such a variable in the future. The application of the trip rates at the zonal level was to the number of households estimated in each stratification cell formed by the cross-classification of the independent variables.

For use in future forecasts, it was noted that the percent of households within each income group would not change even though real income had historically been increasing. This meant that the percentage of households would remain constant in each income group

regardless of any changes in real income. Since it was acknowledged that as income increases the propensity to travel increases, a method was developed to project the change in trip rates for each trip purpose given the change in income over time. This produced different trip rates for their projections into the future.

While the trip production models would normally define the regional control totals of trips, the program does have the ability for different regional control totals to be input and then for the models to allocate the trip productions to the zone level. In either case, the production model for non-home based trips estimates the total regional non-home based trips. The allocation of those trips to each zone is done by the attraction model.

Attractions

Prior to actually running the model that computes trip attractions, another model is run which estimates the amount of employment within each zone by area type (CBD, fringe, urban, suburban, and rural) and income group using the same groups as used in the trip production model. The basis for the model was data from the 1980 Census Urban Transportation Planning Package (UTPP). The results are input to the attraction trip models along with employment by major group (production/distribution, retail, and service), households, and area type.

The trip attraction model is a cross-classification model stratifying trip rates for various independent variables. The trip rates were developed using the 1985 travel survey where trip attractions were summarized by purpose, land use and area type and divided by the appropriate number of households or number of employees to develop trip rates. The home based work model uses trip rates per employee (employees are stratified by income with a rate for each) by income group and trip rates per household. For example, the home based work attraction "trips per low income employee" rates for the low income group was 0.7 while the "trips per household" rate for the low income group was 0.01. The "trips per low income employee" rate for the medium income group was 0 since there could not be any low income employees in the medium income group, while the "trips per household" in the medium income group was 0.04. The home based non-work and non-home based both used trip rates per household and trip rates per employee by major employment group. The

trip rates for the non-work models are stratified for each of the five area types as well. In addition, separate models (i.e., trip rates) were developed for the Boulder Valley area and the Denver Metropolitan area. The non-home based trip attractions were scaled to the regional total non-home based productions and the zonal productions set equal to the scaled zonal attractions. Attraction trip rates for truck trips and internal-external trips were based on the 1971 Travel Model calibration. The rates were simply per household and per employee with no stratification possible. The internal-external attractions were scaled to match the estimated external-internal productions at the external stations.

Special Generators

Special generators were defined based on the projected impact the development could have in terms of level of service changes to transportation facilities. Prospective candidate special generators were identified, and then the difference in estimated trip ends was calculated between the value estimated using the regional model trip rates and that calculated using secondary sources for the particular type of development. If found to exceed the prescribed criteria, the trip ends were divided into productions and attractions using the regional model productions and attractions as a guide for proportionately distributing the trips for all trip purposes except home based work. These were then added to the zonal productions and attractions prior to balancing.

Balancing

In all cases, the trip attractions were scaled to equal the total trip productions. The exception to the procedure used in most areas was that the productions and attractions for special generators were included in the zonal productions and attractions prior to scaling.

MINNEAPOLIS-ST. PAUL, MINNESOTA (9)

Travel demand forecasting in the Minneapolis-St. Paul area is accomplished by the Metropolitan Council. The following descriptions of their trip generation models are based on documentation of their model updates using the results of a 1982 travel behavior inventory which was analyzed with a similar survey done in 1970.

Productions

Using data from the 1970 and 1982 travel behavior inventories, trip production models were evaluated and developed for three trip purposes: home based work, home based other, and non-home based. Home based work (HBW) trips were defined as all trips made for the purpose of work which begin or end at the traveler's home. Home based other (HBO) trips were defined as any trip made with one end at home except for the purpose of work. Non-home based (NHB) trips were any trips which neither began nor ended at home. The evaluation done to develop the trip production models was based on the recommendation that the basic model structure be a cross-classification model with person trips per household stratified by two independent variables. The evaluation included consideration of income (grouped by income quartile), auto availability, and household size as potential independent variables. Using data from 1970 and 1982, person trips per household were stratified by income quartile and household size and also by auto availability and household size for each of the two years that survey data were available. Trip rates were compared to determine the change in travel patterns and to determine any statistically significant differences between trip rates in individual cells and to identify which of the two different stratifications gave better results. While no significant difference could be identified between the two stratifications analyzed, the final model recommended was the cross-classification of person trips per household by auto availability and household size using the trip rates from the 1982 survey. It was found that there was a significant change in trip rates between 1970 and 1982, and it was noted that some mean should be sought to consider those changes in forecasting future travel.

The application of the model also required the disaggregation of households at the zone level into estimates of households within each cell of the cross-classification model, e.g., the number of one-person households in zone "x" that have 0 cars available. Models were developed that, based on the average household size for a zone, would estimate the percentage of households by household size in the zone and, based on the average vehicles per household, would estimate the percentage of households with 0, 1, 2, or 3+ cars available. Using these estimates, an iterative marginal weighting routine could be employed to estimate the number of households within each cell of the cross-classification model.

Attractions

The attraction models for the Minneapolis-St. Paul area were developed in a similar fashion as the trip production models in that data from the 1970 and 1982 surveys were used. The models were linear regression calibrated on a district level (108 districts). Regression equations were developed for 1970 and 1982 (adjusted to 1980) using multiple sets of independent variables with an analysis of each to determine the most reasonable equation which gave the best results. It was found that, statistically, there was a significant difference in the regression results from 1970 and from 1982.

It was recommended that the equations developed using the 1982 data be used. Two equations were developed for each trip purpose (HBW, HBO, NHB), one for non-CBD attractions, and one for CBD attractions. A linear regression equation was also developed for truck attractions and productions with the zonal truck productions being set equal to the zonal truck attractions. The equations for non-CBD and CBD attractions used the same independent variables but had different values for the coefficients. The constants in all of the equations were constrained to zero. HBW trip attractions used total employment as the independent variable. HBO trip attractions used total employment, total population, and retail employment as independent variables. NHB trip attractions used total population and retail employment as independent variables. Truck trips were estimated using total employment, total population, and retail employment as independent variables.

In the development of the attraction models, the independent variables analyzed for possible inclusion in the models were the district's total population; total employment; total number of households; total retail employment; total employment in services; financial, insurance, and real estate employment; total local government employment; total federal and state government employment; total manufacturing and wholesale employment; total transportation, communications and utilities employment; total of all other employment; total school enrollment (primary, secondary, and college); total school population residing in a district; a dummy indicator variable for the CBD (1 if district is part of CBD and 0 otherwise); total employment of an office nature in a district; total industrial employment; and the total government employment. Variables were initially screened with six to eight being selected for analysis based on their correlation with the dependent variable, the

coefficient of determination of an equation with that single variable, and the reasonableness of the variable to being a factor in determining trips for a particular purpose.

It should also be noted that both production and attraction models were developed and calibrated for peak period trips (same model structure as for 24 hour trips). The final attraction model also included optional NHB attraction models which used total employment, total population, and retail employment as independent variables which could be specified by the user in running the models.

Balancing

The final trip generation model allowed the user an option in selecting the control total to be used in balancing productions and attractions. The control totals could be normalized to productions, to attractions, or to an external value directly input by the user. If not specified, the program would normalize to productions for HBW and HBO and to attractions for NHB. The user could also specify final productions and attractions for specific zones, and the program would re-balance the productions and attractions holding the user-specified values constant.

DETROIT, MICHIGAN (14)

Travel demand forecasting for the Detroit, Michigan, area is done by the Southeast Michigan Council of Governments. The following descriptions of their trip generation models are based on documentation of an update of the Southeast Michigan Travel Forecasting Process.

Productions

Trip production models were developed for five trip purposes: home based work (HBW), home based shopping (HBS), home based school (HBSC), home based other (HBO), and non-home based (NHB). Truck trips were estimated using attraction models. HBW trip productions were estimated using a regression model which predicted the number of workers in a zone and then applied a trip rate to those workers to estimate the HBW productions.

Seven independent variables were used to predict the number of workers in each zone: number of households in Income Quintiles Two through Five (four variables), number of households with no children and head of household is less than 65 years of age, number of households with children and head of household is less than 65 years of age, and total population of zone. Home based school (HBSC) trip productions were estimated using a cross-classification model. Trip rates in terms of trips per households were stratified by two life cycle variables (households without children 6 to 17 years old and households with children 6 to 17 years old) and two household size variables (one to three persons per household and four plus persons per household). These trip rates were applied to the estimated number of households having the appropriate characteristics and the results summed to get the total HBSC productions for a zone. Home based shopping (HBS) and home based other (HBO) trip productions were also estimated using a cross-classification model.

Trip rates in terms of person trips per household were stratified by household size (1, 2, 3, 4, and 5+) and auto availability (0, 1, 2, 3+). Using the distribution of households by household size and by income pentile (for each zone), an iterative marginal weighting routine was used to estimate the number of Size One households within each income quintile, Size Two households within each income pentile, etc. Income pentile may be defined as an income range which contains 20 percent of the households. For example, the low income pentile reflects the income range of the 20 percent of the households making the lowest incomes in the region. The low-middle income pentile reflects the next income range (above low) of the 20 percent of the households with the next lowest incomes in the region. Using relationships developed from the 1977 census annual housing survey and given the household size (1, 2, or 3+), the percentage of households with 0, 1, 2, or 3+ autos available can be estimated for each income pentile.

Two sets of relationships were used, one for zones in Detroit and one for zones not in Detroit. This model allows for the estimation of households stratified by household size and auto availability for each zone. The appropriate trip rates are applied to those estimates with the results summed to arrive at estimates of HBS and HBO trip productions for each zone. Note that different trip rates were used for each purpose.

Attractions

The attraction models used in Detroit were all regression models. Each trip purpose used a different model, and an additional model estimating truck attractions was also developed and applied.

The HBW trip attraction model used one independent variable, total employment, with the value of the constant in the equation being zero. HBS trip attractions used three independent variables: wholesale employment plus retail employment, total employment minus the sum of wholesale employment and retail employment, and population. The value of the constant in the equation was not zero. The attraction model for HBO trips used two independent variables, non-basic employment and population. The constant in the equation was not zero. School trip attractions were estimated using a regression model with three independent variables: secondary school enrollment, college enrollment, and primary school enrollment. The value of the constant in that equation was zero.

The trip attraction model for NHB trips used three independent variables: wholesale employment plus retail employment, total employment minus wholesale and retail employment, and population. The constant in the equation was not zero. Truck attractions were also estimated using a regression model with four independent variables: basic employment, wholesale employment plus retail employment, non-basic employment minus wholesale employment and retail employment, and population. Non-basic employment included wholesale, retail, service, public administration, finance, insurance, and real estate employment. Basic employment included manufacturing, natural resources, transportation, communications, and utility employment. Total employment included all employment except construction employment.

Balancing

The balancing of productions and attractions was accomplished during the trip distribution phase of the modeling process. Trip distribution was accomplished using a gravity model which adjusts the attractions after each iteration until total attractions equaled total productions for each trip purpose. The exception to this was school trips where the

total productions for the region and the total attractions for the region were averaged and the zonal productions and attractions normalized to the average for the region.

Special Generators

Trip attractions for special generators were estimated manually and input directly to the trip generation modeling program. Shopping centers and hospitals were identified as special generators, and trip attractions were estimated for them using secondary sources for trip rates, e.g., Institute of Transportation Engineers Trip Generation Report. These input attractions were input to the modeling process and replaced the estimates generated by the regression models.

General Note

It is of interest in reviewing the documentation of Detroit's trip generation models that an analysis was done which compared the results of trip rates and models based on the travel survey done in 1965 with that done in 1980. The results of that analysis was that the 1965 trip rates were used for all trip purposes except for school trips. The same result was found in the analysis of the attraction trip models.

SEATTLE, WASHINGTON (25)

Trip generation and travel demand modeling in Seattle, Washington, is accomplished by the Puget Sound Council of Governments. The following descriptions of their trip generation models are based on an analysis of the FORTRAN program used to develop their zonal productions and attractions.

Productions

The trip generation model employed by the Puget Sound Council of Governments develops zonal productions and attractions for six trip purposes: home based work (HBW), home based other (HBO), home based university (HBU), home based school (HBS), non-home based (NHB), and commercial trips (C). The trip production model as applied computes only trip productions for four of the trip purposes: HBW, HBO, HBU, and HBS.

HBW trip productions are estimated using a regression type model with six independent variables: zonal population, total zonal dwelling units, number of zonal dwelling units in the low income quartile, number of zonal dwelling units in the low-medium income quartile, number of zonal dwelling units in the medium-upper income quartile, and number of zonal dwelling units in the upper income quartile. While the same independent variables were used, different coefficients were used for zones within seven different areas. The basis for these areas was not determined. HBO trip productions were estimated using the same independent variables with different coefficients for zones within six different areas. HBU trip productions were estimated using total dwelling units as the only independent variable. HBS productions were estimated using two independent variables, non-group quarter population and total dwelling units in the zone. None of the trip production equations had a constant value included.

Attractions

The attraction models used in Seattle were also of the regression type. Home based work (HBW) attractions were estimated with five independent variables:

1. retail employment in the zone;
2. combined total of finance, insurance, real estate and government employment in the zone;
3. combined total of manufacturing, wholesale, transportation, communications, and utility employment in the zone;
4. total education employment in the zone; and
5. total dwelling units in the zone.

Home based university (HBU) attractions were estimated using a regression model with only one independent variable, student enrollment. Home based school (HBS) attractions were estimated using a regression model with only one independent variable, educational employment. The regression type cross-classification models were used to estimate home based other (HBO) and non-home based (NHB) attractions. In terms of explanation, it is best to consider them as simple regression models with six independent variables:

1. retail employment;
2. combined finance, insurance, real estate, and government employment;
3. combined manufacturing, wholesale, transportation, communications, and utility employment;
4. educational employment;
5. number of single family residences; and
6. number of multi-family residences.

What gives the model the appearance of a cross-classification model is that the coefficients for the first four variables vary depending upon the area density type of the zone (three area types are used in the model). The coefficients for the last two independent variables, single and multi-family residences, were the same for all zones. Commercial attractions were estimated based on the total NHB attractions, i.e., equal to 0.378 times the number of NHB attractions. Non-home based and commercial productions were set equal to the NHB and commercial attractions for each zone.

SUMMARY

As can be noted from the previous discussions, there is considerable diversity between urban areas in the trip generation models being used, trip purposes being modeled, and various assumptions in the process. The previous discussions did not include all of the urban areas reviewed. Some were excluded due to incomplete information being available on the models. While there was considerable diversity, there were also some similarities between the urban areas. The following were considered to be the major issues of similarity and consistency in trip generation between the areas:

1. Specific models were developed and used for each specific trip purpose;
2. The application of the models was accomplished using disaggregated data at the zone level;
3. The majority of the urban areas reviewed used cross-classification models for estimating trip productions; and
4. The majority of the urban areas reviewed used regression models for estimating trip attractions.

V. TRIP GENERATION - TEXAS PRACTICE

Within the overall process of travel demand modeling, the trip generation phase has historically been accomplished by the TxDOT for urbanized areas in the state of Texas. The estimation of trips being generated within a specified area has normally involved the use of four computerized trip generation programs titled TRIPCAL1, TRIPCAL2, TRIPCAL3, and TRIPCAL4. TRIPCAL1 and TRIPCAL2 were programs written by the TxDOT for use in processing the data obtained from the origin-destination household travel surveys conducted during the 1960's and early 1970's. The principal programs used for most areas since the mid-seventies are TRIPCAL3 and TRIPCAL4. During the 1980's two major urban areas in the state, Dallas-Fort Worth and Houston-Galveston, conducted major travel surveys with the specific purpose of updating their local travel demand models. A third area, San Antonio, also initiated a major travel survey in 1990. These areas have, as a result, developed or initiated efforts to develop new updated trip generation models. The following sections provide abbreviated overviews and summaries of these trip generation models.

TRIPCAL3 (1)

TRIPCAL3 is a program developed and written by the Texas Transportation Institute for the TxDOT. The purpose of the program is to estimate trip attractions for each serial zone within the area under study. Trip attractions are estimated for four different trip purposes: home based work, home based non-work, non-home based, and truck-taxi. The program allows the user the flexibility to input land use in terms of acres or employment or a combination of both, (acres for some zones and employment for others). The ability to input estimates of trip productions and attractions for select activity centers within particular serial zones, usually referred to as special generators, is also provided.

The theoretical basis for TRIPCAL3 is that the number of trips being attracted to a particular zone are directly related to the type and extent of activity within the zone as measured by employment or acres of land use. Three categories of employment or land use are used: commercial, industrial and other. Using data from either previous origin-

destination surveys or other metropolitan areas, trip attraction rates are developed on the basis of trips per employee or trips per acre of land use. These rates are developed for four different trip purposes, home based work, home based non-work, non-home based, and truck-taxi, and for different area types (referred to as generation areas). These areas can be categorized based on a measure of population and employment density or on local knowledge. Typical categories used are central business district, outer business district, urban residential, suburban residential, and rural. TRIPCAL3 allows the user the flexibility to use from one to 100 generation areas.

The basic input data to TRIPCAL3 consist of the following items:

1. Land-use data in terms of acres, dwelling units, and/or employment for each zone. This information must be provided for residential units, commercial units, industrial units, and other units.
2. Trip attraction rates for each of four trip purposes: home based work, home based non-work, non-home based and truck-taxi. This information must be provided for residential units, commercial units, industrial units, and other units.
3. Estimated trip productions and attractions for any special generators and the zone number the special generator lies within. The user is also allowed to input additional non-home based trips.
4. Table of equals which aggregates serial zones to larger areas referred to as "generator areas." These areas are the basis by which the trip attraction rates were developed. The rates are applied to the zones within these areas.
5. A designation as to whether the trip attractions being generated are for auto-driver trips or person trips.

The operation of TRIPCAL3 is fairly straightforward. Land-use information for each serial zone is first input to the program. The trip attraction rates for residential units, commercial units, industrial units, and other units for each generation area are then input to the program. This is also the point at which a designation is made as to whether auto-driver attractions or person trip attractions are being calculated. It should be noted that for each type of land use, four attraction rates are input, one for each trip purpose (home based

work, home based non-work, non-home based and truck-taxi). The program next inputs the table of equals information to identify which serial zones lie within each generation area. This allows the program to determine which trip attraction rates should be used for each zone. The final data input to the program is the special generator information. This consists of the estimated trip productions and attractions by trip purpose and any additional add-on non-home based trips for each zone which has special generators located within it. These are typically computed by hand and input directly to TRIPCAL3. The program then proceeds to calculate the total estimated trip attractions by trip purpose for each serial zone by multiplying the appropriate trip attraction rate by the number of units within the zone. For example, 10 home based work trip attractions per acre of commercial units times five acres of commercial units equals 50 home based work trip attractions for that zone. If that zone had one or more special generators within it, the program would add in the estimated home based work trip attractions that had been input for the special generators within that zone. The input data and the resulting estimates of trip attractions by trip purpose for each zone are stored for input into the next program, TRIPCAL4.

TRIPCAL3 - EVALUATION

Based on the literature review and state of the practice in trip generation, the model used in TRIPCAL3 is basically sound in terms of estimating trip attractions for zones within an urban area. The principal drawback to using TRIPCAL3 is its inflexibility in terms of the trip purposes being estimated and the independent variables used in the model. The model requires attraction rates based on selected categories of employment or on land use stratified by trip purpose and area type. The estimation of attractions in most urban areas is done by models developed from regression analysis or models which use cross-classified attraction trip rates with stratification categories of income, area type, or other locally determined variables. TRIPCAL3 uses a regression type cross-classification model. Trip rates are cross-classified by trip purpose and area type, but the application of the model is the same as using a regression model where the coefficients are defined based on the area type of the zone.

Most urban areas use employment (stratified by different types) as the primary variable(s) in predicting attractions. This is true in regression type models and cross-classification type models. It appears to be accepted that this produces more accurate results than land use acreage. The theoretical basis for the model appears sound and it probably produces estimates of trip attractions that are as accurate as would be obtained from the use of another type of model.

The current TRIPCAL3 program does not provide flexibility for using other variables for estimating attractions nor does it allow the user to estimate attractions for other trip purposes besides home based work, home based non-work, non-home based, and truck-taxi. This is a major limitation to the program because it fails to allow users to utilize other variables and information which may be available for estimating trip attractions. It does not allow the user to estimate other trip purposes such as home based school trips and/or home based shopping trips which may offer opportunities for improvement in both estimates of trip attractions and trip interchange movements from the trip distribution process. This would depend on the area under study. In addition, recent results from travel surveys may offer the opportunity for significant improvements in estimating trip attractions through the development and use of other cross-classification models. TRIPCAL3 does not provide the user with the ability to take advantage of new information and data which could produce more accurate results.

An advantage of TRIPCAL3 is that it also allows the user to input trip productions and attractions for categories of land use classified as special generators. It is generally recognized that there are categories of land use which produce and attract trips in such a manner that the typical models used for estimating trip productions and attractions perform poorly. These land uses should be estimated either by hand or through the input of trip rates developed for those specific land uses. The provision of the ability to input the productions and attractions for special generators is considered a positive aspect of the TRIPCAL3 program.

The principal improvements to make the trip attraction estimation process state of the art for Texas are as follows:

- Expanding the capability of the trip attraction model to estimate attractions for more trip purposes. This will improve the flexibility of the model to utilize the data available at the local area to the maximum extent possible;
- Expanding the capability of the trip attraction model to utilize different independent variables in estimating trip attractions. This will also provide flexibility in the modeling to utilize available data at the local area and improve the overall estimates of attractions;
- Expanding the capability to utilize regression equations as well as cross-classification models for the estimation of trip attractions. Many areas may not have data available for the development and use of cross-classification models. To insure that the modeling procedures are capable of producing reasonable estimates with limited data availability, the ability to use different types of models should be developed and implemented; and
- Expanding the capability to include either direct input of trip productions and attractions for special generators or the trip rates for use in predicting productions and attractions for the special generators. Estimating productions and attractions in an urban area using multiple special generators is a tedious process by hand and is one which can be programmed to reduce the manpower required and the probability of human error.

TRIPCAL4 (1)

TRIPCAL4 is another program developed and written by the Texas Transportation Institute for the SDHPT. The purpose of the program is to estimate trip productions for each serial zone within the area under study and to scale the trip attractions estimated in TRIPCAL3 to where the total attractions (for each trip purpose) equal the total trip productions (for each trip purpose). As in TRIPCAL3, trip productions are estimated for four trip purposes within each serial zone (home based work, home based non-work, non-home based, and truck-taxi). TRIPCAL4 uses a cross-classification methodology. Average household trip rates (auto-driver and person), cross-classified by income and auto ownership, are used for developing estimates of the trips being produced within a zone for home based

work trips, home based non-work trips, and non-home based trips. Truck-taxi trips are input directly to the program and are proportionally distributed to the zones based on the truck-taxi attractions estimated for each zone in TRIPCAL3.

The basic input data to TRIPCAL4 consist of the following information:

1. Trip production data for each zone which includes the zone number, estimated population, dwelling units, and median income of the zone with a code indicating the type trips to be calculated, i.e., auto-driver or person.
2. Cross-classified production trip rates for each income group. For each of five income groups, the following data are input: a) the percentage of households with 0, 1, 2, or 3+ autos available, b) the average auto-driver trips produced by households with 0, 1, 2, or 3+ autos available, c) the average person trips produced by households with 0, 1, 2, or 3+ autos available, and d) the percentage of those trips that will be home based work, home based non-work, and non-home based (both auto-driver and person trips).
3. The total estimated truck-taxi trips produced in the area under study.
4. A table of equals which designates which zones are contained within larger areas referred to as "sectors."
5. Data which specifies the five income groups and ranges to be used in the program. The program has default values which establish for Income Group One the range $0 to $5,000 (low median income), for Income Group Two the range $5,001 to $7,000 (low-medium income), for Income Group Three the range $7,001 to $10,000 (medium income), for Income Group Four the range $10,001 to $15,000 (medium-high income), and for Income Group Five the range $15,001 and above (high income).

The above data allow TRIPCAL4 to calculate the trip productions for each zone given the median income and number of dwelling units for a zone. (Note that the terms "dwelling units" and "households" are used synonymously.) Using the median income, the program calculates the number of households within the zone that have 0, 1, 2, and 3+ autos. Depending upon the type of trips being estimated, i.e., auto-driver or person, the program then selects the production trip rate for households with 0 autos and multiplies it

by the number of households with 0 autos. The result is an estimate of the trips produced within that zone by those households with no autos available. This step is then repeated for households with 1, 2 and 3+ autos. These trips are added together to arrive at a total estimate of productions for the zone. Using the median income, the program then selects the appropriate percentages for home based work, home based non-work, and non-home based trips, and multiplies it by the total productions to arrive at an estimate of the number of home based work trip productions, home based non-work productions and non-home based productions for that zone. Estimates of truck-taxi productions for each zone are calculated by first computing the percentage of truck-taxi trip attractions estimated for each zone in TRIPCAL3. This percentage is multiplied by the total truck-taxi productions (input to TRIPCAL4 directly) to develop the truck-taxi productions for each zone.

Once the trip productions (for each trip purpose) have been estimated for each zone, the final step is to balance the trip productions and trip attractions for the entire area. Totals are computed for both productions and attractions for all zones. An adjustment factor is calculated by dividing the total productions minus the total special generator trip attractions by the total attractions (these do not include the special generator attractions). The special generator trip productions and attractions are input directly to the TRIPCAL3 program, and these values are not adjusted. The estimated trip attractions for each zone (from TRIPCAL3) minus any special generator attractions in the zone are then multiplied by this adjustment factor. It should be noted that these calculations are performed for each trip purpose except truck-taxi. The truck-taxi trip attractions for each zone are set equal to the truck-taxi productions for that zone. Following the scaling, the non-home based trip productions for each zone are set equal to the scaled non-home based attractions for each zone. Total trip productions and total trip attractions for each trip purpose will be the same value.

TRIPCAL4 - EVALUATION

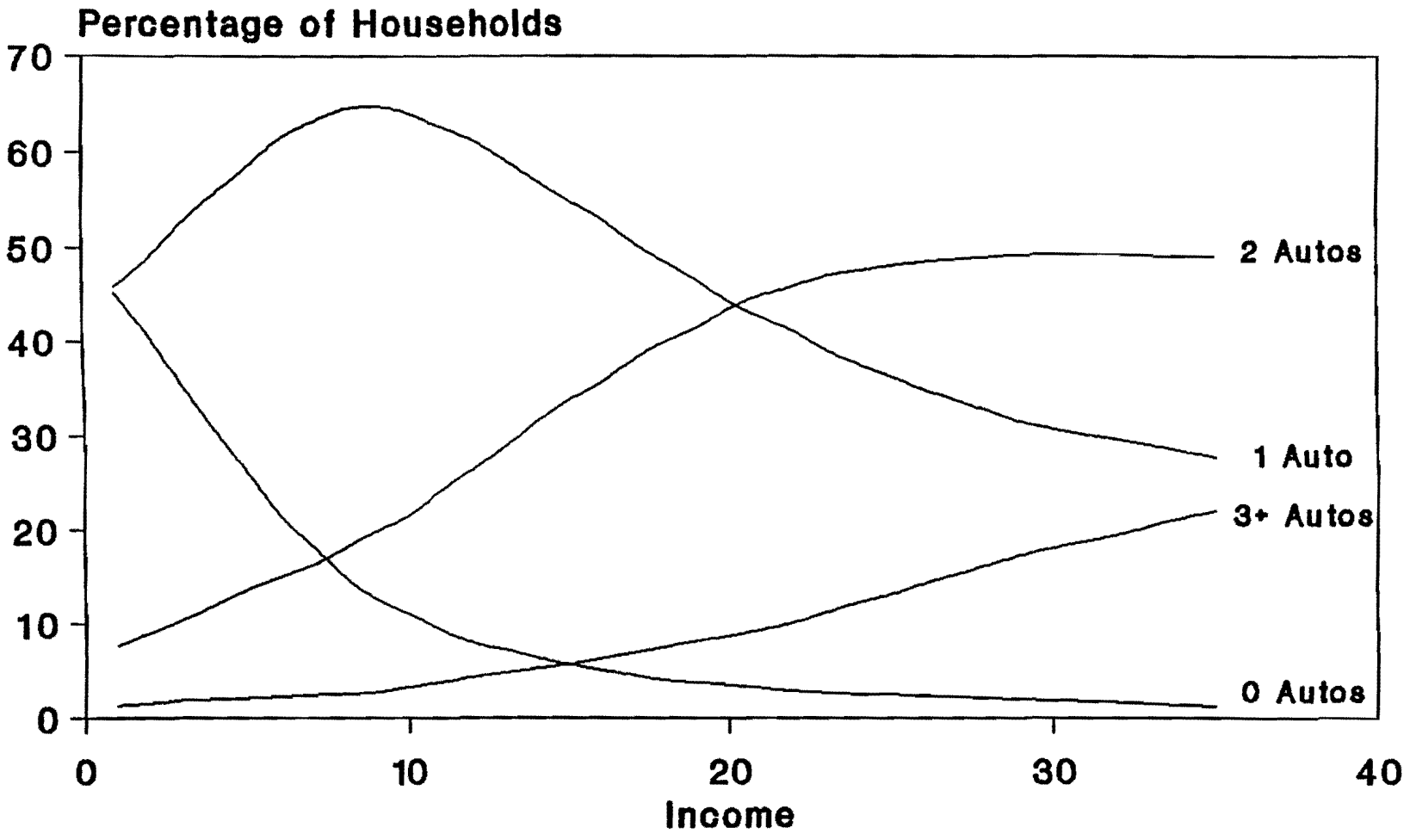
While TRIPCAL3 is considered equivalent to the state of the practice in estimating trip attractions, the same cannot be said for TRIPCAL4. The state of the practice (as well as state of the art) in estimating trip productions consists principally of cross-classification

models (two-way and three-way) with disaggregate trip rates which are applied to disaggregate household socioeconomic estimates at the zone level.

TRIPCAL4 was initially developed with an aggregate model for estimating trip productions. Trip rates (originally) were developed on a zonal basis using average household income and auto ownership as the stratification variables. The auto ownership was estimated using average household income for the zone. An example of the relationships used is presented in Figure 1 which is based on 1980 data for the San Antonio-Bexar County area. Given a mean household income for a zone, the percentage of households in the zone with 0, 1, 2, and 3+ autos may be measured directly from the curves in Figure 1. Typically, these percentages would be input to the TRIPCAL4 program directly for each of the five income groups typically used. The trip rates for each category of auto ownership were developed initially for zones having similar average household incomes. An example of this is shown in Figure 2 where trip rates have been plotted versus average household income for each auto ownership category. Given an average household income and the number of households for a zone, the number of trips being produced within that zone are estimated using the relationships shown in Figures 1 and 2. The estimate of the number of trips by trip purpose is done using the relationship of percentage of trips (by trip purpose) versus average household income. An example is presented in Figure 3. The primary input variable for modeling trip productions in TRIPCAL4 was the average household income (median household income is now used in modeling trip productions in Texas).

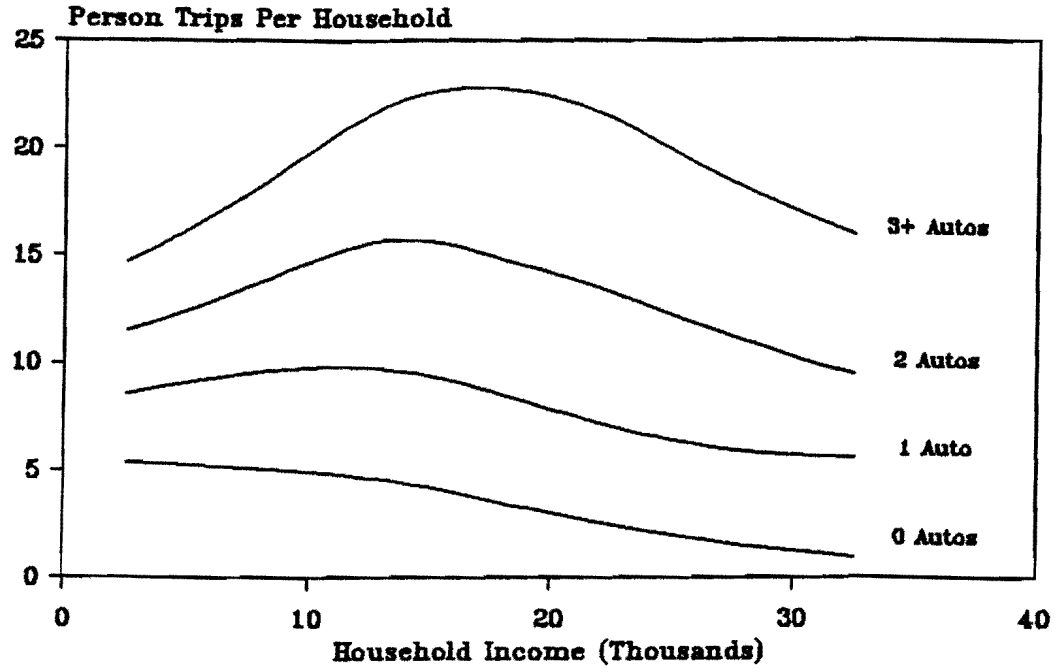
The primary deficiencies in the TRIPCAL4 model are:

- The model is based on the use of aggregate trip rates. This means that the average or median household income input for a zone defines the trip rate used for every household in that zone. Total trip productions may be overestimated because the distribution of households in most census tracts is skewed to the left with a long tail to the right. In addition, the trip rates being input to the model are generally disaggregate trip rates which are applied in an aggregate manner (as is done in TRIPCAL4).



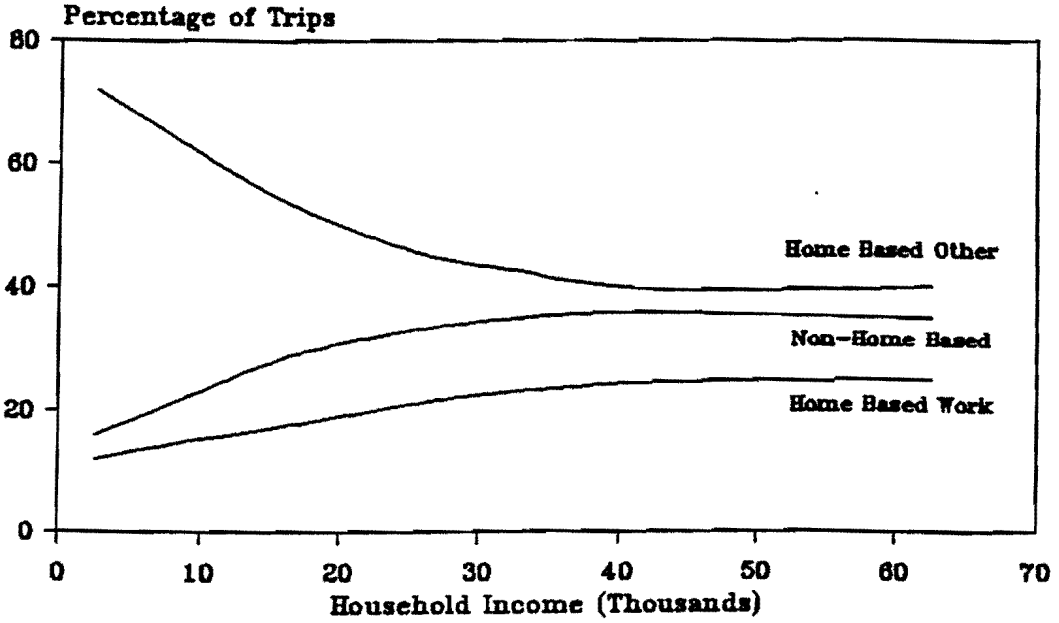
San Antonio-Bexar County
1980 Census

FIGURE 1. Percentage of Households by Auto Ownership and Income.



Illustrative Only
Not Based On Actual Data

FIGURE 2. Household Trip Rate Variations



Illustrative Only
Not Based On Actual Data

FIGURE 3. Variation in Trip Productions By Trip Purpose and Household Income

However, the error in this situation is the misapplication of the model in it's theoretical sense.

- Trip productions are estimated by trip purpose using relationships based on zonal household income. In TRIPCAL4, every zone whose median (or average) household income falls within each of the five income groups used will produce the same percentage of home based work, home based non-work, and non-home based trips. The use of such relationships (as illustrated in Figure 3) is not considered state of the practice or state of the art.
- TRIPCAL4 produces estimates of trip productions for four trip purposes. There is no standard relative to the number or type of trip purposes to use in trip production modeling. Trip production modeling should be flexible enough to allow the user to estimate the specified trip purposes. Estimating trip purposes will provide local areas with the capability to utilize local data to the maximum extent possible and improve the overall estimates of trip productions.
- Trip rates in TRIPCAL4 are stratified by household income and auto ownership. Since the development of TRIPCAL4, household travel has also been found to vary with regard to the size of the household. This relationship is significant because household size has been changing over time and the failure to use this variable in the prediction of trip productions represents a major potential error in the prediction of trip productions areawide and on a zonal basis.

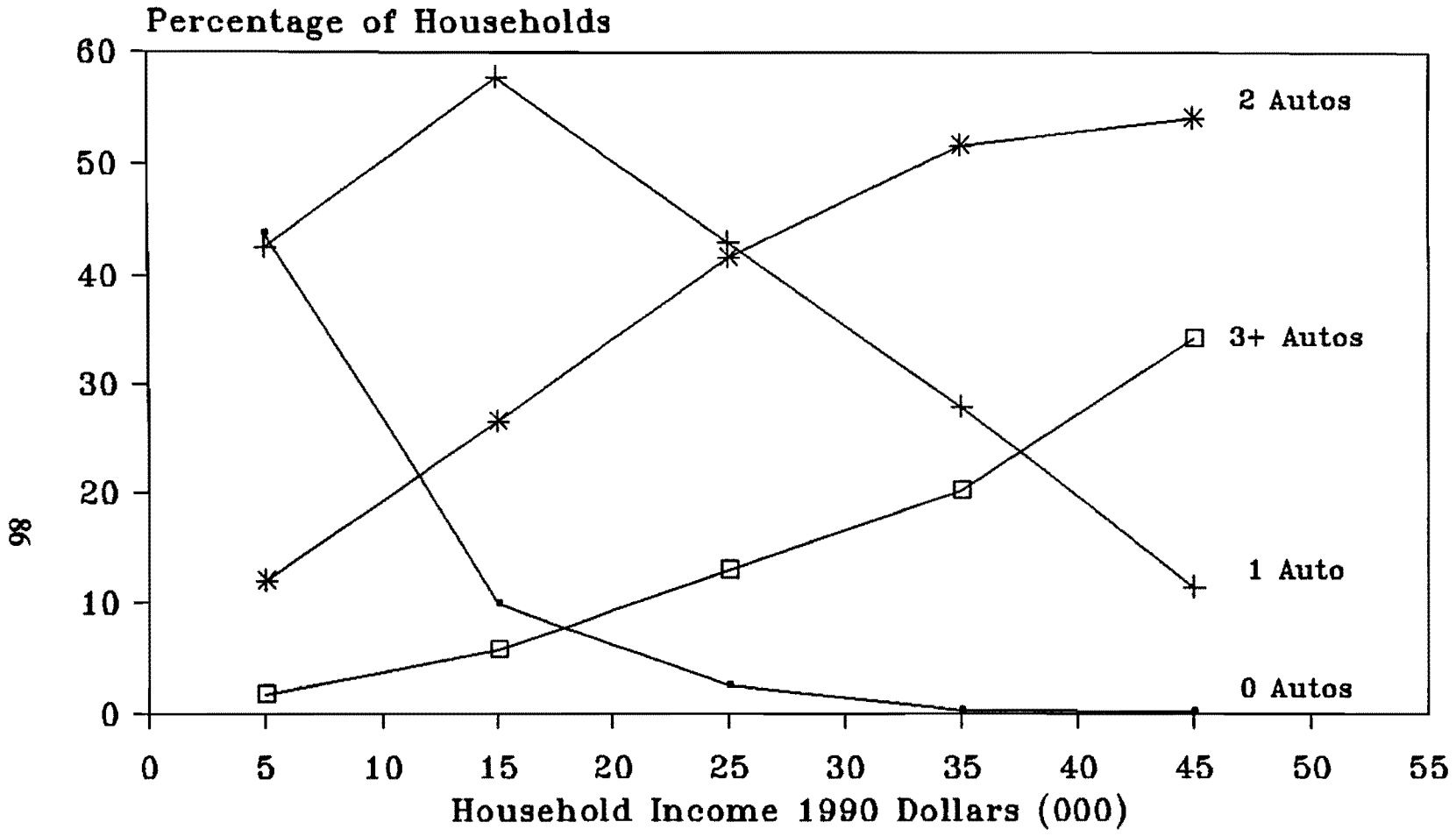
While it is relatively easy to state what are considered to be deficiencies in TRIPCAL4, it is not easy to document precisely the amount of error which may be involved. The difficulty lies in being able to develop comparable tests which utilize TRIPCAL4 as it was designed (with an aggregate model) versus the application of an alternate method. The relative amount of error may be demonstrated through a test which uses TRIPCAL4 as it is most likely to be applied (with disaggregate trip rates) versus the alternative considered

to be state of the art, i.e. disaggregate trip rates stratified by household income and household size.

Data from the 1990 San Antonio-Bexar County travel survey were used to develop the relationships employed in TRIPCAL4 and the stratification of trip rates by household income and household size for three trip purposes (home based work, home based non-work, and non-home based). Using data from the 1980 census for twelve census tracts in the Houston area, estimates of home based work, home based non-work, and non-home based trip productions for each census tract were developed utilizing the TRIPCAL4 procedure. These estimates were compared with the estimates obtained using trip rates stratified by household size and household income for each trip purpose. The actual numbers of households by household income and household size were used when applying the trip rates (stratified in the same manner) to estimate the productions for each trip purpose. Those estimates were considered to be the most accurate and were used as the basis for comparing the estimates from TRIPCAL4. The development of the necessary relationships for the test is discussed in the following sections.

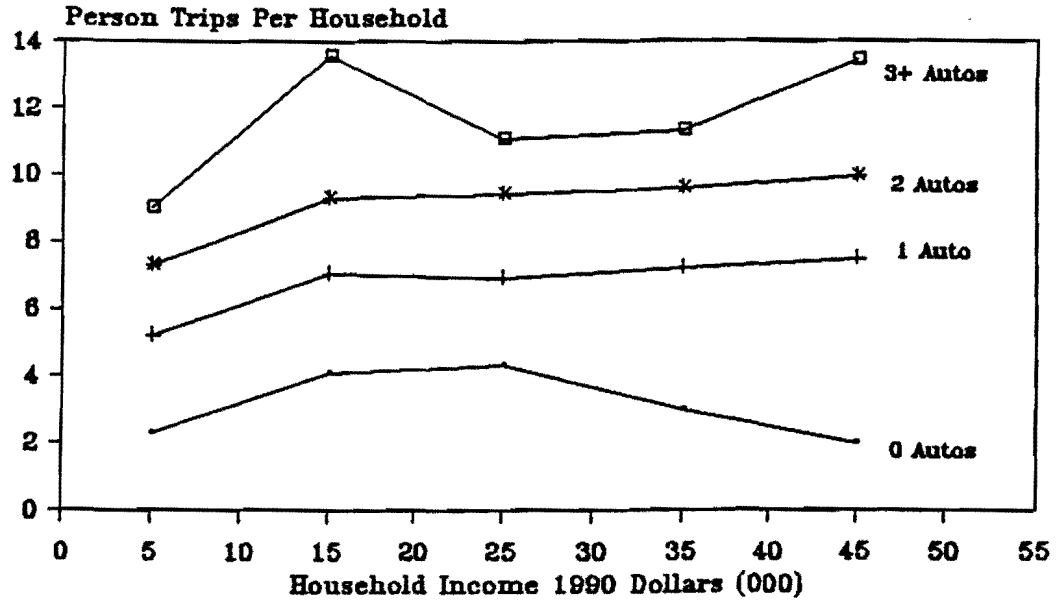
The first step was to develop the relationships used in TRIPCAL4. These relationships consisted of 1) the percentage of households versus household income by auto ownership; 2) the average trips per household versus household income by auto ownership; and 3) the percentage of trips versus household income by trip purpose. Using data from the 1990 San Antonio-Bexar County household survey (26), Tables 52 through 56 were developed. The income groups were selected arbitrarily to coincide with the income ranges used in the survey and to match, as closely as possible, the income ranges reported in the available 1980 census data for Houston. Figures 4, 5, and 6 present the data from those tables plotted to illustrate the same relationships as shown in Figures 1, 2, and 3. No attempt was made to smooth any curves or adjust any trip rates.

The data presented in Tables 52, 55, and 56 are typical examples input to TRIPCAL4 for estimating the zonal productions for an urban area. For purposes of testing, these were used for estimating the trips being produced for 12 census tracts in the Houston area. These tracts were chosen arbitrarily to ensure that at least one would fall within each of the five



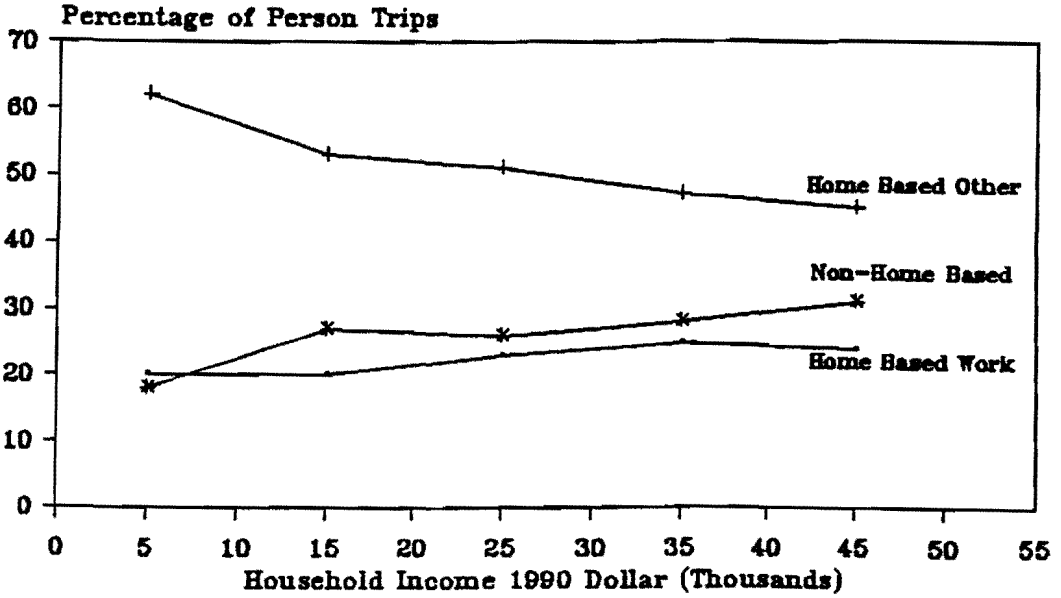
Source: San Antonio-Bexar County 1990 Travel Survey (26)

FIGURE 4. Percentage of Surveyed Households by Auto Ownership and Income



Source: San Antonio-Bexar County
1990 Travel Survey
Adapted From (28)

FIGURE 5. Person Trips per Household by Auto Ownership and Income



Source: San Antonio-Bexar County
1990 Travel Survey
Adapted From (28)

FIGURE 6. Variation in Surveyed Trip Productions by Trip Purpose and Household Income

income groups being used. Table 58 presents the 12 census tracts selected for the test. The current procedure in Texas is to use median household income for estimating trip productions. Using the median household income for each census tract, the income group

Table 52
Percentage of Households by Auto Ownership
San Antonio - Bexar County
1990 Travel Survey

	Auto Ownership				
Income Group	0	1	2	3+	Totals
I. < 10K	43.8	42.5	12.0	1.7	100.0
II. 10K - < 20K	9.9	57.8	26.5	5.8	100.0
III. 20K - < 30K	2.5	43.0	41.6	12.9	100.0
IV. 30K - < 40K	0.3	27.9	51.7	20.1	100.0
V. >40K	0.2	11.5	54.1	34.2	100.0
Totals	13.1	37.1	35.4	14.4	100.0

Source: Adapted from (26)

Table 53
Number of Households Sampled
San Antonio - Bexar County
1990 Travel Survey

	Auto Ownership				
Income Group	0	1	2	3+	Totals
I. < 10K	255	247	70	10	582
II. 10K - < 20K	54	317	145	32	548
III. 20K - < 30K	11	186	180	56	433
IV. 30K - < 40K	1	97	180	70	348
V. >40K	1	62	291	184	538
Totals	322	909	866	352	2449

Source: Adapted from (26)

Table 54
Number of Person Trips[1]
San Antonio - Bexar County
1990 Travel Survey

Auto Ownership

Income Group	0	1	2	3+	Totals
I. < 10K	587	1287	510	90	2474
II. 10K - < 20K	221	2228	1347	433	4229
III. 20K - < 30K	48	1286	1693	618	3645
IV. 30K - < 40K	3	699	1727	791	3220
V. > 40K	2	464	2893	2468	5827
Totals	861	5964	8170	4400	19395

Source: Adapted from (26)

Table 55
Person Trips Per Household[2]
San Antonio - Bexar County
1990 Travel Survey

Auto Ownership

Income Group	0 Autos	1 Auto	2 Autos	3+ Autos	Totals
I. < 10K	2.3020	5.2105	7.2857	9.0000	4.2509
II. 10K - < 20K	4.0926	7.0284	9.2897	13.5313	7.7172
III. 20K - < 30K	4.3636	6.9140	9.4056	11.0357	8.4180
IV. 30K - < 40K	3.0000	7.2062	9.5944	11.3000	9.2529
V. > 40K	2.0000	7.4839	9.9416	13.4130	10.8309
Totals	2.6739	6.5611	9.4342	12.5000	7.9196

Source: Adapted from (26)

[1] Includes all person trips except walk trips that were non-work related.

[2] Rates shown as Totals are unexpanded and should not be used as averages or for comparison purposes.

Table 56
Percentage of Person Trips by Trip Purpose
San Antonio - Bexar County
1990 Travel Survey

Income Group	Home Based Work	Home Based Other	Non-Home Based	Totals
I. < 10K	20	62	18	100
II. 10K - < 20K	20	53	27	100
III. 20K - < 30K	23	51	26	100
IV. 30K - < 40K	25	47	28	100
V. > 40K	24	45	31	100
Totals	23	50	27	100

Source: Adapted from (26)

that the value falls within is first determined. For example, census tract 215.02 has a median household income of $14,909 which falls in Income Group II. From Table 52, the distribution of households by auto ownership in census tract 215.02 would then be estimated as 9.9 percent with zero autos, 57.8 percent with one auto, 26.5 percent with two autos and 5.8 percent with three or more autos. Multiplying these percentages by the number of households, i.e., 1,581, in the census tract produces estimates of the number of households by auto ownership. The next step is to obtain the trip production rate for those households. This is done using the values in Table 55 for Income Group II. The households with zero autos, estimated to be 0.099 times 1,581 or 157, are estimated to produce 4.0926 trips per household. The total number of trips produced by those zero auto households is then 4.0926 times 157 which is 643 (note values are rounded for discussion purposes). Using the same methodology, estimates of the number of trips produced by one, two, and three plus auto households is developed using the appropriate trip rates for Income Group II in Table 55. The resulting estimate of person trip productions for census tract 215.02 was 12,196. The estimate of person trips by trip purpose is developed using data from Table 56. For example, the home based work person trip productions would be estimated by multiplying the total person trip productions of 12,196 by 20 percent as indicated in Table 56 for Income

Group II. The resulting estimates would be 2,439 home based work, 6,464 home based other, and 3,293 non-home based person trip productions for census tract 215.02. Using the same procedure, estimates were also computed for the other 11 census tracts.

The second step of the test was to develop the relationships to produce estimates of person trip productions using the method considered state of the art (and practice). As previously stated, this method uses trip rates stratified by household income and household size. The trip rates are applied to disaggregate data at the zonal level (for purposes of this

Table 57
1980 Houston Area Census Tracts
Used in Test

Census Tract	Average Household Income	Median Household Income	Number Of Households
400.26	$ 7476	$ 4776	2304
201.01	$ 8878	$ 5897	1284
305.01	$ 9520	$ 6611	1754
306.00	$ 13512	$ 10162	2063
215.02	$ 18066	$ 14909	1581
347.02	$ 22133	$ 18564	1902
407.01	$ 27148	$ 19361	2669
438.03	$ 33505	$ 27804	4157
446.02	$ 36841	$ 31709	4316
701.06	$ 40875	$ 36186	4322
445.02	$ 47692	$ 40104	2455
445.01	$ 50822	$ 43283	2062

Source: 1980 Census

test, census tracts are used). Since actual distributions of households by household income and size were available from the 1980 census for Houston, this data was used in lieu of estimates and yielded the best estimates of the person trips produced within each census

tract. This provides a reasonable base for comparing the accuracy of the estimates from the TRIPCAL4 procedure. Based on the survey data from the San Antonio -Bexar County travel study (26), Table 59 presents the number of surveyed households stratified by income and size. Note that the income groups used are the same as applied in the previous example with TRIPCAL4. Tables 60 and 61 present, respectively, the number of home

Table 58
Number of Households Surveyed
San Antonio - Bexar County
1990 Travel Survey

Income Group	Household Size					Totals
	1	2	3	4	5 +	
I. 0 - < 10K	211	138	86	64	83	582
II. 10K - < 20K	140	144	83	78	103	548
III. 20K - < 30K	91	120	79	85	58	433
IV. 30K - < 40K	46	105	81	68	48	348
V. > 40K	32	195	129	113	69	538
Totals	520	702	458	408	361	2449

Source: Adapted from (26)

based work person trips and resulting home based work trip rates for households stratified by income and size. Tables 61 through 64 present the same information for home based other and non-home based person trips. Note that as in the TRIPCAL4 example, the trip rates are taken directly from the reported survey results and no attempt has been made to smooth or adjust them. The household size categories were selected to correspond with the groupings available for the 1980 Houston census. The income categories for the Houston census data did not correspond exactly to the income groups used in stratifying the trip rates. Table 65 presents the data for census tract 215.02 as obtained from the Houston-Galveston Area Council of Governments. It was necessary to combine some of the rows and split some of the rows to estimate the households in the income groups being used in the example. Combining the rows was a straightforward computation. Splitting the rows

Table 59
Home Based Work Person Trips[3]
San Antonio - Bexar County
1990 Travel Survey

Income Group	Household Size					Totals
	1	2	3	4	5 +	
I. 0 - < 10K	63	108	93	95	123	482
II. 10K - < 20K	145	176	156	136	239	852
III. 20K - < 30K	99	248	184	216	104	851
IV. 30K - < 40K	48	216	206	192	141	803
V. > 40K	36	434	369	348	228	1415
Totals	391	1182	1008	987	835	4403

Source: Adapted from (26)

Table 60
Home Based Work Person Trips Per Household[4]
San Antonio - Bexar County
1990 Travel Survey

Income Group	Household Size					Totals
	1	2	3	4	5 +	
I. 0 - < 10K	0.2986	0.7826	1.0814	1.4844	1.4819	0.8282
II. 10K - < 20K	1.0357	1.2222	1.8795	1.7436	2.3204	1.5547
III. 20K - < 30K	1.0879	2.0667	2.3291	2.5412	1.7931	1.9654
IV. 30K - < 40K	1.0435	2.0571	2.5432	2.8235	2.9375	2.3075
V. > 40K	1.1250	2.2256	2.8605	3.0796	3.3043	2.6301
Totals	0.7519	1.6838	2.2009	2.4191	2.3130	1.7979

Source: Adapted from (26)

[3] Includes home based work walk trips.

[4] Rates shown as "Totals" are unexpanded and should not be used as averages or for comparison purposes.

Table 61
Home Based Other Person Trips[5]
San Antonio - Bexar County
1990 Travel Survey

Income Group	Household Size					Totals
	1	2	3	4	5 +	
I. 0 - < 10K	238	277	306	223	498	1542
II. 10K - < 20K	228	454	318	488	750	2238
III. 20K - < 30K	167	380	313	470	510	1840
IV. 30K - < 40K	82	325	324	383	393	1507
V. > 40K	58	549	543	799	684	2633
Totals	773	1985	1804	2363	2835	9760

Source: Adapted from (26)

Table 62
Home Based Other Person Trips Per Household[6]
San Antonio - Bexar County
1990 Travel Survey

Income Group	Household Size					Totals
	1	2	3	4	5 +	
I. 0 - < 10K	1.1280	2.0072	3.5581	3.4844	6.0000	2.6495
II. 10K - < 20K	1.6286	3.1528	3.8313	6.2564	7.2816	4.0839
III. 20K - < 30K	1.8352	3.1667	3.9620	5.5294	8.7931	3.4804
IV. 30K - < 40K	1.7826	3.0952	4.0000	5.6324	8.1875	4.3305
V. > 40K	1.8125	2.8154	4.2093	7.0708	9.9130	4.8941
Totals	1.4865	2.8276	3.9389	5.7917	7.8532	3.9853

Source: Adapted from (26)

[5] Includes all person trips except walk trips.

[6] Rates shown as "Totals" are unexpanded and should not be used as averages or for comparison purposes.

Table 63
Non-Home Based Person Trips[7]
San Antonio - Bexar County
1990 Travel Survey

Income Group	Household Size					Totals
	1	2	3	4	5 +	
I. 0 - < 10K	123	86	61	73	107	450
II. 10K - < 20K	207	230	179	237	286	1139
III. 20K - < 30K	139	246	159	189	221	954
IV. 30K - < 40K	79	252	211	205	163	910
V. > 40K	47	634	390	436	272	1779
Totals	595	1448	1000	1140	1049	5232

Source: Adapted from (26)

Table 64
Non-Home Based Person Trips Per Household[8]
San Antonio - Bexar County
1990 Travel Survey

Income Group	Household Size					Totals
	1	2	3	4	5 +	
I. 0 - < 10K	0.5829	0.6232	0.7093	1.1406	1.2892	0.7732
II. 10K - < 20K	1.4786	1.5972	2.1566	3.0385	2.7767	2.0785
III. 20K - < 30K	1.5275	2.0500	2.0127	2.2235	3.8103	2.2032
IV. 30K - < 40K	1.7174	2.4000	2.6049	3.0147	3.3958	2.6149
V. > 40K	1.4688	3.2513	3.0233	3.8584	3.9420	3.3067
Totals	1.1442	2.0627	2.1834	2.7941	2.9058	2.1364

Source: Adapted from (26)

[7] Includes all person trips except walk trips.

[8] Rates shown as "Totals" are unexpanded and should not be used as averages or for comparison purposes.

Table 65
Census Tract 215.02
1980 Households by Household Size
And Household Income

Household Income	Household Size					Totals
	1	2	3	4	5 +	
< $ 10K	103	151	86	66	106	512
$ 10K - < $ 15K	44	51	48	46	94	283
$ 15K - < $ 20K	29	30	28	46	67	200
$ 20K - < $ 25K	0	19	51	56	52	178
$ 25K - < $ 35K	0	63	17	42	102	224
$ 35K - < $ 50K	0	14	50	31	62	157
> $ 50K	0	0	0	0	27	27
Totals	176	328	280	287	510	1581

Source: Houston-Galveston Area Council of Governments

required some assumptions. For households in the $25,000 to $34,999 range, it was assumed that 50 percent would fall in the $25,000 to $29,999 range and 50 percent would fall in the $30,000 to $34,999 range. This assumption was based on the rationale that this range would fall in the general bell area of the overall distribution and could be expected to be evenly split in the distribution. This assumption was not felt to be valid for splitting the households which fell in the $35,000 to $49,999 range. Here it was reasoned that a greater percentage would fall in the $35,000 to $39,999 range than in the $40,000 to $49,999 range because this area would fall in the tail end of the overall distribution. A reasonable estimate of these two percentages was computed by summing the number of households in those census tracts whose mean household income fell within each of those two income ranges (i.e., $35,000 to $39,999 and $40,000 to $49,999). The resulting percentages (computed by adding the two totals and dividing each by the sum) were 52 percent in the $35,000 to $39,999 range and 48 percent in the $40,000 to $49,999 range. These percentages (as well as the previously assumed 50/50 split) were applied to the households in the appropriate income ranges for all household size categories. The resulting distribution for census tract 215.02 is presented

in Table 66. The same methodology was used for the remaining 11 census tracts to adjust the distribution of the households to the same income groups as used in the TRIPCAL4 example.

Table 66
Census Tract 215.02
Adjusted Distribution of Households by
Household Size and Income

Income Group	Household Size					Totals
	1	2	3	4	5 +	
I. 0 - < 10K	103	151	86	66	106	512
II. 10K - < 20K	73	81	76	92	161	483
III. 20K - < 30K	0	51	60	77	103	291
IV. 30K - < 40K	0	38	34	37	83	192
V. > 40K	0	7	24	15	57	103
Totals	176	328	280	287	510	1581

The estimation of person trip productions for each census tract is a straightforward computation. Using census tract 215.02 as an example, the number of households in each stratification cell is multiplied by the appropriate trip rate for each trip purpose to estimate the number of trips produced by those households. Table 67 shows the calculations for estimating home based work person trip productions for census tract 215.02. The total home based work person trip productions for census tract 215.02 would then be 2,806. A similar procedure was followed for estimating the home based other and non-home based person trip productions. The procedure was repeated for each census tract to develop estimates of person trip productions by trip purpose. Since the actual numbers of households in each stratification cell was used, the resulting estimates are considered to be the best available and are used as the base of comparison with the results from TRIPCAL4.

Tables 68 through 71 compare the trip estimates from the TRIPCAL4 procedure and the procedure considered state of the art for total, home based work, home based other, and non-home based person trip productions. The percentage difference shown is based on the

assumption that the best estimate is given by the state-of- the-art procedure (as illustrated

Table 67
Census Tract 215.02
Computation of Home Based Work
Person Trip Productions

Income Group	Household Size					Totals
	1	2	3	4	5 +	
I. 0 - < 10K	0.2986 x 103 = 30.76	0.7826 x 151 = 118.17	1.0814 x 86 = 93.00	1.4844 x 66 = 97.97	1.4819 x 106 = 157.08	496.98
II. 10K - < 20K	1.0357 x 73 = 75.61	1.2222 x 81 = 99.00	1.8795 x 76 = 142.84	1.7436 x 92 = 160.41	2.3204 x 161 = 373.58	851.44
III. 20K - < 30K	1.0879 x 0 = 0.00	2.0667 x 51 = 105.40	2.3291 x 60 = 139.75	2.5412 x 77 = 195.67	1.7931 x 103 = 184.69	625.51
IV. 30K - < 40K	1.0435 x 0 = 0.00	2.0571 x 38 = 78.17	2.5432 x 34 = 86.47	2.8235 x 37 = 104.47	2.9375 x 83 = 243.81	512.92
V. > 40K	1.1250 x 0 = 0.00	2.2256 x 7 = 15.58	2.8605 x 24 = 68.65	3.0796 x 15 = 46.19	3.3043 x 57 = 188.35	318.77
Totals	106.37	416.32	530.71	604.71	1147.51	2805.62

in Table 67). The comparison results reveal some interesting points. For the census tracts included in this test, the total trips do not appear to be significantly different between TRIPCAL4 and the state-of-the-art procedure. This, however, does not take into account the variation in the estimates for the census tracts. A close examination of the results reveal the following points:

- TRIPCAL4 appears to consistently underestimate travel for census tracts falling in the low income category. This could lead to underestimates of public transit ridership since the majority of these trips will typically come from lower income census tracts/zones;

- TRIPCAL4 appears to consistently overestimate travel for census tracts falling in the high income category; and
- With the exception of the census tracts falling in the low income category, the only census tracts where the estimates from TRIPCAL4 were less than those from the state-of-the-art procedure were those census tracts with a significantly higher average household size than the average for the Houston area.

The implication is that TRIPCAL4 will overestimate travel except for zones in the low income group. There will be exceptions, and these will typically be for zones with high average household sizes. The differences in the zonal estimates will tend to average out for the area as a whole. The significant indication from the results is that large under- and overestimates on the zonal basis can lead to potential problems in later stages of the travel demand modeling process, e.g., trip distribution.

Table 68
Comparison of Total Person Trip Production Estimates

Census Tract	Average Household Size	Average Household Income	Median Household Income	Number of Households	Person Trips		Percent Difference
					TRIPCAL4 Estimate	State-of-the-Art Estimate	
400.26	2.83	$ 7476	$ 4776	2304	9792	13190	- 25.8
201.01	2.62	$ 8878	$ 5897	1284	5457	7204	- 24.3
305.01	2.27	$ 9520	$ 6611	1754	7455	9380	- 20.5
306.00	2.70	$ 13512	$ 10162	2063	15914	12258	+ 29.8
215.02	3.56	$ 18066	$ 14909	1581	12196	13769	- 11.4
347.02	2.47	$ 22133	$ 18564	1902	14672	13471	+ 8.9
407.01	1.78	$ 27148	$ 19361	2669	20589	15540	+ 32.5
438.03	2.73	$ 33505	$ 27804	4157	34995	34563	+ 1.2
446.02	2.95	$ 36841	$ 31709	4316	39928	39534	+ 1.0
701.06	3.30	$ 40875	$ 36186	4322	39983	43628	- 8.4
445.02	2.35	$ 47692	$ 40104	2455	26588	19662	+ 35.2
445.01	2.83	$ 50822	$ 43283	2062	22332	19563	+ 14.2
Totals	--	--	--	30869	249901	241762	+ 3.4

Table 69
Comparison of Total Home Based Work
Person Trip Production Estimates

Census Tract	Average Household Size	Average Household Income	Median Household Income	Number of Households	Person Trips		Percent Difference
					TRIPCAL4 Estimate	State of The Art Estimate	
400.26	2.83	$ 7476	$ 4776	2304	1958	2497	- 21.6
201.01	2.62	$ 8878	$ 5897	1284	1091	1446	- 24.6
305.01	2.27	$ 9520	$ 6611	1754	1491	1866	- 20.1
306.00	2.70	$ 13512	$ 10162	2063	3183	2574	+ 23.7
215.02	3.56	$ 18066	$ 14909	1581	2439	2806	- 13.1
347.02	2.47	$ 22133	$ 18564	1902	2934	3132	- 6.3
407.01	1.78	$ 27148	$ 19361	2669	4118	3787	+ 8.7
438.03	2.73	$ 33505	$ 27804	4157	8049	8022	+ 0.3
446.02	2.95	$ 36841	$ 31709	4316	9982	9371	+ 6.5
701.06	3.30	$ 40875	$ 36186	4322	9996	10205	- 2.0
445.02	2.35	$ 47692	$ 40104	2455	6381	4882	+ 30.7
445.01	2.83	$ 50822	$ 43283	2062	5360	4773	+ 12.3
Totals	--	--	--	30869	56982	55361	+ 2.9

Table 70
Comparison of Total Home Based Other
Person Trip Production Estimates

Census Tract	Average Household Size	Average Household Income	Median Household Income	Number of Households	Person Trips		Percent Difference
					TRIPCAL4 Estimate	State-of-the-Art Estimate	
400.26	2.83	$ 7476	$ 4776	2304	6071	7832	- 22.5
201.01	2.62	$ 8878	$ 5897	1284	3383	4133	- 18.1
305.01	2.27	$ 9520	$ 6611	1754	4622	5262	- 12.2
306.00	2.70	$ 13512	$ 10162	2063	8434	6605	+ 27.7
215.02	3.56	$ 18066	$ 14909	1581	6464	7669	- 15.7
347.02	2.47	$ 22133	$ 18564	1902	7776	6673	+ 16.5
407.01	1.78	$ 27148	$ 19361	2669	10912	7028	+ 55.3
438.03	2.73	$ 33505	$ 27804	4157	17847	16812	+ 6.2
446.02	2.95	$ 36841	$ 31709	4316	18766	19118	- 1.8
701.06	3.30	$ 40875	$ 36186	4322	18792	21485	- 12.5
445.02	2.35	$ 47692	$ 40104	2455	11965	8761	+ 36.6
445.01	2.83	$ 50822	$ 43283	2062	10049	9105	+ 10.4
Totals	--	--	--	30869	125081	120483	+ 3.7

Table 71
Comparison of Total Non-Home Based
Person Trip Production Estimates

Census Tract	Average Household Size	Average Household Income	Median Household Income	Number of Households	Person Trips		Percent Difference
					TRIPCAL4 Estimate	State-of-the-Art Estimate	
400.26	2.83	$ 7476	$ 4776	2304	1763	2861	- 38.4
201.01	2.62	$ 8878	$ 5897	1284	982	1624	- 39.5
305.01	2.27	$ 9520	$ 6611	1754	1342	2252	- 40.4
306.00	2.70	$ 13512	$ 10162	2063	4297	3078	+ 39.6
215.02	3.56	$ 18066	$ 14909	1581	3293	3295	- 0.1
347.02	2.47	$ 22133	$ 18564	1902	3961	3666	+ 8.0
407.01	1.78	$ 27148	$ 19361	2669	5559	4725	+ 17.7
438.03	2.73	$ 33505	$ 27804	4157	9099	9729	- 6.5
446.02	2.95	$ 36841	$ 31709	4316	11180	11045	+ 1.2
701.06	3.3	$ 40875	$ 36186	4322	11195	11938	- 6.2
445.02	2.35	$ 47692	$ 40104	2455	8242	6020	+ 36.9
445.01	2.83	$ 50822	$ 43283	2062	6923	5685	+ 21.8
Totals	--	--	--	30869	67836	65918	+ 2.9

DALLAS-FORT WORTH (5)

Trip generation in the Dallas-Fort Worth area is accomplished primarily by the North Central Texas Council of Governments (NCTCOG) working in cooperation with Districts 2 and 18 of the TxDOT. The models were developed principally by NCTCOG using the results of a regional travel survey conducted in the mid-eighties. The trip generation model used consists of three distinct sub-models which generate for each traffic survey zone a designation of area type, the number of trip productions, and the number of trip attractions. Trip productions and attractions are also calculated for special generators.

The basis for the specific data elements utilized in the calculations may be generated at a different level of analysis than that of the Traffic Survey Zone (TSZ). For that reason

it is necessary to understand the zonal hierarchy used in the Dallas-Fort Worth study area. The entire study area consists of 5,691 traffic survey zones which is the level that basic land-use and demographic data are collected and forecast for use in transportation planning. The TSZ's have been aggregated into 2,218 larger areas which are called local analysis districts (LAD). These LAD have been further aggregated into 605 larger areas called regional analysis areas (RAA). The RAA are aggregated into 236 larger areas called transportation analysis districts (TAD) which are combined into 47 areas called jurisdictions. Five different levels of zone structure can be used depending upon the analysis being done.

Area Type Model

This model calculates an area type designation for each RAA. Population, employment, and land area (size of zone in acres) are input for each traffic serial zone and are then aggregated up to the RAA level. A measure of activity density is calculated for each RAA using the following relationship:

$$\text{Activity Density} = (\text{Population} + 1.67 * \text{Employment}) / \text{Area}$$

Each RAA is designated as being one of five area types: central business district - Type 1, outer business district - Type 2, urban residential - Type 3, suburban residential - Type 4, or rural - Type 5 based on the following ranges:

Area Type	Activity Density
1. Central Business District	> 125/acre
2. Outer Business District	30 - 125/acre
3. Urban Residential	7.5 - 30/acre
4. Suburban Residential	1.8 - 7.5/acre
5. Rural	< 1.8/acre

Each TSZ within the RAA is then given that area type designation.

Trip Production Model

This model estimates person trip productions for each TSZ. The model is similar to the one used in TRIPCAL4 in that it is a cross-classification model. The model is different because of the independent variables by which the trip rates are cross-classified and because the trip rates are developed based on "linked" trips. For example, suppose a person traveled from home to a convenience store and then to work. This trip would be linked, that is, treated as a home based work trip instead of a home based shop trip and a non-home based trip. Results from the regional travel survey conducted during the mid-eighties were used to develop trip rates (in terms of person trips per household) cross-classified by income quartile and household size for home based work, home based non-work, and non-home based trips. Four income quartiles and six household size classifications were used (one person to six or more persons).

Rates were also developed for a fourth trip purpose designated "Other" trips which included truck, taxi, internal-external, and external-external. These trip rates are cross-classified by area type, basic, retail, service, and households. Basic, retail, and service refer to the categories of employment which were developed for each TSZ and used in the trip attraction model. For each area type, person trips per employee were used for basic, retail, and service employment, and person trips per household were used for households.

One of the major differences between this model and that used in other areas is the disaggregation of households by income quartile and household size for each TSZ. Using data from the 1980 census, relationships were developed which allow the percentage of households within each income quartile and each household size to be computed based on the median household income and average household size for each RAA. Using data from the 1980 census, plots were made showing the percentage of households within each income quartile versus the ratio of median income for census tracts divided by the median income for the region. For example, if an RAA's median income was $15,000 and the region's median income was $30,000, the resulting ratio would be 0.5 which, based on the developed relationships, would estimate the percentage of households within the low income quartile to be 54 percent, the percentage of households within the low-medium quartile to be 28 percent, the percentage of households within the medium-high quartile to be 11 percent, and

the percentage of households within the high quartile to be 7 percent. After computing these estimates for all RAAs, the model checks to insure that 25 percent of the households are within each income quartile for the entire region. If not, the distributions for the RAA's are adjusted using an iterative proportional procedure to achieve the regional distribution.

The disaggregation of households by household size is done in a similar manner. Data from the 1980 census were used to develop relationships showing the distribution of households by household size within census tracts given the average household size for a census tract. Using average household size, these relationships will estimate the percentage of one person households, two person households, etc. The model applies these relationships at the RAA level using the average household size in the RAA.

Once the model has computed the percentage of households within each income quartile and the percentage of households within each household size classification for the RAA, a marginal weighting procedure is applied to the 1980 distribution of households by income quartile and household size to develop estimates of the percentage of households within each cell of the income quartile and the household size cross-classification matrix. These values are applied to each TSZ within the RAA to estimate the number of households within the TSZ that are in each income quartile and each household size classification. Once the number of households are calculated within each income quartile and household size, the model selects the corresponding trip rate and multiplies to estimate the person trip productions for each income quartile and household size. For example, assume zone 245 had 500 households in it and was a part of RAA 52. The median income of RAA was $15,000 and the average household size was 2.3. These values for the RAA would result in estimates of 54 percent of the households in Income Quartile One, 28 percent in Income Quartile Two, 11 percent in Income Quartile Three, and 7 percent in Income Quartile Four. The average household size of 2.3 would generate estimates that 30 percent of the households would be composed of one person, 39 percent would be composed of two persons, 14 percent would be composed of three persons, 10 percent would be composed of four persons, 4 percent would be composed of five persons, and 3 percent would be composed of six persons or more. These distributions, after applying the marginal weighting procedure to the 1980 census distribution, yield the following estimates for Income

Quartile One: 22.71 percent one person households, 19.49 percent two person households, 5.71 percent three person households, 3.22 percent four person households, 1.46 percent five person households, and 1.32 percent six or more person households. Applying this information to zone 245 results in an estimate of 97 two person households in Income Quartile One.

A similar procedure would yield estimates of households by household size for every income quartile. The average home based work trip rate (person trips per household) for two person households in Income Quartile One is 1.7. This results in an estimated 165 home based work trip productions for those two person households in Income Quartile One. A similar procedure would be followed to estimate the home based work trip productions for the other income quartiles and household sizes using the appropriate trip rate in each situation.

These steps are repeated for home based non-work and non-home based trips. A slightly different procedure is used for estimating other trip productions because the trip rates are cross-classified by area type, employment type, and households. This means for each area type (i.e., 1 to 5), a trip rate has been developed for basic employment, retail employment, service employment, and households. For example, if zone 245 had an area type designation of 2 and basic employment of 200 employees, the other trip rate for that area type and basic employment is 0.298 which would result in an estimate of 60 other trip productions for that zone. The final end product is an estimate of home based work trip productions for each income quartile, home based non-work trip productions, non-home based trip productions, and other trip productions for each TSZ in the study area. Note that the estimates of home based work trip productions are estimated separately for each income quartile. This is not the case for home based non-work and non-work trips.

Trip Attraction Model

This model estimates person trip attractions for each TSZ. It is similar to the TRIPCAL3 model because it is based on the theory that the number of trips attracted to a zone is dependent on the type and extent of activity within the zone as measured by employment within the zone. Three classifications of employment are used: basic which

includes construction, mining, manufacturing, transportation/communications and wholesale trade; **retail** which includes retail; and **service** which includes finance/insurance/real estate, services, education, and government. This is a cross-classification model which is based on attraction trip rates (person trips per employee or household) cross-classified by area type and basic employment, retail employment, service employment, and households. One of the major distinctions of this model is that home based work trip rates are also stratified by income quartile. This requires the disaggregation of employment by income quartile for each employment classification. The distribution of employees by income quartile is estimated on the basis of the income level of households located in and around a zone. This is accomplished using the following relationships:

PCTEMP_1 = 0.11500 + 0.04486 * HH670_1 + 0.03502 * HE75_1

PCTEMP_2 = 0.15892 + 0.07858 * HH670_2

PCTEMP_3 = 0.17000 + 0.05969 * HH670_3

PCTEMP_4 = 0.41000 + 0.06893 * HH670_4 - 0.00629 * HE50

where:

PCTEMP_I	=	Percent employment of income quartile "i" employees in a zone
HH670_i	=	Ratio of income quartile "i" households within 6.7 miles to the total number of households within 6.7 miles
HE75_i	=	Ratio of income quartile "i" households within 0.75 miles to total employment within 0.75 miles
HE50	=	Ratio of all households within 0.5 miles to total employment within 0.5 miles

The calculated values from the above equations are normalized to insure they sum to one hundred percent for each zone.

The computed distribution of employment is applied to each type of employment within a zone to estimate the number of employees within each income quartile. Then, using the area type designation for the zone, the appropriate trip is selected and multiplied by the number of employees to estimate the home based work person trip attractions. This is done for each type of employment in the zone (basic, retail, and service). Trip attractions for home based non-work, non-home based, and other trip purposes are accomplished using

the area type designation for the zone. The area type designation defines the trip rates to be applied specifically to the basic employment, retail employment, service employment, and households within the zone to estimate the person trip attractions for the zone. The end result is estimated total trip attractions for home based work (for each income quartile), home based non-work, non-home based and other trips for each TSZ.

Additional Applications

The trip generation model for the NCTCOG also includes the capability to identify and input trips for special generators and external stations. Six categories of special generators are used in the current model:

- Regional shopping malls
- Universities and colleges
- Hospitals
- Commercial airports
- Regional recreation facilities
- Military installations

The input data for each TSZ include the employment for the special generators. Attractions are estimated initially by the attraction model in its normal operation, and any additional trips associated with these generators must be input directly by the user. These additional trips are calculated from the difference between the normal trip rate for a particular employment type and the special generator trip rate as determined from the NCTCOG travel survey of a minimum of one special generator of each type.

External trips are also input directly to the model and added to the "other" trip purpose. These trips are equally divided between productions and attractions based on a percentage of through trips and the amount of special generator attractions in the region.

Balancing

The final step in the trip generation procedure is the balancing of productions and attractions for the study area. This is another area where the process applied in the NCTCOG area differs from typical applications. Typically, productions and attractions have

been balanced using productions as the controlling function; that is, attractions have been adjusted to equal productions for the area under study. In the NCTCOG model, the home based work productions are set equal to the home based work attractions for each income quartile. For example, the total home based work attractions for Income Quartile One is divided by the total home based work productions for Income Quartile One to compute an adjustment factor which is then multiplied times the home based work productions for Income Quartile One for each zone. This is repeated for the attractions and productions in each income quartile. The process for home based non-work, non-home based, and other trip purposes balances the attractions to the productions. For each trip purpose, an adjustment factor is computed by dividing the total productions by the total attractions. This factor is used to adjust the zonal attractions. Note that additional trips input for special generators and external stations are not included in the computations to balance productions and attractions. The final result is that total productions will equal total attractions for each trip purpose.

HOUSTON-GALVESTON (6,27)

Trip generation in the Houston-Galveston area is accomplished primarily by the Houston-Galveston Area Council of Governments (HGAC) working in cooperation with the TxDOT and the Harris County Metropolitan Transit Authority (METRO). The models were developed using the results of a regional travel survey conducted by HGAC during the mid-eighties. The basic structure of the models is very similar to those employed in Dallas-Fort Worth by the NCTCOG. There are, however, some differences which are significant relative to the output and use of the results. HGAC basically applies two models, a trip production model and a trip attraction model. These are described in the following sections.

Trip Production

The model used in the Houston-Galveston area is similar to TRIPCAL4 and the NCTCOG models in that it is also a cross-classification model. Its principle differences are in the classifications used, the input data used to develop the trip rates, and the trip purposes for which trips are generated. The classifications used are income by household

size. Five income ranges are used with five household sizes. Using data from the regional travel survey, trip production rates (person trips per household) were developed for home based work trips, home based school trips, home based shop trips, home based other, and non-home based trips. Total truck-taxi trip productions are input directly to the model for the study area. This total is distributed on a pro-rata basis to the zones using the truck-taxi trip attractions estimated for the zones. External-local and external through trips are also estimated manually and input directly to the model.

The application of the model is also similar to the procedure followed in Dallas-Fort Worth. The households are disaggregated into the income ranges and household size classifications at the zonal level before calculating the trip productions. Using data from the 1980 census, plots were made showing the percentage of households in each household size category (one person, two person, etc. up to five or more persons) versus the average household size at the census tract level. Given the average household size for a zone, these relationships were used to estimate the percentage of households in that zone which are one person, two person, etc. The estimation of the number of households within each income range was accomplished using relationships developed from the 1980 census. Plots were made showing the percentage of households in each income range versus the median income for each census tract. These were then used to estimate the distributions of households (percentage) in each income range for any zone based on the median income for the zone. Once the distribution of households in a zone by household size and income range was calculated, a marginal weighting procedure was used to estimate the number of households in each income range within each household size category. Note that in this procedure the disaggregation was done at the zonal level whereas in Dallas-Fort Worth, it was done at the Regional Analysis Area level and applied consistently to each zone within the RAA. The estimation of trip productions was accomplished by selecting the appropriate trip rate and applying it to the estimated households. The resulting values were summed for each trip purpose over all household sizes and income ranges to compute the total trip productions by trip purpose for each zone.

Trip Attractions

The trip attraction models used in the Houston-Galveston area are distinctly different from those used in TRIPCAL3 and Dallas-Fort Worth. Using data from the regional travel survey conducted by HGAC in the mid-eighties, trip attraction models were developed at sector levels (zones were aggregated up to 47 sectors) using regression analysis. These models were used to identify (based on the analyst's judgment) the primary and secondary causal variables with respect to trip attractions. Using the primary causal variables, additional regression analysis was performed at the sector level to develop models for application at the zonal level. Where the sector level model was different from the zonal level model, the sector level model was used to develop the sector level control total estimate of trip attractions. The sector trip attractions were then allocated to the zonal level using the results of the zonal model application. In certain cases, the sector containing the central business district was isolated and a specific model developed for it. The final trip attraction models and their application level are as follows:

Home Based Work Attractions	
1.24 * Total Employment	Applied to sectors and zones
Home Based Shop Attractions	
0.714 * Households + 1.278 * Retail Employment	Applied to Sectors 2 through 47
0.299 * Retail Employment	Applied to Sector 1 only
3.517 * Retail Employment	Applied to zones in Sectors 2 through 47
0.299 * Retail Employment	Applied to zones in Sector 1 only
Home Based School (Elementary)	
1.332 * (2,3,4,&5+ Person Households)	Applied to sectors
11.661 * Non-University Educational Employment	Applied to zones

Home Based School (University)	
0.744 * University Enrollment	Applied to sectors and zones
Home Based Other Attractions	
1.959 * Households +	Applied to sectors
0.637 * (Office + Other Employment) +	
0.3 * Industrial Employment	
0.9 * Households +	Applied to zones
2.172 * (Office + Other Employment) +	
0.3 * Industrial Employment	
Non-Home Based Attractions	
0.524 * Households + 2.454 * Other Employment +	Applied to Sector 1 and zones
2.593 * Retail Employment +	in Sector 1
0.212 * (Office + Industrial Employment)	
0.740 * Households + 3.464 * Other Employment +	Applied to Sectors 2 through 47
3.659 * Retail Employment +	and to zones in Sectors 2
0.300 * (Office + Industrial Employment)	through 47

The application of the above models is done in two steps. The first is to apply the appropriate model to each sector to develop estimates of the total attractions within each sector by trip purpose. The second step is to apply the appropriate zonal level model to the zones within each sector to develop initial estimates of the attractions for each zone by trip purpose. These initial zonal estimates are then scaled to total the estimated attractions within the sector.

The estimation of truck-taxi attractions is accomplished using trip rates cross-classified by employment type and area type. Only two area types, central business district and urban, are used. These rates are applied to the zonal estimates of employment to develop initial estimates of truck-taxi attractions for each zone. These estimates are then adjusted on a pro-rata basis to force the total attractions to equal the total truck-taxi

productions which were input directly to the model. External-local trips are allocated to zones using non-home based attractions as a relative attraction measure in combination with a gravity model.

Additional Applications

The trip generation models used in Houston-Galveston also include the capability to identify and input trips for special generators. The estimation of trips for these special generators is done using trip rates developed locally by HGAC or rates from other major cities or professional publications (e.g., Institute of Transportation Engineers Trip Generation Manual). The special generators in the Houston-Galveston area were airports, coastal beaches, three major public parks, and major hospital complexes (e.g., the Texas Medical Center).

SUMMARY

The previous discussions have presented descriptions of trip generation procedures being used in practice in urban areas within Texas and urban areas outside of Texas. The state of the art in trip generation at this time is the use of cross-classification models applied to disaggregate data at the zone level for estimating both trip productions and attractions. Within Texas, the trip generation models being used in the Dallas-Fort Worth area and in the Houston-Galveston area are state of the art in terms of estimating trip productions. The Dallas-Fort Worth trip attraction model is also considered state of the art. The models being used in other urban areas in Texas are TRIPCAL3 and TRIPCAL4. TRIPCAL3 may be considered state of the art since it utilizes a cross-classification model. The procedures in TRIPCAL4 are not considered to be state of the art or practice.

While TRIPCAL3 is considered state of the art in terms of the model being used, it may still be improved significantly through the incorporation of additional flexibility and expansion of capability within the program to address the varying conditions which may be encountered in urban areas within Texas.

The procedures used in TRIPCAL4 need to be revised and updated to state of the art. The current model is estimated to over-predict total urban travel by a minimum of 3

percent. The model is estimated to under-predict travel for low income zones by over 20 percent and over-predict travel for high income zones by over 10 percent. The potential negative impact of these under- and overestimates at the zone level are considered significant in the later stages of travel demand forecasting, i.e., trip distribution, mode split, and traffic assignment. The current procedures in TRIPCAL*4* do not account for the impact of changes in average household size on total travel and estimates of travel at the zone level within urban areas.

In summary, a quantum improvement in the accuracy of travel demand estimates and subsequent transportation planning may be achieved in Texas through the development of a new state-of-the-art trip generation program for estimating trip productions and attractions.

VI. RECOMMENDATIONS

Based on the information presented in the previous chapters, a multi-functional trip generation program, TRIPCAL5, is proposed which will provide the Texas Department of Transportation with the flexibility and capability to estimate zonal trip productions and trip attractions using state-of-the-art models commensurate with the level of detail and data available for an urban area. With varying levels of detail and technical support for urban areas within the state of Texas, it is both practical and necessary to structure the trip generation process such that it is able to utilize to the maximum extent possible the data and detail available at the local level. The program will also continue to provide the user with the capability to estimate productions and attractions using the same procedures contained in TRIPCAL3 and TRIPCAL4.

BACKGROUND

The current trip generation practice in the state of Texas is typified by the procedures contained within the modeling programs TRIPCAL3 and TRIPCAL4. These procedures have been significantly revised and modified in the Dallas-Fort Worth and Houston-Galveston urban areas to incorporate updated data elements and more universally accepted trip generation models in use in urban areas in other states. The major changes in the Dallas-Fort Worth and Houston-Galveston areas from the procedures in TRIPCAL3 and TRIPCAL4 are as follows:

1. Cross-classification production models were developed and applied for each trip purpose. This is considered to state of the art and was also the typical method found in the review of modeling procedures employed in other urban areas outside of Texas. The current procedure in TRIPCAL3 and TRIPCAL4 provides for the percentage of trips by trip purpose to be input to the program.
2. Cross-classification production models were developed using disaggregated travel survey data and were applied to disaggregated zonal data in estimating trip productions by zone. This is considered to be state of the art and was

found to be the typical method employed in urban areas outside of Texas. There were, however, urban areas found that used regression models which were calibrated on disaggregate survey data. The current cross-classification production model employed in TRIPCAL4 uses trip rates developed with disaggregated data from travel origin-destination surveys but is applied to zonal aggregated data.

3. The attraction trip models were all different in some aspect. Dallas-Fort Worth used attraction rates in a cross-classification model where the home based work attraction model was a three-way cross-classification, and the other three trip purposes were two-way cross-classification models. Houston-Galveston used a district level regression model to estimate attractions for districts which were then allocated to the zones within the district using different regression models or other means. TRIPCAL3 uses a two-way cross-classification model with attraction trip rates stratified by employment type and households versus generation area. Different rates are applied for different trip purposes. The basic reasons for the differences were data availability. The typical attraction model employed in urban areas outside of Texas was a regression model. This, in most cases, was due primarily to data limitations, e.g., the only data available were from a home travel survey.

4. The Dallas-Fort Worth and Houston-Galveston areas both balanced home based work trips on the attractions and not the productions. This varied somewhat between urban areas outside of Texas. The current procedure in other Texas urban areas is to balance total attractions to total productions for all trip purposes.

5. The number of trip purposes and definitions of those purposes varied widely. Dallas-Fort Worth used four trip purposes (or seven if home based work by income quartile is counted as four different purposes): Houston-Galveston used seven trip purposes. The number of trip purposes used in areas outside of Texas varied from a low of four to a high of seven. In other urban areas in Texas, trip estimates for four trip purposes are usually developed.

6. While the type of models used may have been the same, it was found that the independent variables used for estimating both trip productions and attractions varied considerably. For example, Dallas-Fort Worth used household size (1, 2, 3, 4, 5, and 6 or more) and income quartiles (four groups) for cross-classifying their production trip rates. Houston-Galveston used household size (1, 2, 3, 4, and 5 or more) and income (five income ranges) for cross-classifying their production trip rates. The usual operation of TRIPCAL4 inputs production trip rates cross-classified by auto ownership (0, 1, 2, and 3 or more except for truck-taxi) and median income (low, low-medium, medium, medium-high, and high). Urban areas outside Texas varied concerning the independent variables used in their cross-classification models and regression models.

While the above discussion describes some of the major differences, it does not describe all of the distinctions between the various trip generation models reviewed. It is intended to give a general background and serve as a basis for most of the subsequent recommendations concerning the trip generation modeling system utilized in the state of Texas. Due to the wide variability of models employed in trip generation and the large number of urban areas within Texas with varying levels of data and technical needs, it is proposed that the revised trip generation modeling procedure for the State be as flexible as possible to allow the analyst the ability to fit the appropriate models to individual areas as warranted.

OVERVIEW

It is recommended that distinct trip generation models (both production and attraction) be applied for each trip purpose to be used in the travel demand modeling forecasts. In the event that this is not feasible, the proposed program will allow the user to input the percentage of trips by trip purpose for the area as a whole or stratified by a particular variable (for example, income). The program will allow up to ten trip purposes to be modeled. 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

In general, 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 will be 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. These are recommended because they are the most commonly used variables in trip production models, and research has shown that trips per household increase as income household size increases. Income ranges are recommended because, historically, there have been shifts in income with families earning more money in terms of real dollars. Use of income quartiles or other percentage based groupings do not allow the models to be sensitive enough to account for real shifts in income and the resulting increase in the propensity to travel. An example would be to cross-classify person trips per household by five income ranges and five household sizes. It is also suggested that consideration be given to developing the program to allow the use of a three-way cross-classification model, the third classification having up to four categories. The ability to use a regression type trip production model for trip productions can also be included. This report includes the specifications to include that ability, but these can be removed if desired.

The recommended trip attraction model is a regression type cross-classification model (similar to the one used in TRIPCAL3) 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 type model using trip rates per employee and per

household [are] stratified by area type for up to 24 generation areas. It is referred to as a regression type 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 would normally be based on data from a workplace survey and not developed using statistical regression techniques. This can, however, be an option for the user. This is similar to TRIPCAL3 which allows trip rates by employment type and households for each trip purpose to be input for up to 100 generation areas. This type of model allows the use of current or updated procedures. Regression equations can be developed if data are available, or trip rates can be used based on small sample workplace surveys or "borrowed" from other similar areas. While most areas will not have data available for developing cross-classification trip attraction models, it is still recommended that the capability to use a cross-classification model with trip rates cross-classified by up to four depth categories, six row categories, and six column categories be incorporated into the model. Since many urban areas do not have the data available for developing trip rates in this manner, regression type models will be the most widely used for estimating trip attractions. An option is also included to allow two levels of regression models to be 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.

An option is also included which allows regional control total trip productions and/or trip attractions to be input directly for each trip purpose. It is further recommended that land use activities considered unique within an urban area continue to be handled as a special generator and the estimation of productions and attractions for special generators be accomplished using the same procedures currently in practice. These estimates will be input directly to TRIPCAL5, or the program may be modified at a later date to compute productions and attractions directly for special generators.

Program Overview

The program is proposed to be developed to accomplish the following major functions:

1. Program/model structure delineation
2. Data input
3. Calculation of trip productions
4. Calculation of trip attractions
5. Balancing trip productions and attractions
6. Printing results
7. Production and attraction output for distribution

The following sections describe in more detail the proposed specifications/options for each of the functions.

Program/Model Structure Delineation

The purpose within this function is to establish the parameters and model structure that will be used to estimate the productions and attractions. It will accomplish the following:

1. Input a control record specifying the number of zones, number of sectors, number of generation areas, name of urban area, year of estimates, code indicating if trip models are developed for each trip purpose, code indicating whether auto-driver trips or person trips are being estimated and code indicating whether add-on trip records are to be input. Suggested format is:

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A2	"PS" indicates it is a program control/specification record.
Name	A15	Name of urban area.
Zones	I7	Number of zones to be input and generate productions and attractions.
Sectors	I4	Number of sectors to have data reported in output.

Generation Areas	I4	Number of generation areas to be used in attraction model.
Year	I5	Year for which estimates are being made.
Trip Type	I2	"0" if person trips being estimated; "1" if auto-driver trips.
Purpose Code	I2	"0" indicates distinct trip models used for each trip purpose. "1" indicates percentage by trip purpose will be input by row category. "2" indicates percentage by trip purpose will be input by column category. "3" indicates percentage by trip purpose will be input by depth category.
Add-on Records	I2	"0" if special generator or add-on trip records will not be input. "1" indicates they will be input.
Data Specification	I2	Data specification code. This code is not used.
Median Income	R10	Median income for area.
CPI	R8	Consumer Price Index (1967 as base) for year that income figures are based, i.e., year for which constant dollars are being used.
Truck-Taxi	I2	Default truck-taxi model code (0 = use truck-taxi default model to computer control total for truck-taxi trips; 1 = do not use truck-taxi default model).

2. Input trip purpose/model records. Each record will specify the trip purpose, model to be used, etc. The suggested content and format is:

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A2	"TP" record indicates trip purpose.
Purpose Code	I3	Code number which identifies trip purpose involved. Value can be from 1 to 10.
Name	A20	Name of trip purpose.

Production Model	A1	Value specifies which production model will be used for this trip purpose. See options that follow.
Attraction Model	A1	Value specifies which attraction model will be used for this trip purpose. See options that follow.
Balance Code	A1	"P" indicates attractions are to be balanced to productions for this trip purpose. "A" indicates productions are to be balanced to attractions for this trip purpose.
Flag	A1	Flag which indicates particular trip purpose. "N" indicates non-home based and "T" indicates truck-taxi.
Control Total	R10	Control total of trips for this trip purpose. Trip type is indicated by which type the total trips will be forced to equal, i.e., whether attractions are forced to equal productions or vice versa. Value of 0 implies control total will be calculated from model selected.

3. The production model has the following options:

Recommended Option:	a)	Two-way cross-classification model (For example: Income x Household Size)
Other Options:	b)	Three-way cross-classification model (For example: Income x Household Size x Age of Head of Household)
	c)	Regression model.

If option "a" or "b" is selected (a two-way or three-way cross-classification model), the next (up to three) records should input the number and name of the categories in each classification. The first record input should be the column categories, name and values, up to six. The next record should input the name and value of the row categories. If a three-way classification is to be used, the next record should input the name and values for those categories. Up to three records would then be input in the following formats:

RECORD ONE

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"PCI" identifies record as column information input for production two-way cross-classification model.
Name	A10	Name of column independent variable.
Default Code	A1	Indicates which marginal default model should be used. "N" implies none of the default models should be used which means marginal distributions will be input for each zone; "I" indicates income; "H" indicates household size; and "A" indicates auto ownership.
Number	I1	Value indicates number of columns in cross-classification model.
Column 1	A10	Column 1 data description.
Column 2	A10	Column 2 data description.
::	::	::
::	::	::
::	::	::
Column 6	A10	Column 6 data description.

RECORD TWO

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"PRI" identifies record as row input record for two-way cross-classification production model.
Name	A10	Name of row independent variable in cross-classification table.
Default Code	A1	Indicates which marginal default model should be used, i.e., "N" implies none of the default models should be used which means marginal distributions will be input

		for each zone; "I" indicates income; "H" indicates household size; and "A" indicates auto ownership.
Number	I1	Value indicates number of rows in model.
Row 1	A10	Row 1 data description.
Row 2	A10	Row 2 data description.
::	::	::
::	::	::
::	::	::
Row 6	A10	Row 6 data description.

RECORD THREE - (read only if three-way cross-classification is used)

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"PDI" identifies record as third input record for three-way cross-classification production model.
Name	A10	Name of independent variable for third classification in model.
Default Code	A1	Indicates which marginal default model should be used. "N" implies none of the default models should be used which means marginal distributions will be input for each zone; "I" indicates income; "H" indicates household size; and "A" indicates auto ownership.
Number	I1	Value designates number of categories (maximum of four).
Depth 1	A10	Depth 1 data description.
::	::	::
::	::	::
::	::	::
Depth 4	A10	Depth 4 data description.

If a regression model is selected, the next record read should input the trip purpose code, number of independent variables, value of the constant in the equation, number of the first independent variable (number according to input in "Data Input" routine), coefficient for the first variable, etc., until all the independent variables and their respective coefficients have been input. The dependent variable is assumed to be trip productions per household. Unless it was stipulated in Step 1 that the trip models would not be input for each trip purpose, records will continue to be read in the same format until a record has been read for each trip purpose for which a regression equation was indicated. The following format is used:

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"PMR" identifies record as production regression model record.
Trip Purpose	I2	Trip purpose code which identifies trip purpose for model.
Independent Variables	I3	Number of independent variables in equation (maximum of six).
Constant	R8	Value of equation constant.
Variable No.	I2	Value identifies which input variable is to be used as first independent variable.
Coefficient	R8	Value of coefficient for first independent variable.
Variable No.	I2	Value identifies which input variable is to be used as second independent variable.
Coefficient	R8	Value of coefficient for second independent variable.
::	::	::
::	::	::
::	::	::
Variable No.	I2	Value identifies which input variable is to be used as sixth independent variable.
Coefficient	R8	Value of coefficient for sixth independent variable.

The number of records read in the above format would be determined by the number of trip purposes selected to use a regression type model.

4. The attraction model may be selected from the following options:

Recommended Option:	a)	Regression type cross-classification model with trip rates stratified by area type (up to 24).
Other Options:	b)	Regression model.
	c)	Cross-classification model, two-way or three-way (for example: Employment x Income x Area Type).
	d)	Regression model for districts and regression model for zones within the districts.

If option "a" (regression type cross-classification) is selected, the next record read will input the trip purpose code, the area type code, number of independent variables, number of the first independent variable (number according to input in "Data Input" routine), value of the coefficient (trip rate) associated with that independent variable, etc., until all independent variables and their coefficients have been input. Unless it was indicated in Step 1 that the models were not developed for each trip purpose, records will continue to be read in the same format until a record has been read for each trip purpose (and each area type). Under the recommended option, a typical example would have five records input for each trip purpose, one for each area type (CBD, CBD fringe, urban, suburban, and rural). The coefficients for the independent variables (basic employment, retail employment, service employment, and households) would be the trip rate (trips per employee or trips per household) for that area type and trip purpose. The following format is used:

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"AMC" identifies record as attraction model regression 1 type record.
Trip Purpose	I4	Trip purpose code which identifies trip purpose for model. Value of 1 to 10.

Area Type	I4	Area type code identifies the areas where model will be used.
Independent Variable	I4	Number of independent variables in equation (maximum of six).
Variable No.	I2	Value identifies which input variable is to be used as first independent variable.
Coefficient	R8	Coefficient value (trip rate) for first independent variable.
Variable No.	I2	Value identifies which input variable is to be used as second independent variable.
Coefficient	R8	Coefficient value (trip rate) for second independent variable.
::	::	::
::	::	::
::	::	::
Variable No.	I2	Value identifies which input variable is to be used as sixth independent variable.
Coefficient	R8	Coefficient value (trip rate) for sixth independent variable.

If option "b" (simple regression) is selected, the next record should input the trip purpose code, number of independent variables, value of the constant in the regression equation, number of the first independent variable (number according to input in "Data Input" routine), value of the coefficient associated with that independent variable, etc., until all independent variables and their coefficients have been input. The following format is used:

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"AMR" identifies record as attraction model simple regression record.

Trip Purpose	I2	Trip purpose code which identifies trip purpose for model. Value of 1 to 10.
Independent Variables	I3	Number of independent variables in equation (maximum of six).
Constant	R8	Value of constant in equation.
Variable No.	I2	Value identifies which input variable is to be used as first independent variable.
Coefficient	R8	Value of coefficient for first independent variable.
Variable No.	I2	Value identifies which input variable is to be used as second independent variable.
Coefficient	R8	Value of coefficient for second independent variable.
::	::	::
::	::	::
::	::	::
Variable No.	I2	Value identifies which input variable is to be used as sixth independent variable.
Coefficient	R8	Value of coefficient for sixth independent variable.

If option "c" (cross-classification) is selected, the next record should input the name and number of column categories with values or names for each (up to six). The next record should input the name and number of row categories with values or names for each (up to six) and, if a three-way classification is being used, the next record should input the name and number of depth categories. The format for these records are:

RECORD ONE

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"ACI" identifies record as column information input for attraction two-way cross-classification model.
Name	A10	Name of column independent variable.
Number	I1	Number of columns in cross-classification model.

Column 1	A10	Column 1 data description.
Column 2	A10	Column 2 data description.
::	::	::
::	::	::
::	::	::
Column 6	A10	Column 6 data description.

RECORD TWO

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"ARI" identifies record as row information input for attraction two-way cross-classification model.
Name	A10	Name of row independent variable.
Number	I1	Number of rows in cross-classification model.
Row 1	A10	Row 1 data description.
Row 2	A10	Row 2 data description.
::	::	::
::	::	::
::	::	::
Row 6	A10	Row 6 data description.

RECORD THREE

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"ADI" identifies record as depth information input for attraction three-way cross-classification model.
Name	A10	Name of depth independent variable.
Number	I1	Number of categories (maximum of four).
Depth 1	A10	Depth 1 data description.
::	::	::
::	::	::
::	::	::

Depth 4	A10	Depth 4 data description.

If option "d" (two-tier regression) is selected, the next record should input the districts and the zones within each district. These would have the following format:

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	2	"ED" indicates this is a district-to-zone equals record setting up the zones-to-district equivalencies.
District	I3	District number.
Zones	I5	Zone number. Consecutive zone numbers can be specified by using a dash.
::	::	::
::	::	::
::	::	::
Zone	I5	Zone number. Consecutive numbers can be specified by using a dash.

The next record will input a code identifying the record as a district regression record, trip purpose code, number of independent variables, value of the constant in the equation, number of the first independent variable (number according to input in "Data Input" routine), value of the coefficient associated with that independent variable, etc., until all independent variables and their coefficients have been input. The following format is used:

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"DR" indicates this is a district regression record.
Trip Purpose	I2	Trip purpose code for regression equation.
Independent Variable	I3	Number of independent variables in equation.
Constant	R8	Value of constant in equation.

Variable No.	I2	Value identifies which input variable is to be used as first independent variable.
Coefficient	R8	Value of coefficient for first independent variable.
Variable No.	I2	Value identifies which input variable is to be used as second independent variable.
Coefficient	R8	Value of coefficient for second independent variable.
::	::	::
::	::	::
::	::	::
Variable No.	I2	Value identifies which input variable is to be used as sixth independent variable.
Coefficient	R8	Value of coefficient for sixth independent variable.

Records will continue to be read for each trip purpose indicated. The next record will input a code identifying it as a regression for zones within a district, trip purpose code, number of independent variables, value of the constant in the equation, number of the first independent variable (number according to input in "Data Input" routine), value of the coefficient for that variable, etc., until all independent variables and their coefficients have been input. The following format is used:

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"DZR" indicates this is a district-to-zone regression allocation record.
Trip Purpose	I2	Trip purpose code.
Independent Variables	I3	Number of independent variables in equation.
Constant	R8	Value of constant in equation.
Variable No.	I2	Value identifies which input variable is to be used as the first independent variable.

Coefficient	R8	Value of coefficient for first independent variable.
Variable No.	I2	Value identifies which input variable is to be used as the second independent variable.
Coefficient	R8	Value of coefficient for second independent variable.
::	::	::
::	::	::
::	::	::
Variable No.	I2	Value identifies which input variable is to be used as sixth independent variable.
Coefficient	R8	Value of coefficient for sixth independent variable.

Unless it was indicated in Step 1 that the models were not developed for each trip purpose, records will continue to be read in the same format until records have been read for each trip purpose.

5. If a cross-classification trip production model is selected, the next input to the program will be the regional distribution of households by the cross-classification variables. The number of records input will depend on the cross-classification model selected. If a two-way cross-classification model is selected, up to six records will be input. If a three-way cross-classification model is selected, up to 24 records will be input. Each record will specify the type of record, the depth category, the row category, and the regional percentage of households within each by column category. The format of the record is as follows:

REGIONAL DISTRIBUTION INPUT

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"PCR" indicates record is regional distribution input record.
Depth "i"	I2	Number of depth category in three-way cross-classification. Not used in two-way cross-classification.

Row "j"	I2	Number of row category.
% Households	R5	Percentage of regional households in Depth "i" category, Row "j" category, and Column 1 category.
% Households	R5	Percentage of regional households in Depth "i" category, Row "j" category, and Column 2 category.
::	::	::
::	::	::
::	::	::
% Households	R5	Percentage of regional households in Depth "i" category, Row "j" category, and Column 6 category.

6. The next input to the program is the production trip rates for each trip purpose. The number of input records will depend on the cross-classification model selected. If a two-way cross-classification model is selected, there will be up to six records input for each trip purpose. If a three-way cross-classification model is selected, there will be up to 24 records input for each trip purpose. Each record will have a trip purpose code, depth category code, row category code, and trip rate corresponding to each column category being used. The following format is used:

PRODUCTION TRIP RATE INPUT

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A2	"PT" identifies record as production trip rate record.
Trip Purpose	I2	Trip purpose code.
Depth "i"	I2	Number of depth category in three-way cross-classification. Not used in two-way cross-classification.
Row "j"	I2	Number of row category.
Trip Rate	R8	Trip rate for Depth "i," Row "j" category, and Column 1 category.
Trip Rate	R8	Trip rate for Depth "i," Row "j" category, and Column 2 category.

::	::	::
::	::	::
::	::	::
Trip Rate	R8	Trip rate for Depth "i," Row "j" category, and Column 6 category.

7. If a cross-classification trip attraction model was selected, the next input to the program will be the regional distribution of the units for the attraction trip rates. If a two-way classification model is being used, up to six records will be input. If a three-way classification model is being used, up to 24 records will be input. The records will input the percentage of regional units within each cell of the cross-classification model being used for estimating attractions. The following format is suggested:

ATTRACTION REGIONAL DISTRIBUTION INPUT

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"ACR" indicates record input regional distribution for attraction cross-classification variables.
Depth "i"	I2	Number of depth category in three-way cross-classification. Not used in two-way cross-classification.
Row "j"	I2	Number of row category.
Unit %	R5	Percentage of regional units being used for attraction trip rates within Depth "i," Row "j," and Column 1 category.
Unit %	R5	Percentage of regional units being used for attraction trip rates within Depth "i," Row "j," and Column 2 category.
::	::	::
::	::	::
::	::	::

Unit %	R5	Percentage of regional units being used for attraction trip rates within Depth "i," Row "j," and Column 6 category.

8. The next input is the attraction trip rates for the cross-classification attraction model by trip purpose. If a two-way classification is selected, each trip purpose will have up to six records. If a three-way classification is selected, each trip purpose will have up to 24 records. Each record input will have a trip purpose code; the depth category code; the row category code; and, in respective order, the trip rate for each of the column categories. These records will continue to be read in the same format until trip rate tables have been completed for each trip purpose. The following record format is used:

ATTRACTION TRIP RATE INPUT

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A2	"AT" identifies record as an attraction trip rate record.
Trip Purpose	I2	Trip purpose code.
Depth "i"	I2	Number of depth category in three-way cross-classification. Not used in two-way cross-classification.
Row "j"	I2	Number of row category.
Trip Rate	R8	Trip rate for Depth "i," Row "j" category, and Column 1 category.
Trip Rate	R8	Trip rate for Row "i" category and Column 2 category.
::	::	::
::	::	::
::	::	::
Trip Rate	R8	Trip rate for Row "i" category and Column 6 category.

9. If the purpose code indication was input on the program control/specification record that there would not be district models for each trip purpose, the percentage of trips

by trip purpose will have to be input. The option is given to allow the user to split these percentages by the depth, row, or column category being used in the production cross-classification model. If a straight percentage is being applied (e.g., 30 percent of all trip productions are home based work), the same percentage value would be input for each category specified. The following is the record format to be used:

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"PCT" indicates record is the input percentage breakdown of trips by trip purpose for region.
Category "i"	I2	Value indicates for which category percentages are being read. The program control/specification record has already indicated whether percentages are split by row, column, or depth. This value specifies which category within those classifications is indicated.
% Trips	R4	Percentage of trips for trip purpose 1 by Category "i."
% Trips	R4	Percentage of trips for trip purpose 2 by Category "i."
::	::	::
::	::	::
::	::	::
% Trips	R4	Percentage of trips for trip purpose 10 by Category "i."

Data Input

This function will provide for the input of zonal equivalency relationships, optional user disaggregation models, and the necessary socioeconomic data to calculate the productions and attractions. The first data input are the equivalency relationships, i.e., zone-to-sector equivalencies and zone-to-generation area equivalencies. The following formats are specified:

SECTOR TABLE OF EQUALS

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A2	"ES" indicates this is a zone-to-sector equivalency input record.
Sector	I3	Sector number.
Zones	I5	Zone number of zone within sector; consecutive zone numbers can be specified by using a dash between zone numbers.
::	::	::
::	::	::
::	::	::
Zone	I5	Zone number of zone within sector; consecutive zone numbers can be specified by using a dash between zone numbers.

GENERATION AREA TABLE OF EQUALS

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A2	"EA" indicates this is a zone-to-generation area equivalency input record.
Generation Area	I3	Generation area number.
Zone	I5	Zone number of zone within generation area; consecutive zone numbers can be specified by using a dash between zone numbers.
::	::	::
::	::	::
::	::	::
Zone	I5	Zone number of zone within generation area; consecutive zone numbers can be specified by using a dash between zone numbers.

The second set of items which can be input under this function are the user-specified data for disaggregating households in a zone into marginal distributions for use in the calculation of trip productions using a two-way cross-classification model. The variables which provide this capability are household income, household size, and auto ownership. The user can input disaggregation curves which, given a zone's median income and average household size, will compute the percent of households in that zone which fall within each income range being used, have a household size within each size being used, or have 0, 1, 2, 3 or more autos available. The program will include a default model which estimates these values if the disaggregation curves and marginal distributions are not input for a zone. Technical documentation on developing these disaggregation curves and supporting the default models is provided under a separate document. The following is the format for inputting the disaggregation curves:

INCOME DISAGGREGATION CURVES

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A2	"IC" identifies this as the income disaggregation data input record.
Ratio	R5	Value of ratio of zonal median income to regional median income. Values begin at 0.1 and go up to 2.5 in increments of 0.1, (total of 25 records input).
% Households	R6	Percentage of households in Income Category 1 at that value of the ratio.
% Households	R6	Percentage of households in Income Category 2 at that value of the ratio.
::	::	::
::	::	::
::	::	::
% Households	R6	Percentage of households in Income Category 6 at that value of the ratio.

HOUSEHOLD SIZE DISAGGREGATION CURVES

ITEM	TYPE/LENGTH	DESCRIPTION
Records Type	A2	"HH" indicates record is a household size disaggregation data input record.
Household Size	R5	Value of average household size. Values will range from 1.1 to 3.5 in increments of 0.1, (25 data records will be input).
% Households	R6	Percentage of households in Household Size Category 1 when average household size is value input.
% Households	R6	Percentage of households in Household Size Category 2 when average household size is value input.
::	::	::
::	::	::
::	::	::
% Households	R6	Percentage of households in Household Size Category 6 when average household size is value input.

AUTO OWNERSHIP DISAGGREGATION INPUT

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A2	"AU" indicates this is an auto ownership disaggregation curve data input record.
Income	R6	Median household income. Beginning value of range.
Income	R6	Median household income. Ending value of range. Zero implies last range with all incomes above beginning value.
% Households	R6	Percentage of households with 0 autos owned or available in that range of median household income.
% Households	R6	Percentage of households with 1 auto owned or available in that range of median household income.

% Households	R6	Percentage of households with 2 autos owned or available in that range of median household income.
% Households	R6	Percentage of households with 3 or more autos owned or available in that range of median household income.

It is also necessary when using income and household size in the cross-classification model to input the ranges being used as well as the year that the dollar figures represent, i.e., base year for calculation of constant dollars. The following formats should be used:

INCOME RANGES

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"IR" identifies record as input record for income ranges.
Year	I5	Represents base year income figures.
Range 1	R10	Ending value of income range in Income Category 1.
Range 2	R10	Ending value of income range in Income Category 2. Zero implies last range which includes all values above ending value of previous range.
::	::	::
::	::	::
::	::	::
Range 6	R10	Value of 0 which implies last range which includes all values above ending value of previous range.

HOUSEHOLD SIZE RANGES

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"HS" identifies this household size range data input record.
Range 1	R5	Ending value of household size range in Household Size Category 1.

Range 2	R5	Ending value of household size range in Household Size Category 2. Value of 0 implies last range which will then include all values over the ending value of the previous range.
::	::	::
::	::	::
::	::	::
Range 6	R5	Value of 0 implies last range which will then include all values over the ending value of the previous range.

Data definition records may be input; this identifies the independent variables being input on the second data record. The format for this record is:

VARIABLE NAME RECORD

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"NAM" identifies record as inputting name of independent variable.
Number	I3	Number of independent variable on second data record. Locates variable on record.
Name	A10	Name of independent variable.

The next input will be the socioeconomic data for each zone. Five data records may be input for each zone. The first record for each zone is not optional. The second record is optional but, if included, must be included for each zone. The last three records are optional and may be included for some zones and excluded for others. The first data record input will contain the zone number, zone size (in acres), population in zone, number of households in zone, median household income of zone, total employment in zone, total basic employment in zone, total retail employment in zone, and total service employment in zone. The second data record input will contain additional variables which are to be used in the various models specified. It will contain the zone number and up to eight variables. The third, fourth, and fifth data input records are optional and, if included, will contain zonal

data disaggregated by the categories specified in the cross-classification model. These are the marginal distributions of households by the independent variables being used in the production and/or attraction models. The format of the input data records is as follows:

INPUT DATA RECORD ONE

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"DA1" identifies record as first data input record for a zone.
Zone	I5	Zone number.
Size	R5	Size of zone in acres.
Population	R5	Total population in zone.
Households	R5	Total households in zone.
Household Size	R5	Average household size for zone. If left blank, program will compute and assume it was read in as this variable.
Income	I5	Median household income in zone.
Employment	R5	Total employment in zone. If this is 0, program will compute this value by adding the next three values input.
Basic Employment	R5	Total basic employment in zone.
Retail Employment	R5	Total retail employment in zone.
Service Employment	R5	Total service employment in zone.

INPUT DATA RECORD TWO

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"DA2" identifies record as second data input record for a zone.
Zone	I5	Zone number.
Variable	R9	Value of selected independent variable.
Variable	R9	Value of selected independent variable.
::	::	::

::	::	::
::	::	::

Up to 8 Variables

INPUT DATA RECORD THREE

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"DA3" identifies this as third data input record for a zone.
Zone	I5	Zone number.
Households	R5	Percentage of production unit variable in Column Category 1.
Households	R5	Percentage of production unit variable in Column Category 2.
::	::	::
::	::	::
::	::	::
Households	R5	Percentage of production unit variable in Column Category 6.
Number	R5	Percentage of attraction unit variable in Column Category 1.
Number	R5	Percentage of attraction unit variable in Column Category 2.
::	::	::
::	::	::
::	::	::
Number	R5	Percentage of attraction unit variable in Column Category 6.

INPUT DATA RECORD FOUR

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"DA4" identifies record as fourth data input record for a zone.
Zone	I5	Zone number.
Households	R5	Percentage of production unit variable in Row Category 1.
Households	R5	Percentage of production unit variable in Row Category 2.
::	::	::
::	::	::
::	::	::
Households	R5	Percentage of production unit variable in Row Category 6.
Number	R5	Percentage of attraction unit variable in Attraction Row 1.
Number	R5	Percentage of attraction unit variable in Attraction Row 2.
::	::	::
::	::	::
::	::	::
Number	R5	Percentage of attraction unit variable in Attraction Row 6.

INPUT DATA RECORD FIVE (input only if three-way cross-classification production model used)

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"DA5" identifies record as data input record number 5 for a zone.
Zone	I5	Zone number.

Households	R5	Percentage of production unit variable in Depth 1 category.
::	::	::
Households	R5	Percentage of production unit variable in Depth 4 category.
Number	R5	Percentage of attraction unit variable in attraction Depth 1.
::	::	::
Number	R5	Percentage of attraction unit variable in attraction Depth 4.

The employment data to be input for each zone is proposed to be basic, retail, and service defined according to the following:

TYPE	SIC RANGE	INDUSTRY GROUP
Basic	1000-1499	Mining
	1500-1799	Construction
	2000-3999	Manufacturing
	4000-4999	Transportation, Communications, Public Utilities
	5000-5199	Wholesale Trade
Retail	5200-5999	Retail Trade
Service	6000-6799	Finance, Insurance, Real Estate
	7000-8199	Services
	8200-8299	Education Services
	8300-8999	Services
	9000-9799	Government

Since the recommended production model is a two-way cross-classification model with trip rates cross-classified by household size and income, the program will include the capability to disaggregate the zonal household data into estimates of households for each cell based on the zonal averages, i.e., median household income and average household size.

This will be executed only if disaggregation curves are not input and/or marginal distributions are not input for individual zones. The program will disaggregate the row and column totals into the cell values using an iterative marginal weighting routine which estimates the cell values.

Following the input of the zonal data, the special generator productions and attractions including additional add-on productions and/or attractions will be input. The number of records input will be variable and will stop when no more records are read. The format for this input would be as follows:

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"SGP" indicates record is zonal production input for a special generator. "SGA" indicates record is zonal attraction input for a special generator. "AOP" indicates record is add-on trip production input. "AOA" indicates record is add-on trip attraction input.
Zone	I5	Zone to which trips are to be added.
Trip Purpose	I2	Trip purpose of trips being added.
Trips	I5	Number of trips added for that trip purpose.
Trip Purpose	I2	Trip purpose of trips being added.
Trips	I5	Number of trips added for that trip purpose.
::	::	::
::	::	::
::	::	::
Trip Purpose	I2	Trip purpose of trips being added.
Trips	I5	Number of trips added for that trip purpose.

Information for the special generators that should be included in zonal tabulations is input to the program by the suggested following record:

ITEM	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"SGZ" indicates that the record is a special generator data record.
Zone	I5	Zone number the special generator is located within.
Population	R7	Population of special generator.
Households	R7	Total households in special generator.
Household Size	R7	Average household size in special generator.
Income	R7	Median household income for special generator.
Employment	R7	Total employment in special generator.
Basic	R7	Total basic employment in special generator.
Retail	R7	Total retail employment in special generator.
Service	R7	Total service employment in special generator.

Additional general information about the special generators may be input using the following record format:

TYPE	TYPE/LENGTH	DESCRIPTION
Record Type	A3	"CMT" indicates record is comment record.
Zone	I5	Zone number to which comments apply.
Comments	A71	Comments concerning special generators and/or other conditions noted for that zone.

Calculate Trip Productions

The purpose of this function is to compute the trip productions by trip purpose for each zone. It will be accomplished by applying the trip rates or appropriate regression equation to the disaggregated zonal data, e.g., number of households or employment. Any additional productions input directly will also be added to the appropriate zones in this routine (productions from special generators will not be added at this point).

Calculate Trip Attractions

The purpose of this function is to compute the trip attractions by trip purpose for each zone. It will be accomplished by applying the trip rates or appropriate regression equation to the aggregated zonal data, (number of households or employment). Attractions will also be computed for truck-taxi trips using the model selected earlier in the program and any additional attractions input directly (not including those for special generators) will be added to the appropriate zones.

Balance Trip Productions and Attractions

The purpose of this function is to balance the productions and attractions. The total productions and attractions for each trip purpose will be computed. Based upon the input record which sets up the trip purposes, appropriate scale factors will be calculated and applied to the productions or attractions (depending upon which is set to be the control) for each zone. The productions and attractions for the special generators and any add-on trips will be added to the appropriate zones in this routine. 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.

Print Results

The output from TRIPCAL5 will be user-specified. A control record will be input that will specify the output desired. The following descriptions outline the basic content of the information available as output from TRIPCAL5.

Trip Model Output - This output will print out the production and attraction model specified by the user for each trip purpose. Included in the printout will be the trip rates input if it is a cross-classification model and/or the constant and coefficients input if it is a regression model. Length of this output will be approximately one to two pages per trip purpose.

Equivalency Output - This output will print out the zone-to-sector and zone- to-area type equivalencies. Length of this output will be dependent upon the number of sectors, area types, and zones.

Regional Distribution - This output is available if a cross-classification model is being used. It is simply a printout of the regional distribution input to the program for either/both production and attraction cross-classification models.

Unscaled Results - This output will contain the unscaled productions and attractions for each trip purpose by zone. Length will depend on the number of zones.

Scaling Results - This output will contain the unscaled total productions and attractions with the scaling factors computed and the resulting scaled values.

Aggregate Sector Results - This output can be printed in two forms. The first is a summary by sector. The second is a summary by each zone within each sector. One or both forms may be specified. The information printed will be sector number, zone number (if second form is requested), and final trip productions and attractions by trip purpose.

Aggregate Area Type Results - This output can also be printed in two forms. The first is a summary by area type only. The second is a summary by each zone within each area type. One or both forms may be specified. The information printed will be area number, zone number (if second form is requested), and final trip productions and attractions by trip purpose.

Disaggregate Sector Results - This output contains the disaggregate results printed for each sector. If a cross-classification production model is being used, the output will contain the number of households by category and the unscaled productions by trip purpose for each category (i.e., each cell in the cross-classification matrix). If a cross-classification attraction model is being used, the output will contain the number of attraction units (what was specified by the user) for each category and the resulting unscaled attractions by trip purpose for each category (i.e., each cell within the cross-classification matrix). The productions and attractions by trip purpose are also printed for special generators and any add-on trips input to the program. If regression models are used, the output will be the unscaled productions and attractions by trip purpose.

Disaggregate Area Type Results - This output is the same as that for disaggregate sector results except it is printed for each area type only.

Disaggregate Zonal Results - This output is the same as that for disaggregate sector and area type results except it is printed for each zone only.

Sector Characteristics Summary - This output may be printed in two forms; the first is by sector only and the second is by zone within each sector. The information printed will be general characteristics with results from the trip generation model in various measures. Specifically, the output will contain the sector number, the zone number (if the second form is requested), the sector or zone size, the population, number of dwelling units, average household size, median household income, total employment, employment by type (e.g., basic, service, etc.), autos per household, autos per person, trips per person by trip purpose, and trips per household by trip purpose.

Area Type Characteristics Summary - This output is the same as that for the sector characteristics summary except it is for each area type and/or each zone within each area type.

Zonal Characteristics Summary - This output is the same as that for sector and area type characteristics summary except it is for each zone only.

Zonal Results - This output is simply a printout of the final trip productions and attractions by trip purpose for each zone.

It is anticipated that the above output will be produced in about the same order as described. The reports desired are selected by the user on a data input record. The format for the record is as follows:

Item	Type/Length	Description
Record Type	A3	"TBL" indicates that record is specifying the reports to be printed out.
Report	I5	Number indicates report desired to be printed.
Report	I5	Number indicates report desired to be printed. If preceded by dash, all reports numbered from the preceding report number and this number will be printed.

Report	I5	Number indicates report desired to be printed. If preceded by dash, all reports numbered from the preceding report number and this number will be printed.
Report	I5	Number indicates report desired to be printed. If preceded by dash, all reports numbered from the preceding report number and this number will be printed.
::	::	::
::	::	::
Report	I5	Number indicates report desired to be printed. If preceded by dash, all reports numbered from the preceding report number and this number will be printed.

The following table lists the reports and their respective numbers which can be printed from TRIPCAL5.

Table 72
TRIPCAL5 Output

Table Number	Title of table
1	TRIP MODELS BEING USED
2	ZONE TO SECTOR TABLE OF EQUALS
3	ZONE TO DISTRICT TABLE OF EQUALS
4	ZONE TO AREA TYPE TABLE OF EQUALS
5	REGIONAL DISTRIBUTION
6	UNSCALED RESULTS
7	SCALING FACTOR COMPUTATIONS
8	AGGREGATE PRODUCTIONS AND ATTRACTIONS BY SECTOR
9	AGGREGATE PRODUCTIONS AND ATTRACTIONS BY ZONE WITHIN SECTOR
10	AGGREGATE PRODUCTIONS AND ATTRACTIONS BY AREA TYPE
11	AGGREGATE PRODUCTIONS AND ATTRACTIONS BY ZONE WITHIN AREA TYPE
12	DISAGGREGATE SECTOR RESULTS
13	DISAGGREGATE AREA TYPE RESULTS
14	DISAGGREGATE ZONAL RESULTS
15	STUDY AREA CHARACTERISTICS SUMMARY BY SECTOR
16	STUDY AREA CHARACTERISTICS SUMMARY BY ZONE WITHIN SECTOR
17	STUDY AREA CHARACTERISTICS SUMMARY BY AREA TYPE
18	STUDY AREA CHARACTERISTICS SUMMARY BY ZONE WITHIN AREA TYPE
19	STUDY AREA CHARACTERISTICS SUMMARY BY ZONE
20	FINAL PRODUCTIONS AND ATTRACTIONS
21	SEE USER'S MANUAL FOR THIS DESCRIPTION

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