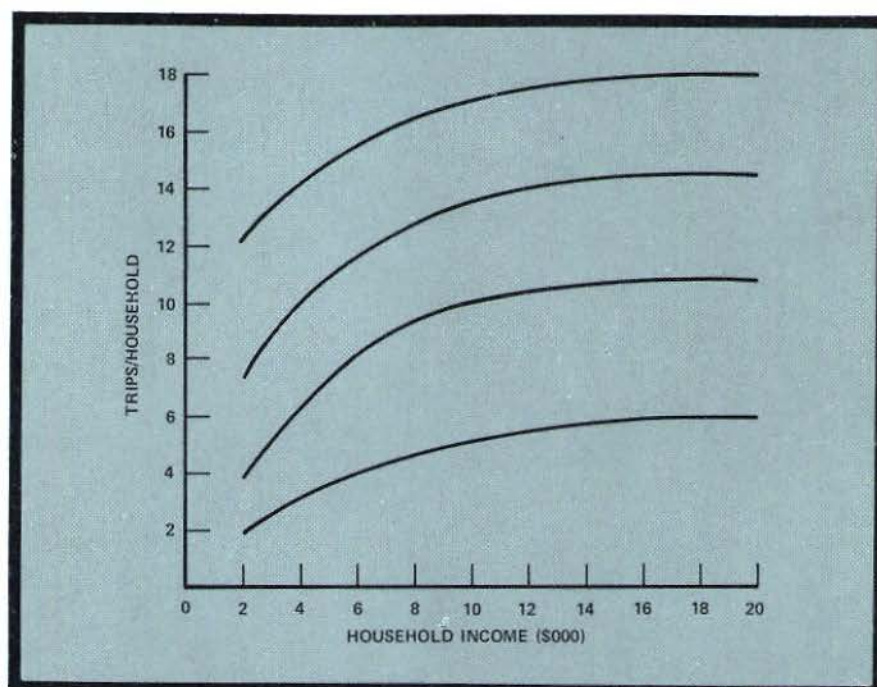


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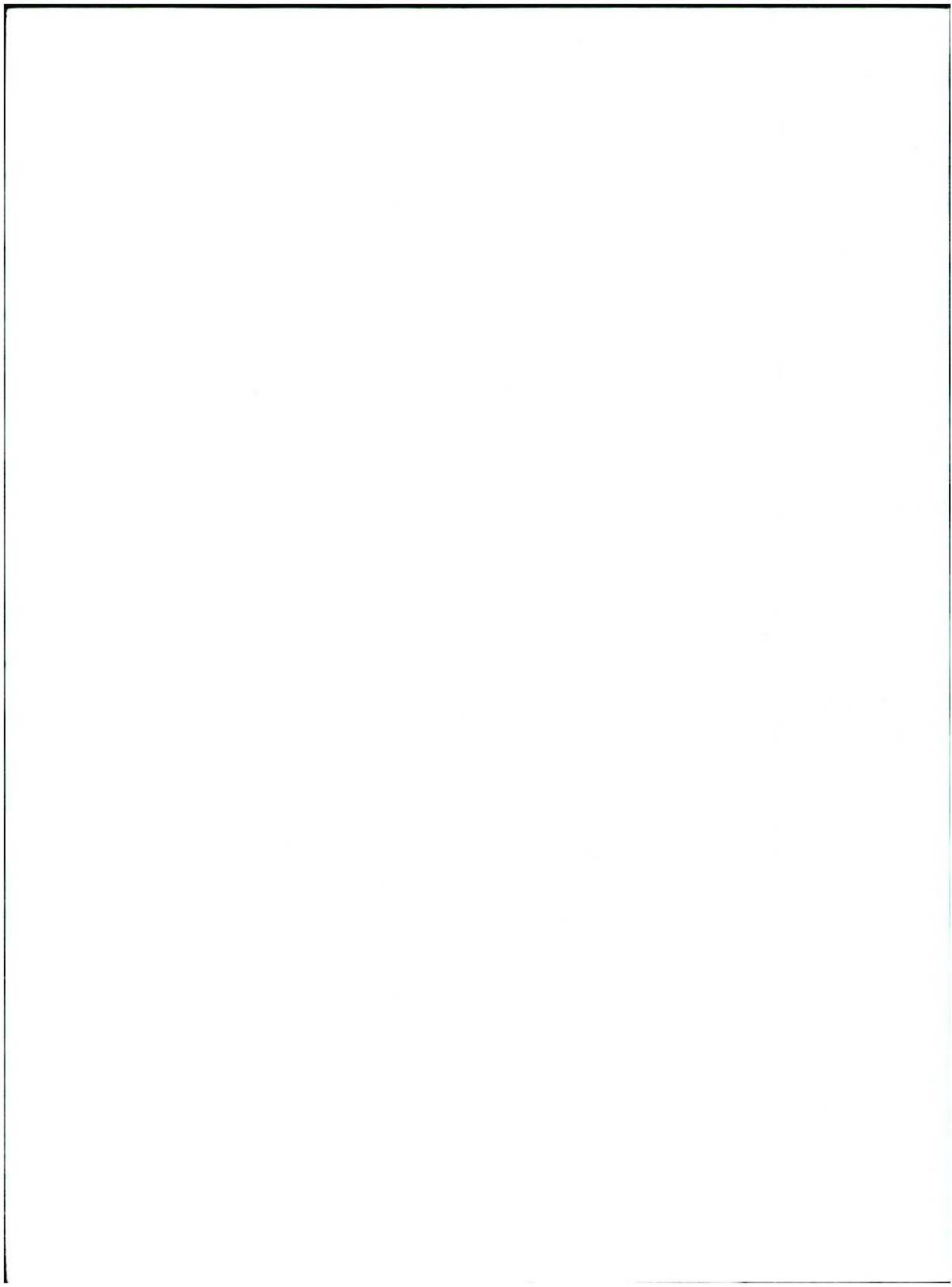
TRIP GENERATION ANALYSIS

August 1975



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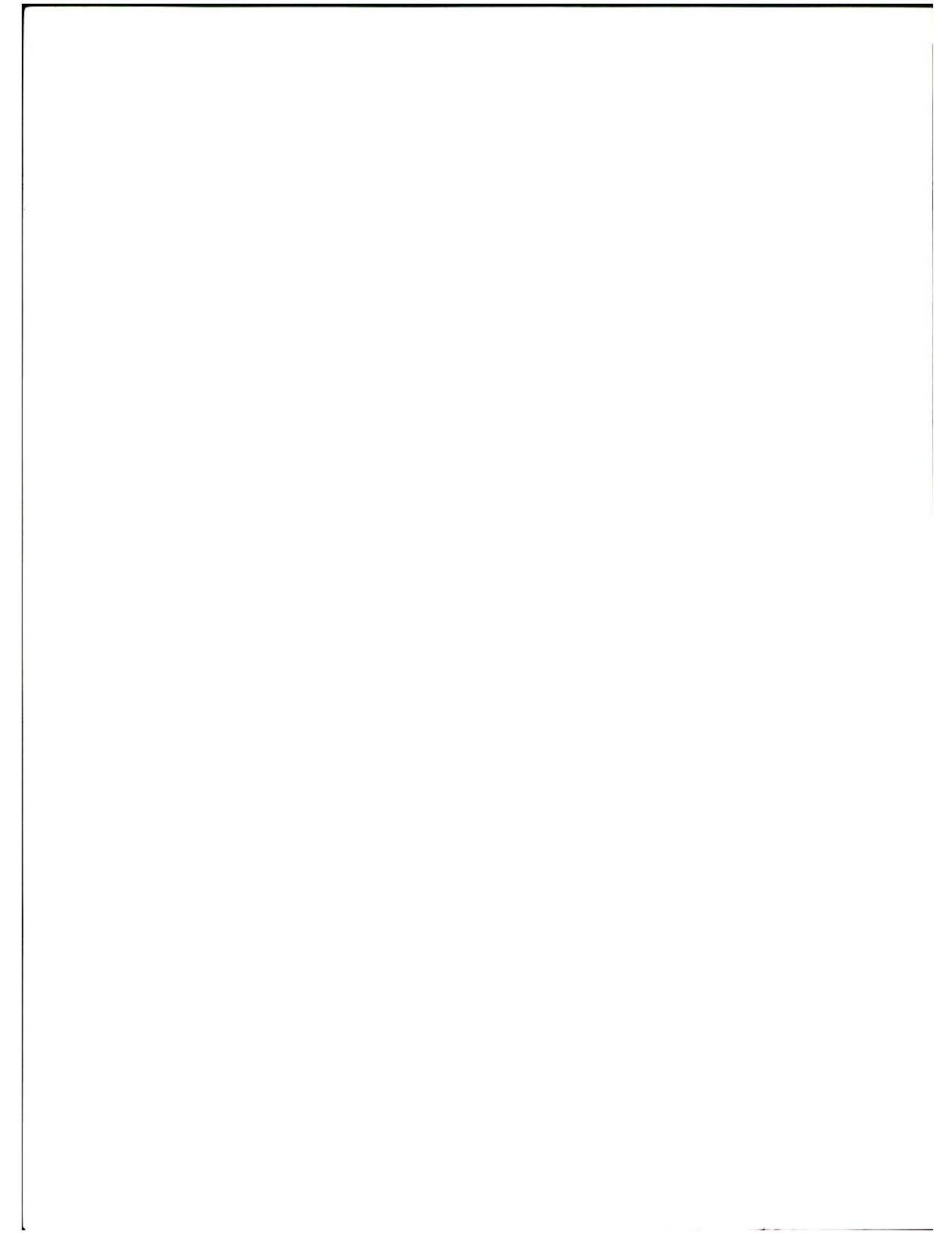
U.S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration
Urban Planning Division



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PREFACE

There is currently a significant amount of work being accomplished relative to travel demand forecasting. Much of this work is aimed toward single models encompassing the current trip generation, trip distribution and mode split model approaches. Most of the activity considers disaggregate model formulations advantageous relative to the current basic use of aggregate analysis. The research activities in demand forecasting are looking towards improved operationally tested models.

For the next few years at least, the currently applied methods for trip generation, trip distribution and modal split will provide the necessary tools for policy planning, alternate systems planning and project planning. A considerable amount of research and development has already taken place in the development of models currently in use and in many cases very specific recommendations can be made relative to approach and values for a particular application.

The purpose of trip generation analysis is to provide the means for relating the number of trips to and from activities in an area to the land use and socio-economic characteristics of the activities measured in terms of land use intensity, character of the activities and location within the urban environment. The study of trip generation attempts to identify and quantify the trip ends related to various urban activity without describing other trip characteristics such as direction, length or duration. Usually, the interest is in trips per average weekday, but may be for weekend or special purpose travel.

Almost all currently applied trip generation analysis can be categorized as described below:

- (1) Relating trip ends to land use and socio-economic characteristics through regression analysis.
- (2) Relating trip ends to land area, floor area or other use measures such as employment through trip rates.

- (3) Classifying trip ends by characteristics of the analysis unit generally referred to as cross-classification analysis.

Although no general theory of trip generation for current application in an operational framework has emerged, enough work has been accomplished to allow the presentation of a recommended approach to trip generation analysis.

The purpose of this document is to provide a step-by-step approach to trip generation analysis which should be pertinent in many current urban studies. The approach is straightforward, is based upon logic and common sense, is more easily monitored and can be updated with more efficient use of survey and secondary source data, is easily understood by the administrator and the public and allows application to the various areal units required for regional, corridor and small area study. The approach is based upon cross classification for residential trip generation and upon rates for non-residential generation.

The procedures and suggestions contained in this manual reflect the current views and ideas of the Urban Planning Division, Office of Highway Planning. Preparation of the text for publication, except for revisions and final editing, was accomplished under contract with the Comsis Corporation, Wheaton, Maryland.

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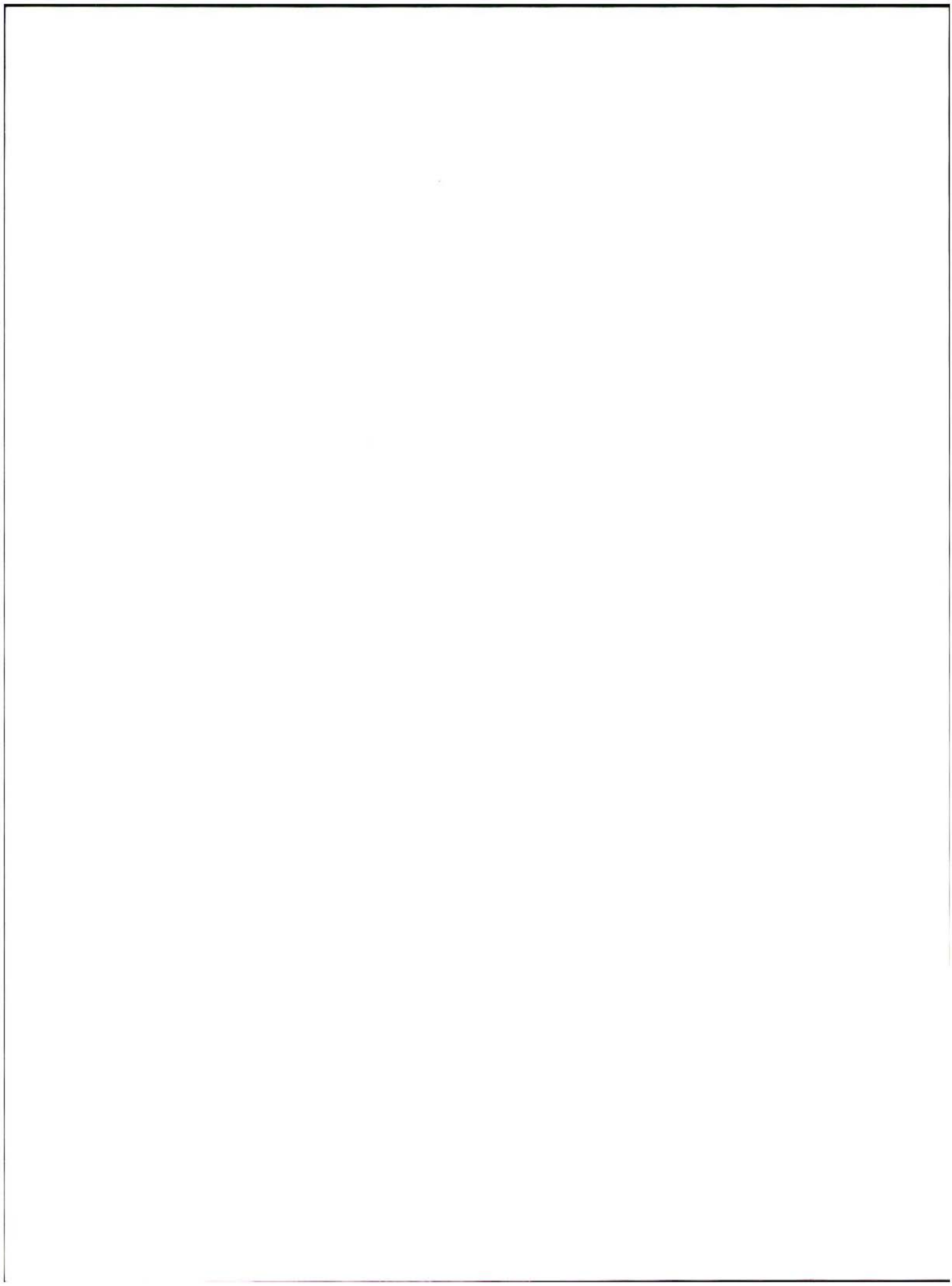
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CHAPTER I INTRODUCTION TO TRIP GENERATION

DEFINITION AND GENERAL DESCRIPTION

Trip generation provides the linkage between land use and travel. Trip generation may be separated into two phases. In the first, an understanding and quantification of the travel-land use linkage is developed. In the second phase, the results of the quantification are applied to forecasted land use characteristics to develop future travel estimates.

For trip generation purposes travel is considered in terms of trip ends. That is, the number of trips. It does not consider their other characteristics such as direction, length or duration. The trips considered are usually those generated for an average weekday but they may also be for weekend travel, for a particular trip purpose, by mode of travel or other stratification required for a specific analysis or forecasting purpose. Trip ends may be in terms of origins and destinations or in terms of productions and attractions dependent upon the purpose of the forecast and the subsequent models to be used for trip distribution and modal choice.

Land use for trip generation purposes is usually described in terms of land use intensity, character of the land use activities, and location within the urban environment. These measures, described in greater detail later in this chapter, are input to trip generation. Initially the land use and travel are linked for some measured current period utilizing techniques such as cross classification, trip rates or regression analysis. These relationships are then utilized and applied to forecasts of land use to develop future travel.

Early travel forecasts utilized the results of origin-destination studies to describe existing travel patterns in the form of tables of trip origin and destination and by "desire lines" to indicate the major trip movements. This data was often extended into the future by some form of extrapolation. In the early 1950's analytical techniques were developed to quantify urban trip volumes in terms of measurable land use and socio-

economic characteristics of the people making trips. Trip generation rates were developed from the O-D surveys and land use data and applied to a land use plan for the forecast year. In the late 1950's and early 1960's regression techniques which developed equations relating trips to land use and socio-economic characteristics found favor and were widely applied. The relative ease with which many variables could be considered often resulted in equations that could not be easily understood, that were often misinterpreted, that could not easily be monitored and updated and that required forecasts of characteristics which could not be forecasted with acceptable degrees of confidence. However, much was accomplished through regression analysis in gaining basic insight into travel and providing background to further development.

In the last few years a shift in emphasis from aggregated zonal analysis utilizing regression procedures to a disaggregated household cross classification approach also often termed category analysis has occurred. This latter work has the advantages of:

- making efficient use of survey information
- being valid in forecasting as well as in the base year
- being easily monitored and updated
- being straightforward and understandable

Sufficient work has already been accomplished in trip generation analysis to allow the presentation of a step-by-step approach for consideration in urban study applications.*

TRIP GENERATION IN TODAY'S TRANSPORTATION PLANNING PROCESS

Regional Study .

Trip generation plays a role in many phases of transportation planning and traffic engineering related activities. The continuing urban transportation planning process depicted in Figure 1 generally is based on a comprehensive study of an urbanized area. The overall technical process includes the major phases of (1) formulation of goals and objectives; (2) organization for the process and the assembling of data; (3) analysis of current conditions including the calibration of models; (4) areawide

*While this publication suggests a simplified approach, alternative methods of trip generation analysis were treated equally in "Guidelines for Trip Generation Analysis" (13).

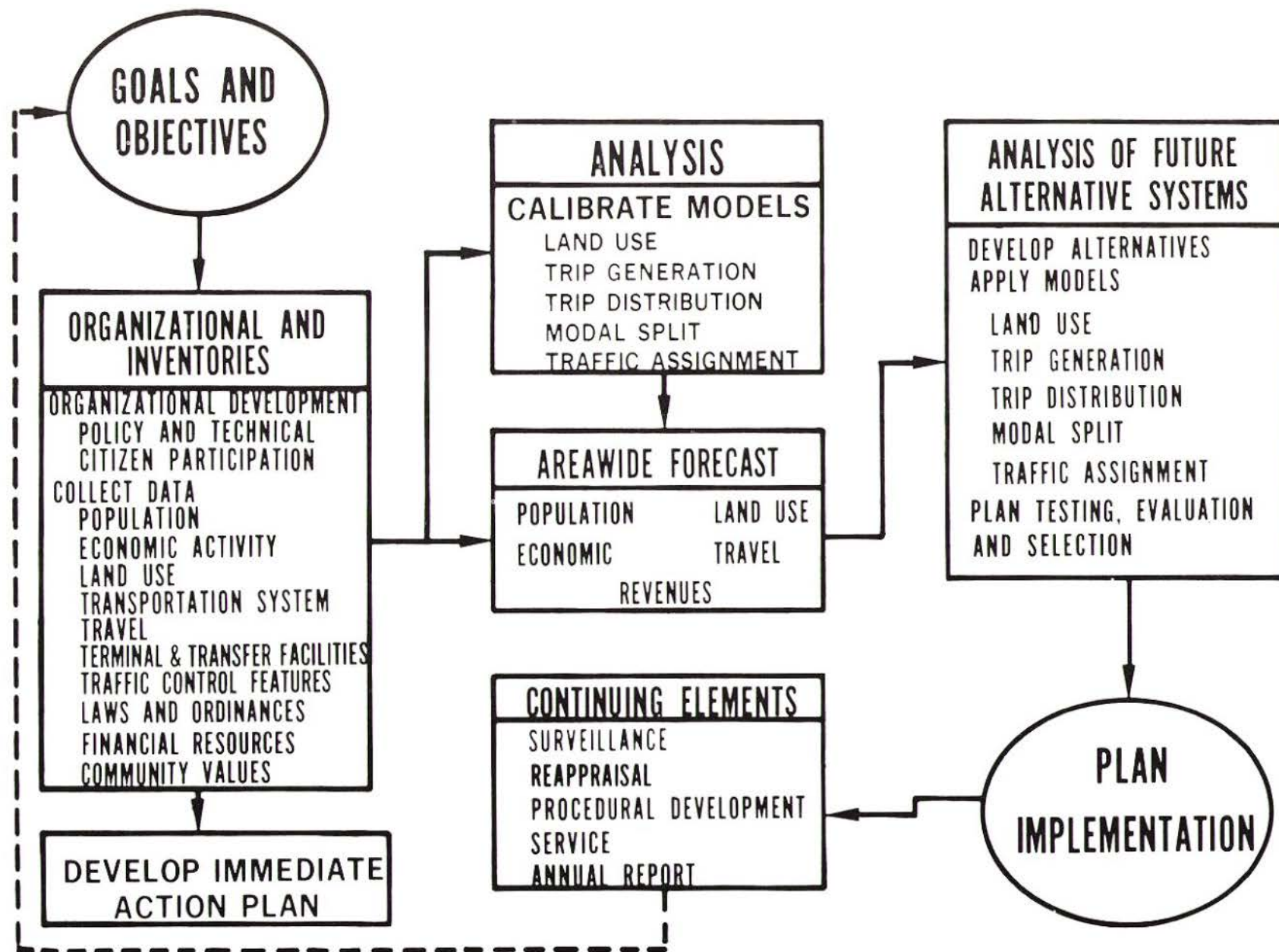


FIGURE I-1
THE CONTINUING URBAN TRANSPORTATION PLANNING PROCESS

forecasts of future conditions; (5) the analysis of future alternative systems; (6) the continuing elements of surveillance, reappraisal, procedural development, service and annual report. The models developed and applied usually include those for land use, trip generation, trip distribution, modal split and traffic assignment. Population and economic studies are used to develop input to land use models in terms of the magnitude of population, employment and other economic characteristics. Land use models are used to determine where the activities will be located throughout the region and provide input to trip generation models which are used to predict the number of trips the activities will generate. Trip distribution models take the output of trips to and from the land use activities produced by the trip generation model and determine their spatial orientation-or where the trips will go. These trip interchanges are usually input to a modal choice model which determines how much of each trip interchange will be by each of the modes considered. The assignment process then determines the loading of the highway and mass transportation facility segments resulting from the trip interchange desires.

For regional study, the broad range of land use and related social-economic characteristics must be considered in the base year trip generation analysis and in application of the trip generation relationships to forecasted activities. Trip generation analysis usually is stratified into two components:

- trip generation at the household level
- trip generation at the non-residential level

At the household level, characteristics usually considered for trip generation include car ownership, income, density of development and household size. The household generation results generally are used as a "control" on the total of non-residential generation which usually considers characteristics such as employment, type of land use (retail, office, etc.), and type of area (CBD, suburban, shopping center, etc.). "Special generators" such as the airports and stadiums are usually separately handled from the rest of the analysis because of their unique travel generating characteristics.

Of necessity, regional trip generation analysis is broad in nature considering the full range of travel and land use activities. The trips analyzed are usually for an average weekday with statistics developed on a zonal level for input to subsequent models.

The continuing transportation planning process requires adequate monitoring and updating of trip generation relationships when sufficient change warrants. Since trip generation provides the linkage between land use and travel, it is important that the relationships established be evaluated periodically for stability and applicability. Likewise, changes in land use and social-economic characteristics must be monitored on a continuing basis to evaluate changes in trip generation from the most current forecasts. To accomplish this, selected land use and social-economic data must be maintained through an on-going surveillance program to assure the ability to evaluate, and if necessary, update previous forecasts through a routine review process.

Corridor and Small Area Study

The transportation planning process has seen a shift in emphasis from long range plan development to short range planning and the evaluation of specific corridor needs, special detailed area study and other service functions. There has been a demonstrated need for the incorporation of policy sensitive factors in the estimation process with the corresponding need to increase the sensitivity of the modeling process to "current" problems. Examples of these more current problems are:

- Evaluation of transportation demand resulting from redevelopment or rezoning an area within a city.
- Determining the impact of a new office building complex on the surrounding system.
- Detailed evaluation of alternate highway configurations, ramp spacing locations, etc.
- Evaluation of alternate modes for a heavy demand corridor.

There has been considerable study of sub-areas and corridors in the past, generally based upon regional level analysis. As the shift to shorter range detailed area study progresses there will, of necessity, be requirements for trip generation at a more detailed level of application. Much of the increased interest in small area detailed study appears to be from counties, cities and towns within regional transportation study boundaries.

There is much interest at this level of government to study in detail the transportation implication of the regional systems being developed in their areas. Many regional studies have already geared up to support these local applications through providing data, computer support, and technical know-how.

Trip generation analysis for corridor planning must be accomplished at a finer level of detail than generally used for regional study. This is based upon the requirement for traffic assignments to be made to more detailed networks utilizing smaller zones. The choice of technique used for trip generation on the regionwide basis has an impact in corridor and sub-area study. Generation analysis at a zonal level for the residential analysis will usually result in problems in application to zone sizes different from the zone sizes used for relationship development, especially when regression techniques are used. Disaggregate analysis such as that accomplished with cross-classification at the household level will produce results which can be applied at any level for which land use and related characteristics can be developed. Likewise, at the non-residential end, sufficient disaggregation is desirable to allow a detailed accounting for the specialized land uses in the area of study. Usually, a rate approach with specialized handling of major generators can provide the required level of detail. It has been found that a high proportion of trips in an area are attracted to a small portion of the land. The following sections discuss special generators and new development evaluation.

Special Generators

Regionwide trip generation analysis must of necessity be somewhat general in the treatment of the wide diversity of land uses in an urbanized area. There

are specific generators which are of sufficient size and perhaps unique in their trip generation characteristics to warrant special consideration in the trip generation analysis and forecasts. Such generators might include airports, sports stadiums, hospitals, army bases, and large regional shopping centers. These land uses are generally handled separately from the regionwide analysis, and the results merged together prior to trip distribution in the forecasting process. In addition to the development of trip generation rates for specific sites for merging into regional forecasts of travel, site analysis is of considerable use in the assessment of impacts of new developments on the current transportation system and in the determination of improvements to the highway and mass transit system to serve new developments on a short range basis. This use is further discussed in the next section.

Most trip generation analysis for regionwide application has relied on trip information collected in a home interview survey with the land use and non-residential socio-economic characteristics obtained from field surveys and secondary sources. For example, work trip generation at the work place is usually based upon employment, with the trips accumulated at the work place from a sample survey collected at the home. There have been studies which have supported this approach and others which have recommended that site collected trip data is more appropriate for such analysis. For regionwide analysis aimed at total systems planning, the home interview survey data should be sufficient for analysis at the non-home end. Where appropriate, special sites should be evaluated through trip data collected at the site. For impact analysis, corridor and small area studies, site analysis and the other phases of the continuing planning process, better information on the generation of travel can be obtained by collecting both trip and land use information at the site rather than relying on home interview data. Such an approach can be established as a continuous monitoring process possibly eliminating the need for additional home interview data.

Major generators are relatively few in number in most urbanized areas. Concentrating data collection and analysis on the few major generators, should provide more accurate estimates than using the same resources to thinly cover all areas. It is recommended that the

base trip data used for trip generation (usually home interview data) be supplemented with more specific information for the few sites requiring more detailed data and analysis. In base year model development site analysis is useful to improve the accuracy of non-residential trip generation estimates. In the continuing phases of regionwide study collection of travel information at selected sites can supply much of the necessary update information. Such data with perhaps very small home interview sample updates can provide the framework for the continuing trip generation analysis. Consideration should also be given to "borrowing" the needed rates. See the next section for references.

New Development Evaluation

Trip generation is important to the traffic engineer in considering the impact of a new office complex, shopping center or residential development. Of interest at this level is the amount of traffic a new development will generate, the necessary upgrading or improvement to existing facilities, traffic control requirements and any new connecting facilities required. For these purposes trip generation is obviously most pertinent relative to traffic at a specific land use activity. The range of specific activities might include:

Shopping centers

- Regional Shopping Centers
- Community Shopping Centers
- Neighborhood Shopping Centers
- Free Standing Discount Stores
- Strip Commercial Areas

Residential developments

- Subdivisions
- Apartments
- Mobile home parks
- High rise apartments
- Retirement communities

Industrial developments

- Industrial parks
- Warehousing
- General Industry

Office Buildings

- Doctors Clinics
- Trucks and Rail Terminals
- Hospitals

Colleges
High Schools
Elementary Schools
Civic Centers
Libraries
Airports
Theatres
Hotels
Parks

Data for this type of trip generation analysis is also more specific than required for regionwide transportation forecasting. Sites are chosen for study which are expected to be representative of the proposed development. Traffic counts are made at all entrances to and exits from the sites chosen for analysis. These are usually made over perhaps a week. In addition to counts, background information on the site is compiled in order to develop the required traffic generation rates. This background data might include dwelling units, aircraft off and on passenger loadings, number of employees, residing doctors, etc. Two rather complete documents containing trip generation rates by specific site types for regions of the United States are: Volume XV Travel Generation prepared by the National Association of County Engineers and Trip Generation by Land Use Part I, A Summary of Studies Conducted prepared by the Maricopa Association of Governments (1,2). An Institute of Traffic Engineers Technical Committee is currently compiling and analyzing rates from studies around the country in an on going study and results should be available mid 1975 (16). Rates from sources such as these can be very useful in providing a ready reference to estimating the probable impact of a proposed activity.

BASIC TRIP GENERATION CONSIDERATIONS

The goal of trip generation model development is to establish a functional relationship between travel and the land use and socio-economic characteristics of the units to and from which the travel is made. A causal relationship is desired in which the following types of questions are answered:

- What is the difference in trip making between a family living in a high rise apartment close to the central business district and a similar family living in a single family home in the suburbs?
- What is the difference in trips to a 50 store shopping center serving a suburban area as compared to 50 stores of a similar size and nature located in a central business area?

Questions of the above nature can be considered in terms of intensity of land use, the character of the land use and its location within the urban environment.

Intensity of Land Use

Intensity of land use is the amount of activity to be found in a given areal unit (i.e. zone) and is usually stated in terms of a density measure such as employees per square foot of floor area or acre of some specific land use category, or dwelling units per acre. As an example, the number of trips per dwelling unit generally decreases as the number of dwelling units per residential acre increases. High rise apartments (dense) and other dense residential developments are usually within walking distance of many services, thus alleviating the need for a vehicular trip. When residential density is low (perhaps less than 10 dwelling units per acre) trip rates are high since almost all trips must be made by vehicle.

Character of Land Use

Land use intensity measures are usually not sufficient in themselves for trip generation relationship development. There is additional variation in travel that is accounted for by variables that may be termed the "character" of land use. On a household level, character is expressed in socio-economic terms such as family income and car ownership. With all other conditions the same, families with higher incomes generally own more automobiles and make more trips. Low income families often own no cars, rely on public transportation and walking and thus exhibit low vehicular trip making potential. The higher trip making families usually show increases in shopping and social-recreational trips with trips for work remaining relatively stable.

For non-residential land uses character is usually reflected in the type of activity (e.g., manufacturing, retail, commercial).

Location of Land Use Activity

This factor relates to the spatial distribution of land uses and land use activities within a study area. The location of residential land is important as may be shown by the higher trip rates of a high rise complex in the suburbs versus rates for a similar complex in

the CBD. Likewise, a department store in the CBD with the same floor space, number of customers, same merchandise, etc., as one in the suburbs would have a lower "trip" generation rate since many customers walk to the store.

It is difficult to separate the individual effects of intensity, character, and location. Each type of variable explains some of the variation in trip making. These types of variables are used in trip generation model development regardless of the type of analysis used--cross-classification, regression analysis or rate development.

Procedures for Trip Generation

Cross-classification is a technique in which the change in one variable (trips) can be measured when the changes in two or more other variables (land use-socio-economic) are accounted for. Cross classification is not heavily dependent upon assumed distributions of the underlying data and, as such, is some times referred to as a "nonparametric" or distribution free technique. Basically, the technique stratifies "n" independent variables into two or more appropriate groups, creating an n-dimensional matrix. Observations on the dependent variable are then allocated to the cells of the matrix, based on values of the several independent variables and then averaged.

The land activity rate approach is based upon the development of rates in which trips are related to land use characteristics reflecting the character, location and intensity of land use. The method may also be considered a type of cross-classification analysis.

Non-residential trip generation is usually based upon an initial stratification of trip data by trip purpose and attraction variables considered most pertinent. For example, work trip rates may be based upon total employment, school trips on school enrollment and shop trips on retail sales. The rates should further be stratified by land use density or categories within an activity type (e.g., regional shopping center, CBD or strip commercial). The rates developed are strictly ratios between trips and the variable chosen such as trips/employee or trips/student. The data used is usually aggregate data summarized to some multizonal system.

Details of regression analysis can be found in "Guidelines for Trip Generation Analysis" (13). In summary, the regression process consists of developing equations in which trips or a trip rate (i.e., trips/household) is related to independent variables which explain the variation in the dependent variable (trips or trip rate). The equations are usually developed by trip purpose and generally are based on data aggregated to the zone level as observations. Although regression is a linear technique fitting straight lines through data, transformations of variables into log functions, taking reciprocals etc., can be made resulting in curvilinear representations.

The important statistics used in evaluating the equations developed include: the multiple correlation coefficient which indicates the degree of association between the independent and dependent variables in the equation; and the standard error of estimate which indicates the degree of variation on the data about the regression line established. A statistics text should be referred to if further detail on regression and correlation analysis is required (3).

Regression analysis has been an important tool in trip generation analysis. A wealth of understanding of travel has resulted from application of the technique and most transportation studies undertaken in the 1960's relied on the technique. The procedure has good applicability to some current planning problems which will be discussed later in this document. However, based upon the regression analysis of the past and current work using cross-classification and rate analysis, it appears that more efficient and straightforward trip generation procedures can now be recommended.

Data Sources

The basic data source for trip generation analysis has been the home interview survey. Within this one survey most, if not all, of both the travel and land use-socio economic factors can be obtained for relationship development at the residential end. It is at the residential end that the home interview survey is most useful since it is here that the sample is selected, data collected and the survey is most accurate. Non-residential trips may be accumulated from the home interview survey and related to non-residential land use characteristics. The trips to this land from the home interview are less stable since the accumulation at the non-home end is a rare attribute with respect to each dwelling unit within a study area. It is expected, however, that for general land uses such as office buildings, the accumulations from a home-interview survey are suitable.

Other sources should, however, be considered and used where desirable. For example, special surveys of transit travel, i.e. on board surveys, should be considered to supplement the dwelling unit survey when samples of transit trips are scarce. Special generators should be studied utilizing on the ground surveys where actual counts are made of trips to the generator.

Forecasting Land Use-Socio Economic Characteristics

It must be kept in mind that the purpose of the trip generation estimating procedure is to forecast future travel based upon forecasts of land use and socio-economic characteristics. The trip generation estimating procedure is therefore, only as good as the quality of the future estimates of land use and socio-economic characteristics. The analyst should be sure not to become so involved in the analytical techniques used for developing the trip generation relationships that the goal of meaningful forecasts is lost. Great care must be exercised in the selection of characteristics to include in the relationships developed, keeping in mind the two important factors of: a) ability to forecast; b) the contribution provided in the trip generation relationship. These are sometimes at odds and a careful evaluation is required.

Some other factors to be considered are: an evaluation of the trip growth rates as expressed by application of future land use and socio-economic characteristics for reasonableness; the development of control totals on an area wide basis for trip production and attraction to allow evaluation of possible changes in trip generation characteristics or further analysis of land use.

The land use and socio-economic characteristics to be included in the relationships developed should reflect changing conditions. For example, dwelling units per acre or total dwelling units for the analysis unit might be chosen rather than net residential acreage in order to reflect changing intensity.

Land use and social-economic forecasting for transportation planning is usually a two step process in which total study area or regional forecasts are first made for the entire area for characteristics such as population, employment, income and car ownership,

and the areawide forecasts are then allocated to small areas (i.e., zones) within the area. Common methods for population forecasts for an entire area include trend based methods, ratio methods (based on relationships of population growth in one area to that of other areas) and component methods (based on analyses of net migration and natural population increase). Economic activities projections have been based on trend line projection, input-output models, sector analysis, etc.

In allocating regional forecasts to sub-areas a number of models have been developed. Most areas have used and still use judgement or trend analysis. Of the land use models currently in use, residential models are the most advanced.

A discussion of the several models finding application in land use forecasting is contained in the Federal Highway administration report An Introduction to Urban Development Models and Their Use in Urban Transportation Planning (4).

FUTURE DIRECTION IN TRAVEL DEMAND FORECASTING

Behavioral Disaggregate Approach

A considerable amount of research and application of techniques has been undertaken over the last decade in travel demand forecasting. The current research and direction in demand forecasting should result in considerable improvement in forecasting. This section will describe some of the current thinking in the area of improved travel demand forecasting techniques.

The basic difference between aggregate and disaggregate estimation generally is in data efficiency. An aggregate model is usually based upon home interview origin destination data that have been aggregated into units (e.g., zones) and average values developed as parameters for model development. Disaggregate modelling relies on samples over a range of household types and travel behavior and uses these observations directly (without aggregation) for model calibration.

The advantages of behavioral disaggregate models include:

- savings in data required to calibrate models

- transferability to different situations such as regional analysis and detailed corridor analysis
- transferability between cities
- ability to express non-linear relationships which are often lost in the case of aggregate analysis
- ability of more rapid data evaluation and analysis and development of relationships in a more timely fashion
- more easily understood
- more efficient monitoring and updating

In a behavioral disaggregate model approach to trip generation, observations of the behavior of individuals (households) are used directly for estimation. This is in contrast to the aggregate approach which has generally been used (zonal estimates) where observations for households are combined and then used for estimation. Behavioral models are formulations in which estimation "is directed at capturing elements of travel makers' decision processes and forecasting becomes an application of the derived parameters to new sets of information about the independent variables."

In the regression approach to trip generation widely used in the past, hypotheses about the association between socio-economic variables and trip making are compared with regression results to indicate the validity of the developed model. Statistical goodness-of-fit measures are used to measure goodness of fit in an effort to provide a close replication of base year data.

Behavioral models attempt to replicate portions of the traveller's decision making process. These decisions may either have a significant impact on travel choice or may be relevant to some specific issue(s) which must be addressed by the model forecasts.

Travel Demand Models

Current transportation planning models usually consist of a sequential set of steps from trip generation through trip distribution, modal split and traffic assignment. The formulation of models is associative in that for trip generation as an example, hypotheses concerning association between travel and land use and

socio-economic variables are generally compared through regression. Goodness-of-fit statistics are used in trying to provide a replication of base year data under the assumption that similar fits are obtained in future year application. The current models are usually somewhat choice abstract in that attributes of the transportation system are handled independently of a given mode's attributes. The analysis is usually of an aggregate nature in that model development is based upon zonal averages of travel and land use characteristics. The models currently used are generally deterministic in that they output "single value" predictions rather than predicting each individual's probability of choosing a destination, mode, etc. (probabilistic) (5).

Within the last few years there has been increasing activity in the developing of overall demand models incorporating trip generation, trip distribution and modal split into a single estimation process. It appears that much future research and development will be aimed at total-demand models. These direct demand models tend to be behavioral in that the model includes traveler decision processes which have a significant impact on travel choices and/or are relevant to specific issues which must be addressed by the model forecasts. These next generation models may be sequential or simultaneous in nature considering a number of decisions such as whether or not a trip is to be made, which destination to travel to, which mode to select and what path to take. The models will tend to be disaggregate in nature and will tend toward probabilistic structures in which each individual's probability of taking a trip, selecting a mode, selecting a destination, etc., will be considered. The models will also tend toward choice specific representations in which specific attributes of the transportation mode(s) being considered are represented.

A conference conducted jointly by the Highway Research Board and the U.S. Department of Transportation at Williamsburg, Virginia in December 1972, addressed the entire area of urban travel demand forecasting. The findings of the conference were (6):

- travel forecasts are required for informed transportation decision-making

- improvements are needed
- information is now available that can be used to achieve immediate improvements in operational capabilities (approximately in a 1-3 year time frame)
- a repertory of improved methods should be developed
- substantial improvements in forecasting capabilities can be achieved in the future (perhaps in a 5-10 year time frame)
- improved information dissemination and training are needed

There is no question that improvements in demand forecasting will be continuously made. Much of the change is probably far enough off in the future to discourage serious consideration in practical application over the next few years. The sequential application of trip generation, trip distribution, mode choice and traffic assignment will still provide the needed tools for some years to come. However, newer improved methods which can be implemented within this modelling framework deserve strong consideration. Disaggregate trip generation techniques using cross classification analysis can be applied with today's methodology and provide significant advantages over aggregate methods. For this reason, use of the approach deserves serious consideration by the transportation planner.

The purpose of this chapter is to provide a summary of the current state of the art in trip generation as well as probable future direction. The next chapter will provide the details of a simplified approach to trip generation analysis.

CHAPTER II

A RECOMMENDED APPROACH TO TRIP GENERATION

The purpose of this chapter is to describe in detail a recommended approach to trip generation. This recommendation is based upon the considerable amount of research and application in the area of trip generation over the last fifteen years. It is believed that this past work provides the basis for the presentation of a simple, efficient approach. The approach allows incorporation of policy sensitive factors and at the same time allows development and application in a relatively short time period and at a lesser cost than previously applied methods.

This procedure is presented as a workable, tested trip generation analysis method which will help reduce the expenditure of planning resources. Other tested options are available, such as regression analysis and cross-classification employing different independent variables than those recommended here.

This chapter will describe the general approach and advantages of the approach, describe the development of a cross classification matrix, provide examples of the results of applying the recommended approach in some selected areas and describe the application of the developed relationships.

GENERAL FORECASTING APPROACH

Summary of Procedure

The approach for forecasting is based upon use of cross classification analysis for residential trip generation and trip rates and some modified cross classification for non-residential trip generation. The process is based upon developing trip productions and trip attractions as generally used for input to the gravity model trip distribution process. Other trip end values such as origins and destinations may be used with only slight variations necessary to the described process.

The approach is based upon a control of total trips at the home end. The amount of home end travel generated is a function of the number of households and the household characteristics of income and car ownership. This residential trip generation analysis is based upon two basic relationships.

The first relates the percentage of households with 0, 1, 2 and 3 or more autos to household income. The second relationship relates person trips per household to car ownership and income. Density of households is also a suggested variable.

At the non-home end, a distribution index is developed based upon land use characteristics. The recommended variables are the number of employees by employment category by type of land use, school enrollment and households. Total regionwide trips by purpose from an O-D survey are accumulated by land use activity type (e.g., residential, school, retail, etc.). The trips are then related to an indicator of the intensity of the type of activity such as trips/retail employee.

Advantages of Approach

The attributes of the above approach, which are attributes any good modelling procedure should have include:

- Ease of understanding-government officials and the public can easily grasp the idea of trips as related to household characteristics and rates expressed in terms of trips per employee etc. This can be contrasted with regression equations where one must try to understand interrelationships, constants, factors, etc.
- Efficient use of data - sufficient information for the residential generation development is available in O-D surveys, and if no current survey is available, a small specially designed stratified sample survey will provide sufficient data (6). For trip attractions, employment and population characteristics are all that are necessary. Site analysis may be used to supplement available data.
- Easily monitored and updated - the form of the relationship allows monitoring the trip rates through small sample surveys and site analysis to check particular trip rates. When sufficient change is indicated a larger updating effort might be undertaken.
- The process is valid in forecasting as well as in base year accuracy measures.
- The process can be made policy sensitive by introducing factors representing the relevant issues into the cross classification procedure. For example, one can assess the impact of differing population density levels through the stratification of the trip rates by income, car ownership and density . Also, auto saturation levels can be evaluated and introduced as a policy issue.

- Application at differing study levels-since the approach is based upon household level data for the residential generation and type of land use on the attraction end, the rates developed should be applicable to any areal level of study. The rates developed may be applied to districts, zones, subzones, for regional study, corridor study, new development evaluations, etc.
- Transferability between areas-since the analysis is based upon household data at the production end, the variables used for stratification should allow application in other areas. In effect, it is easier to synthesize trip generation by use of a cross classification approach through its transferability between different cities. Income and auto ownership have been found to be strong indicators of travel. The relationship seems to be stable from area to area so that synthesis is possible.
- Use of census data - the socio-economic data used for the residential trip generation models are covered through established census surveys. Only the results of small sample surveys would be required to supplement the Census data.

Examples of Developing Rates

This section will provide examples illustrating the development of a cross classification matrix for trip production at the household and the development of rates for shopping trips at the attraction end. The purpose here is to describe the process for rate development. Detail discussion of the process for developing total production, trip purpose, mode, car ownership and attraction relationships are provided in subsequent sections of this chapter. The last section of the chapter will describe application of the procedure to a future forecast.*

The first example to be described is for the development of trips per household stratified by car ownership and income. Assume there are twenty (20) households in a sample for cross classification analysis.

* The descriptions in this chapter are mostly graphic and simplified examples. Methods to accomplish the development and application of the trip generation relationships by computer are described in other publications (13,14)

For each household information is available on number of trips, income and car ownership as typically obtained from the home interview survey, shown in Table 1.

TABLE 1

Example of Household Data for Cross Classification

<u>Household</u>	<u>Trips</u>	<u>Income</u>	<u>Cars</u>
1	2	4000	0
2	4	6000	0
3	10	17000	2
4	5	11000	0
5	5	4500	1
6	15	17000	3
7	7	9500	1
8	4	9000	0
9	6	7000	1
10	13	19000	3
11	8	18000	1
12	9	21000	1
13	9	7000	2
14	11	11000	2
15	10	11000	2
16	11	13000	2
17	12	15000	2
18	8	11000	1
19	8	13000	1
20	9	15000	1

A matrix would be established based upon cars owned and income with the results of the analysis perhaps indicating using the groups shown in the following Table 2. The numbers in the matrix represent the household sample numbers shown in Table 1.

TABLE 2

Example of Matrix for Cross Classification

		Cars Owned		
		0	1	2 or more
INCOME (\$000's)	≤6	1,2	5	--
	6-9	8	9	13
	9-12	4	7,18	14,15
	12-15	--	19,20	16,17
	>15	--	11,12	3,6,10

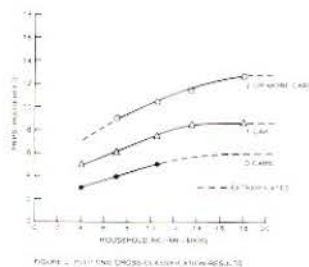
The mean of the trips for the households in each cell represented in the above matrix would then be obtained and shown in the table as below (Table 3). For example, the mean trip rate for two or more car households with incomes greater than \$15,000 would be the sum of 10,15 and 13 trips from Table 1 divided by 3 households or 12.7 trips.

TABLE 3

Example of Trips/Household for Cross Classification

		Cars Owned		
		0	1	2 or more
INCOME (\$000's)	≤6	3.0	5.0	--
	6-9	4.0	6.0	9.0
	9-12	5.0	7.5	10.5
	12-15	--	8.5	11.5
	>15	--	8.5	12.7

The results of the matrix would next be plotted as shown in Figure 2.



The data from the matrix is fit with smooth curves which may be extended out past the data points based upon the shape of the curves and logic. The curve values are then used to develop a completed matrix which is used for future trip forecasts. An example of the application of this type of cross classification matrix will be described in the last section of this chapter.

To illustrate the procedure for developing land activity rates for non-residential trip generation, the following example for shopping trip attractions is provided. Table 4 presents some data for shop trips attracted to shopping sites along with other information on type of land use. The trip data will come from the O-D survey, perhaps in combination with information from a site analysis on the two largest shopping centers, for example. Supplemental data sources or a site analysis would supply the employment information.

TABLE 4
Example Data for Rate Development

Zone	Location	Retail	Shop Trip Attractions
1	CBD	3000	7200
2	CBD	1400	2500
3	Shop Cntr.	600	6000
4	Shop Cntr.	200	1100
5	Shop Cntr.	1400	14000
6	Fringe Strip	250	900
7	Fringe Strip	100	350
8	Fringe Strip	75	200
9	Local	15	50
10	Local	25	70
11	Local	50	140
12	Shop Cntr.	600	5500
13	Shop Cntr.	1000	10000
14	Fringe Strip	200	750
15	Fringe Strip	125	600
16	Local	60	120
17	Local	40	120
18	Local	70	200
19	Local	30	85
20	Local	10	40

The trip rate for the CBD would be based upon summing the employees and the shop trip attractions for zones 1 and 2 and dividing the trips by the employees to develop the rate ($9700/4400=2.20$ trips/employee). The results of this analysis would be:

<u>Location</u>	<u>Shop trips/employee</u>
CBD	2.20
Shop Center	9.79
Fringe Strip	3.73
Local	2.75

The above analysis does not have to be tied to zones as shown for the example, but in many cases zones may be the most logical summarization areas.

Application of these types of land activity rates will be illustrated in the last section of this chapter.

RESIDENTIAL TRIP GENERATION PRODUCTIONS

This section will describe the stratification suggested for residential trip generation using the recommended cross classification analysis in addition to providing some samples from an operational study.

It is suggested that the variables to be used for the residential trip generation be income and car ownership and that the trip rate be either person trips or auto driver trips per household depending on the approach to transit planning utilized. For smaller cities under about 200,000 population or where there is very minor transit use currently and no appreciable growth is expected, the trip rate may be auto driver trips per household. The location of "0-Car" households could then be utilized to define areas of high transit potential. As described in the section "Forecasting car ownership", the development of households with "0" cars is an integral part of the recommended procedure.

Table 5 shows the suggested matrix for trip productions using the cross-classification approach.

TABLE 5

Matrix Suggested for Total Person Trip Productions
Per Household

Car Ownership (by autos)	Income Level						
	1	2	3	4	5	6	7
0							
1							
2							
3 or more							

The income levels are ranges of income, which may vary depending upon the area being studied. The standard census urban transportation planning package provides number of households stratified by car ownership (0, 1, 2, 3 or more) and income (7). The income ranges used are: under \$2,000, 2-\$4,000, 4-\$6,000, 6-\$8,000, 8-\$10,000, 10-\$12,000, 12-\$15,000, 15-\$20,000, 20-\$25,000, and 25-\$50,000.

In most areas another variable should also be considered and it is recommended that density be used since there is a trade-off between walking and vehicular trips when density increases which the analyst may wish to consider. One check to determine if additional stratification of the income variable should be considered or other variables considered is to evaluate the standard deviations of the cell trip rates. Where the deviation is high, additional stratification may be indicated. The analyst should establish evaluation criteria for determining when the standard deviation is too high and what actions should be taken. The types of variables to be added might be residential density

(dwelling units/acre), location (central city, near suburbs, far suburbs) or persons/household. In many cases just car ownership and income should be sufficient. As an example of curve development, some sample data from Wichita Falls, Texas, population 100,000 is used in the further explanation below (21). The trip rates are shown stratified by income group range and autos owned in Table 6. The rates shown are based upon areawide origin-destination data.

TABLE 6

Sample Trip Rates for Wichita Falls, Texas (21)

Total Person Trips Per Household						
		Autos Owned				Average Rate
Income	Group	0	1	2	3+	Per Income Group
	1	3.6	6.4	11.6	17.7	6.4
	2	4.1	9.7	12.9	18.5	10.8
	3	5.0	11.1	14.6	19.2	12.5
	4	5.4	11.4	15.6	20.1	14.2
	5	5.3	12.9	16.2	20.5	16.1

The income ranges utilized were:

<u>Income Group</u>	<u>Income Range</u>	<u>Range Mean for Plotting</u>
1	\$0-4999	\$4,000
2	\$5,000-6999	\$6,000
3	\$7,000-9999	\$8,500
4	\$10,000-14999	\$12,500
5	\$15,000 & Over	\$18,000

The values from the matrix (Table 6) should next be plotted and a smooth curve drawn through the points as shown in Figure 3.

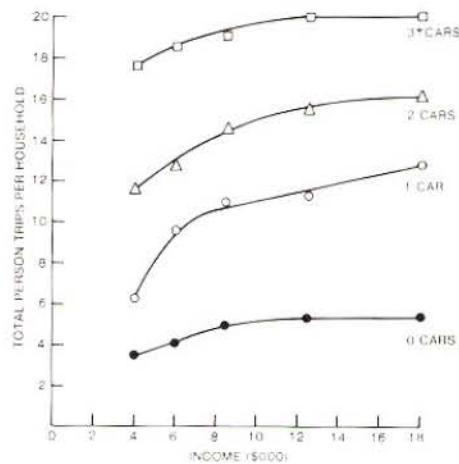


FIGURE 3. WICHITA FALLS URBAN TRANSPORTATION STUDY (21) ANALYSIS OF PERSON TRIPS PER D.U. BY INCOME LEVEL AND AUTO OWNERSHIP

The values from the curves would then be used to forecast by entering them at a given income value (e.g., average zonal income) with the number of dwelling units with 0, 1, 2, and 3 or more cars to develop the trip rates. Some may prefer to tabulate the curve values into a matrix before use in forecasting.

While trip generation relationships can be developed without auto ownership estimates, it is a basic variable in the recommended approach. This is suggested for several reasons, among them the built-in sensitivity of the modelling approach to auto ownership saturation levels and the usefulness of auto ownership for estimating transit usage.

DEVELOPING THE TRIP PURPOSE MODEL

The trip purpose stratifications are usually dictated by the trip distribution and modal split models utilized. For internal area travel, the choice of purpose will vary somewhat by size of area. The larger studies will usually consider 5 purposes: home based work, home based shop, home based school, home based other and non-home based. Taxi and truck trips must also be handled and will be discussed in Chapter IV. Some of the larger studies have also broken out social-recreational travel from the "other" category and some have separated shopping trips into "convenience" shopping trips and "other" shopping trips. This is usually done for trip distribution purposes in an attempt to come closer to the basic trip distribution characteristics. In smaller urban areas (under 100,000 population) three trip categories have been used successfully: (1) home based work (2) home based other and (3) non-home based.

The non-home based trip purpose in the household trip generation production is used as a control on total areawide trips produced. The zonal non-home based productions and attractions used for the trip distribution model input are allocated to the proper zones by using the indices developed in the trip attraction model (see page 40).

For the Wichita Falls, Texas, example used previously, the three purpose model is used. The data are shown in Table 7. (21)

TABLE 7
Percent Trip Distribution by Purpose
Wichita Falls Urban Transportation Study (21)

Income Group	Percent Distribution by Purpose		
	% HBW	% HBNW	% NHB
1	21	55	24
2	18	57	25
3	16	59	25
4	14	60	26
5	14	59	27

The number of income groups may vary by city depending upon the range in trip rates and income. The income grouping shown above is only one example of a possible stratification for income. These data are obtained from the most recent O-D study. Small sample surveys should provide sufficient information for developing this type of distribution. The distribution is developed by accumulating the number of survey trips for each purpose within each income group and finding the percentage of the total trips each purpose constitutes within the income group. The distribution can then be plotted as shown in Figure 4.

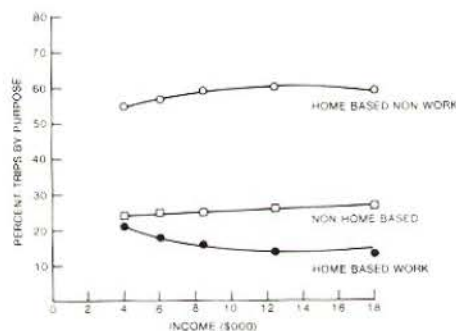


FIGURE 4 WICHITA FALLS URBAN TRANSPORTATION STUDY (21) ANALYSIS OF PERSON TRIPS BY PURPOSE ACCORDING TO INCOME LEVEL

As an alternate approach, where survey data are not available, the trip purpose stratification can be synthesized by using data from a study of similar character and size. The example, Figure 4, shows little change in the percentage distribution of trips by purpose as related to income. In larger cities the differences are greater. As an alternate, some studies have utilized car ownership as the variable for the purpose stratification. An example of the use of car ownership and the resulting distribution is shown in Figure 5.

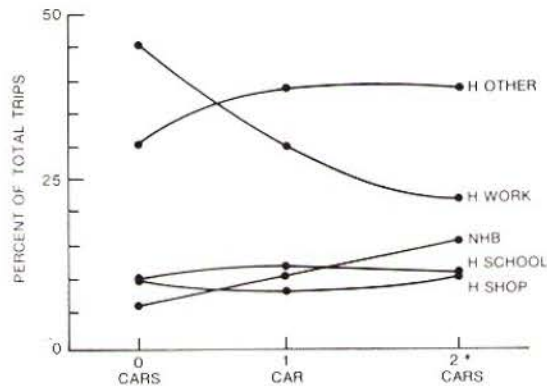


FIGURE 5. EXAMPLE OF PURPOSE STRATIFICATION BY CAR OWNERSHIP

DEVELOPING A MODE CHOICE MODEL

As mentioned previously, the type of trips to forecast (i.e., purpose, mode) is primarily related to the objectives and requirements of the study, the size of the area involved and the type of models to be utilized. When considering mode choice analysis and the implications relative to trip generation, the basic decision is whether mode choice is accomplished before or after trip distribution. Sometimes, in small areas where transit use is a very small portion of total travel and is expected to remain so into the future, auto trips are directly estimated in the trip generation phase.

In at least the smaller urban areas (under about 250,000 population) long range transit planning should probably be deemphasized in favor of short range study (e.g. 1-5 years). This shorter range planning is also a necessary component of transportation planning in all urbanized areas (8). This short

range planning is heavily oriented toward the transportation disadvantaged generally comprised of the young, the old, the poor, and the handicapped. Much of the data collected for trip generation model development is useful for measuring travel demand for short-range transit planning, although it must be supplemented. A suggested procedure (8) consists of: (1), isolating places of high transit trip production potential by identifying areas having a high percentage of dwelling units at low income and/or low auto ownership and from a knowledge of the area locating concentrations of the young, the old, the poor, and the handicapped; (2), estimating the latent demand from these areas through subjective analysis of areas with high attraction potential or through a latent demand survey; and (3), the results of the above 2 items would be used to estimate a total travel demand based upon system improvements or changes. The types of systems for transit that might be evaluated include standard buses, taxicabs, jitneys, "dial-a-ride" bus systems, cooperatively-owned vehicles, rental vehicles, and carpools.

In long-range forecasting, for all but the smallest areas after person trip ends have been forecast, the proportion of future travel by transit is estimated by modal split procedures either before or after trips are distributed. A diagram depicting these two possibilities is shown in Figure 6. Additional information on long-range transit planning and modal choice procedures for larger areas can be found in references 30, 31, and 32.

In smaller urban areas, the emphasis in long-range planning should be on assessing the impact of various transit alternatives on the highway plan, rather than actually developing a long-range transit plan. Transit for smaller areas is flexible, e.g., buses, and planning is normally not necessary for more than a few years in the future.

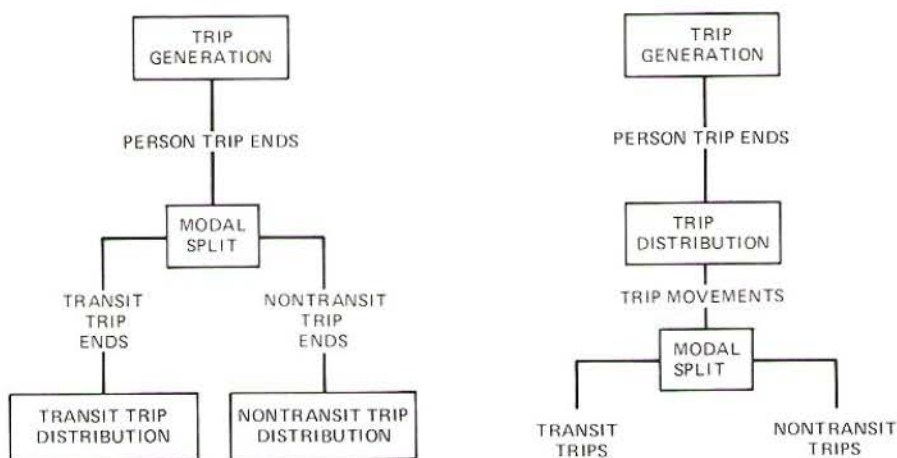


FIGURE 6. LOCATION OF MODAL CHOICE WITH RESPECT TO TRIP GENERATION ANALYSIS IN THE TRANSPORTATION PLANNING PROCESS.

One suggested approach would be to develop work-trip modal choice and auto occupancy models for long- and short-range highway planning. For those areas needing a modal split model, a simple work-trip choice model has been developed based on the 1969-70 Nationwide Personal Transportation Study data by the Urban Mass Transportation Administration. Direct generation (cross-classification) would be accomplished for short-range estimates of non-work transit and auto trips. This could be done with separate transit and auto models or with a modal split procedure which "fits" with the other phases of trip generation and uses person trip productions as input. In the latter case, trips would be stratified by transit and by automobile based upon trip purpose and household income from the O-D survey. Table 8 is an example of the resulting cross-classification matrix.

TABLE 8

Illustration of Matrix for Percent Transit Trips

	Percent Transit Trips						
	Income Level						
Purpose	1	2	3	4	5	6	7
HB School							
HB Shop							
HB Other							
N-HB							

For each cell, the total trips and transit trips would be accumulated and the percent transit trips developed based upon the total trips.

A graph would then be developed for each purpose by plotting the cell percentages as shown in the example in Figure 7.

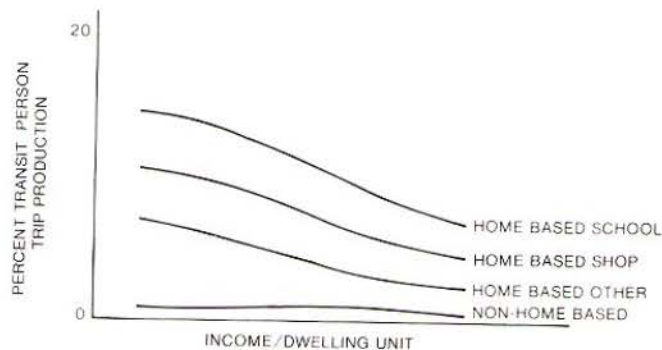


FIGURE 7 ILLUSTRATION OF CURVES FOR PERCENT TRANSIT TRIPS

The approach taken in the Wichita Falls study was to develop two purpose distribution models (person and auto driver) as illustrated in Figure 8. (21) This allows a total control on person trips with a direct estimation of auto driver trips which are the most significant in smaller cities. A car occupancy rate can be applied to the auto driver trips and the results subtracted from person trips to produce an estimate of mass transportation travel.

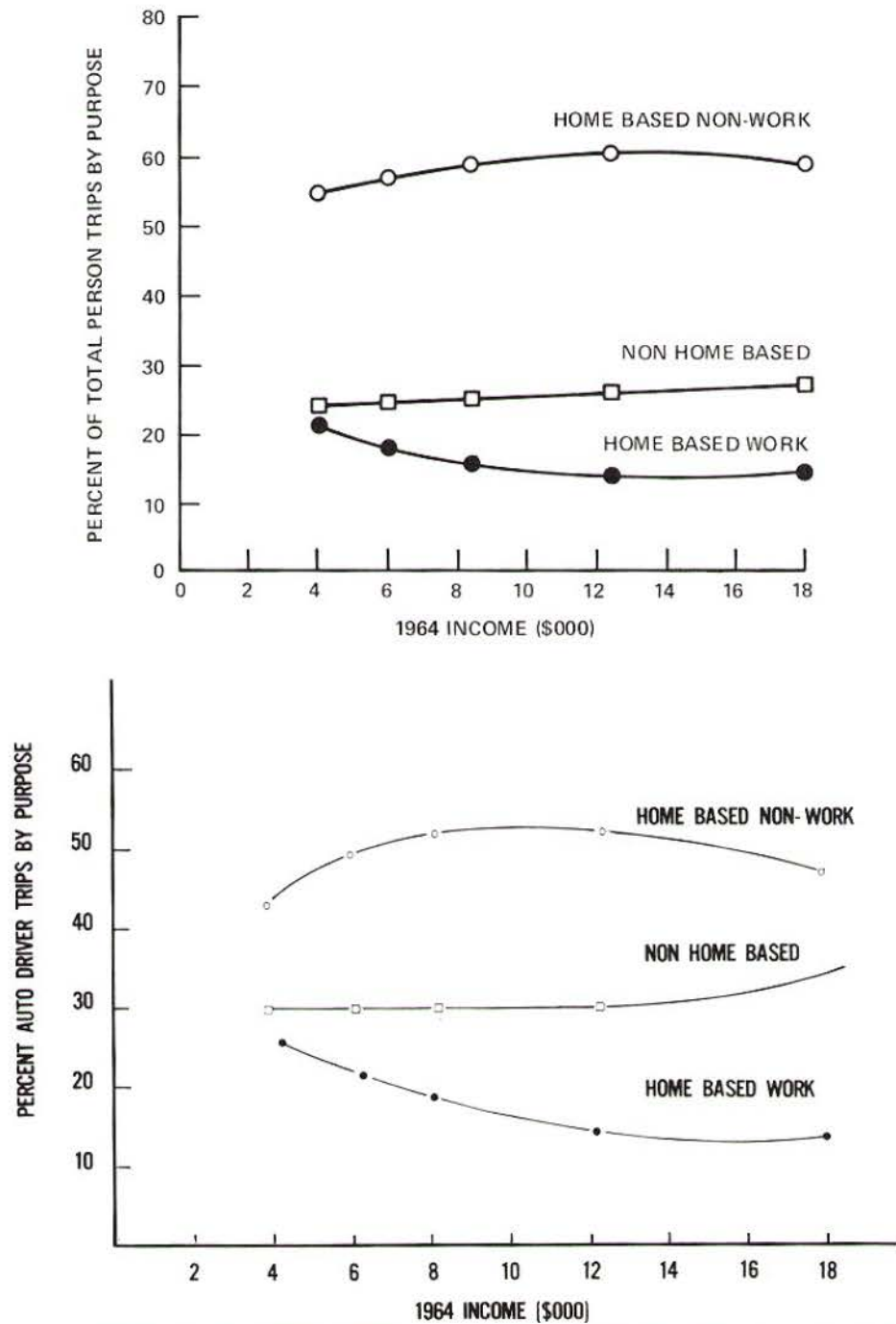


FIGURE 8. EXAMPLE OF TRIP GENERATION RELATIONSHIPS USED IN WICHITA FALLS, TEXAS (21)

An alternative to the above is to develop transit and auto use based upon a car ownership stratification. An example matrix is shown as Table 9. This data could be converted to percentage transit and plotted as a series of curves by purpose.

FORECASTING CAR OWNERSHIP

Most of the process described thus far relies heavily upon income as a predictive variable. Car ownership is highly correlated to income but is included in the process as a basic factor. This is based upon the usefulness of car ownership for modal choice models, the need to consider auto ownership saturation levels in the planning process, and the high elasticity in vehicle purchasing and travel with respect to income. The trip generation procedure recommended, is therefore, a two step process based upon a car ownership relationship with income and a trip relationship with income and car ownership.

The variable considered in this process for predicting car ownership is again income which is the key variable throughout this procedure.* The same stratification for income used for the trip rate curves, trip purpose, and mode forecasting should be used here. An example cross classification table to be established is shown in Table 10. Within income group and auto ownership class, the number of total households would be accumulated. The percent each cell is of total households within an income class would then be computed.

TABLE 10

Example of Cross Classification Matrix for Car Ownership

	Autos Owned								
Income Group	0		1		2		3		Total
	obser- vations	%	obser- vations	%	obser- vations	%	obser- vations	%	HOUSEHOLDS
1									
2									
3									
4									
5									
6									
7									

* See Appendix A for a discussion on income forecasting.

TABLE 9

Mode Choice Estimating-Illustration Using
Car Ownership

Purpose	Level of Vehicle Ownership of Households								
	0			1			2		
	Total	Public	Private	Total	Public	Private	Total	Public	Private
Home to Work									
Home to School									
Home to Shop									
Home to Other									
Non Home Based									
TOTAL									

The data in the table would then be plotted. An example of a completed table is shown as Table 11 for Wichita Falls, Texas.

Data for the car ownership model is available from most origin destination surveys. The 1970 Census Urban Transportation Planning Package also provides the necessary data to complete the above. Curves have been developed from the census package for a number of areas. Generally the findings of the plots indicate that the shape of the curves is rather constant across the country. Two examples, one for Great Falls, Montana and the other for Providence, Rhode Island are shown in Figure 9. Additional curves are shown in Appendix B. When plotting the data and developing curves for car ownership, care should be taken that the summation of percent households at each income should add to one-hundred percent.

The example for Providence tends to indicate a leveling out of 0 auto households close to 1%. One auto households at about 23%, 2 auto households at about 53% and 3 or more auto households at 22%. If the assumption is made that the 3 or more category averages about 3.3 autos per household, the ownership level for the leveling out point can be calculated as $(0.23 \times 1 + 0.55 \times 2 + 0.22 \times 3.1)$ or 2.02 cars per household. Should average car ownership values be required for a planning purpose, the curves plotted can be converted as shown in the development of the 2.02 value for Providence. The average car ownership curve, plotted by income group, for Providence is shown in Figure 10.

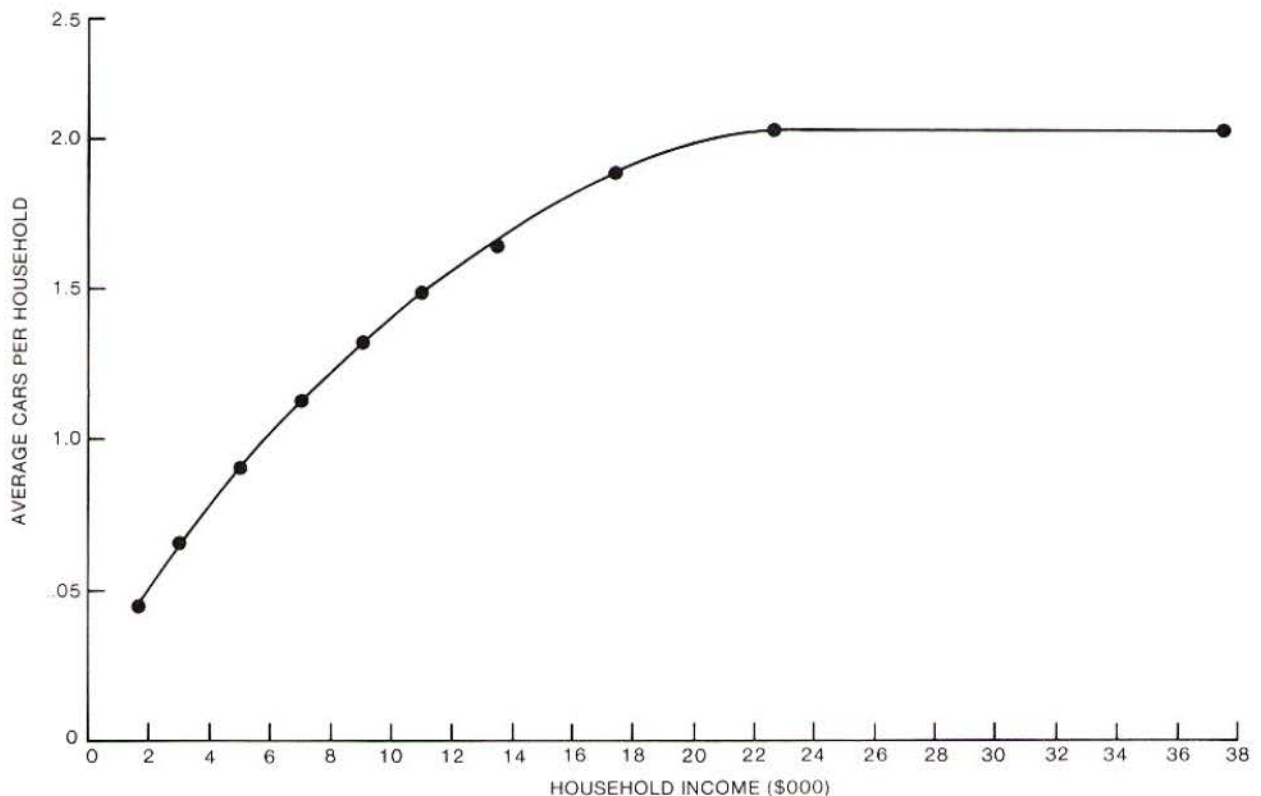
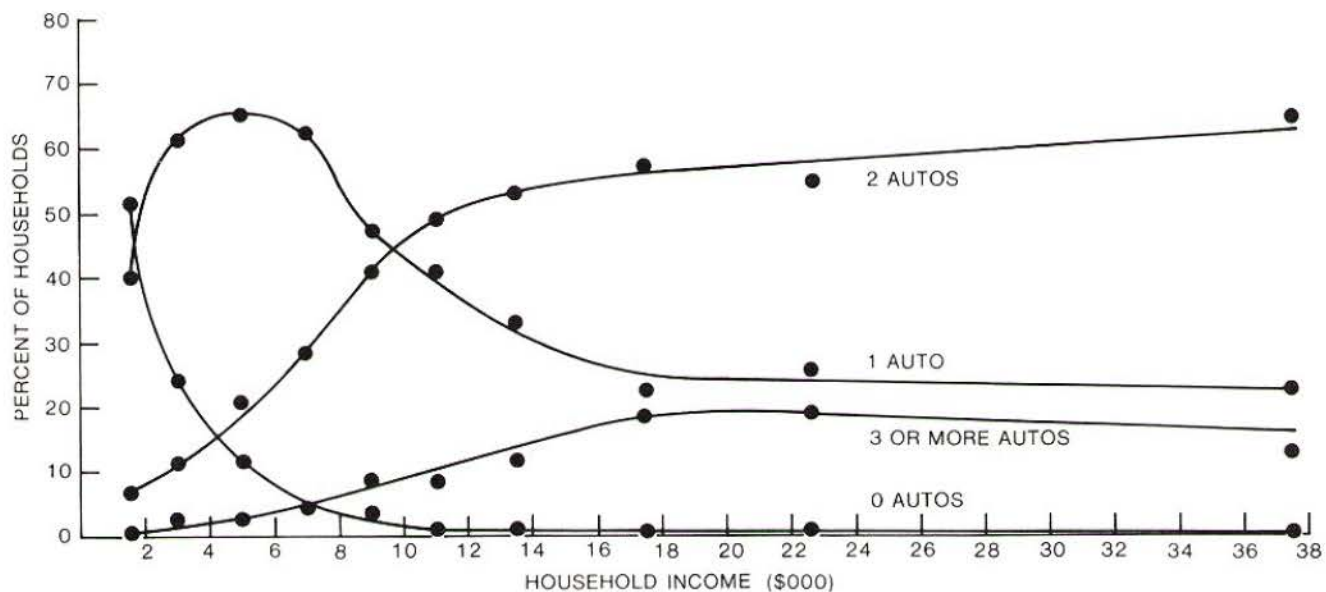
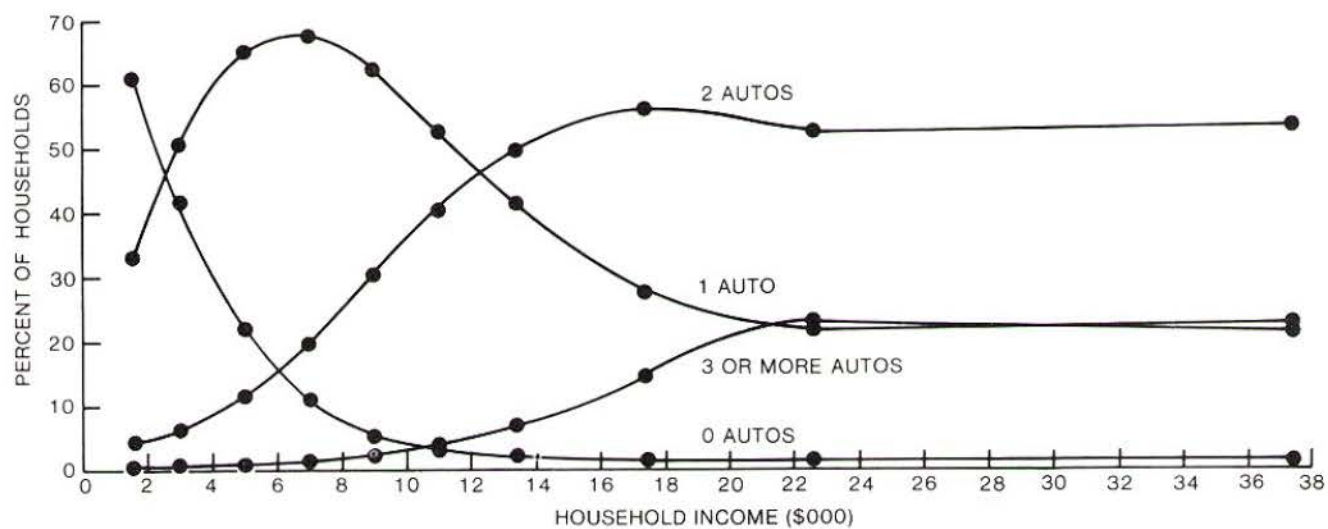


FIGURE 10 EXAMPLE OF AVERAGE CAR OWNERSHIP CURVE FOR PROVIDENCE, R.I. 1970



SOURCE: SMOOTHED CURVES BASED ON 1970 CENSUS URBAN TRANSPORTATION PLANNING PACKAGE DATA, GREAT FALLS, MONTANA.



SOURCE: SMOOTHED CURVES BASED ON 1970 CENSUS URBAN TRANSPORTATION PLANNING PACKAGE DATA, PROVIDENCE, RHODE ISLAND

FIGURE 9. EXAMPLES OF CAR OWNERSHIP CURVES.

TABLE 11

Example for Wichita Falls, Texas

Household Observations by Autos Owned(21)

Income Group	Autos Owned								Total Households	Average Autos Per Household
	0		1		2		3+			
	Obs.	%	Obs.	%	Obs.	%	Obs.	%		
1	104	32.1	169	52.1	44	13.6	7	2.2	324	0.86
2	2	0.7	183	68.0	77	28.7	7	2.6	269	1.33
3	9	2.1	246	58.6	153	36.4	12	2.9	420	1.40
4	7	1.5	188	39.3	241	50.4	42	8.8	478	1.67
5	1	0.9	32	28.0	58	50.9	23	20.2	114	1.90

Although generally not necessary, some may wish to further stratify the car ownership relationships based upon other variable(s) in addition to income. Some other variables which have been used are density of development and persons per household. Both affect car ownership and do explain additional variation. Density may be stratified into a number of ranges as shown below.

Low density	0-19 persons per acre
Medium density	20-39 persons per acre
High density	40+ persons per acre

The above range values are for illustrative purposes only. The selection of ranges for low, medium and high density may vary by urbanized area. Generally it will be found that for a specific income level, vehicle ownership decreases with increasing density.

The Charlotte-Mecklenburg Transportation Study (North Carolina) utilized income and persons per household in their car ownership model. The results are shown in Figure 11.

FORECASTING INCOME

A key variable in the suggested procedure for trip generation is income. In many instances income is provided to the transportation planner by land use planning personnel. There may be instances, however, where an approach to forecasting income in the form required for transportation planning is required. A procedure is described in Appendix A for developing income forecasts by zone.

The procedure described is based upon an examination of income distributions for several past years on a constant dollar base. The technique allows for the extrapolation of the historical income distributions to the forecast year based upon the knowledge that the proportion of families in the lower income ranges is decreasing and that the proportion of families in the higher income ranges is increasing. The procedure is iterative in nature, requiring the application of differential growth factors to income ranges and the subsequent plotting of the resulting distribution to determine if the distribution appears to "fit" the historical changes in the income distribution.

A number of sources are available for future income forecasts, income distribution data and consumer price index information. These sources as well as details of the procedure, including examples, are contained in the appendix.

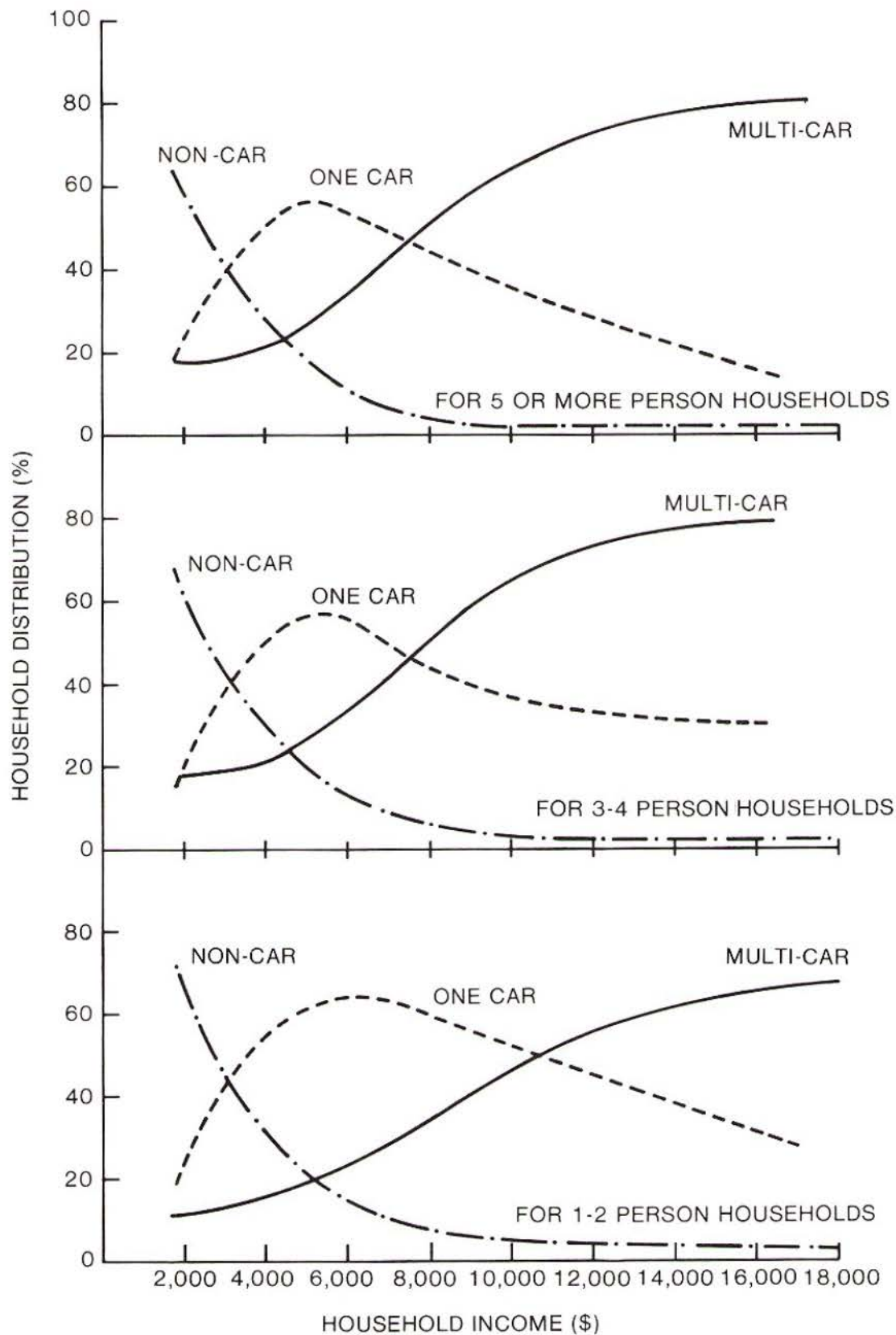


FIGURE 11 CAR OWNERSHIP MODEL CHARLOTTE-MECKLENBURG TRANSPORTATION STUDY (20)

NON-RESIDENTIAL TRIP GENERATION-ATTRACTIONS

The previous sections of this chapter have described a residential trip generation procedure for estimating trip productions by purpose. In this section approaches to trip attraction estimating will be described. Basically, trip attraction is related to non-residential land use for most trip purposes. For example, home based shopping trip attractions are to locations where goods are sold-basically commercial areas. There may be some few shopping trips to residential land, but not an amount worth considering. On the other hand, "home based other" trips usually include trips for social-recreational purposes and by their nature include travel to residential land. Likewise, non-home based attractions would have some residential association.

For trip distribution purposes, trip production and trip attraction estimates should have an areawide balance by purpose. For each home-based purpose the areawide summation of attractions should equal the area-wide summation of productions as estimated by the trip generation models. If production and attraction areawide summations are not in agreement the trip production estimates are taken as the control since characteristics of the home such as car ownership and population generally more adequately reflect changing travel characteristics than do non-residential variables. However, where the difference is significant it is important to re-evaluate the attraction procedures being used to determine if there will be perhaps shifts in trip purposes, shifts between travel to areas (i.e., CBD versus suburbs) or changes in the intensity of travel.* Once this is done and the planner is satisfied with the distribution of attractions by purpose and area, the zonal attractions are used as an index to distribute the trip productions developed at the household level.

Trip attractions have been handled in several ways, including zonal regression, land area trip rates or cross classification analysis. A simplified approach is suggested based upon the development of trip rates within a matrix. Reference should be made to Table 12 for a suggested matrix for the rate development. The procedure reflects the character, location and intensity of land use. The character is reflected by the land use categories used (residential, retail, etc.).

*See also page 57, "Controls".

TABLE 12
Example of Procedure for Trip Attraction Estimates

Person Trip Attractions*

Trip Purpose	Trips Per Household	Trips Per Employee				Univ.	High School	Other
		Non Retail	Retail					
			CBD	Shop Center	Other			
Home Based Work	--	1.70	1.70	1.70	1.70	--	--	--
Home Based Shop	--	--	2.00	9.00	4.00	--	--	--
Home Based School	--	--	--	--	--	0.90	1.60	1.20
Home Based Other	0.70	0.60	1.10	4.00	2.30	--	--	--
Non-Home Based**	0.30	0.40	1.00	4.60	2.30	--	--	--

* Illustration data only-not to be used directly.

** Non-Home Based Productions and Attractions have same rate and are used to allocate to zones the areawide control total developed in the trip production model.

Location considers the spatial distribution of the land and in this procedure is represented by CBD, shopping centers, etc. The intensity of the land use is reflected by the activity as measured by number of employees, students or households.

For the matrix represented in Table 12, the trip rate is based upon employees by type and/or location, number of students by type, and number of dwelling units depending upon the purpose of the trip. To develop the trip attraction rates, origin-destination survey trips are accumulated according to land use at the attraction end of the trip for each trip purpose. Usually, large shopping centers are coded as separate zones to allow the trip accumulation as shown in Table 12. To stratify the school trips by type of school, the age of the student can be used if other data in the survey does not allow the stratification. Trips for the entire area are accumulated within the matrix shown. To obtain the trip rate per dwelling unit for "home based other" trips as an example, the trips within the cell are divided by total areawide dwelling units. To obtain the rate for the cell "home based work-non retail", the trips accumulated are divided by total areawide non-retail employment.

As has been previously discussed, there are often special trip generators that comprise land uses which are unique and do not show the same trip attraction characteristics that are typical within the study area. For these cases, it may be desirable to conduct special generator studies to develop a trip rate that is characteristic of the special activity. This would involve special traffic counts and an inventory of some measure of the activity (i.e., number of enplaned passengers for an airport, or number of beds for a hospital, etc.). Various rates have been compiled from studies such as these around the country and might be a good source for "a first cut" or "borrowed" rates (1,2,16).

The procedure described above is based upon rates per employee, per student and per household. There has been application of similar procedures based upon rates per acre or square foot of land use such as the number of shopping trips per square foot of commercial area.

A procedure very similar to that described above was utilized by the Metropolitan Washington (DC) Council of Governments and is described here for illustrative purposes (Reference 22). The trip rates shown in Table 13 are based upon employees and dwelling units depending on whether the land use is non-residential or residential. School trips are not shown in the table. The non-residential attractions are based on a land use stratification (industrial, office, etc.) and on location within the area (core, fringe, suburb, Silver Spring, etc.). Care must be used in applying rates developed as shown to some future land use projection since competition between areas and the development of additional facilities may shift the competitiveness between areas. For example, the building of a new suburban shopping area which may draw from current use of Silver Spring may reduce the trip rate per employee in Silver Spring.

TABLE 13

Example of Trip Attraction Procedure for Metropolitan Washington Council of Governments (22)

<u>Non-Residential (TRIPS/EMPLOYEE)</u> <u>LU</u>	<u>HB</u> <u>WORK</u>	<u>HB</u> <u>SHOP</u>	<u>HB</u> <u>OTHER</u>	<u>NHB</u> <u>ATTR</u>
Other	1.78	0	5.87	.90
Industrial	1.62	0	0.45	0.34
Institutional	1.20	0	1.43	.35
Office-Core (Ring 0&1)	1.60	0	0.15	0.13
Fringe (Ring 2)	1.63	0	0.22	0.23
Sub (Ring 3-7)	1.74	0	0.45	0.30
Shopping-Retail Core	1.68	2.00	1.17	1.05
Fringe DC	1.68	0.39	2.33	1.26
DC Non Core	1.68	2.54	2.23	1.86
Arlington-Alex.	1.68	4.72	3.82	3.46
Silver Spring	1.68	3.85	2.52	2.34
Alexandria	1.68	4.50	2.43	2.64
Suburban	1.68	8.99	4.34	4.59
<u>Residential (TRIPS/HH)</u>				
Core	0.66	0	1.08	0.42
Remainder	0.06	0	0.57	0.23

APPLICATION OF SIMPLIFIED PROCEDURE

The previous sections have described in detail the development of a recommended trip generation procedure including the development of relationships between car ownership and income, trips and income and car ownership, and between trip purpose and income. This section will provide an illustration of the application of the procedure to some hypothetical data.

The residential trip generation estimation procedure is based upon a process that is summarized in Figure 12. It is pertinent to an understanding to step through the following example describing application of the process.

The data contained in the example has been prepared to illustrate the approach and as can be seen is not representative of the type of land use mixes normally found in a zone.

Given:

Zone 26:

Total Number of Dwelling Units = 1,000

Zonal Average Income/Dwelling Unit * = \$12,000

Solution:

- 1 - Enter Curve A (Figure 12) with zonal income/dwelling unit to determine car ownership level by household

2% "0" auto households	=	20 Dwelling Units
32% "1" auto households	=	320 Dwelling Units
52% "2" auto households	=	520 Dwelling Units
14% "3" auto households	=	140 Dwelling Units
		<u>1,000</u>

* As a better alternative, percent households in the zone by income category (e.g., low, medium, high), given the zonal average income, could be estimated. Each step in the example would then involve multiple calculations, one pass through the step for each income category. Published 1970 Census reports are a good source for this information. See Appendix A for more detail.

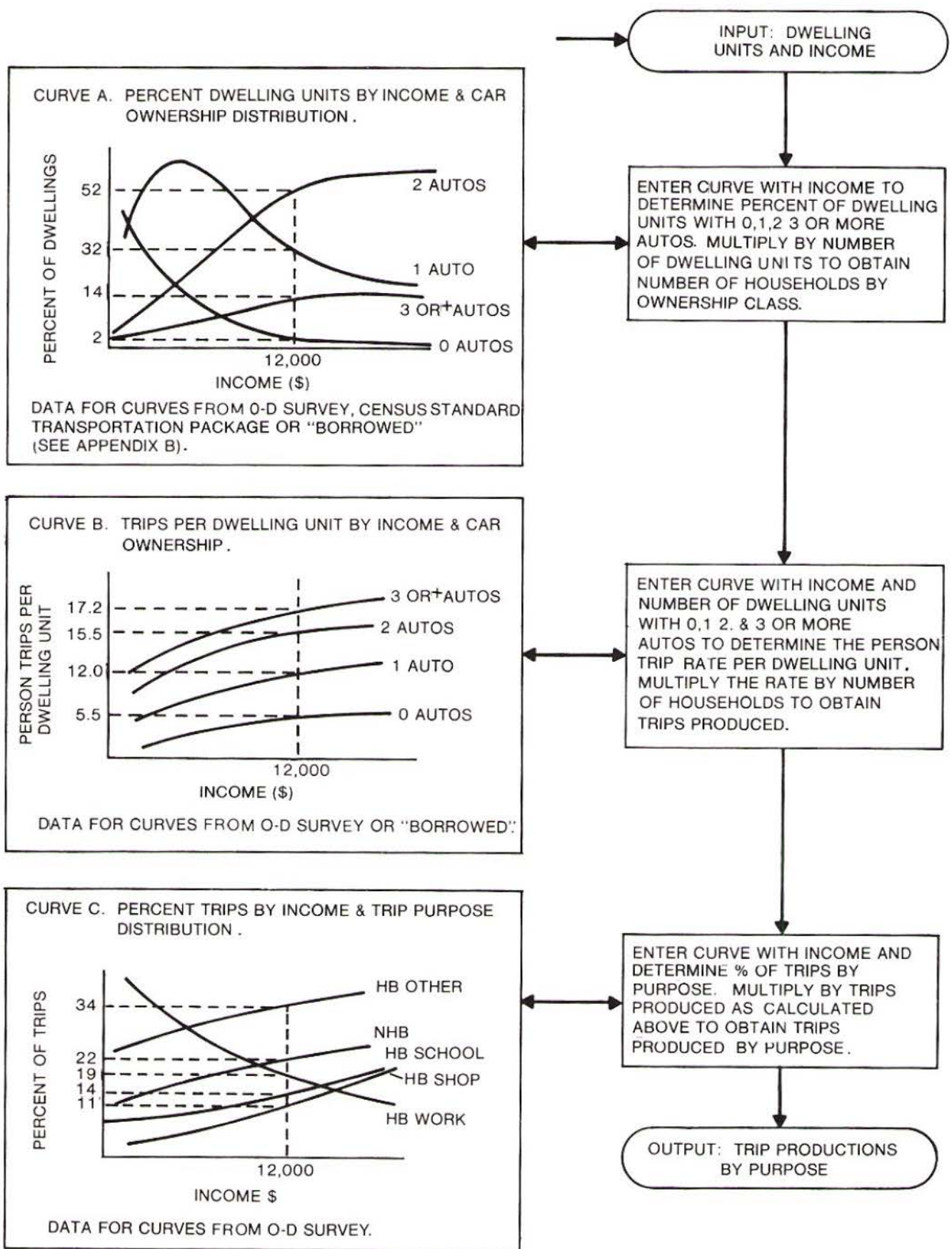


FIGURE 12. EXAMPLE OF URBAN TRIP PRODUCTION PROCEDURE.

- 2 - Enter Curve B (Figure 12) with income, to determine the total production from each household - Person Trips.

$$\text{Trips from "0" auto household} = 5.5 \text{ trips/DU} \times 20 \text{ DU} = 110 \text{ trips}$$

$$\text{Trips from "1" auto household} = 12.0 \text{ trips/DU} \times 320 \text{ DU} = 3840 \text{ trips}$$

$$\text{Trips from "2" auto households} = 15.5 \text{ trips/DU} \times 520 \text{ DU} = 8060 \text{ trips}$$

$$\text{Trips from "3" auto households} = 17.2 \text{ trips/DU} \times 140 \text{ DU} = 2408 \text{ trips}$$

$$\text{Total trips} = 14,418$$

$$\text{Average trips/DU} = 14.4$$

- 3 - Enter Curve C (Figure 12) with income to determine the trips produced by purpose.

$$\text{Home to Work trips} = 19\% \times 14,418 = 2739 \text{ trips}$$

$$\text{Home to Shop trips} = 11\% \times 14,418 = 1586 \text{ trips}$$

$$\text{Home to School trips} = 14\% \times 14,418 = 2018 \text{ trips}$$

$$\text{Home to Other trips} = 34\% \times 14,418 = 4903 \text{ trips}$$

$$\text{Non-Home Based} = 22\% \times 14,418 = \underline{3172 \text{ trips}}$$

14,418 trips

The approach to trip attraction development can be visualized by reviewing Table 12 on page 41. For each trip purpose (home based work, shop, school, and other, and non-home based) rates are developed based upon type of land use and the most appropriate denominator for the rate (i.e., number of students for the school trip rate and employment for the work trip rate). Again, the example is based upon hypothetical data which does not necessarily reflect real mixes of land use.

Given:

Number of dwelling units	=	3,000
High School Students	=	800
Elementary School Students	=	1,800
Shopping Center Retail Employees	=	200
Other Retail Employees	=	100
Non Retail Employees	=	50
Total Attractions	=	11,465

Solution:

The trip attraction rates would be obtained from Table 12 and multiplied by the above as follows:

$$\begin{aligned}\text{Home Based Work Attractions} &= \\ &1.7 \times (\text{Total Zonal Employees}) \\ &= 1.7(350) = 595\end{aligned}$$

$$\begin{aligned}\text{Home Based Shop Attractions} &= \\ &2.00 \times (\text{CBD Retail Employees}) + \\ &9.00 \times (\text{Shopping Center Retail Employees}) + \\ &4.00 \times (\text{Other Retail Employees}) \\ &= 2.00(0) + 9.00(200) + 4.00(100) = 2200\end{aligned}$$

$$\begin{aligned}\text{Home Based School Attractions} &= \\ &0.90 \times (\text{University Students}) + \\ &1.60 \times (\text{High School Students}) + \\ &1.20 \times (\text{Other School Students}) \\ &= 0.90(0) + 1.60(800) + 1.20(1800) = 3440\end{aligned}$$

$$\begin{aligned}\text{Home Based Other Attractions} &= \\ &0.70 \times (\text{Number of Households}) + \\ &0.60 \times (\text{Non Retail Employees}) + \\ &1.10 \times (\text{CBD Retail Employees}) + \\ &4.00 \times (\text{Shopping Center Retail Employees}) + \\ &2.30 \times (\text{Other Retail Employees}) \\ &= 0.7(3000) + 0.60(50) + 1.00(0) + 4.00(200) \\ &\quad + 2.3(100) = 3160\end{aligned}$$

$$\begin{aligned}
&\text{Non Home Based Attractions} = \\
&\quad 0.30 \times (\text{Number of Households}) + \\
&\quad 0.40 \times (\text{Non Retail Employees}) + \\
&\quad 1.00 \times (\text{CBD Retail Employees}) + \\
&\quad 4.60 \times (\text{Shopping Center Retail Employees}) + \\
&\quad 2.30 \times (\text{Other Retail Employees}) \\
&\quad = 0.30(3000) + 0.40(50) + 1.00(0) \\
&\quad \quad + 4.60(200) + 23(100) = 2070
\end{aligned}$$

$$\text{Total Attractions} = 11,465$$

The purpose of this chapter was to explain in detail the simplified approach to trip generation recommended. The procedure is based upon the use of logic and judgment without a great involvement in statistical measures being necessary. The procedure allows introduction of policy and judgmental factors such as household size and car ownership saturation levels. There are a number of computer programs available for developing and applying cross classification matrices. These programs are described elsewhere (14).

The remaining chapters of this document will cover the evaluation of trip generation results, additional considerations such as the handling of external trips and truck and taxi forecasting, monitoring and surveillance for trip generation.

CHAPTER III EVALUATION OF TRIP GENERATION RESULTS

If handled with care, cross classification derives its basic strength from the need to maximize logical structuring of the variables. It is basically a common sense approach which minimizes the amount of statistical evaluation required. There are some applicable statistical evaluation measures but not as many as with a regression approach. This chapter will discuss statistical as well as reasonableness checks for trip generation and provide some factors to consider in analysis.

REASONABLENESS CHECKS

The design of the cross classification matrix is based upon the choice of independent variables on which to stratify the trip rate and the categories chosen to stratify the variables. For the choice of variables it is recommended that the chosen trip rate (i.e., trips per dwelling unit) be plotted against the possible choices for stratifying the trip rate in the cross classification matrix to develop a "feel" for the data and relationships at hand. While plots of the data are extremely useful, they are only two dimensional. Because of this too much reliance should not be placed on the scatter diagram alone since the relationships may change when a third variable is added. Regression and correlation also can provide useful information to assist in the choosing of stratifying variables for the cross classification matrix. A simple correlation matrix will provide the interrelationships between the trip rate and possible stratifying variables. The coefficient of simple correlation (r) is a measure of association between two variables and the matrix gives the correlation coefficients for all possible pairs of variables (3). An examination of this matrix will provide information about relationships between the independent and dependent variables. Strong relationships may then be evaluated for logic. Although the above tools are important, variables which appear to be the most logically related to the trip rate variable should receive the most attention. Variables which reflect a causal relationship which has some likelihood of remaining stable over time should receive the highest priority.

Some rules of thumb may be considered in the development of the cross classification matrix. The number of observations for any "cell" of the matrix should be large enough so that the mean rate developed for the cell can be reflective of travel for future application. It is suggested that at least twenty-five observations be accumulated in each cell. Where there are less observations, consideration should be given to combining the cell with another. Another solution for too few samples in a cell would be to ignore the cell when plotting results of the cross classification and then using the value from the smoothed curve. Secondly, the cell values should not have too wide a dispersion as reflected by the standard deviation of the observations about their mean. The analyst should establish criteria for evaluating this dispersion. Where many cells of the chosen cross classification matrix have a large standard deviation, consideration should be given to either stratifying on an additional variable or re-evaluating the initial choice of variables. Where only a few of the cells of a matrix have a large standard deviation as a percent of the mean, the ranges established should be re-evaluated to determine if new ranges should be used or if certain cells should be subdivided. For example, if a matrix utilizes income stratified into \$4000 increments (i.e., 0-\$4000, 4-\$8000, 8-\$12,000, etc.) and results in a high standard deviation in the trip rates, then perhaps a stratification on \$2000 income increments should be tested (i.e., 0-\$2000, 2-\$4000, etc.) In addition to the standard deviation which is automatically determined by programs such as XCLASS, it may be appropriate to evaluate the shape of a cell's distribution where high standard deviations are found. Such an evaluation can be accomplished manually. For cells that require evaluation the frequency distribution of values would be plotted as shown in Figure 13. The left curve shows a normal distribution. Where the standard deviation is within about the established percentage of the mean no further evaluation is warranted. Where the value is outside the established percentage of the mean, and the other cells are generally within the guidelines then consideration should be given to further stratification of the column or row containing the cell in question. If a "skewed" distribution is found as shown in the right half of Figure 13, consideration should be given to a further stratification or redefining of the ranges established for the matrix variables.

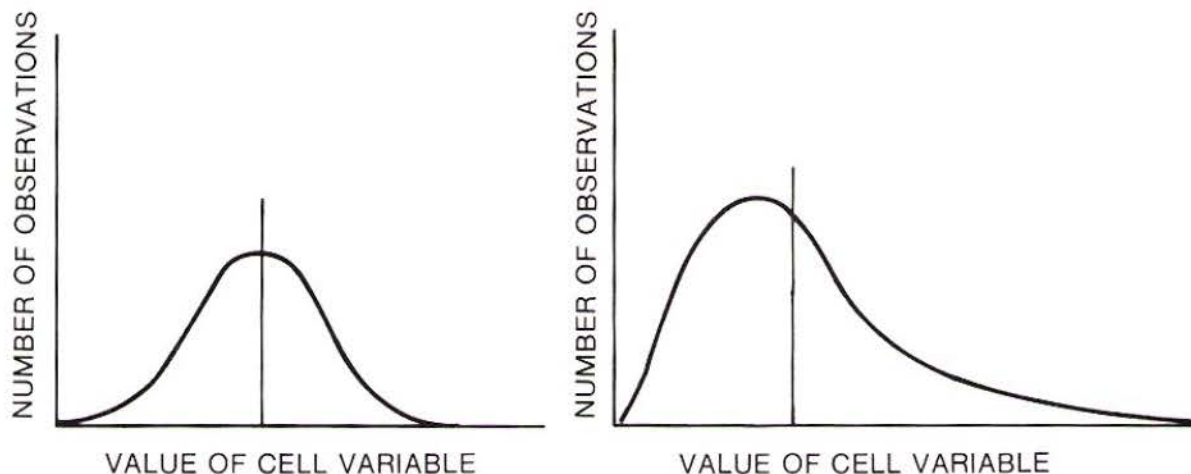


FIGURE 13 ILLUSTRATION OF THE SHAPE OF DISTRIBUTIONS FOR CROSS CLASSIFICATION CELL VALUES

The values accumulated in the cells of a cross classification matrix should always be plotted. The purpose of the plots is three fold. First, such a plot will indicate if the results of the matrix design are logical. For example, if a plot shows a number of dips and rises rather than a smoother functional relationship, further investigation should be made of ranges established and the distribution of values within the cells. Secondly, if a very flat relationship is found showing little variation in the trip rate with the matrix value, then consideration should be given to use of an alternate matrix-stratifying variable. Thirdly, if the curve shows a relationship contrary to logic, such as trips per dwelling unit decreasing with increasing car ownership, then consideration should be given to further evaluation of the source data for accuracy and soundness.

Although the cross classification approach suggested is basically a household level analysis on the residential end and a "site" analysis at the non-residential end, the application of the process is usually at the zonal level in which the pertinent land use and socio-economic data are accumulated. This is based upon further application of the trips generated in trip distribution and assignment models. As a "reasonableness" check, the trip generation relationship developed should be applied to "base" year data to develop zonal trip productions and attractions. These may then be compared to "actual" base year productions and attractions from the O-D surveys. A plot of observed against estimated values will be

useful in this evaluation. This tool, while rarely used, is an excellent means of locating analysis areas which exhibit unique characteristics. An example of such a plot is shown in Figure 14. Analysis areas represented by data points falling well away from the "45-degree line" may be located on a map of the study area and examined for unique characteristics or geographical bias. This type of plot is suggested for all of the matrices developed including trip productions, trip attractions, car ownership, and purpose stratifications.

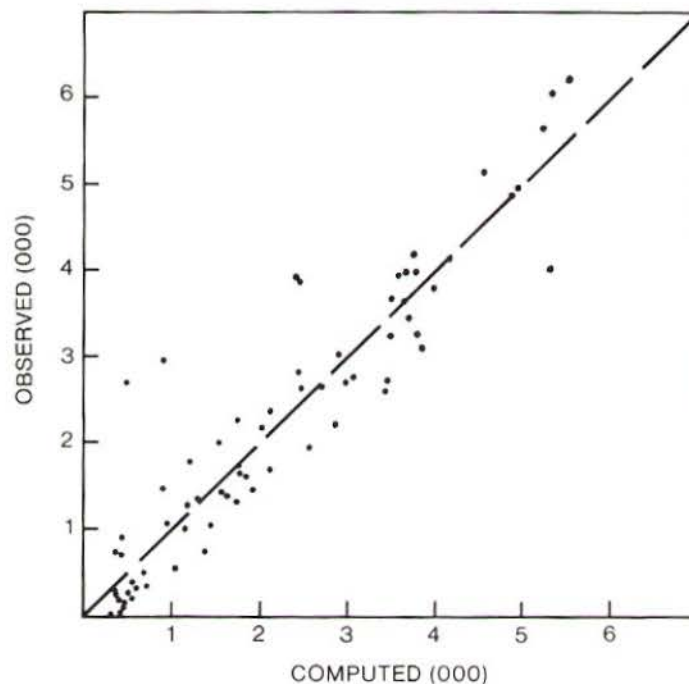


FIGURE 14 PLOT OF OBSERVED VS. ESTIMATED VALUES OF THE DEPENDENT VARIABLE--TOTAL TRIP PRODUCTION BY ZONE

The results of applying the cross classification matrix approach can be improved if unique traffic generators are removed from the matrix. A major shopping center or an air terminal are typical examples which may warrant deletion from the classification analysis. Separate analyses are then required for these areas. For example, future trip ends in the airport zone should be forecast as a function of independent projections of air passenger volumes. Time series analyses are both useful and desirable in analyzing special generators if

the appropriate data are available. A straight line or curve is fitted to the monthly or yearly observations which are treated as values of the independent variable in order to determine a long term trend. In the case of a large airport, for example, the relationship of trips to air passenger volumes may be studied over an extended length of time. Any trend that is detected will be important in forecasting trips generated by that airport.

STATISTICAL EVALUATION

As previously stated, the cross classification approach provides little facility for testing the statistical significance of various explanatory variables which are thought to affect trip generation. The analyst must rely heavily upon experience, the logic associated with trip making and good common sense. He should not become overly involved with the "statistics" associated with other procedures such as with the regression approach.

A recent article, Category Models -- A Case for Factorial Analysis (9), indicated that statistical significance tests can be performed with factorial analysis and sometimes even with the least squares regression technique. The objective of the factorial analysis is to determine the main effects and interactions of variables in a cross classification analysis and to test their significance. Basically, the main effect of a factor is determined from the average value of the dependent variable for each level of the factor. This is accomplished by holding the effects of other variables constant across the levels of the main effect being examined. The differences, if any, between the values for consecutive levels indicate the effect of the factor on the dependent variable. In addition to the above, tests are suggested by the article's authors based on analysis of variance where the basic objective is to compare the variation of the dependent variable that can be attributed to the individual factors with what can also be attributed to mere chance or random errors. The significant tests of individual factors and their interactions are performed by means of F tests. The computer programs BMD02V, Analysis of Variance for Factorial Design, and BMD05V, General Linear Hypothesis, can be used for the analysis. The reader is referred to the

above mentioned article for further details.*

Again, it is more important that the relationship developed in the cross classification be logical and the reasonableness checks discussed previously be accomplished to the analysts' satisfaction than tedious, often difficult to perform and understand, statistical tests be accomplished.

Since the cross classification is based upon mean values developed for cells of a matrix, the adequacy of source data is obviously of concern. The number of observations per cell must be sufficient and the criteria for evaluating the distribution of values about the cell mean should be met. Most O-D surveys will provide adequate data. If a survey is to be designed to collect information for cross classification analysis the sample size should be established to meet the cell size and standard deviation criteria. If possible, all variables used in the cross classification analysis should come from the same source. If a new O-D survey sample is to be collected both the travel and land use-socio-economic data should be obtained. It is difficult to merge information from several sources and expect to develop relationships as acceptable as when all data is from a single source. There are usually individual variations in each source caused by sampling which are difficult to reconcile when data are combined for use in trip generation analysis.

TIME STABILITY OF GENERATION VALUES

Generally, it is considered that since trip generation models based on zonal data aggregates are unstable from one-area to another there is little reason to assume that they will be stable over time. Cross classification at the household level however, appears to have some stability in application between areas and therefore should have some degree of validity over time. Also, the form of the cross classification matrix is such that the analyst can hypothesize changes in trip making for a matrix cell based upon some study of the past and logical determinations about the future. This type of evaluation of possible changes in trip rates should be a part of the monitoring and evaluation functions of the

* The Urban Planning Division, FHWA, is currently researching further the application of a General Linear Analysis of Variance. Application will be facilitated by the development of computer software in 1976.

continuing transportation planning activity. The form of regression approaches using aggregate zonal data makes it very difficult to "observe" the changes in trip making that may be occurring over time. It is also difficult to introduce such changes into the equations for future application. This is due to the rather complex interrelationships between independent variables, their factors and the constant of a regression equation.

To summarize, the procedure described in this document is basically a common sense approach to trip generation. A minimum of effort should be applied to statistical evaluation with the bulk of evaluation applied to reasonableness checks.

CHAPTER IV ADDITIONAL CONSIDERATIONS

A basic approach to trip generation has been presented in the preceding chapters. The purpose of this chapter will be to highlight some important areas of consideration in the development and application of trip generation procedures as well as discuss the handling of additional activities not previously covered such as external travel and truck and taxi forecasts.

FORECASTING REQUIRED CHARACTERISTICS

The procedure described in Chapter II, A Recommended Approach to Trip Generation, relies on the forecast of a few key land use and socio-economic variables for the estimation of future trip ends. These variables are income, car ownership and dwelling units for trip productions and employment, school enrollment and dwelling units for trip attractions. It is important that these land use and socio-economic variables be forecast for future year application with care since all travel forecasts and transportation systems analysis will be dependent upon such forecasts.

The assumption of the stability of the relationships between trips and land use and socio-economic variables over time is basic to forecasting. No matter how carefully the trip generation procedure is developed or how accurately the estimating relationships mirror observed data, considerable forecasting error may result unless the variables used are forecast within a reasonable degree of accuracy and the relationship in fact does remain constant over time. It is often easy to forget that the quality of the trip generation estimating procedure is only as good as the quality of the future estimates of the land use and socio-economic forecasts. Also, since the assumption of time invariance is generally made when forecasting, it is extremely important that relationships be chosen which are expected to exhibit a high level of stability over time. The transportation planner must not become so involved in the mechanics of model development that he loses sight of the goal of providing meaningful travel forecasts.

Since the development of trip generation procedures and their application are usually accomplished by a transportation planner/analyst and forecasts of land use and socio-economic characteristics are developed by land use planners, it is important that a dialogue and close working relationship be established in the development of procedures for trip generation to insure a full understanding of pertinent considerations early in the process.

CONTROLS

As previously discussed it is important in the application of trip generation procedures to obtain an areawide balance between the trip production and trip attraction estimates. The importance is related to insuring a consistency in the forecasts and also based upon trip distribution processes used such as the gravity model which relies on such an areal balance. The balancing involves the summation of zonal productions and attractions by trip purpose. If the two are not in agreement the trip production estimates are usually taken as the control since characteristics of the home such as auto ownership and income more adequately reflect changing travel characteristics than do nonresidential variables. However, if there are large discrepancies it is important that more than a cursory evaluation and adjustment be undertaken. Both the production and attraction relationships should be examined to determine if adjustments are required in future application due to unforeseen situations. For example, there may be some overbuilding of shopping facilities resulting in higher than expected shopping trips when applying the shopping trip attraction generation rates. An evaluation of this might indicate a lowering of the shopping trip rate for shopping center locations and leaving the rates constant for CBD and other non shopping center locations*. Likewise, the percentage of trips in each purpose category should be examined for consistency with known trends. For example, most repeat origin-destination studies show that work trips are declining as a percentage of total trips.

In addition to the above control checks and considerations for forecasting, close examination should be made of the growth rates in the socio-economic and land use data as they relate to the growth rate in trips. The upper portion

*It is also quite possible that increases in trips to a particular land use type activity (e.g., shopping centers) would be reasonable because of increases in the attractions of such activities over time and not because of a general rise in socio-economic levels at the production (or residential) end of the trip. Reducing the trip attractions to balance with the productions could result in an under estimation of future total travel.

of Table 14 shows an example of socio-economic survey data for a study area with corresponding future estimates. The resulting growth rates are also shown. Note the significant differences in these rates. The lower part of the table shows the areawide growth in trips and trip rates which resulted when the forecast land use and socio-economic data were applied to the base year relationships developed in this hypothetical generation analysis. By calculating ratios of combined trip and socio-economic information, a check may be made on the reasonableness of the growth in trips (line 15 in the table) against the growth in the socio-economic data used to estimate the future trip productions.

Presenting trip and socio-economic information in this manner serves two valuable purposes. First, the adequacy of the various trip estimates in reflecting the forecast socio-economic data can be evaluated. Secondly, an emphasis is placed on evaluating the forecast socio-economic data for reasonableness. For example, the growth in population by zone should reflect a similar growth in dwelling units or labor force. Often it is helpful in this type of evaluation to compare the growth rates for the combined trip and socio-economic data (Table 14, lines 16-19) with the growth rates of other study areas of similar size.

Parking Availability

In addition to the above type of controls it is important to evaluate land use changes in relation to available parking and travel to the central business area. Parking availability in the future year should be related to the auto travel forecasts. Turnover rates by time of day and/or trip purpose can be developed from a parking survey or obtained from such a study in a similar area. These turnover rates should be applied to the future estimates of travel to the CBD to assess parking requirements in relation to expected parking availability. Such an assessment may indicate that there is sufficient parking. Another result may be that sufficient parking will not be available for some trip purposes. This may result in the necessity for additional shifts in travel to mass transportation or to other locations in the metropolitan area.

Adjustment For Under-reporting

Normally trips obtained from household origin-destination surveys will be under-reported for a number of reasons including: The interviewee forgot a trip he made, overlooked

a trip some other family member made, or a family member that made trips on the travel day was not present at the household on the interview day. Trip data from the home interview are usually adjusted upward using counted traffic as a bench mark and the resulting factors often added directly to the trip cards(29).

The best method of incorporating the adjustment for under-reporting would be to locate it as an integral part of the development of the cross-classification matrix of trip rates. This could be accomplished either internally within the computer program as it builds the matrix, or externally by hand adjusting the matrix values. Currently the DUSUM and XCLASS programs in the FHWA Battery use the unexpanded trip data, each record being a trip, and any adjustment is not incorporated. Another program, PRKTAB, which can also be used as a matrix builder similar to XCLASS, has the capability of reading a factor from each trip record and applying it to the trip values being developed.

There are several other points during the process at which required adjustment factors can be applied: (1) To the zonal trip production estimate after the cross-classification matrix has been applied, or (2) the analyst can take into consideration the fact that estimated trip volumes are likely to be somewhat low when evaluating forecast trip assignment results. The simplistic nature of the dwelling unit cross-classification technique has the advantage of allowing the analyst to introduce reasonable external adjustments based on sound judgement.

Table 14.--Summary of areawide totals of typical socio-economic and land use data--a hypothetical example

	Survey data	Future estimates*	Growth factor
1 Dwelling units	19,540	27,300	1.40
2 Population	61,450	88,900	1.45
3 Cars owned	20,100	36,700	1.83
4 Labor force	23,700	33,800	1.43
5 Residential acres	3,261.4	4,557.6	1.40
6 Total employment	23,800	35,746	1.50
7 Retail sales (000's \$)	109,840	158,905	1.45
8 Commercial floor space (000's sq. ft.)	3,065	4,445	1.45
9 Industrial acres	437.2	638.4	1.46
10 Persons per car	3.06	2.42	0.79
11 Persons per dwelling unit	3.14	3.26	1.04
12 Persons per residential acre	18.84	19.51	1.04
13 Dwelling units per residential acre	5.99	5.99	1.00
14 Cars per dwelling unit	1.03	1.34	1.30
COMBINED TRIP AND SOCIO-ECONOMIC INFORMATION			
15 Total home based trip production	84,532	159,288	1.88
16 Home based trip production per car	4.21	4.34	1.03
17 Home based trip production per dwelling unit	4.33	5.83	1.35
18 Home based trip production per person	1.38	1.79	1.30
19 Home based trip production per residential acre	25.92	34.95	1.35

* Land use and socio-economic estimates are for illustration only, and are based largely on assumed data.

EXTERNAL TRIP FORECASTING

The procedures described in this document have concentrated on the development of trip generation relationships considering internal travel made by residents of the area. These trips begin and end within the cordon line of the transportation study and generally comprise 80 to 90 percent of the total trips in a typical study area. Practically all of the remaining trips have one end in the study area and the other beyond the cordon line-- external trips. Also, there are trips that have neither end in the urban area--through trips. These through trips may be of significant magnitude in the smaller urban areas. These latter through trips are usually handled by a factoring of inventoried through trips using a procedure such as the FRATAR trip factoring process. However, growth factors must be developed to apply such a method to the through trips. Such growth factors are developed based upon forecasts of facility development which may add or remove some of the attractiveness for going through the area in question and expected growths in population and economic activity in the region of the country from which the through trips develop.

There are several approaches to handling internal-external travel. One procedure for forecasting and distribution is to group external trips so that they are "produced" at the external stations on the cordon line and "attracted" to the internal analysis units (zones). The volume of external trip attractions are a function of the character of the zone and also of the distance from the cordon. Earlier research has shown a consistency in the pattern of external trip ends in a study area (Figure 15) (10). For example, the central business district normally attracts proportionally more external trips than do other zones in the study area.

Generally there are not enough external trip ends to allow them to be analyzed independently of the internal trips. It is suggested in trip generation analysis, therefore, to treat the internal ends of external trips as a proportion of all other internal trip ends. The ratio:

$$\frac{\text{No. of internal ends of external trips/zone}}{\text{No. of all other internal trip ends/zone}}$$

calculated by zone forms the basis for this approach. The average of the zonal ratios by rings can then be calculated

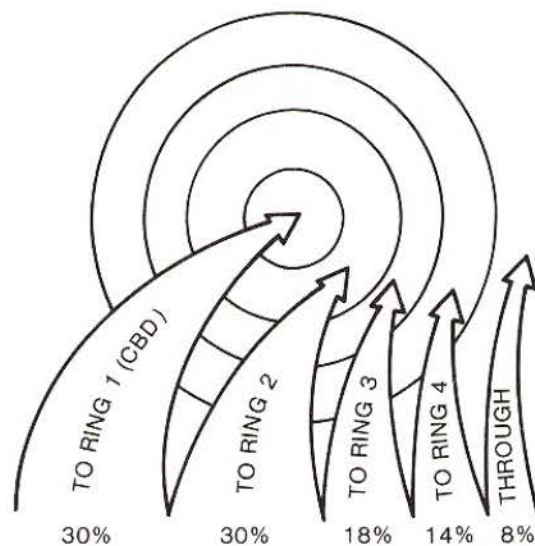


FIGURE 15 DISTRIBUTION OF TRAFFIC APPROACHING A TYPICAL METROPOLITAN AREA OF ONE MILLION POPULATION

and analyzed to determine if there is any consistent pattern. An alternative, if no pattern is discernable, might be to average the zonal ratios by district and then examine for a pattern. When a large traffic generator, such as a shopping center, draws a significant amount of external trips, it should be analyzed separately. Another approach is to use the attractions as developed for internal trips as the index for distributing the external productions at the stations to the internal zones.

The percentage of external traffic destined to various rings may change over time. Estimates of changes can be related to the growth of the city. Figure 16 illustrates the shifting distribution of external traffic as the city grows (10).

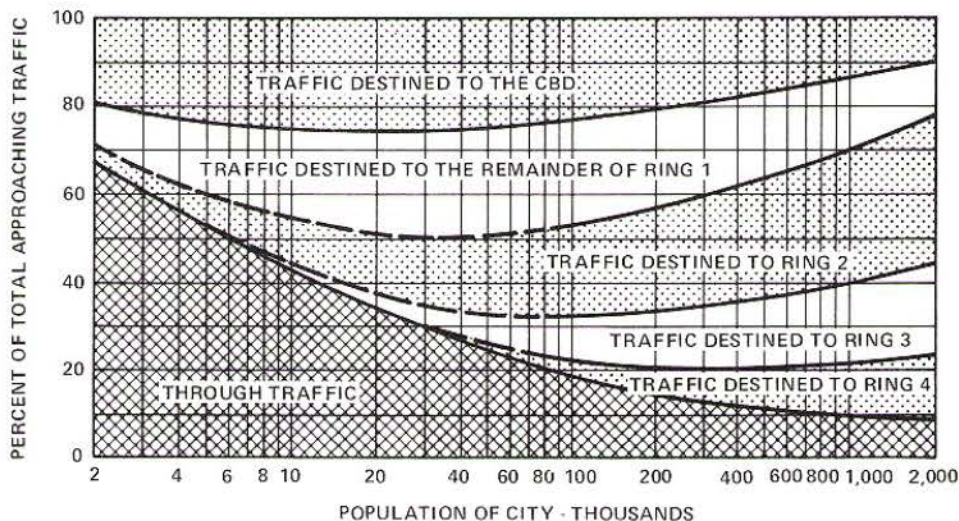


FIGURE 16. DISTRIBUTION OF TRAFFIC APPROACHING CITIES OF VARIOUS SIZES.

At the external station (production end of the trip), the forecast of future trip ends should be based upon a growth factor that reflects the growth in travel within the corridor of the station, including the growth in the area beyond the cordon which is tributary to the external station. In forecasting it is necessary to balance the growth in trips, as determined from the external factors, with the growth determined from the analysis of the zonal ratios by ring. The more reasonable and logical total value should be used as a control. The distribution model handles the problem directly if the attraction values are considered as indices by which the station productions are distributed.

TRUCK AND TAXI TRIP FORECASTING

If the volumes are sufficient, forecasts of truck travel can be accomplished by undertaking a separate truck trip generation analysis. Where volumes are low, however, truck trips are often combined with nonhome based trips, as the factors that influence the latter are also found to be important in describing truck trip generation. In the case of an unusually large truck terminal or manufacturing site with a high rate of truck trip activity, separate growth factors which reflect the potential growth characteristics of the individual site may be required. A special generator-analysis could be conducted.

Taxi trips may also be analyzed separately or combined with the nonhome based trip category, depending on their magnitude. Taxi trips usually exhibit a rather definite pattern. For example, taxi trip generation rates usually decrease in number in direct proportion to distance away from the CBD, as well as to increases in auto ownership.

When taxi and/or truck trips are significant enough to require separate analysis they can be handled in a manner similar to non-home based attractions as previously described, developing rates based upon dwelling units and employment.*

The trip productions and attractions would be set equal. In some applications truck and taxi trips have been combined and handled as a single "purpose". In one such application the following type of rates were developed based upon acres of land use (Table 15).

* See page 40, "Non-Residential Trip Generation Attractions," and Table 12.

Table 15

Example of Average Truck-Taxi Trip Rates (21)

Area Description	Trips Per Land Use Acre			
	Resid.	Comm.	Indust.	Other
Central Business District	17.37	55.96	131.50	11.92
Remainder of Area	2.04	14.33	3.78	0.83
Military	-----	-----	-----	0.68

COMPLETE SYNTHESIS OF TRAVEL

A considerable amount of research and development has been accomplished relative to procedures and methodology for transportation planning. Most of the significant work has been done by the larger urban areas in which origin and destination surveys with significant sample rates have been taken along with rather complete land use, socio-economic and transportation facility inventories. This past work in over two hundred areas provides background information which may be used to synthesize travel demand and systems use in other areas. Most work relative to synthesizing an entire travel pattern and system use has been accomplished in smaller urban areas where perhaps complete O-D surveys and other inventories cannot be justified. It would not be unreasonable, where the need arises, for an urbanized area (over 50,000 population) to synthesize the trip generation element of the forecasting process. Most approach the problem by synthesizing current travel patterns using model formulations calibrated in another, and if possible similar, area. After the models are adjusted to synthesize current patterns they can be used for forecasting future travel.

The procedures described in this document for trip generation are easily transferable to areas other than for which they are developed. The number of variables (land use, and social-economic) required for the travel estimates is small and usually available from secondary sources. The relationships shown in Appendix B can be "borrowed" for synthesizing purposes.

A procedure for a transportation planning process in small urban areas has been described in a document "Travel Simulation For Small Cities" to be published in 1975 as a FHWA Highway Planning Technical Report. An outline of the procedure described in the report is presented in Table 16.

Table 16

Outline of Simulation Procedure

- I. Data Collection and Network Development
 - A. Socio-Economic Data
 1. Population
 2. Auto Ownership
 3. Income
 4. Employment
 5. Inventory of Transportation Facilities
 - B. Traffic Counting
 1. External Cordon Survey
 2. Screenline Crossings
 3. Major Traffic Generators (hospitals, stadiums, etc.)
 4. CBD Cordon Checks
 5. VMT Estimates
 - a. areawide
 - b. subareas
 - c. functional classes
 - C. Select Highway Network and Zones
 1. Functionally Classify Network
 2. Code Network
 3. Determine Speeds
 4. Check Minimum Time Paths
- II. Trip Generation
 - A. Internal Trips
 1. Select trip purposes and percent of trips for each purpose from other studies.
 2. Select trip generation relationships from other studies.
 3. Calculate productions and attractions for each purpose by zone.
 4. Balance productions and attractions.
 5. Check results by use of control zones, and by comparison of trip rates per dwelling unit and per capita to other studies, and by comparing estimated VMT with counted VMT.
 6. Readjust trip generation model if necessary.
 - B. External-Internal Trips
 1. Determine external-internal and through productions and attractions using linear regression model based on an external origin-destination study.
- III. Trip Distribution
 - A. Internal Trips
 1. Distribute productions and attractions by purpose using the gravity model and friction factors derived from other transportation studies.
 2. Check resulting trip length frequencies for each trip purpose for reasonableness and compare to frequency curves from similar urban areas of similar character.
 3. Compare ground counts across screenlines to movement across screenlines indicated by the distribution model and compare desires to and from CBD with cordon counts around CBD.

Table 16 (continued)

- a. Add time penalties to compensate for topographical barriers if necessary.
 - b. Make zone-to-zone adjustments as necessary.
 - B. External-Internal Trips
 - 1. Distribute synthetic external-internal productions and attractions by purpose using the gravity model and friction factors derived from other transportation studies.
 - 2. Calibrate gravity model by adjusting friction factors until the resulting synthetic trip length frequency curves matches the frequency curve produced by a distribution of internal-external O-D trips.
 - 3. Assign the internal-external O-D trip matrix and the synthetic external-internal model trip matrix to the existing network.
 - a. Separate links into volume groups for root mean square analysis.
 - b. Compare O-D and model distribution of trips across screenlines.
 - c. Make any zone-to-zone adjustments as needed to properly distribute the synthetic trips to reproduce O-D movements.
- IV. Assignment and Checks
 - A. Assign all trips in origin-destination format to the existing network.
 - B. Gross Checks
 - 1. Compare total VMT for assigned trips and ground counts.
 - 2. Using screenlines, cutlines, and CBD cordon, compare total volumes for ground counts and model trips.
 - C. Fine Tuning Checks
 - 1. Compare assigned and counted VMT disaggregated by functional class and area type.
 - 2. Compare assigned volumes on specific links with ground counts.
- V. Model Adjustments
 - A. Validity checks indicate that model trips and VMT do not agree with ground counts and actual VMT.
 - 1. Examine network and alter if necessary.
 - 2. Adjust zonal productions and attractions up or down.
 - 3. Adjust speeds to get better link-by-link agreement with ground counts.
 - B. Checks indicate model VMT and screenline checks are good
 - 1. Adjust speed if necessary to smooth out assigned trips
 - C. Model VMT is good but distribution is poor
 - 1. Make zone-to-zone adjustments if appropriate.
 - 2. Alter friction factors.

CHAPTER V

MONITORING AND SURVEILLANCE FOR TRIP GENERATION

The continuing transportation planning process **emphasizes** the need to monitor and, if needed, update trip volume estimates in light of changing land use and socio-economic characteristics. Since trip generation estimating relationships are usually derived from cross-sectional data for one period in time, and are subject to change with time, it is also extremely important that the relationships be evaluated periodically.

DATA REQUIREMENTS

Since trip generation supplies the direct link between travel and changes in the land use pattern it is necessary to periodically evaluate the relationships for stability. Additionally, the changing character and intensity of land use must be accounted for.

The intensity and character of land use in a study area are continually undergoing transformation. The most dramatic example can be seen in the central business district of most any city in the country. Small, old office buildings give way to parking lots sandwiched between two surviving buildings which eventually yield to the forces of time in the same fashion. After a brief existence, the parking lot becomes the site of a large modern office building. Changing character and intensity of residential land is just as evident. Small apartment houses are replaced with higher ones, resulting in a considerable increase in residential density. In the newer areas vacant land is utilized in developing commercial and residential land uses.

The procedure for trip generation described in Chapter II is efficient concerning data requirements for monitoring and surveillance. For residential trip generation, the land use and socio-economic forecasts include the number of dwelling units and income. For non-residential generation, the forecasts required are dwelling units, employment and school enrollment. The need for updating this information is primarily a function of the age and growth pattern of a metropolitan area. In older cities

actual updating may not be as critical as in rapidly growing urban areas. This does not however alleviate the need for adequate and timely evaluations in all areas. To stay abreast of travel demands and changing land use activity in a dynamic and rapidly growing area, evaluation of the forecast annually may not be too often.

In addition to application of trip generation rates to changing land use patterns it is important to evaluate the trip generation relationships. For example, for some unknown reason the trip making rate of a one car household with a \$10,000 income may be increasing. The analyst should periodically evaluate the stability of the developed relationships over time. For the recommended procedure the data requirements for monitoring change in the trip generation relations may be limited to a small sample travel survey coupled with site surveys of selected nonresidential land uses.

Significant research by the Transportation Center at Northwestern University has probed several areas in an attempt to develop an understanding of the relationship between nonresidential land use and travel (11). It was found, for example, that stratification of nonresidential land use "parcels" into "major" and "minor" trip attractors, with analysis conducted on each, would facilitate the investigation of nonresidential trip generation. For the study area data that were used in the research, about 70 percent of the trip ends were attracted to about 15 percent of the land use parcels within the area. If detailed site analysis were concentrated on the relatively few land use activities that comprise the "major" trip attractors, a means of monitoring nonresidential trip generation would exist.

Findings in a continuing study by the California Department of Transportation as well as by other States indicates that individual site analysis is indeed feasible (12). In this continuing effort, which could well be the forerunner of future practice, traffic counts are being taken at selected sites with a range of land use characteristics. The traffic counts on vehicles entering and leaving the sites are related to characteristics of the sites to obtain trip rates in terms of trips per employee, trips per unit of floor area, etc. Hourly recordings of traffic counts are being obtained over a period of from two or three days a week. This type of

study not only offers a more intensive analysis of the trip attraction characteristics of major land uses, but permits an investigation of trip generation rates by hour of the day and day of the week.* Day-to-day variability in travel habits has long been known to be a major contributor to the unexplained variance in trip generation. Although most site analysis has been done at non-residential land uses, site analysis can be done for residential areas such as apartment complexes, townhouse developments and single family home communities. The traffic count data collected would be related to characteristics of the area as might be found in census data.

CHECKS TO BE CONSIDERED

Trip generation procedures are critical at two stages of transportation study reappraisal. The first is during routine review when traffic data are required for project planning and design. If land use activity differs significantly from that originally projected then original trip generation estimates will not be valid and the current land use and socio-economic information should be used for a new trip projection in those areas with significant growth differences. If the difference between the original estimates and the revised trip estimates is significant for the corridor in which the project is located, consideration would be given to rerunning the whole chain of forecasting models to obtain an updated forecast year assignment. The analyst will then be in a position to determine the effect of the difference in the trip forecast on the system.

These steps indicate that continuing transportation studies maintain selected land use and socio-economic data on a current basis through an adequate, on-going surveillance program, thus assuring the ability to make evaluations of, or updates to, the original forecasts. In addition, estimates of the impact of proposed changes in land use are often required. Such information should be readily available both for project planning and as a "service" product of the continuing planning process.

*Results of the compilation of such studies around the nation have been produced by the National Association of County Engineers (1), and the Maricopa Association of Governments (2). An Institute of Traffic Engineers Technical Committee is currently compiling and analyzing rates from studies around the country in an on-going project (16). Results should be available in 1975.

A second stage occurs during a major review. The need for more extensive data than that obtained during routine review may be indicated if original travel forecasting procedures are technically inadequate by current standards or if the original procedures cannot reproduce current travel patterns, as measured through a system surveillance program. Enough information, therefore, must be obtained so that existing models can be refined or, if refinement is not possible, new models calibrated. Because of both the cost involved and the need for timely information, areawide comprehensive home interview surveys are not necessarily appropriate for supplying data for this refinement or model updating function. Site analysis may well supply the required information. If necessary, consideration may be given to a small sample travel survey allowing cross classification analysis for trip generation and other model inputs such as trip length distributions. Consideration should also be given to the possibility of "borrowing" basic trip generation rates from other (and similar) transportation studies. See Appendix B and references 1, 2 and 16 for examples.

APPENDIX A FORECASTING INCOME

INTRODUCTION

Income is a key variable in the trip generation forecasting procedure outlined in this manual and income forecasting can be a difficult tool to use in the process unless precautions are exercised along the way. For example, the use of national and regional stepped-down control totals will help to insure reasonable forecasts. Sources mentioned in the next section are available in this regard.

In addition, location and density affect travel demand of a household within any given income group. It was suggested in the main text and is suggested again here that measures of density be used as a third independent variable in the forecasting process. Other factors that are becoming more important today and are related to income are not so easily dealt with, however. For example, changes in family life style as measured by the effects of energy constraints, inflation, and unemployment will all affect the resources a family can spend on transportation. Although it is difficult to precisely quantify these factors so that they may be explicitly treated in trip generation forecasting, the resulting effect of energy constraints on trip making has been noted in a few cases (26,27). As a minimum, however, the rather flexible and understandable framework which is the basis for trip generation technique provides the analyst the opportunity to easily test alternative future conditions. As time goes by and transportation studies continually update their forecasts and data bases, new values and additional information will be available to add to the forecasting process.

SOURCES OF AVAILABLE DATA

There are useful income forecasts that are produced by Federal agencies that may be used as a base. These estimates are generally available on an SMSA basis. The most complete forecast has been prepared by a joint effort of the Bureau of Economic Analysis of the Department of Commerce and the Economic Research Service of the Department of Agriculture for the U.S. Water Resources Council (15). The data are contained in a seven-volume set and include historical and projected measures of population, employment, personal income and earnings for States, Economic Areas, Standard Metropolitan Statistical Areas (SMSA's), and Water Resource Regions. Volume V contains SMSA

projections and is a good source of estimated per capita income (\$1967), based on Series 'E' population projections, through the year 2020. The volume contains tables for each of 253 SMSA's, the United States, and the sum of SMSA's. An example is shown in Table 17. Similar information is contained in another Bureau of Economic Analysis publication: "Area Economic Projections, 1990" (17).

The above source provides areawide statistics on income which must be stratified by geography (i.e., zones). The census data provides a source for such a process at least on a historical basis. The PC(1) series for each State provides income distribution data for SMSA's, urbanized areas and places and is available every ten years. In the 1970 census the number of families and unrelated individuals in each of the following income ranges was provided: less than \$1,000, 1,000-\$1,999, 2,000-\$2,999, 3,000-\$3,999, 4,000-\$4,999, 5,000-\$5,999, 6,000-\$6,999, 7,000-\$7,999, 8,000-\$8,999, 9,000-\$9,999, 10,000-\$11,999, 12,000-\$14,999, 15,000-\$24,999, 25,000-\$49,999, \$50,000 and more. Also included are the median and mean incomes. For the procedure to be described the ranges above \$10,000 should be stratified into \$1,000 groupings up to about 20-\$25,000. This can be done by plotting cumulative curves from the data given and entering the cumulative curve to obtain income in \$1,000 increments.

TABLE 17
EXAMPLE TABLE IN OBERS PROJECTIONS (15)

SMSA 001 Abilene, Tex.

1972-E OBERS Projections

Table 1.—Population, Employment, Personal Income, and Earnings by Industry, Historical and Projected, Selected Years, 1950-2020

	1950	1962*	1969	1970	1971	1980	1985	1990	2000	2020
Population, midyear.....	86,236	129,684	116,965	114,542	116,313	114,300	115,800	117,200	118,900	123,500
Per capita income (1967 \$).....	1,865	2,253	2,916	3,154	3,166	4,200	4,800	5,500	7,400	12,300
Per capita income relative (U.S. = 1.00).....	.90	.87	.85	.91	.89	.90	.90	.90	.92	.93
Total employment.....	32,124	47,281	46,337	46,337	46,337	48,790	49,400	50,100	52,700	54,800
Employment/population ratio.....				.40		.43	.43	.43	.44	.44
In Thousands of 1967 Dollars										
Total personal income.....	160,830	292,153	341,014	361,237	368,247	489,400	565,500	653,400	890,100	1,531,500
Total earnings.....	127,997	231,052	264,058	276,538	279,476	369,400	425,300	489,600	663,600	1,154,000
Agriculture, forestry and fisheries.....	17,010	13,579	14,780	20,257	16,208	19,300	20,590	21,900	25,000	32,400
Agriculture.....						19,300	20,500	21,900	24,900	32,400
Forestry and fisheries.....						(S)	(S)	(S)	(S)	(S)
Mining.....	16,298	15,148	10,104	8,872	7,963	6,700	6,300	5,900	5,700	5,900
Metal.....										
Coal.....						6,600	6,200	5,800	5,600	5,800
Crude petroleum and natural gas.....						(S)	(S)	(S)	(S)	(S)
Nonmetallic, except fuels.....										
Contract construction.....	7,906	19,646	12,866	14,037	12,630	17,200	19,400	22,000	28,700	46,700
Manufacturing.....	12,867	26,836	26,715	26,898	27,761	37,500	42,700	48,700	63,200	100,800
Food and kindred products.....						8,900	9,200	9,400	10,300	17,600
Textile mill products.....						2,500	3,000	3,700	5,000	8,100
Apparel and other fabric products.....						(S)	(S)	(S)	(S)	(S)
Lumber products and furniture.....						(S)	(S)	(S)	(S)	(S)
Paper and allied products.....						(S)	(S)	(S)	(S)	(S)
Printing and publishing.....						3,200	3,700	4,200	5,600	9,300
Chemicals and allied products.....						(S)	(S)	(S)	(S)	(S)
Petroleum refining.....						1,000	1,100	1,200	1,500	2,100
Primary metals.....						1,400	1,600	1,900	2,600	4,200
Fabricated metals and ordnance.....						1,400	1,700	2,000	2,600	4,100
Machinery, excluding electrical.....						2,900	3,800	5,000	8,000	16,500
Electrical machinery and supplies.....										
Motor vehicles and equipment.....						4,000	4,500	5,000	6,100	8,600
Transportation equip., excl. mtr. vehs.....						9,800	11,400	13,300	17,800	29,400
Other manufacturing.....										
Trans., comm. and public utilities.....	11,518	15,072	18,437	19,261	18,872	23,800	26,500	29,600	38,700	61,600
Railroad transportation.....						2,200	2,000	1,800	1,600	1,300
Trucking and warehousing.....						7,300	8,200	9,300	12,100	19,200
Other transportation and services.....						1,500	2,100	2,500	3,300	5,700
Communications.....						6,100	7,200	8,500	11,900	21,300
Utilities (elec., gas, sanitary).....						6,200	6,700	7,300	9,100	13,800
Wholesale and retail trade.....	28,639	44,319	49,521	46,852	48,335	60,100	66,400	73,400	93,500	144,200
Finance, insurance and real estate.....	4,702	10,017	12,088	11,893	12,430	18,900	22,500	26,800	38,300	69,700
Services.....	17,822	34,406	49,226	52,188	52,423	84,600	102,400	123,900	183,500	359,800
Lodging places and personal services.....						5,600	5,800	6,000	6,700	8,500
Business and repair services.....						10,400	12,900	15,000	24,200	49,300
Amusement and recreation services.....						1,100	1,200	1,400	1,800	3,000
Private households.....						3,100	3,100	3,100	3,200	3,600
Professional services.....						64,200	79,100	97,600	147,500	295,100
Government.....	11,237	52,030	70,319	76,282	82,853	100,900	117,600	137,000	187,000	332,500
Federal government.....	1,780	6,833	10,581	10,966	11,474	14,300	17,300	20,100	27,300	50,600
State and local government.....	8,727	17,385	27,493	29,300	30,834	43,500	52,200	62,500	90,200	167,800
Armed forces.....	730	27,812	32,746	35,924	40,545	42,500	48,900	54,300	69,400	114,000

*Employment is for 1960.

a—represents 80.0 to 99.9 percent of the true value
b—represents 60.0 to 79.9 percent of the true value

c—represents 40.0 to 59.9 percent of the true value
d—represents 20.0 to 39.9 percent of the true value

e—represents zero to 19.9 percent of the true value

BASIS FOR PROCEDURE

The following forecasting procedure is based upon using an income projection for an entire study area and the distribution of families by income class for the area under study. A review of income data indicates a change in the distribution of families by income class as time progresses. Figure 17 shows the distribution of families by total family income for the periods 1951, 1961 and 1971 for the United States based upon constant 1971 dollars. It is clear that the proportion of families in the lower income ranges is decreasing and that the proportion of families in the higher income ranges is increasing. The curves indicate that the rate of income growth experienced by families in the lowest income class is greater than in the higher income classes.

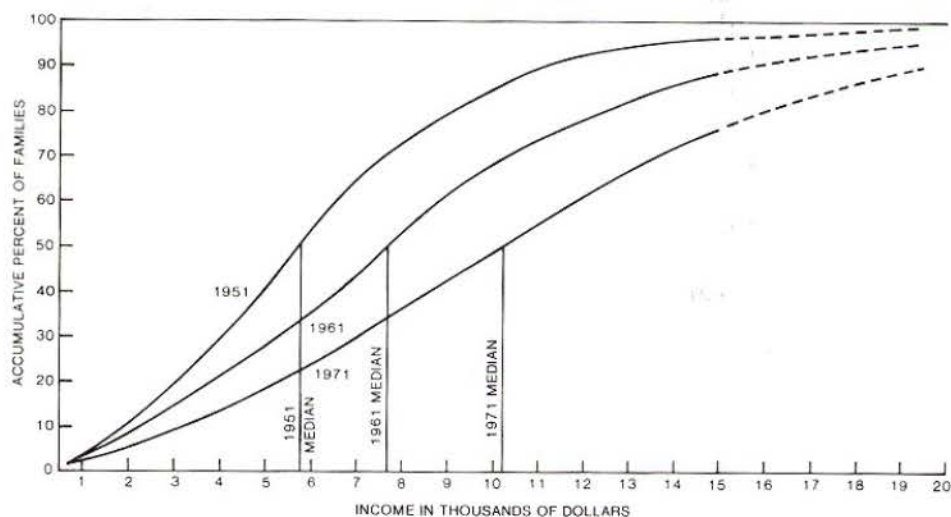


FIGURE 17 DISTRIBUTION OF FAMILIES BY TOTAL FAMILY INCOME IN CONSTANT 1971 DOLLARS

A study completed by the New York State Department of Transportation indicates that for the lowest income class (0-\$2,999) the rate of income growth is about 1.5 times that for the \$10,000-\$14,999 income class (18). Another characteristic found in this study is that the percent of income in quintiles of the population remains relatively stable. For the U.S. between 1960 and 1969, approximately 5% of total income is within the first 20% of the population, 12% within the next 20%, 18% within the third quintile and 24 and 41 percent respectively in the fourth and fifth quintiles. These characteristics and the sources mentioned previously provide a method for forecasting future distributions of income.

INCOME FORECASTING EXAMPLE

To illustrate the process Figure 18 and table 18 present example data for an urbanized area. The Figure shows the percent of families within \$1,000 income ranges as may be obtained from the Census PC(1) series.

Table 18
EXAMPLE DATA - INCOME FORECASTING

\$ in Thousands	Percent 1960 Fami- lies	Accum. Percent 1960 Fam.	Percent 1970 Fami- lies	Accum. Percent 1970 Families
0-1	14.56	14.56	2.70	2.70
1-2	15.22	29.78	5.40	8.10
2-3	14.35	44.13	6.84	14.94
3-4	13.48	57.61	7.92	22.86
4-5	11.74	69.35	8.46	31.32
5-6	9.57	78.92	8.64	39.96
6-7	6.09	85.01	8.46	48.42
7-8	4.13	89.14	8.10	56.52
8-9	3.04	92.18	7.20	63.72
9-10	1.52	93.70	6.30	70.02
10-11	1.08	94.78	5.40	75.42
11-12	.87	95.65	4.50	79.92
12-13	.54	96.19	3.78	83.70
13-14	.48	96.67	2.88	86.58
14-15	.43	97.10	2.34	88.92
15-16	.39	97.49	2.16	91.08
16-17	.32	97.81	1.62	92.70
17-18	.26	98.07	1.26	93.96
18-19	.21	98.28	0.94	94.90
19-20	.17	98.45	0.90	95.80
20 +	1.55	100.00	4.20	100.00

Table 18 presents the same data along with the accumulated percent of families. The first step in the forecast is to adjust the 1960 income distribution to a 1970 dollar base. This is done utilizing the consumer price index (19). An example table for the U. S. is shown as Table 19. This table shows 1971 as the base. To convert to another year as a base, divide all the values in the table by the index for the year desired to be the base and multiply by 100. To convert to a 1970

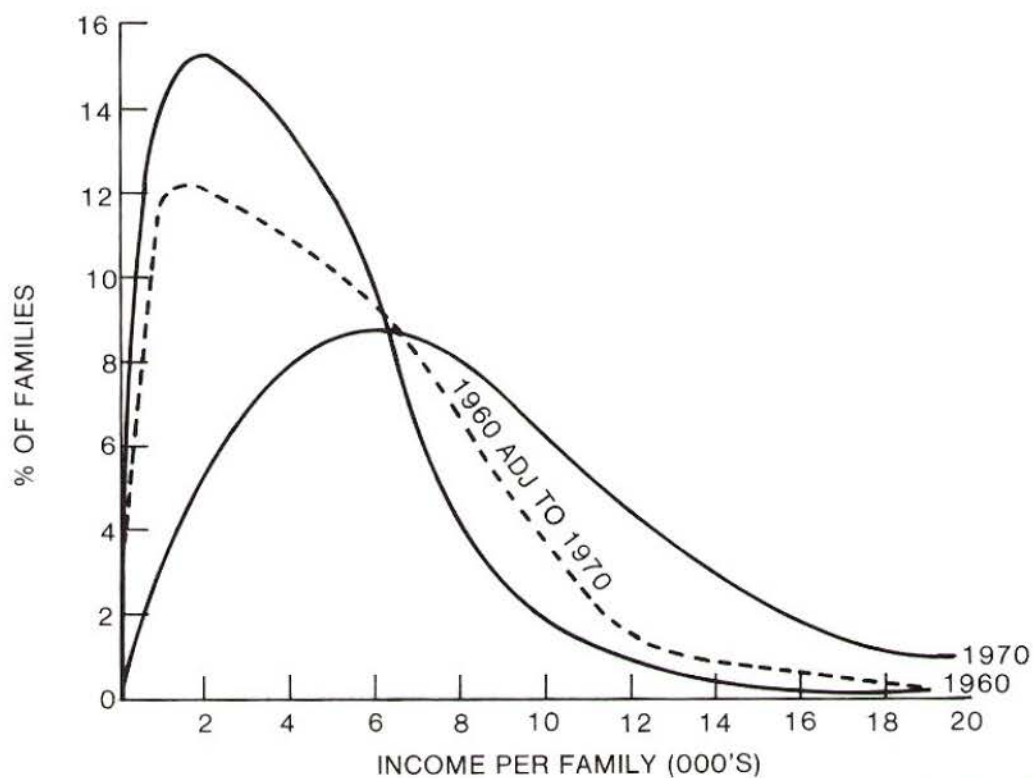
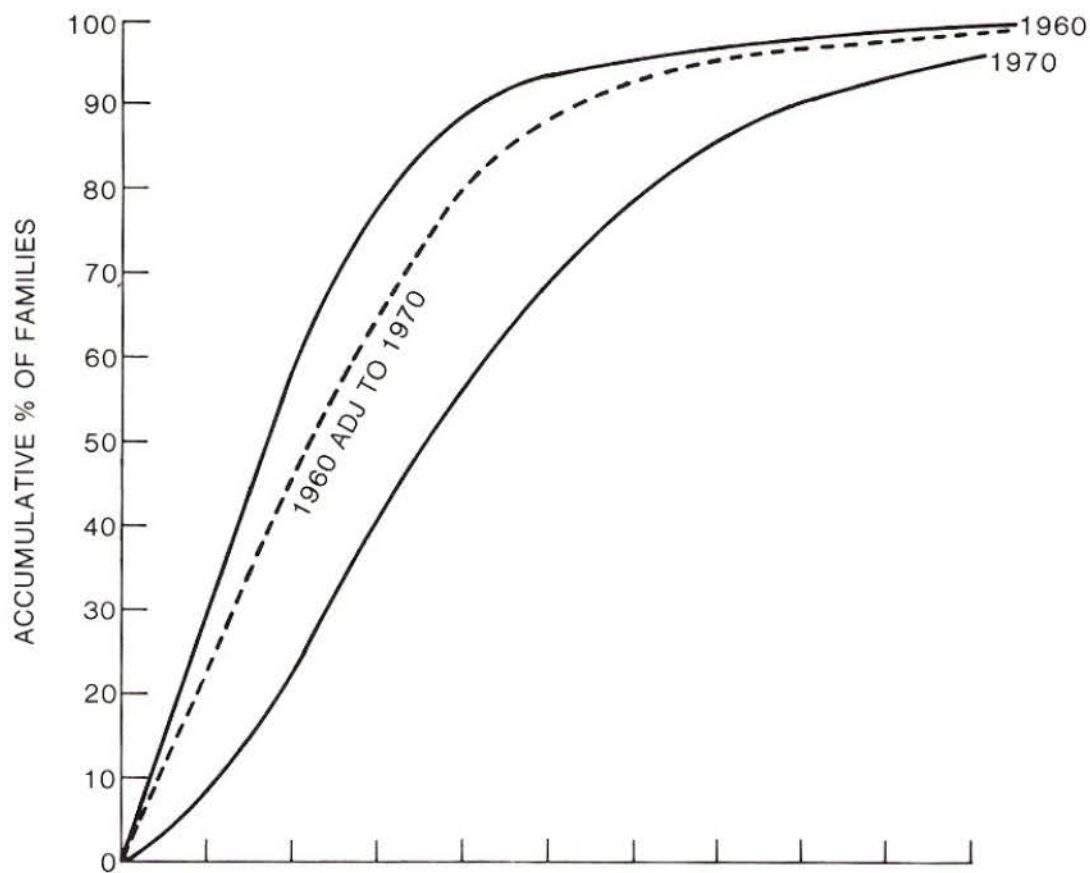


FIGURE 18 ADJUSTMENT OF 1960 CURRENT DOLLARS TO 1970 CONSTANT DOLLARS

base all values would be divided by 95.9. To convert the example 1960 income distribution, the price index would be developed as $[(73.1/95.9) \times 100] = 76.2$. The data shown in Table 19 is also available by major city or Standard Metropolitan Statistical area (19).

Table 19
Consumer Price Index
1971 = 100

YEAR	INDEX	YEAR	INDEX	YEAR	INDEX	YEAR	INDEX
1947	55.2	1953	66.0	1959	72.0	1965	77.9
1948	59.4	1954	66.4	1960	73.1	1966	80.1
1949	58.9	1955	66.1	1961	73.9	1967	82.4
1950	59.4	1956	67.1	1962	74.7	1968	85.9
1951	64.1	1957	69.5	1963	75.6	1969	90.5
1952	65.5	1958	71.4	1964	76.6	1970	95.9
						1971	100.0

The adjustment factor to convert 1960 current dollars to 1970 base dollars would be $100.00/76.2 = 1.31$.

The above steps of converting the table value to a 1970 base are, however, not necessary to convert 1960 current dollars to 1970 base dollars. By entering any year as base Consumer Price Index Table, the 1970 index would be divided by the 1960 index - in the above table 95.9 divided by 73.1, to obtain the factor 1.31. Table 20 shows each range of income factored by 1.3 with the percent of families in the new range taken from Table 18. To obtain the percent of families within the original \$1,000 increment ranges, the "Accumulated % of Families" from Table 20 would first be plotted as shown in the top half of Figure . The curve would then be entered at each \$1,000 increment to obtain the % of families in \$1,000 ranges" as shown in the last column of Table 20 and as plotted in the bottom half of Figure 18. This figure shows for the test city the change in the income distribution between 1960 and 1970 in constant 1970 dollars. As can be seen there is a shift in families from the lower income ranges to the higher incomes.

Table 20
Income Forecasting - Adjustment for Cost of Living
1960 to 1970 Dollars

<u>\$ in Thousands</u>	<u>1960 \$ Range Adj. to 1970 Dollars (000's)</u>	<u>Accum. % of 1960 Families</u>	<u>% of Families in \$1,000 Ranges</u>
0-1	0-1.31	14.56	12.0
1-2	1.31-2.62	29.78	12.0
2-3	2.62-3.93	44.13	11.6
3-4	3.93-5.24	57.61	11.0
4-5	5.24-6.55	69.35	10.0
5-6	6.55-7.86	78.92	9.5
6-7	7.86-9.17	85.01	8.0
7-8	9.17-10.48	89.14	6.5
8-9	10.48-11.79	92.18	5.0
9-10	11.79-13.10	93.70	4.0
10-11	13.10-14.41	94.78	2.2
11-12	14.41-15.72	95.65	1.5
12-13	15.72-17.03	96.19	1.3
13-14	17.03-18.34	96.87	1.0
14-15	18.34-19.65	97.10	0.8
15-16	19.65-20.96	92.49	0.6
16-17	20.96-22.27	97.81	0.5
17-18	22.27-23.58	98.07	0.4
18-19	23.58-24.89	98.28	0.3
19-20	24.89-26.20	98.45	0.2
20 +		100.00	1.6

To forecast 1990 incomes, a 3% annual real income growth rate is to be used for the example. The value for an actual city would be locally developed or obtained from a source such as the one shown in Table 17.

Table 21 and Figure 19 illustrate the forecasting of a 1990 income distribution. An initial assumption is made that the lower income families will grow at a faster rate than the higher incomes. For the example shown, 4.0% is utilized for the lower incomes up to \$4,000 which accounts for about 23% of the population. 3.5% is used for the range \$4,000-\$7,000 which accounts for about 25% of the population. Three percent is used for the range \$7,000-\$14,000 (38%). To calculate the percent for

the last range such that the average will equal 3% the following is used. As a generality, 5%, 12%, 18%, 24%, and 41% is the distribution of income by quintiles of the population. A 4.00% growth is used for the first quintile, a 3.50% increase for approximately the second quintile, a 3.00% increase for a little more than the third and fourth quintiles. To obtain the fifth quintile value the following approximation is used:

$$.05(4.00) + .12(3.5) + .42(3.0) + .41(x) = 3.0$$

$$.02 + .42 + 1.26 + .41x = 3$$

$$.41x = 1.12; x = 2.73 \text{ use } 2 \frac{3}{4}\%$$

The above choice of growth factors for each quintile is based upon judgement and a review of income distribution changes over the years for the area under study. Should the results of the choice not be suitable, another set of factors would be chosen and tried. The percent growth rate is converted to a factor as shown in the "Factor" column of Table 21 by a table look-up in a compound interest table with 20 years and the growth rate used. A new range is determined by multiplying the "Income Range" in the first column of Table 21 by the "Factor". The "Accumulated Families" is then plotted against the "Factored Range" as shown in the top half of Figure 19.

Table 21
1990 Income Calculation

Income Range \$(000's)	1970 Income Distrib. % of Families	Accum. Families	% Increase (3% avg.)	Factor	Fact. Range	% Fam. in \$1,000 Ranges
0-1	2.70	2.70	4.00	2.19	0-2.19	1.0
1-2	5.40	8.10	4.00	2.19	-4.38	1.6
2-3	6.84	14.94	4.00	2.19	6.57	2.0
3-4	7.92	22.86	4.00	2.19	8.76	2.3
4-5	8.46	31.32	3.50	1.99	9.95	3.0
5-6	8.64	39.96	3.50	1.99	11.94	3.4
6-7	8.46	48.42	3.50	1.99	13.93	3.9
7-8	8.10	56.52	3.00	1.81	14.48	4.2
8-9	7.20	63.72	3.00	1.81	16.29	4.4
9-10	6.30	70.02	3.00	1.81	18.10	5.2
10-11	5.40	75.42	3.00	1.81	19.91	5.6
11-12	4.50	79.92	3.00	1.81	21.72	6.0
12-13	3.78	83.70	3.00	1.81	23.53	5.9
13-14	2.88	86.58	3.00	1.81	25.34	5.4
14-15	2.34	88.92	2.75	1.72	25.80	4.6
15-16	2.16	91.08	2.75	1.72	27.52	4.0
16-17	1.62	92.70	2.75	1.72	29.24	3.5
17-18	1.26	93.96	2.75	1.72	30.96	3.0
18-19	0.94	94.90	2.75	1.72	32.68	2.6
19-20	0.90	95.80	2.75	1.72	34.40	2.3
20 +	4.20	100.00	2.75	1.72	--	26.1

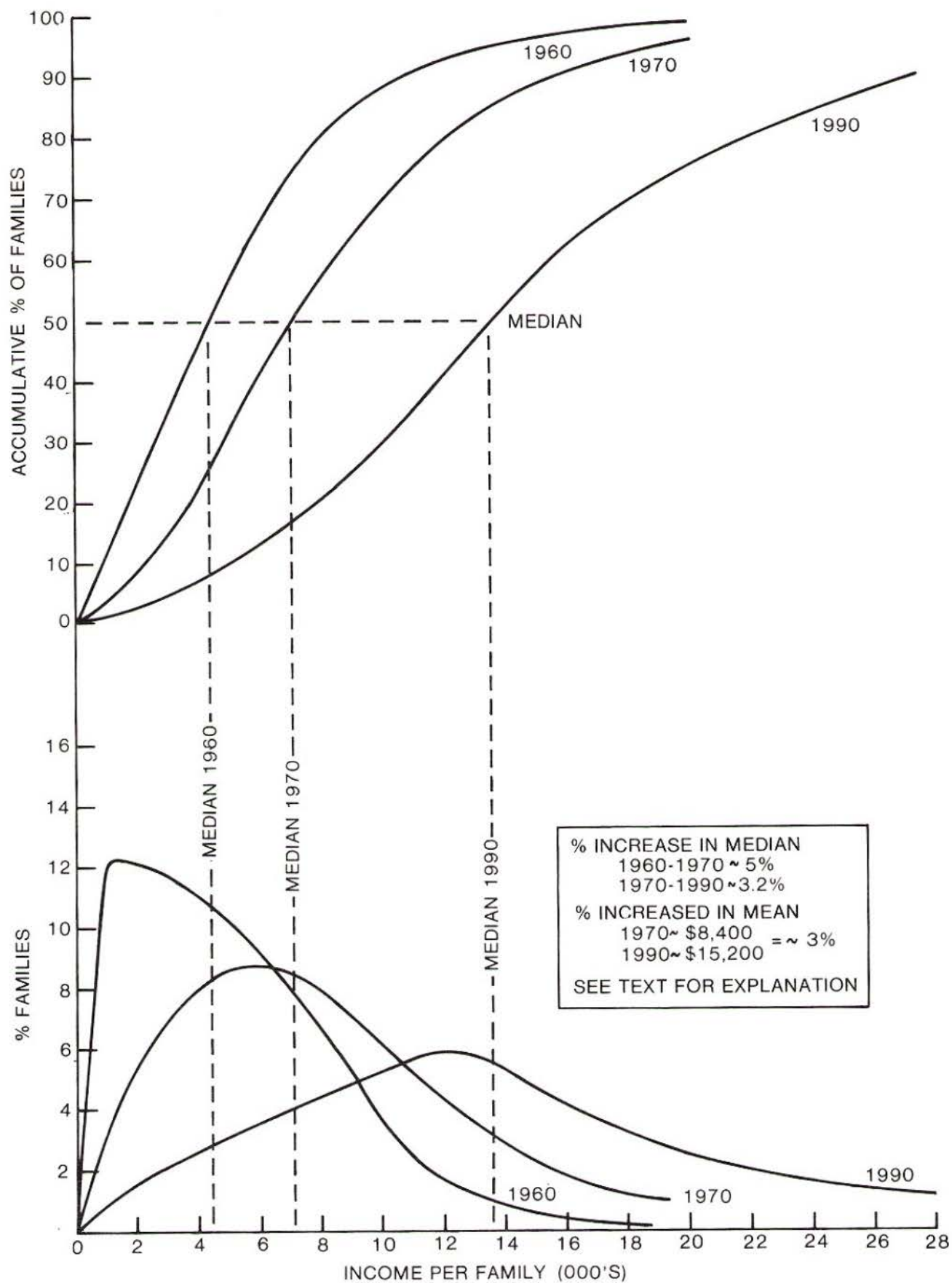


FIGURE 19. 1990 INCOME DISTRIBUTION FORECAST (1970 DOLLARS).

This accumulated curve is then entered at \$1,000 increments to obtain the values for the last column "% Families in \$1,000 ranges". These values can then be plotted as shown in the bottom half of Figure 19.

The median incomes can be obtained directly from the plotted curves as shown in Figure 19. The mean income is calculated by multiplying the number of families in each income range by the mean income of the range, summing these values and dividing by the number of families. The mean income for the example case is shown to have increased annually by the assumed 3%.

If the resultant curve from the previous calculations does not "look" like it fits the previous trends (in this case 1960 and 1970), the distribution can now be modified by adjusting the growth rates used and re-calculating the distribution. Once an acceptable areawide distribution is obtained, individual zonal incomes may be forecast.

APPLICATION TO ZONAL INCOMES

Although the previous discussion has been based upon family income (the unit for which income is provided by census), households or dwelling units are the units usually considered in transportation planning since these are the units generally used in collecting travel data. The income growth factors as developed above for families should be applicable to zonal incomes by household or dwelling unit as described here.

The growth rates determined for use (See Table 21) are now applied to 1970 average incomes by zone (or by household or groups of households within zone if such is available and household incomes are desired). The proper growth factor is applied to corresponding incomes. For example, 1970 zonal incomes between 0 and \$4,000 are factored by 2.19 to obtain 1990 average zonal incomes in the illustration used. Once factors are applied to all cases, a distribution similar to Figure 19 may be drawn to check the results. Minor adjustments may now be required to assure the desired number of households within each income range.

The income forecasting procedure described allows the forecasting of a mean household income. There are situations where an income distribution would be useful, and in fact, the trip generation procedure described can be structured to be applicable to a classification of households by income within a zone. Some work has been undertaken by FHWA to evaluate a distribution of income relationship with mean income. Figure 20 shows the results for one SMSA, Reading, Pennsylvania. Income has been structured into low, medium and high based upon the ranges: under \$8,000, \$8,000-\$12,000 and above \$12,000 respectively. The data points used were by tract. The source of the data was the 1970 Census of Population and Housing PHC(1)-171 series.

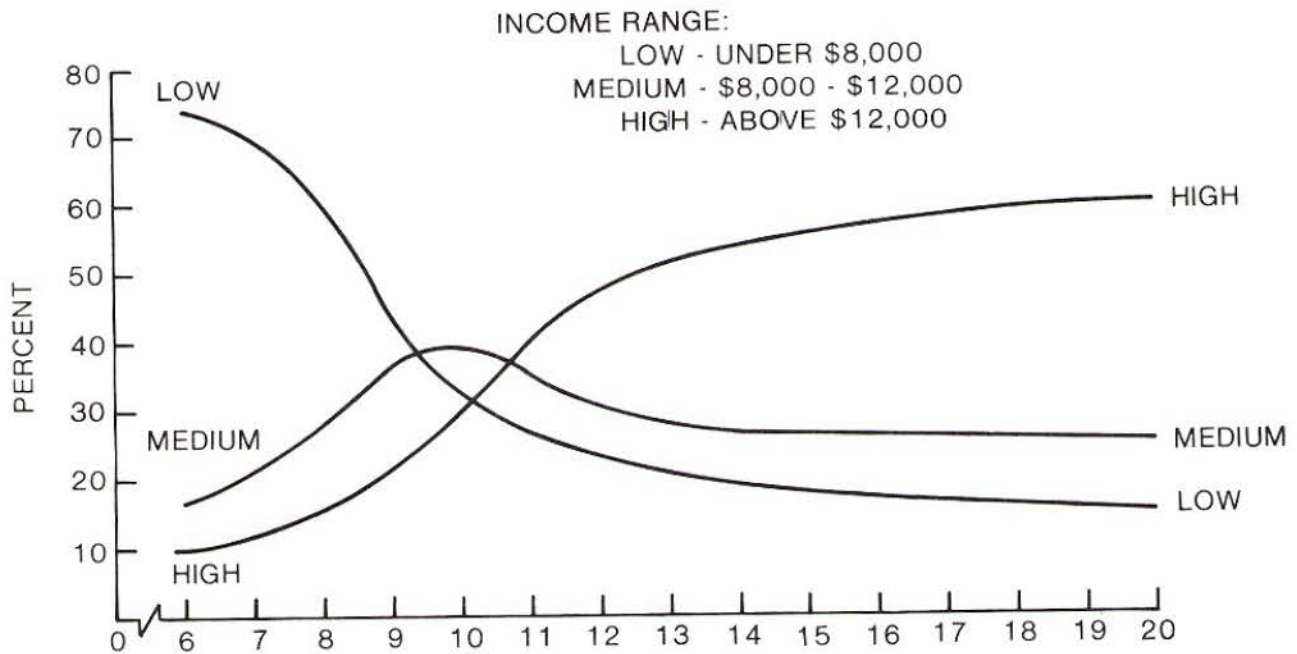


FIGURE 20. INCOME DISTRIBUTION BY TRACT IN LOW, MEDIUM & HIGH INCOME RANGES.

APPENDIX B
A COMPENDIUM OF HOUSEHOLD TRIP GENERATION RATES AND INCOME/AUTO
OWNERSHIP RELATIONSHIPS

INTRODUCTION

The technical transportation planning process has evolved into a relatively complex and sophisticated set of procedures. Much criticism has been aimed at the fact that this process is too cumbersome to provide appropriate answers to planning questions within a reasonable time limit. The criticism generally is directed at two major problem areas: (1) The need to perform updates to the planning process quickly so that a continuing long-range planning program is maintained and (2) the need to provide "overnight" answers to short-range and project planning questions.

The simplified trip generation analysis described in this manual is intended to help alleviate these problems. As an additional step, a number of transportation studies are moving toward synthesizing internal travel by "borrowing" data for certain parameters from other study areas as a means of reducing the resource requirements of the planning process. Synthesis has been relatively widespread among the small urban areas (under 50,000 population) for sometime. From recent work by the Federal Highway Administration (FHWA) and several States, and as a result of 1970 census data, the feasibility of synthesizing urban travel for larger areas has become promising. This appendix is included to provide basic trip generation relationships following the recommended approach in this manual. Such relationships (both trips per household and income/auto ownership) are intended to serve as a supplemental source for comparison with locally developed relationships or as default or "fall back" relationships for synthesis.

The appendix is divided into two parts: (1) Household trip generation rates based on home interview data, and (2) income/auto ownership relationships. The household rates are based on data obtained from transportation study home interviews around the country and from published reports. Notes accompanying each set of rates give further explanation and source information. The user should be cautioned, however, that in some cases the rates have not been adjusted for any possible underreporting in the individual home interview survey.* The

*The reader is referred to comments on adjustments for underreporting on page 58.

income/auto-ownership relationships, shown as curves, were developed from Part II data in over 70 special Urban Transportation Planning Packages prepared by the Census Bureau (7). The curves have been grouped for easier application.

A third source of trip rate data is a set of individual land use activity trip generation rates from various studies around the country (2). Work along similar lines by the Institute of Traffic Engineers will result in additional trip rate data based on studies conducted by State and local agencies at about 1000 individual sites around the country (16). The reader is referred to these sources for trip rates, particularly non-residential rates.

HOUSEHOLD TRIP GENERATION RATES

NATIONWIDE PERSONAL TRANSPORTATION STUDY 1969 TOTAL PERSON TRIPS PER HOUSEHOLD

Income	Autos			
	0	1	2	3+
0-2,999	1.1	3.5	5.5	-
3-3,999	2.2	4.8	8.9	-
4-4,999	2.2	5.8	9.3	12.0
5-5,999	2.4	5.3	7.8	12.3
6-7,499	2.8	6.5	8.0	10.6
7.5-9,999	3.2	7.3	9.3	12.8
10-14,999	2.8	7.0	8.7	12.1
15+	3.3	6.1	10.5	13.0

Note: 1. Table obtained from Report 11, page 56, Table 26.

CAGUAS, PUERTO RICO, METRO AREA TRANSPORTATION STUDY 1973
 AUTO DRIVER TRIPS PER HOUSEHOLD
 Population - 65,844

Income	Autos		
	0	1	2+
0 - 1,999	-	2.8	-
2 - 3,999	0.2	2.8	5.2
4 - 7,999	0.2	2.8	5.8
8 -11,999	-	3.2	6.3
12 -15,999	-	3.7	6.9
16 -19,999	-	4.1	7.5
20 -22,999	-	4.2	7.7
23 +	-	4.2	7.7

- Note: 1. Table developed by Urban Planning Division, FHWA
 (Table obtained from Technical Memoranda).
2. Table developed from data in "Caguas (Puerto Rico)
 Metropolitan Area Transportation Study Technical
 Memoranda - Trip Generation."

CHARLOTTE, NORTH CAROLINA 1969
 TOTAL PERSON TRIPS PER HOUSEHOLD
 Population - 279,530

Income	Autos		
	0	1	2+
0 - 2,999	1.9	4.9	7.3
3 - 4,999	2.5	5.6	7.4
5 - 5,999	3.7	6.1	8.9
6 - 6,999	4.1	6.8	8.7
7 - 7,999	-	6.8	9.3
8 - 8,999	-	7.3	9.2
9 - 9,999	-	8.2	9.5
10 -14,999	-	8.2	10.4
15+	-	7.8	11.7

- Note: 1. Trips not adjusted for under-reporting.
2. Table obtained from Charlotte-Mecklenburg Urban
 Area Transportation Study, Report: Mathematical
 Modeling, North Carolina State Highway Commission.

DETROIT, MICHIGAN 1965
TOTAL AUTO-DRIVER TRIPS PER HOUSEHOLD
Population - 3,970,584

Income	Autos			
	0	1	2	3+
0 - 2,999	0.05	2.08	4.31	5.50
3 - 5,999	0.07	3.32	5.25	9.38
6 - 7,999	0.20	4.32	6.18	7.90
8 - 9,999	0.22	4.65	6.98	9.63
10 -14,999	0.33	5.05	7.40	11.35
15+	0.0	4.91	8.44	11.34

FLINT, MICHIGAN 1966
TOTAL PERSON TRIPS PER HOUSEHOLD
Population 447,767

Income	Autos			
	0	1	2	3+
0 - 1,999	1.23	4.57	9.22	-
2 - 4,999	2.58	7.82	11.28	-
5 - 6,999	4.27	9.41	12.05	15.96
7 - 9,999	4.10	11.54	11.76	19.00
10 -14,999	2.33	10.93	15.04	20.99
15+		13.38	17.91	21.63

- Note: 1. Trips adjusted for under-reporting.
2. No raw data available.
3. Table obtained from Michigan Department of State Highways and Transportation.

FRESNO-CLOVIS, CALIFORNIA
TOTAL PERSON TRIPS PER HOUSEHOLD (EXCL. WALK)
Population - 262,908

Income	Autos			
	0	1	2	3+
0 - 2,999	1.42	6.59	11.44	13.31
3 - 3,999	2.52	9.68	14.03	18.58
4 - 4,999	3.76	10.59	12.83	10.83
5 - 5,999	2.10	10.18	17.63	23.44
6 - 6,999	2.25	10.32	14.59	19.31
7 - 7,999	1.20	11.84	15.50	21.39
8 - 8,999	21.40	14.18	12.85	18.36
9 - 9,999	7.10	12.11	19.14	16.03
10 -12,499	13.10	12.46	17.32	22.37
12.5 -14,999	1.40	9.25	20.26	25.89
15 -19,999	4.00	12.76	18.99	21.12
20 -24,999	2.80	14.63	20.11	23.93
25+	-	14.76	17.98	27.36

- Note: 1. Trips adjusted for under-reporting
2. Table obtained from California DOT.

HOLLAND, MICHIGAN 1967
TOTAL PERSON TRIPS PER HOUSEHOLD
Population 57,300

Income	Autos			
	0	1	2	3+
0 - 1,999	0.24	5.83	11.38	-
2 - 4,999	2.87	7.03	14.47	-
5 - 6,999	3.14	13.85	16.41	16.63
7 - 9,999	3.20	15.13	18.19	25.17
10 -14,999	-	16.14	19.24	27.38
15+	-	10.50	19.69	22.13

- Note: 1. Trips adjusted for under-reporting.
2. No raw data available.
3. Table obtained from Michigan Department of State Highways and Transportation.

IRON MOUNTAIN, MICHIGAN 1968
TOTAL PERSON TRIPS PER HOUSEHOLD
Population 21,100

Income	Autos			
	0	1	2	3+
0 - 2,999	1.68	7.60	12.53	-
3 - 4,999	2.65	11.34	17.26	26.33
5 - 6,999	6.99	15.43	20.12	22.20
7 - 9,999	-	19.47	24.37	29.65
10 -15,999	-	18.06	24.32	28.74
16+	-	21.13	22.56	27.89

- Note: 1. Trips adjusted for under-reporting.
2. No raw data available.
3. Table obtained from Michigan Department of State Highways and Transportation.

JACKSON, MICHIGAN 1967
TOTAL PERSON TRIPS PER HOUSEHOLD
Population 105,970

Income	Autos			
	0	1	2	3+
0 - 1,999	0.86	6.22	9.08	-
2 - 4,999	1.89	9.80	15.06	17.47
5 - 6,999	2.71	13.17	16.58	24.02
7 - 9,999	5.10	16.88	21.24	25.44
10 -14,999	-	18.90	21.42	32.70
15+	-	20.25	26.12	27.41

- Note: 1. Trips adjusted for under-reporting.
2. No raw data available.
3. Table obtained from Michigan Department of State Highways and Transportation.

MIAMI, FLORIDA (SOUTHEAST FLORIDA REGIONAL STUDY) 1973
HOME BASED PERSON TRIPS PER HOUSEHOLD
(Single Family Dwelling Units)
Population - 1,219,661

Family Size	Autos		
	0	1	2+
1	1.0	2.9	5.6
2	1.9	4.5	5.9
3	2.9	6.2	7.7
4	4.1	8.5	10.7
5	5.8	10.2	13.7

(Multi Family Dwelling Units)

Family Size	Autos		
	0	1	2+
1	1.18	2.75	3.55
2	1.75	4.60	5.90
3	2.80	6.10	8.25
4	4.20	7.50	9.70
5	5.70	10.00	10.15

Note: 1. Table obtained from data in memorandum dated 12/19/74.

MIDLAND, MICHIGAN 1969
TOTAL PERSON TRIPS PER HOUSEHOLD
Population 51,600

Income	Autos			
	0	1	2	3+
0 - 2,999	2.92	6.75	11.50	-
3 - 4,999	2.45	8.51	13.33	-
5 - 6,999	2.98	12.35	18.06	-
7 - 9,999	9.12	14.56	18.83	22.88
10 - 15,999	13.91	17.14	20.64	27.74
16+	-	17.72	23.62	23.56

- Note: 1. Trips adjusted for under-reporting.
2. No raw data available.
3. Table obtained from Michigan Department of State Highways and Transportation.

MODESTO-STANISLAUS, CALIFORNIA
TOTAL PERSON TRIPS PER HOUSEHOLD (EXCL. WALK)
Population - 106,107

Income	Autos			
	0	1	2	3+
0 - 2,999	1.17	6.69	10.49	13.56
3 - 3,999	1.60	8.25	10.18	14.38
4 - 4,999	2.38	10.44	10.82	12.26
5 - 5,999	5.04	11.17	13.96	16.15
6 - 6,999	0.52	9.53	16.12	18.67
7 - 7,999	0.70	9.91	19.19	21.52
8 - 8,999	-	12.89	16.23	19.73
9 - 9,999	-	12.40	13.81	20.10
10 -12,499	-	13.15	16.68	19.96
12.5 -14,999	-	13.66	18.07	21.27
15 -19,999	-	10.92	17.48	20.66
20 -24,999	-	10.45	16.08	24.00
25+	-	9.46	17.67	24.40

- Note: 1. Trips adjusted for under-reporting.
2. No raw data available.
3. Table obtained from California DOT.

NEW YORK CITY (TRI-STATE REGION) 1963-64
TOTAL PERSON TRIPS PER HOUSEHOLD
Unlinked Trips
Population 16,206,841

Income	Autos			
	0	1	2	3+
0 - 3,999	1.50	3.47	6.49	15.06
4 - 7,499	3.10	5.39	8.93	13.16
7.5 - 9,999	4.31	7.07	10.35	14.01
10 -14,999	4.73	8.08	10.90	13.25
15+	4.54	9.20	12.11	14.58

PHILADELPHIA, PENNSYLVANIA 1960
TOTAL PERSON TRIPS PER HOUSEHOLD
Population - 4,021,066

Income	Autos			
	0	1	2	3+
0 - 1,999	0.65	2.52	5.45	5.17
2 - 2,999	1.24	3.19	5.39	8.64
3 - 3,999	1.80	3.94	6.36	8.26
4 - 4,999	2.30	4.52	6.61	7.41
5 - 6,499	2.74	5.33	7.10	8.83
6.5 - 7,999	3.23	5.88	7.81	9.40
8 - 9,999	3.66	6.38	8.36	9.89
10 -14,999	4.18	6.67	8.65	10.11
15 -24,999	3.17	6.61	9.40	11.88
25+	0.56	4.87	8.44	10.74

Note: 1. Table obtained from "Interim Report on Trip Generation" by Creighton, Hamburg, Inc., July 19, 1974.

SACRAMENTO, CALIFORNIA 1970
TOTAL PERSON TRIPS PER HOUSEHOLD
Population - 633,732

Income	Autos			
	0	1	2	3+
0 - 2,999	1.24	4.66	6.00	5.40
3 - 3,999	2.10	5.30	8.67	8.00
4 - 4,999	2.42	6.12	9.12	8.50
5 - 5,999	2.75	6.63	11.16	10.71
6 - 6,999	4.78	7.12	9.26	12.14
7 - 7,999	3.94	7.61	9.47	12.11
8 - 8,999	7.00	8.39	9.52	12.80
9 - 9,999	7.60	9.67	11.18	14.07
10 -12,499	5.38	9.16	11.13	15.41
12.5 -14,999	5.11	9.53	12.11	17.01
15 -19,999	4.64	8.77	11.84	16.32
20 -24,999	15.00	10.51	11.54	15.53
25+	6.75	9.24	12.00	13.62

Note: 1. Trips adjusted for under-reporting.

2. Table obtained from California DOT.

SALINAS-MONTEREY, CALIFORNIA
TOTAL PERSON TRIPS PER HOUSEHOLD (EXCL. WALK)
Population - 62,456

Income	Autos			
	0	1	2	3+
0 - 2,999	1.13	5.24	9.51	12.35
3 - 3,999	2.08	7.66	10.67	17.20
4 - 4,999	2.25	8.21	11.31	12.40
5 - 5,999	2.32	8.59	16.90	23.36
6 - 6,999	2.42	9.34	11.81	24.57
7 - 7,999	1.80	11.76	15.75	26.93
8 - 8,999	4.69	10.36	13.81	21.79
9 - 9,999	4.04	11.70	16.37	15.80
10 -12,499	4.20	11.59	18.91	23.26
12.5 -14,999	--	12.87	16.99	30.67
15 -19,999	--	10.42	15.19	24.18
20 -24,999	--	10.72	16.81	25.68
25+	--	10.37	15.25	25.49

Note: 1. Trips adjusted for under-reporting
2. Table obtained from California DOT.

SAN ANGELO, TEXAS 1964
TOTAL PERSON TRIPS PER HOUSEHOLD
Population - 63,884

Income	Autos			
	0	1	2	3+
0 - 4,999	1.1	5.8	9.6	15.3
5 - 6,999	3.6	8.6	11.7	15.9
7 - 9,999	5.0	10.0	12.7	16.6
10 -14,999	6.3	10.8	13.6	17.6
15+	7.0	11.5	13.9	17.8

TOTAL AUTO-DRIVER TRIPS PER HOUSEHOLD

Income	Autos			
	0	1	2	3+
0 - 4,999	0.3	3.7	6.6	11.3
5 - 6,999	1.7	5.6	8.1	12.3
7 - 9,999	3.0	6.8	9.1	13.1
10 -14,999	4.3	7.5	9.9	14.0
15+	4.8	8.1	10.3	14.2

Note: Tables obtained from Technical Report dated October 1974.

SAN DIEGO, CALIFORNIA
TOTAL PERSON TRIPS PER HOUSEHOLD
Population - 1,198,323

Income	Autos			
	0	1	2	3+
0 - 2,999	1.10	3.58	7.36	8.88
3 - 3,999	2.14	4.98	8.59	12.14
4 - 4,999	3.12	6.34	9.56	15.90
5 - 5,999	2.75	6.79	10.21	12.90
6 - 6,999	1.70	6.88	10.64	12.10
7 - 7,999	1.73	8.35	11.85	15.04
8 - 8,999	2.21	8.15	13.22	16.46
9 - 9,999	3.38	8.23	12.56	14.28
10 -12,499	1.75	9.17	12.84	16.56
12.5 -14,999	1.31	8.77	12.65	17.10
15 -19,999	1.55	9.61	13.14	30.60
20 -24,999	5.71	8.00	13.66	19.04
25+	--	8.05	15.81	14.64

- Note: 1. Trips adjusted for under-reporting.
2. Table obtained from California DOT.

TEXARKANA, ARKANSAS-TEXAS 1965
TOTAL PERSON TRIPS PER HOUSEHOLD
Population - 58,570

Income	Autos			
	0	1	2	3+
0 - 4,999	2.2	7.0	10.4	12.2
5 - 6,999	3.4	9.0	11.9	13.7
7 - 9,999	4.6	10.8	13.4	15.0
10 -14,999	6.0	13.0	15.7	17.0
15+	6.4	14.0	17.2	19.0

TEXARKANA (CONTD.)
TOTAL AUTO-DRIVER TRIPS PER HOUSEHOLD

Income	Autos			
	0	1	2	3+
0 - 4,999	0.1	4.0	7.0	8.3
5 - 6,999	0.6	5.4	8.3	9.9
7 - 9,999	0.9	6.6	9.4	11.4
10 -14,999	1.6	8.2	11.1	13.2
15+	2.0	9.3	12.2	15.4

Note: 1. Tables obtained from Technical Report, October 1973.

TRAVERSE CITY, MICHIGAN 1966
TOTAL PERSON TRIPS PER HOUSEHOLD
Population - 23,100

Income	Autos			
	0	1	2	3+
0 - 1,999	0.61	6.70	11.49	-
2 - 4,999	1.56	13.22	14.21	-
5 - 6,999	4.47	16.97	21.09	26.90
7 - 9,999	-	20.48	25.90	39.28
10 -14,999	-	20.30	26.82	32.11
15+	-	18.78	30.57	37.62

- Note: 1. Trips adjusted for under-reporting.
2. No raw data available.
3. Table obtained from Michigan Department of State Highways and Transportation.

WASHINGTON, D.C. 1968
TOTAL PERSON TRIPS PER HOUSEHOLDS
Population 2,481,489

Income	Autos			
	0	1	2	3+
0 - 2,999	1.29	2.70	5.14	5.08
3 - 3,999	1.58	3.02	4.63	14.33
4 - 5,999	2.16	3.88	6.17	9.78
6 - 7,999	2.47	4.64	6.78	10.03
8 - 9,999	2.97	5.04	7.29	10.09
10 - 11,999	3.28	5.37	7.61	10.58
12 - 14,999	3.50	6.18	8.04	10.74
15 - 19,999	4.12	6.10	8.16	11.22
20 - 24,999	3.04	6.12	8.59	10.88
25+	2.42	5.32	8.85	11.32

Note: 1. Trips not adjusted for under-reporting.

2. Table developed by Urban Planning Division, FHWA.

WICHITA FALLS, TEXAS 1964
TOTAL PERSON TRIPS PER HOUSEHOLD
Population 97,564

Income	Autos			
	0	1	2	3+
0 - 4,999	3.6	6.4	11.6	17.7
5 - 6,999	4.1	9.7	12.9	18.5
7 - 9,999	5.0	11.1	14.6	19.2
10 - 14,999	5.4	11.4	15.6	20.1
15+	5.4	12.9	16.2	20.5

TOTAL AUTO-DRIVER TRIPS PER HOUSEHOLD

Income	Autos			
	0	1	2	3+
0 - 4,999	0.6	3.9	7.4	12.2
5 - 6,999	1.3	6.0	8.4	13.0
7 - 9,999	1.7	7.0	9.7	14.0
10 - 14,999	2.1	7.7	10.5	15.2
15+	2.3	8.7	11.6	15.8

Note: 1. Table obtained from Technical Report, January 1974.

INCOME/AUTO OWNERSHIP RELATIONSHIPS

The following curves were developed from data in over 70 special Census Urban Transportation Planning Packages for various cities across the country. The curves were hand-fitted and smoothed through the data points available from the cross-tabulation in the census packages. The data points have, however, been left on the plots.

To facilitate their use, the curves have been grouped first by urbanized area population in the following categories:

50,000 - 100,000
100,000 - 250,000
250,000 - 750,000
750,000 +

The curves were then arrayed (low to high) by urbanized area density (population per square mile) within each population grouping. A listing of each area with densities in population groupings is given in Table 22.

Other factors in addition to density and population should be considered in choosing the appropriate curve. These would include the type of metropolitan area (commercial or industrial, relative per capita income, blue collar/white collar split of employment, etc.), location of the area, age of the area, etc.

The following symbols are used throughout this set of curves:

0 cars = 0
1 car = $\triangle$
2 cars = X
3+ cars = $\square$

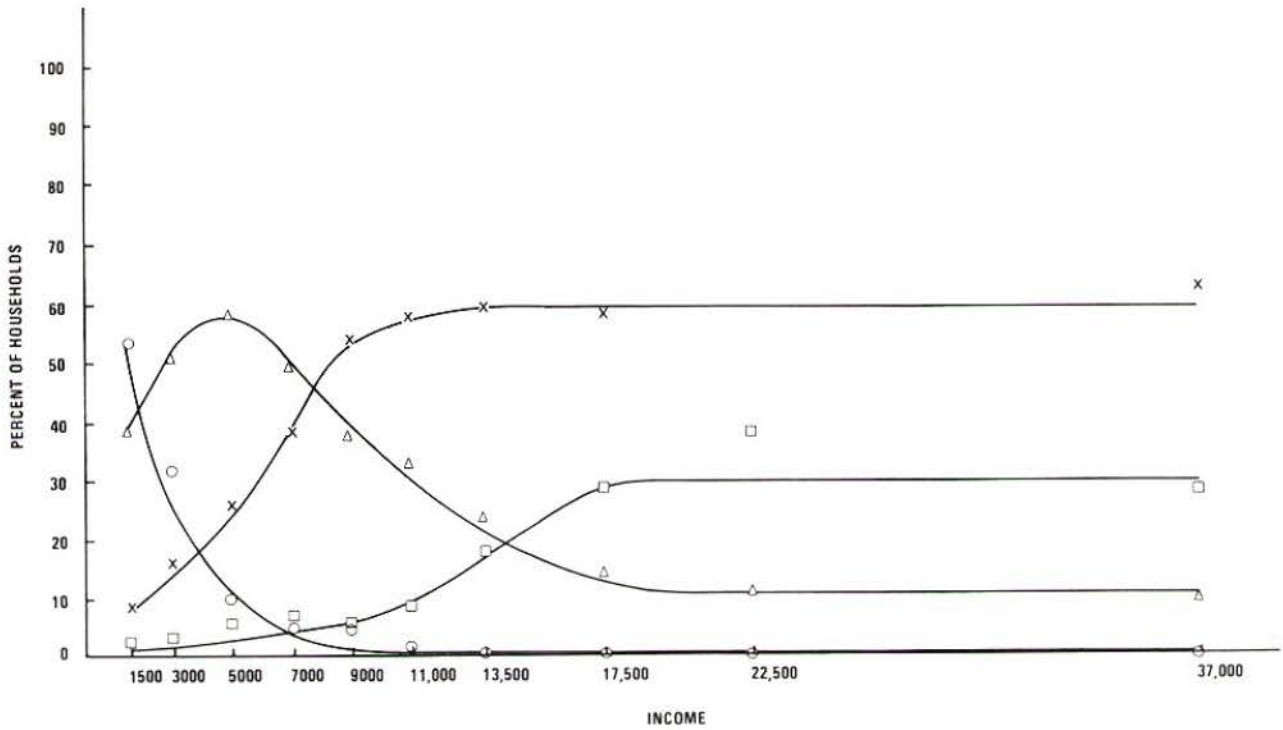
Urbanized area population and density is shown on each curve.

Table 22
Income/Auto Ownership Relationships-
Cities Sorted by Population and Density

Population 50,000-100,000	Density (Persons Per Sq. Mile)		
Gadsden, Al.	1,231	Stockton, Ca.	3,410
Fitchburg- Leominster, Ma.	1,282	Santa Barbara, Ca.	3,510
Highpoint, N.C.	1,789	Eugene, Or.	3,672
Mansfield, Oh.	1,883	Ann Arbor, Mi.	3,968
Santa Rosa, Ca.	1,969	Erie, Pa.	3,987
Hamilton, Oh.	2,385	Reading, Pa.	4,086
Salem, Or.	2,510		
Lima, Oh.	2,593	250,000-750,000	
Billings, Mt.	2,643	Mobile, Al.	1,534
Bay City, Mi.	3,014	West Palm Beach, Fl.	2,114
Great Falls, Mt.	3,232	Springfield-Chicopee- Holyoke, Ma.	2,159
Dubuque, Ia.	3,432	Grand Rapids, Mi.	2,416
Johnstown, Pa.	3,444	Birmingham, Al.	2,478
Fargo-Moorhead, N.D.-Mn.	3,560	Sacramento, Ca.	2,592
Springfield, Oh.	3,742	Akron, Oh.	2,660
Altoona, Pa.	4,061	Tucson, Az.	2,801
Lafayette-W. Lafayette, In.	4,172	Fort Lauderdale, Fl.	2,894
Salinas, Ca.	4,183	Toledo, Oh.-Mi.	2,937
		Dayton, Oh.	3,062
100,000-250,000		Youngstown-Warren, Oh.	3,070
Lorain-Elyria, Oh.	1,812	Austin, Tx.	3,076
Kalamazoo, Mi.	2,082	Omaha, Ne.	3,262
Raleigh, N.C.	2,136	Fresno, Ca.	3,330
Winston-Salem, N.C.	2,171	Wilmington, De.	3,376
Oxnard-Ventura, Ca.	2,188	Louisville, Ky.	3,521
Columbia, S.C.	2,348	Honolulu, Hi.	3,846
Greensboro, N.C.	2,495	Trenton, N.J.	4,212
Savannah, Ga.	2,557		
Brockton, Ma.	2,812	750,000+	
Spokane, Wa.	2,964	Atlanta, Ga.	2,695
Madison, Wi.	2,977	San Diego, Ca.	3,141
Lancaster, Pa.	2,998	Providence, R.I.	3,259
Harrisburg, Pa.	3,084	San Jose, Ca.	3,703
Bakersfield, Ca.	3,090	St. Louis, Mo.-Il.	4,085
Modesto, Ca.	3,108	Miami, Fl.	4,710
Lansing, Mi.	3,145	Buffalo, N.Y.	5,079
Canton, Oh.	3,169	Chicago, Il.-In.	5,254
York, Pa.	3,346	Philadelphia, Pa.	5,346

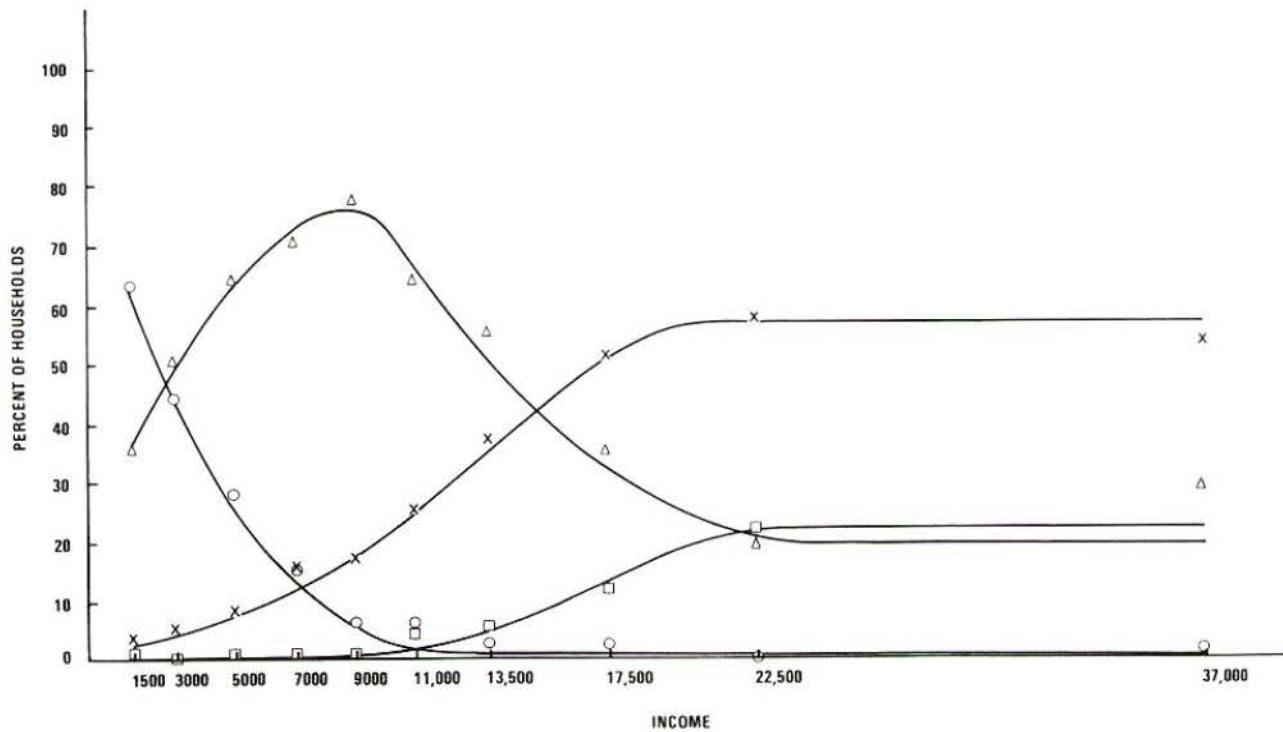
GADSDEN, ALABAMA

67,697 1,231

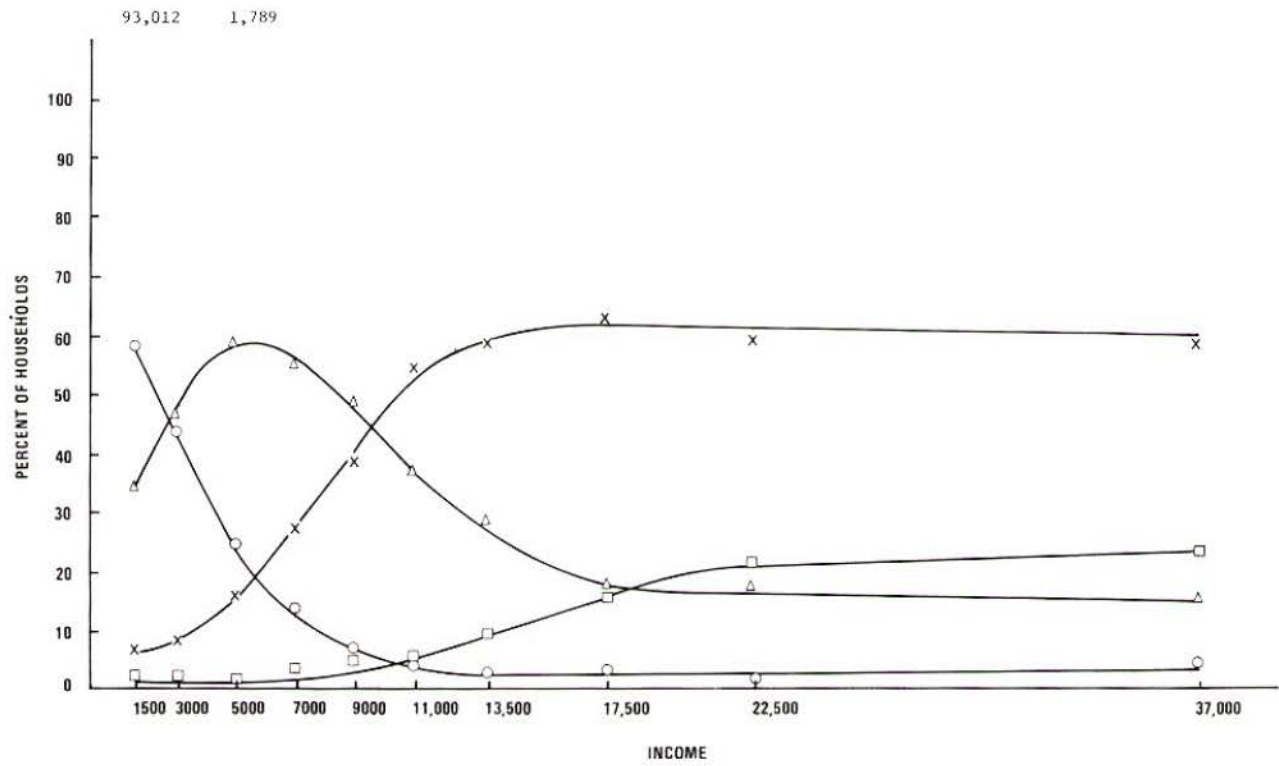


FITCHBURG-LEOMINSTER, MASSACHUSETTS

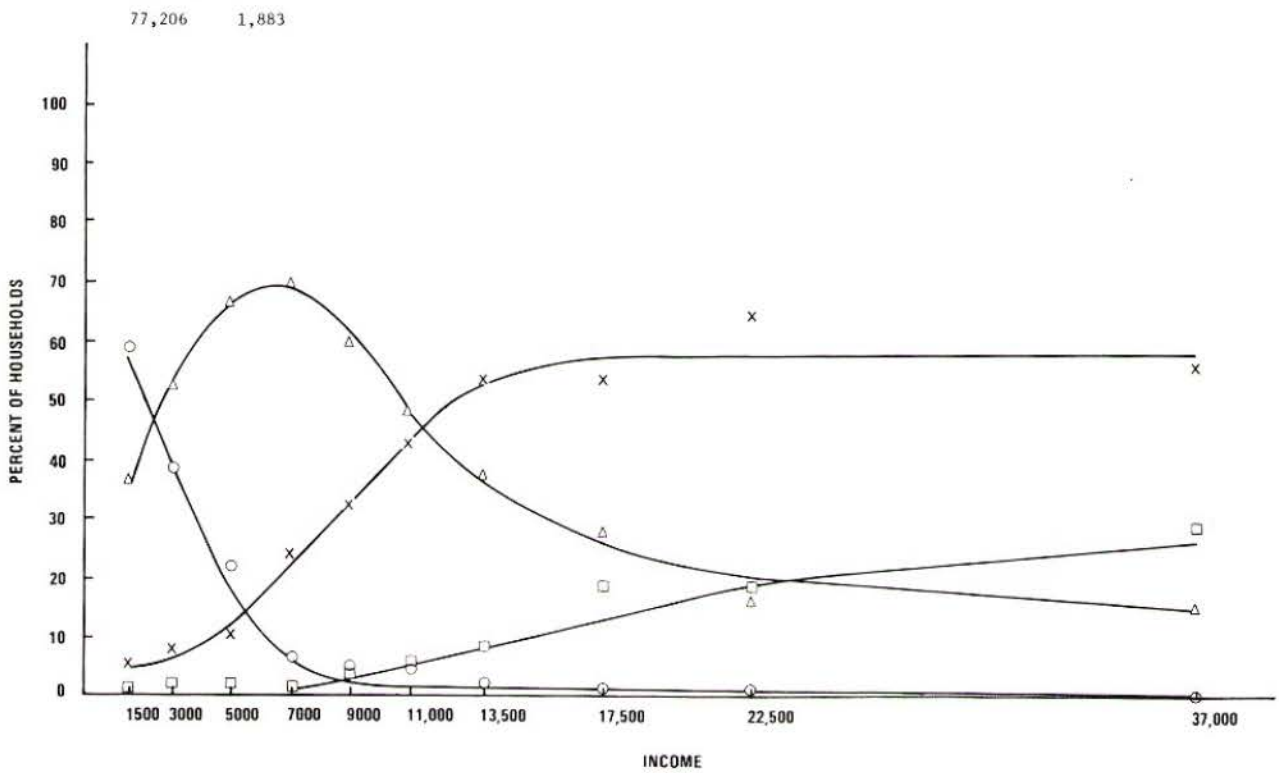
78,053 1,282



HIGHPOINT, NORTH CAROLINA

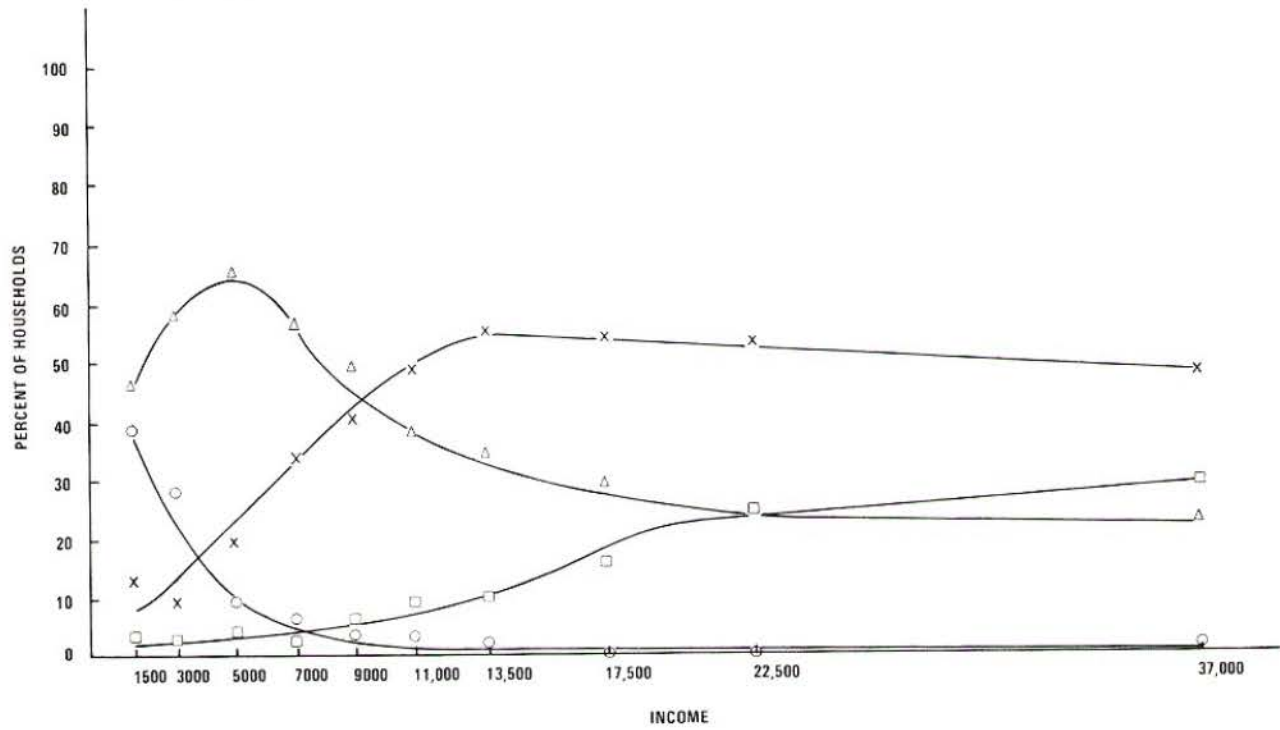


MANSFIELD, OHIO



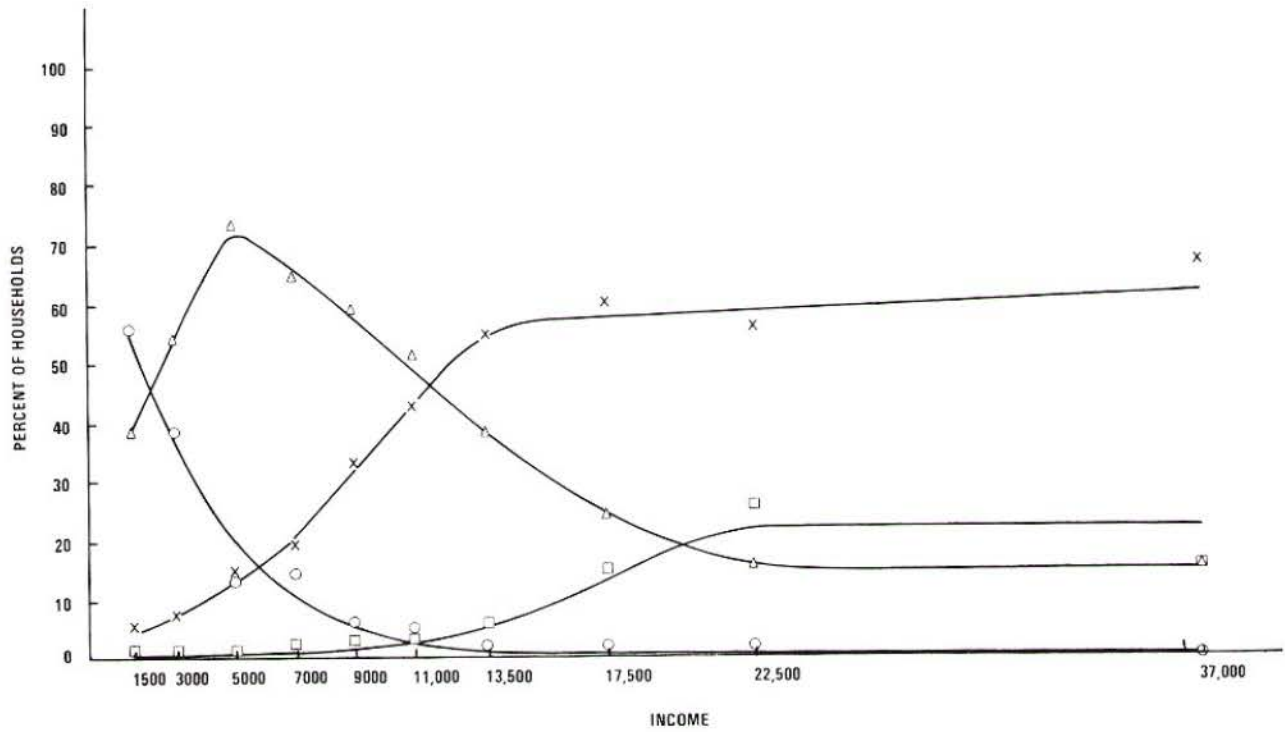
SANTA ROSA, CA.

76,836 1,969



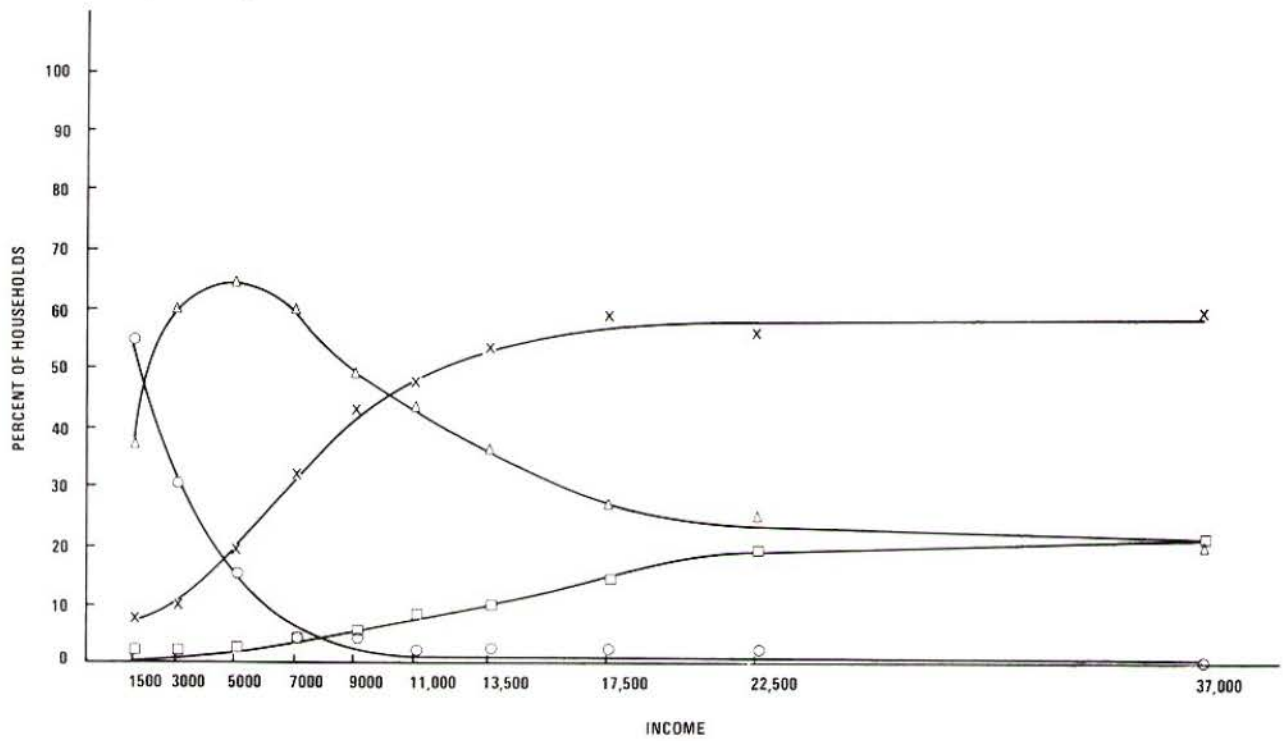
HAMILTON, OHIO

90,646 2,385



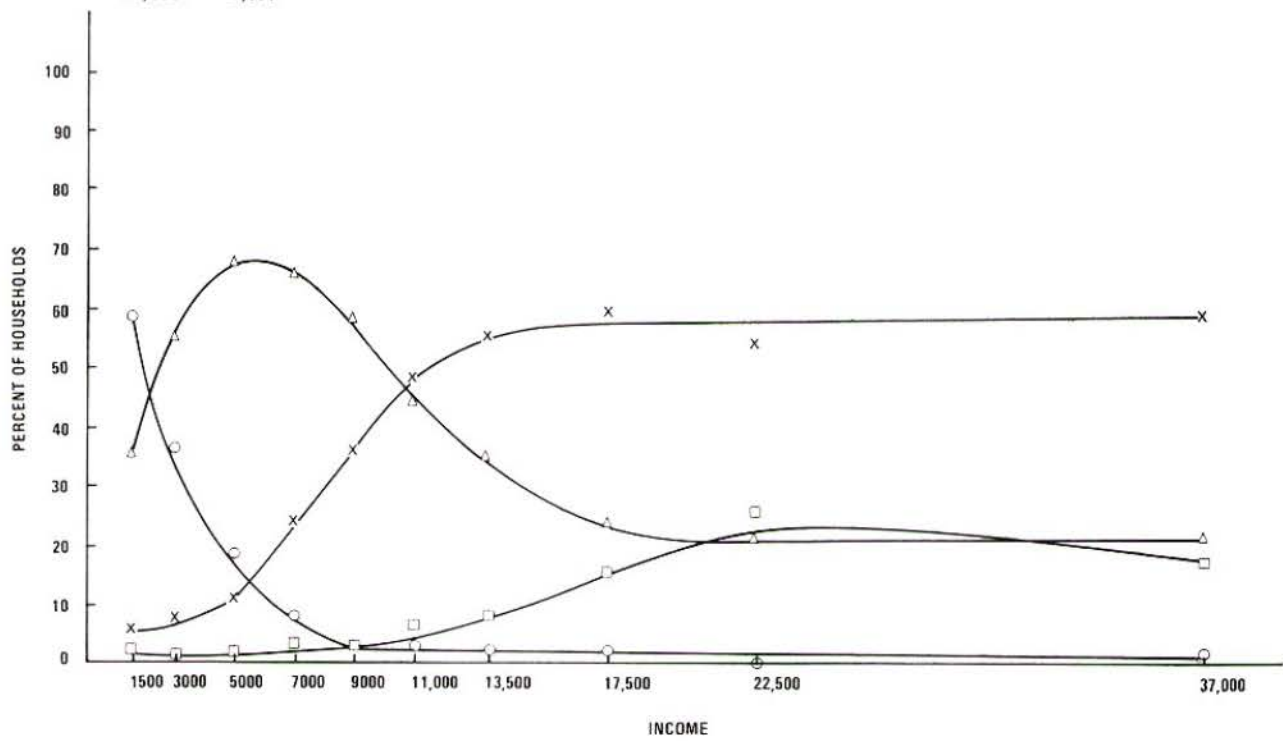
SALEM, OREGON

92,866 2,510

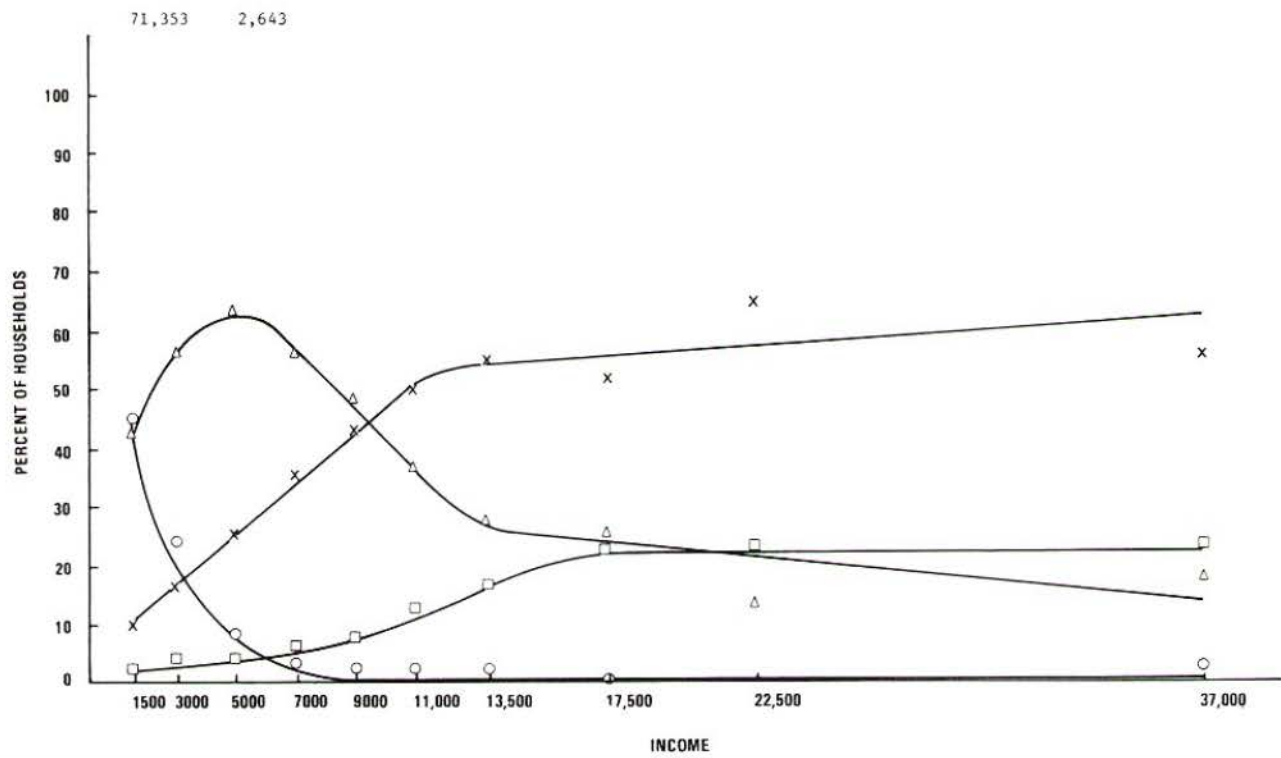


LIMA, OHIO

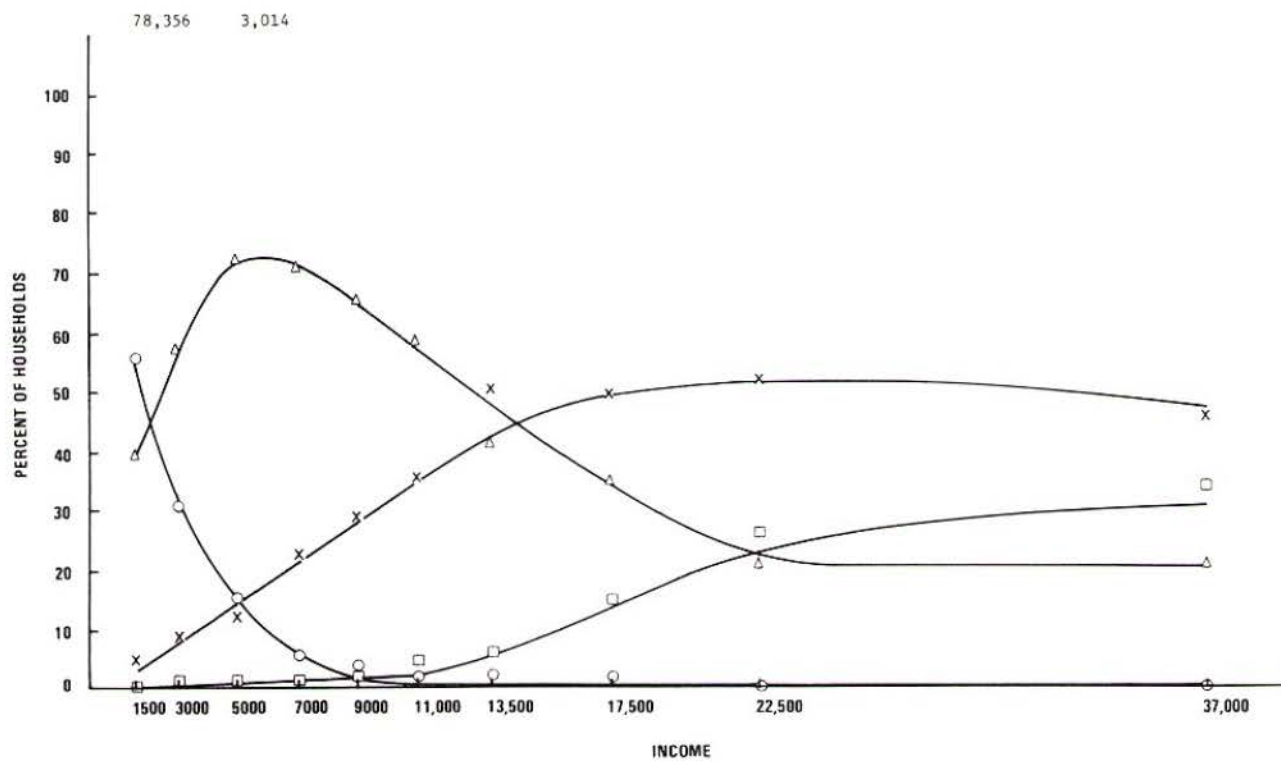
70,012 2,593



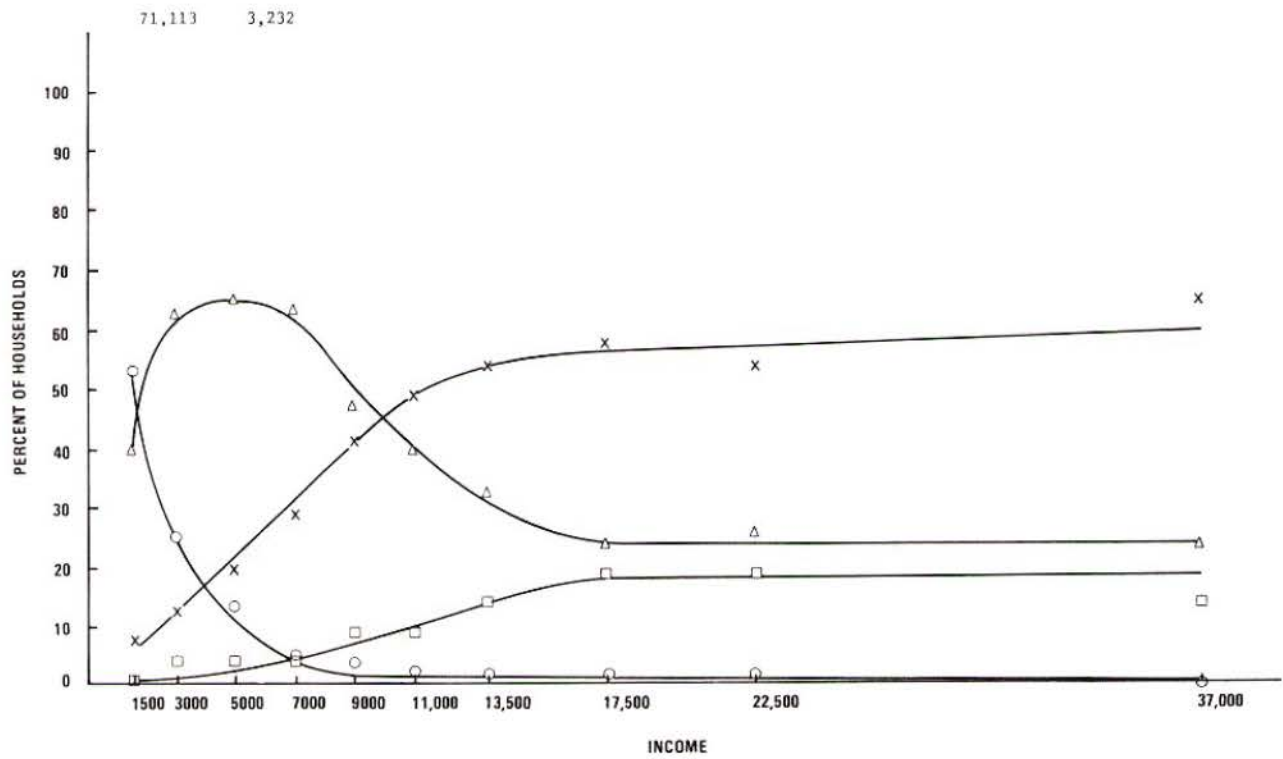
BILLINGS, MONTANA



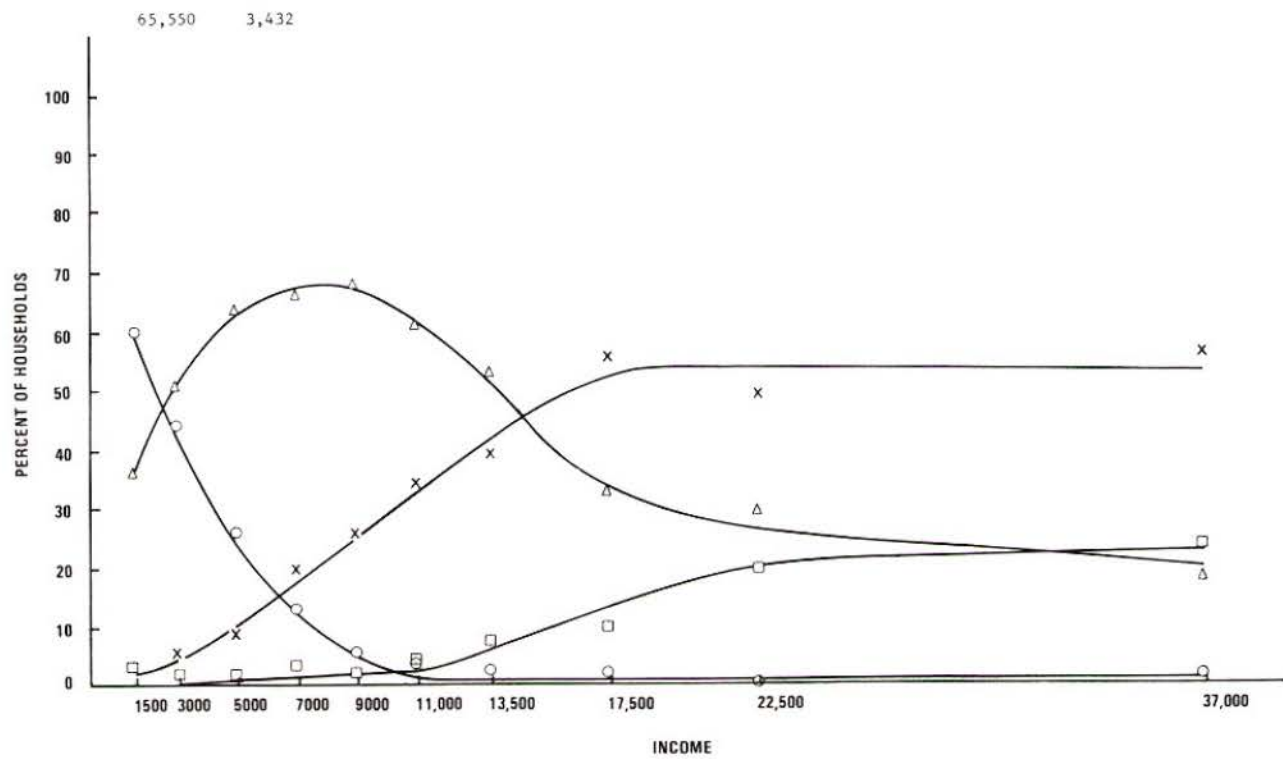
BAY CITY, MICHIGAN



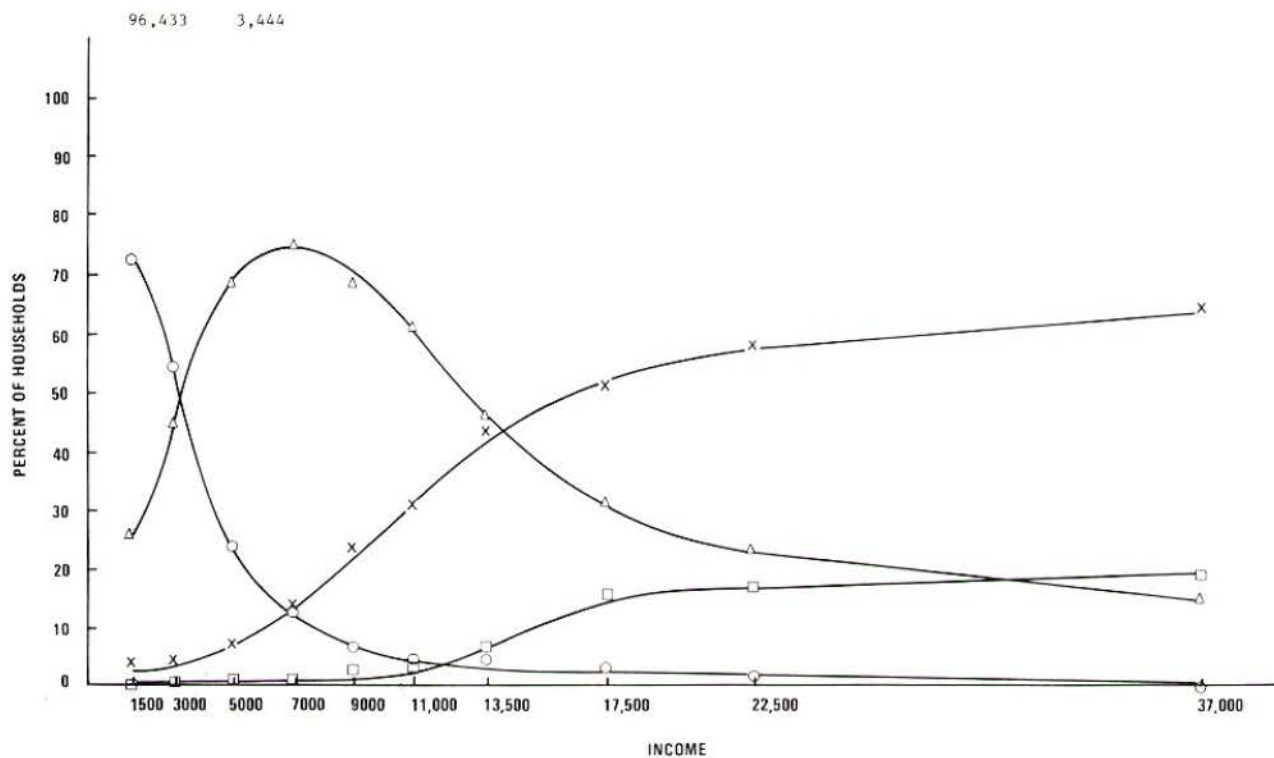
GREAT FALLS, MONTANA



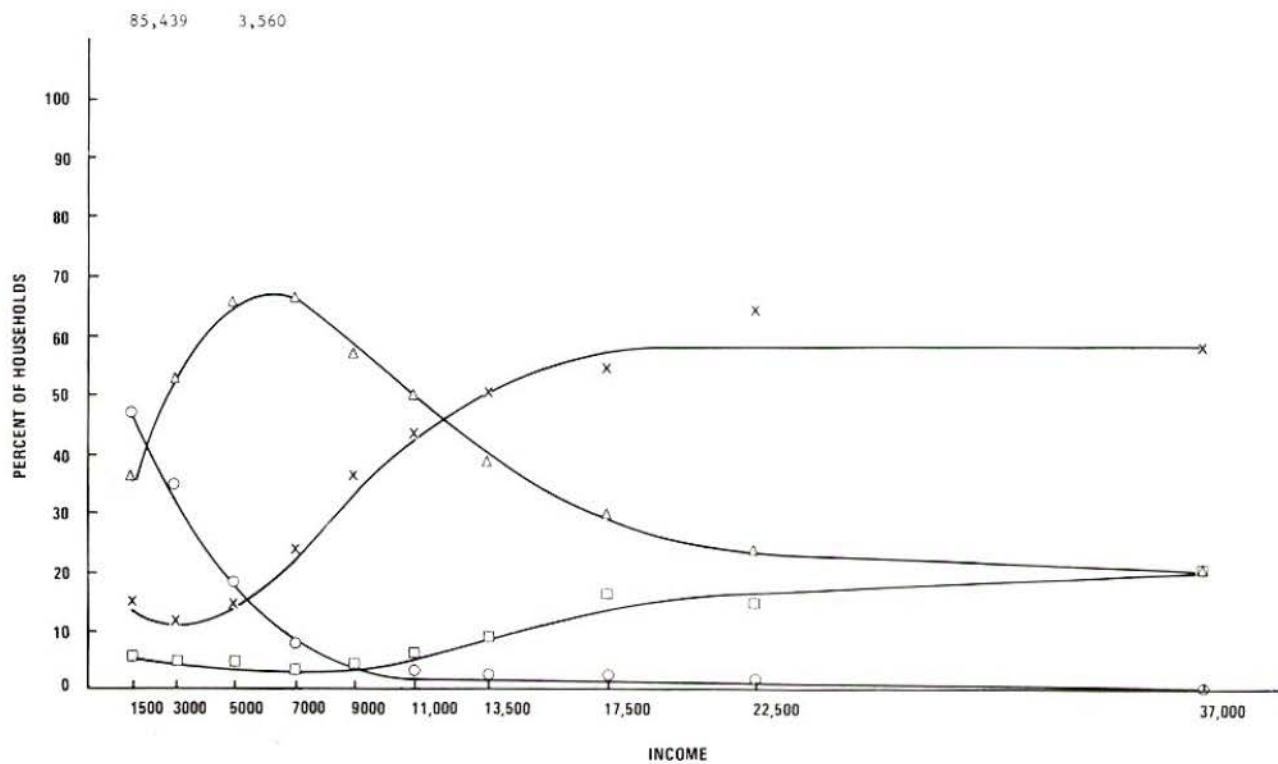
DUBUQUE, IOWA



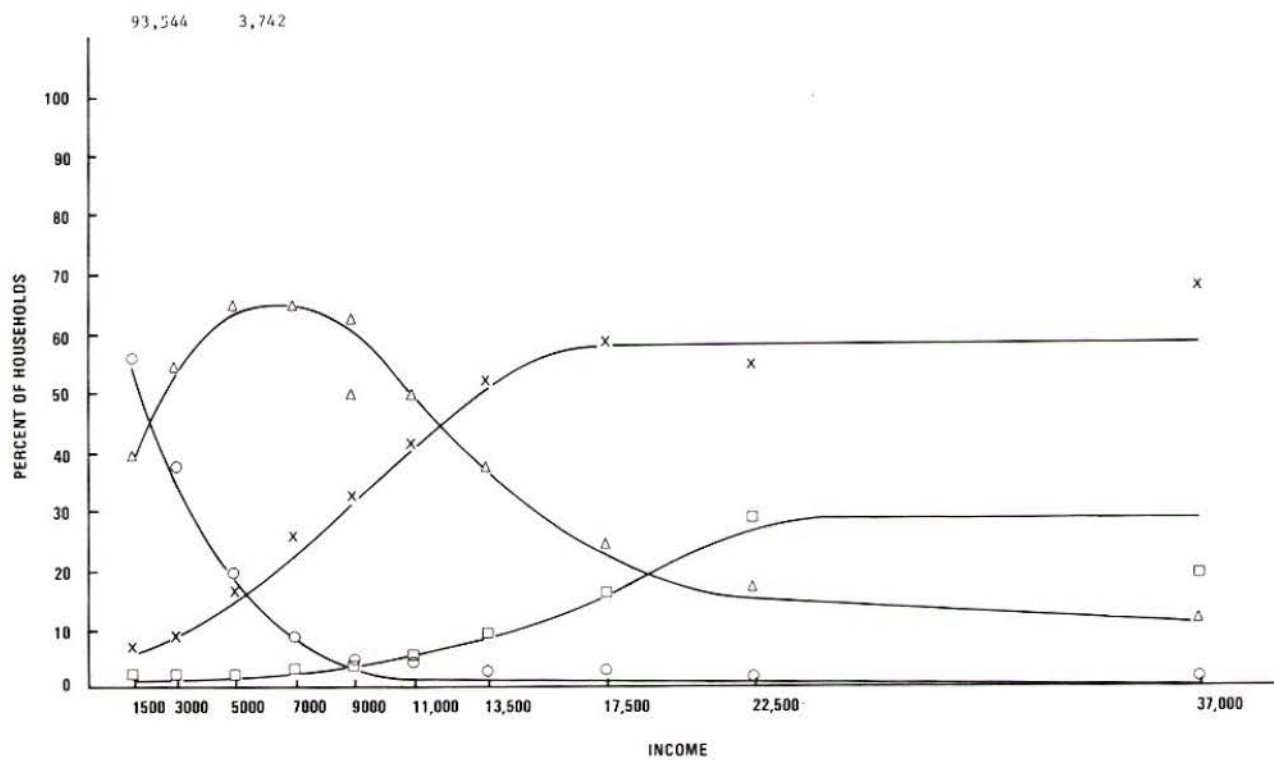
JOHNSTOWN, PENNSYLVANIA



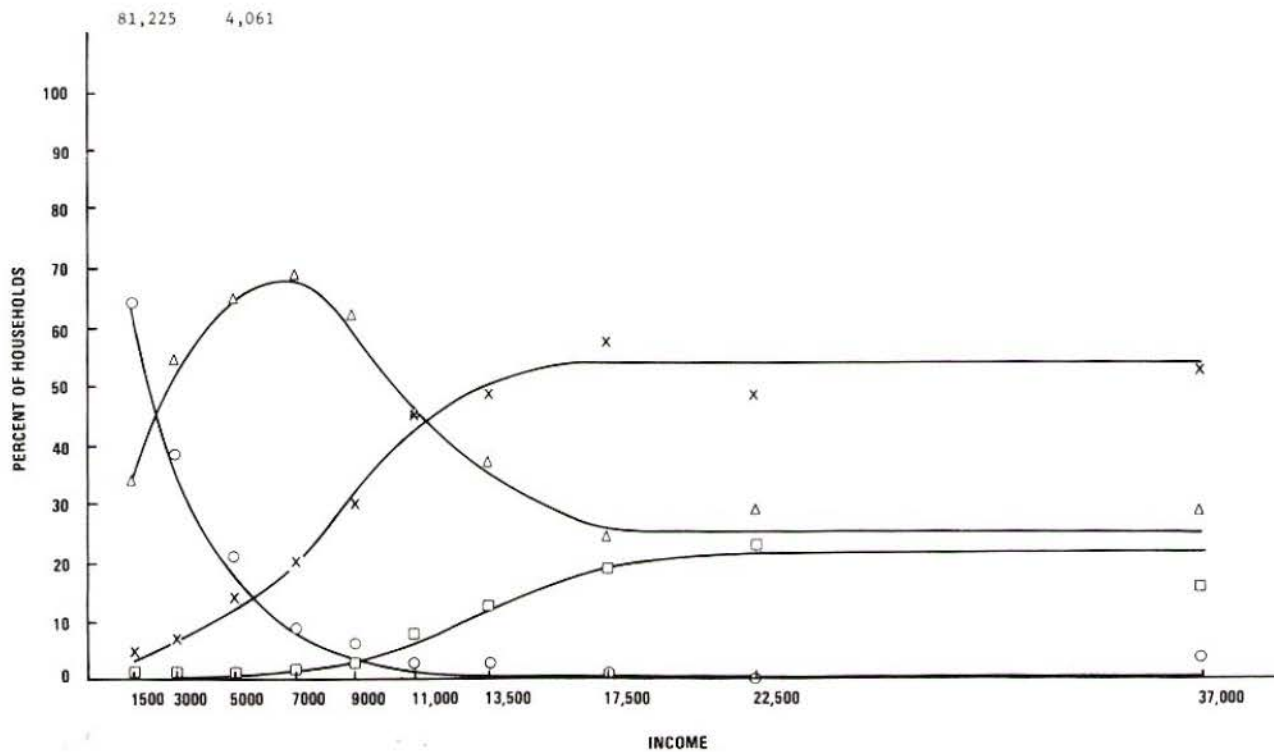
FARGO-MOORHEAD, NORTH DAKOTA-MONTANA



SPRINGFIELD, OHIO

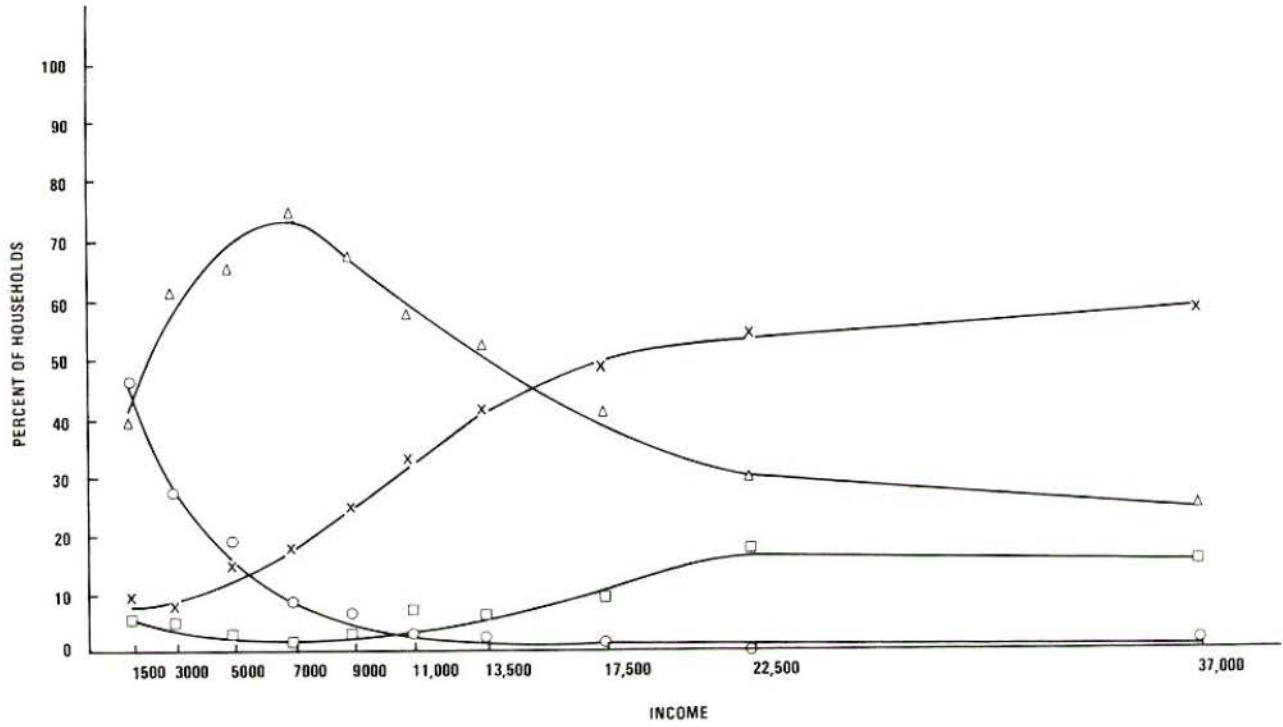


ALTOONA, PENNSYLVANIA



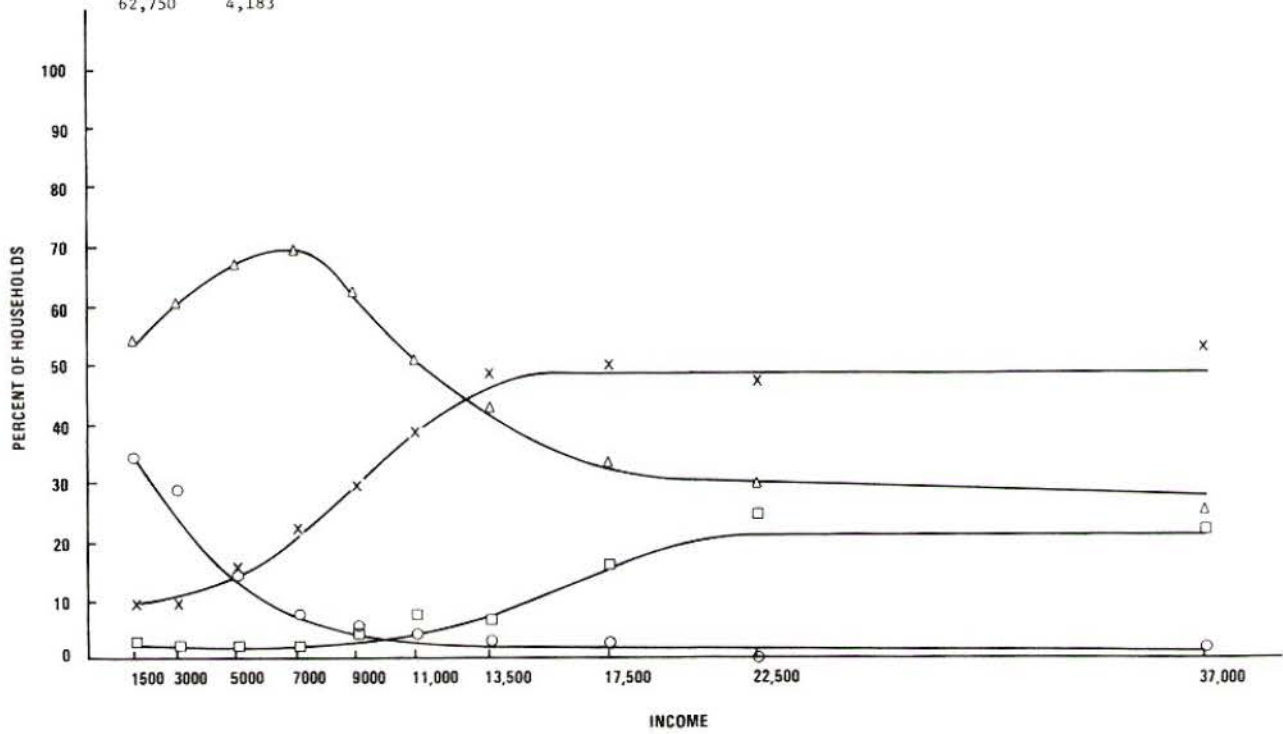
LAFAYETTE—WEST LAFAYETTE, INDIANA

79,275 4,172



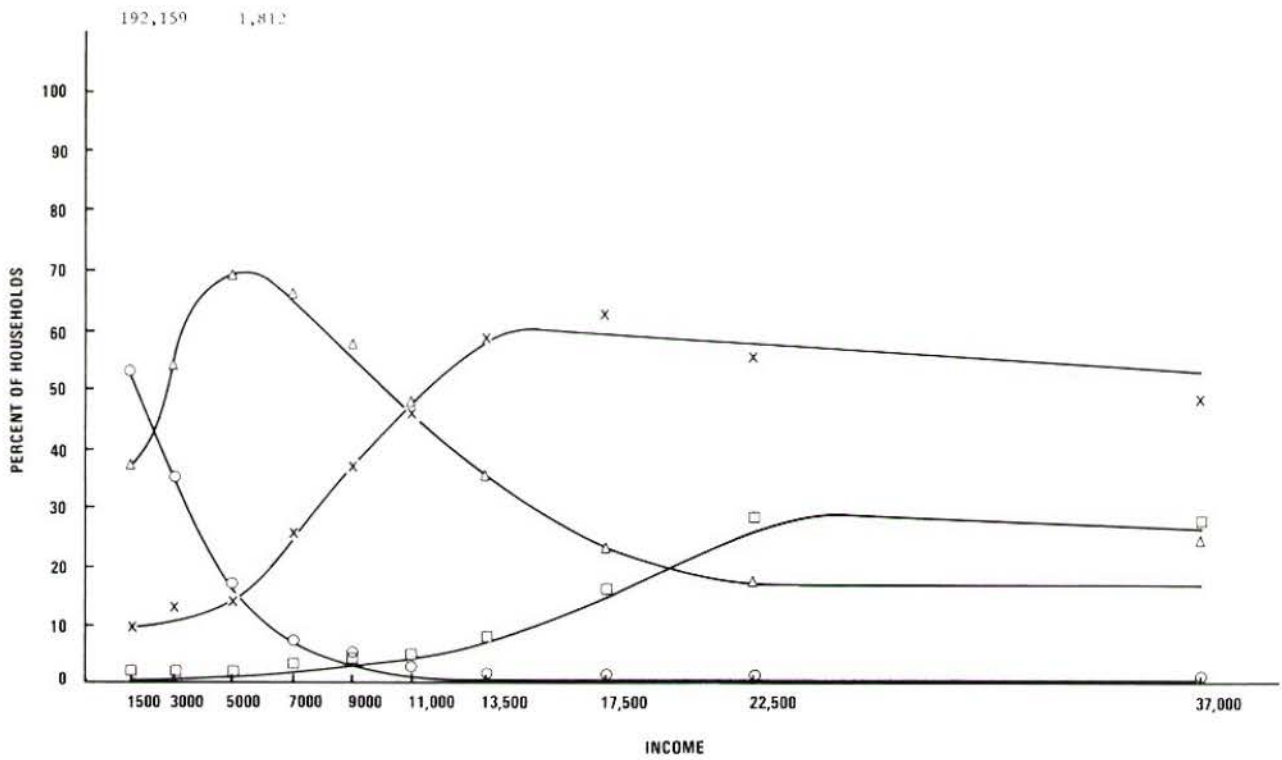
SALINAS, CA.

62,750 4,183

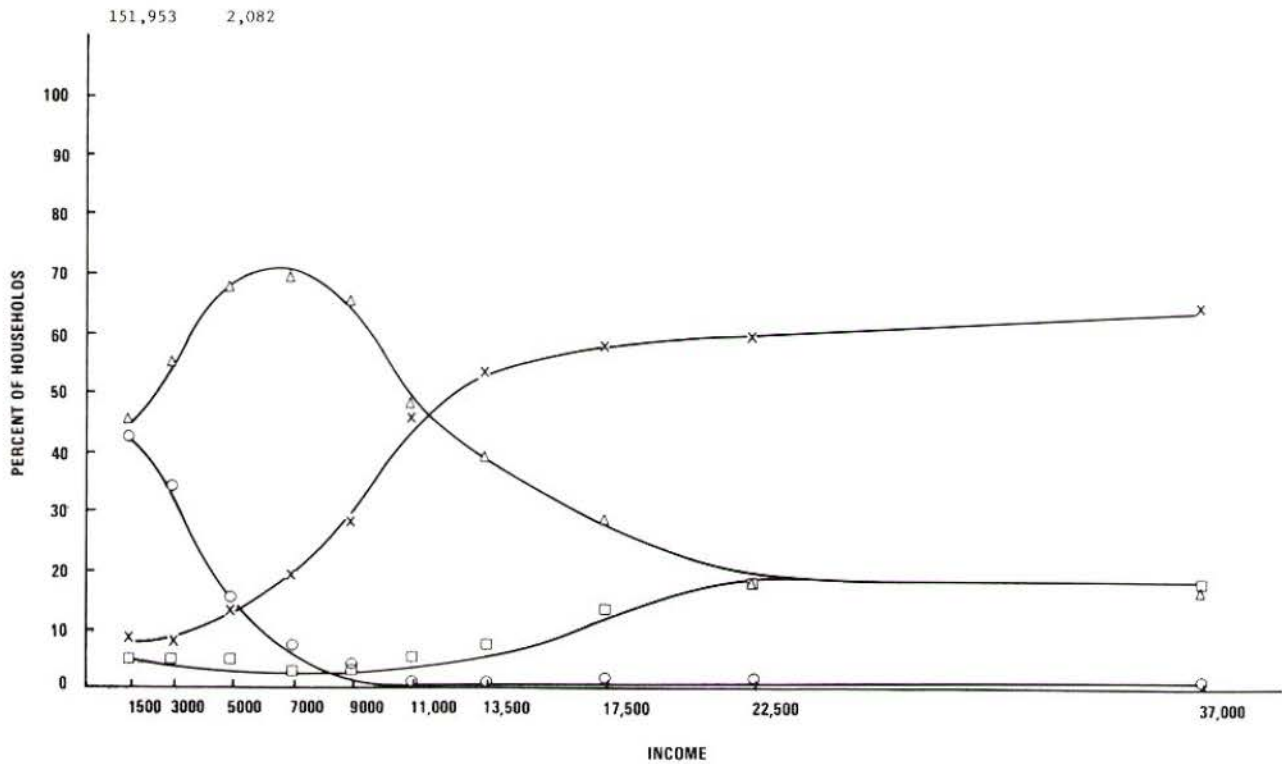


POPULATION 100,000-250,000

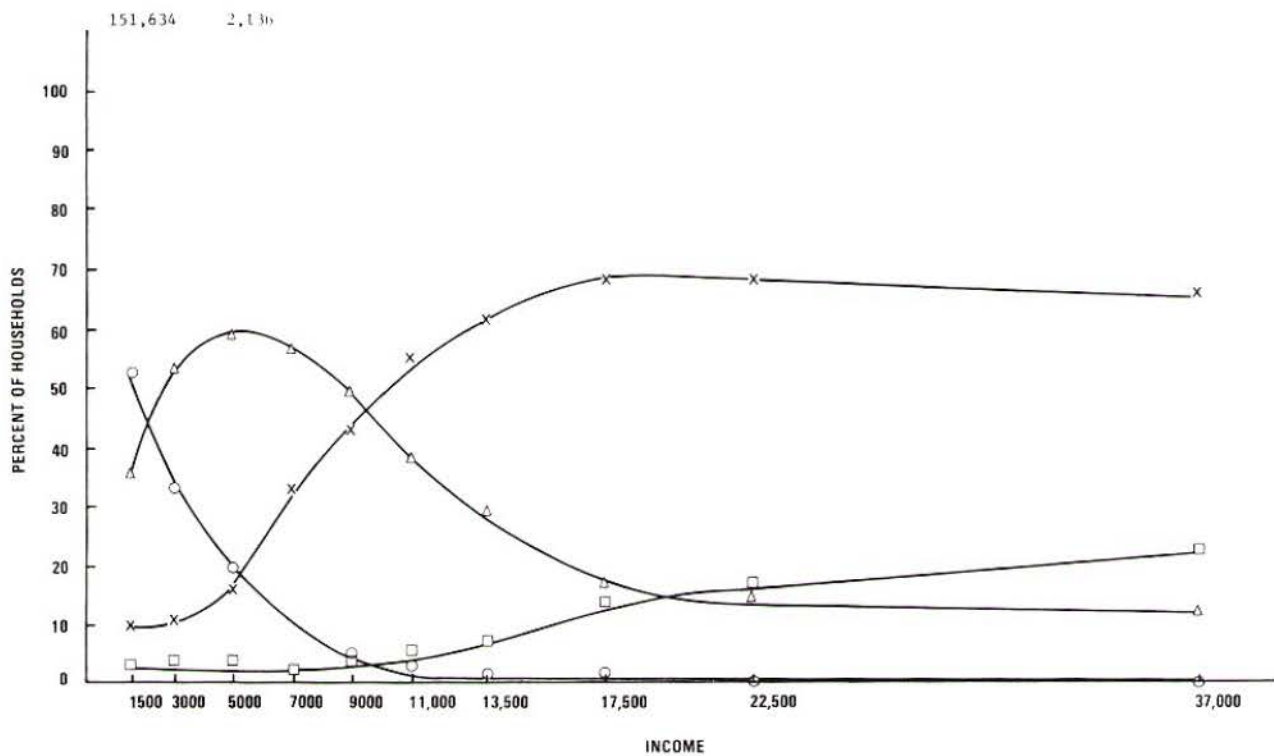
LORAIN-ELYRIA, OHIO



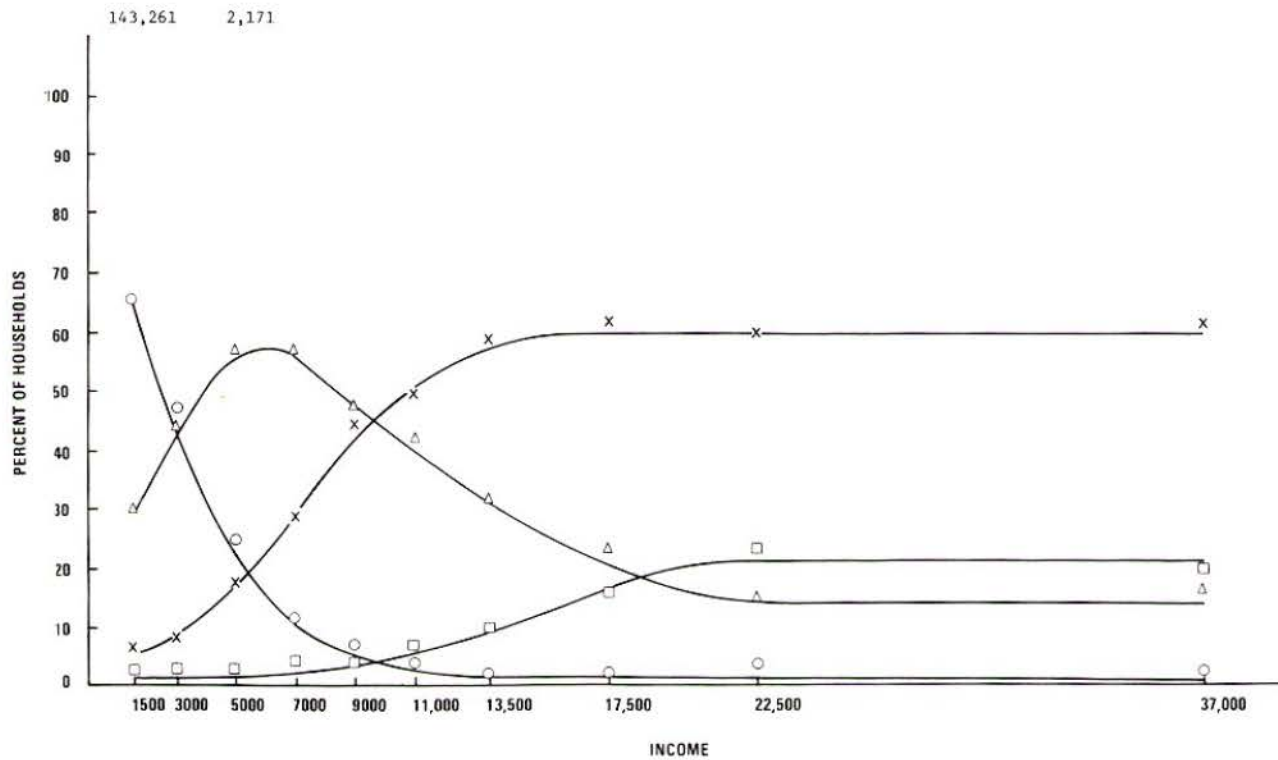
KALAMAZOO, MICHIGAN



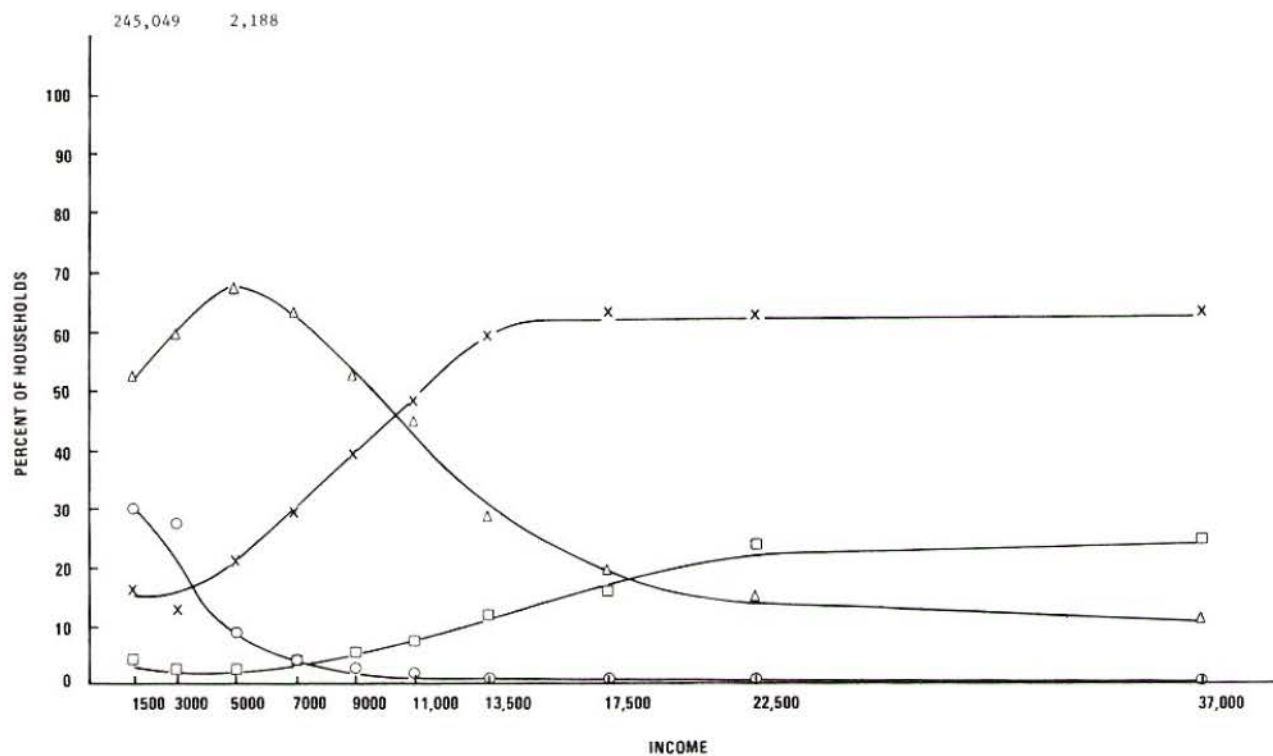
RALEIGH, NORTH CAROLINA



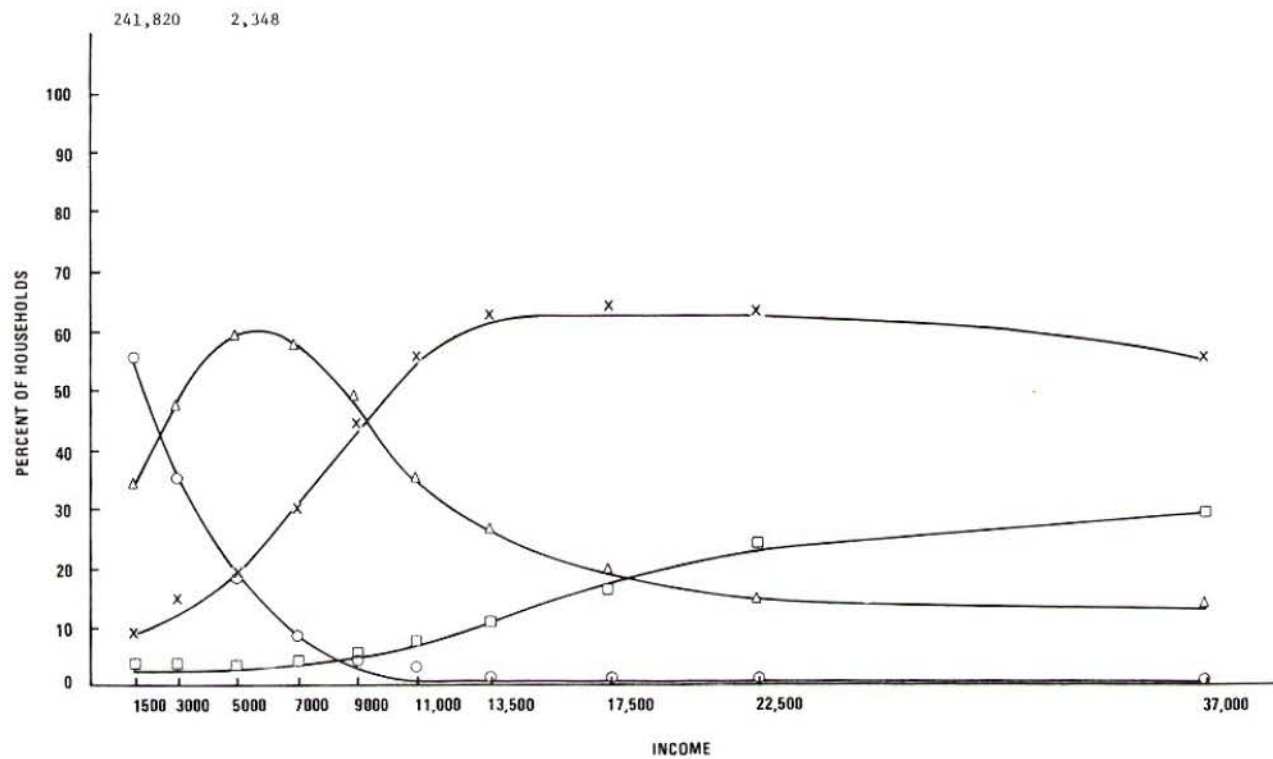
WINSTON-SALEM, NORTH CAROLINA



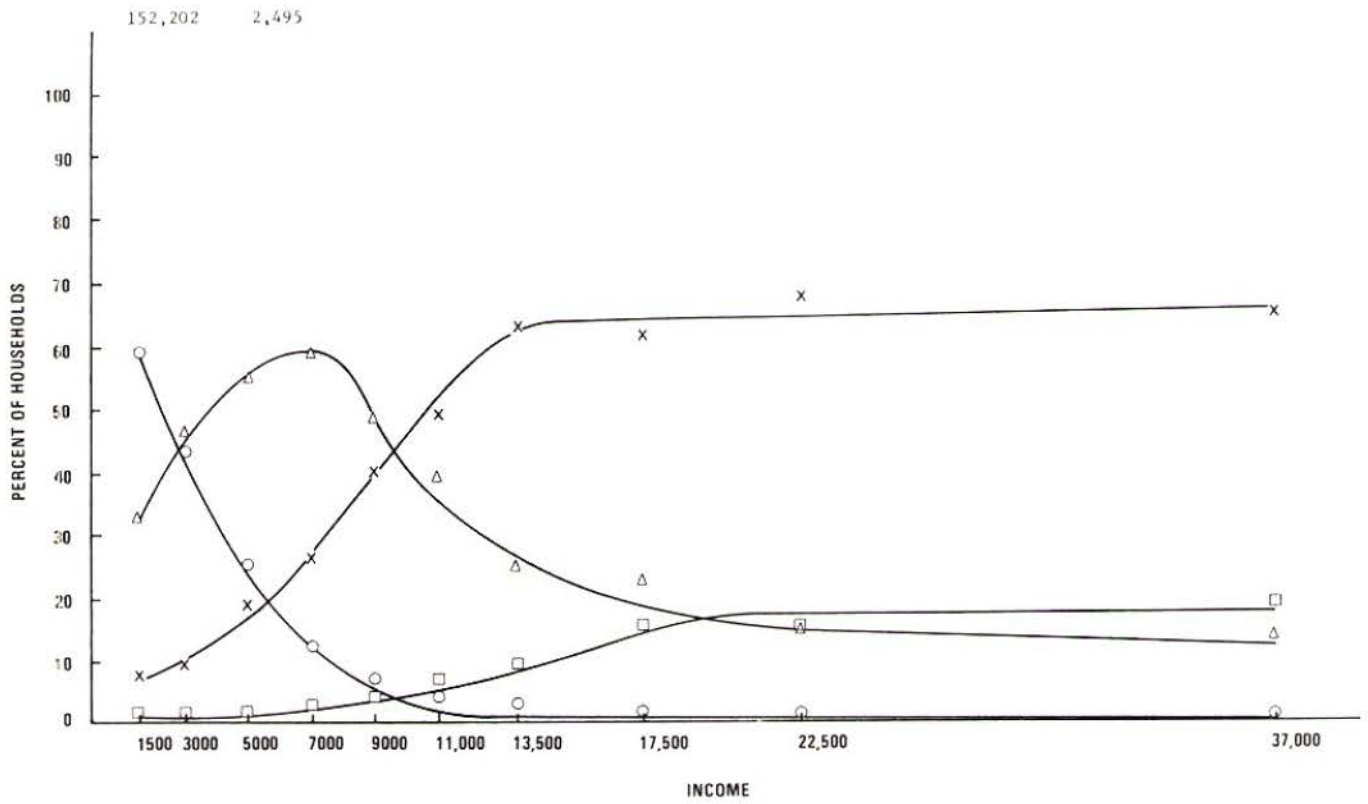
OXNARD-VENTURA, CALIFORNIA



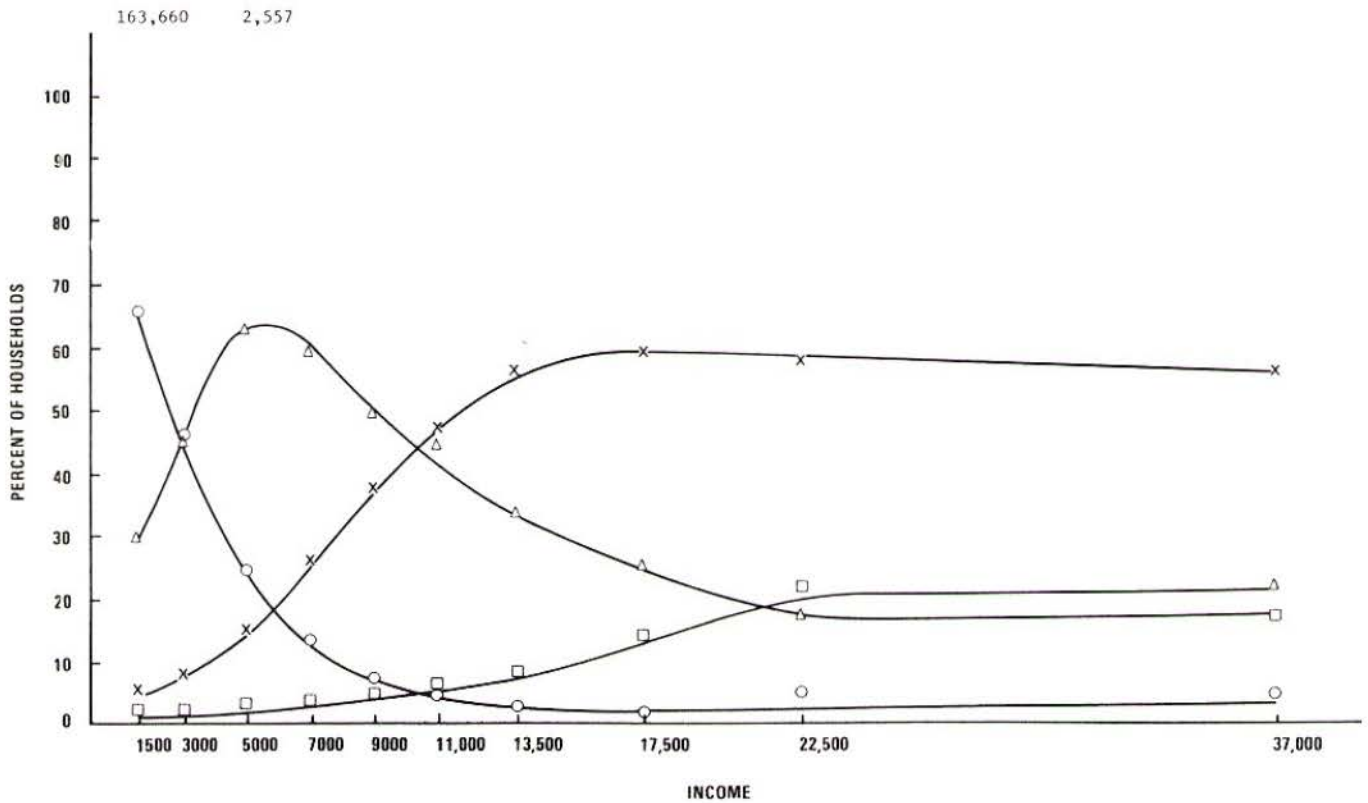
COLUMBIA, SOUTH CAROLINA



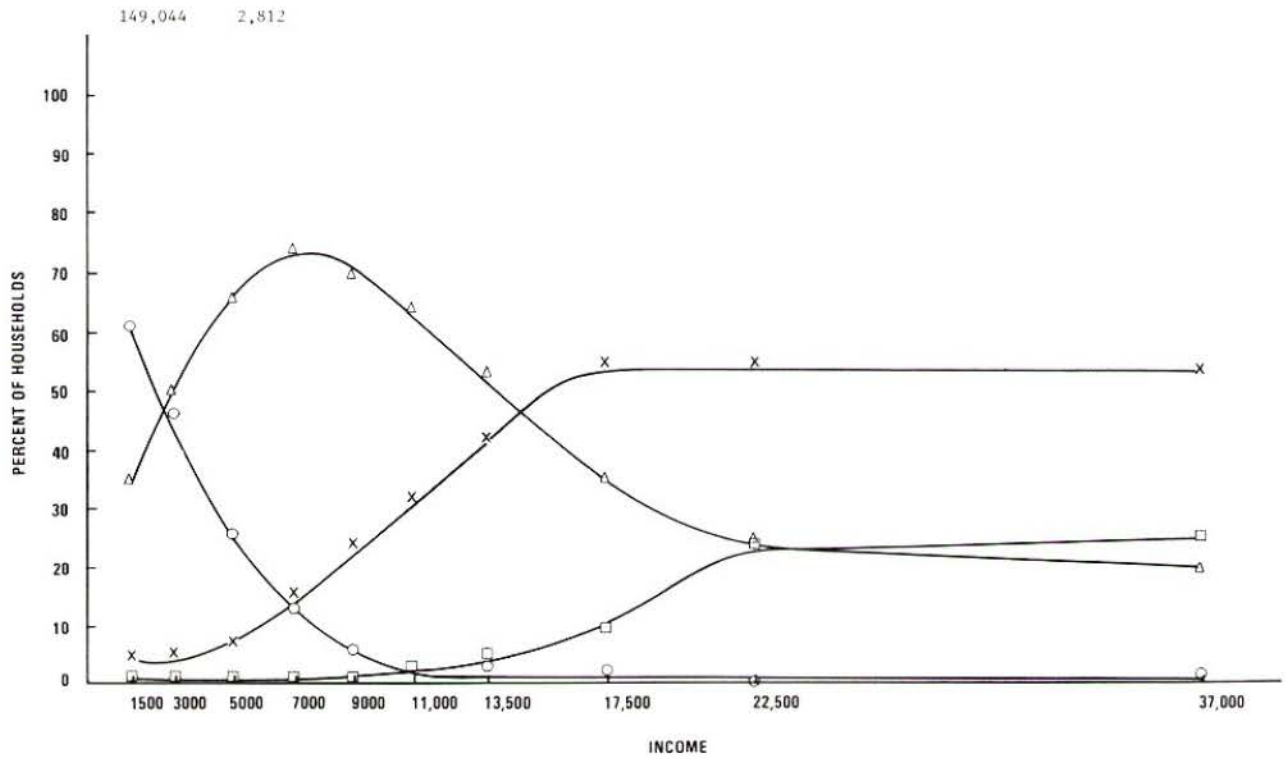
GREENSBORO, NORTH CAROLINA



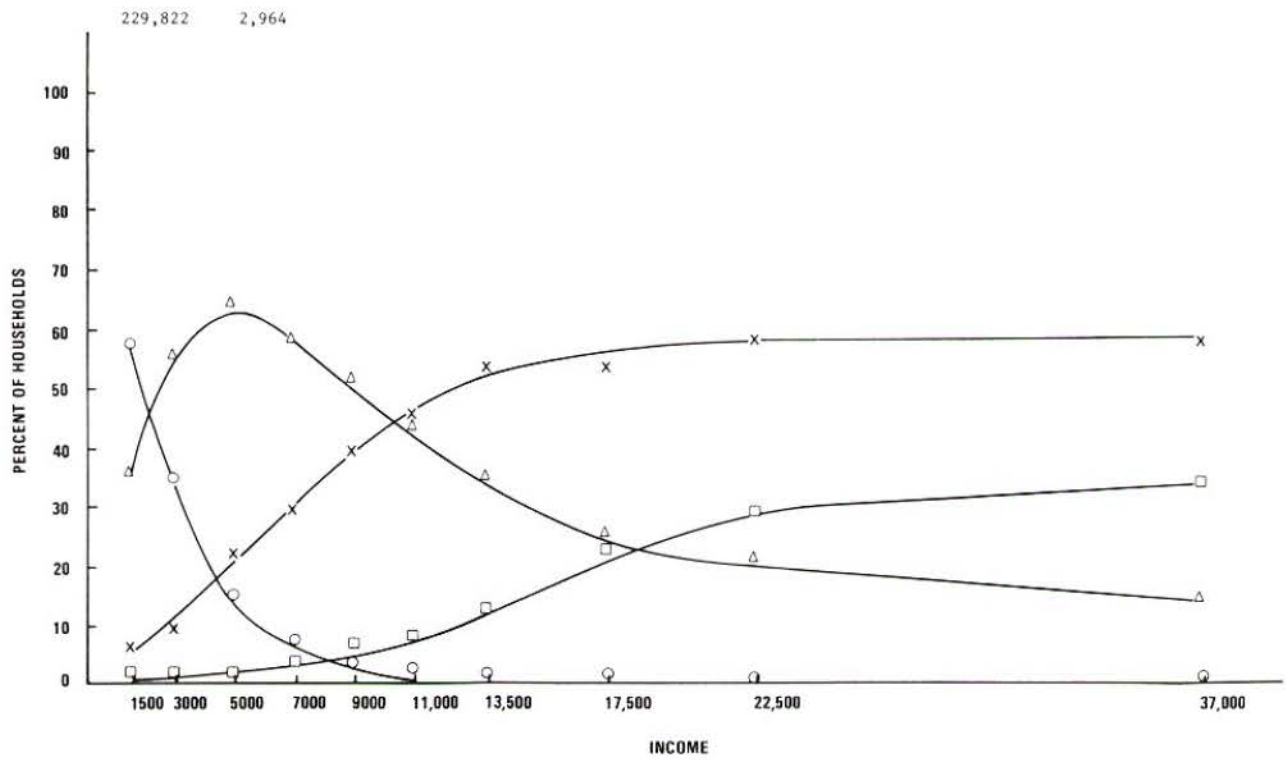
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BROCKTON, MASSACHUSETTS

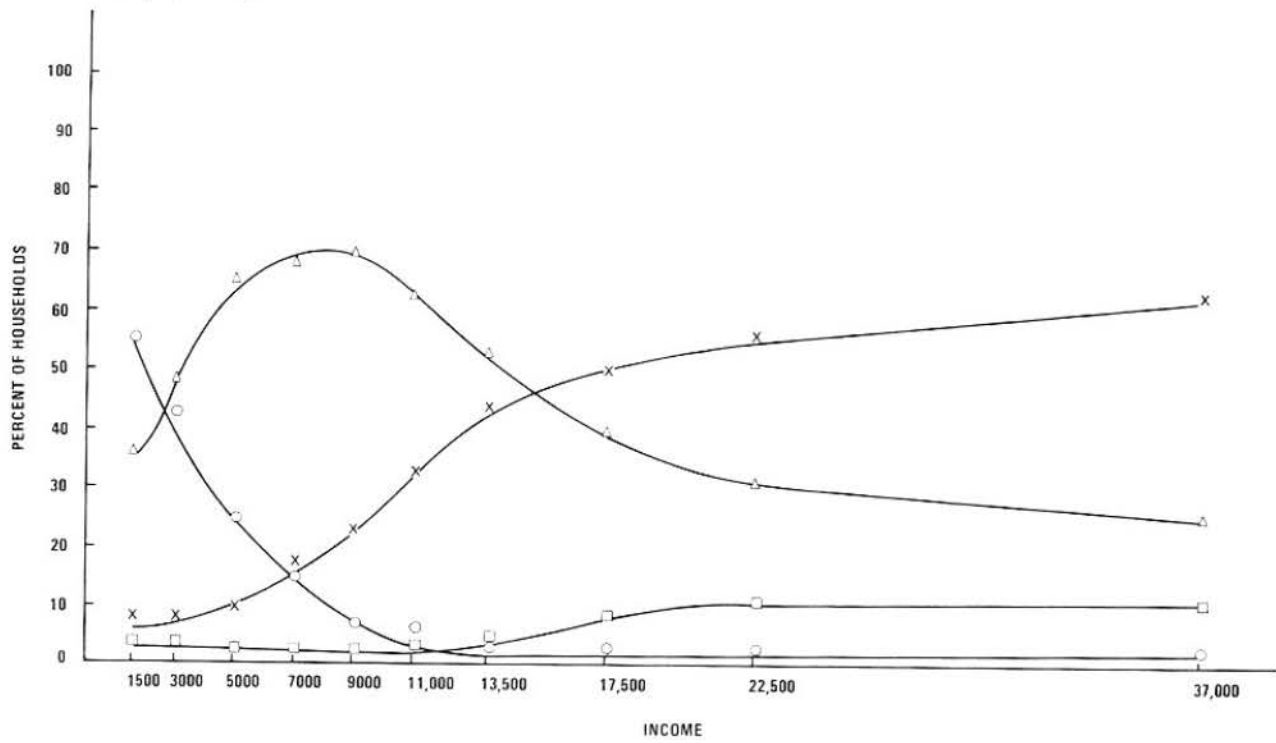


SPOKANE, WASHINGTON



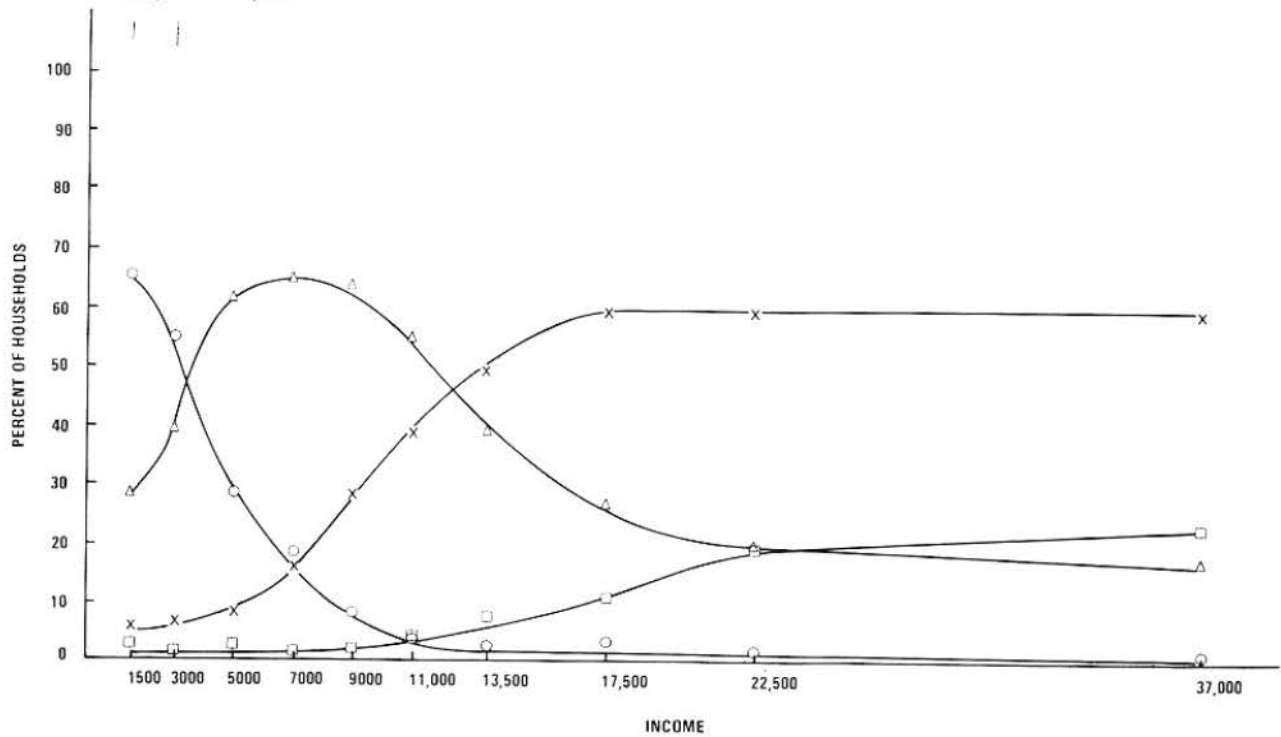
MADISON, WISCONSIN

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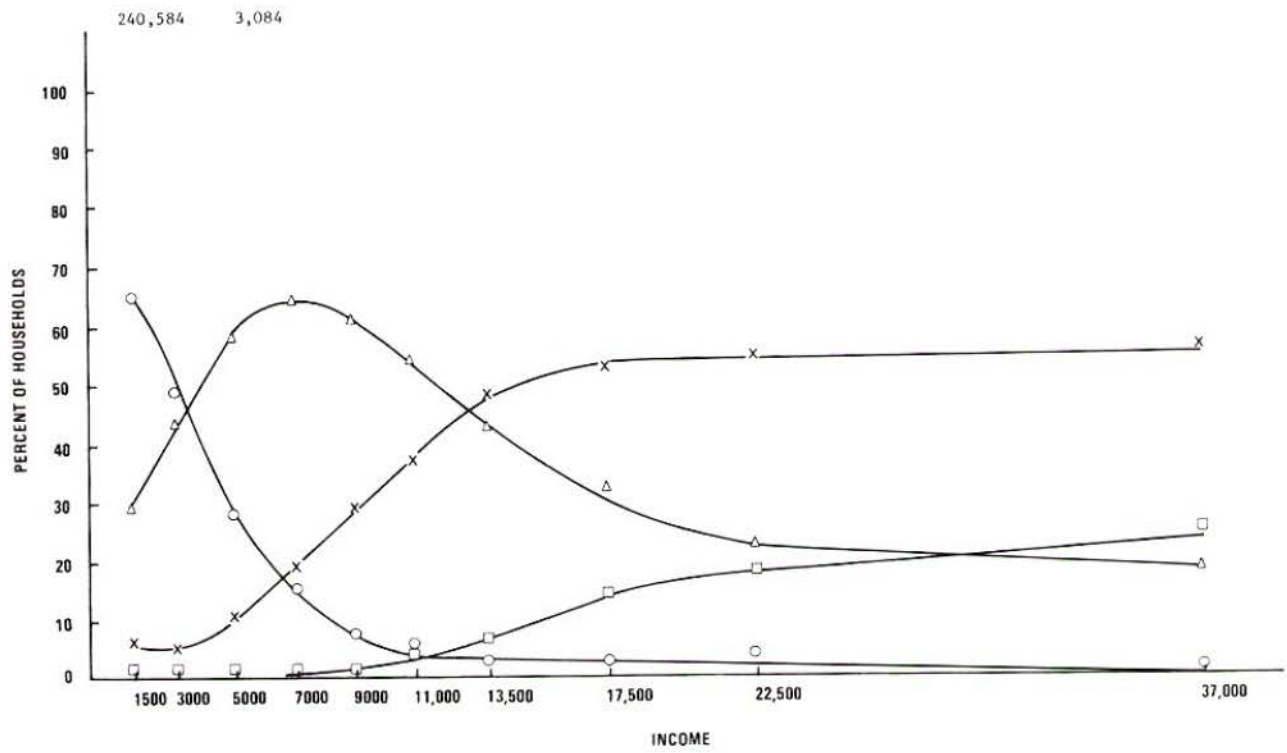


LANCASTER, PENNSYLVANIA

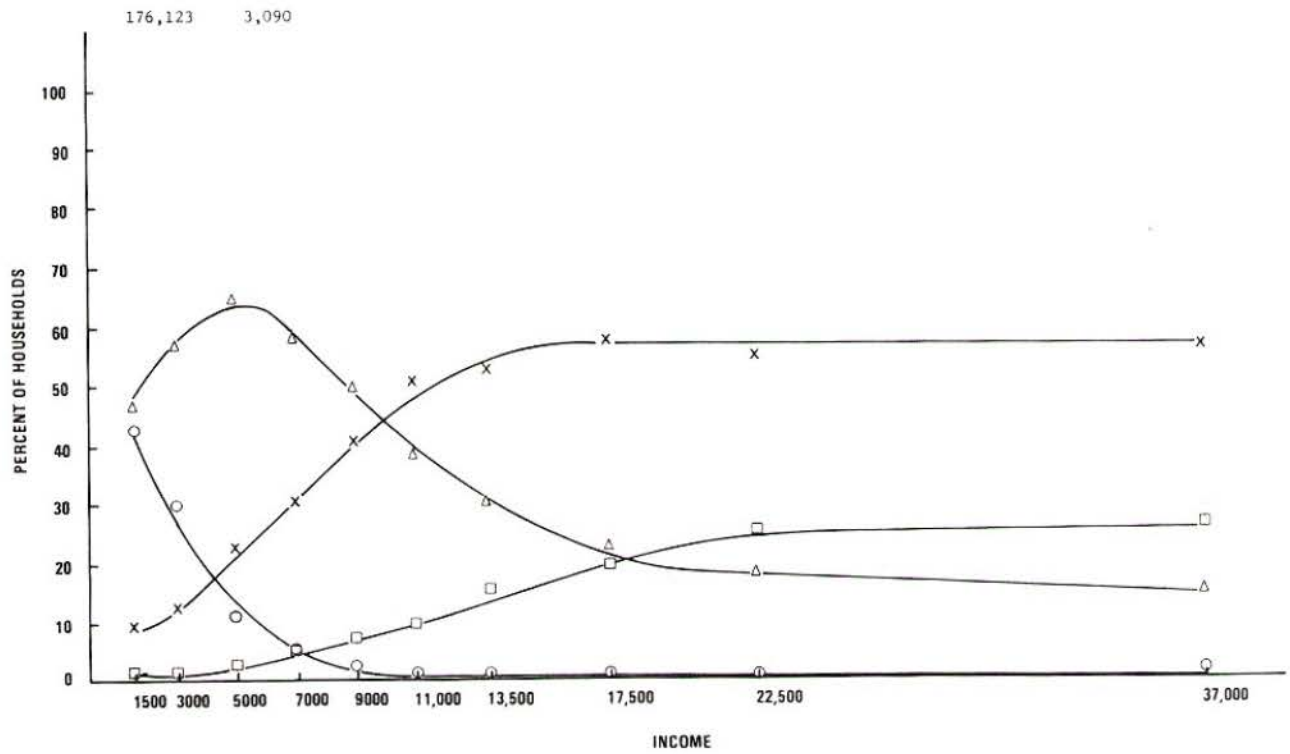
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HARRISBURG, PENNSYLVANIA

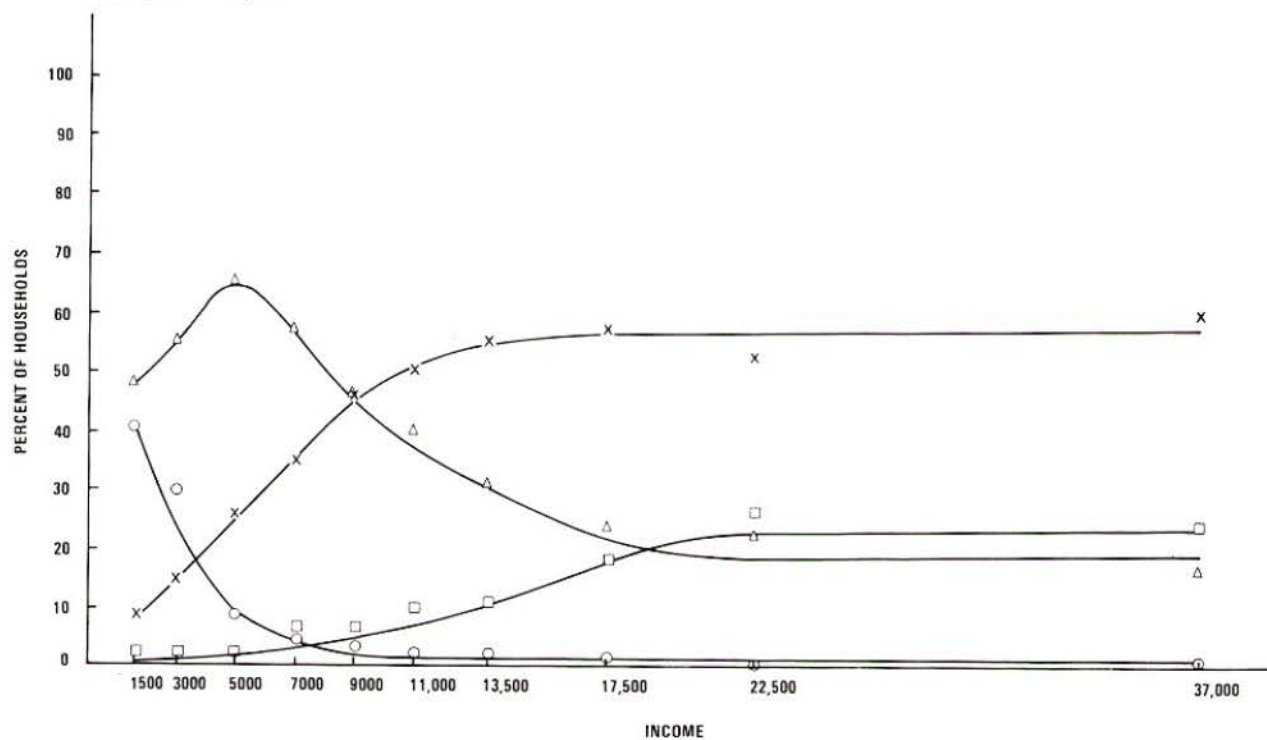


BAKERSFIELD, CA.



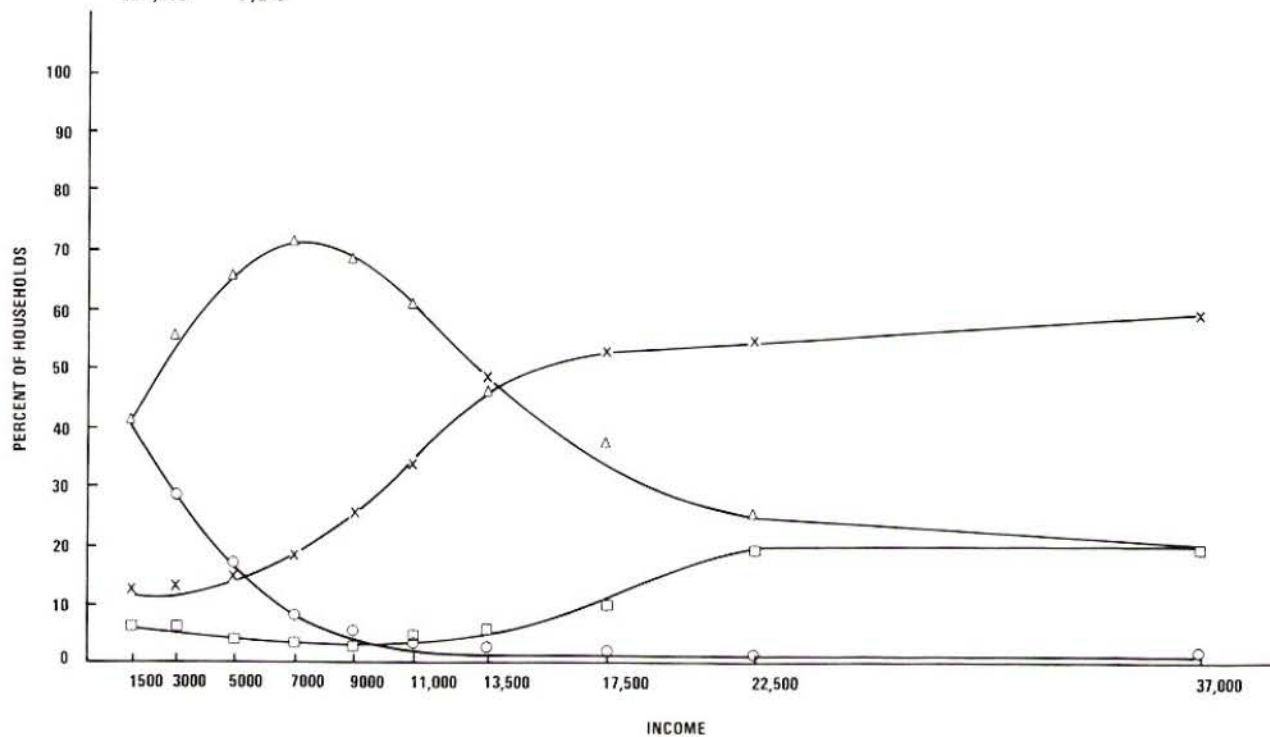
MODESTO, CALIFORNIA

105,683 3,108

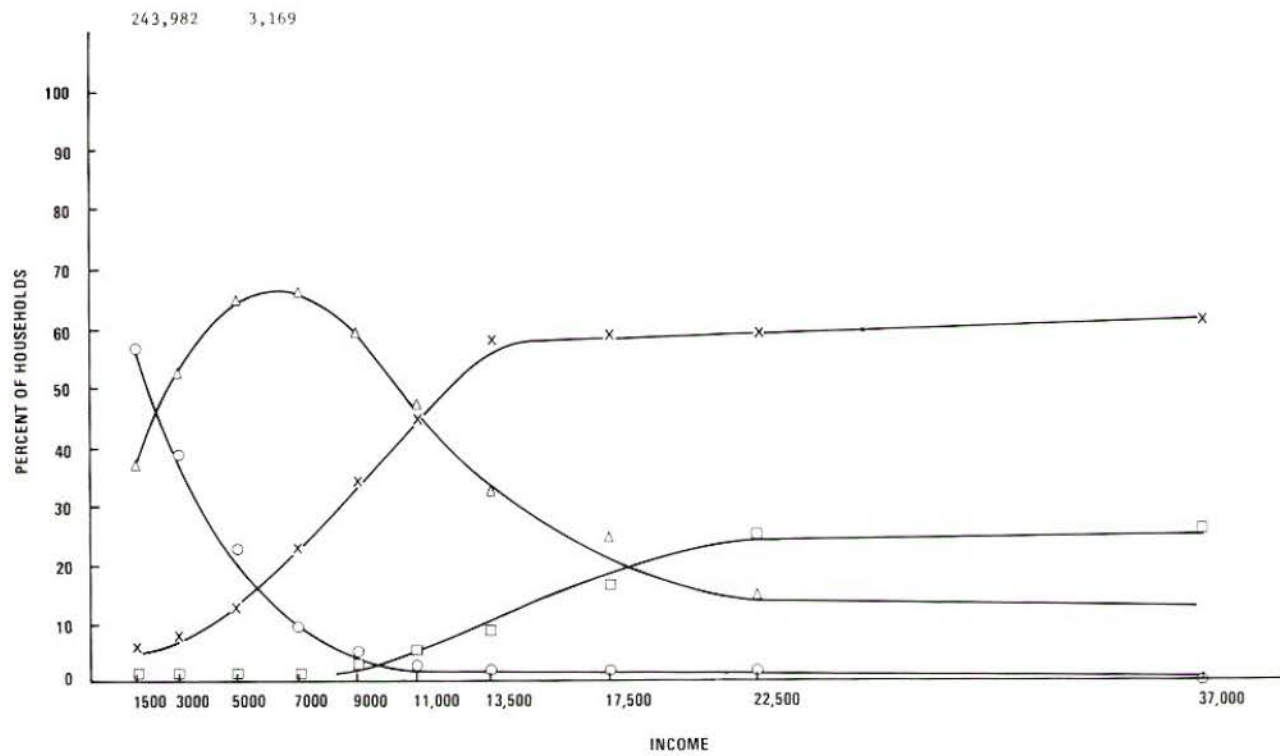


LANSING, MICHIGAN

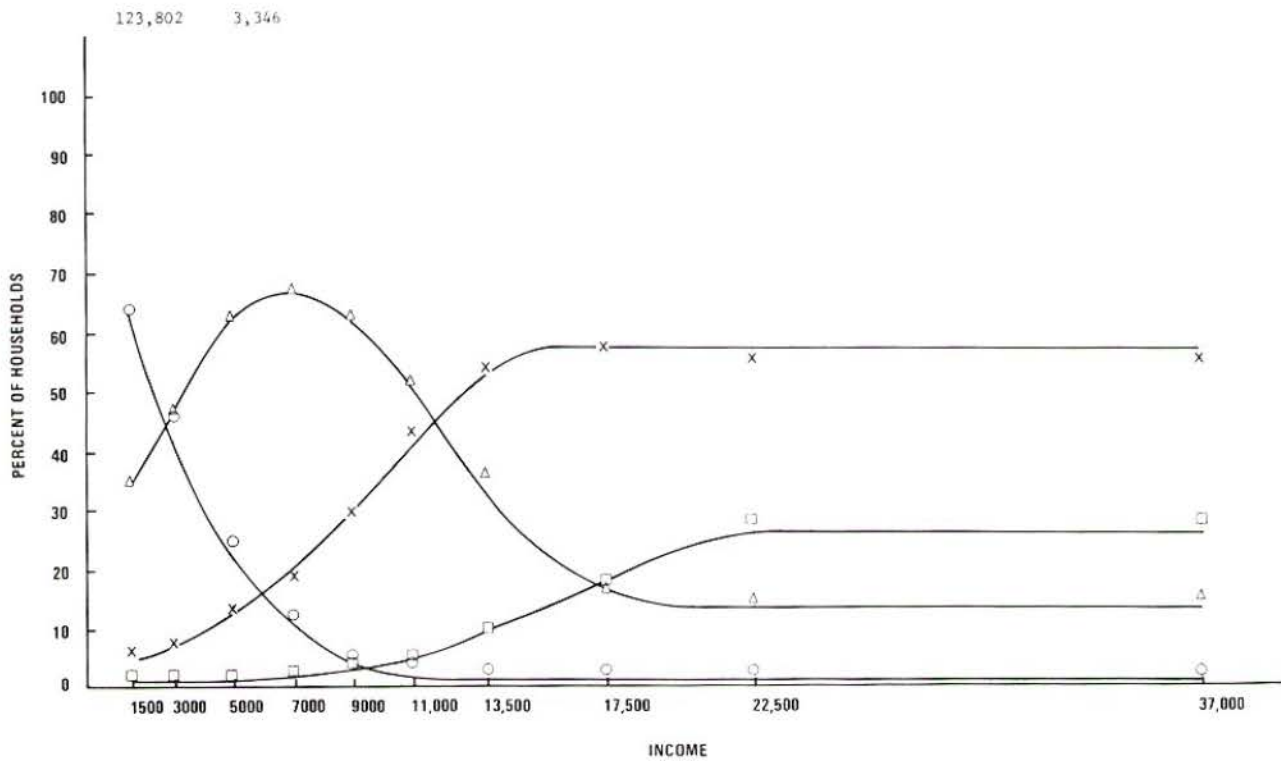
229,603 3,145



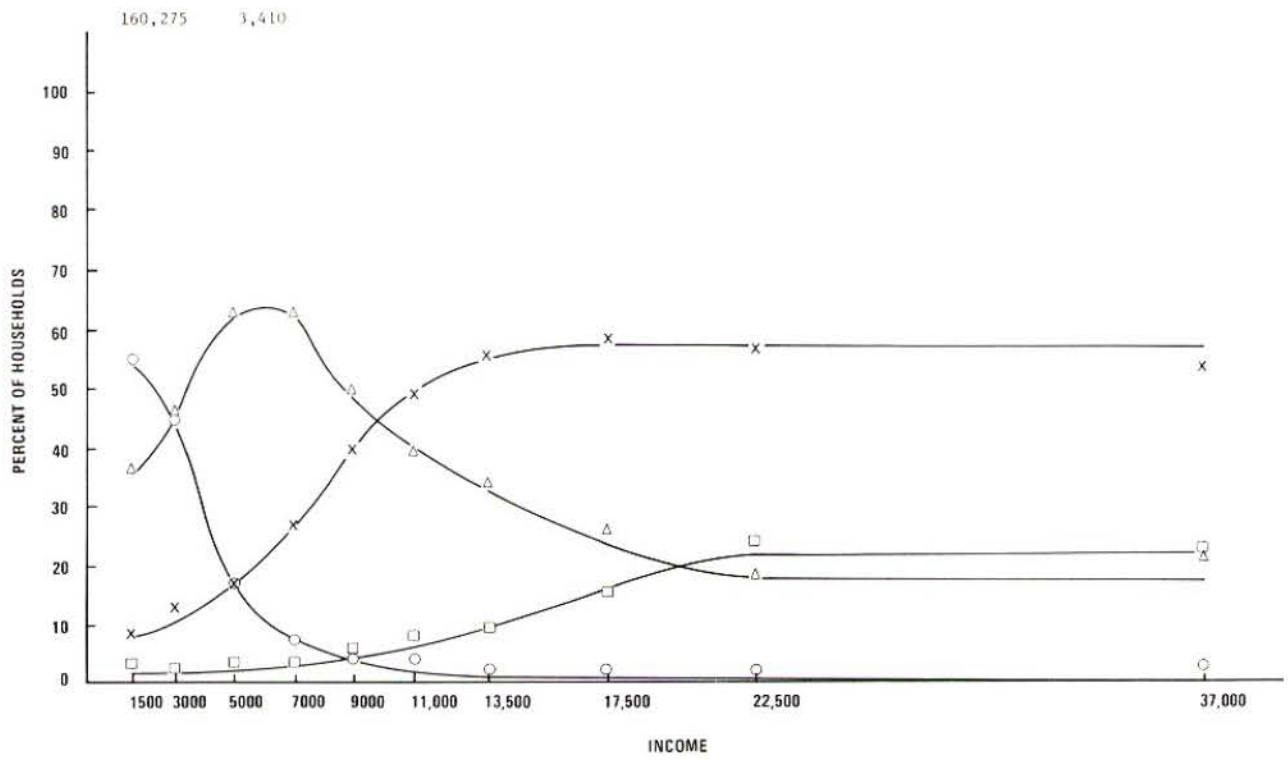
CANTON, OHIO



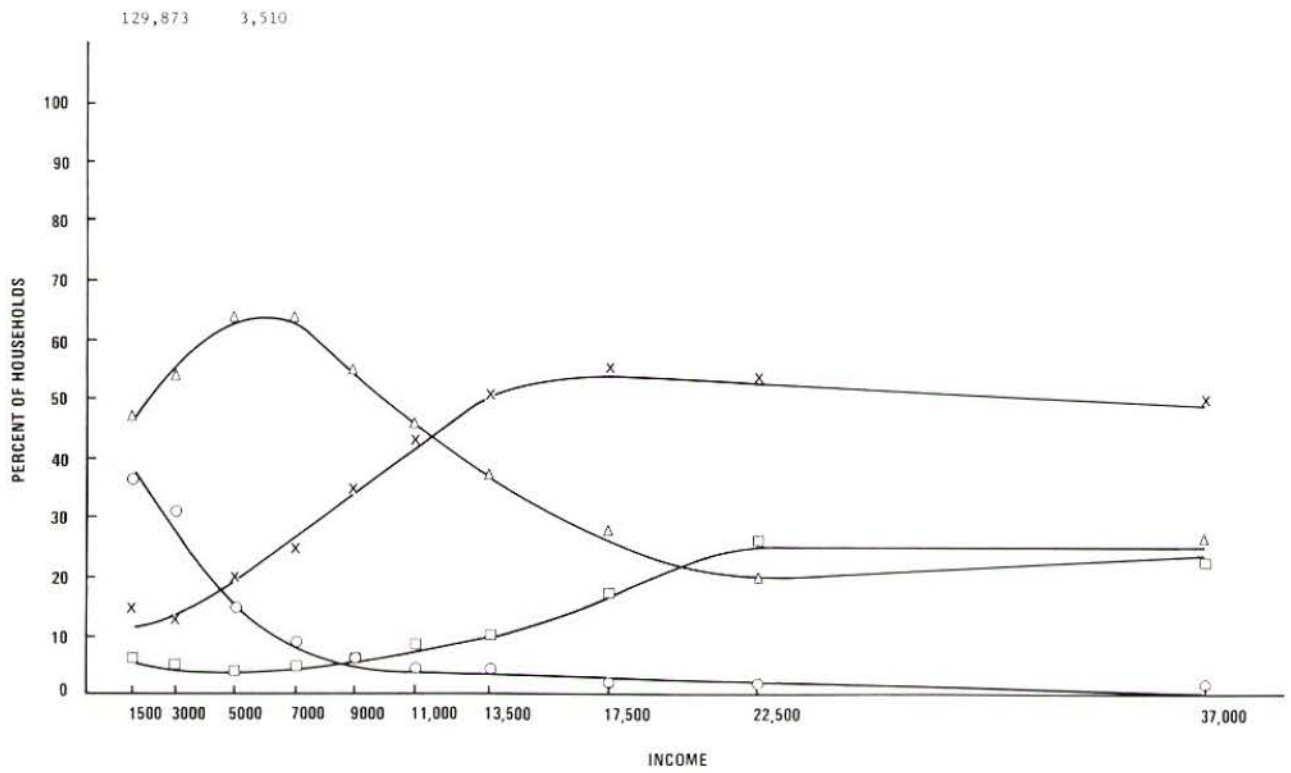
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STOCKTON, CALIFORNIA

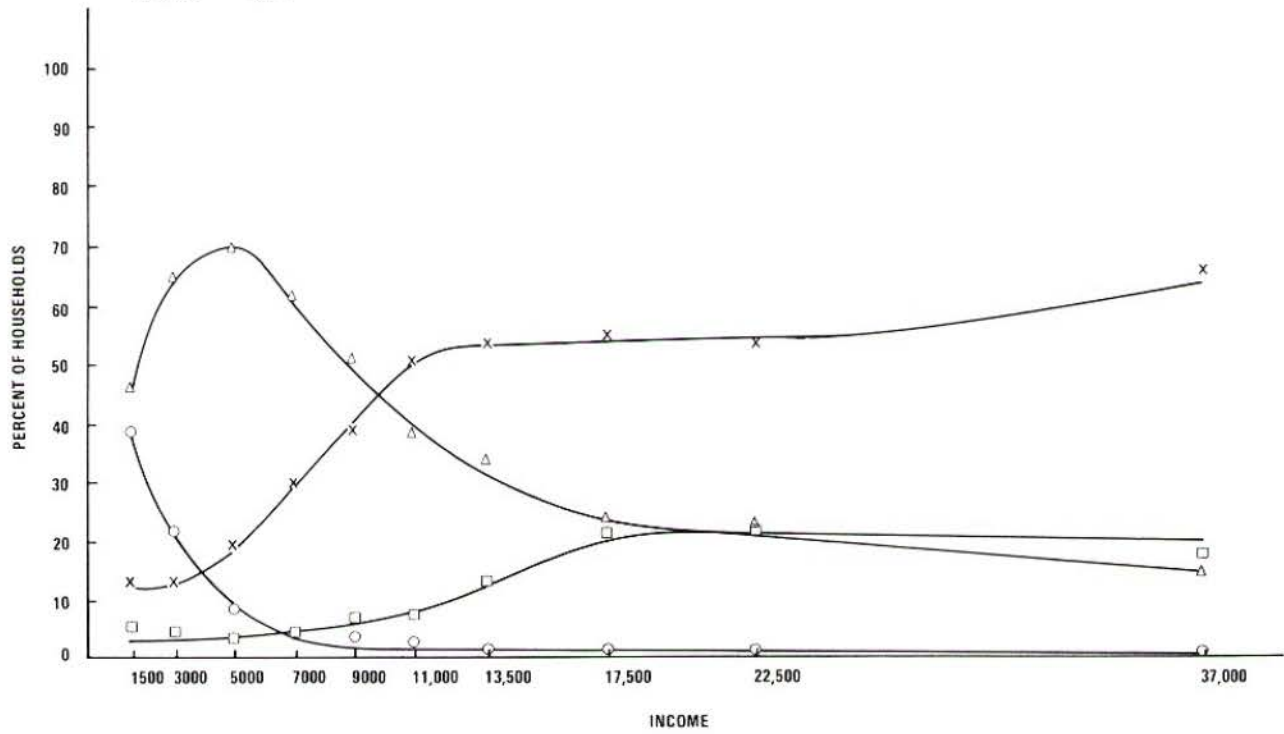


SANTA BARBARA, CALIFORNIA



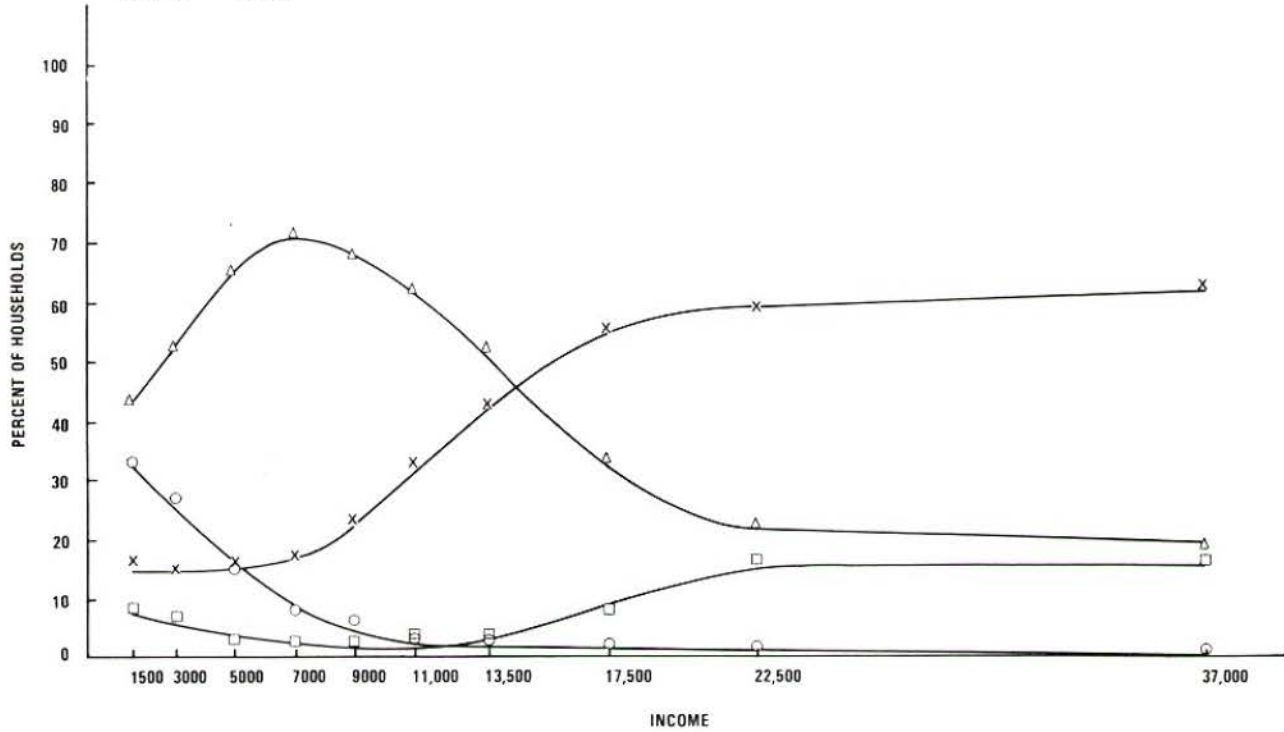
EUGENE, OREGON

139,319 3,672

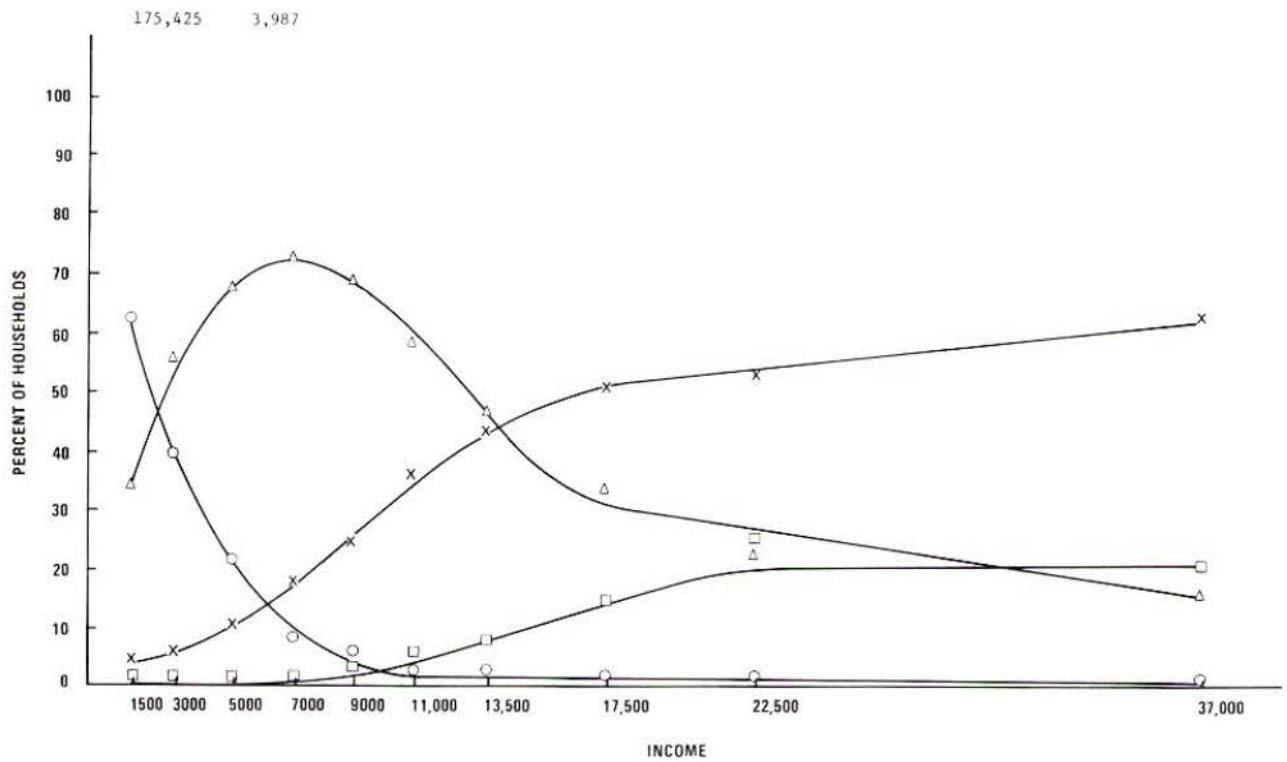


ANN ARBOR, MICHIGAN

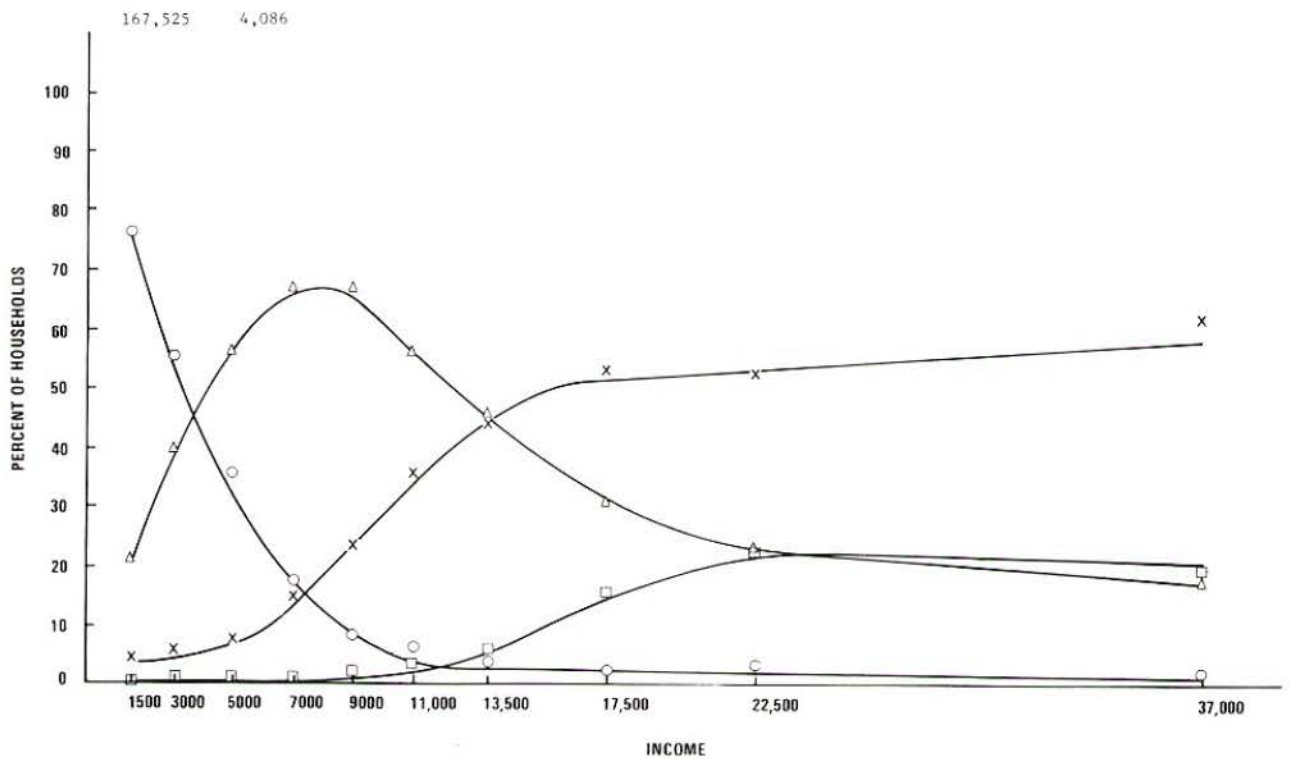
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ERIE, PENNSYLVANIA



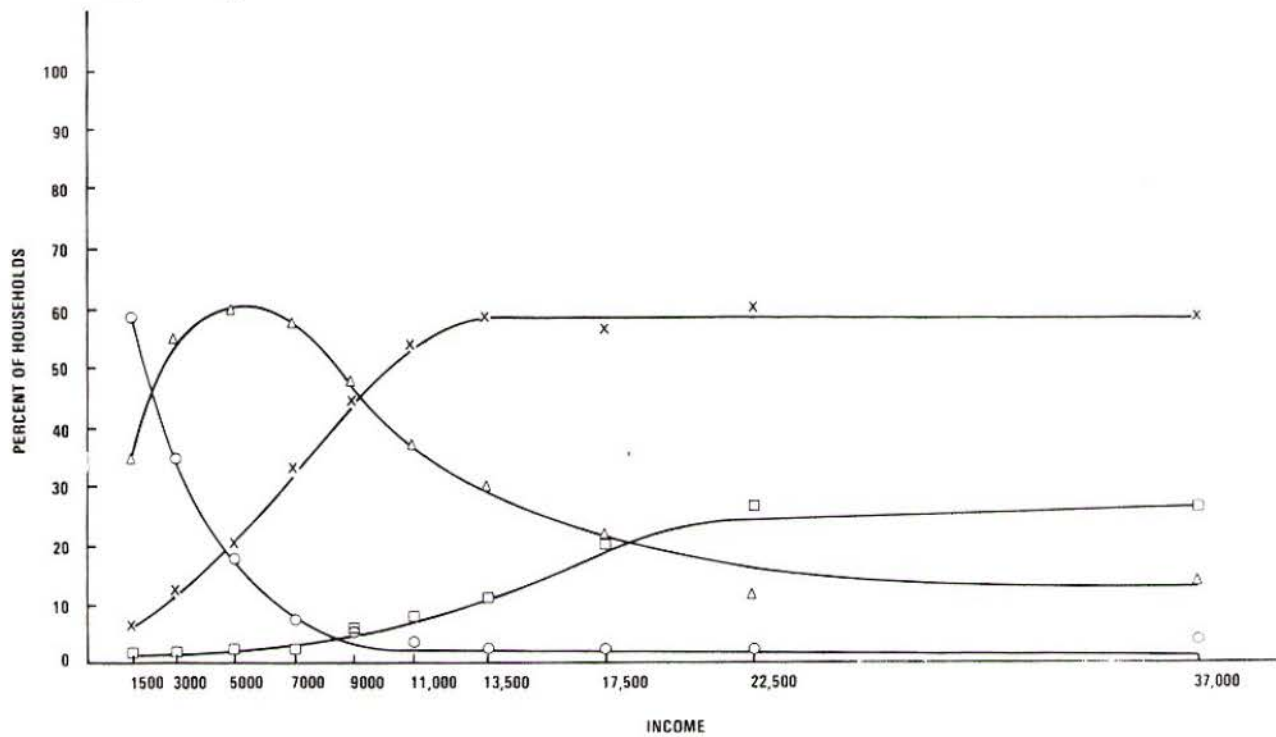
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POPULATION 250,000-750,000

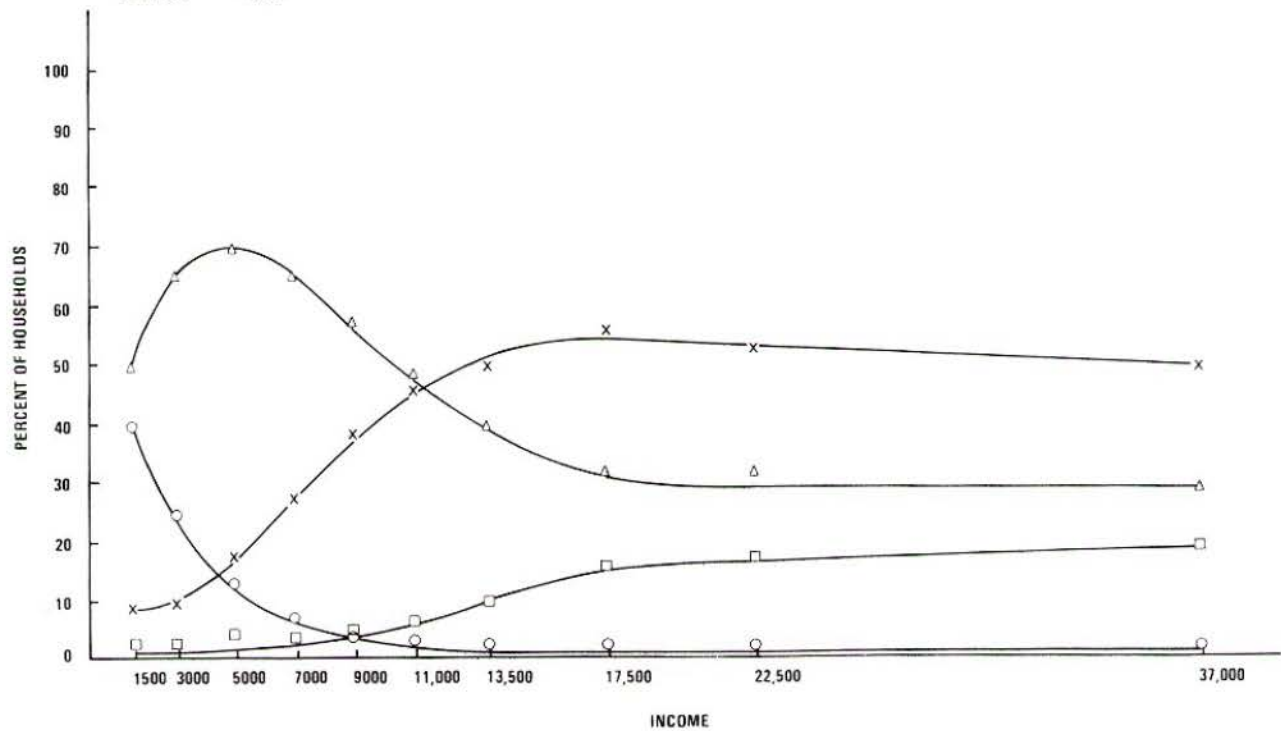
MOBILE, ALABAMA

257,650 1,534

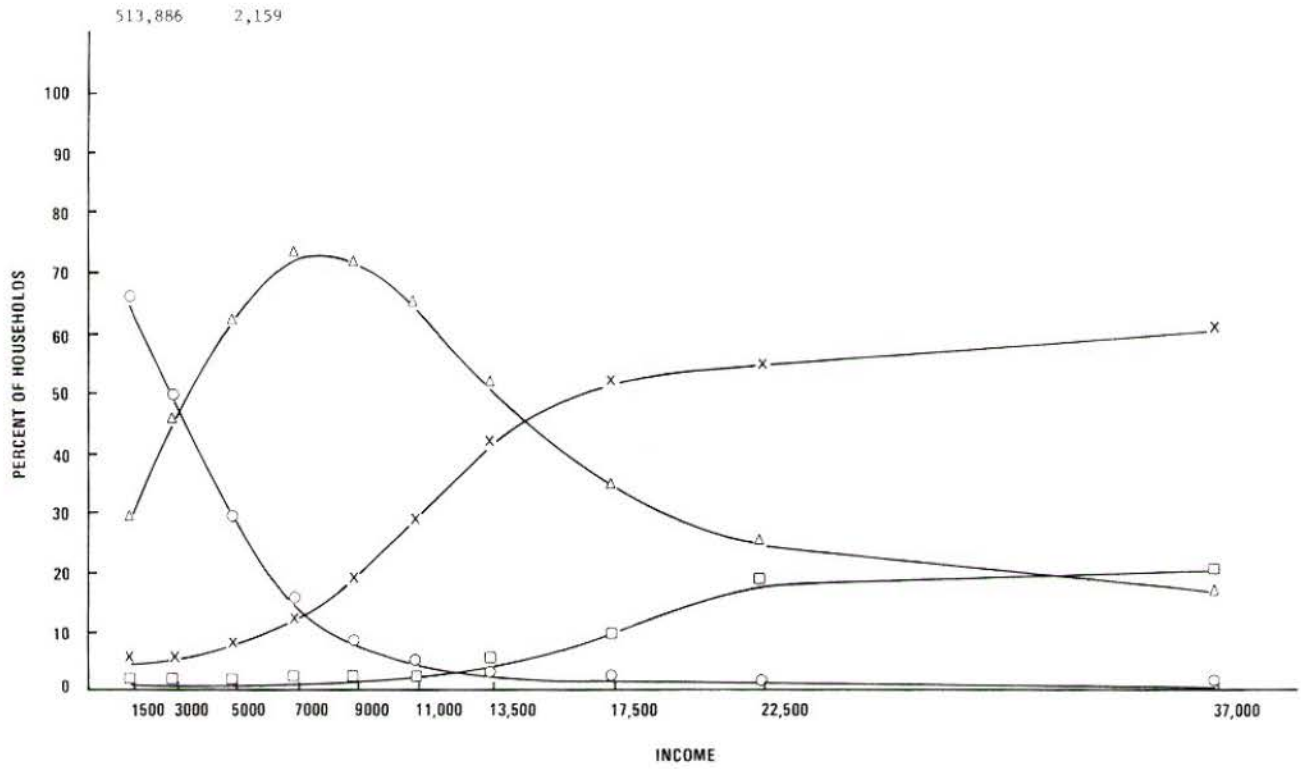


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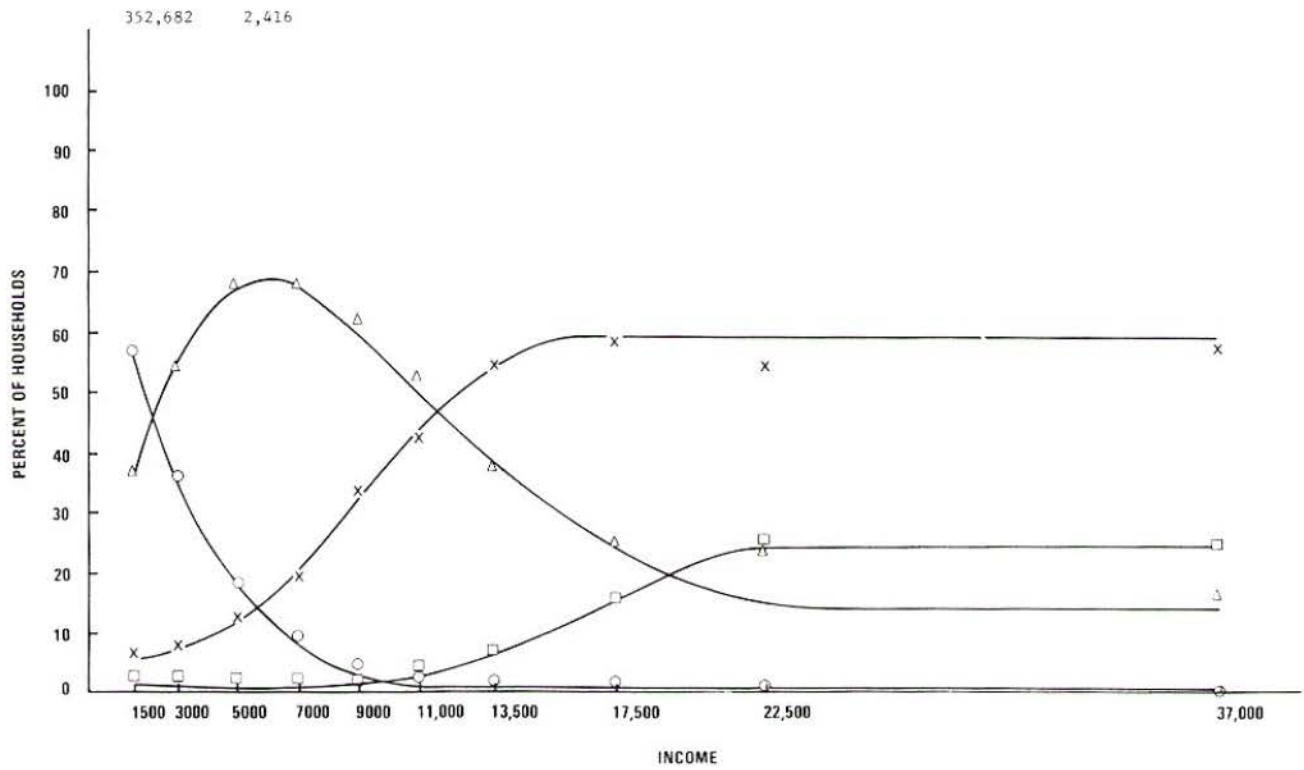
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SPRINGFIELD-CHICOPEE-HOLYOKE, MASSACHUSETTS

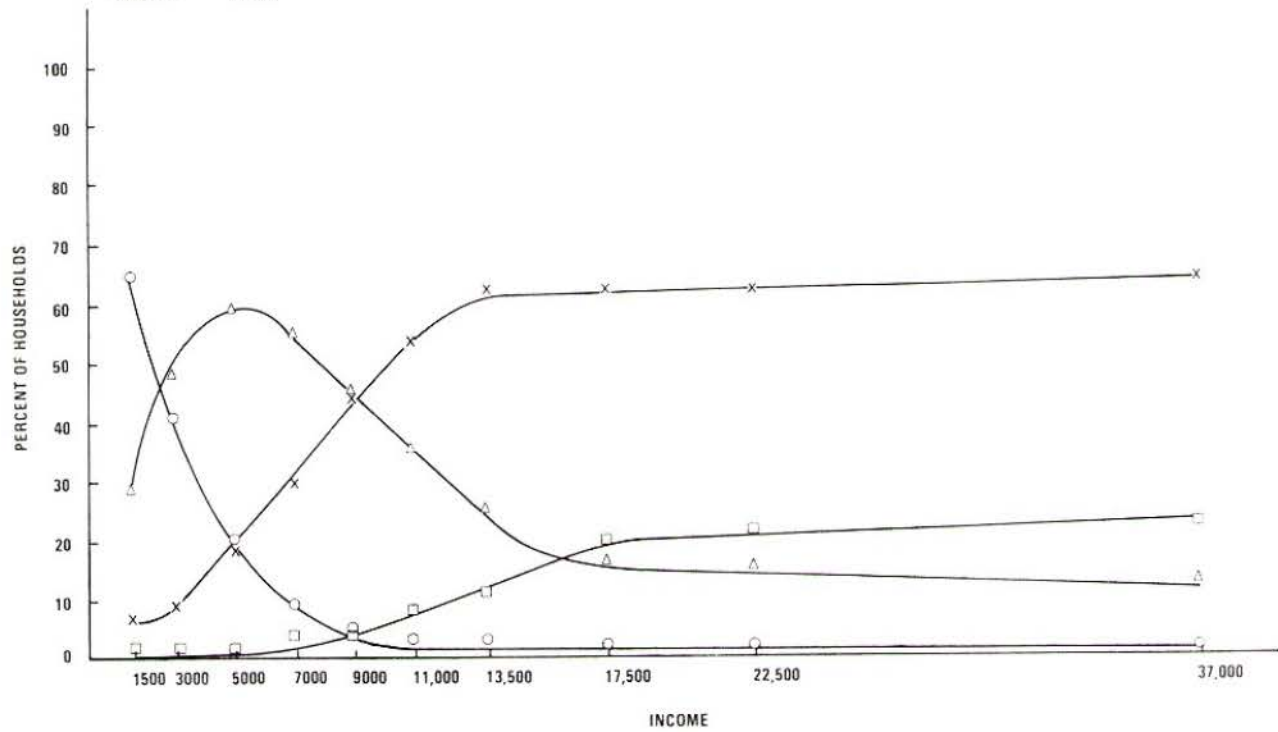


GRAND RAPIDS, MICHIGAN



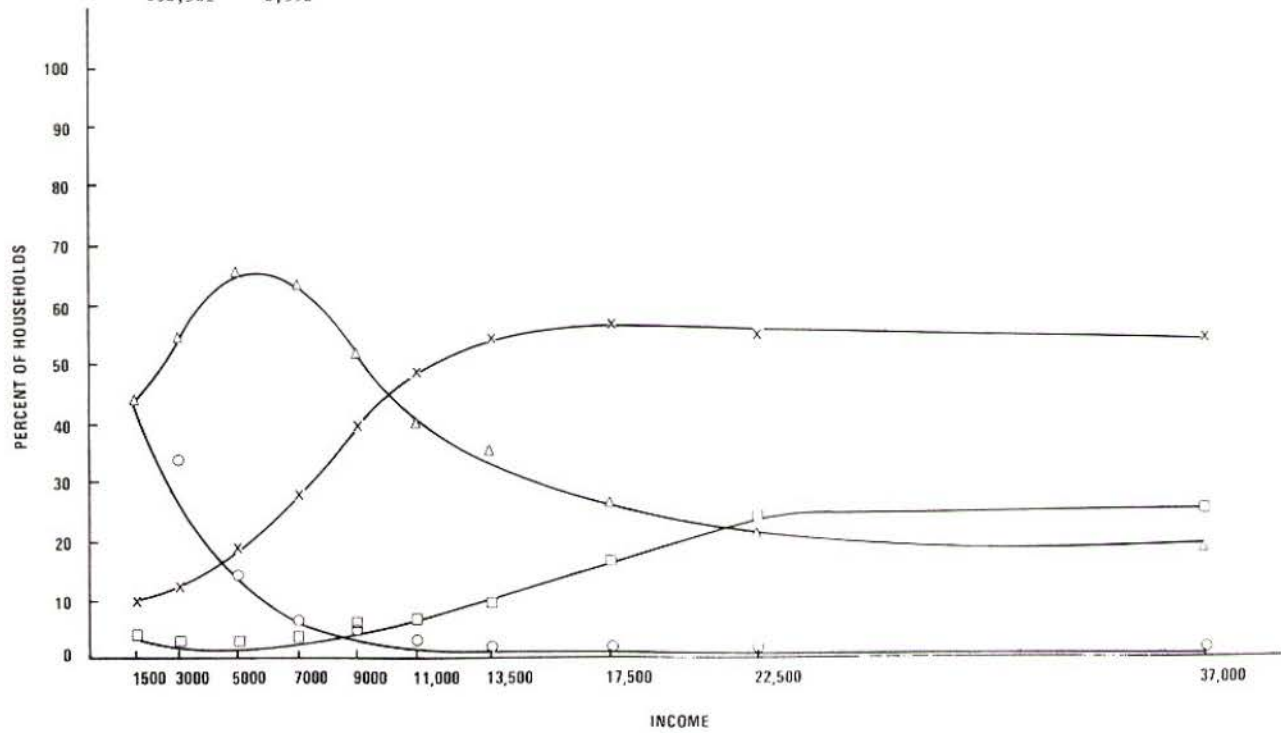
BIRMINGHAM, ALABAMA

557,570 2,478

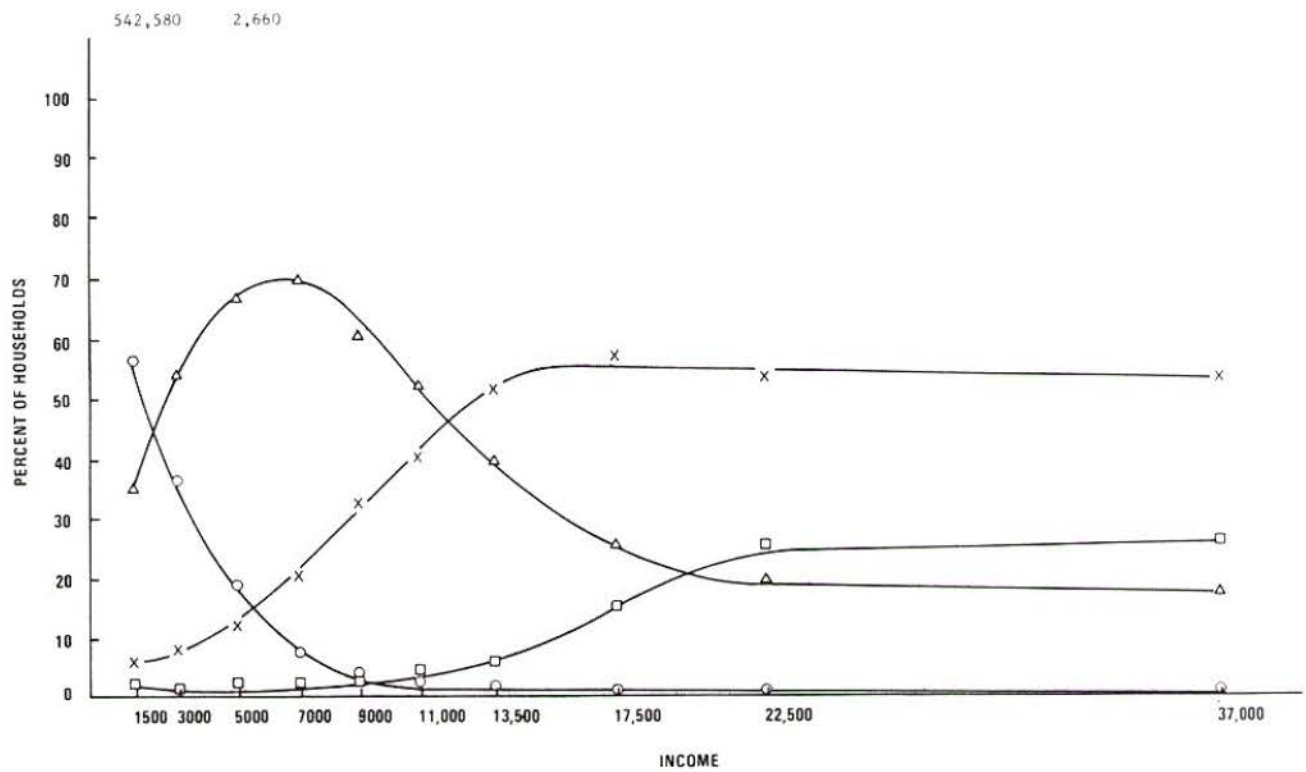


SACRAMENTO, CALIFORNIA

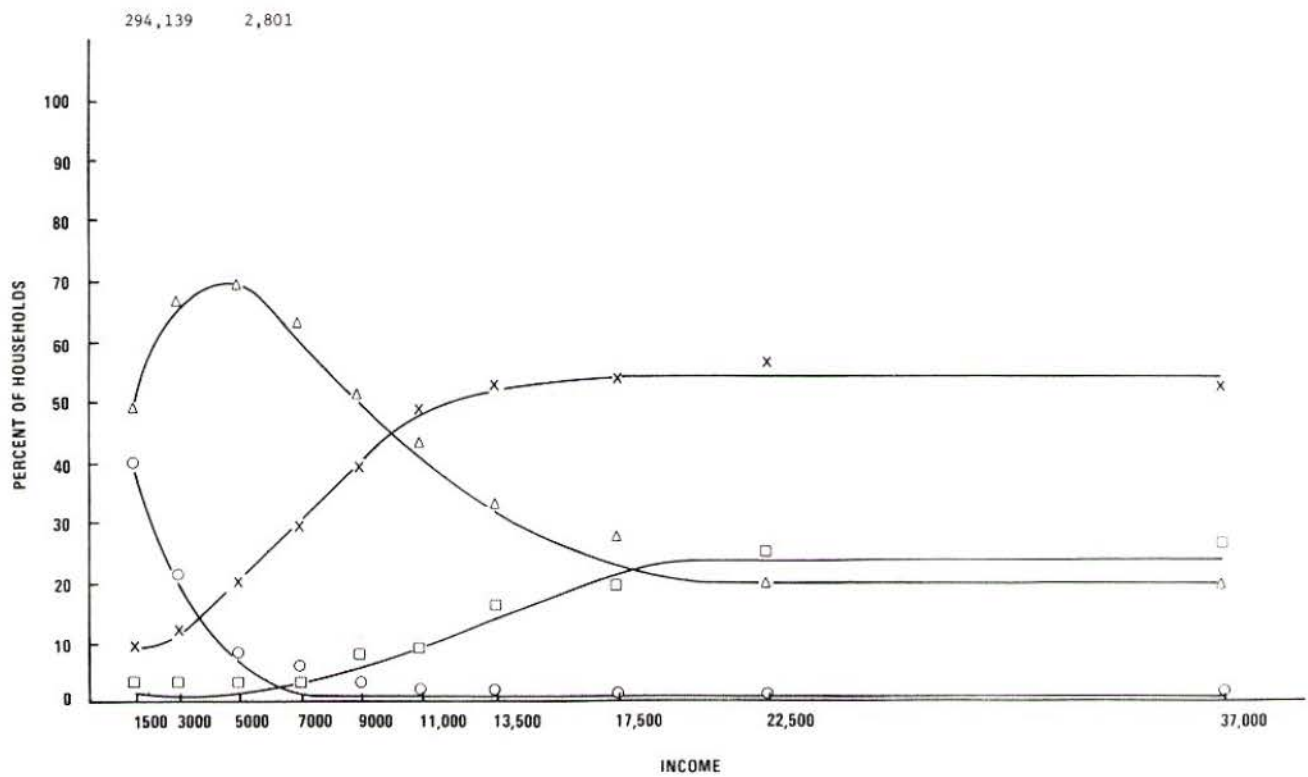
632,521 2,592



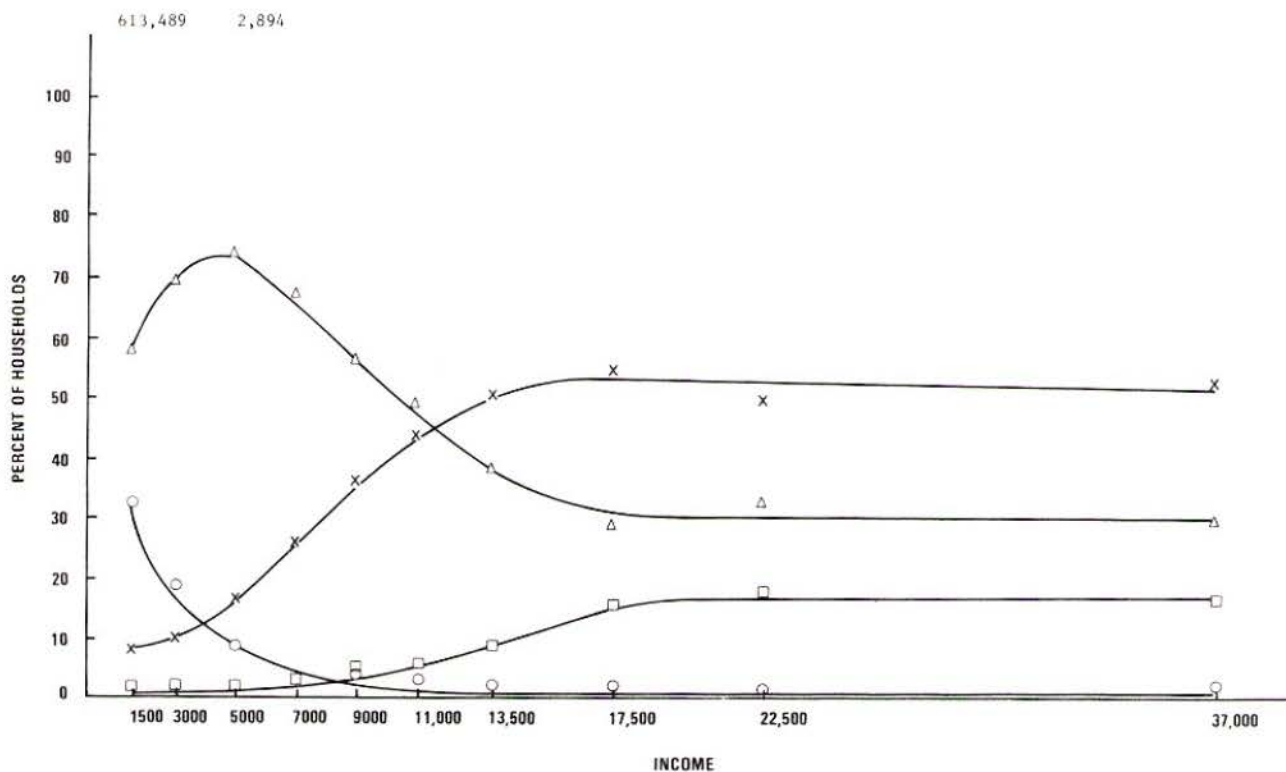
AKRON, OHIO



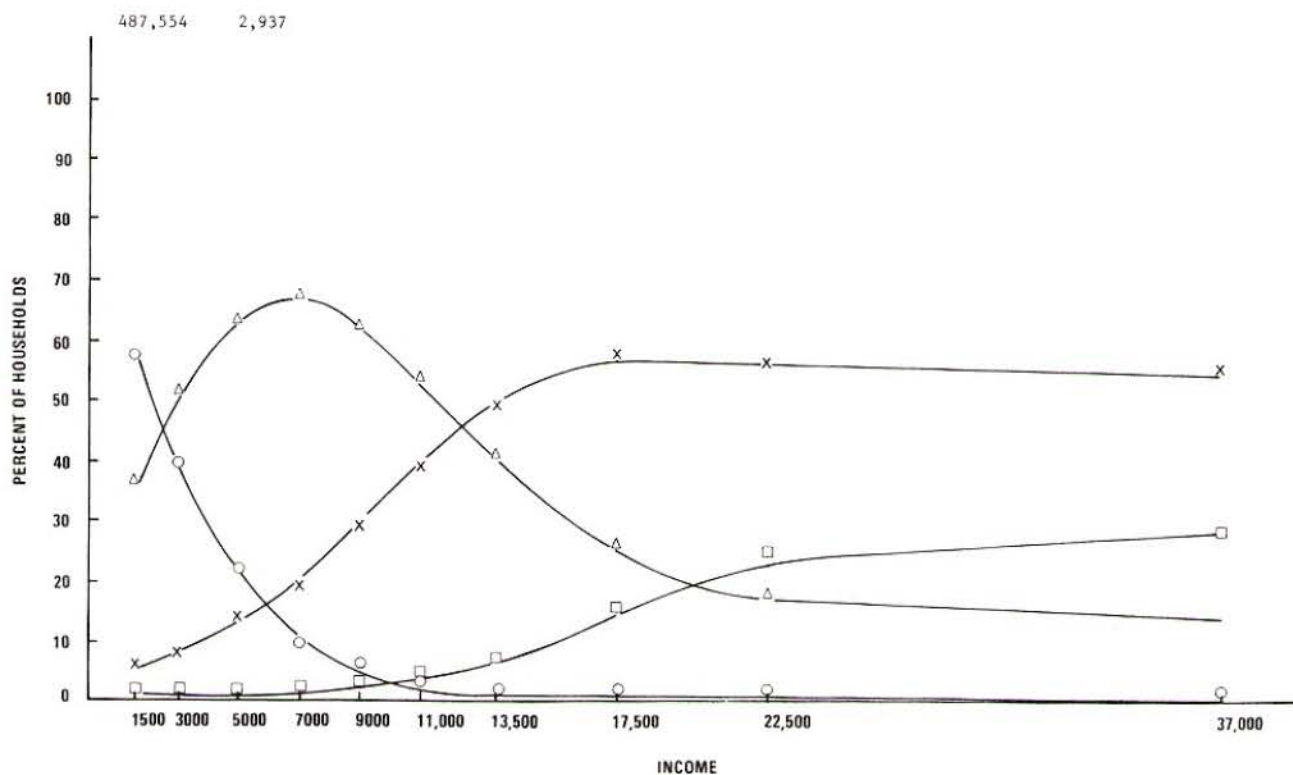
TUCSON, ARIZONA



FORT LAUDERDALE, FLORIDA

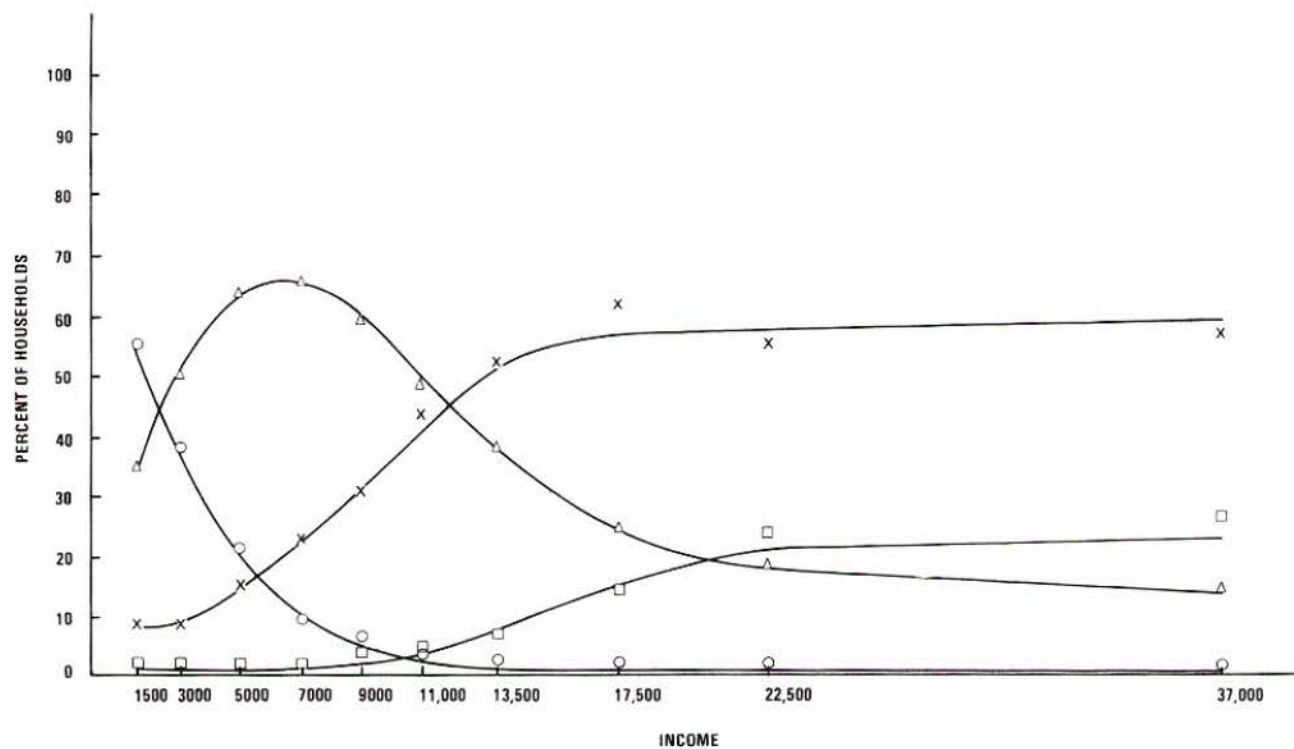


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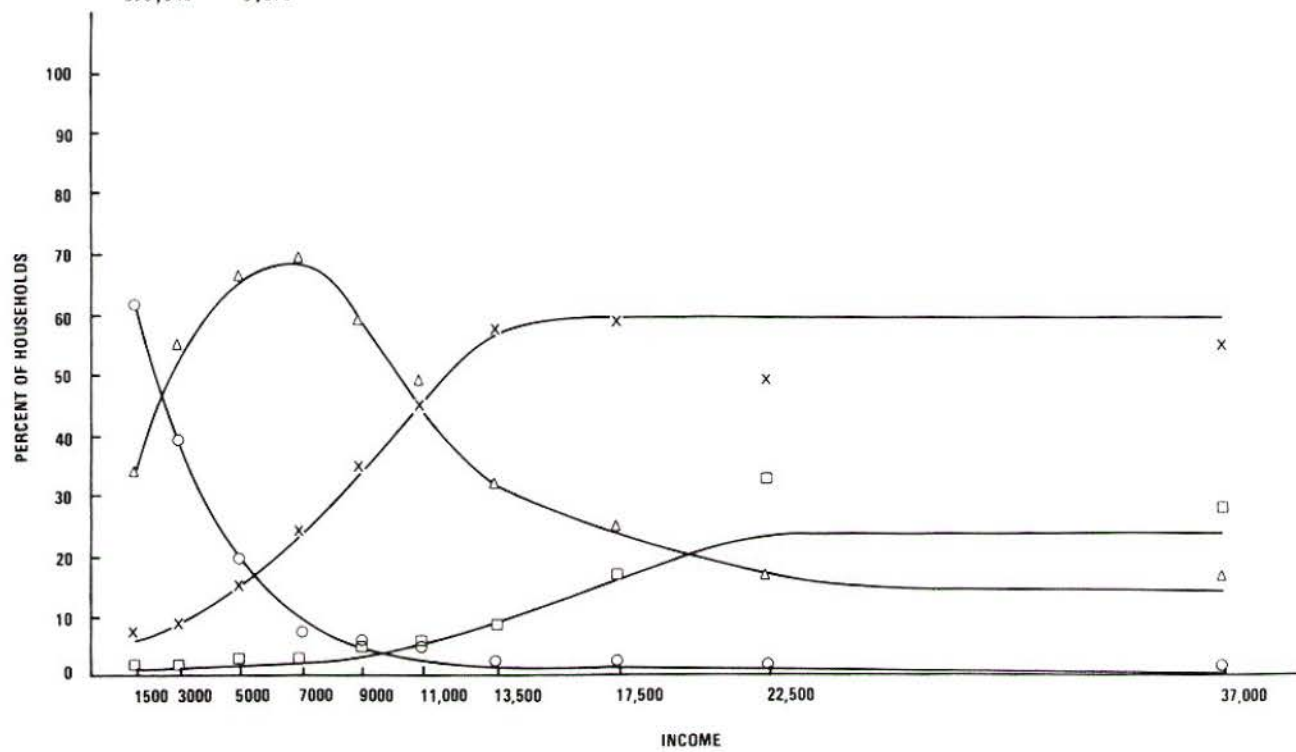
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685,949 3,062

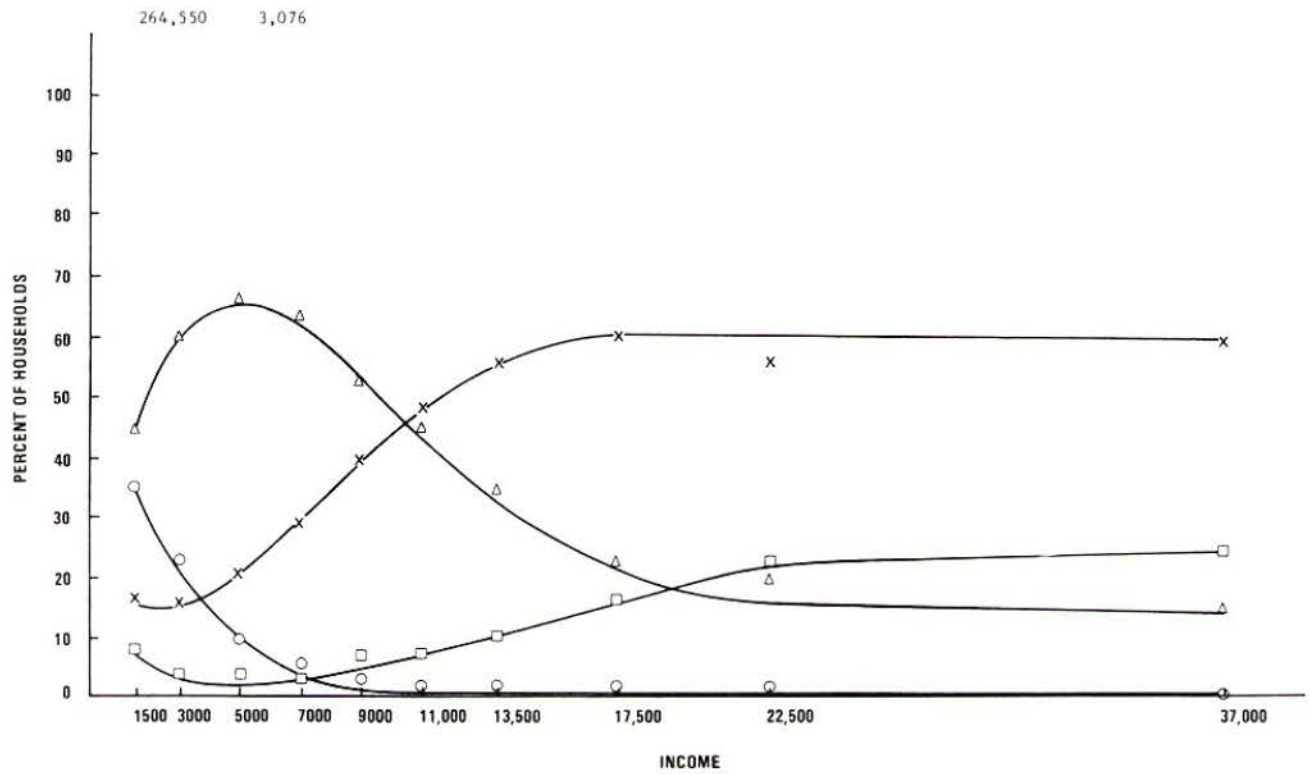


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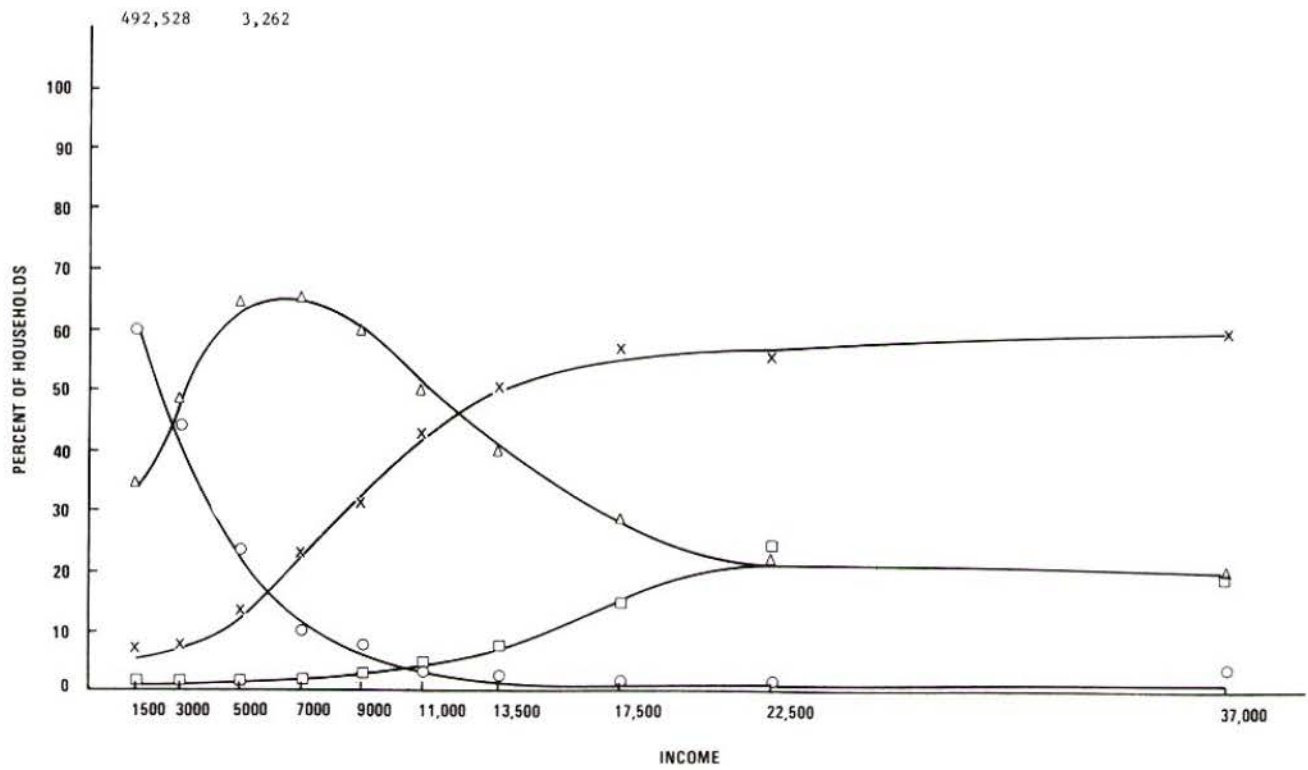
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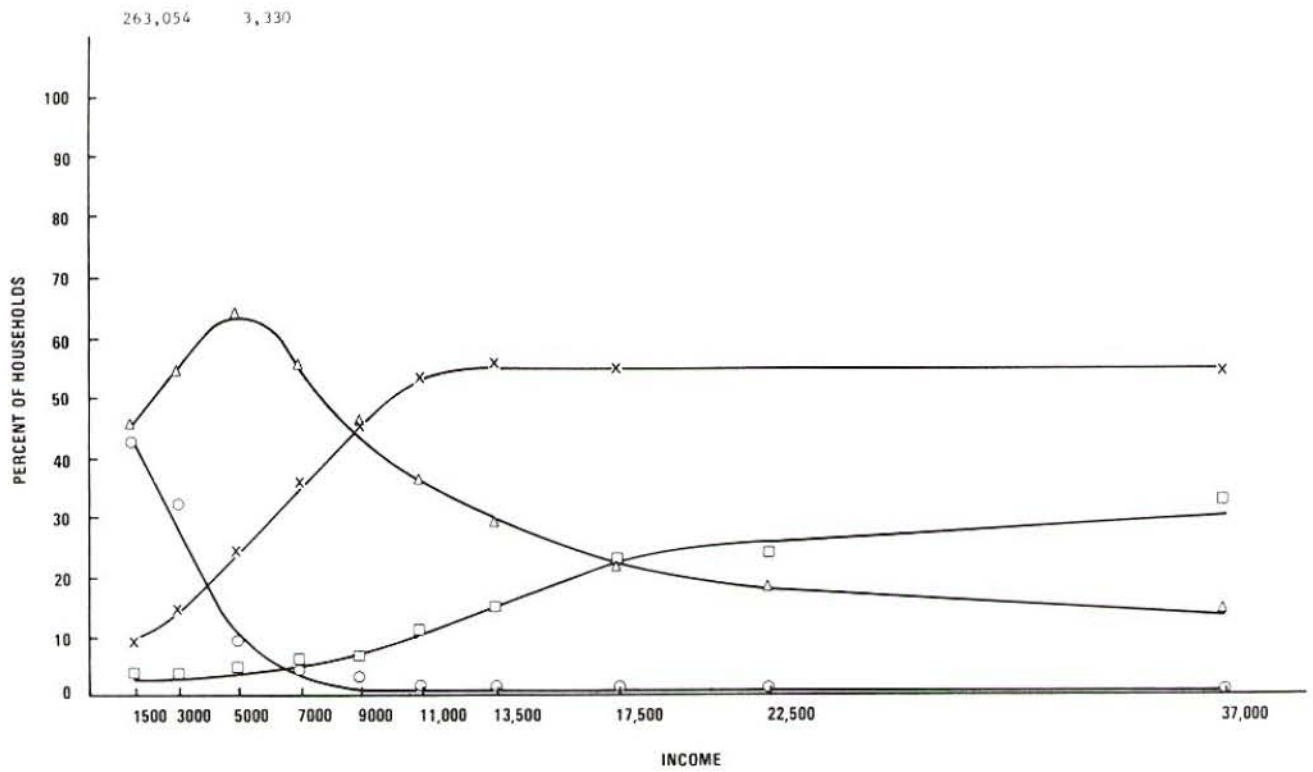
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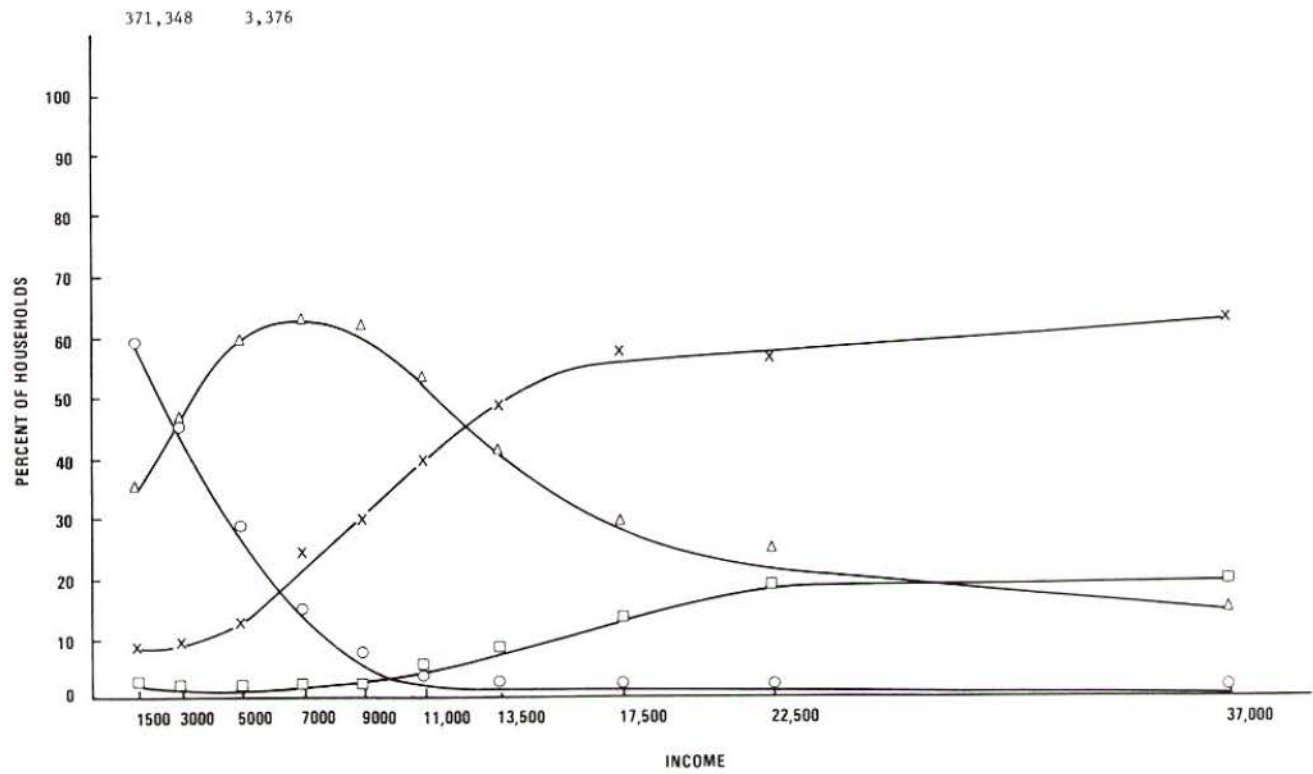
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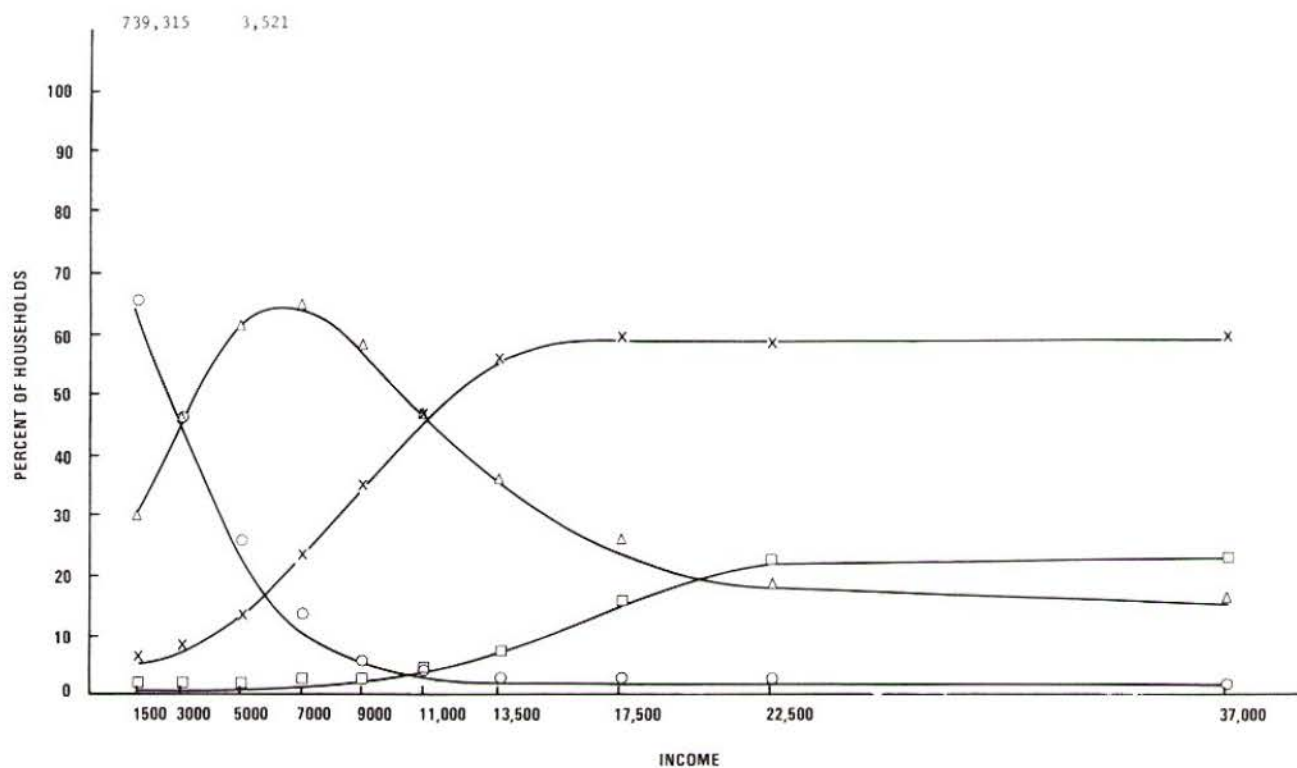
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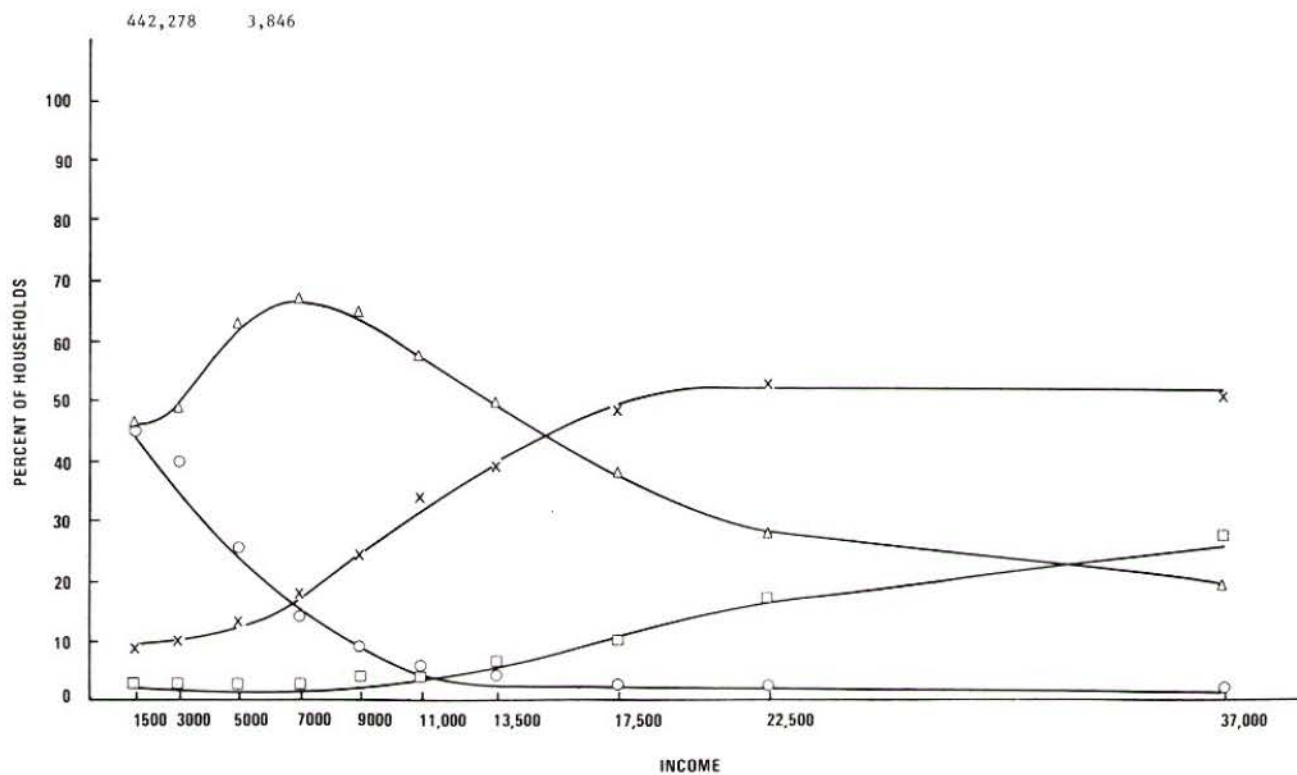
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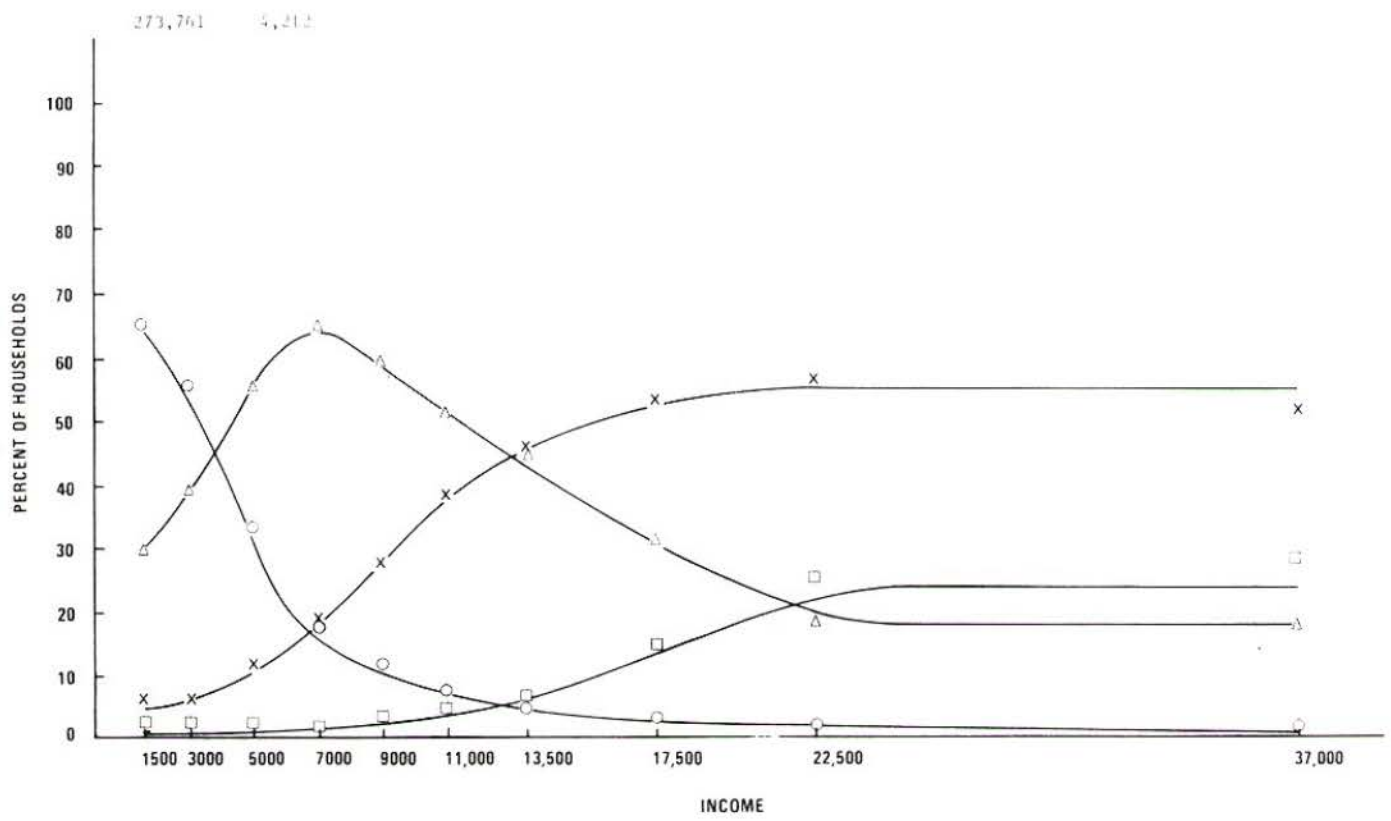
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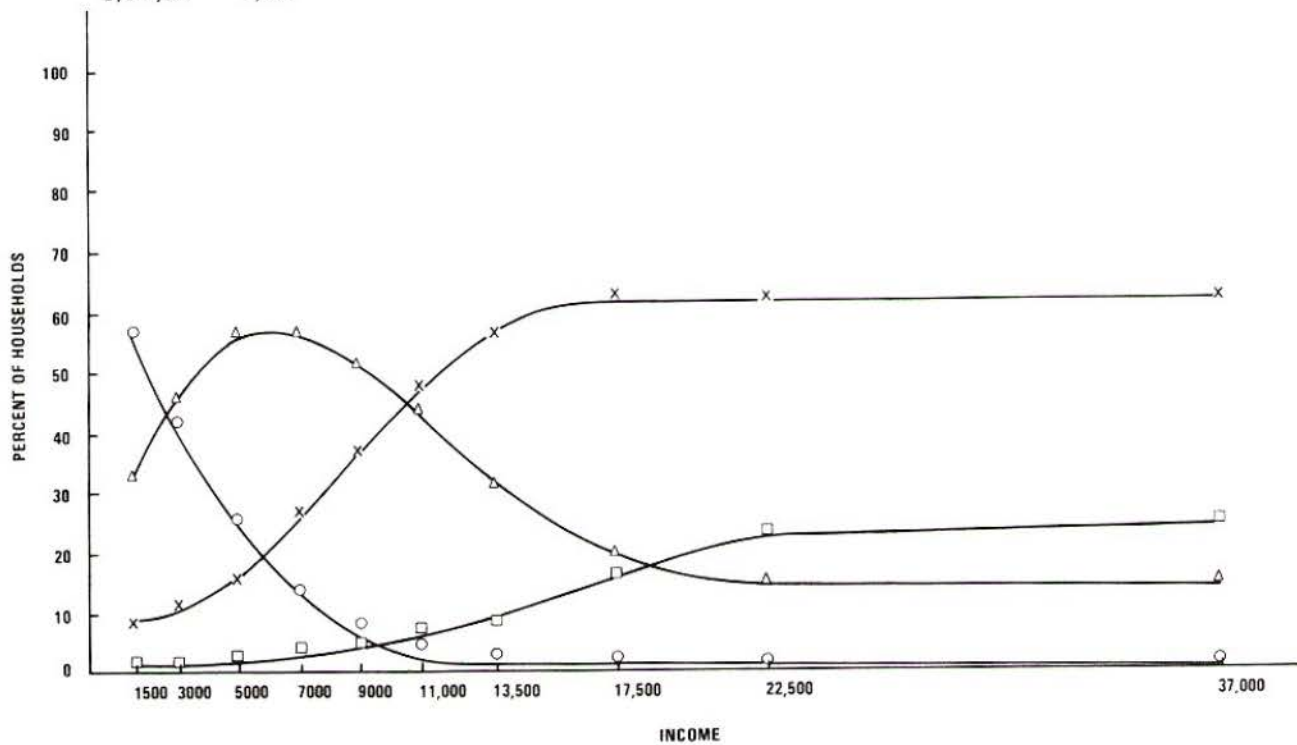


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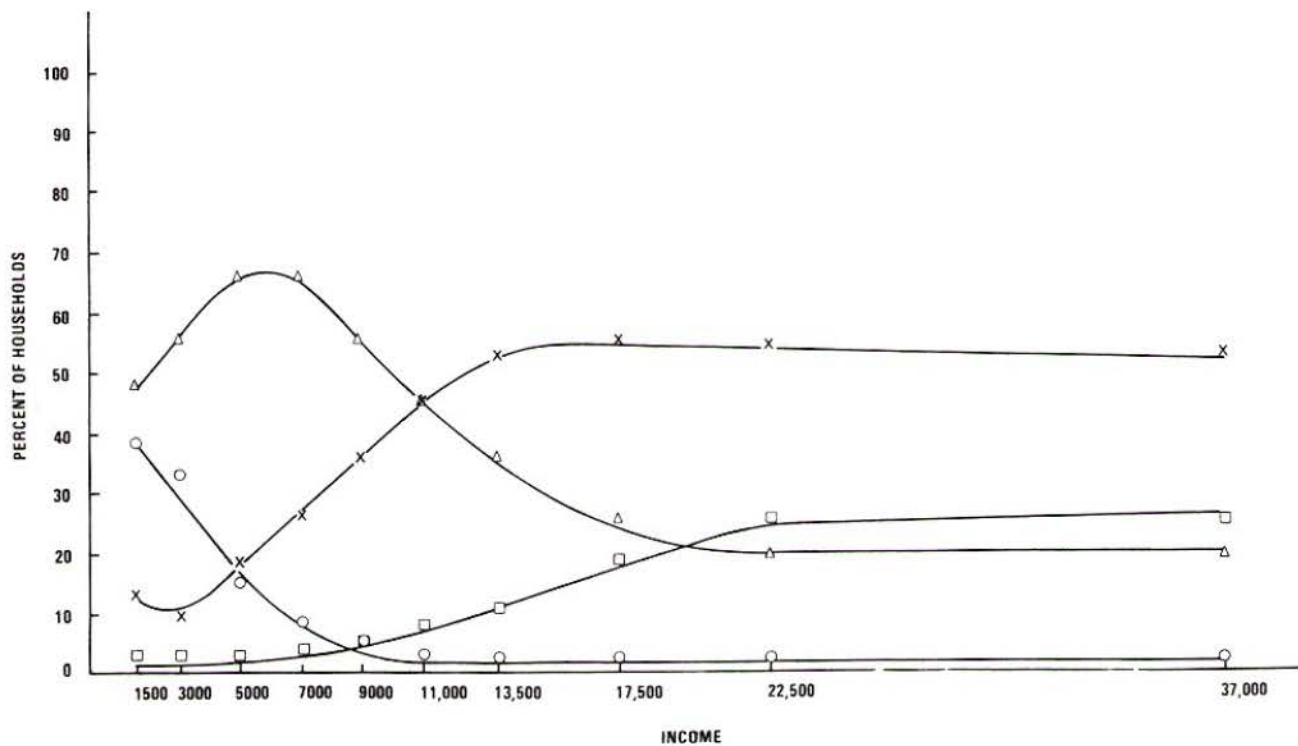
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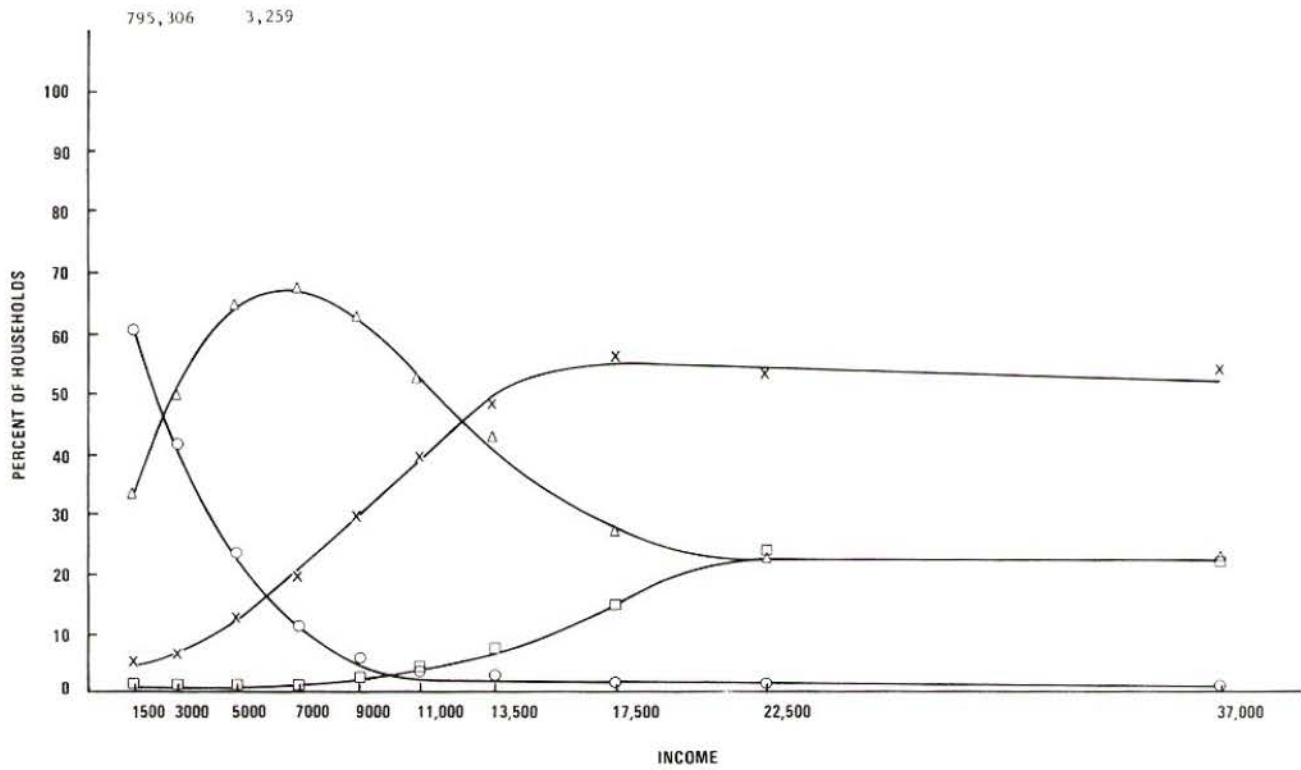


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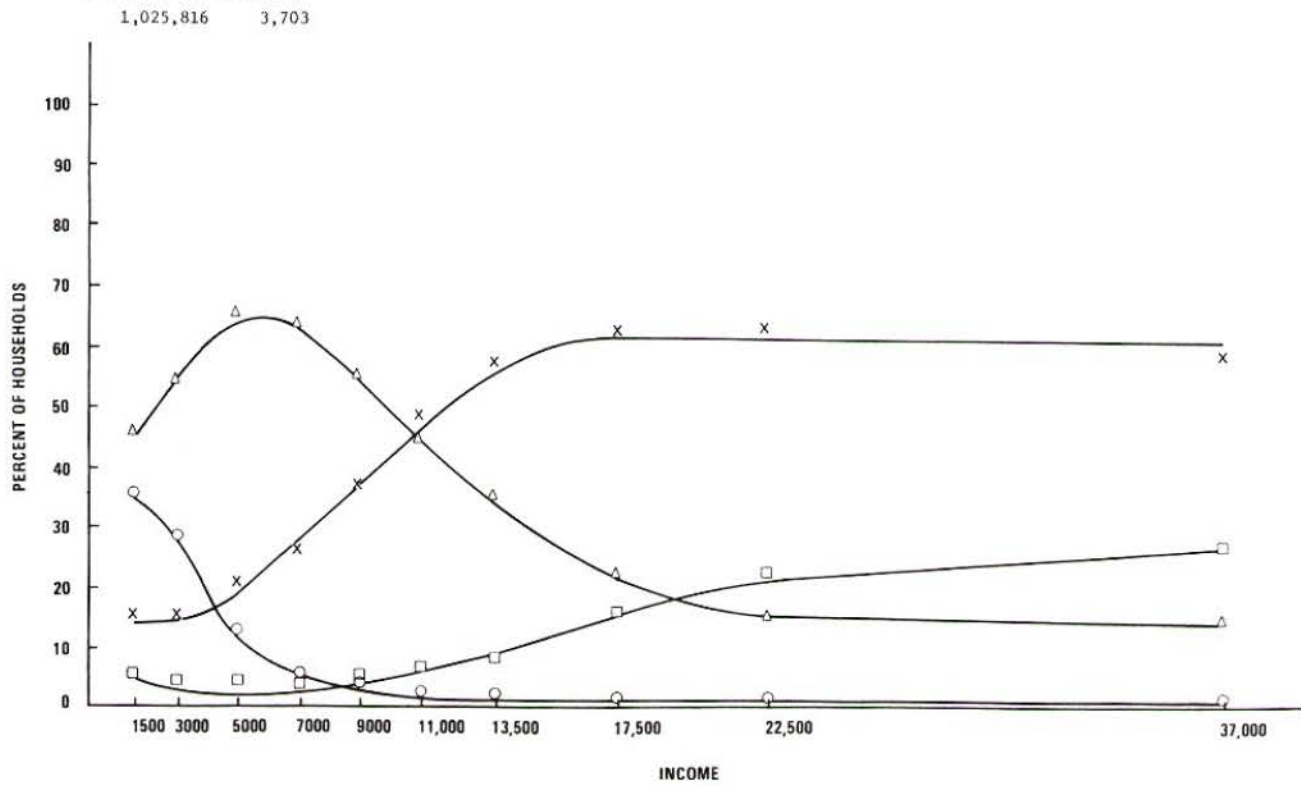
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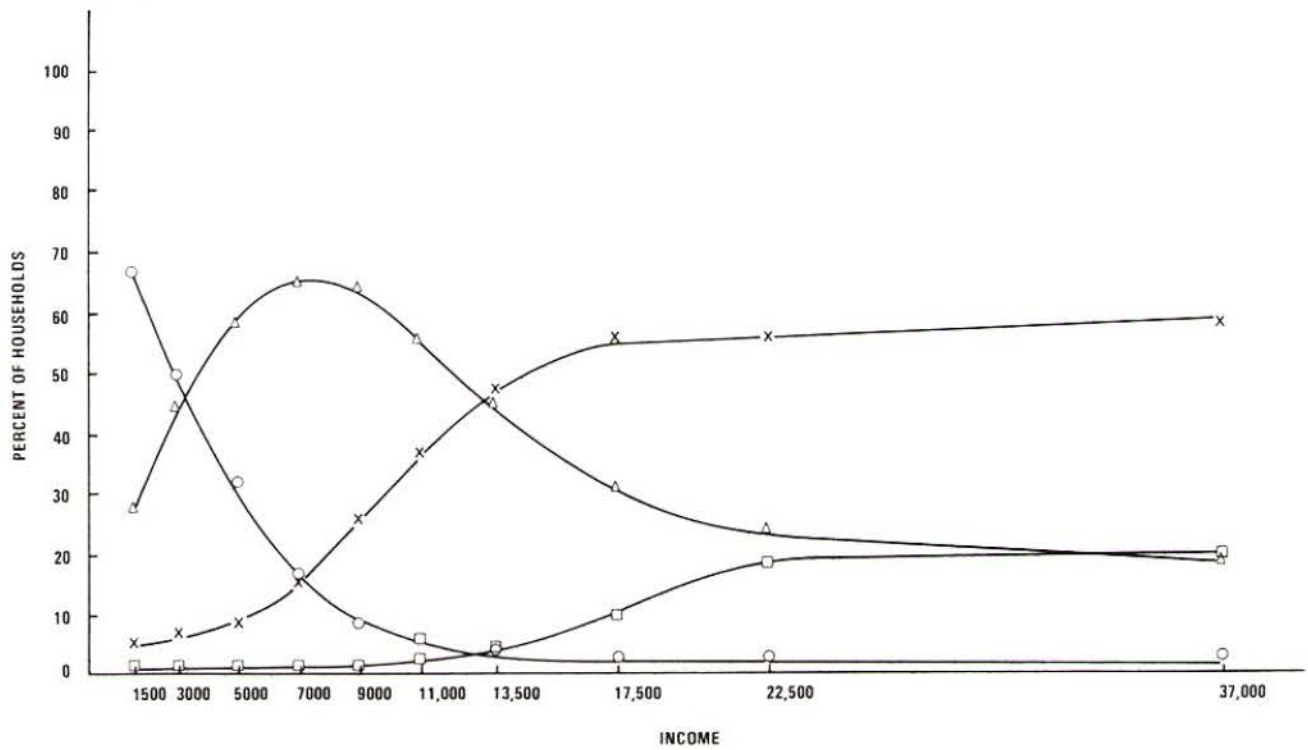


SAN JOSE, CALIFORNIA



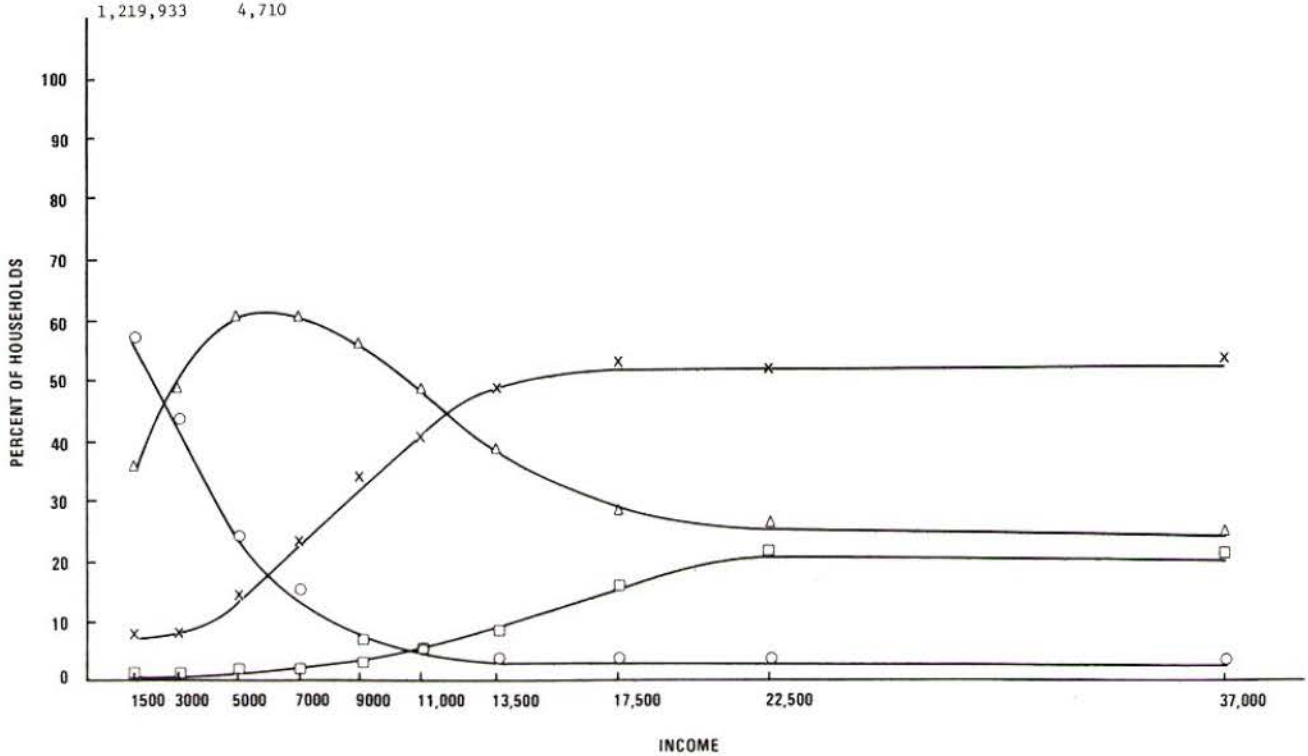
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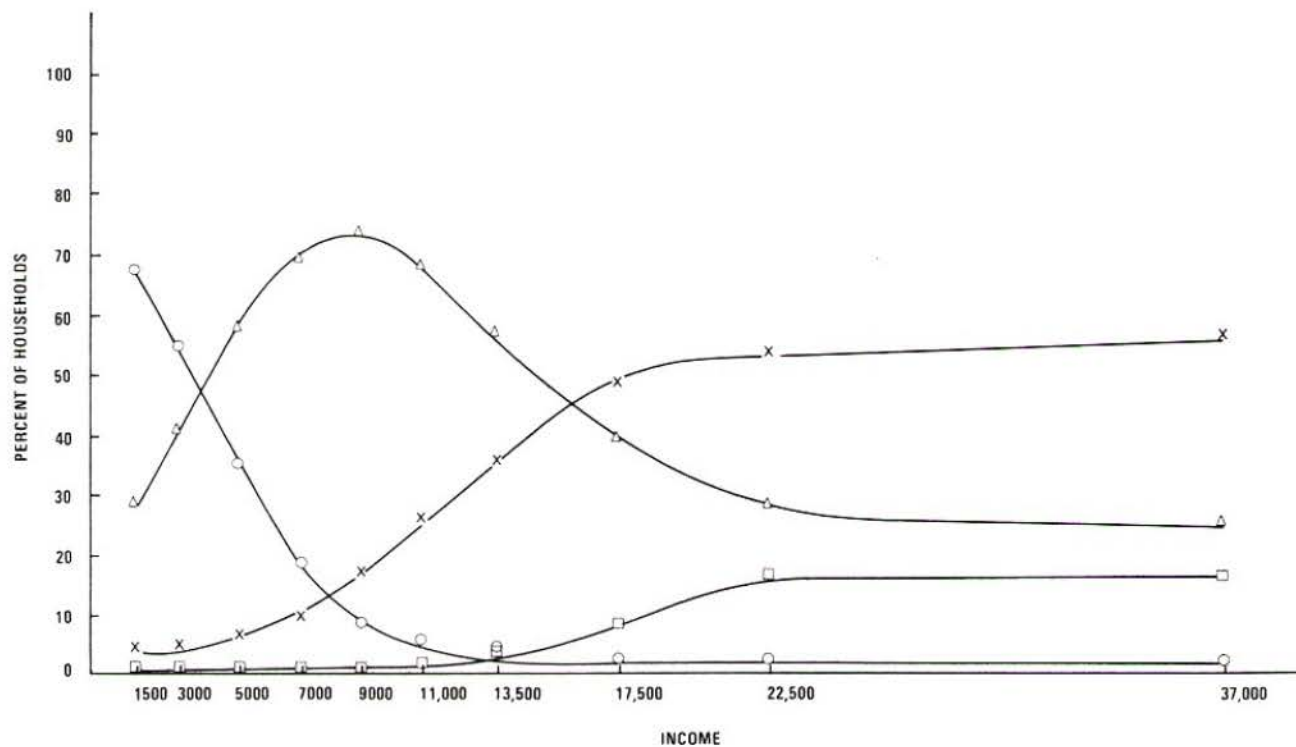
MIAMI, FLORIDA

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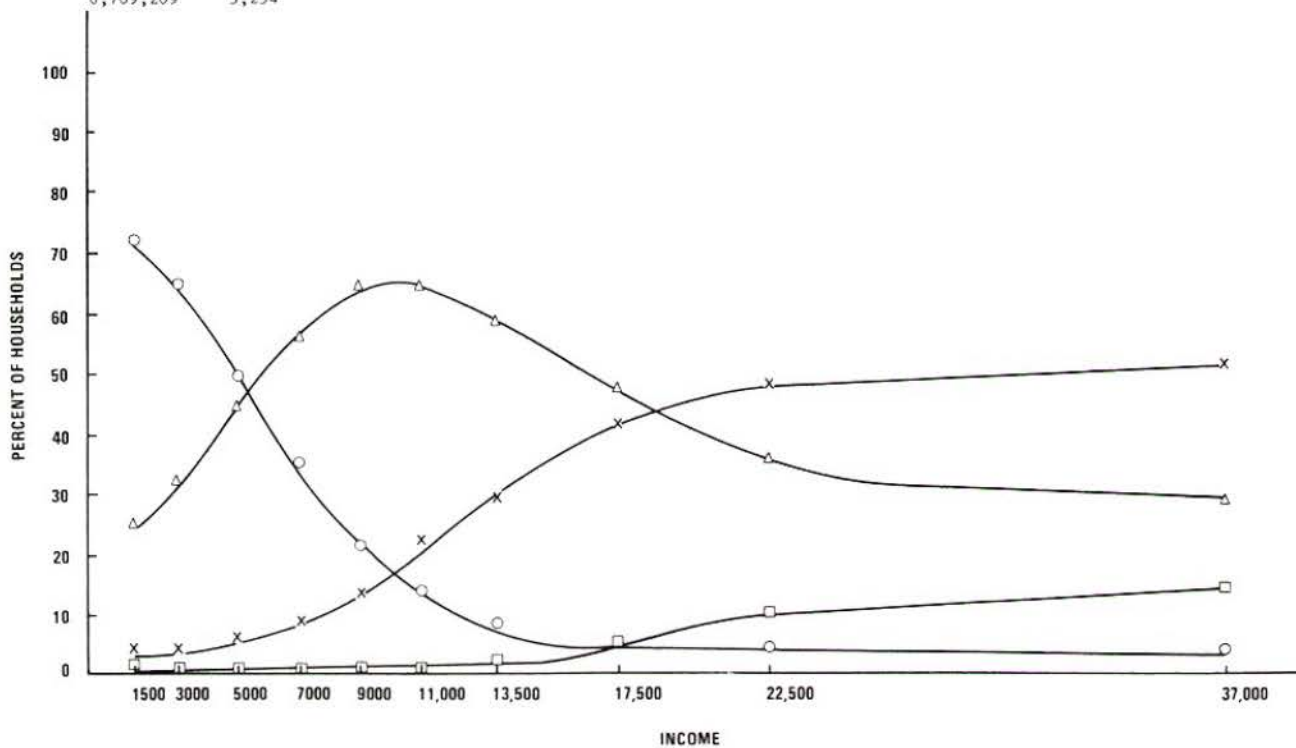
BUFFALO, NEW YORK

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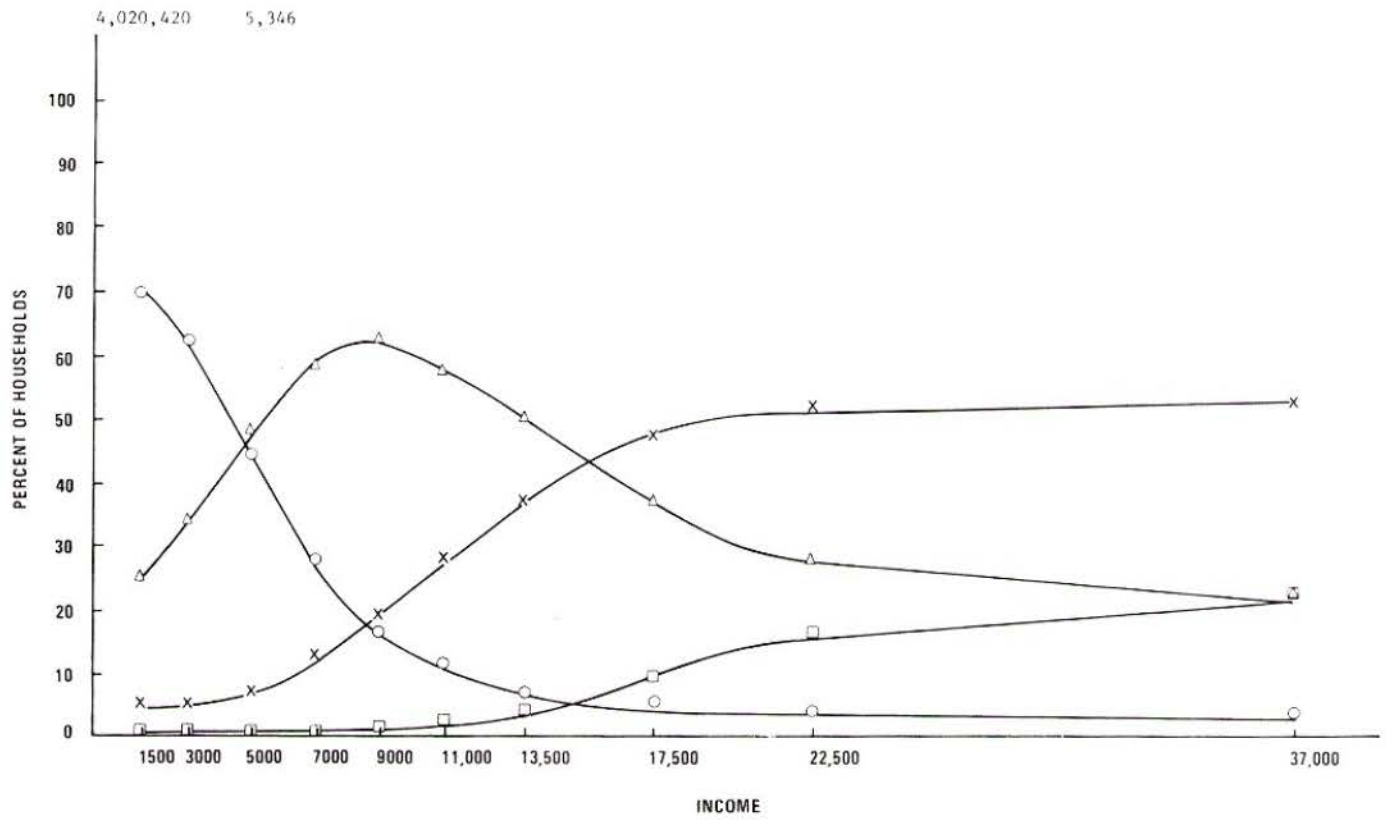


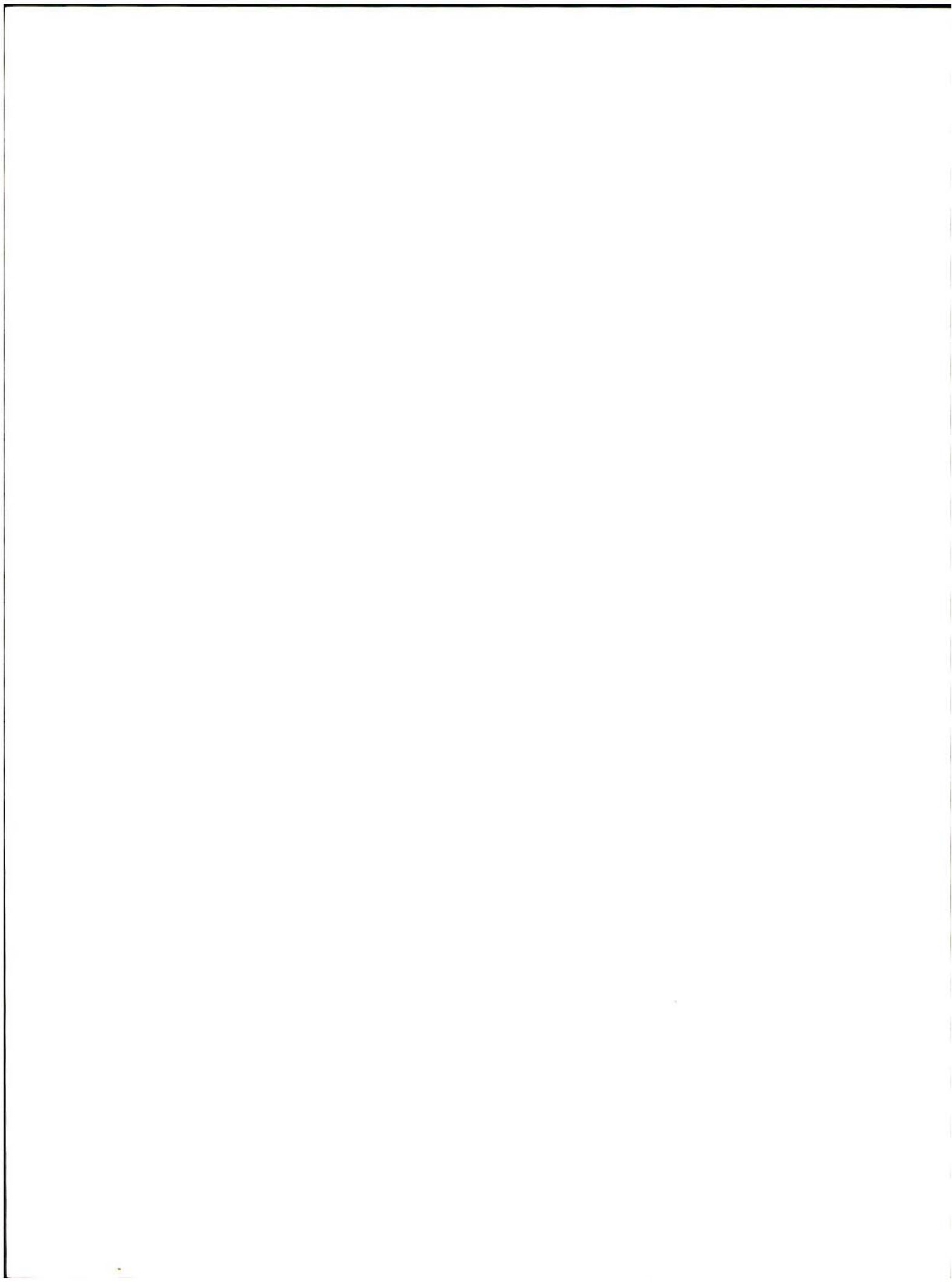
CHICAGO, ILLINOIS

6,709,209 5,254



PHILADELPHIA, PENNSYLVANIA





APPENDIX C TRAVEL FORECASTING

The procedures outlined in this manual are oriented to providing estimates of trip ends under varying socio-economic conditions. It is clear, however, that the number of trips produced in an area does not give a complete picture of the total travel demand for the area. Other elements in the forecasting process must be brought into play in order to obtain estimates of trip destination, mode, and route choice, in addition to the trip frequency obtained from the trip generation element.

In the course of activity in a transportation study these other aspects of travel demand estimation will normally follow the trip generation analysis and it is not until the end of the model sequence that a measure of travel can be obtained. It is important, therefore, to be able to consider quickly and early the impact of total travel, as measured by vehicle miles. Vehicle miles of travel (VMT) is a useful measure, in addition to trip production, to gauge the impact of varying conditions and combinations of policy alternatives.

With current concerns over energy consumption and restrictions on travel, quick estimates of the extent of travel under different alternatives is necessary. The relationship of travel to socio-economic indicators has been shown (23). Recent experience and study has shown that income and auto ownership are two of the strongest indicators of trips and travel in urban transportation studies. The relationship between income and car ownership shows a high degree of stability across urban regions based on individual urban origin-destination study data as well as data from the 1970 census (24). This was demonstrated in Figure 9, page 36 and in Appendix B. The same relationship, based on a nationwide sample, also shows similar characteristics (25). The interaction between sampled household income and auto ownership is shown in Figure 21. One of the main attributes of the relationship is that it incorporates the effects of auto ownership saturation, and the attendant effect on travel, beyond certain income ranges. Travel forecasts have often been made based on population, income, or vehicle registrations, but not often incorporating the combined effects of varying auto and income levels at the same time. Nor have forecasts of VMT often been made directly from estimates of future socio-economic levels in transportation studies. It is felt, however, that this is an important phase of the technical process and could serve several valuable purposes.

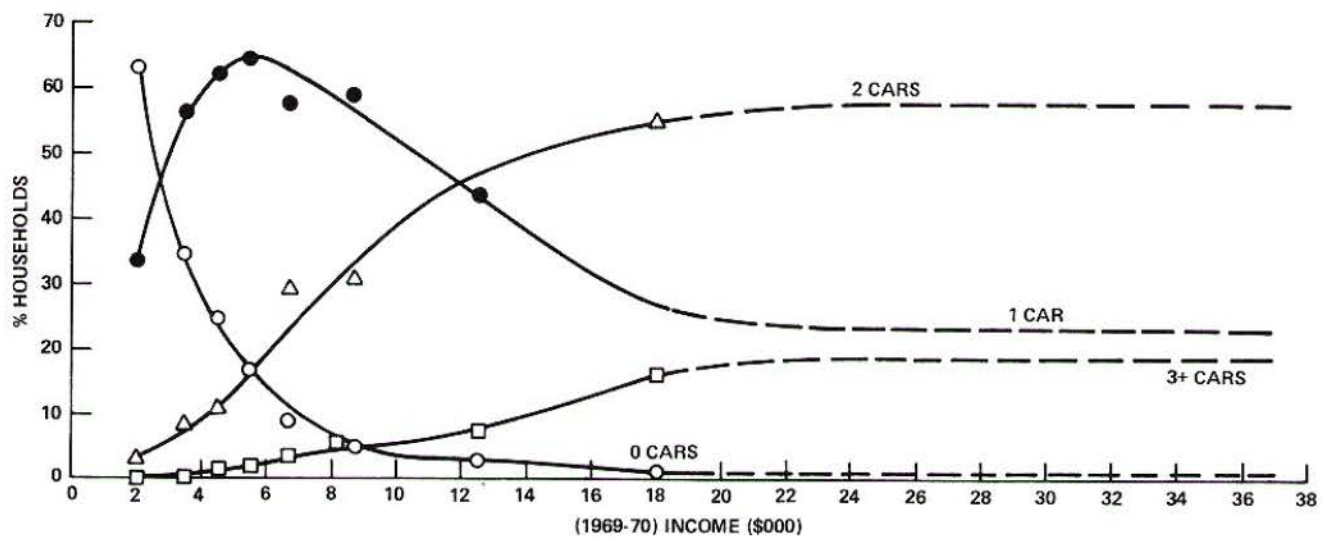


FIGURE 21. AUTOMOBILE OWNERSHIP VS. INCOME (25)

VMT is made-up of trips produced and their length. By assuming an overall average trip length for the study area (either known or "borrowed" from another, and similar, area) and estimating area wide VMT through a forecasting technique, an independent check on trip generation (either base year or forecast year) is available early in the forecasting process. In addition, VMT can be derived from trip lengths (in terms of miles "skimmed" off the base year or forecast year network for each trip origin-destination pair) times the number of trips between the respective origin and destination. Thus, two benchmarks are available (one as a forecast based on socioeconomic data, and one resulting from alternative system configurations) which will aid the analyst and decisionmaker in dealing with policy considerations. By varying either assumed trip length or trip production, an estimate of the resultant regional travel is available for alternative policy consideration. A third variable (auto ownership) is available when the auto ownership model is used as described previously.

For application the income-auto ownership relationship would be developed for the individual study area as described in the section in the text on "Auto Ownership Model," using survey data or could be "borrowed" from another area. The 1970 census curves make an excellent source for this model (see Appendix B for representative curves). A third alternative would be to use the relationship shown in Figure 21 based on the Nationwide Personal Transportation Study (1969-70).

Income could be forecast as outlined in Appendix A. Once a future year projection of the income distribution is established it would be divided into quintiles, each quintile representing 20 percent of the households as shown in the figure below:

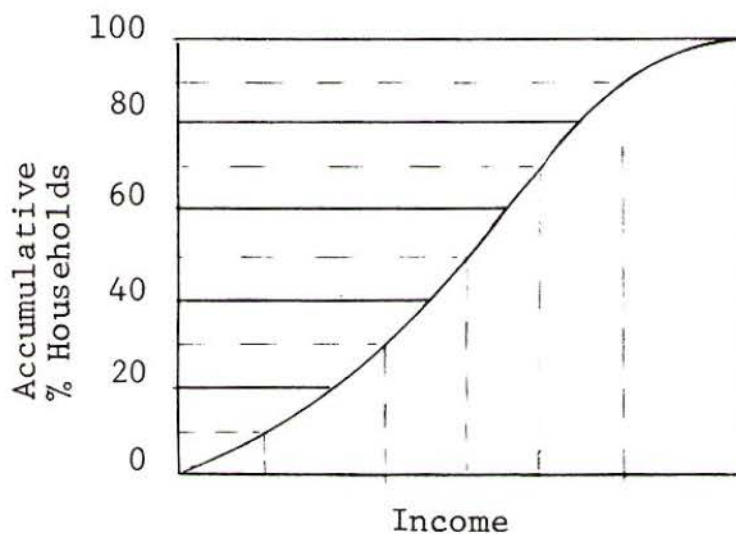


Figure 22

Median income values for each quintile would be picked off the distribution curve and used to enter the auto ownership model to determine the percent households by auto ownership within each income category. The result would be a matrix similar to the one below:

		Cars			
		0	1	2	3+
Quintile	1				100%
	2		%H.H.		"
	3				"
	4				"
	5				100%

Figure 23

Total households in each cell would be obtained by multiplying the percent households in each cell by the total households in each quintile (20% of the total forecast households for the study area).

Ideally VMT/H.H. by auto ownership and income category developed from individual transportation study data would be applied to the household values obtained from the matrix in Figure 23. As mentioned previously, however, it is not likely that VMT per household information will be available from individual transportation study-home interview data for model development. Therefore, existing relationships from other sources could be "borrowed" for the purpose of a rough overall travel estimate. Again, the NPTS offers such a source as seen in the following table for average weekday VMT/HH (25, 28):

		1969 Income (\$000)							
		<3	3-4	4-5	5-6	6-7.5	7.5-10	10-15	15+
Car Ownership	1	14.3	16.3	20.7	25.0	26.4	26.4	29.0	32.9
	2	45.5	32.9	39.3	48.2	40.4	48.2	55.1	57.7
	3+	--	89.2	41.8	58.0	51.9	58.5	80.9	86.4

Plotted, the relationships are seen in Figure 24. While the income categories will probably not be identical to those developed by quintile previously (Figure 23), VMT/H.H. values can be read off the curves in Figure 24 at the appropriate income values.

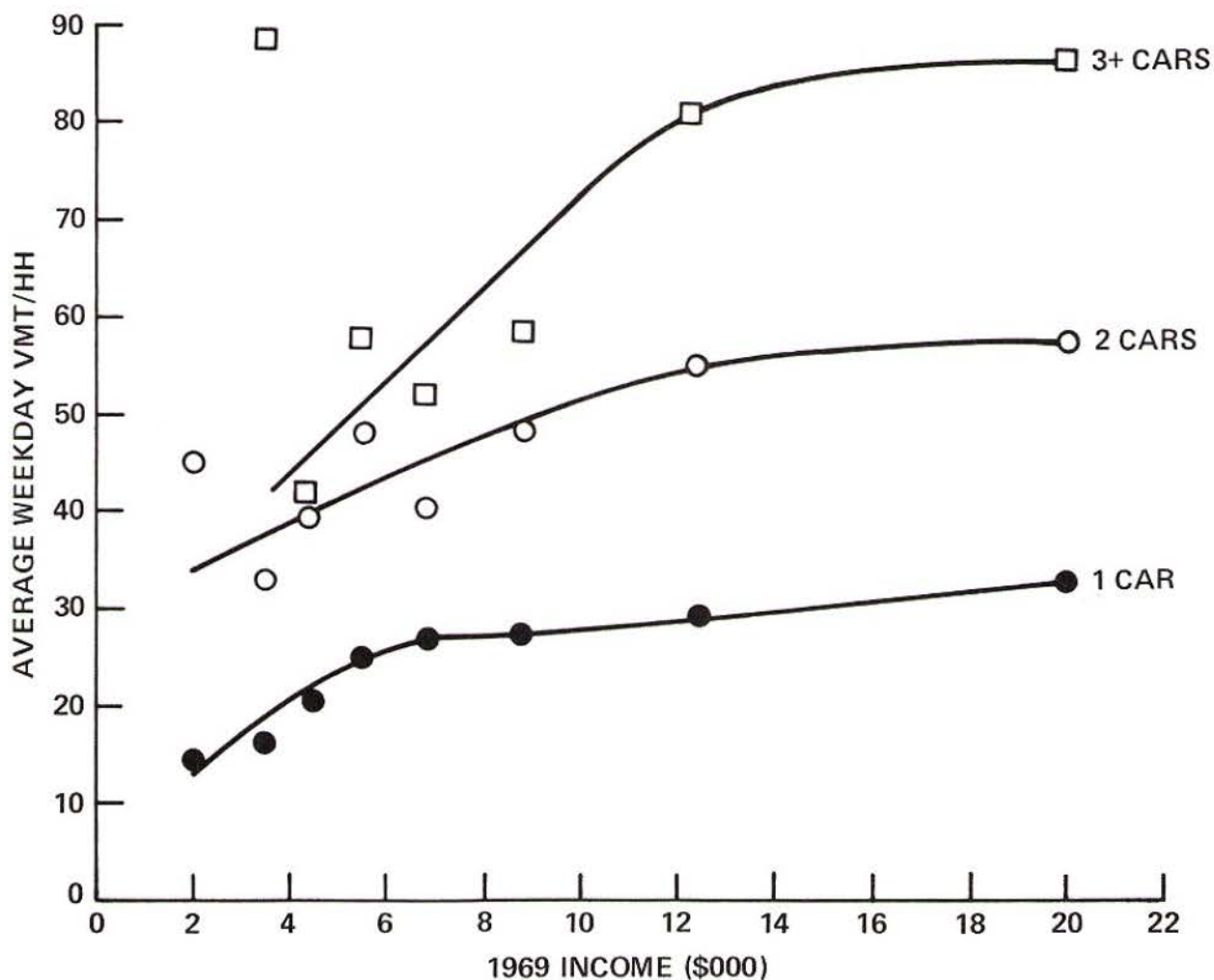


FIGURE 24. VEHICLE MILES OF TRAVEL PER HOUSEHOLD BY INCOME AND CAR OWNERSHIP

It is felt that VMT estimation by this procedure will provide the analyst with an adequate tool to test the impact of alternative assumptions of auto usage and economic levels at a regional scale. Additional detail and specification of relationships would have to be introduced in order to apply this technique to any scale other than an overall regional level. Additional work along these lines is planned by the Federal Highway Administration, and through surveys being planned* or underway, additional information will be available concerning the characteristics of household travel to add to existing data.

The results of applying the VMT forecasting procedure as a national travel estimating technique demonstrates the applicability of such a tool (23). The cross-classification procedure utilized the latest national census projections of income distributions and the basic income-auto ownership relationships (Figure 21) and travel per household based on the NPTS. The forecasting procedure (assuming Series E population growth and 3.0 percent compound annual income growth) applied to 1970 and 1990 resulted in a 2.5% annual compound growth rate in vehicle miles of travel between these two years. This is compared to a "medium" growth rate (2.6%) based on estimates of licensed drivers** and 2.4% annual growth rate based on the aggregate of individual estimates from the States for the Interstate Cost Estimate as modified (23).

*For example a second nationwide travel survey is being considered for 1976-77 and the Annual Housing Survey sponsored by the U.S. Department of Housing and Urban Development will provide information on household trip lengths.

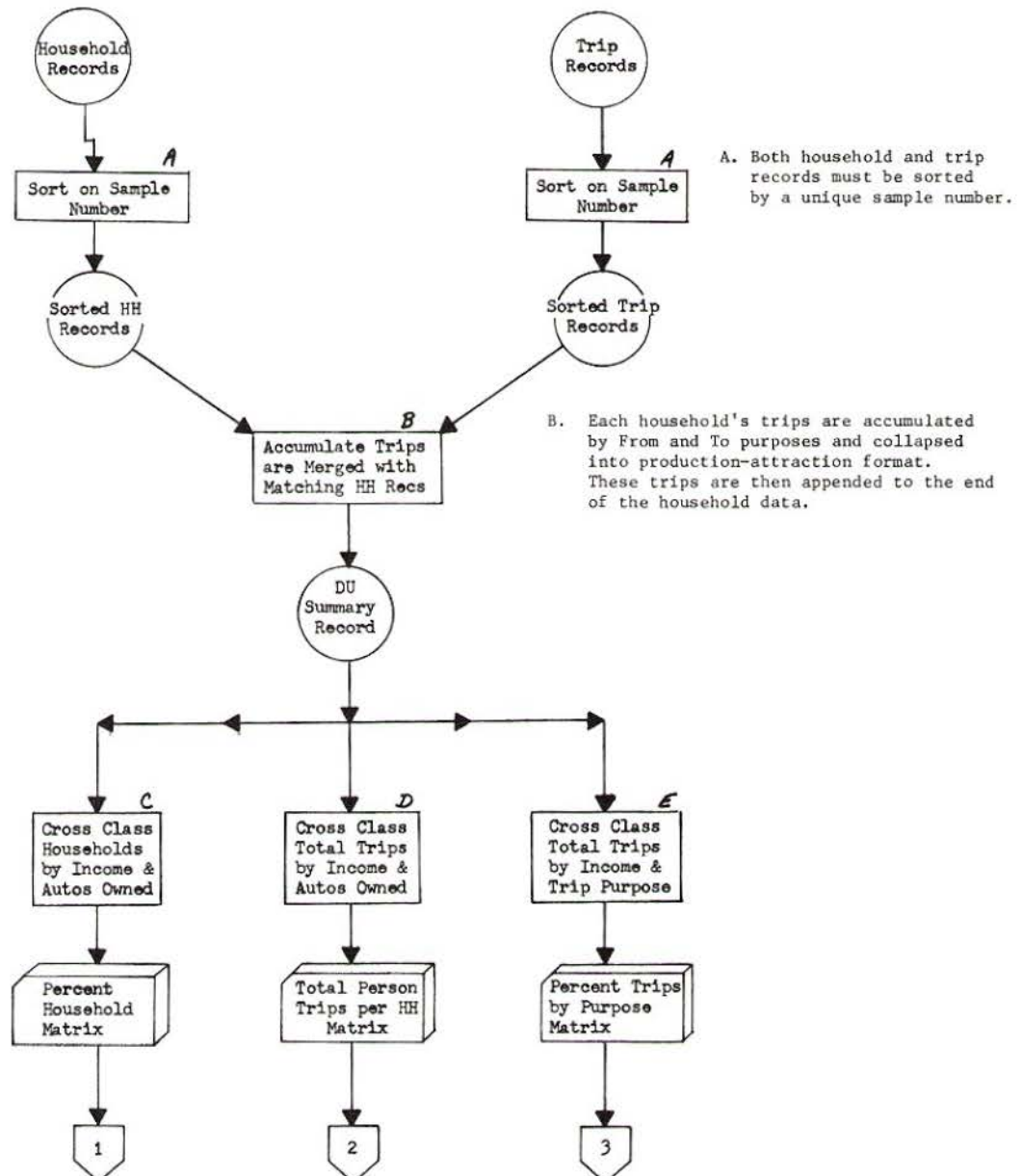
**Highway Statistics Division, FHWA, June 1974.

APPENDIX D
FLOW CHARTS OF PRACTICAL APPLICATION
OF TRIP GENERATION

The following flow charts and their descriptions illustrate the steps involved in the practical development and application of trip generation models. Flow Chart I is the development of household and trip data from an origin-destination survey. Flow Chart II is the application of these models using zonal forecasts of social-economic data (obtained from land use models).

FIGURE 25

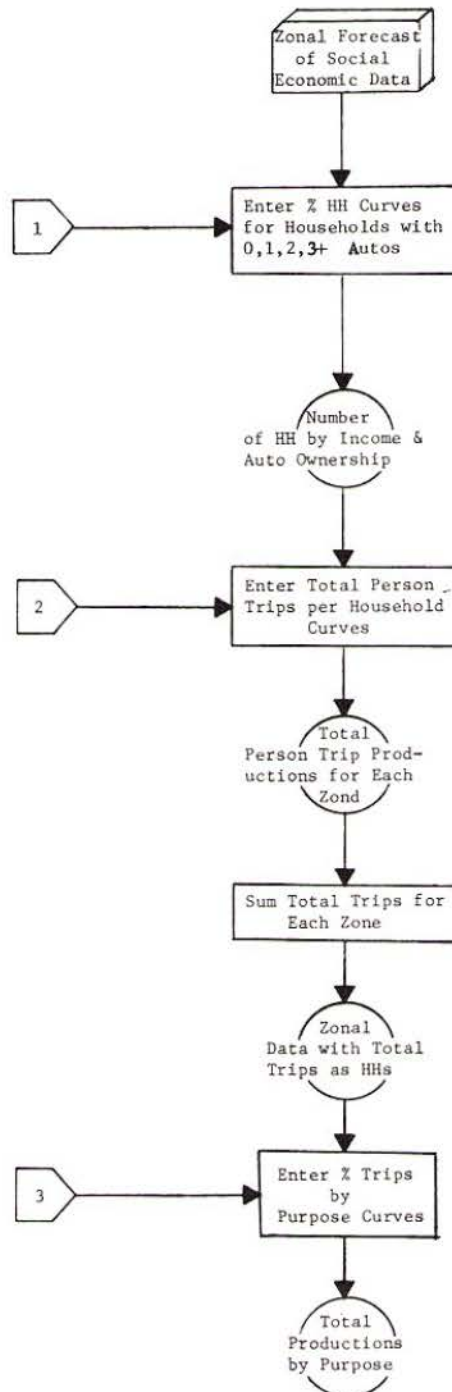
MODEL DEVELOPMENT



- C.,D. Using categories of annual household income and autos owned (i.e. 0,1,2,3+) develop two matrices:
- (c) Count of households falling in each cell, then divide each cell by its within income category total to get % households within income categories. (See note below)
 - (d) Count of trips made by households in each cell, then divide each cell by the number of households in matrix (c) above to get total person trips per household. (See note below)
- E. Using annual household income and trip purpose data from the trip records (e.g., HB work, HB shop, HB other, NHB) develop a matrix of counts of trips for each cell and divide each cell by its within-income-category total to get % trips (of total) by purpose by income category. (See note below)
- NOTE: Each matrix (C,D,E) above is plotted and smooth curves drawn. A new matrix is developed from the smooth curves which is used to solve for future estimates.

FIGURE 26

MODEL APPLICATION



NOTE: Only two variables are forecast for each zone (average annual household income and total households) therefore each zonal data set is divided into four parts to match the autos owned categories (0,1,2,3+).

F. Enter the % households curves four times for each zone (once for each auto category). The output is percent households owning 0,1,2, & 3+ autos. Multiply % households by total number of households in the zone.

G. Enter total person trips per household curves with the number of households in each auto ownership category (F). Output is total person trip production for each zone.

H. Sum the four auto categories to obtain total person trips per zone.

I. Enter % trips by purpose curves for each purpose category to get total trip productions by purpose.

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REFERENCES

1. Hansen, Dennis L.,
Volume XV Travel Generation, National Association
of County Engineers Action Guide Series, National
Association of Counties Research Foundation, July
1972.
2. Trip Generation by Land Use Part I, A Summary of
Studies Conducted, Maricopa Association of
Governments, Transportation and Planning Office,
Urban Area of Maricopa County, Arizona, April
1974. (Limited number of copies available from FHWA,
Urban Planning Division, Washington, D. C.)
3. Draper, N.R. and Smith, H.
Applied Regression Analysis, John Wiley & Sons,
Inc., 1966.
4. An Introduction to Urban Development Models and
Their Use in Urban Transportation Planning,
Urban Development Branch, Federal Highway
Administration, Draft Report.
5. Adler, Thomas J., Bottom, John A.,
Formulation of Travel Demand Modelling Requirements,
Center for Transportation Studies and Transportation
Systems Division, Department of Civil Engineering,
Massachusetts Institute of Technology, November,
1973.
6. "Urban Travel Demand Forecasting", Proceedings of a
conference held at Williamsburg, Virginia, December
3-7, 1972, Special Report 143, Highway Research
Board, 1973.
7. Federal Highway Administration, FHWA Notice,
"U.S. Census Bureau-Urban Transportation Planning
Package", April 18, 1972.
8. Hillegass, T.,
Transit Travel Analysis in Smaller Urbanized Areas,
Public Transportation Branch, Federal Highway
Administration, March 1973.

9. Chatterjee, Arun and Khasmabis, Snehamay, "Category Models-A Case for Factorial Analysis," Traffic Engineering Magazine, Institute of Traffic Engineers, October 1973, pp. 29-33.
10. Hansen, Walter G., "Traffic Approaching Cities," Public Roads, Volume 31, No. 7, April 1961, pp. 155-158.
11. Thomas, Edwin N., Horton, Frank E., and Dickey, John W., Further Comments on the Analysis of Non-Residential Trip Generation, Research Report, The Transportation Center at Northwestern University, November 1966.
12. California Division of Highways, District 4, Seventh Progress Report on Trip Ends Generation Research Counts," 1971.
13. Guidelines for Trip Generation Analysis, Urban Planning Division, Federal Highway Administration, U.S. Department of Transportation, June 1967.
14. FHWA Computer Programs for Urban Transportation Planning, Federal Highway Administration, U.S. Department of Transportation, July 1974, pp. 60-70.
15. OBERS Projections, Economic Activity in the U.S., U.S. Department of Commerce, Bureau of Economic Analysis, and U.S. Department of Agriculture, Economic Research Service for the U.S. Water Resources Council, Vol. I-VII, Washington, D.C., 1972.
16. Institute of Traffic Engineers Technical Committee, 6A6--"Trip Generation Rates," On-going analysis to be completed in 1975.
17. "Area Economic Projections 1990," U.S. Department of Commerce, Social & Economic Statistics Administration, Bureau of Economic Analysis (no date).
18. Donnelly, Elene, "Differential Income Growth in the United States, 1960-1969," Research and Applied Systems Section, Planning and Research Bureau, New York State Department of Transportation, May 1972.

19. Handbook of Labor Statistics, 1972 Bulletin 1735, U.S. Department of Labor, Bureau of Labor Statistics, 1972.
20. Mathematical Modelling, Charlotte-Mecklenburg Urban Area Transportation Study, Planning and Research Department of the North Carolina Highway Commission, September 1972.
21. Wichita Falls Urban Transportation Study, The Development and Application of Trip Generation and Distribution Models 1964-1990, Texas Highway Department Planning and Research Division, January 1974.
22. Develop Travel Forecasting Model Techniques, Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, July 1974.
23. Highway Travel Forecasts, Federal Highway Administration, Washington, D.C., November 1974.
24. Fleet, C.R., "Applications and Uses of the Census Urban Transportation Planning Package," Transportation Research Board Special Report No. 145, Washington, D.C., 1974.
25. "Automobile Ownership," Report No. 11, Nationwide Personal Transportation Study, Federal Highway Administration, Washington, D.C., December 1974.
26. The Immediate Impact of Gasoline Shortages on Urban Travel Behavior, Federal Highway Administration, Washington, D.C., April 1975.
27. Skinner, Louise E., The Effect of Energy Constraints on Travel Patterns, Gasoline Purchase Study, Federal Highway Administration, Washington, D.C., July 1975.
28. Special tabulations based on the Nationwide Personal Transportation Study, for the Federal Highway Administration in 1969-70.
29. Urban Origin-Destination Surveys, U.S. Department of Transportation, Federal Highway Administration, Washington, D.C. (no date).

30. A Review of Operational Urban Transportation Models,
U.S. Department of Transportation, Federal Highway
Administration, Washington, D.C., April 1973.
31. Introduction to Urban Travel Demand Forecasting, Volume I,
Demand Modeling, Cambridge Systematics, Cambridge,
March 1974. Can be obtained from NTIS, Springfield,
Virginia 22150, PB 236848/AS.
32. Ongoing work by the Planning Methodology and Technical
Support Division, Office of Transit Planning, Urban
Mass Transportation Administration, Washington, D.C.

