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COMPUTER SOLUTIONS TO THE URBAN
TRANSPORTATION PLANNING PROCESS

by

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INTRODUCTION

The United States is rapidly becoming an urban nation. At the present time, 75% of our population and most of the industrial capacity of this nation is concentrated in urban or suburban areas. Most of the growth is taking place in outlying areas around the central city. By 1980, three of every five persons in metropolitan areas will live in the suburbs (5).^{*} Decentralization of the city and suburban sprawl are taxing the existing transportation facilities in many U.S. cities. It is imperative that the transportation planners in urban areas strive to meet this domestic challenge and create cities that are economically healthy and thriving, and at the same time attractive and satisfying places for living and working.

It is essential to the economic health of any urban area that the transportation system provides the efficient movement of both people and goods. Transportation plans must be continually updated to coordinate land use and the development of transportation facilities. All transportation planning should be based on a systems analysis approach in which the planned facility must be examined in conjunction with the interaction of all its subsystems, as well as their whole environment.

The passage of the Federal-Aid Highway Act of 1944 provided the first regular Federal-aid highway funds for use within urban areas, and the Bureau of Public Roads (now the Federal Highway Administration) has actively promoted urban transportation planning since that time. Section 9 of the Federal-Aid Highway Act of

^{*}Numbers in parentheses refer to references at the end.

1962 required that programs for Federal-aid highway projects approved after July 1, 1965, for urban areas of more than 50,000 population be based on continuing, comprehensive transportation plans. (5) This program must be carried on cooperatively by the state and local community.

The complete, comprehensive character of the planning process requires an extensive inventory of the transportation system, community goals and objectives, and growth potential of the community. The economic factors effecting development, population growth and land-use characteristics of the area must be analyzed. Estimates of future demands for transportation for both persons and goods must be made. A traffic system and control inventory for the area is also necessary. The scope of the inventories and the extent to which the various analyses are carried will vary depending upon such factors as city size, age, proximity to other centers of population, and growth potential. There have been many guidelines established to aid in the analysis of travel forecasting.

Urban traffic patterns have been primarily a function of three items:

1. The pattern of land use in an area, including the location and intensity of use,
2. The various social and economic characteristics of the population of an area, and
3. The type and extent of the transportation facilities available in an area.

Relating these factors provides quantitative information about the travel demands generated by alternate land-use patterns and transportation systems.

To obtain this information and provide a comprehensive urban transportation plan the planner must proceed through four general phases:

1. Inventories
2. Analysis of existing conditions and the calibration of forecasting techniques.
3. The forecasting of future conditions.
4. An analysis of future transportation systems which also provides for essential feedbacks between the transportation and land-use elements.

Figure 1 illustrates the elements which comprise the four phases of the urban transportation process.

Because of the large amounts of data required to conduct an urban transportation plan, the application of computers to solve traffic problems evolved. The application of computers to transportation planning has permitted further development and refinement of the profession. The Bureau of Public Roads began utilizing computers for transportation planning in 1956, and a "battery" of transportation planning computer programs was initiated on the first IBM 704 in 1958. In 1961-1962 a library system which included 60 individual urban planning programs called BELMN was established for the IBM 7090/7094 computer. Another library of programs was begun at Texas A&M University during this period and was called the Texas system. The Texas and BELMN libraries are essentially duplicates except for the selected link analysis on the Texas system and the capacity diversion analysis on BELMN. Both have been extensively used in the United States, Europe, the Orient and the Southern hemisphere (5).

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URBAN TRAVEL FORECASTING PROCESS

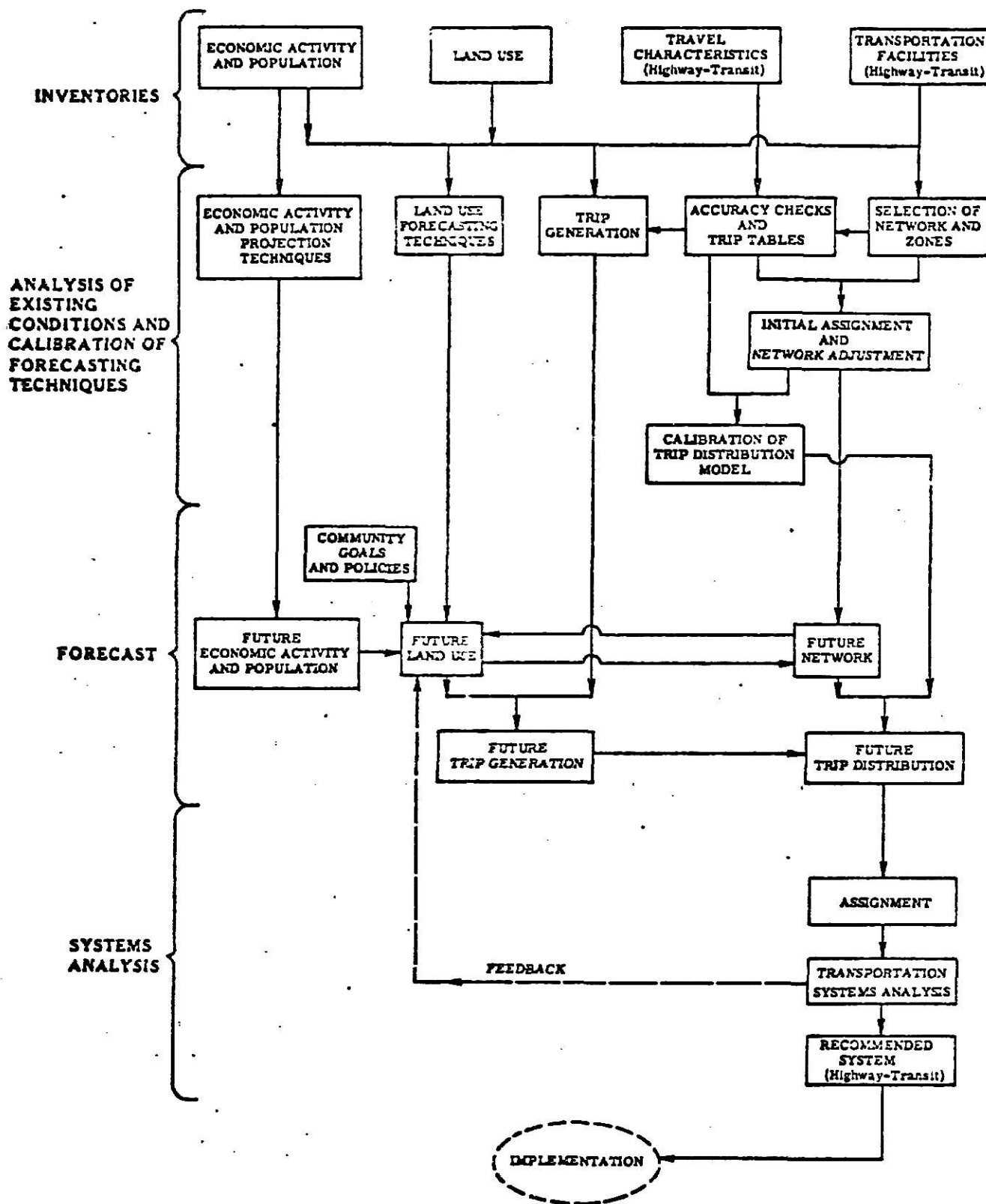


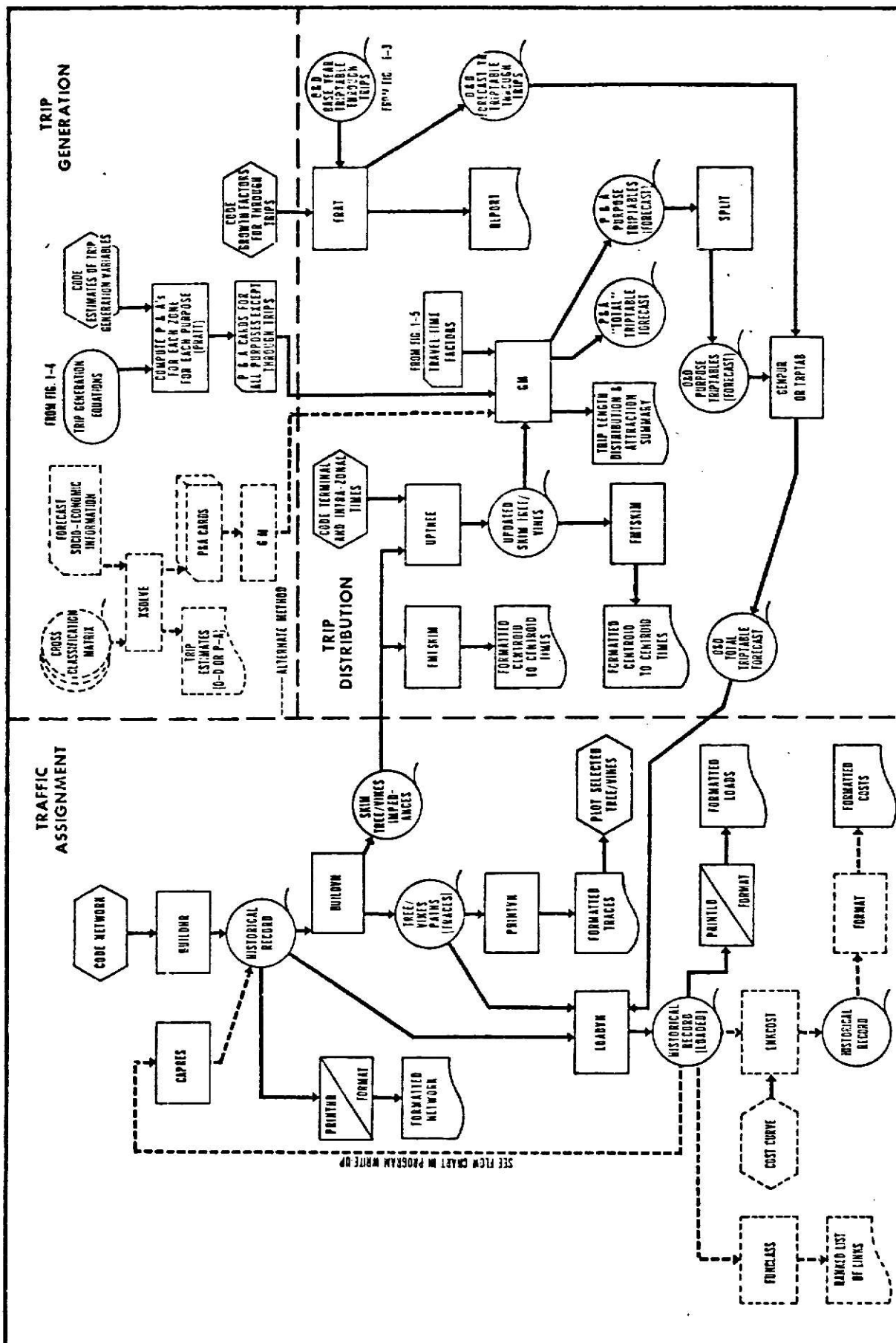
Figure 1: Urban Travel Forecasting Process

In 1964 the Bureau of Public Roads prepared a battery of transportation planning programs for the IBM 360. The IBM 360 was chosen since the intended users of the battery, the state highway departments, had the IBM 360 for their own computer installations. In addition to the basic program sets for traffic assignment and trip distribution the FHWA battery includes special analysis programs for capacity calculations, parking studies, cross tabulations, etc. The system flow chart for the FHWA program is shown in Figure 2.

The Urban Transportation Planning System (UTPS) was developed by the Urban Mass Transportation Administration (UMTA) in the 1970's. UTPS is a collection of IBM system/360-370 computer programs for use in planning multimodal, urban transportation systems. For this reason the UMTA package has greater capabilities that can be utilized by large cities.

Smaller computer packages commonly referred to as "teaching packages" have also been written and used for special purposes. They were developed primarily for educational uses, but they have capability for planning in small areas. For areas larger than twenty or thirty zones it appears that the efficiency of these smaller packages decreases and the computer cost rises.

Two "teaching" packages will be examined in this report. One of these programs was written by various classes at Northwestern University and revised by students at Purdue University and adopted for the CDC6500 computer. This program was further revised and rewritten by the author, with assistance of computer consultants,



for use on the IBM 360 and will be used in future transportation planning courses. The other "teaching" package examined was written at the Institute of Transportation and Traffic Engineering of the University of California for use on the IBM 1620.

URBAN TRANSPORTATION PLANNING PROCESS

Introduction

The urban transportation process is an extremely complex process. The sequential process which the analyst must follow is made up of the following discrete steps: inventories, trip generation, trip distribution, traffic assignment and modal split which may be either pre- or post-distribution. The theory and description of these processes is discussed in this section of the report and applied in following sections.

Inventories

The comprehensive nature of the transportation planning process requires a large amount of data collection. The process relies on measurable and observed base-year characteristics as a basis for forecasting future system requirements. The inventories usually require information about the following elements:

1. Land Use (Economic factors affecting development)
2. Population
3. Transportation facilities
4. Travel Patterns (Origin-Destination Surveys)
5. Legislation
6. Financial Resources
7. Social and community-value factors

Population and land-use characteristics are analyzed to establish historic trends in growth patterns, intensity and location of land use in urban areas, and to prepare population density

and zoning maps. This data can be obtained from home and telephone interviews, census data, field surveys, aerial photographs and fire insurance atlases.

Transportation facility inventories are made on existing highway and transit systems, including their terminals. These inventories are essential to the whole process, particularly in the traffic assignment phase. Street and highway capacities, traffic volumes, travel times and functional classification of streets are items found from the highway inventory. The transit and terminal system inventory provides information about the area served, operating statistics, passenger volume, revenue, cost and system data. Data about the transportation system can usually be obtained from the following sources:

1. Existing records
2. Supplemental field work
3. Data from previous studies
4. Traffic counts
5. Transit studies
6. Terminal studies
7. Operational studies
 - a. Travel time
 - b. Accidents

Origin-Destination surveys are used to provide information about existing travel patterns within an urban area. Estimates of future travel are then based on adjusting these existing patterns to some future year. This information is then used to determine

location and design of new transportation facilities. There are basically three types of surveys which provide information about vehicle and person travel in an urban area:

1. Home interview - Origin-Destination Survey
2. Truck and taxi interviews
3. External or internal cordon line surveys

The home interview survey obtains a measure of the total trips made by residents in an urban area. The truck and taxi survey is designed to obtain a picture of the existing commercial travel in the urban area. The cordon line survey usually intercepts 95% of the travel crossing the study area boundary, and is used to obtain travel patterns for private and commercial travel from outside the survey area. Since the data of the origin-destination survey is a sample, it is necessary to expand the data and check the accuracy with a screenline comparison. The screenline intersects the cordon line at two points usually at natural or man-made barriers such as rivers, railroads or expressways. Classified hourly counts are made at each screenline crossing and compared to the expanded interview data.

The legal factors which may affect the implementation of a transportation plan must also be examined with regard to the operation and standards of the governing administration. Zoning ordinances, subdivision regulations and building codes of the study area should be guidelines for the plan.

The financial resources of the planning area should be studied by the planner's staff. It is unrealistic to suggest a plan for

a city which is beyond the budget, or cannot be funded by other sources. If funding sources are available to a city they should be pointed out within the plan.

It is important to establish the socio-economic trends which are associated with increased demand for transportation facilities. Typically, in a comprehensive study, inventories on the following socio-economic characteristics should be made:

1. Population growth over time
2. Employment, income, education and vehicle ownership
3. Transportation costs and revenues
4. Vehicle travel and transit usage
5. Residential neighborhood character
6. Construction, utility and maintenance costs
7. Environmental factors, pollution and aesthetics.

The data collected in inventories is expanded, summarized and processed for analysis purposes to develop trends and relationships for the design year. This data forms the basis for developing workable models for trip generation, trip distribution, modal choice and traffic assignment.

Trip Generation Models

Trip generation may be defined as the analytical process by which the planner projects the number of trips which will originate or terminate within each zone. These trips are estimated from their relationship with characteristics of the area such as land use, population, employment and other economic activity measures.

Before the planner begins the trip generation phase he must first make initial decisions about the following:

1. Trip end stratification
2. Land use stratification
3. Model for prediction purposes
 - a. Land Area Trip Rate Analysis
 - b. Cross Classification Analysis
 - c. Regression Analysis

Since all trips are not homogeneous in character, it is best to create separate models for different trip purposes. The stratification of trip purpose at the trip generation stage depends on the distribution model to be used. The choice of distribution model is a function of the scope and objectives of the study as well as the size of the urban area involved. The number of trips in each category and trip length characteristics for each trip purpose must also be considered. In small cities modeling is often done on only three trip purposes: home-based work, non-home-based, home-based other.

Trips are sometimes stratified by both purpose and land use at their origin and destination. The predictive ability of the estimating equations can be increased and checked by stratification. For example, zones in the Central Business District should produce less home-based work trips than residential zones. It is not recommended that stratification become so fine that there is a large number of zones in which the observed value of the dependent variables, trips, is low.

Prediction of trip making activity is possible by several methods. All should take into account intensity, character and

location of land-use activity and the socio-economic conditions affecting travel patterns. Three methods which are commonly used in planning will be discussed briefly in the following sections.

The land area trip rate analysis was utilized in the Chicago and Pittsburg transportation studies (1). The methodology was primarily the same for both studies. The traffic zones were grouped into eight concentric rings centered about the CBD. Base year, trip-generation rates were calculated for various land uses on a per acre basis. Base year trips were then applied to the developed acreage in the design year, with the total trips calculated by aggregating zonal totals. This land-use based total was then compared to a population based total for the design year calculated from an aggregation of zonal estimates of trips per person based on future car ownership and net residential density. Whichever estimate appears by inspection and judgment of the planner to be the most reliable is accepted as the control figure. The last step is to allocate the total trips for the forecast year to the individual traffic zones. This method is rarely used due to the large data requirements.

The technique of cross-classification analysis is a method of determining the value of the response variable (in this case person trips), at various levels of one or more independent predictive variables. In its use of independent predictive variables, the method resembles the multiple regression technique. Since distribution of values within the cells can be unknown,

and is of no consequence to the model, the technique is non-parametric. Cross classification is essentially discrete in approach (the number of values is limited to the number of cells used), whereas regression techniques are continuous in nature. The primary disadvantage of the model is that its statistical validity cannot be tested. The major advantage to the method is that there is no assumption of linearity between the dependent and independent variables.

Regression analysis is a statistical procedure in which the relationship between two or more related items may be expressed in an optimum mathematical form according to specified criteria. Multiple regression techniques are the most widespread methods used for trip generation analysis. The high-speed electronic computer has made the development of trip generation equations a relatively fast, "prepackaged" process. It is important that the analyst does not become disassociated from the data. Both the statistical validity and the reasonableness of the model should be determined. Methods of evaluation of multiple regression trip generation analyses are discussed in the following paragraphs.

Since multiple regression is a statistical analysis technique, it is important that the various standard tests of validity be considered and that the model be evaluated by these means. The model obtained from multiple regression is only as accurate as the validity of the basic assumptions made and the statistical significance of the results. The first basic assumption made is that all variables are assumed to be random with a normal distribution. The second is that the predictive variables are assumed

to be independent of each other. The effects of violating either of these assumptions will be discussed and illustrated later in the report.

The greatest advantage of the multiple-regression approach is the ease with which the analyst can determine the degree of relationship between the dependent and independent variables, and define the precision of the model itself. Some of the common measures of statistical validity are:

1. The Coefficient of Multiple Determination (R^2) is a measure of the amount of variance described by the model.
2. The Standard Error Estimate (S_y) is a measure of deviation of observed trip values from values predicted by the model.
3. Partial Correlation Coefficient (r_j) of an independent variable describes the relation between the dependent variable and the particular independent variable under consideration.
4. "t" tests indicate the statistical significance of the regression coefficient of each independent variable in the regression equation.
5. The simple correlation matrix contains correlation coefficients for all combinations of variables - independent and dependent

Applications of these measures of statistical validity is discussed and illustrated later in the report.

The trip generation model selected from regression analysis may possess statistical validity yet give unreasonable results. Only independent variables which can be forecasted within a reasonable degree of accuracy should be used in trip generation equations. It should be remembered by the analyst that the trip generation equations are only as good as the future estimates of

the independent variables. Only variables which will be stable over time and have a causal relationship with the dependent variable, trips, should be chosen. In order to have a meaningful relationship and confidence in the forecast, the independent variables must have a causal relationship with the dependent variable. Equations containing independent variables that demonstrate a high degree of colinearity (not independent of each other) must be avoided. The result of using a model with two colinear variables is in effect to count the same factor twice.

Zonal aggregates and rates should not be intermixed in the same trip generation equation. The analyst must use logic when examining the positive or negative contribution of the independent variables in a regression equation. When the contribution of a dependent variable appears to be illogical it should be omitted. Application of the above rules to trip generation models will be studied in the "Skokie" area example problem.

The desired end product in trip generation analysis is an accurate prediction of trips within the transportation study area. These trip end volumes are difficult to forecast directly and depend on many diverse variables such as income, location, automobile ownership, etc. The goal of the trip generation analysis is to establish a functional relationship between trip-end volumes, land use and socio-economic characteristics within the study area.

Trip Distribution Models

After the trip generation phase, the planner has knowledge of the number of trips generated in each zone, broken down by

trip purpose. The trip distribution analysis determines to what zones the trips are going, i.e., a zone to zone trip matrix is obtained. There are basically two types of models used for distributing trips, growth factor and mathematical models. Mathematical models depend greatly upon the origin-destination study for calibration purposes (1).

Growth factor methods project into the future on the basis of existing travel patterns, determined from origin-destination survey data and growth projected. Growth factors are developed for each zone and trip purpose. Successive iterations are made based on the ratio of newly calculated trip ends to projected trip ends for the design year. The growth factor methods used are the uniform factor, average factor, Detroit and Fratar methods. The most widely used growth factor method is the Fratar method. The Fratar method is presently used in the FHWA battery for external-internal trips. The greatest advantage of growth factor techniques is that they reflect many unique travel patterns in urban areas. They are most applicable to slow growing areas. In major urban studies, land-use changes force extensive adjustments to the procedure. For this reason large cities have typically used the mathematical models to distribute trips.

The mathematical models synthesize travel patterns by relating them to characteristics of land use and the transportation system. The two most commonly used mathematical models are the gravity and intervening opportunity models. These models measure the producing and attracting power in a zone in terms of trip ends.

The trip interchange is a function of the producing and attracting powers of the zones and spatial separation between them.

The best documented and most widely used mathematical model is the gravity model. The gravity model has no theoretically valid basis, but in form is analogous to Newton's gravitational law. The theory of the model is that all trips starting from a given zone are attracted by various traffic generators that "compete" for these trips in direct proportion to the size of the attractor, compared to all other attractors and inversely proportional to the friction or separation between the areas. This friction or separation is usually accepted as the zone-to-zone traveltime via the specified transportation system. In mathematical terms the gravity model may be stated:

$$T_{ij} = \frac{P_i A_j F(t)_{ij} K_{ij}}{\sum_{\text{all } i,j} A_j F(t)_{ij} K_{ij}} \quad i, j = 1, 2 \dots n$$

where T_{ij} = trips produced at i and attracted at j

P_i = total trip production at i

A_j = total trip attraction at j

$F(t)_{ij}$ = friction factor based on the traveltime
distance between zone i and j

K_{ij} = socio-economic adjustment factor for interchange ij

n = number of zones

Four separate parameters are required before the trip interchanges (T_{ij}) can be calculated. Two of these parameters, the

number of trips "produced" (P_i) and "attracted" (A_j) by each traffic zone, are related to land use and socio-economic characteristics of the people who make trips. These are obtained from the "trip generation" phase. Traveltime or friction factors [$F(t)_{ij}$] express the effect that spatial separation has on trip interchange. The factor "F" is a function equal to $1/\text{time}^{n^*}$, where the power " n^* " is obtained empirically in the calibration of the model and is generally a function of trip-length distribution. A different "F" factor is obtained for each trip length (by time increments). Calibration is accomplished when a complete set of "F" factors is arrived at that will "reproduce" the known trip-length frequency curve of the base year data. The fourth input, only used when necessary, to the gravity model formula is the socio-economic factor (K_{ij}). This is sometimes necessary to reflect the effect on travel patterns that an unusual social or economic characteristic of a zone that make the usual calibration unrealistic. Although the gravity model provides for these adjustments, few cities have found it necessary to use them.

Calibration of the gravity model requires the determination of a traveltime factor that will reproduce zone-to-zone trip tables for the base year trip ends. These traveltime factors are then assumed to be constant over time, and then applied to the forecast year trip ends found from trip generation analysis. The planner can then compute zone-to-zone future trip tables. It is also possible to select initial traveltime factors from other similar transportation studies, which makes calibration faster and saves computer time.

The other mathematical model commonly used in transportation planning is the intervening opportunity model. The opportunity model is based on the premise that total travel time from a zone is minimized given that each destination zone has a specified probability of being acceptable. In other words, the probability that a trip will end in a certain zone is the conditional probability that the trip can be satisfied in that zone, given the probability that it was not satisfied before it reached that zone, i.e., in a zone that was closer, timewise. If the probability of a destination being acceptable is independent of the order in which the destinations are considered, the order that will minimize travel time is clearly that of time proximity. The probability that a certain trip ends at a particular destination depends on trip purpose, how many destinations are available to satisfy that particular purpose and their respective distances. The mathematical model can be expressed as follows:

$$T_{i-j} = P_i [e^{-LT} - e^{-L(T+T_j)}]$$

where T_{i-j} = trips originating in zone i with destination in zone j

P_i = trip origins in zone i

T = trip destinations considered prior to zone j

T_j = trip destinations zone j

L = empirically derived measure of probability that a random destination will satisfy the needs of a particular trip. It is an empirically derived function which describes the rate of trip decay with increasing trip destinations and increasing length of trip.

e = base of natural logarithms (2.718)

The derivation of the mathematical model was based on the premise that the probability parameter, L , was constant. Studies have shown that this is true only if the model operates on trips stratified by time groups. The stratification is usually grouped into two classes, short and long trips. Those trips which were expected to be short, have a high " L " value, and those expected to be longer with more selective destinations, have a low " L " value. Different trip purposes also have different " L " values in each zone of origin. Thus, trips are usually stratified into short trips, long residential trips and long non-residential trips. It has been found that short trips make up approximately two-thirds of all travel.

Like the gravity model, the intervening opportunity model must also be calibrated. Empirical parameters, used for the probability function, must be determined and reproduce present, known, travel patterns. These " L " values of the base year are initially computed to give correct proportioning of short or intrazonal trips, however, they give erroneous answers when applied to future trips. With the increased densities and destinations of the design year, the same " L " values result in shorter intrazonal trips. It is necessary that calibration of the model for distribution of future trips be carried out in two steps:

1. Determination of a " L " value which keeps the same proportion of trips within the zones.
2. Use of travel times to rank opportunities in terms of nearness to zone of origin. Minimum time paths and the future trip end totals are used.

The quality of any trip distribution model is measured by the accuracy with which the synthetic trip distribution reproduces the observed, base-year distribution. Unique travel situations are very hard to account for in any model. Models must be checked to guarantee that extraordinary conditions have been adequately met. In some models it may become necessary to apply adjustment factors, such as the socio-economic factors, to modify basic model relationships. These factors should be quantitatively related to land use, barriers to travel or socio-economic characteristics of the study area.

The wide use of mathematical trip distribution models in urban areas has made the need of additional extensive home-interview surveys questionable. These surveys are necessary for the growth factor methods which require stable zone to zone trip movements. But for calibration of mathematical models only certain parameters of travel patterns are required. Most important are measures of trip length, purpose and a knowledge of generation. These characteristics can usually be established from small random samples. The validity of the mathematical trip distribution models may be checked through a comprehensive series of screenlines rather than against the home interview trips. The only problem is the establishment of socio-economic factors which eliminate error or bias which may occur in mathematical models.

Traffic Assignment

After the distribution of trips from origins and destinations, the next stage in the urban transportation planning process is to

assign the traffic to the transportation network. Traffic assignment may therefore be defined as the process of allocating a given set of trip interchanges to a specific transportation system. With the volume of traffic between any origin and destination zone known, the routes which traffic follows is simulated. The process is used to test the existing network by simulation of present conditions or to test for deficiencies in the design year with estimated future traffic.

The traffic assignment process requires that the planner input considerable network information from the inventory. A complete network description, designating all links and nodes, is required. Nodes represent intersections or zone centroids. Links are sections of the highway network defined by a node at each end. Capacity, travel time or speed and distance on all links are also needed. The following summarizes the information required:

1. Location and numbers of zone centroids
2. Definition of network
3. Connection of centroids, location of nodes
4. Assignment of node numbers
5. Coded turn penalties
6. Coded turn prohibitors
7. Defined link parameters.

A measure of travel resistance, which provides a criterion for selecting routes in a network--time, distance, cost, etc.--should be provided. An estimation of future or existing inter-zonal trips is required from the trip generation and distribution phases.

The present methods for traffic assignment are relatively new. Before 1950, assignment was based on the "experienced judgment" of the planner. Machine-based solutions to the problem began in the 1950's due to the widespread use of the digital computer, but at that time the computer was only used for data storage. In 1957 E. F. Moore published an algorithm for the calculation of minimum paths through a maze(1). "Moore's Algorithm" is now used to determine minimum time, minimum distance, or minimum cost routing between two points. There are programs available which are capable of taking into account congestion on the transportation system (capacity restraint), and will also split assignment between parallel freeways and arterial street system (diversion).

The assignment process can be one or a combination of four types, all-or-nothing, diversion, capacity restraint or proportional assignment with capacity restraint. The all or nothing process assigns all traffic to the minimum time path between zone centroids. Diversion refers to the allocation of a trip interchange to two possible routes in a designated proportion which depends on some specified criterion. Diversion curves have been established to determine the split of traffic between parallel freeways and arterials based on speed, time and distance. Capacity restraint does what the all-or-nothing assignment fails to do, adjusts for the capacity of the street network when calculating minimum paths. The capacity restraint assignment equation is usually based on the volume to capacity ratio, and provides more realistic results than the all-or-nothing process. Proportional

assignment divides traffic between two zones to several routes on the basis of relative travel times (travel time of a route as a proportion of the summation of travel time of all routes considered).

The steps that may be followed in computer assignment can be summarized as follows:

1. Calculate minimum time paths from selected nodes and writes them out in external storage. (Builds trees)
2. Assigns a table of interzonal movements to the minimum paths according to the all-or-nothing method.
3. Performs an analysis of turning movements, vehicle hours and miles of travel, and prepares results for printing.
4. Edits the network description (link data) input data and prepares the network description table.
5. Update network description, if necessary, add new links, change existing links, or delete links to form a new description.
6. Provide selected link and node analysis.

After completing the first assignment process, it may be necessary to modify the network where the desired level of service can not be obtained or where the proposed facility is not justified. This modified network is used for a second assignment and a further review made. The steps in the review process are:

1. Compare peak hour directional volumes with calculated capacities.
2. Determine needed changes in transportation system.
3. Check distribution of traffic on downtown streets.
4. Compute benefit-cost ratios for alternate solutions within the system.
5. Develop revised plans, reassign traffic and repeat process until volume-capacity ratios are satisfactory.

Modal Split

Modal split is the division of future travel demand into two components, demand for public transportation and demand for private transportation. A modal split model estimates the proportion of future intercity travel demand for both public transit and the private automobile. There are basically three variables used in modal split models:

1. Characteristics of the trip
2. Characteristics of the tripmaker
3. Characteristics of the transportation system.

The models have been classified as either trip-end or trip-interchange models.

The trip end modal split model estimates the proportion of productions and attractions by public transit and private automobile, prior to trip distribution. Figure 3 illustrates how a trip end model operates. The percent of people that travel by transit and automobile is found. Transit and auto trips are then distributed using different distribution models.

The trip interchange modal split model also gives the proportion of trip interchanges by public transit and private auto and is shown schematical in Figure 4. Using this approach, total productions and attractions are generated by purpose and distributed by the gravity model. The trip interchanges are then proportioned between transit and auto using the modal split model. The transit and auto-driver trips are then assigned to their respective networks.

Conclusion

The basis of the urban transportation process has been briefly summarized in this section of the report. The discussion of the

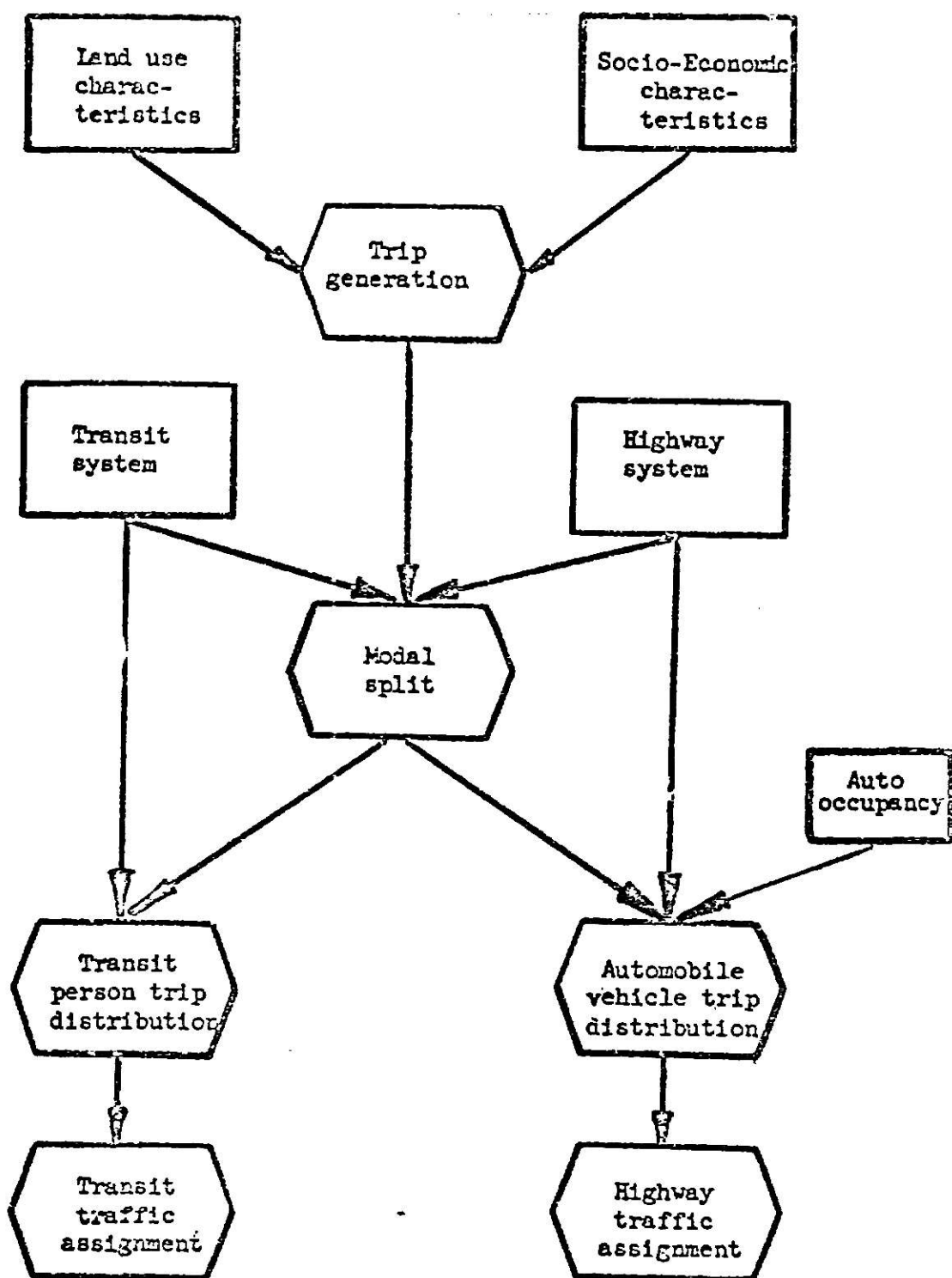


Figure 3: Trip End Modal Split Model

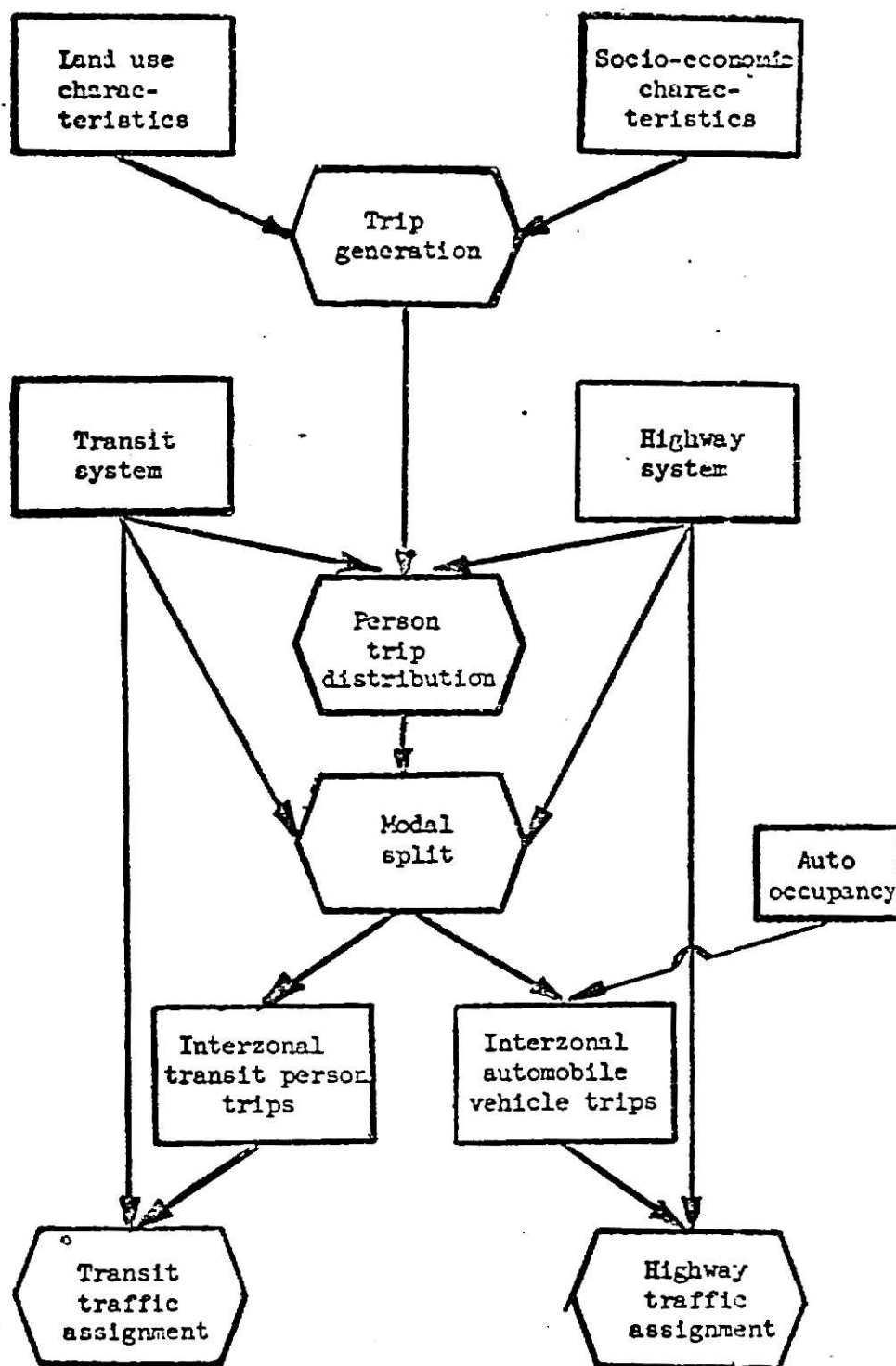


Figure 4: Trip Interchange Modal Split Model

process has been abbreviated and perhaps, oversimplified in some areas.. It does, however, establish the functional relationships of the major elements of the process. It is important to look upon the elements of the transportation process as integrated components. Trip generation, distribution and assignment must be coordinated so that they contribute to a logical, comprehensive urban transportation plan which has the capability to be continually updated. It cannot be overemphasized that the models are only "tools" for use by the planner and not a substitute for his knowledge, experience and/or judgment. The principles of the process were applied when examining and revising the following computer programs.

PURDUE TEACHING PACKAGE

Introduction

The Purdue Teaching Package consists of a set of four computer programs prepared as an educational aid for students in Urban Transportation Planning. The programs were written at Northwestern University and revised by transportation planning classes at Purdue University. The programs carry out the three basic elements of transportation planning: trip generation, trip distribution and traffic assignment.

Trip generation is carried out through the use of multiple stepwise regression. Trip distribution can be obtained by either the gravity model or the opportunity model. Either model can be used with the best model selected for the final result. It is necessary to calibrate both the gravity and opportunity models on the base year data for a specific location, unless a set of valid friction factors ($F(t)$'s) or probability parameters (L values) can be provided for the location. After the model is calibrated, it is used for trip distribution. Traffic assignment is carried out as an all-or-nothing assignment with optional capacity restraint. It is based on a version of Moore's Algorithm for minimum time paths through a network.

It is important that the user realize that this package was designed as a teaching aid rather than a large-scale, sophisticated, urban transportation planning program. The programs are presently limited to a maximum of 22 zones with 150 nodes in the network. Higher maxima could be established by rewriting the input, output

and program control subprograms. Since these programs will be used primarily for urban transportation planning courses, the logic of changing these limitations is questionable.

Since the program is restricted in the amount of data read, the computer cost is minimal when compared to large scale programs. A complete transportation plan for a 22 zone study area can probably be prepared for less than two hundred dollars of computer time, provided the planner uses the package efficiently. In their present form the input-output phases of the distribution and assignment programs are rigidly laid out, and must be observed if computer time is to be minimized. It is believed from a cost, efficiency and educational viewpoint that this package is excellent for use in future urban transportation classes. A user's documentation manual is presented in Appendix A of this report.

Trip Generation

Multiple stepwise regression was selected to carry out the trip generation process for the Purdue Teaching Package. Multiple stepwise regression provides a means of choosing independent variables which will provide the best predictive equation with the fewest independent variables. The method constructs a predictive equation, one independent variable at a time. The first variable chosen for the equation is the best single predictor. The second independent variable added to the equation is that which provides the best prediction in conjunction with the first variable. Other variables are added step-by-step until the desired number of variables has been included or until no other variable will make

a significant contribution to the prediction equation. At each step the optimum variable is selected, given the other variables in the equation.

Two parameters are used to select the order of entry of independent variables into the equation. The first parameter is the normalized regression coefficient value, beta (β), that the independent variable would have if it were brought into the equation on the next step. The significance of the regression coefficient is measured by the F-ratio. The F-ratio is the proportion of the mean square due to regression to the mean square due to residual variation, which arise in the analysis of variance table. If the F-ratio is too small, there is little reason to add that independent variable to the equation.

The tolerance level is the second parameter used in the selective process of bringing independent variables into the equation. If the tolerance is small, then that variable is nearly a linear combination of variables already in the equation. A large tolerance indicates that the variable adds to the prediction equation. The amount of additional variance explained by adding the new variable is the product of the normalized regression coefficient squared and the tolerance. Thus, even if the prospective β is large, a small tolerance value will negate the value of that variable being added to the equation. Independent variables, therefore, cannot be brought into the equation if the tolerance is below a specified minimum. This helps to insure the computational accuracy of the program (4).

The SPSS multiple regression program uses Gauss elimination for the mathematical computations. Gauss elimination is the underlying theory of stepwise regression. The accuracy of the program has been found to be sufficient for social science and engineering problems. The tolerance level insures additional computational accuracy when stepwise regression is used.

The cost of computer time for the SPSS multiple stepwise regression program is small. An experienced user of the package can make a 22 zone trip generation analysis for less than two dollars. Considerable savings in computer time results from a new method of handling variables which are not in the regression equation. This method allows the analyst to have the statistics printed for variables not included in the equation.

The primary reason for selecting the SPSS package was the simplicity of the control cards for stepwise regression. The multiple regression subprogram is called and activated by the procedure card containing the control word REGRESSION in columns 1 to 15. The regression calculations consist of two steps:

1. Computation of correlation matrix including all variables.
2. Regression calculations are made using the assembled correlation matrix.

The list of variables to be read in from cards or tape is given on the VARIABLES LIST card in the control card deck. The dependent variable is always listed first. An example of a variable list card is shown in the example deck set-up on Figure 5.

The REGRESSION list card specifies the multiple regression calculations desired. The REGRESSION list is of the form:

REGRESSION = dependent variable, (parameters) with inclusion
list

Card Column	1	16
	RUN NAME	OPTIONAL
	VARIABLE LIST	DEPENDENT VARIABLES, INDEPENDENT VARIABLES
	VAR LABELS	YHAT, TRIPS PER D.U. X1, HH PER ACRE X2, AUTOS PER D.U. ETC.,
	INPUT FORMAT	FIXED (F6.1, 4F6.0)
	# OF CASES	22
	REGRESSION	VARIABLES = DEPENDENT VARIABLES, INDEPENDENT VARIABLES REGRESSION = DEPENDENT VARIABLES, (n, F, T) WITH INCLUSION LIST
	STATISTICS	ALL
	READ INPUT	DATA

DATA PUNCHED ACCORDING TO
INPUT FORMAT

Figure 5: Input for SPSS Multiple Regression

The parameter specification gives the user control over the regression calculations. These optional parameters specify the maximum number of steps (n) in the calculation, the minimal F-level (F), and the minimum tolerance level (T) for the inclusion of variables in the stepwise mode. The parameters have default values of (80, 0.01, 0.001) for (n, F, T), respectively. After the desired number of steps, no more independent variables are added to the equation regardless of inclusion level or significance. The number of steps desired can be changed from 80 without specifying the F-level or tolerance in the parameter list as, (n). The number of steps must be specified if the F-level is changed from the default value as follows: (n, F). To specify a tolerance level the user must also specify the number of steps and the F-level.

The inclusion list is a list of names from the VARIABLES list which may be followed by an inclusion level enclosed in parentheses. The inclusion level is a number from 0 to 99 which controls the order of selection of independent variables for the regression list. There is not a default value for inclusion level, so each independent variable in the regression list must be assigned a level. Each variable name can have an inclusion level given following it in parentheses, or it is assigned the next inclusion level to follow in the regression list. The usual procedure is to assign the final variable name an inclusion level which gives all variables in the regression list the same level.

There are two modes of inclusion, multiple and stepwise. Variables with the same odd inclusion level are in the stepwise

mode and enter the equation one at a time as long as the variable makes a significant contribution to the regression equation. Variables with an even inclusion level are in the multiple mode and are brought into the equation regardless of how significant a contribution they make. Variables having the same even inclusion level are entered on the same step. As soon as all variables at a given inclusion level have been considered, variables at the next lower level are considered. Variables with a zero inclusion level are never brought into the regression equation, but are included in certain parts of the output.

The optional statistics which may be obtained from the SPSS package are selected by the use of a STATISTICS card. The STATISTICS card follows the REGRESSION card in the control card deck. The control word STATISTICS begins in column one and beginning in column 16 appears the numbers 1 or 2, or the keyword ALL. If ALL is used both statistics 1 and 2 are selected. Statistic 1 provides a printout of the correlation matrices. If statistic 2 is selected the means and standard deviations of all variables are printed. An example control card deck for the SPSS package is shown in Figure five (4).

The output from the multiple regression subprogram can be divided into two parts; (1) step-by-step results, and (2) the summary table. The step-by-step results provides output for the user everytime variables are added to the regression equation. The summary table is provided only after the final step and gives a brief description of each step.

The output at the end of each step should be carefully examined by the analyst. First appears a list of variables entered during the step, which will be one variable in the stepwise mode, or one or more in the multiple mode. Below this is a statistical summary of the prediction equation, which includes multiple R, R-square, and the standard error. The remainder of the output includes an analysis of the regression. The first line is for the regression equation, the second for residuals. Residuals represent the difference between the predicted and observed value of the dependent variable, and are used to check the precision of the regression equation. The sum of squares, mean sum of squares and F-ratio is given for both cases. The F-ratio is the ratio of the two mean squares and it measures the significance of the regression equation. The proper degrees of freedom are also included in the output. Variables in the regression equation and variables still in the inclusion list are also printed after each step.

For variables in the regression equation, four values are printed. The B and BETA values are the regular and normalized regression coefficients, respectively. The standard error of B measures the significance of the regression coefficient. The range of the regression coefficient may be interpreted as B plus or minus the standard error. The fourth value in this part of the output is the F value. This F value measures the relative size of B and the standard error, S. F is calculated as $(B/S)^2$. Statistical significance of these F-statistics can be determined in tables.

For variables in the inclusion list, four different values are printed on the right side of the output. The first is the beta coefficient if the variable were brought into the equation on the next step. The second is the partial correlation between the prospective independent variable and the dependent variable. The third value is the tolerance of the independent variable. The F statistic is given in the next column and measures the significance of the potential independent variable. If the independent variable is entered on the next step, the F value will remain the same.

Information for each independent variable at the conclusion of the final step is given in the summary table. The multiple R, the R-squared, and the change in R-squared from the previous step is presented in this table. The simple R also appears in this table, giving the correlation between the independent and dependent variables. This shows the analyst the effect of other independent variables and the relationship between the two variables.

The steps which the planner must go through in the analysis of the SPSS package will be illustrated in the "Skokie" area study later in the report. The goal of this analysis is, of course, to find the best predictive trip generation model.

Trip Distribution

The Purdue Teaching Package has two programs available for trip distribution, the gravity model and the intervening opportunity model. There are a large number of options available for running the two models. Two separate runs are usually made for the models;

a calibration run using present data, and trip distribution using the friction or probability factors obtained from the calibration run.

The program called GRAVITY divides the trip distribution into three distinct parts. The first part tabulates and plots the observed data. The travel time matrix and trip matrices are printed. The trip frequency is tabulated by time increments and the results shown both in tabular form and graphically on a Calcomp plot as shown in Figures 6 and 7. The second part is the calibration phase based on existing trip patterns. An iterative process is used to calculate a set of friction factors, called $F(t)$'s, for each trip purpose. The initial $F(t)$'s are assumed and then adjusted to fit the base year data. A chi-squared test can be performed between the predicted trip length distribution and the observed trip length distribution. If the chi-squared shows a significant difference between the two trip length distributions, further calibration runs must be made using more iterations. The calibrated $F(t)$ values are assumed to be constant over time and used as input to the third part of the GRAVITY program. The third part of the program distributes future produced and attracted trips for each zone and trip purpose. The calibrated $F(t)$'s are punched out in the second phase of the program and are used to distribute the future productions and attractions. Trip matrices, travel distributions and friction factors are printed and plotted in phases two and three as shown in Figures 8 and 9. In addition, the final total trip matrix may be obtained as punched output

TRIP FREQUENCY BY TIME INTERVAL IN MINUTES

HOME TO WORK

TIME INTERVAL	NUMBER OF TRIPS	PERCENT OF TOTAL TRIPS
0. - 2.	0.	0.0
2. - 4.	726.	2.11
4. - 6.	578.	1.68
6. - 8.	3601.	10.45
8. - 10.	4651.	13.50
10. - 12.	5934.	17.23
12. - 14.	6736.	19.56
14. - 16.	4338.	12.60
16. - 18.	5199.	15.10
18. - 20.	1396.	4.05
20. - 22.	116.	0.34
22. - 24.	90.	0.26

NON-HOME BASED TRIPS

TIME INTERVAL	NUMBER OF TRIPS	PERCENT OF TOTAL TRIPS
0. - 2.	0.	0.0
2. - 4.	1166.	2.37
4. - 6.	1071.	2.18
6. - 8.	9300.	18.93
8. - 10.	9371.	19.07
10. - 12.	7291.	14.84
12. - 14.	2158.	4.39
14. - 16.	2321.	4.72
16. - 18.	989.	2.01
18. - 20.	292.	0.59
20. - 22.	30.	0.06
22. - 24.	12.	0.02

HOME TO OTHER

TIME INTERVAL	NUMBER OF TRIPS	PERCENT OF TOTAL TRIPS
0. - 2.	0.	0.0
2. - 4.	1799.	2.91
4. - 6.	4850.	7.84
6. - 8.	11090.	17.93
8. - 10.	19270.	31.16
10. - 12.	9058.	14.65
12. - 14.	3308.	5.35
14. - 16.	3667.	5.93
16. - 18.	1175.	1.90
18. - 20.	357.	0.58
20. - 22.	30.	0.05
22. - 24.	30.	0.05

Figure 6: Tabulation of Trip Frequency Intervals

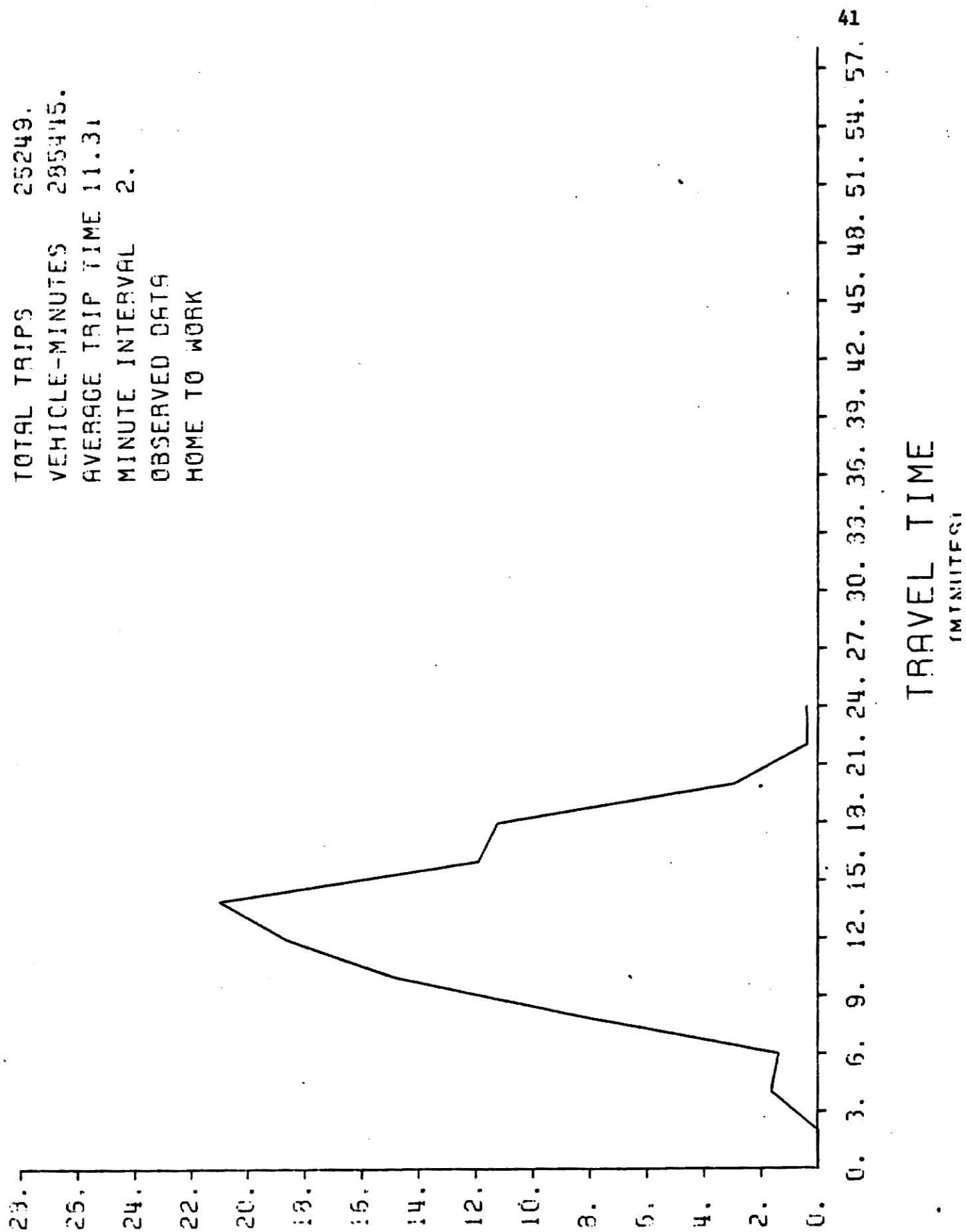
ILLEGIBLE DOCUMENT

**THE FOLLOWING
DOCUMENT(S) IS OF
POOR LEGIBILITY IN
THE ORIGINAL**

**THIS IS THE BEST
COPY AVAILABLE**

PERCENT OF TOTAL TRIPS

Figure 7: Calcomp Plot of Trip Frequency Intervals



NUMBER OF TRIPS MOVING BETWEEN ZONES

NCN-HOME BASED TRIPS

ATTRACTED TO ZONE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1	130.	778.	87.	61.	55.	24.	23.	12.	30.	6.	14.	13.	5.	2.	1.	3.	5.	5.	8.	7.	1.	116.	
2	232.	8366.	457.	328.	108.	47.	45.	23.	258.	26.	59.	191.	7.	11.	1.	39.	29.	68.	47.	30.	18.	331.	
3	46.	818.	268.	79.	8.	3.	3.	2.	32.	6.	14.	14.	1.	2.	0.	3.	7.	11.	11.	10.	3.	122.	
P	4	25.	457.	61.	71.	26.	5.	5.	6.	32.	3.	6.	21.	2.	1.	0.	4.	3.	7.	5.	3.	2.	36.
R	5	34.	721.	9.	39.	124.	18.	21.	37.	52.	15.	10.	74.	3.	4.	0.	4.	5.	4.	8.	23.	1.	58.
O	6	50.	330.	13.	26.	63.	80.	26.	14.	16.	3.	15.	50.	28.	6.	1.	10.	7.	5.	12.	11.	1.	40.
D	7	62.	404.	16.	32.	92.	33.	54.	20.	13.	8.	19.	163.	35.	24.	6.	26.	9.	5.	32.	28.	1.	105.
U	8	37.	246.	10.	43.	188.	20.	23.	30.	57.	16.	11.	82.	3.	4.	0.	5.	6.	4.	9.	26.	1.	64.
C	9	20.	659.	39.	51.	56.	5.	3.	12.	203.	43.	58.	99.	5.	2.	0.	6.	23.	34.	36.	31.	5.	252.
E	10	4.	65.	9.	5.	18.	1.	2.	4.	50.	92.	158.	71.	2.	4.	0.	31.	35.	11.	56.	23.	3.	436.
D	11	5.	67.	9.	5.	6.	2.	2.	1.	50.	71.	1047.	34.	2.	13.	1.	31.	79.	17.	39.	51.	4.	1098.
12	7.	353.	14.	28.	67.	13.	34.	15.	82.	52.	55.	348.	30.	21.	2.	23.	27.	19.	28.	24.	5.	673.	
R	13	13.	59.	6.	15.	11.	35.	33.	2.	21.	8.	15.	141.	106.	56.	3.	27.	7.	5.	34.	29.	1.	110.
Y	14	2.	36.	4.	3.	7.	3.	9.	1.	4.	5.	40.	39.	22.	101.	5.	45.	20.	14.	68.	132.	4.	495.
15	1.	3.	0.	0.	1.	0.	2.	0.	0.	0.	2.	3.	1.	4.	1.	4.	1.	1.	16.	14.	0.	44.	
16	1.	72.	3.	6.	4.	3.	5.	1.	5.	23.	51.	23.	6.	25.	3.	66.	25.	5.	91.	78.	1.	354.	
17	3.	54.	7.	4.	5.	2.	2.	1.	19.	25.	127.	27.	2.	11.	1.	25.	412.	98.	225.	26.	26.	876.	
18	2.	109.	9.	8.	3.	1.	1.	1.	24.	7.	24.	16.	1.	6.	0.	5.	85.	175.	61.	53.	64.	198.	
19	4.	84.	11.	7.	7.	3.	7.	2.	29.	40.	61.	27.	7.	36.	10.	87.	220.	69.	1037.	366.	18.	1145.	
20	7.	103.	18.	8.	39.	5.	11.	8.	48.	30.	152.	45.	11.	130.	17.	142.	49.	112.	691.	1461.	30.	836.	
21	7.	336.	29.	26.	9.	3.	3.	2.	75.	22.	73.	50.	3.	20.	1.	14.	263.	741.	189.	163.	145.	613.	
22	28.	264.	54.	21.	23.	4.	9.	5.	91.	154.	774.	291.	10.	115.	13.	151.	382.	99.	509.	197.	27.	4866.	

DISTRIBUTED DATA

DISTRIBUTED DATA

PLARDE UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING

Figure 8: Distributed Final Total Trip Matrix

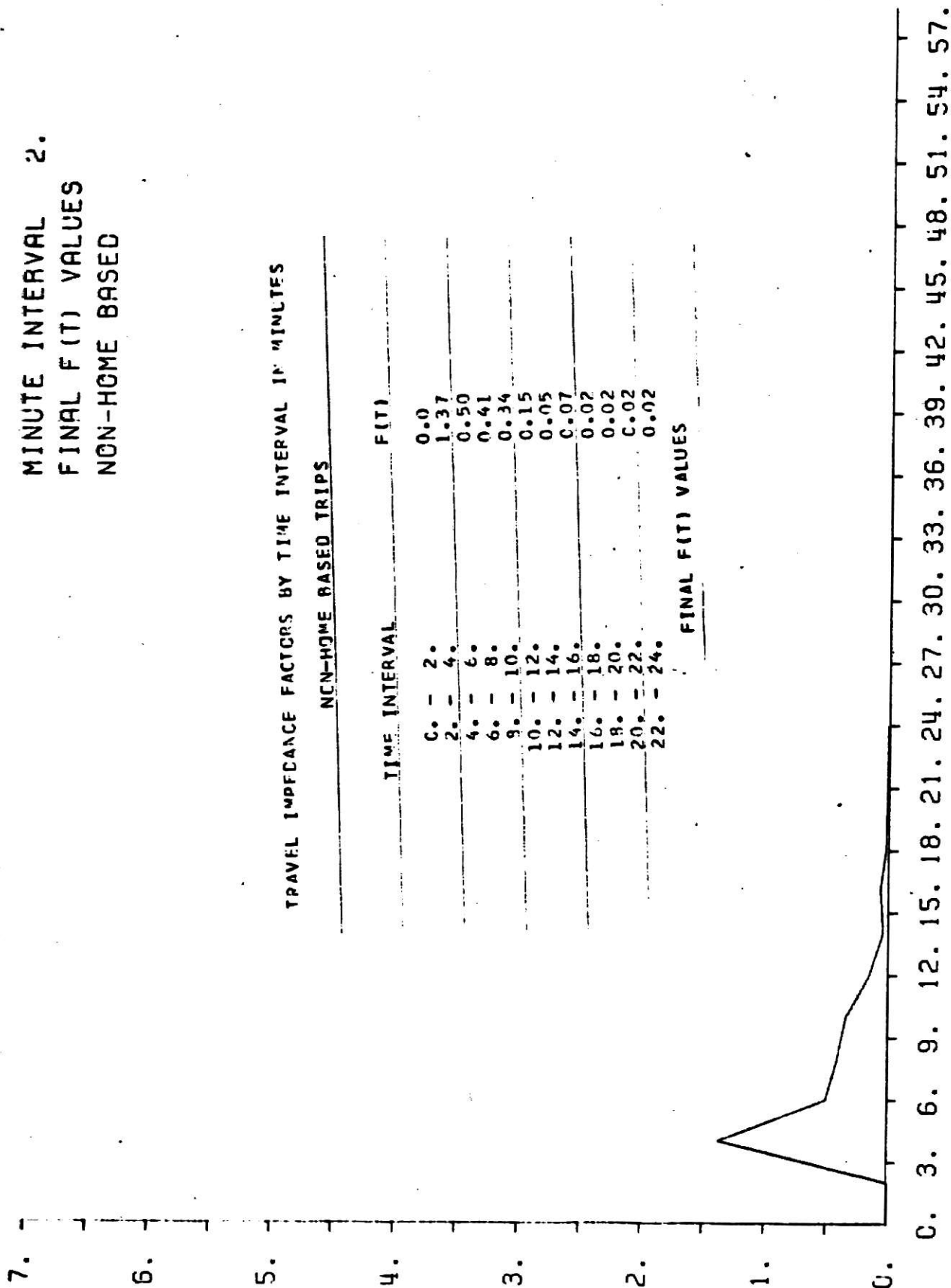
MINUTE INTERVAL 2.
 FINAL F(T) VALUES
 NON-HOME BASED

TRAVEL IMPEDANCE FACTORS BY TIME INTERVAL IN MINUTES

NON-HOME BASED TRIPS

TIME INTERVAL	F(T)
0. - 2.	0.0
2. - 4.	1.37
4. - 6.	0.50
6. - 8.	0.41
8. - 10.	0.34
10. - 12.	0.15
12. - 14.	0.05
14. - 16.	0.07
16. - 18.	0.02
18. - 20.	0.02
20. - 22.	0.02
22. - 24.	0.02

FINAL F(T) VALUES



TRAVEL IMPEDANCE FACTOR, F(T)

Figure 9: Computer and Calcomp Output
 For Final Calibrated F(t)

TRAVEL TIME
 (MINUTES)

and used as input cards for the network assignment program. The GRAVITY program is usually run in two parts; phases one and two together, and phase three separately. The user's guide in Appendix A completely explains the input requirements of the program GRAVITY.

The program OPPRTY represents one version of the intervening opportunities model for trip distribution. Similar to the program GRAVITY, OPPRTY divides the distribution process into three parts: tabulating and plotting the observed data, calibration of the model, and distribution of future productions and attractions. The model calculates a set of probabilities, called L values, for each zone and trip purpose by an iterative process. The user may specify an initial L-value to begin the calibration procedure and an allowable error in closure between successive iterations. L values usually range from 10^{-3} to 10^{-6} , with an allowable error in closure of one-half to five percent.

The calibration technique and model formulation for the OPPRTY program was developed by Earl R. Ruiter and used in the Chicago Area Transportation Study. Calibration is carried out on the basis of a single mean trip length using the relationship:

$$L_i = F(L_i) = \frac{L_i \sum_{j=1}^n d_{oj} [\exp(-L_i V_{i,j}) - \exp(-L_i V_{i,j})]}{F_o [1 - \exp(-L_i V_{i,n})]}$$

where: F_o = average trip length from zone o

d_{oj} = distance from zone o to zone j

n = total number of zones

exp = natural logarithm to the power $(-L_i V_{i,j})$

L_i = probability a destination from zone i being accepted if it is considered

V_{ij} = the possible destinations already considered from zone i.

The program operation of OPPRTY is also explained in Appendix A.

Network Assignment

Traffic assignment is carried out by the program called NETANAL. NETANAL is the main program of the Purdue Teaching Package with OPPRTY and GRAVITY being subroutines. The package may be run with a trip distribution model used as a subroutine of NETANAL, or NETANAL may be run separately. It is recommended that NETANAL be run separately, since the inclusion of a trip distribution model makes the package inefficient in terms of use of computer core storage and also generates an excessive amount of output for a single run. If the distribution phase is included in the package, it can be run separately, so there is nothing to be gained in running the two together. It is suggested that the three programs, GRAVITY, OPPRTY, and NETANAL be loaded and run separately from disk.

The NETANAL program has several options available. These options are listed below and in the user documentation manual:

1. Operate as a tree building program only.
2. Operate as an uncapacitated assignment model.
3. Operate as an iterated capacity restrained assignment model.
4. Calculate travel times from link data for use in trip distribution.
5. Obtain turning movements and originating and terminating traffic at selected nodes using selected node option.

6. Obtain an origin and destination breakdown of traffic on selected links using selected link option.
7. Impose a certain level of through traffic on the network.

The purpose of the assignment process is to determine the amount of traffic each street in the network can carry in the design year. The effects of proposed improvements on the system and the desired minimum path of vehicles between zones can then be studied.

NETANAL assigns all traffic to its minimum time path, i.e. all-or-nothing assignment is used. When the capacity restraint option is used, link times are recalculated based on the volume of the link in the previous iteration and capacity of the link. The new link travel time is then used and new trees are built for the next iteration.

The capacity restraint function was changed by the author. The restraint function that originally appeared in the program was written by A. S. Rathrau and appeared in the Chicago Area Transportation Study (11). The restraint function was:

$$t_i = t_i^o \left(\frac{V_i}{C_i} \right)^2$$

where: t_i = time required to traverse link i if volume on the link is V_i

t_i^o = time required to traverse link i under operating speed (i.e. no volume speed)

V_i = traffic volume assigned to link i

C_i = design capacity of link i

This restraint is an arbitrary algorithm and is not based on any strict empirical relationship. The function above becomes unreasonable when the volume-to-capacity ratio becomes greater than one. Extremely long and questionable travel times often result, which consequently cause the range of the travel time matrix dimension in the program to be exceeded, and meaningless output is then printed.

Because of these obvious deficiencies in the restraint function, the formula was changed to that used in the FHWA assignment battery. The adjusted link travel time is now computed by use of the following equation (5):

$$T = T_o [1 + 0.15(V/C)^4]$$

where T = travel time that the traffic volume (V) can travel on the link

T_o = free-flow travel time; observed travel time at capacity (level of service C) times 0.87

This restraint function has been found to give much more reasonable results than that used in the original program.

The design capacities of each link are calculated by using a table derived by the Chicago Area Transportation Study. The details of the table appear in Appendix A.

If predetermined link travel times are not given in the input phase, the computer calculates them. The time required to traverse a specific link i under normal operating conditions is:

$$t_i^o = \frac{d_i}{s_i}$$

where: d_i = length of link i

s_i = operating speed on link i

The operating speed on the link is calculated from the following expression (11):

$$S_i^o = \frac{21,600 d_i S_i^P}{21,600 d_i + S_i^P (S_i^P + 45) [F(n)]}$$

where: S_i^P = posted speed on link i

$F(n)$ = factor based on the total number of signalized intersections on link i

$$\begin{aligned} F(n) &= 0 \text{ if } n = 0 \\ &= 0.5 \text{ if } n = 1 \\ &= n - 1 \text{ if } n > 2 \end{aligned}$$

NETANAL is currently limited to 150 nodes, 22 load nodes, and a maximum of four links per node. The maximum minimum time path is 900 time units. If any of these maxima are exceeded, error messages will result and the program will fail to operate correctly.

Summary

The step-by-step process which the transportation planner must follow when using the Purdue Teaching Package follows:

1. Code the network and obtain link data.
2. Obtain observed zone to zone trip matrices for all trip purposes.
3. Obtain future productions and attractions from the trip generation phase.
4. Use NETANAL to find the zone to zone minimum time paths.
5. Punch a traveltime matrix found in Step 4.
6. Use traveltime matrix and observed data to calibrate the distribution models (GRAVITY and OPPRTY).
7. Use the χ^2 test to find the best distribution model.

8. Have the friction factors, $F(t)$'s, or probability parameters, L 's, punched out.
9. Distribute the trips using the calibrated factor and have the total trip matrix punched out.
10. Run NETANAL using the total trip matrix and determine future deficiencies in the transportation network.
11. Generate alternative solutions to network deficiencies.
12. Select the best solution.

The input requirements and the output printed from each program is summarized in Figure 10.

The Purdue Teaching Package is an exceptional tool for learning the urban transportation process. A comparison of the package to a large scale battery would be an interesting project, and give an indication of the teaching package's efficiency.

There are a few deficiencies in the Purdue Teaching Package which complicates its usage. The most serious is that the volume to capacity (V/C) ratios must be averaged for each iteration. The program could be written to average the V/C ratios and print out the overloaded links and specialized link data. Also, more than one load link could be provided for some zones. This deficiency becomes apparent in the Skokie and Pittsburg analyses.

The main problems encountered when converting this package from the CDC 6500 to the IBM 360 were format errors. The K.S.U. IBM 360 on-line printer is limited to 133 printed spaces, whereas the CDC 6500 prints up to 150 spaces. These errors were relatively simple to correct after they were located. Logic errors were also created when the program was recompiled. These types of errors were the most difficult to locate and correct. Several arrays

<u>Program</u>	<u>Function</u>	<u>Input</u>	<u>Output</u>
SPSS multiple stepwise regression	Trip Generation Analysis	Dwelling Unit Data by Zone	1. Best predictive equation for forecasting future trips 2. The future productions and attractions
GRAVITY	Trip Distri- bution	1. Interzonal Travel- times 2. Observed trip matrices of three trip purposes for calibration 3. Future productions and attractions for distri- bution	1. Calibrated friction factors [F(t)'s] punched out 2. Final total trip matrices (future or observed) for assignment punched out
OPPRY	Trip Distri- bution Analysis	1. Interzonal Traveltimes 2. Observed trip matrices of three trip purposes for calibration 3. Future productions and attractions for distri- bution	1. Calibrated probability para- meters (L) punched out 2. Final total trip matrices (future or observed) for assignment punched out
NETANAL	Traffic Assign- ment	1. Link data 2. Total trip matrix to be assigned to network 3. Zone to zone travel times and minimum timepaths	1. Volume of traffic expected on each link in network 2. Capacity of each link in network 3. Zone to zone travel times and minimum timepaths

Figure 10: Summary of input and output for Purdue Teaching Package

had to be re-dimensioned. These errors were found by running a debug, subcheck and subtrace routine on the program. This routine indicated what parameters were going out of range, and this gave an indication of what array was dimensioned too small. Most of the errors that were created when recompiling the program to the IBM 360 computer were elementary in nature, but because of the size of the package were sometimes extremely difficult to locate.

"SKOKIE, ILLINOIS" TRANSPORTATION STUDY

Introduction

This study summarizes the application of the Purdue Teaching Package to a small urban area, Skokie, Illinois. The various stages of the transportation planning process are the development of a trip generation model, the analysis of the gravity and intervening opportunities models for trip distribution, the assignment of trips to the present or altered street system, and the generation, evaluation and recommendations of a future street and highway system.

The inventories necessary to make a planning study were completed prior to this project and were given to the students. These included: inventories of existing transportation facilities, land use patterns, socio-economic activities, and travel patterns. The information from these inventories were used as inputs to the appropriate phases of the study.

A map of Skokie and the coded network are shown in Figures 11 and 12, respectively. The area consists of twenty-two zones with the Heathington Expressway serving as a major bypass facility. Important land use includes the Central Business District located in Zone 22, a large shopping center in Zone 2, and a lake in Zone 12.

This report will summarize the process that the planner must go through to select the best transportation plan for a small area such as this. The formal problem statement and the given data are shown in Appendix B.

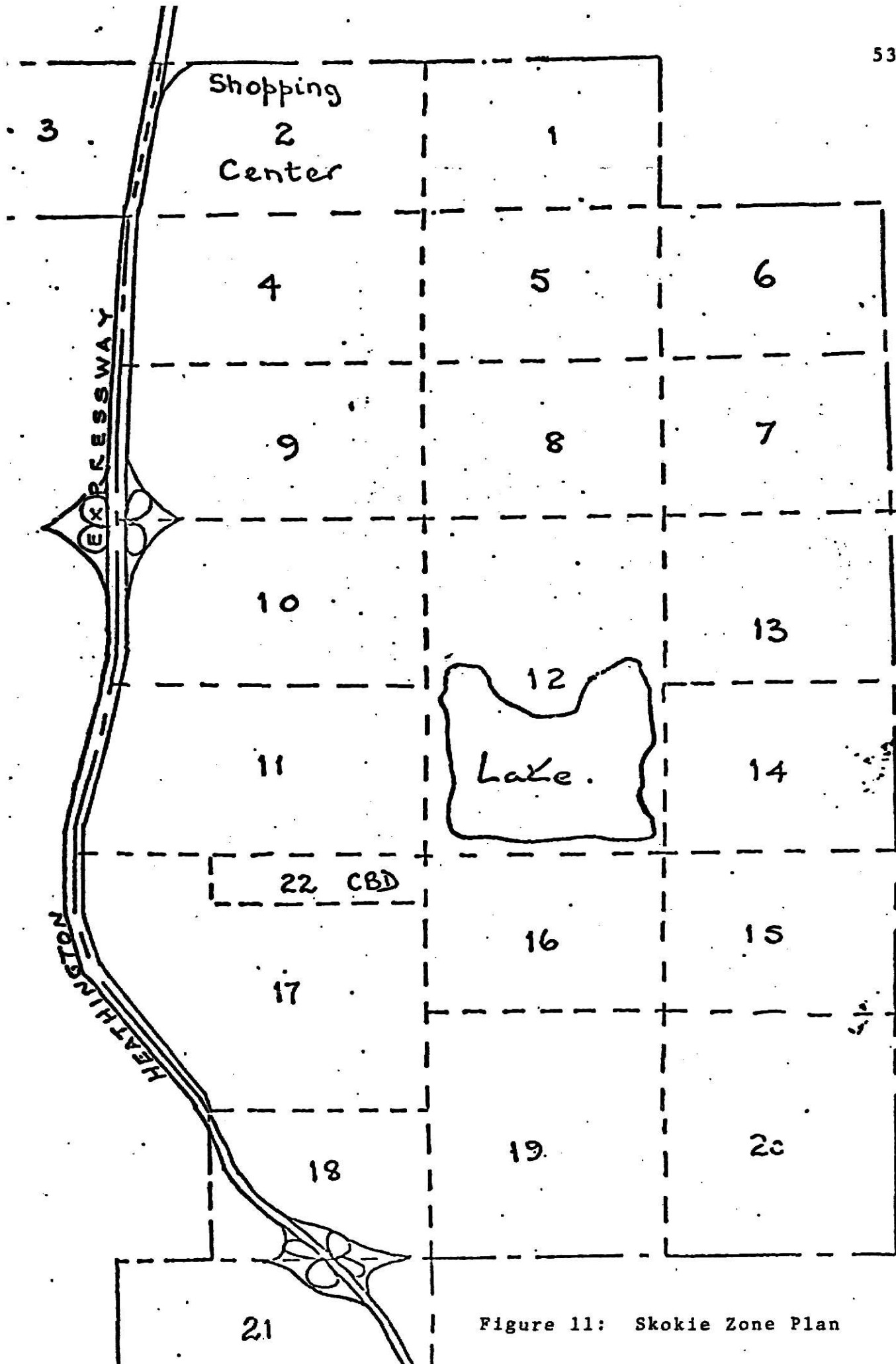


Figure 11: Skokie Zone Plan

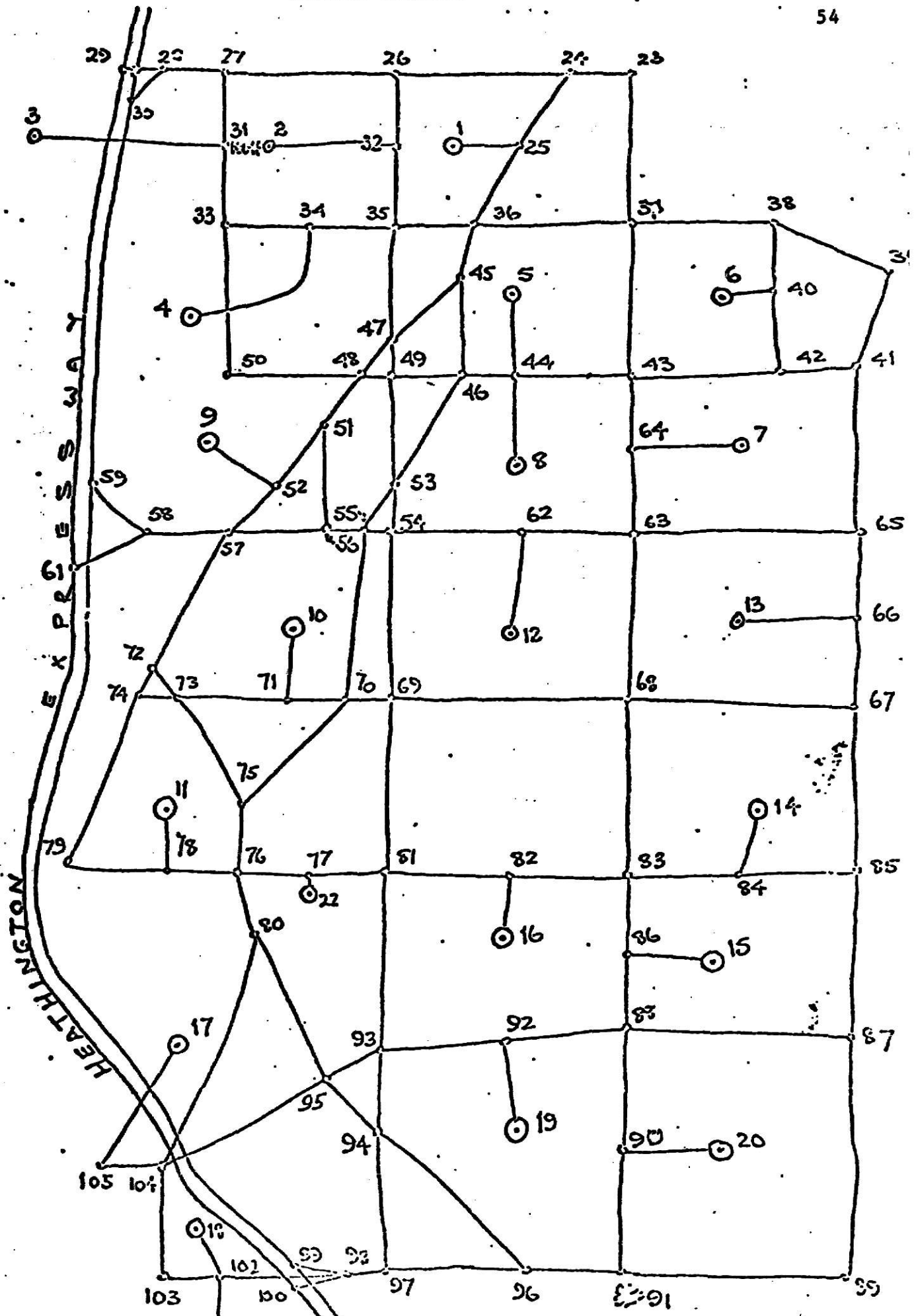


Figure 12: Skokie Coded Network

Trip Generation Analysis Using the Zonal Rates and Zonal Totals Regression Models

The data that is usually input into the trip generation phase is usually aggregated into zones. Either of two sets of data can be used: zonal totals or zonal averages. The planner must then determine which set of data gives the best model.

The analyst must also determine the best independent variables to use in the equation. The variables should have a linear, logical and casual relationship with the dependent variable, trips. Plots of the independent variables versus the dependent variable were made for both sets of data (Table 1 and 2). If a variable does not show a linear relationship with trips it should either be deleted from the model or be transgenerated or separated into dummy classes. All of the dependent variables in the zonal totals models were linear when plotted against trips. Total autos, workers and income showed the strongest, most linear plots. Income per dwelling unit of the zonal rates data gave the plot which was the least linear with independent variable trips per dwelling unit. (Data plots for all variables are shown in Figures 13-20.)

Zonal Rates Regression Model

The first model examined in this study was the zonal rates model. The dependent variables studied were: (Also see computer print out in Appendix C)

Zonal Rates Model

YHAT = Trips/Dwelling Unit
 X_1 = HH/Acre
 X_2 = Autos/HH
 X_3 = Workers/HH
 X_4 = Workers/Ml²
 X_5 = Income/HH

TABLE 1

DATA USED IN ZONAL RATES REGRESSION MODEL

	DEPENDENT VARIABLE	*	INDEPENDENT VARIABLES CONSIDERED IN TRIP GENERATION PHASE			
CONF	AVG. TRIPS/ DWELL. UNIT	*	AVG. WORKERS/ DWELLING UNIT	AVG. INCOME/ DWELL. UNIT	AVG. AUTOS/ DWELL. UNIT	AVG. DENSITY D.U./ACRE
1	1.2801	*	1.2800	13085.00	1.4604	1.3167
3	1.2576	*	1.0200	11615.00	1.4279	.7156
4	1.2139	*	1.1200	11705.00	1.4295	1.9714
5	1.5569	*	1.6800	13800.00	1.5589	3.2656
6	1.6702	*	1.2200	16435.00	1.6856	2.6477
7	1.7489	*	1.6000	13360.00	1.5883	2.9375
8	1.6940	*	1.7900	13490.00	1.5642	4.1875
9	1.0699	*	1.0400	9800.00	1.2760	4.2906
10	1.0910	*	.6500	10395.00	1.3366	5.0500
11	1.0601	*	.9500	9865.00	1.1899	3.6375
12	1.1749	*	1.0200	10710.00	1.3186	4.1094
13	1.7054	*	1.4300	10860.00	1.6406	3.9562
14	1.5855	*	1.2100	10085.00	1.4609	2.1563
15	1.4101	*	1.4700	11030.00	1.3237	1.7375
16	1.1668	*	.8200	10260.00	1.4022	3.6906
17	.9557	*	1.0100	8905.00	1.2090	3.9469
18	1.2648	*	.8200	12055.00	1.5151	2.0750
19	1.7483	*	1.6100	10180.00	1.3486	1.8375
20	1.6951	*	1.6300	10190.00	1.5183	1.0250
21	1.2217	*	1.2900	13565.00	1.5792	2.7625

TABLE 2

DATA USED IN ZONAL TOTALS REGRESSION MODEL

ZONF	DEPENDENT	INDEPENDENT VARIABLES				
	VARIABLE	CONSIDERED IN TRIP GENERATION PHASE				
	TOTAL		TOTAL	TOTAL	TOTAL	
	TRIPS	TOTAL INCOME	HOUSEHOLDS	WORKERS	AUTOS	
1	809.00	8269720.00	632.00	808.00	923.00	
3	288.00	2659835.00	229.00	223.00	327.00	
4	766.00	7385855.00	631.00	706.00	902.00	
5	1627.00	14421000.00	1045.00	1755.00	1629.00	
6	1413.00	13904010.00	846.00	1032.00	1426.00	
7	1644.00	12558400.00	940.00	1504.00	1493.00	
8	2270.00	18076600.00	1340.00	2358.00	2096.00	
9	1469.00	13455400.00	1373.00	1427.00	1752.00	
10	1763.00	16798320.00	1616.00	1050.00	2160.00	
11	1234.00	11482860.00	1164.00	1105.00	1385.00	
12	3090.00	28167300.00	2630.00	2682.00	3468.00	
13	2159.00	13748760.00	1266.00	1810.00	2077.00	
14	1094.00	6958650.00	690.00	834.00	1006.00	
15	392.00	3066340.00	278.00	408.00	368.00	
16	1378.00	12117060.00	1181.00	968.00	1656.00	
17	1207.00	11247015.00	1263.00	1275.00	1527.00	
18	800.00	8004520.00	664.00	544.00	1006.00	
19	1028.00	5985840.00	588.00	946.00	793.00	
20	278.00	1671160.00	164.00	267.00	249.00	
21	540.00	5995730.00	442.00	570.00	698.00	

The SPSS regression program was selected to determine the model, with the variables entering the model according to the significance of the regression coefficient.

If the analyst looks at the correlation matrix, shown on Page 3 of Appendix C, collinearity between independent variables is noted. First note that Income per Household is more highly correlated to Autos per Household (0.768) than it is to the dependent variable trips (0.419). This indicates that if these two independent variables appear in the regression equation together, the partial effect of each on the number of trips per dwelling unit will be distorted due to collinearity and one should be deleted. Because of the larger amount of scatter in the data plot, it was decided to delete the income per H.H. variable from the regression model. Workers per square mile also was more correlated to the independent variable workers per H.H. (0.41794) than to the dependent variable (0.272). Because of this collinearity and poor data plot, workers per square mile was also dropped from the model.

The SPSS stepwise regression program was utilized with the following trip generation model obtained:

$$\text{Average Trips/DU} = -0.349 + 0.527 \text{ Workers/HH} + 0.745 \text{ Autos/HH}$$

$$(R^2 = 0.7851; S_y = 0.133)$$

The equation indicates that the number of trips per dwelling unit will increase as the number of workers per household increase if the number of autos per household is held constant, and vice versa. This interpretation is very logical, and one would expect this to hold true in real life. The constant term is negative,

indicating that a dwelling unit could produce negative trips if workers or autos per HH were zero; however, since the model is intended for large amounts of data it does not necessarily mean the model is invalid.

Note for future comparison with the zonal total model, that the coefficient of multiple determination is 0.786, with a standard error of 0.133.

Zonal Totals Regression Model

The data that is given in Table 2, was first plotted individually against the dependent variable, total trips, and are shown in Figures 13 through 15. As mentioned in the introduction, all four plots show a linear relationship between the dependent variable and the four independent variables.

Again the SPSS stepwise multiple regression program was utilized to develop the model. The output is shown in Appendix D. The correlation matrix is shown on Page 3 of the appendix. Examination of the correlation matrix reveals that total trips is most highly correlated to total autos (0.971). It is also necessary to check the correlation matrix for collinearity, e.g., independent variables which are more highly correlated to each other than to the dependent variable. Collinearity can be seen to exist as autos are more correlated to households than to trips (0.981 compared to 0.971). Also income is more highly correlated to autos than to trips (0.983 compared to 0.960). If any two or all of these independent variables are left in the model, the total number of trips per dwelling unit will be inaccurately predicted.

Leaving all variables into the trip generation model results in the following regression equation:

$$\text{Trips} = -7.463 + 1.246 (\text{Total Autos}) + 0.373 (\text{Total Workers}) \\ - 0.665 (\text{Total Households}) - 0.00002 (\text{Income})$$

Although this model results in a very high R^2 value equal to 98.57% ($S_y = 96.108$), it is illogical because of the negative sign in front of the Total Households regression coefficient indicating that trips decrease as the number of households increase. The main reason for this illogical relationship is the collinearity which exists between income, autos, and households.

By examining Step 3, of the multiple regression output in Appendix D, the model can be examined by dropping the total income variable. The regression equation is now:

$$\text{Trips} = -7.460 - 0.652 (\text{Total Households}) + 0.357 (\text{Total Workers}) + 1.105 (\text{Total Autos}) \quad (S_y = 96.108)$$

Again the R^2 is high (0.986), but the negative sign in front of total households is present, due to the collinearity between autos and households.

By removing households from the equation, the collinearity between variables was no longer present and the regression equation as shown on Page 4, Appendix D is selected:

$$\text{Total Trips} = 9.853 + 0.554 (\text{Total Autos}) + 0.453 (\text{Total Workers})$$

The variable total autos entered the model first to give a coefficient of multiple determination of 0.942. In the second step, total workers entered the model increasing R^2 to 0.976 with a standard error equal to (S_y) 116.761. This is the model which

was selected as the best zonal totals trip generation model, and ultimately as the best trip generation model for the study area.

The forecasted total trips for both the zonal rates and totals trip generation models are shown in Table 3. The difference between the predicted trips are small, but it is noted that the zonal rates model always indicated more trips per zone. The zonal totals model is preferred because the R^2 value is considerably higher (0.9761 compared to 0.7851), and it is otherwise more acceptable. This model explains (accounts for) 98% of the total variation within and between zones, leaving only 2% variation due to the deviation of the computer variables from the observed.

Trip Distribution Analysis

For this portion of the study the following information was given:

1. The present trip matrices for each of three trip purposes
 - a. Home-to-Work
 - b. Home-to-Other
 - c. Non-home based
2. Observed minimum time path travel times for 22 zones
3. Design year trip productions and attractions for each zone

The output from both the GRAVITY and OPPRTY programs include a wide variety of Calcomp plots and trip length tabulation tables. Examples of these are assembled in Appendix E. The Calcomp plots show the trip length frequency distributions for both the observed

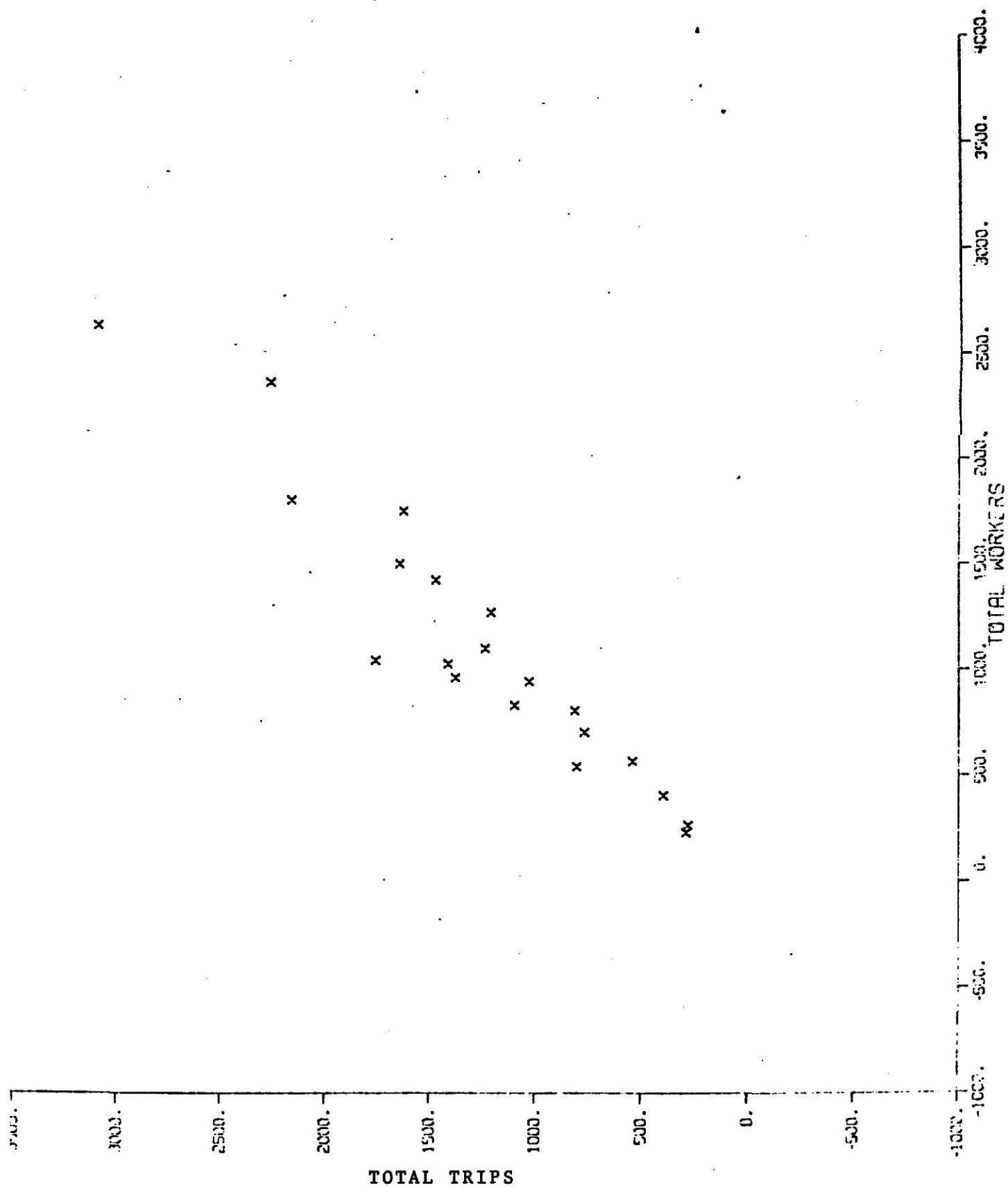


Figure 13: Total Worker vs. Total Trip Data Plot

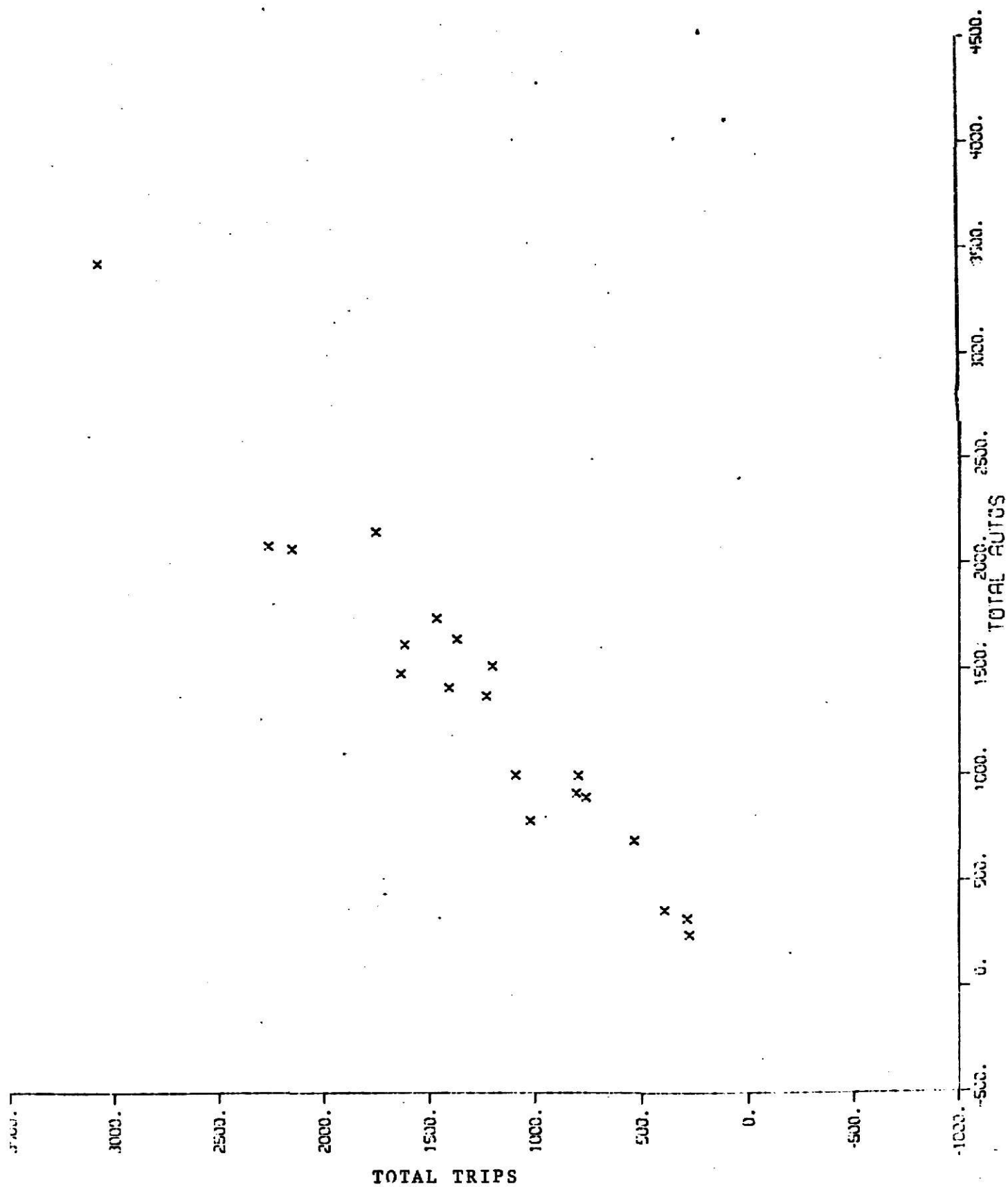


Figure 14: Total Autos vs. Total Trips Data Plot

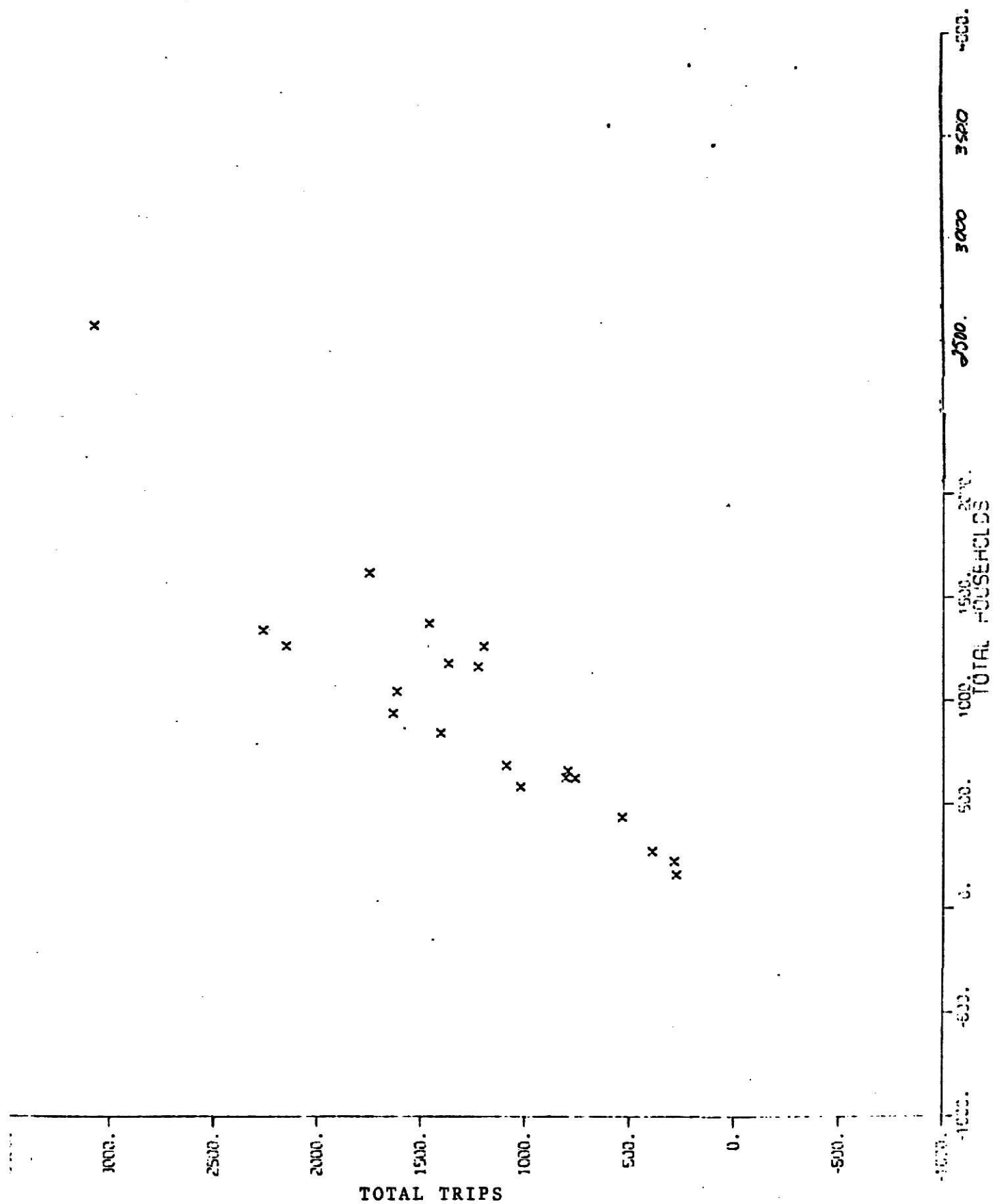


Figure 15: Total Households vs. Total Trips Data Plot

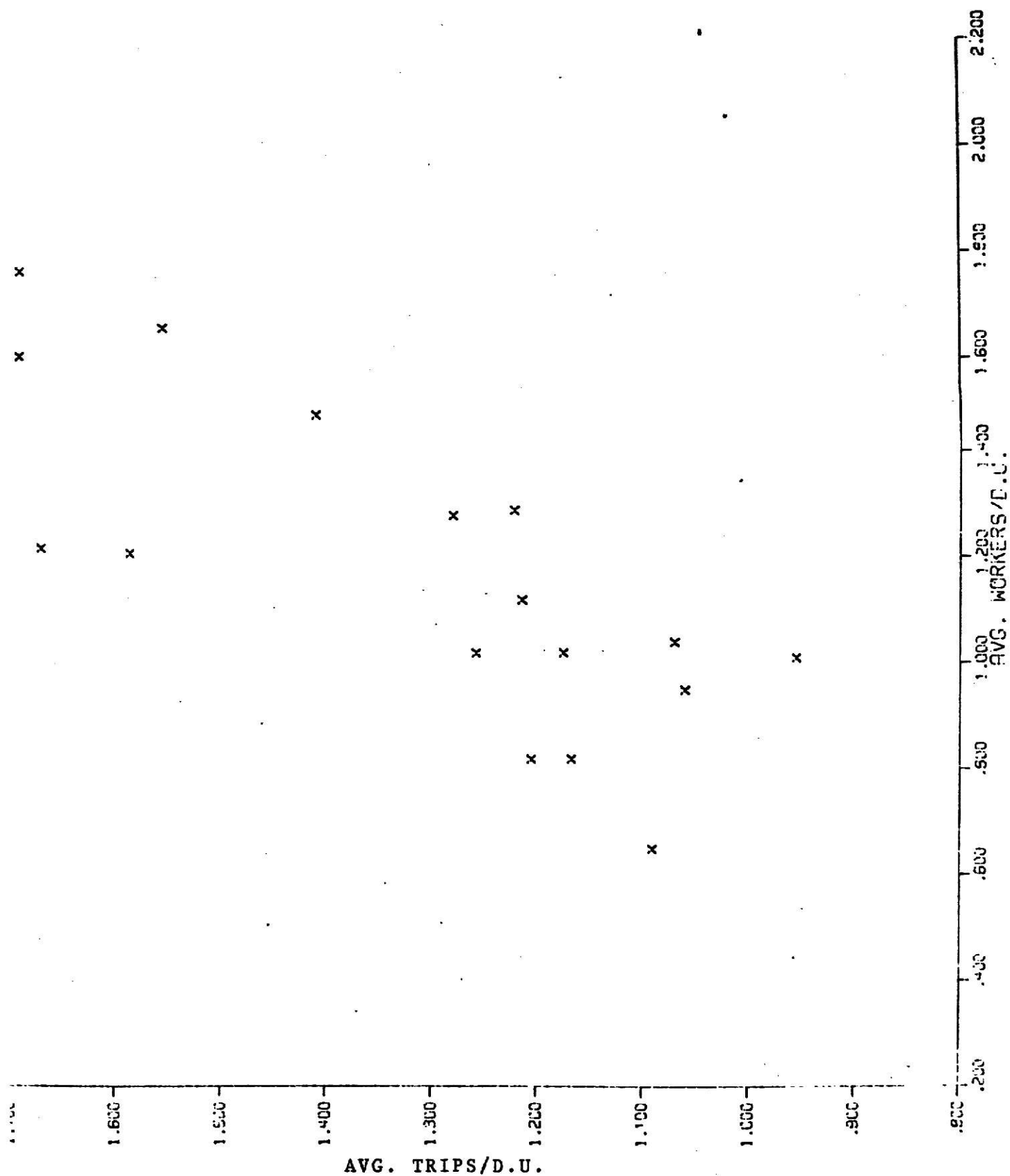


Figure 16: Average Workers/D.U. vs. Average Trips/D.U. Data Plot

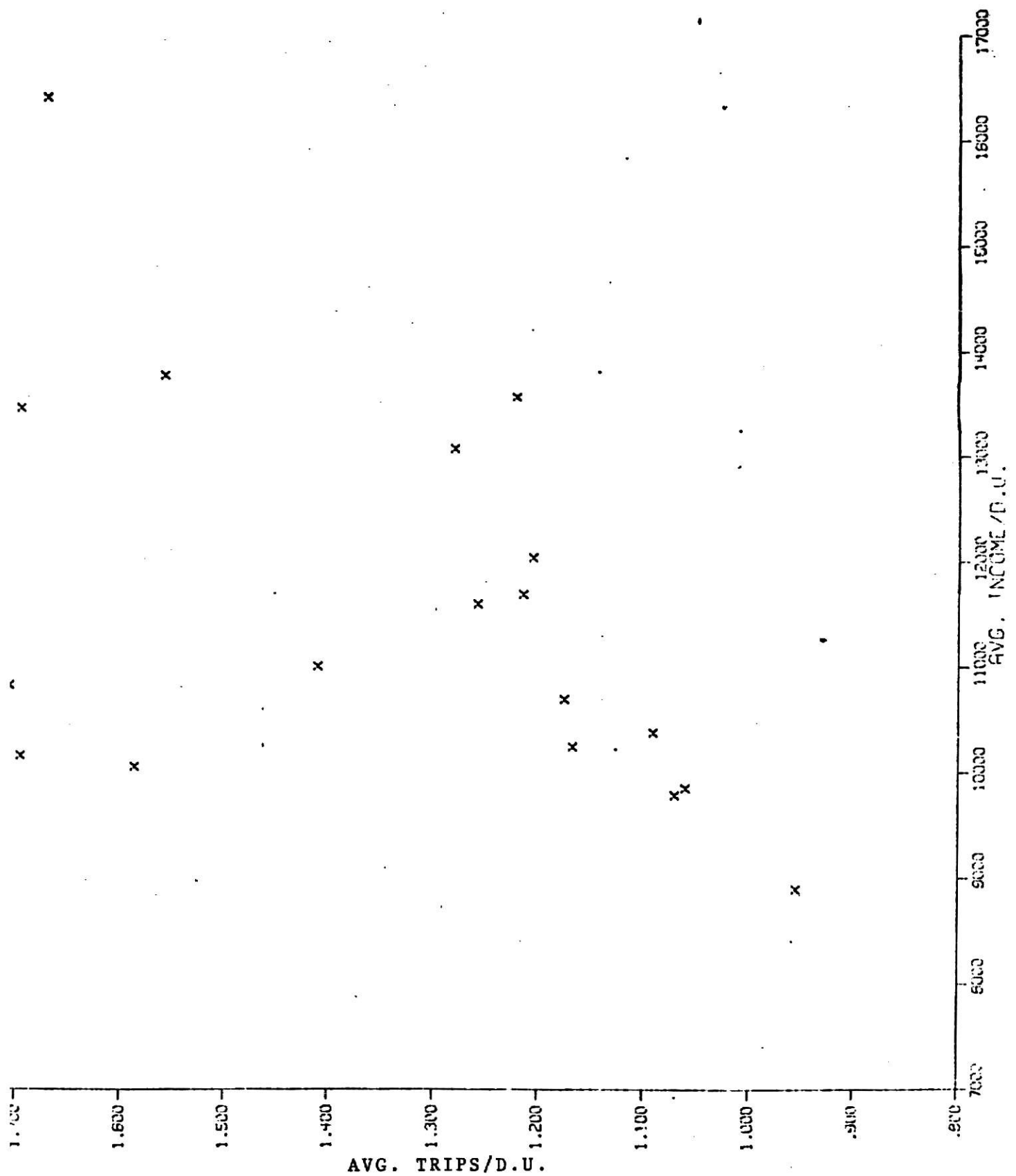


Figure 17: Average Income/D.U. vs. Average Trips/D.U. Data Plot

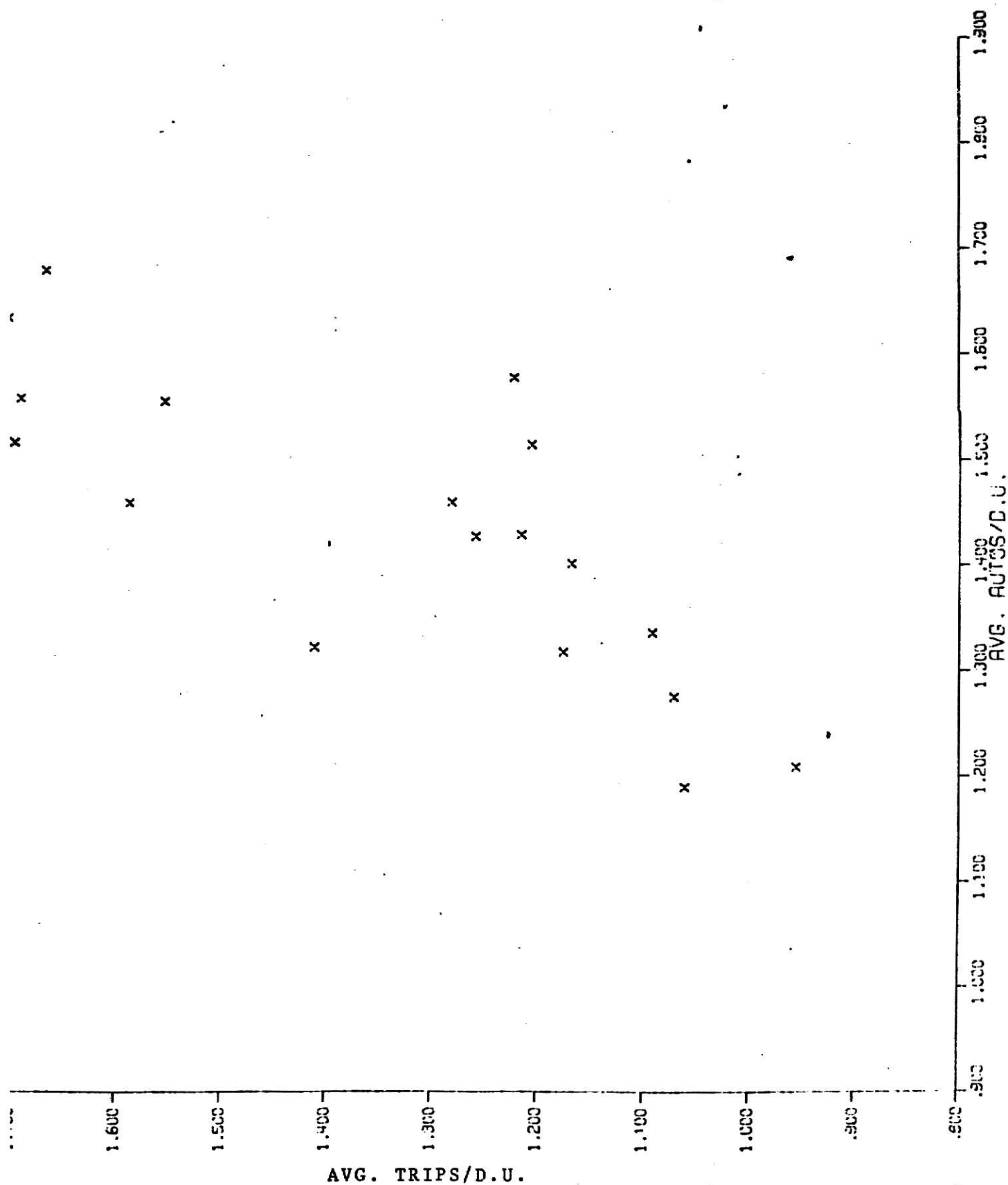


Figure 18: Average Autos/D.U. vs. Average Trips/D.U. Data Plot

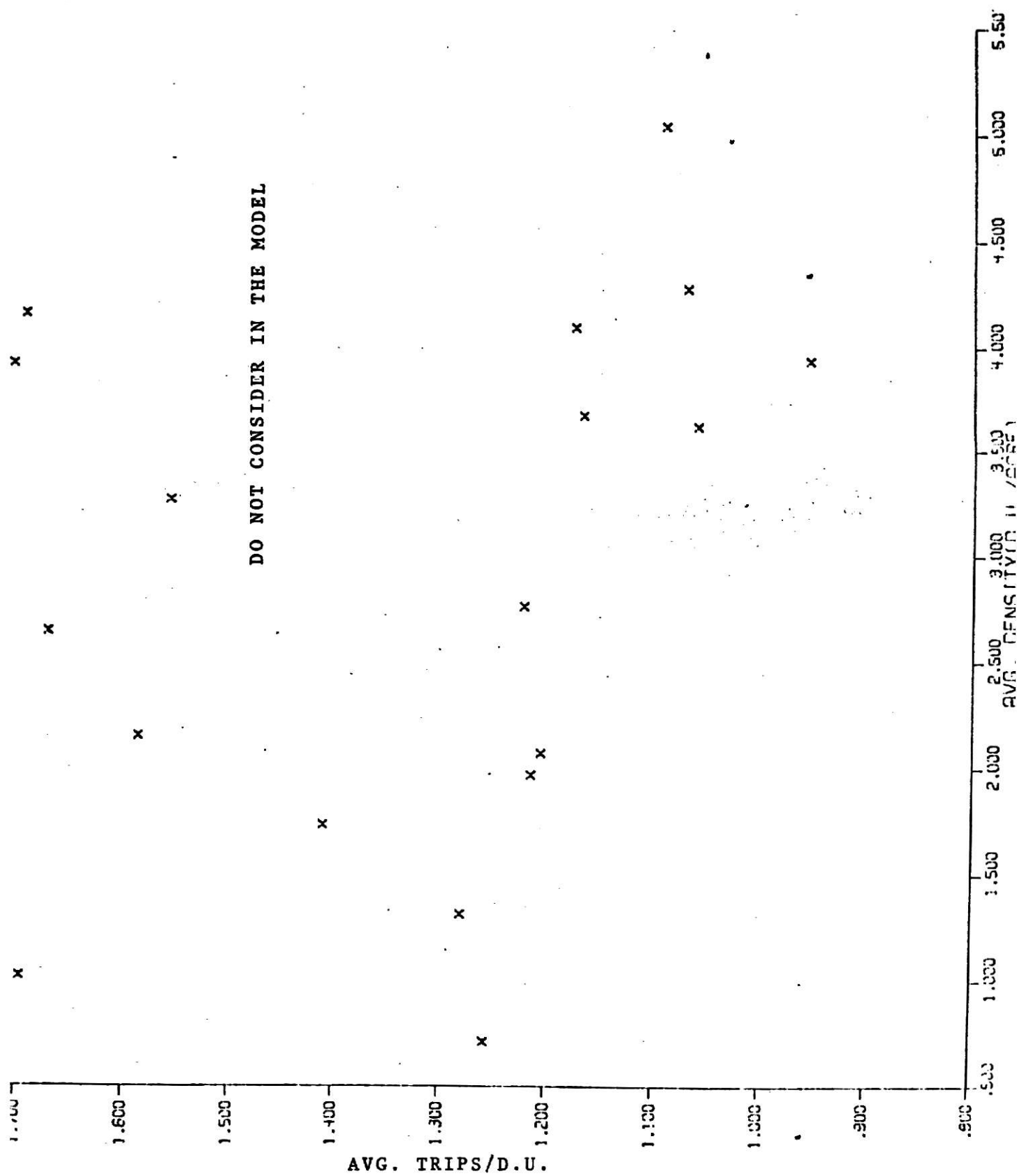


Figure 19: Average Density/D.U. vs. Average Trips/D.U. Data Plot

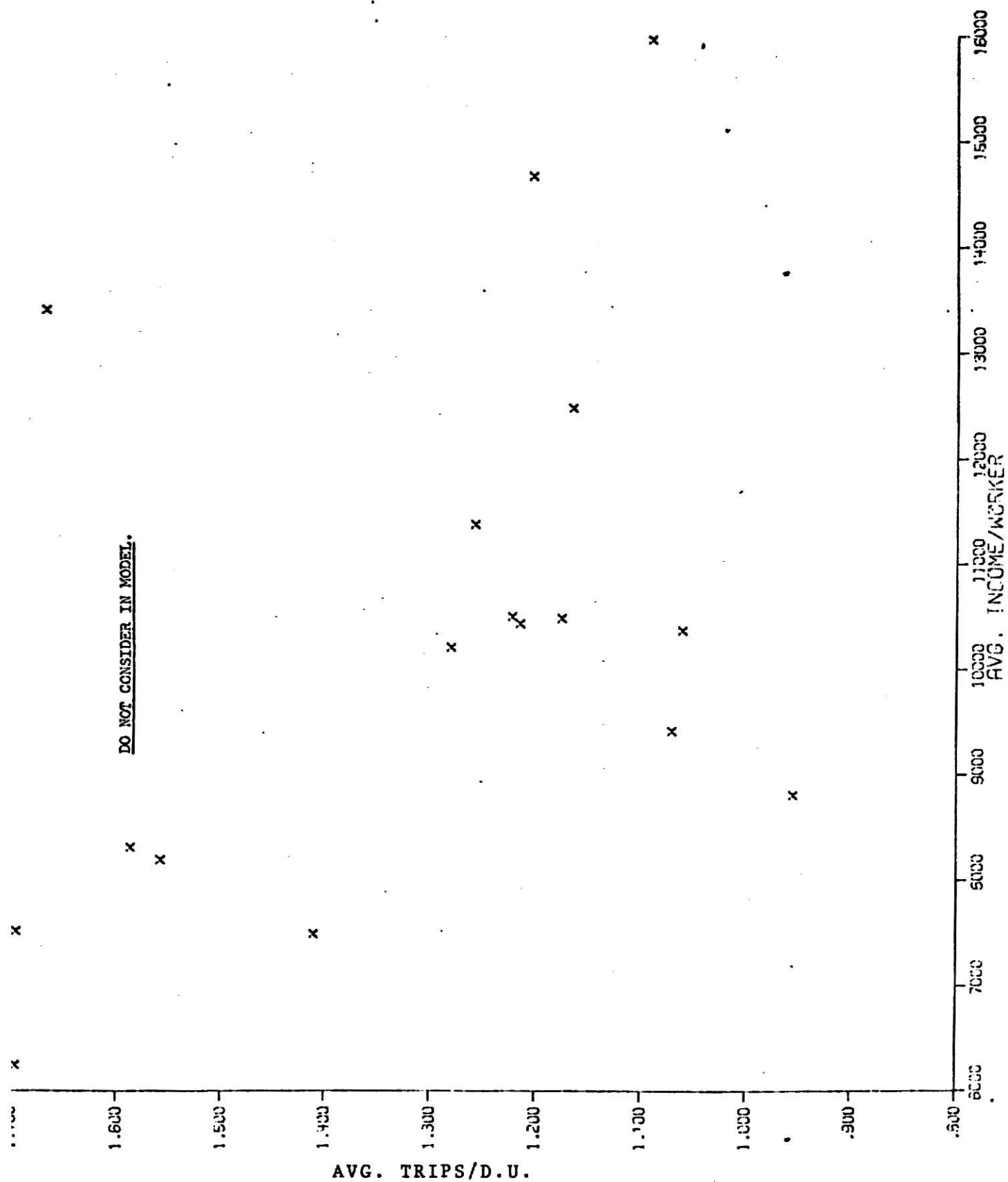


Figure 20: Average Income/Worker vs. Average Trips/D.U. Data Plot

TABLE 3
FORECASTED FUTURE TRIPS

*	*	Zonal Rates	*	Zonal Totals	*
* Zone	*	Model	*	Model*	*

* 1	*	2907	*	2765	*
* 2	*	832	*	803	*
* 3	*	3657	*	3510	*
* 4	*	1620	*	1595	*
* 5	*	2990	*	2898	*
* 6	*	2758	*	2661	*
* 7	*	1866	*	1733	*
* 8	*	2794	*	2582	*
* 9	*	2320	*	2178	*
* 10	*	2226	*	2148	*
* 11	*	1642	*	1619	*
* 12	*	4291	*	4057	*
* 13	*	2399	*	2233	*
* 14	*	1227	*	1152	*
* 15	*	532	*	503	*
* 16	*	1859	*	1757	*
* 17	*	2114	*	1987	*
* 18	*	1045	*	992	*
* 19	*	1170	*	1090	*
* 20	*	328	*	312	*
* 21	*	805	*	758	*
* 22	* CBD - No future trips forecasted*				

* Preferred Model for Prediction Purposes.

and predicted data of the three trip purposes. These plots indicate that home-to-work trips have the largest average trip length. A bi-modal characteristic in the home-to-other trip length distribution is also apparent. This characteristic indicates that the home-to-other category might warrant further breakdown into two distinct trip length populations.

Using the travel time matrix and the present trip matrices, a calibration run was, made with both the GRAVITY and OPPRTY programs. Chi-squared tests were then performed between the observed and predicted trip length distributions. The results of the chi-squared statistical tests are shown in Table 4. From this analysis the Gravity model, the two minute interval run with four iterations was selected. It can be seen from this table that the simulated, non-home based distribution did not quite satisfy the statistical criterion (the chi-squared test between the predicted and observed trip length distribution). However, since the non-home based trips are known to be a relatively small proportion of all trips and the computed and critical values of chi-square were close, it was concluded that the calibrated friction factors ($F(t)$'s), based on four iterations would be adequate. The plots of these friction factors are shown in Appendix E.

Of the two distribution models considered, the Gravity model calibrated on a two minute interval appeared to be the best, and it was adopted for use in the traffic assignment phase. The gravity model is usually superior for use in small urban areas, even though it lacks the sound theoretical basis of the opportunity

TABLE 4

SUMMARY OF CHI-SQUARE TESTS ON TRIP LENGTH
FREQUENCY DISTRIBUTIONS

* MODEL *	* TRIP PURPOSE *	* DISTRIBUTIONS *	* COMPUTED χ^2 *	* CRITICAL χ^2 *	* REMARKS *
* Gravity Model -	* Home-Work	* Obsd. vs. It. 4*	* 5.19 *	* 30.14 *	* Acceptable *
* 1 Minute Interval	* Home-Other	* Obsd. vs. It. 4*	* 7.62 *	* 30.14 *	* Acceptable *
	* Non-home Based	* Obsd. vs. It. 4*	* 71.82 *	* 30.14 *	* Not Acceptable *
* Gravity Model -	* Home-Work	* Obsd. vs. It. 4*	* 1.40 *	* 18.31 *	* Acceptable *
* 2 Minute Interval	* Home-Other	* Obsd. vs. It. 4*	* 0.07 *	* 18.31 *	* Acceptable *
	* Non-home Based	* Obsd. vs. It. 4*	* 48.05 *	* 18.31 *	* Not Acceptable **
* Opportu- nities Model	* Home-Work	* Obsd. vs. Sim. *	* 5289.75 *	* 30.14 *	* Not Acceptable *
	* Home-Other	* Obsd. vs. Sim. *	* 7788.96 *	* 30.14 *	* Not Acceptable *
* 1 Minute Interval	* Non-home Based	* Obsd. vs. Sim. *	* 3105.62 *	* 30.14 *	* Not Acceptable *
* Opportu- nities Model	* Home-Work	* Obsd. vs. Sim. *	* 3002.70 *	* 18.31 *	* Not Acceptable *
	* Home-Other	* Obsd. vs. Sim. *	* 6740.60 *	* 18.31 *	* Not Acceptable *
* 2 Minute Interval	* Non-home Based	* Obsd. vs. Sim. *	* 1792.31 *	* 18.31 *	* Not Acceptable *

** Although this test was not statistically acceptable, the Gravity Model for two minute intervals is the preferred model and will be used for future trip distributions as it is the best available.

model. This fact has been observed in other reports. The opportunity model does not calibrate well on base year data for small urban areas. It appears to take large amounts of data such as one would have from a city the size of Chicago. If the output from the trip distribution phase is questionable, then the ability of the transportation analyst to determine the best alternative plan based on the results of traffic assignment phase is considerably weakened.

Traffic Assignment and Skokie Plan Formulation

The traffic assignment phase used the trips distributed to each zone in the study area and assigns them to the existing network. The number of trips on each link can then be compared with the capacity of the link. When the traffic volume exceeds the capacity ($V/C > 1$) an obvious deficiency in the traffic system exists. To remove or alleviate these deficiencies link characteristics may be changed to improve its traffic carrying capabilities, or the excess traffic may be reduced by diverting it to another path. After the future traffic deficiencies are discovered, the real transportation planning begins. The goals of the transportation system should be established before the planning begins. Some of these goals, for example, could be: promote the accessibility to the Central Business District and new shopping center, do not separate or socially disrupt neighborhoods with transportation systems, do not route through traffic into major areas, promote safety, and do not promote a plan that exceeds the economic budget of the study area.

As previously mentioned in the report the capacity restraint function was ultimately rewritten by the author. However, it was not revised before the Skokie study was formulated. Therefore, the restraint function used for this report is:

$$t_1 = t_1^0 2^{\left(\frac{V_1}{C_1}\right)}$$

where: t_1 = time required to traverse link 1, if volume on the link is V_1

t_1^0 = time required to traverse link 1

V_1 = traffic volume assigned to link 1

C_1 = design capacity of link 1

The steps of the traffic assignment process of the Purdue Teaching Package was applied to the Skokie area. First the present trips were assigned to the existing network. This base-year assignment process has two purposes, to check the creditability of the model (not possible in this case), and to point out deficiencies in the present network. (See Figure 1, Appendix F) Since there were not any traffic counts of the study area available, the accuracy of the model in distributing base year traffic could not be checked. Next, the design year total trip matrix was assigned to the existing network. (See Figure 2, Appendix F) The deficiencies of the original network with future traffic assigned were used as a starting point for future improvements. Criteria were established for evaluating these improvements, such as; (1) a volume to capacity ratio not exceeding one is acceptable, (2) removal of parking is considered before widening on an arterial,

(3) construction of new streets or expressways should be minimized, and (4) minimize through traffic in the Central Business District.

The deficiencies that existed from the future trips being assigned to the present network were plotted on the network diagram as shown in Figure 2, Appendix F. By using the selected link option, the origins and destinations of all trips for the link specified were printed. With this information, alternate plans can be proposed to eliminate the estimated deficiencies.

Several alternatives were investigated, but the alternative shown in Figure 3 was chosen as the best plan. This alternative involved the creation of a north-south pair of one-way streets around the CBD involving nodes 75-109-76-80 and 80-107-108-75. A second one-way pair running east and west was created with the routes 78-76-107-77 and 77-108-109-78. Additional one-way links were made by upgrading local streets. The entire route between nodes 79 and 24 was upgraded by removing parking and widening streets. The route between 73-75-70-55 was upgraded by removing parking and widening the streets. With this plan most of the system showed a V/C ratio less than 0.5, with only route 73 to 69 with a V/C greater than 1.

In addition the following links had to have the capacity increased by widening or the removal of parking or both: 28-29, 28-30, 24-25, 23-37, 43-44, 88-93, 104-105, 90-91, and 65-85.

It should be pointed out that there is no "perfect" or the "best" solution to the transportation problem. It must be remembered that planning packages are only tools, and must be

used with judgment. This fact is especially apparent when using a teaching package and emphasize the idea that the planner should never replace his own good sense, basic thinking and judgment with a planning package.

"PITTSBURG, KANSAS" TRANSPORTATION STUDY

This study also utilized the Purdue Teaching Package to provide a plan for future transportation facilities in Pittsburg, Kansas. The study was based on the results of a comprehensive origin-destination survey conducted in the Pittsburg Metropolitan Area in 1961. These travel patterns, with the use of the teaching package, have been projected to the design year 1981.

Inventories for this study were primarily obtained from a Transportation Survey written in 1962 by Burgwin and Martin, Consulting Engineers, in cooperation with the State Highway Commission of Kansas. Data taken from this report included: street classifications and widths, parking characteristics, intersection controls, land use, travel times, and 1981 projected zonal percent increases in internal driver trips. The 1961 trip matrices for the three trip purposes were obtained from the State Highway Commission.

The first step in this planning process was to code the network for 22 zones. The coded network was quite similar to that used in the State Highway Commission Study except that only 22 zones and one load link could be used. After the network was coded, the link data cards were punched and used in the NETANAL program to determine the zone-to-zone travel times. The design year productions and attractions were determined by applying the factors given in the table on the following page. Since this table was used to find the 1981 productions and attractions, it was not necessary to make a trip generation analysis.

TABLE 5

INTERNAL DRIVER TRIP ENDS BY ZONES
1961 - 1981

<u>ZONE</u>	<u>1961 DRIVER TRIP ENDS</u>	<u>1981 DRIVER TRIP ENDS</u>	<u>PER CENT INCREASE</u>	<u>ZONE</u>	<u>1961 DRIVER TRIP ENDS</u>	<u>1981 DRIVER TRIP ENDS</u>	<u>PER CENT INCREASE</u>
59	19,736	37,522	90.1	77	3,788	6,213	64.0
60	4,603	6,647	44.4	78	2,538	4,122	62.4
61	2,799	3,922	40.1	79	7,040	13,334	89.4
62	1,933	3,104	60.6	80	4,469	9,466	111.8
63	3,508	5,221	48.8	81	4,141	8,272	99.8
64	953	1,235	29.6	90	1,253	2,203	75.8
65	3,959	5,792	46.3	91	233	699	200.0
66	2,702	4,414	63.4	92	363	1,377	279.3
67	2,544	3,676	44.5	93	163	421	158.3
68	5,741	8,807	53.4	94	775	1,426	84.0
69	3,161	4,580	44.9	95	427	635	48.7
70	2,381	3,463	45.4	96	88	157	78.4
71	3,851	5,410	40.5	97	52	79	51.9
72	3,567	5,143	44.2	98	3,678	6,901	87.6
73	5,523	9,438	70.9	99	2,635	4,968	88.5
74	2,599	4,043	55.6	TOTAL	105,859	180,358	70.4
75	2,424	3,851	58.9				
76	2,232	3,817	71.0				

Trip Distribution

The travel time matrix and observed travel matrices for each trip purpose were input into both programs GRAVITY and OPPRTY. The models were both calibrated and it was discovered through the use of the chi-squared statistical test that the gravity model calibrated on a two minute interval provided the best model. The model was therefore selected to distribute the trips for use in the traffic assignment phase.

Traffic Assignment

The first step in the traffic assignment phase was to assign the observed total trip matrix obtained from the distribution model to the existing network. This analysis indicated that there were some deficiencies in the existing network when the present trips were assigned. These problems were especially evident in the Central Business District. Angle parking should be changed to parallel in the CBD adjacent to Fourth Street and Broadway to alleviate the existing capacity deficiencies. This reduction in parking spaces should be offset by the creation of off-street facilities which is sometimes difficult.

The next step taken in the assignment process was to assign the future trip matrix to the existing network. This analysis estimated several deficiencies in the existing network during the design year. The following revisions were then made in the network in attempt to reduce the deficiencies:

1. Change angle parking to parallel parking in the CBD.
2. Revision of the one-way street system.
3. Provision for a north-south expressway.
4. Restricting parking or widening some overloaded links.

These revisions reduced the volume to capacity ratio to below one on all links except those next to a load link. The load link connects the zone centroid to the street network. Those next to a load link were overloaded due to the restriction in the program which allows only one load link per zone. These overloaded links were therefore ignored, and the recommended plan was established.

OTHER URBAN TRANSPORTATION ANALYSIS PROGRAMS

UMTA Transportation Planning System (UTPS)

This package was developed by the Urban Mass Transportation Administration and is a collection of IBM System/360-370 Computer programs for use in planning multimodal urban transportation systems. The objective of UTPS is to provide readily available, easy-to-use, and fully tested planning tools to transportation planners, for application to a wide variety of problems. The user's documentation manual and test procedures for all UTPS programs have been bound and will be submitted with this report. This manual contains all of the JCL needed to use the UTPS package.

The methodologies of UTPS are new and are being continually refined by UMTA. In its current release, UTPS consists of the following computer programs:

<u>Program Name</u>	<u>Function</u>
UFMTR	Prints selective, element by element, visual comparison of two to six matrices and optionally their trip end summaries. Plots trip-length distributions. Provides graphic comparisons of matrices.
ULOAD	Assigns trips to elements of the transportation system using the shortest (weighted) time paths.
UMCON	Copies, merges, modifies, and/or converts matrices such as trip tables, skim trees, etc.
UMNIP	Performs arithmetic operations (addition, subtraction, multiplication, division) on cells of a matrix using a scaler or another matrix.
UMODEL	General purpose program for demand estimation. Outputs up to nine trip tables for various modes and submodes, as well as calibration statistics.

<u>Program Name</u>	<u>Function</u>
UNET	Generates datasets describing the transit system and network for use by other programs' based on link and line data cards. Produces reports and plots describing the network.
UPATH	Computes the shortest (weighted) interzonal transit paths and a zone-to-zone fare matrix.
UPRAS	Produces additional detailed assignment reports and plots based on output of uload.
UPSUM	Generates up to twelve zone-to-zone matrices giving the component parts of the weighted time path between each zone.
UREGRE	A generalized linear multiple regression program for developing and calibrating mode choice models.
UROAD	A generalized highway traffic assignment model, which finds shortest paths, skims paths for interzonal costs, times, and distances, loads paths with all-or-nothing, stochastic, and/or capacity restraint techniques.
USQUEX	A matrix compressing and expanding program.
USTOS	Generates a station-to-station trip matrix and/or access/egress station matrices.

The programs are written in Fortran IV, (H), Cobol, and 360 assembly language using the full operating system/360. All of the programs are interdependent in that one creates or reads the input or output of another.

The reference manual which accompanies this report may be reproduced by executing the cataloged procedures described in Chapter Five of the manual. The following table summarizes the contents of the reference manual:

TO LEARN HOW TO:	READ CHAPTER(S)					
	II	III	IV	V	VII	VIII
Install UTPS				X		
Print a program writeup			X	X		
Read a program writeup			X			
Use cataloged procedures	X					
Prepare data for a program		X				X
Test a program	X			X		
Modify a cataloged procedure					X	
Print a transit network develop manual				X		

The application of UTPS in Kansas and some other states will be limited. UTPS is primarily used for large cities which have a multimodal transportation system. Extensive transit surveys are required to use the package. The FHWA program is more realistic for use in areas where automobiles is the primary transportation mode.

Urban Planning System 360 (FHWA)

The Urban Planning System 360 program battery was developed by the Federal Highway Administration (FHWA). The purpose of the package was to develop programs for use in urban and statewide transportation studies. Two documents have been written to facilitate the user in implementation and utilization of this program battery. The first document is a general information

guide which provides the necessary background of the urban transportation planning process. It is intended to provide information related to the computer applications. The second document is titled, "Urban Planning System 360--Program Documentation," and contains the required information for utilizing each program in the battery. The description contained in the general information document provides a basis for the use of the program documentation manual. System flow charts for the FHWA package are shown in Figures I-3 through I-9 in the general information document.

The FHWA package was not utilized in this study, except to provide the methodology to use other urban transportation programs. It is recommended that this package be utilized at Kansas State University for complete and accurate transportation plans. However, for educational purposes the Purdue Teaching Package is more efficient and economically feasible.

California Teaching Package

This computer package was developed over a period of years at the Institute of Transportation and Traffic Engineering, University of California. Similar to the Purdue Teaching Package this package was written with an educational objective in mind. Each program performs one step at a time, which permits the students to see the results and review them prior to proceeding to the next step. Teaching packages can usually be refined to be more efficient and faster, but these changes typically destroy their main purpose of being an educational tool.

The California teaching package has been written for an IBM 1620 (20K, disk) computer in Fortran II-D. The program could be used on the IBM 360 with very minor alterations. The changes necessary include adjusting control cards, elimination of references to the on-line typewriter and modification of dimension cards so as to permit work with larger networks, if necessary.

Since the Kansas State University computer facility has an on-line printer, all output statements for the package should be reviewed. Any punched output which will not become input for a subsequent program can be routed to the printer from the on-line typewriter. The output can be printed by changing the PUNCH statement to PRINT. This saves the unnecessary use of cards and makes the output easier to read. Output which must remain in card format could also be printed. Care must be taken, however, when replacing a PUNCH statement that is within a loop.

This program has been partially keypunched and will be submitted with this report. The author regrets the fact that no test data could be run this semester because of the time element involved. It is felt, however, that with less than one semester's work that this program could be fully operational. The changes that need to be made to convert this program to the IBM 360 are minimal and require little background in computer science. After this program is operational the possibilities of comparisons and future research with the various computer transportation models is unlimited.

CONCLUSIONS

The application of computers to transportation planning has enhanced the development of the profession. It is physically impossible for the large quantities of data collected in origin and destination surveys to be processed manually in a form usable by transportation planners. Large scale computer programs were assembled to process the data and provide a tool for generating alternative transportation plans.

Two large scale urban transportation planning programs have been assembled by the Federal Highway Administration (FHWA) and Urban Mass Transit Association (UMTA). The programs written by the Federal Highway Administration are now extensively used by the majority of State highway departments. The FHWA programs are extremely useful in all phases of planning a state transportation system. The programs written by UMTA are more adaptable for use in multimodal urban areas. Both of these packages utilize large amounts of computer storage and time, and are therefore expensive to use.

The Purdue and California Teaching packages provide a means to study small urban areas without using large amounts of computer time. The objective of these programs is not to provide a transportation plan, but to educate students about the urban transportation planning process. The programs are written so that computer time is minimized.

There are several areas where continued projects would be beneficial. The possible areas include:

1. Setting up the FHWA and UMTA programs on the KSU installation.
2. Making the California Teaching Package fully operational on the IBM 360.
3. A comparison of the teaching packages to the large scale programs.
4. Provide a subroutine that will average the volume-to-capacity ratios for all iterations in the Purdue Teaching Package.
5. Examination of the effect of modifying the dimensioning of the teaching package so as to permit work with larger networks.

One of the more important items learned this semester is that to understand computers, one must work at it and run programs but it can be easily learned with adequate effort. Another item realized was that a large scale transportation plan would be impossible without the aid of the computer.

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APPENDIX A

**PURDUE TEACHING PACKAGE
USERS DOCUMENTATION MANUAL
FOR
TRIP GENERATION
TRIP DISTRIBUTION
TRAFFIC ASSIGNMENT**

**ORIGINALLY WRITTEN AT
PURDUE UNIVERSITY,
AND
REVISED AT
KANSAS STATE UNIVERSITY**

GENERAL DESCRIPTION

The program package consists of a set of four computer programs devised as a teaching aid in Urban Transportation Planning. These programs carry out

1. Trip Generation
2. Trip Distribution
3. Network Assignment

Trip Generation is carried out by the use of regression analysis. Trip Distribution can be carried out by the use of a Gravity Model and an Opportunity Model. In each case, it is necessary to calibrate the model on one set of data for a specific location, after which it may be used for distribution, unless a set of $F(t)$'s or L values can be provided for the location. Network assignment is carried out as an all-or-nothing assignment with optional capacity restraint. It is based on a version of Moore's Algorithm for minimum time paths through a network.

Data Requirements

In order to use this package to forecast future trips, the following data are necessary:

1. Zone and Coded network system for the study area
2. Production and Attractions (P 's and A 's) for each zone in the study area
3. Relevant zonal parameters for present and forecast year
4. Trip time matrix (for all inter- and intra-zonal movements)
5. Trip matrix for the study area

All other information can be generated by the package. In addition to Item 2, it may be desirable to use a trip matrix Item 5 as input to the calibration of the distribution models.

Internally Generated Data

The internally generated data can be summarized as follows:

1. From regression trip generation - future P 's and A 's
2. From distribution - future total trip matrix

The future P's and A's obtained from the trip generation are input for the distribution mode of the Gravity and Opportunity Model. The present trip matrix can be assigned by using either the same trip matrix as item 5 in the previous section or the optional punched output of the calibration mode of the distribution model. The future trip matrix is assigned by obtaining the punched output of total trips from the distribution mode of the distribution models.

Limitations

These programs are designed as teaching aids rather than large-scale, sophisticated U.T.P. programs. In their present form the input-output phases of the distribution and assignment programs are rigidly laid out and must be observed. The programs will accept up to a maximum of a 22 zone system with 150 nodes in the network. Higher maxima can only be used if the input, output and program control subprograms are rewritten.

GRAVITY MODEL

Program Description

The program called GRAVITY represents one version of the familiar gravity model for trip distribution. The model divides the trip distribution process into three distinct parts.

The first part involves tabulating and plotting the observed data. A travel time matrix and the several trip matrices are printed. The total travel is tabulated by time increments and the results shown both in tabular form and graphically on a Calcomp plot.

The second part involves calibrating the gravity model, based on the existing trip patterns. The model calculates a set of friction factors, called $F(t)$'s, for each trip purpose by an iterative process. The various trip matrices, travel distributions, and current set of friction factors are printed and plotted at the end of each iteration to illustrate model convergence.

Calibration must be made on the existing trip matrices, and a set of produced and attracted trips, called P's and A's, representing the existing situation. Also, the user may insert a set of initial friction factors or allow the model to set the initial values of the $F(t)$'s equal to one. Finally, the model may be calibrated on either one or two minute intervals. Another option provides punched output of the final $F(t)$'s to be used as input to the third part.

The third part of the process involves trip distribution. Here, one or more sets of predicted future produced and attracted trips for each zone and trip purpose are distributed according to a set of $F(t)$'s obtained during calibration or from some other source. Again, trip matrices, travel distributions, and friction factors are printed and plotted for each set of P's and A's specified. In addition, the final total trip matrix may be punched out to be used as input to the network assignment program.

The three parts of the model may be carried out by separate runs, all together, or in various combinations. The appropriate inputs, discussed below, must be included, of course.

The model is currently constrained to run on exactly 22 zones and for three trip purposes, namely home to work, home to other, and non-home based. For computational efficiency the user may select only one of these trip purposes, if desired.

The basic gravity model formulation used in this model is the following:

$$T_{ij} = \frac{P_i A_j F(t)_{ij}}{\sum A_j F(t)_{ij}} \quad i, j = 1, 2, \dots, 22$$

where T_{ij} represents the one-way trips from zone i to zone j ,

P_i represents the total produced trips from zone i ,

A_j represents the total attracted trips to zone j , and

$F(t)_{ij}$ represents the friction factor based on the time distance between zones i and j .

A separate model is developed for each trip purpose specified.

Program Operation

The various system, control, and data cards needed for running program GRAVITY under each of its various options will be discussed below:

A. System cards:

1. Allow central memory requirement of 72000₈.
2. A time limit of 60 seconds should be adequate for most usages of the model.
3. Set up for plotting.
4. Line count may be 6000 or more depending upon the usage of the model.

B. Program GRAVITY Fortran deck.

C. End of record card.

D. Program control card:

1. col. 1, option code:
 - 0 - calibrate but do not tabulate observed data
 - 1 - tabulate observed data only; no calibration
 - 2 - tabulate observed data and calibrate
 - 3 - distribution only (see general note #1) distribution is optional with codes 0 and 2; see 9 below.

2. col 2-4: YES if P's and A's are included for calibration
NO or blank if trip matrix alone is used for calibration.
3. col 5: 1 if calibration is to be done on 1 minute intervals.
2 if calibration is to be done on 2 minute intervals.
(See note 5 below.)
4. col 6-8: YES if a table of $F(t)$'s are to be supplied.
NO or blank if $F(t)$'s are to set equal to one initially.
5. col 9-11: Number of $F(t)$'s to be read in. (see note 2 below)
6. col 12: Number of iterations for calibration, typically 3-5.
7. col 13: First trip type included. (see note 3 below)
8. col 14: Last trip type included. (see note 3 below)
9. col 15-17: YES if P's and A's for distribution are included.
NO or blank if no distribution is desired.
10. col 18: Number of sets of P's and A's to be distributed, 0-9.
11. col 19-21: YES if final $F(t)$ values are to be punched out.
12. col 22-24: YES if final total trip table is to be punched out.
(see note 4 below)

Notes: 1) All characters must be right-justified on control card.

- 2) As an example, if interzonal travel times range from 0 to 44 and calibration is on 1 minute intervals, 44 $F(t)$'s would be inserted. 22 $F(t)$'s would be inserted for calibration on two minute intervals. If the largest time is an odd number, such as 45, 23 $F(t)$'s would be required for a 2 minute calibration. The maximum number of $F(t)$'s is set at 100.

Notes: 3) Trip type combinations available:

	col. 13	col. 14	
a)	1	1	home to work only
b)	2	2	home to other only
c)	3	3	non-home based only
d)	1	2	home to work & home to other
e)	2	3	home to other & non-home based
f)	1	3	all trip types plus total trips

See also general note #2.

- 4) Total trip matrix should be punched only when trip type combination (f) above has been specified.
- 5) If distribution only is being run, either 1 or 2 is still required to be punched here.

E. Travel time matrix:

The travel time matrix consists of 22 cards punched as follows:

(10x, 22F3.1)

The data is case-wise by rows; that is, each card represents the travel time from that zone to every other zone. The zone number and identifier TT are punched in cols. 1-10.

F. Trip matrices:

The three trip matrices each consist of 22 pairs of cards punched in the following format:

(10x, 11F6.0/10x, 11F6.0)

This data is also case-wise by rows. The zone number, the code A or B denoting the first or second card, and the identifiers HW, HO, or NH are punched in cols. 1-10.

The three matrices are inserted in the order of:

- 1) home to work
- 2) home to other
- 3) non-home based

G. Produced and attracted trips for calibration:

If a set of P's and A's are desired for calibration (YES in cols. 2-4 on the control card), they are inserted here as follows:

(10X, 11F6.0/10X, 11F6.0)

Only twelve cards are required, which are inserted in the following order:

- 1) home to work productions
- 2) home to other productions
- 3) non-home based productions
- 4) home to work attractions
- 5) home to other attractions
- 6) non-home based attractions

Columns 1-10 contain the identifier HWP, HOP, HWA, HOA, or NHA, plus the code A or B for the first or second card. Card A contains data for zones 1-11; card B for zones 12-22.

H. F(t) table:

If a set of F(t)'s are to be furnished (YES in cols. 6-8 on the control card), the cards are inserted here according to the following format:

(10X, 3F10.0)

One card is provided for each time interval (punched in cols. 1-10 along with the appropriate minute interval identifier MIN 1 or MIN 2) with the $F(t)$'s for all three trip types on each card. Home to work $F(t)$'s appear in cols. 11-20, home to other in 21-30, and non-home based in 31-40. The data should appear as a keypunched decimal and may appear anywhere in the field.

I. Produced and attracted trips for distribution:

P's and A's for distribution are inserted here if YES appears in cols. 15-17 on the control card. The format is the same as discussed in (G) above. Up to 9 sets of P's and A's may be inserted, in sequence, as specified in col. 18 of the control card.

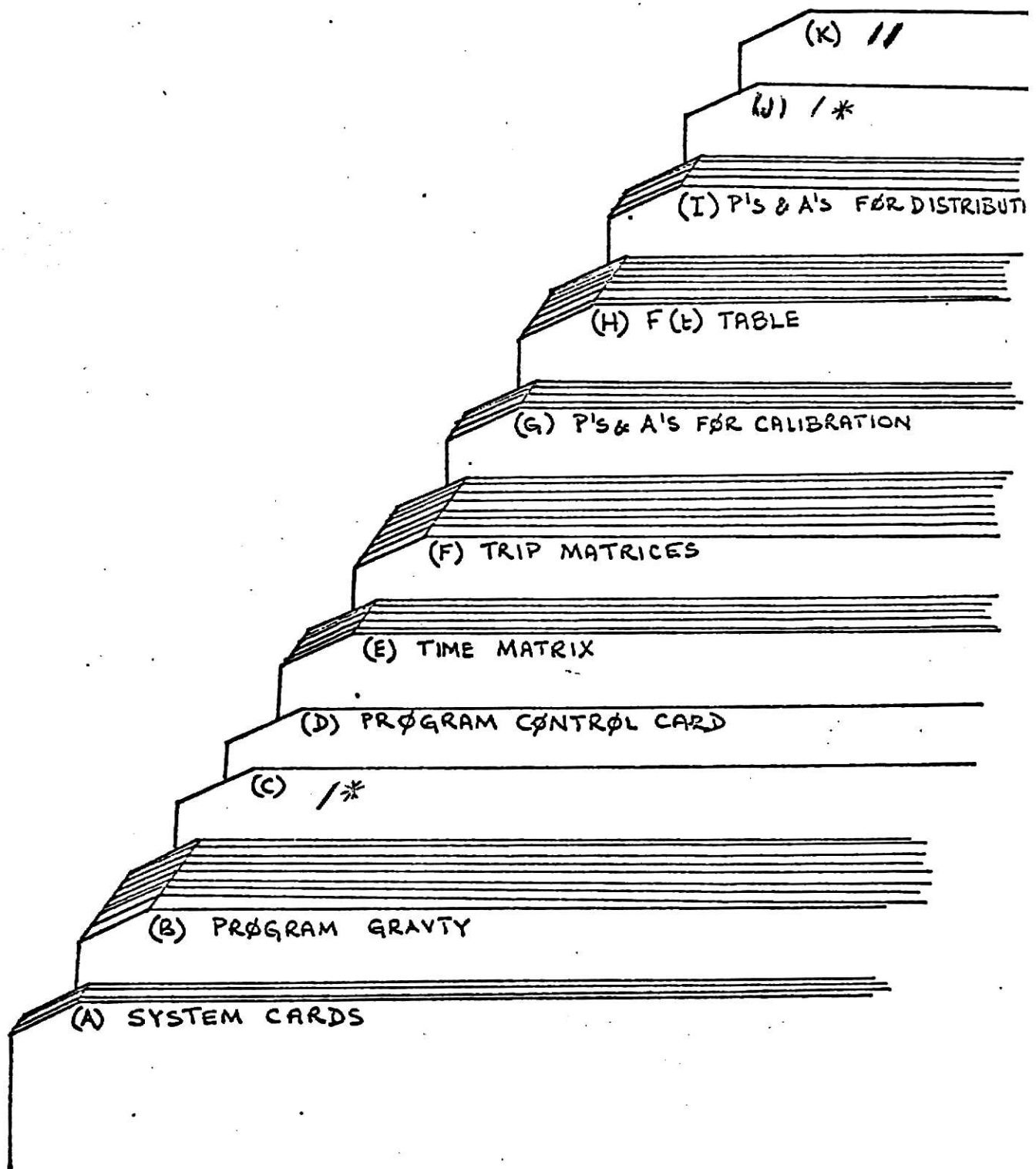
J. End of record

K. End of information (6-7-8-9 in column 1)

General Notes:

1. When the model is used for distribution only (option code 3 in col. 1 of the control card), items (F) and (G) above must be omitted. Items (E), (H), and (I) must be included in full.
2. Data for all trip types must be included even if only one trip type is specified in cols. 13 and 14 on the control card.
3. Punched trip matrices may be obtained as output from either the calibration or distribution phases.
4. Care must be taken at all times to insure that consistency among parameters and between parameters and data input is maintained.

GRAVITY DECK STRUCTURE



OPPORTUNITY MODEL Program Description

The program called OPPRTY represents one version of the intervening opportunities model for trip distribution. The model divides the trip distribution process into three distinct parts

The first part involves tabulating and plotting the observed data. A travel time matrix and the several trip matrices are printed. The total travel is tabulated by time increments and the results shown both in tabular form and graphically on a Calcomp plot.

The second part involves the calibration of the opportunity model, based on the existing trip patterns. The model calculates a set of probabilities, called L-values, for each zone and for each trip purpose by an iterative process. The various trip matrices, travel distributions, and the final calibrated L-values are printed out to represent the simulated current trip pattern obtained by using the model.

Calibration must be made on the existing trip matrices, and a set of produced and attracted trips, called P's and A's, representing the existing situation. Also, the user must specify an initial L-value to begin the calibration procedure and an allowable error in closure between successive iterations. Alternatively, a matrix of different L-values for each zone and purpose may be read in. The final L-values for each zone may be punched out to be used as input to the third part.

The third part of the process involves trip distribution. Here, one or more sets of predicted future produced and attracted trips for each zone and trip purpose are distributed according to a set of L-values obtained during calibration or from some other source. Again, trip matrices, travel distributions, and L-values are printed and plotted for each set of P's and A's specified. In addition, the final total trip matrix may be punched out to be used as input to the network assignment program.

The first two parts of the model are carried out together. The third part may be accomplished as a separate run or together with the first two. The appropriate inputs, discussed below, must be included, of course.

The opportunity model formulation used in this model is the following:

$$T_{ij} = O_i [\exp(-L_i V_{i,j}) - \exp(-L_i V_{i,j+1})]$$

where: $\exp(xx)$ represents e^{xx} ,
 T_{ij} represents the one-way trips from zone i to zone j,
 O_i represents the trip origins (productions) from zone i,
 L_i represents the probability of a destination from zone i being accepted if it is considered, and

$V_{i,j}$ represents the possible destinations already considered from zone i , or the subtended volume.

A separate model is developed for each trip purpose specified.

Calibration is carried out on the basis of a single mean trip length using the relationship:

$$L_i = F(L_i) = \frac{L_i \sum_{j=1}^n d_{oj} [\exp(-L_i V_{i,j}) - \exp(-L_i V_{i,j+1})]}{\bar{r}_o [1 - \exp(-L_i V_{i,n})]}$$

where: \bar{r}_o represents the average trip length from zone o ,
 d_{oj} represents the distance from zone o to zone j ,
 n represents the total number of zones,
 and other parameters as above.

This calibration scheme and model formulation was developed by Earl R. Ruiter of the Chicago Area Transportation Study and is described in more detail in Highway Research Record 165, in an article entitled "Improvements in Understanding, Calibrating, and Applying the Opportunity Model". The user is directed to this article for a more complete discussion of the model.

Program Operation

The various system, control, and data cards needed for running program OPPRTY under each of its various options will be discussed below:

A. System Cards:

1. The central memory requirement for this program should be denoted as CM70000.
2. A time limit specification as 40 seconds should be adequate for most usages of the model.
3. Set up for plotting.
4. Line count may be 5000 or more depending upon the usage of the model.

B. Program OPPRTY Fortran Deck.

C. End of record card.

D. Program control card:

1. col. 1, option code:

- 0 - tabulate observed data and calibrate.
- 1 - distribution only. (see general note #1.)

Distribution is optional with code 0; see.8 below.

- 2. Cols. 2-4: YES if P's and A's are included for calibration. NO or blank if trip matrix alone is used for calibration.
- 3. cols. 5-14: Initial L-value for calibration; typically 10^{-3} to 10^{-6} as a keypunched decimal; i.e., 0.0001 (see general note #1)
- 4. cols. 15-24: Allowable error in closure for L-value calibration; typically $\frac{1}{2}$ to 5% as a keypunched decimal; i.e., 0.01 (see note 1 below)
- 5. cols. 25-26: Maximum number of iterations for closure, typically 20-40.
- 6. cols. 27-29: YES if all produced trips should be forced into distribution. NO or blank otherwise.
- 7. cols. 30-32: YES if table of L-values is to be read in. NO or blank if initial L-values are to be set equal to the value appearing in cols. 5-14.
- 8. col. 33: First trip type included. (see note 2 below)
- 9. col. 34: Last trip type included. (see note 2 below)
- 10. cols. 35-37: YES if P's and A's for distribution are included. NO or blank if no distribution is desired.
- 11. col. 38: Number of sets of P's and A's to be distributed, 0-9.
- 12. col. 39-41: YES if final L-values are to be punched out.
- 13. cols. 42-44: YES if final total trip table is to be punched out. (see note 3 below)

Notes: 1) All characters except items 3 and 4 above must be right-justified on the control card. Items 3 and 4 may appear as a keypunched decimal anywhere in the appropriate field.

2) Trip type combinations available:

	col. 13	col. 14	
a)	1	1	home to work only
b)	2	2	home to other only
c)	3	3	non-home based only
d)	1	2	home to work & home to other
e)	2	3	home to other & non-home based
f)	1	3	all trip types plus total trips

See also general note #2.

3) The total trip matrix should be punched only when trip type combination (f) above has been specified.

E. Travel time matrix:

The travel time matrix consists of 22 cards punched as follows:

(10X, 22F3.1)

The data is case-wise by rows; that is, each card represents the travel time from that zone to every other zone. The zone number and identifier TT are punched in cols. 1-10.

F. Trip matrices:

The three trip matrices each consist of 22 pairs of cards punched in the following format:

(10X, 11F6.0/10X, 11F6.0)

This data is also case-wise by rows. The zone number, the code A or B denoting the first or second card, and the identifiers HW, HO, or NH are punched on cols. 1-10. The three matrices are inserted in the order of:

- 1) home to work
- 2) home to other
- 3) non-home based

G. Produced and attracted trips for calibration:

If a set of P's and A's are desired for calibration (YES in cols. 24 on the control card), they are inserted here in the following format:

(10X, 11F6.0/10X, 11F6.0)

Only twelve cards are required, which are inserted in the following order:

- 1) home to work productions
- 2) home to other productions
- 3) non-home based productions
- 4) home to work attractions
- 5) home to other attractions
- 6) non-home based attractions

Columns 1-10 contain the identifier HWP, HOP, NHP, HWA, HOA, or NHA, plus the code A or B for the first or second card. Card A contains data for zones 1-11; card B for zones 12-22.

H. L-value table:

If a set of L-values are to be furnished (YES in cols. 30-32 on the control card), the cards are inserted here according to the following format:

(10X, 3F10.0)

A total of 22 cards are provided, one for each zone, (punched in cols. 1-10) with the L-values for all three trip types on each card. Home to work L-values appear in columns 11-20, home to other in 21-30, and non-home based in 31-40. The data should appear as a keypunched decimal and may appear anywhere in the field..

I. Produced and attracted trips for distribution:

P's and A's for distribution are inserted here if YES appears in cols. 35-37 on the control card. The format is the same as discussed in (G) above. Up to 9 sets of P's and A's may be inserted, in sequence, as specified in col. 38 of the control card.

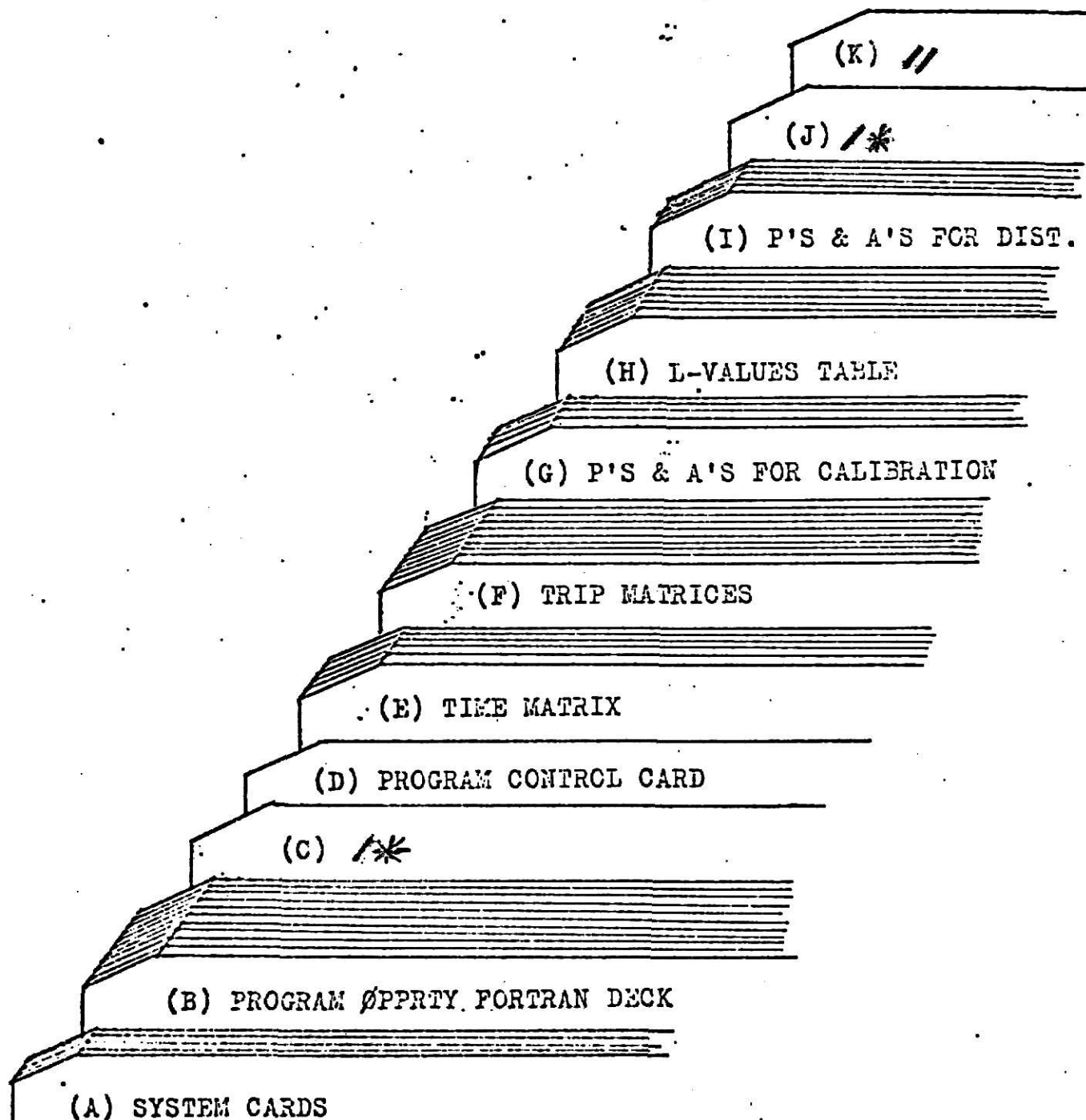
J. End of record card.

K. End of information card (6-7-8-9 multiple punch in column 1)

General Notes:

1. When the model is used for distribution only (option code 1 in col. 1 of the control card), items (F) and (G) above must be omitted. Items (E), (H), and (I) must be included in full.
2. Data for all trip types must be included even if only one trip type is specified in cols. 13 and 14 on the control card.
3. Punched trip matrices may be obtained of the observed or the distributed total number of trips.
4. Care must be taken at all times to insure that consistency among parameters and between parameters and data input is maintained.

OPPORTUNITY DECK STRUCTURE



Program Description

NETWORK ASSIGNMENT

The program called NETANAL represents a network assignment package of the network analysis type. The package may be used in one of two basic ways.

It may be used with a trip distribution model as a subroutine inside the package to generate a trip matrix for assignment. When the distribution model is incorporated in NETANAL, the output of the program will include the output of the distribution model (see, for instance, program descriptions of OPPRTY and GRAVITY).

If a trip distribution model is not included in the package, the assignment will be carried out using an input trip matrix. It is recommended that the package is used in this manner, since the inclusion of a trip distribution model makes the package inefficient in terms of use of computer core store and also generates an excessive amount of output for a single run. Even when included in the package, the distribution phase is run effectively as a separate entity, so there is nothing to be gained in running the two together.

The package, whether or not it includes a distribution model, has a number of options available. These options are:

1. Operate as a tree-building program only
2. Operate as an uncapacitated assignment model
3. Operate as an iterated capacity restrained assignment model
New trees all built at commencement of each iteration.
4. Calculate travel times from link data or use predetermined travel times
5. Obtain turning movements and originating and terminating traffic at selected nodes (selected node option).
6. Obtain an origin and destination breakdown of traffic on selected links (selected link option).
7. Impose a certain level of through traffic on the network.

The tree-building subroutine in NETANAL is based directly on Dial's version of Moore's Algorithm (see Dial, R. H. "Transit Pathfinder Algorithm", Highway Research Board, H.R.R. #205, 1967, pp. 70-74; Moore, E. F. "The Shortest Path Through a Maze", International Symposium on the Theory of Switching Proceedings, Harvard University Press, 1957). When using option 3, above, new trees are built at the commencement of each iteration of the assignment.

The program operates as an all-or-nothing assignment, i.e. all traffic is assigned to its minimum time path. Since trees are built at the commencement of each iteration only, traffic is assigned to its minimum path regardless of capacity, even in the capacity restrained option. This option causes a recalculation of a link time, based on the volume of traffic on that link in the previous iteration. The new link travel time is then used when trees are built for the current iteration.

The restraint function used is:

$$T = T_o [1 + 0.15(V/C)^4] \quad (\text{See Federal Highway Administration,}$$

"Urban Transportation Planning--General Information," Page III-15, March, 1972)

where: T = balance travel time (at which traffic (V) can travel on the subject link)

T_o = free-flow travel time; observed travel time
(at capacity, level of service "C") times 0.87

V = traffic volume assigned to the link

C = design capacity of link

The design capacity may be calculated in a number of ways. For this program, the design capacities are based on those derived by C.A.T.S., (see Lowe, E. J., "Arterial Network Coding Procedures", CATS, publication 34, February 1966.) Details of this are given in Appendix A.

If predetermined link travel times are not used in the program, a link travel time will be calculated according to the following:

The time required to traverse a specific link i under normal operating conditions is

$$t_i^o = \frac{d_i}{s_i^o} \quad \text{where } d_i = \text{length of link } i$$

s_i^o = operating speed on link i

A convenient expression for s_i^o is

$$s_i^o = \frac{21,600 d_i s_i^p}{21,600 d_i + s_i^p (s_i^p + 45) (F(n))}$$

where s_i^p = posted speed on link i

$F(n)$ = factor based on the total number of signalized intersections on link i

$$\begin{aligned} F(n) &= 0 && \text{if } n=0 \\ &= 0.5 && \text{if } n=1 \\ &= n-1 && \text{if } n \geq 2 \end{aligned}$$

This is the link time calculated by the program for option 4.

The capacity of the program is currently 150 nodes, 22 load nodes, and a maximum of 4 links per node. The maximum longest minimum time path is 900 time units. If any of these maxima are exceeded either on the control card or in the data, error messages will result and the program will fail to operate.

Program Operation

The various system, control, and data cards needed for running program NETANAL under each of its various options will be discussed below:

A. System cards:

1. The central memory requirement for this program should be denoted as CM100000.
2. A time limit specification as 60 seconds should be adequate for most usages of the model.
3. Line count may be 8000 or more depending upon the usage of the model.

B. Program NETANAL Fortran deck.

C. End of record card.

D. Program control card:

1. col. 1, assignment option code:

0 - carry out assignment and trip distribution.
1 - carry out trip distribution only.

2. cols. 11-14: The maximum number of nodes anticipated in the network. The actual number of nodes must never exceed the value given here. The maximum value that the program can accept is 150.
3. cols. 15-18: The maximum number of load nodes in the network. Maximum allowable value is 22.
4. cols. 19-22: The maximum length of a cumulative minimum time path in the Moore Algorithm tree-building program. It should normally be set to the program maximum of 900.
5. cols. 23-26: The maximum number of links from a node. Maximum value is 4.
6. cols. 27-30: The number of iterations that are desired in the assignment process. If the value is
 - 0 - only minimum time trees are built
 - 1 - one complete assignment is performed. This is an uncapacitated assignment.
 - 2,3,etc. - the specific number of iterations to be performed. Capacities are revised at the end of each iteration, prior to commencing the next iteration.
7. cols. 31-34: This value converts the link travel time (which is in seconds) into appropriate units for the assignment routine. A value of 6 is recommended for the sample data set. The travel times in output are then given in minutes x 10.
8. cols. 35-36: Trip distribution option code:
 - 0 - carry out assignment only
 - 1 - carry out trip distribution and assignment using the OPFRTY subroutine /
 - 2 - carry out trip distribution and assignment using the GRAVTY subroutine. /

/N.B. - The necessary modified trip distribution model must be included in the NETANAL deck for either of these options.
9. cols. 39-42: The value in this field applies a global factor to the amount of through traffic on all the links in the network. If zero, no through traffic will be present.

All values, except the last (9), are entered as integers and must be right-justified. The last value is entered as a floating point number in format F4.2. Do not punch a decimal point in this field.

E. Network data:

The network data consists of 1 card for every one-way or two-way link in the network. The first cards in the deck must comprise at least one loading link for every loading node in the same order as the trip matrix. (If loading nodes are met in the order 1, 2, 4, 3, 6, etc. and the trip matrix has trips to and from 1, 2, 3, 4, 5, etc. in that order, zones 1 and 2 will be assigned the correct traffic, but zone 4 will receive 3's traffic, 3 will receive 4's, 6 will receive 5's, etc.) Cards for additional loading links after the first for each loading node may be placed in sequence after the first loading link for that loading node, or anywhere further on in the deck. The order of the remainder of the network deck will dictate the order in which data is output.

The link data are set up to refer to a one-directional link. If the link is defined as a two-way link (cols. 26-33), two identical links will be set up a from-link and a to-link (in terms of the first node name). In this case, the specified width is assumed to be the total two-way road width, and if there is parking it is assumed to occur on both sides of the road.

The data on these cards is made up as follows:

1. cols. 1-8: Link number on the from-link (must be non-zero).
2. cols. 9: If 0 the originating node is a load node otherwise non-zero.
3. cols. 10-17: Node number from which link originates.
4. cols. 18-25: Node number at which link terminates.
5. cols. 26-33: Link number for to-link. If non-zero a return to-link will be defined with the same properties as the from-link.
6. cols. 36: Facility type, 1-9, see Appendix A.
7. cols. 38: Area classification, 1-3, see Appendix A.
8. cols. 39: Set at 1 if parking is permitted.
9. cols. 40: Set at 1 to identify as one-way (zero in cols. 26-33). Otherwise capacity is calculated for a two-way roadway.
10. cols. 41-45: Link length in hundredths of a mile, e.g. 23 (cols. 44-45) = 0.23 miles. (Required for calculated travel time and must be non zero)

11. cols. 46-50: Speed limit in miles per hour (Required for calculated travel time and must be non zero)
12. cols. 51-55: Curb-to-curb roadway width in feet.
13. cols. 56-60: Number of signalled intersections on the link (not including origin and terminal intersections). (Required for calculated travel time).
14. cols. 61-65: Predetermined travel time in seconds.
15. cols. 66-72: Amount of through traffic on the link in 10's of vehicles per day. i.e. 1 in col. 72 = 10 v.p.d. (See general note #1).

Last card of the network deck must contain the alphabetic "FINISH" in columns 1-6. This card must be located after the last card containing link data. All network data cards are punched in integer form and must be right-justified.

F. Trip Matrix:

If a distribution model is not to be used inside NETANAL, the trip matrix should be included here. These cards must be of the same format as those produced by GRAVITY or OPPRTY i.e. (10X, 11 F6.0/10X, 11 F6.0).

The data is case-wise by rows. The zone number, the code A or B, denoting the first or second card, and the identifier TOT are punched in cols. 1-10 if total trips are to be assigned.

If a distribution model is included in the package, its control card, and data decks (excluding the travel time matrix) should be inserted here following a blank card.

G. Specialized Output Cards:

One card is required for each selected link or node option that is required. If none are required, no cards should be placed here.

The selected link and node option cards are:

1. cols. 1-4: If the word NODE is entered here, turning volumes with origins and destinations will be emitted from the node specified.
If the word LINK is entered here, selected link output is emitted giving the origin and destination of all trips for the link specified.
2. cols. 5-12: Node number for node option (Blank for Link).
3. cols. 13-20: Node number from which selected link originates. (see general note 2).

4. cols. 21-28: Node number at which selected link terminates.
(see general note 2).

The specialized outputs are only performed on the final iteration.

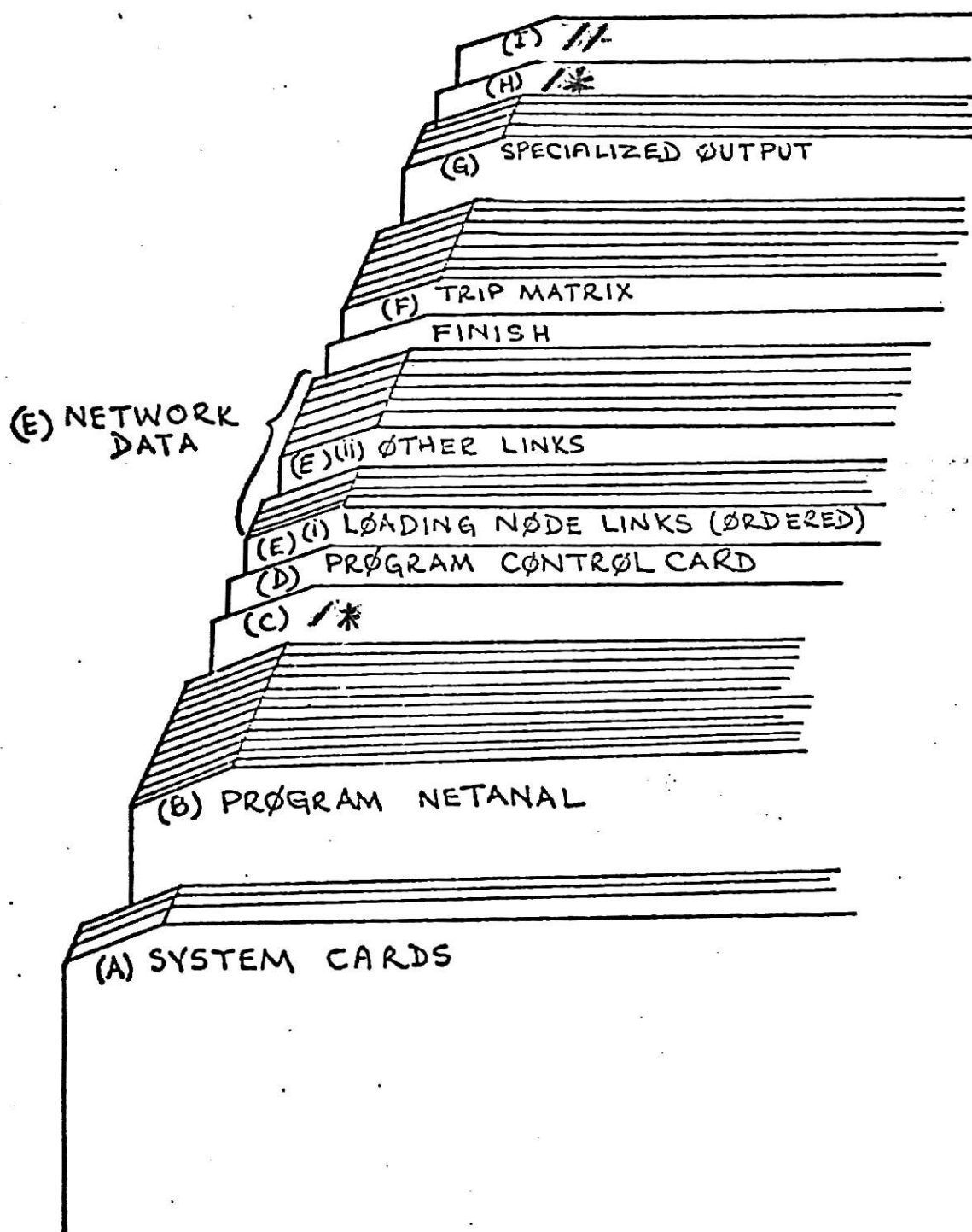
H. End of Record Card.

- I. End of information card - (6-7-8-9 multiple punch in col. 1.)

General Notes

1. At the present time, through traffic may be imposed on the network by subtracting a volume of through traffic from the link capacity. i.e. the through traffic is given priority over all local traffic on the network, and is unaffected by the build-up of traffic on any link. If cols. 37-42 of the control card are designated FACTOR, cols. 66-72 of the link card THRU, then an amount $\text{FACTOR} * \text{THRU} * 10,000$ is subtracted from total one-way capacity. It must be ensured that neither FACTOR nor THRU can generate a total volume of through traffic on any link greater than the capacity of that link.
2. The selected link option defines one direction of a link. If both directions are required, two cards must be used giving, e.g., node 1 -- node 2 and node 2 -- node 1.
3. If the model is used for distribution only (option code 1 in col. 1 of control card) then the distribution option code (cols. 35-38 of control card) must never be zero.
4. Care must be taken at all times to ensure that consistency among parameters and between parameters and data input is maintained.
5. NETANAL has a set of diagnostic error messages. These are detailed in Appendix B.

NETANAL DECK STRUCTURE



NETANAL ERROR MESSAGES

The following is a list of the possible error messages that can be given by the NETANAL program.

PARAMETER OVERFLOW ----- EXIT

The call to EXIT is made from program NETANAL. The program was terminated because one or more of the values of the parameters MAXN, MAXT, MAXS, MAXL being read in, exceeded the maximum allowable value for these parameters dimensioned in the program. The maximum values are 150, 900, 4, 22 respectively, for the parameters listed.

LOAD NODE OVERFLOW,>NNL = MAXL = ----- EXIT

The call to EXIT was made from subroutine INPUT. This message indicates that the number of load nodes,>NNL, exceeds the maximum number of load nodes allowed, MAXL.

NODES OVERFLOW,>NNN = MAXN = ----- EXIT

The call to EXIT was made from subroutine INPUT. The total number nodes in the network>NNN, exceeds the maximum number of nodes MAXN.

LINKS OVERFLOW, NODE = ----- EXIT

The call to EXIT was made from subroutine INPUT. There are more than the maximum number of links, MAXS, emanating from the node indicated.

ERROR DETECTED IN TREE BUILDING ROUTINE

TABLE REFERENCES GO OUT OF RANGE SPECIFIED ----- POSSIBLE CAUSES INCLUDE

- A IC, ITABLE DIMENSIONED TOO SMALL, MUST (AT LEAST) EXCEED
- B SOME NODE(S) CANNOT BE REACHED

OUTPUT (ALTHOUGH INCOMPLETE) FOLLOWS FOR DIAGNOSTIC USE

The message is self explanatory

ERROR IN SUBROUTINE TREE LOGIC ----- EXIT

The call to EXIT is made from subroutine tree. The routine is trying to search for more nodes than the maximum number of nodes, MAXN.

NO LINK EXISTS FROM i TO j

LOGIC ERROR ----- ASSIGN

The program was unable to find a link described in the tree table ITREE.

PLAN FORMULATION

The plan formulation to be carried out is the production of a single network plan capable of accommodating a supposedly inelastic demand. This represents the first phase of an iterative planning process which will generate an initial plan, evaluate it on economic grounds and propose modifications and alternatives, which will in turn generate further plans.

The criterion which should be applied to the plans formulated is a judgement of the ability of the planned network to accommodate the entire predicted demand with a minimal alteration of the present network.

The purposes of this phase of the process can be summarized as follows:

To design a network which is capable of accommodating all the forecast traffic in the design year without undue congestion or travel times (cumulative travel times should be similar to those at the present). In order to achieve this, it will be necessary to project possible network changes which must disrupt the community. The best plan is that one which has the least unfavorable impact on the environment. (i.e. large scale re-location or addition of links is highly undesirable).

Due to the limitations of the network assignment package, the possible means of achieving the desired network are constrained. The permissible alterations are as follows:

- 1) Addition of new links provided that the addition of such links does not cause any node in the system to be served by more than 4 links.
- 2) Addition of new nodes up to a limit of a total of 150 nodes in the network.
- 3) Relocation of a loading link (it is not permitted for any loading node to be served by more than one link).
- 4) Widening of existing roads.
- 5) Prohibition of parking on existing roads.
- 6) Change in predetermined travel times as a result of 4) or 5) above.
- 7) Imposition of one-way systems, N.B. ensure that such systems allow any loading node to be served by links carrying traffic in both directions.
- 8) Addition of further connections to the Expressway.
- 9) Building of a new expressway.

The plans devised should be based on the network assignment of design year trips distributed by the gravity model or the opportunity model, the selected link and node analyses, and the total trip matrix of the design year.

APPENDIX B

SKOKIE AREA URBAN TRANSPORTATION STUDY

PROBLEM STATEMENT

TRIP GENERATION PHASE

The following information will be needed to perform the desired regressions:

1. Data from 20 zones is supplied.
2. Means, standard deviations, and correlation coefficients will be needed to analyze the output.
3. Free regressions are to be performed; i.e., the lines are not to be forced through (0,0).
4. Labeled variables are easier to trace through the program.
5. The data is punched on the cards in the following manner:
Cols. 1 - 4, total trips generated
Cols. 5 - 8, total number of households
Cols. 9 - 12, total number of cars
Cols. 13 - 16, total workers per household; 0121 = 1.21 workers per household
Cols. 17 - 20, area of zone; 0075 = 0.75 square miles
Cols. 21 - 26, average household income in dollars
Cols. 27 - 80, ignore data punched here
6. A list of residuals is desirable and plots are necessary
7. A plot of the dependent variable against each independent variable is required. (If independent variables are transgenerated, then use these for plots.)
8. All variables will be assigned a control value of either 1 or 2 depending on the particular equation being generated. Forced variables will not be necessary.

DEVELOPMENT FORECASTS, 1970-1990

i. Population

A net increase in population is forecast for the entire city equivalent to 25% of the current (1970) number of households. It is assumed that this growth will be spread uniformly across the population, regardless of income class, occupation, etc.

ii. Income

An average annual increase in gross household income of 2% per annum (compound) is forecast for the entire city over the period 1970-1990. It is assumed that the current shape of the city-wide income distribution will be maintained.

iii. Car Ownership

It is assumed that the average level of annual expenditure on car purchase and operation will remain constant within each of three income groupings over the next 20 years, and that there will be a net decrease in the annual cost of automobile operation which will exactly balance any purchase price inflation computed on an annual basis.

Income Group	Annual Gross HH Income	1970 Car Ownership (Average for all HH in group)
Low	\$7000	1.0
Medium	\$7000 - \$12000	1.4
High	\$12000	1.7

An ultimate saturation ownership of 2.0 cars per household is assumed regardless of household income.

iv. Employed Persons

It is assumed that the current zonal average ratios of "No. Workers"/"total zonal population" will be maintained over the next 20 years.

v. Location of New Housing Developments

Only six zones are available within the city and its immediate hinterland for new housing developments. After making allowance for zoning and density requirements to ensure that any future development will be compatible with that which exists at the present, the following "expansion capacities" may be assumed:

<u>Zone</u>	<u>Households</u>
1	2000
2	1000
3	4000
4	700
5	1000
6	1500

Assume that new development will be distributed uniformly across all 6 zones in proportion to their expansion capacities.

vi. Urban Renewal

A total of 355 household units are scheduled for demolition in zones 10, 11 and 12. These households are to be rehoused elsewhere in the city and the cleared areas turned into local play areas for children in the immediate neighborhood.

Zone	10	116 HH. scheduled for demolition
	11	164
	12	75

vii. Location of New Industry and Employment

Three major industrial/commercial developments are forecast for the next 20 years

- a. an industrial/research park in zone 21
- b. a new shopping center/office complex in zones 19 and 20
- c. an expansion of existing manufacturing activity in zone 11

Further, minor employment increases will occur also in zones 2, 5, 14, 16 and 22.

REQUIREMENTS FOR TRIP GENERATION PHASE

1. Determine the "best" equation to be used for forecasting future residential trips where the dependent variable will be (a) total residential trips per zone, and (b) trips per household. Possible independent variables to be examined should include density.
2. Forecast the total residential trips by zone for the design year.

TRIP DISTRIBUTION PHASE
(GRAVITY MODEL)

Each group will be provided with two punched data decks and one program deck for the Gravity Model. The first data deck will consist of a time matrix and trip matrices for the present, and the second data deck will comprise productions and attractions for the design year trips for each zone.

There are a large number of options available for running the Gravity Model program. Each group will carry out two separate runs. The first run will be a calibration run, using present data, which will print out the observed data and perform a number of iterations of the model to determine the "friction factor" values $[F(t)]$. The run will produce a set of $F(t)$'s punched on cards for use when distributing future trips.

² The calibration will be set up to run 3 iterations only. A X^2 test must be performed between the trip-length distribution of the third iteration and the observed trip-length distribution. If the value of X^2 is significant at the 5% level, a fresh run using more iterations must be carried out after checking with Dr. Heathington.

There will be three trip purposes used: (1) Home to work, (2) Home to other, and (3) Non-home based. Convergence testing should be carried out on all three purposes. Select the time interval (one or two minute) which appears on inspection to have the smallest proportional differences between the last iteration and the observed data. (Use the same time interval for all trip purposes.)

When satisfactory convergence has been achieved, the punched $F(t)$'s and the design year Productions and Attractions will be used as input for distribution only. This will provide a trip matrix of design year trips.

TRIP DISTRIBUTION PHASE
(OPPORTUNITY MODEL)

Each group will be provided with a copy of the Opportunity Model program deck. The same data decks used for the Gravity Model will be used as data input to the Opportunity Model. The Opportunity Model will be used in a similar manner to the Gravity Model, and each group will deal with the trip purpose indicated below.

The Opportunity Model requires a set of initial L values for calibration. All groups will use an initial L value of 10^{-4} and will specify a maximum of 40 iterations to closure. A closure criterion of 1% will be used.

The model will be run in two stages: calibration and distribution. χ^2 tests should be carried out on the final calibrated trip length distribution similar to the gravity model.

There will be three trip purposes used: (1) Home to work, (2) Home to other, and (3) Non-home based. Convergence testing should be carried out on all three purposes. Select the time interval (one or two minute) which appears on inspection to have the smallest proportional differences between the final calibrated trip length distribution and the observed trip length distribution. (Use the same time interval for all trip purposes.)

Selected comparisons should be made between the final trip matrices for the present and design year from the Gravity Model and the Opportunity Model. Comments should be prepared about the differences or lack of differences between the two distributions. It is suggested that such comments should be based on about a 10% sample of Tij's.

TRAFFIC ASSIGNMENT PHASE

The purpose of this phase is to assign the interzonal trip movements to the arterial network. Two assignments will be run, both using capacity restraints. The first assignment will be of the present observed total trip movements and the second will be of one of the model forecasts of the design year total trip movements. The first iteration of a capacity restrained assignment, using this model, is an unrestrained assignment.

Control Card

The NETANAL control card should be made up so that the values of MAXN, MAXL, MAXT, and MAXS are set to their maximum values. The number of iterations, MAXITR, should be set to 4, and NSEC set to 6. FACTOR should be set to 0.50 for present assignments and to 1.00 for design year assignments.

Selected Link and Node Options

No selected link or node options will be run for the present assignment. The present assignment will be used to determine the best locations for these options for the design year assignment. A maximum of 3 links and 10 nodes may be specified (neither of these values may be exceeded) and the links MUST BE specified in BOTH DIRECTIONS (i.e. two cards per link, unless the link is a one way link.)

APPENDIX C

**SKOKIE AREA URBAN
TRANSPORTATION STUDY**

**TRIP GENERATION
ZONAL RATES OUTPUT**

STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES SPSSH - VERSION 5.01 01/30/75 PAGE 1

RUN NAME REGRESSION PROBLEM 2 RAW DATA AND CARD INPUT CEC
 VARIABLE LIST YHAT,X1,X2,X3,X4,X5
 VAR LABELS YHAT,TRIPS PER DWELLING UNIT/
 X1,HOUSEHOLDS PER SQUARE MILE
 X2,AUTOS PER DWELLING UNIT/
 X3,WORKERS PER DWELLING UNIT/
 X4,WORKERS PER SQUARE MILE/
 X5,INCOME PER DWELLING UNIT
 INPUT FORMAT FIXED (F7.4,F10.4,2F7.4,F10.4,F6.0)

ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

VARIABLE	FORMAT	RECORD	COLUMNS
YHAT	F 7. 4	1	1- 7
X1	F10. 4	1	8- 17
X2	F 7. 4	1	18- 24
X3	F 7. 4	1	25- 31
X4	F10. 4	1	32- 41
X5	F 6. 0	1	42- 47

THE INPUT FORMAT PROVIDES FOR 6 VARIABLES. 6 WILL BE READ. A MAXIMUM OF 47 COLUMNS ARE USED ON A RECORD.
 IT PROVIDES FOR 1 RECORDS ('CARDS') PER CASE.

PRINT FORMATS YHAT(1), X1 TO X5(0)
 # OF CASES 20
 REGRESSION VARIABLES=YHAT,X1,X2,X3,X4,X5/
 REGRESSION=YHAT,(80,.00001,.00001) WITH X1 TO X5(1)
 STATISTICS ALL
 READ INPUT DATA

FILE NNAME (CREATION DATE = 01/30/75)

VARIABLE	MEAN	STANDARD DEV	CASES
YHAT	1.3755	0.2706	20
X1	1834.0333	785.5245	20
X2	1.4417	0.1406	20
X3	1.2330	0.3242	20
X4	2196.8155	1028.8759	20
X5	11569.5000	1862.0623	20

REGRESSION PROBLEM 2 RAW DATA AND CARD INPUT CEC

FILE NONAME (CREATION DATE = 01/30/75)

CORRELATION COEFFICIENTS

A VALUE OF 99.00000 IS PRINTED

IF A COEFFICIENT CANNOT BE COMPUTED.

	Y-AT	X1	X2	X3	X4	X5
	TRIPS/DU	YH/ACRE	AVTOS/HN	WORKERS/HN	WORKERS/HN	INCOME/HN
YHAT						
X1	1.00000	-0.28904	0.49266	0.81861	0.27205	0.41886
X2	-0.28904	1.00000	-0.21390	-0.26678	0.73066	-0.16704
X3	0.49266	-0.21390	1.00000	0.48360	0.19945	0.76829
X4	0.81861	-0.26678	0.48360	1.00000	0.41794	0.36108
X5	0.27205	0.73066	0.19945	0.41794	1.00000	0.17680
	0.41886	-0.16704	0.76829	0.36108	0.17680	1.00000

REGRESSION PROBLEM 2 RAW DATA AND CARD INPUT CEC

01/30/75

PAGE 4

FILE NONAME CREATION DATE = 01/30/75

***** MULTIPLE REGRESSION ***** VARIABLE LIST 1
 DEPENDENT VARIABLE.. YHAT TRIPS PER DWELLING UNIT
 REGRESSION LIST 1

VARIABLE(S) ENTERED ON STEP NUMBER 1.. X3

ANALYSIS OF VARIANCE				MEAN SQUARE		F
				SUM OF SQUARES		
				DF		
MULTIPLE R	0.81861					
R SQUARE	0.67012			0.93256		
STANDARD ERROR	0.15070			0.45906		
				18.	0.02550	
						36.56591

VARIABLES IN THE EQUATION

VARIABLES NOT IN THE EQUATION					
VARIABLE	R	BETA	STD ERROR B	F	
X3	0.68332	0.81861	0.11300	36.566	
(CONSTANT)	0.53301				
X1		-0.07606		-0.12762	0.92883
X2		0.38738		0.59035	0.76613
X4		-0.13631		-0.08491	0.82543
X5		0.14176		0.23016	0.86962
					0.951

VARIABLE(S) ENTERED ON STEP NUMBER 2.. X2

ANALYSIS OF VARIANCE				MEAN SQUARE		F
				SUM OF SQUARES		
				DF		
MULTIPLE R				0.88605		31.05169
R SQUARE				0.78509		
STANDARD ERROR				0.13264		
				REGRESSION		0.54628
				RESIDUAL		0.01759
				17.		

VARIABLES IN THE EQUATION

VARIABLES NOT IN THE EQUATION					
VARIABLE	R	BETA	STD ERROR B	F	
X3	0.52695	0.63127	0.10723	24.151	
X2	0.74539	0.38738	0.24717	9.094	
(CONSTANT)	-0.34879				
X1		-0.04107		-0.08495	0.91942
X4		-0.08366		-0.16395	0.82532
X5		-0.26052		-0.35965	0.40958
					2.377

Model SELECTED

REGRESSION PROBLEM 2 RAW DATA AND CARD INPUT

FILE NONAME (CREATION DATE = 01/30/75)

-----VARIABLE LIST-----
-----REGRESSION LIST-----

-----VARIABLE LIST-----
-----REGRESSION LIST-----

DEPENDENT VARIABLE.. YHAT TRIPS PER DWELLING UNIT

VARIABLE(S) ENTERED ON STEP NUMBER 3. X5 INCOME PER DWELLING UNIT

	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
MULTIPLE R	0.90160				
R SQUARE	0.81289	3.	1.13124	0.37708	23.17031
STANDARD ERROR	0.12757	16.	0.26039	0.01627	

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD ERROR B	F	VARIABLE	BETA IN	PARTIAL	TOLERANCE	F
X3	0.52348	0.62772	0.10315	25.805	X1	-0.04247	-0.09415	0.91936	0.134
X2	1.13383	0.58925	0.34640	10.714	X4	-0.07501	-0.15736	0.82141	0.381
X5	-0.00006	-0.26052	0.00002	2.377					
CONSTANT	-0.46707								

VARIABLE(S)	ENTERED ON STEP NUMBER	X4	WORKERS PER SQUARE MILE
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9
10	10	10	10
11	11	11	11
12	12	12	12
13	13	13	13
14	14	14	14
15	15	15	15
16	16	16	16
17	17	17	17
18	18	18	18
19	19	19	19
20	20	20	20
21	21	21	21
22	22	22	22
23	23	23	23
24	24	24	24
25	25	25	25
26	26	26	26
27	27	27	27
28	28	28	28
29	29	29	29
30	30	30	30
31	31	31	31
32	32	32	32
33	33	33	33
34	34	34	34
35	35	35	35
36	36	36	36
37	37	37	37
38	38	38	38
39	39	39	39
40	40	40	40
41	41	41	41
42	42	42	42
43	43	43	43
44	44	44	44
45	45	45	45
46	46	46	46
47	47	47	47
48	48	48	48
49	49	49	49
50	50	50	50
51	51	51	51
52	52	52	52
53	53	53	53
54	54	54	54
55	55	55	55
56	56	56	56
57	57	57	57
58	58	58	58
59	59	59	59
60	60	60	60
61	61	61	61
62	62	62	62
63	63	63	63
64	64	64	64
65	65	65	65
66	66	66	66
67	67	67	67
68	68	68	68
69	69	69	69
70	70	70	70
71	71	71	71
72	72	72	72
73	73	73	73
74	74	74	74
75	75	75	75
76	76	76	76
77	77	77	77
78	78	78	78
79	79	79	79
80	80	80	80
81	81	81	81
82	82	82	82
83	83	83	83
84	84	84	84
85	85	85	85
86	86	86	86
87	87	87	87
88	88	88	88
89	89	89	89
90	90	90	90
91	91	91	91
92	92	92	92
93	93	93	93
94	94	94	94
95	95	95	95
96	96	96	96
97	97	97	97
98	98	98	98
99	99	99	99
100	100	100	100

	ANALYSIS OF VARIANCE			SUM OF SQUARES	MEAN SQUARE	F
		DF				
MULTIPLE R	0.90617					
R SQUARE	0.81752	4.		1.13768	0.28442	16.80052
STANDARD ERROR	0.13011	15.		0.25394	0.01693	

VARIABLES IN THE EQUATION	VARIABLES NOT IN THE EQUATION
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12
13	13
14	14
15	15
16	16
17	17
18	18
19	19
20	20
21	21
22	22
23	23
24	24
25	25
26	26
27	27
28	28
29	29
30	30
31	31
32	32
33	33
34	34
35	35
36	36
37	37
38	38
39	39
40	40
41	41
42	42
43	43
44	44
45	45
46	46
47	47
48	48
49	49
50	50
51	51
52	52
53	53
54	54
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56	56
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61	61
62	62
63	63
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66	66
67	67
68	68
69	69
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71	71
72	72
73	73
74	74
75	75
76	76
77	77
78	78
79	79
80	80
81	81
82	82
83	83
84	84
85	85
86	86
87	87
88	88
89	89
90	90
91	91
92	92
93	93
94	94
95	95
96	96
97	97
98	98
99	99
100	100

VARIABLE	R	BETA	STD ERROR R	F	VARIABLE	BETA IN	PARTIAL	TOLFRANCE	F
X3	0.55031	0.65926	0.11353	23.497	X1	0.41644	0.23466	0.05794	0.816
X2	1.12570	0.58503	0.35355	10.138					
X5	-0.00004	-0.25540	0.00003	2.191					
X4	-0.00002	-0.07501	0.00003	0.381					
(CONSTANT)	-0.45307								

REGRESSION PROBLEM 2 RAW DATA AND CARD INPUT CEC

01/30/75

PAGE 6

FILE NONAME (CREATION DATE = 01/30/75)

***** MULTIPLE REGRESSION ***** VARIABLE LIST 1
DEPENDENT VARIABLE.. YHAT TRIPS PER DWELLING UNIT REGRESSION LIST 1

VARIABLE(S) ENTERED ON STEP NUMBER 5.. XI HOUSEHOLDS PER SQUARE MILE

MULTIPLE R	0.90971	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
R SQUARE	0.82757	REGRESSION	5.	1.15167	0.23033	13.43858
STANDARD ERROR	0.13092	RESIDUAL	14.	0.23996	0.01714	

----- VARIABLES IN THE EQUATION -----

----- VARIABLES NOT IN THE EQUATION -----

VARIABLE	R	BETA	STD ERROR B	F	VARIABLE	BETA IN	PARTIAL	TOLERANCE
X3	0.77401	0.32725	0.27274	8.054				
X2	1.16081	0.60327	0.35786	10.522				
X5	-0.00003	-0.22131	0.00003	1.552				
X4	-0.00013	-0.50096	0.00013	1.057				
X1	0.00014	0.41644	0.00016	0.816				
(CONSTANT)	-0.85383							

ALL VARIABLES ARE IN THE EQUATION

REGRESSION PROGRAM 2 RAW DATA AND CARD INPUT CEC

FILE NONAME (CREATION DATE = 01/30/75)

***** MULTIPLE REGRESSION ***** VARIABLE LIST 1
 DEPENDENT VARIABLE.. YHAT TRIPS PER DWELLING UNIT REGRESSION LIST 1

SUMMARY TABLE

Variable	MULTIPLE R	R SQUARE	RSD CHANGE	SIMPLE R	R	BETA
X3	0.81861	0.67012	0.67012	0.81861	0.77401	0.92725
X2	0.88605	0.78509	0.11497	0.69266	1.16081	0.60327
X5	0.90160	0.81289	0.02780	0.41886	-0.00003	-0.22131
X4	0.90417	0.81752	0.00463	0.27205	-0.00013	-0.50096
X1	0.90971	0.82757	0.01005	-0.28904	0.00014	0.41644
(CONSTANT)					-0.85303	

APPENDIX D

**SKOKIE AREA URBAN
TRANSPORTATION STUDY**

ZONAL TOTAL OUTPUT

STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES SPSSM - VERSION 5.01 09/16/75 PAGE 1

CHRIS COVERT

REGRESSION PROBLEM 3 TOTAL TOTALS MODEL

VARIABLE LIST YHAT,X1,X2,X3,X4

VAR LABELS YHAT,TOTAL TRIPS/

X1,TOTAL INCOME/

X2,TOTAL HOUSEHOLDS/

X3,TOTAL WORKERS/

X4,TOTAL AUTOS

INPUT FORMAT FIXED (F4.0,F9.0,F5.0,F7.2,F5.0)

ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

VARIABLE FORMAT RECORD COLUMNS

YHAT	F 4.0	1	1- 4
X1	F 9.0	1	5- 13
X2	F 5.0	1	14- 18
X3	F 7.2	1	19- 25
X4	F 5.0	1	26- 30

THE INPUT FORMAT PROVIDES FOR 5 VARIABLES. 5 WILL BE READ
IT PROVIDES FOR 1 RECORDS (CARDS) PER CASE. A MAXIMUM OF 30 COLUMNS ARE USED ON A RECORD.

PRINT FORMATS YHAT(1), X1 TO X4(0)

OF CASES 20

REGRESSION VARIABLES=YHAT,X1,X2,X3,X4/

STATISTICS ALL REGRESSION=YHAT WITH X1 TO X4(1)

READ INPUT DATA

02/16/75

CHRIS COVERT

REGRESSION PROBLEM 3 TOTAL TOTALS MODEL

FILE NAME (CREATION DATE = 02/16/75)

VARIABLE	MEAN	STANDARD DEV	CASES
WHAT	1262.4500	715.1769	20
X1	10708718.1500	6201990.6518	20
X2	949.1000	573.2870	20
X3	1116.6474	660.5544	20
X4	1347.1500	767.6179	20

REGRESSION PROBLEM 3 ZONAL TOTALS MODEL

CHRIS COVERT

02/16/75

PAGE 3

FILE NAME (CREATION DATE = 02/16/75)

CORRELATION COEFFICIENTS

A VALUE OF 00.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.

	YHAT	X1	Y2	X3	X4
YHAT	1.00000	0.05053	0.02137	0.05273	0.97067
X1	0.05053	1.00000	0.05885	0.00342	0.08345
Y2	0.02137	0.05885	1.00000	0.84704	0.08082
X3	0.05273	0.00342	0.84704	1.00000	0.89800
X4	0.97067	0.08345	0.08082	0.89800	1.00000

FILE NAME CREATION DATE = 02/16/75
 *** MULTIPLE REGRESSION *** VARIABLE LIST 1
 DEPENDENT VARIABLE.. WHAT TOTAL TRIPS
 VARIABLE(S) ENTERED ON STEP NUMBER 1.. X4 TOTAL AUTOS

ANALYSIS OF VARIANCE				MEAN SQUARE		F
	DF	SUM OF SQUARES				
REGRESSION	1.	9156474.07278		9156474.07278		293.47209
RESIDUAL	18.	561608.87722		31200.49318		

VARIABLES IN THE EQUATION						VARIABLES NOT IN THE EQUATION	
VARIABLE	R	BETA	STD ERROR R	F		PARTIAL	TOLERANCE
X4	0.00426	0.07067	0.05270	293.472	X1	0.11296	0.03282
(CONSTANT)	44.13886				X2	-0.65483	0.03800
					X3	0.76637	0.19359

*** TOTAL WORKERS ***
 VARIABLE(S) ENTERED ON STEP NUMBER 2.. X3

ANALYSIS OF VARIANCE				MEAN SQUARE		F
	DF	SUM OF SQUARES				
REGRESSION	2.	9486320.02836		4743160.01418		347.01467
RESIDUAL	17.	231762.92164		13633.11304		

VARIABLES IN THE EQUATION						VARIABLES NOT IN THE EQUATION	
VARIABLE	R	BETA	STD ERROR R	F		PARTIAL	TOLERANCE
X2	0.55404	0.50467	0.07931	48.800	X1	-0.13194	0.03070
X3	0.45334	0.41872	0.09217	24.194	X2	-0.60908	0.03243
(CONSTANT)	0.85280						0.436

"MODEL SELECTED"

FILE NAME (CREATION DATE = 02/16/75)

DEPENDENT VARIABLE.. YHAT TOTAL TRIPS

VARIABLE(S) ENTERED ON STEP NUMBER 3.. X2 TOTAL HOUSEHOLDS

MULTIPLE R		ANALYSIS OF VARIANCE		SUM OF SQUARES		MEAN SQUARE		F	
R		R SQUARE		REGRESSION		RESIDUAL		TOTAL	
0.00247		0.00500		3190746.14681		9111.53185		350.18987	
0.00574		0.03014		145784.50954					
0.00574		0.03014							

VARIABLES IN THE EQUATION

VARIABLE	R	BETA	STD ERROR B	F	VARIABLE	BETA IN	PARTIAL	TOLERANCE	F
X4	1.10543	1.18449	0.10885	33.549	X1	-0.15611	-0.22274	0.03054	0.783
X3	0.35744	0.33014	0.08156	19.207					
X2	-0.65157	-0.52230	0.21211	9.636					
(CONSTANT)	-7.66029								

VARIABLES NOT IN THE EQUATION

VARIABLE(S) ENTERED ON STEP NUMBER	4..	X1	TOTAL INCOME
------------------------------------	-----	----	--------------

VARIABLES IN THE EQUATION

MULTIPLE R		ANALYSIS OF VARIANCE		SUM OF SQUARES		MEAN SQUARE		F	
R		R SQUARE		REGRESSION		RESIDUAL		TOTAL	
0.00285		0.00574		2394082.75238		9236.79603		250.27635	
0.00574		0.03014							
0.00574		0.03014							

VARIABLES NOT IN THE EQUATION

VARIABLE	R	BETA	STD ERROR B	F	VARIABLE	BETA IN	PARTIAL	TOLERANCE	F
X4	1.26664	1.33784	0.24963	24.931					
X3	0.37311	0.36662	0.08601	19.727					
X2	-0.66533	-0.53333	0.21613	9.656					
X1	-0.00002	-0.15611	0.00002	0.783					
(CONSTANT)	-7.66393								

MAXIMUM STEP REACHED

FILE NONAME (CREATION DATE = 02/16/75)

***** MULTIPLE REGRESSION ***** VARIABLE LIST 1
 DEPENDENT VARIABLE.. YHAT TOTAL TRIPS REGRESSION LIST 1

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSD CHANGE	SIMPLE R	R	RFTA
X4 TOTAL AUTOS	0.97067	0.94221	0.94221	0.97067	1.24644	1.33784
X3 TOTAL WORKERS	0.98800	0.97615	0.03394	0.95273	0.37311	0.36642
X2 TOTAL HOUSEHOLDS	0.99247	0.98500	0.00885	0.92137	-0.66533	-0.53133
X1 TOTAL INCOME	0.99285	0.98574	0.00074	0.95953	-0.00002	-0.15611
(CONSTANT)					-7.66393	

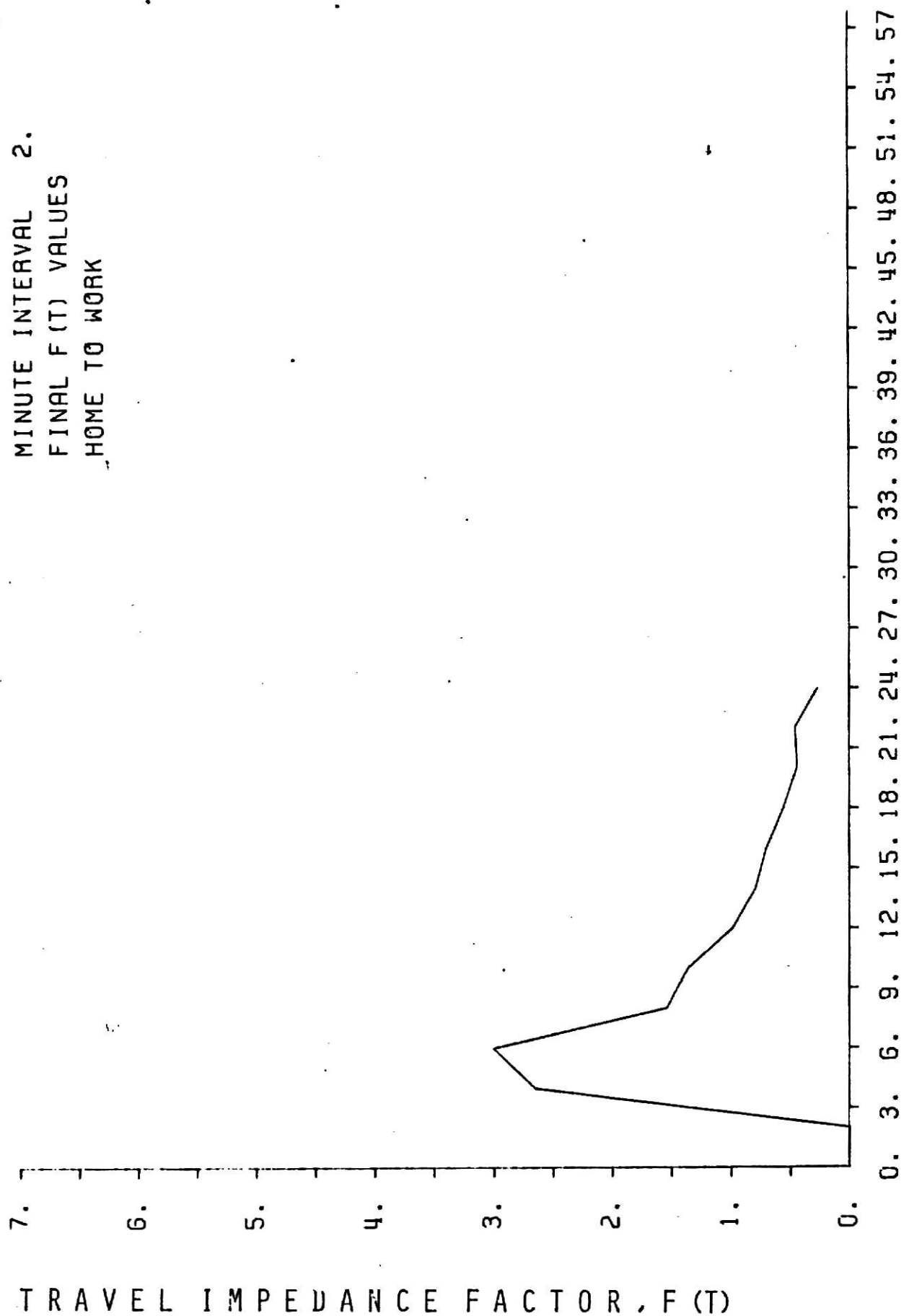
APPENDIX E

**SKOKIE AREA URBAN
TRANSPORTATION STUDY**

**TRIP DISTRIBUTION
GRAVITY AND OPPRTY OUTPUT**

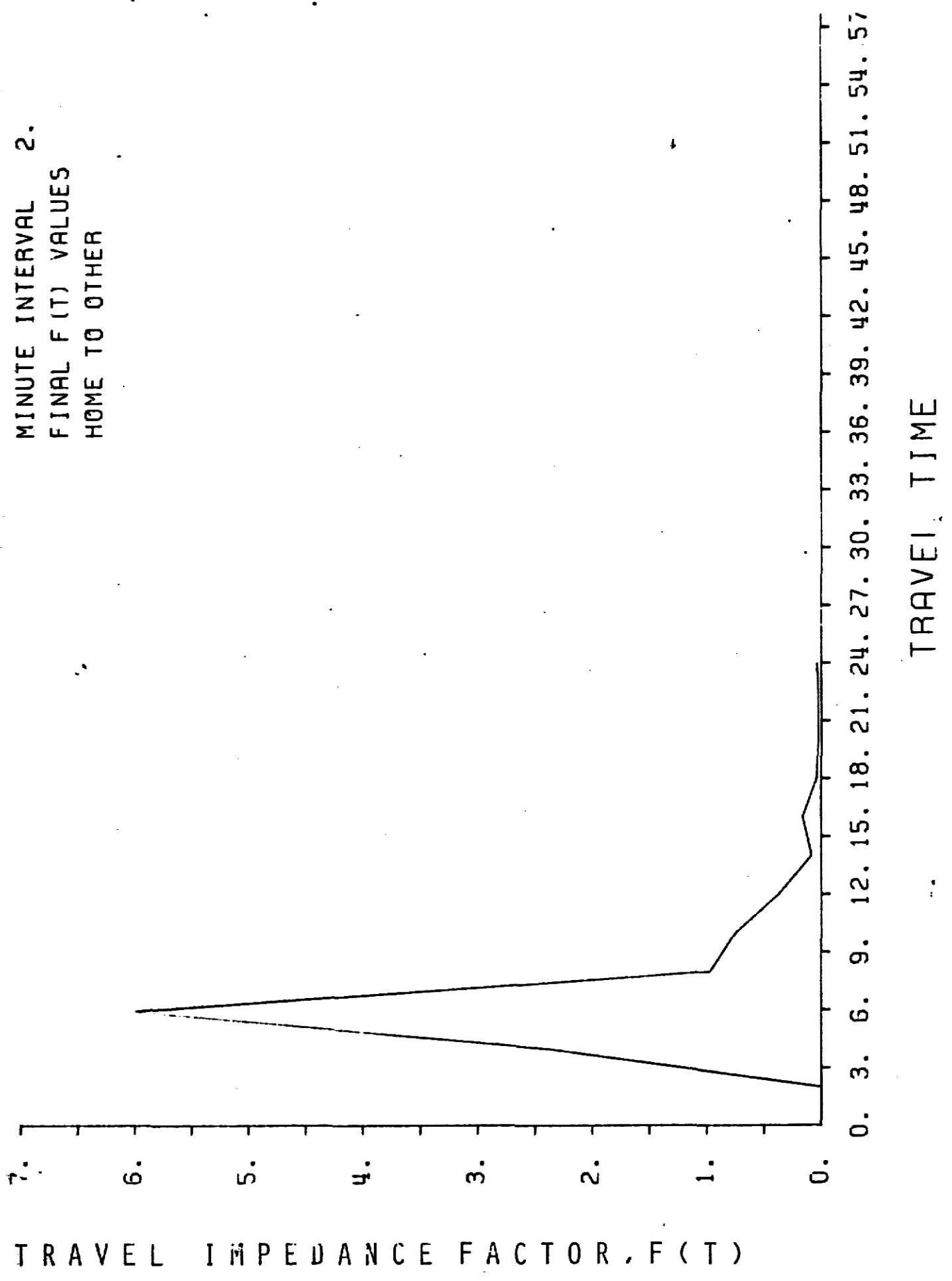
GRAVITY OUTPUT
FOR SKOKIE AREA

MINUTE INTERVAL 2.
FINAL F(T) VALUES
HOME TO WORK

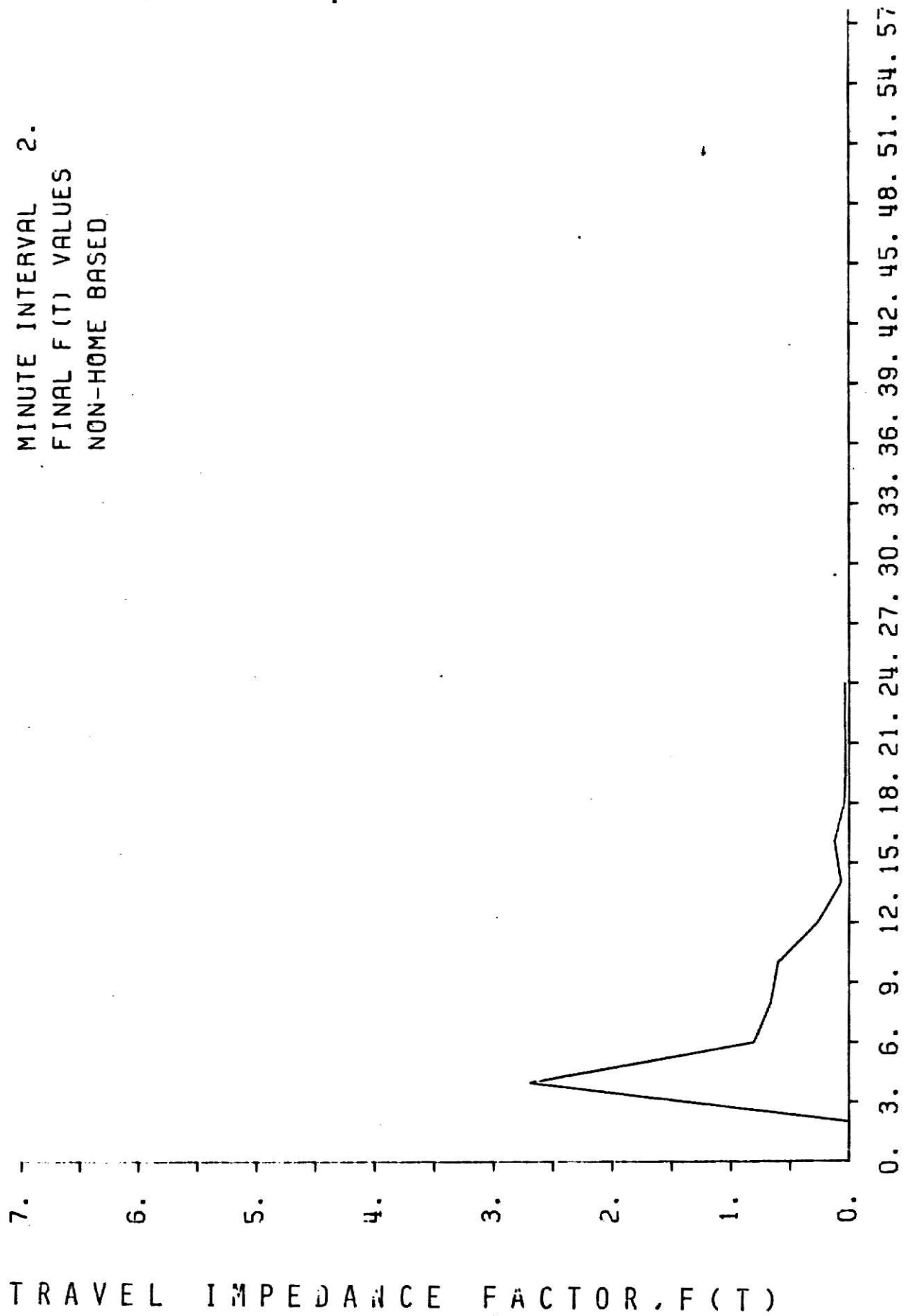


TRAVEL TIME

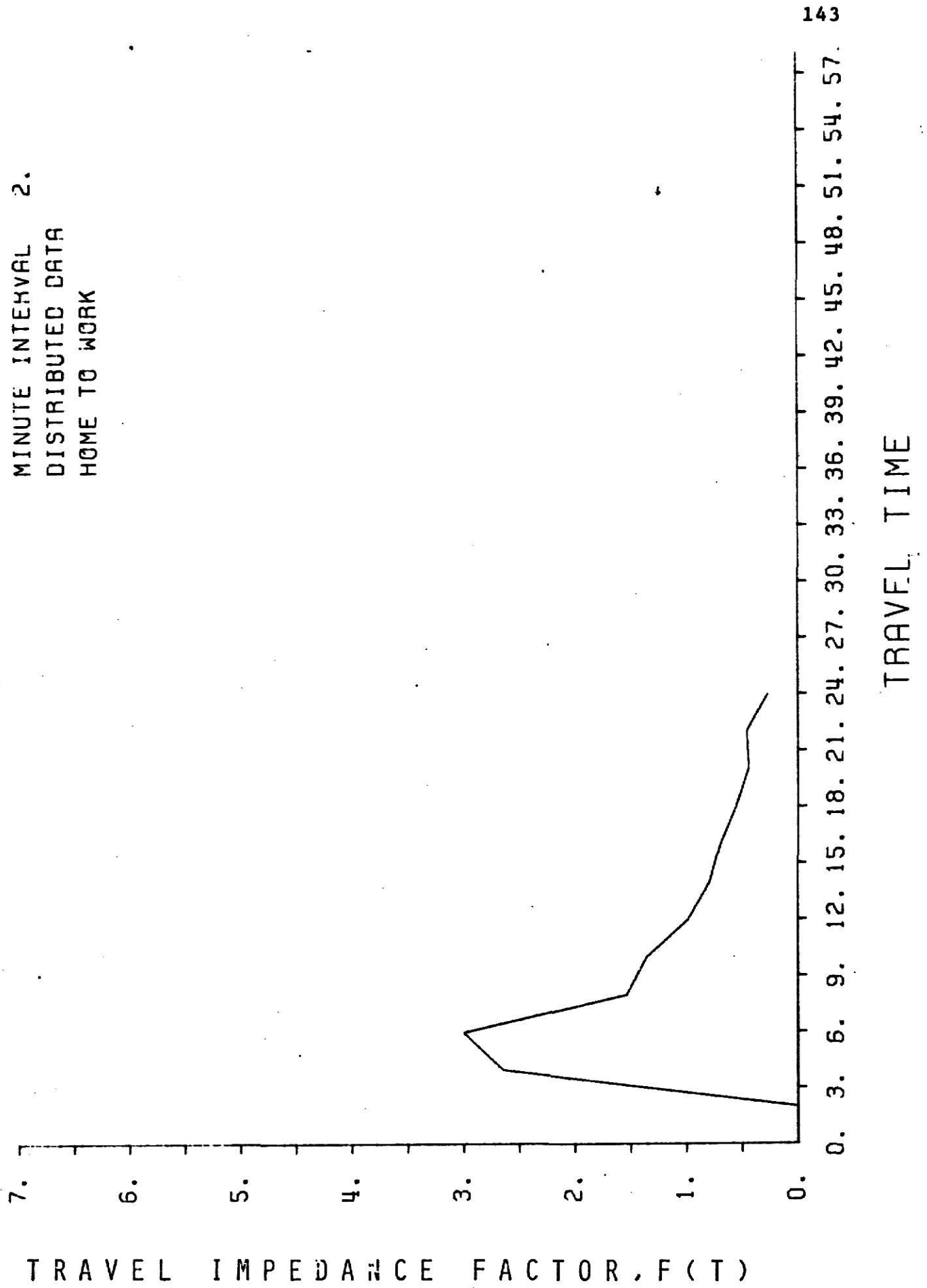
MINUTE INTERVAL 2.
FINAL F(T) VALUES
HOME TO OTHER



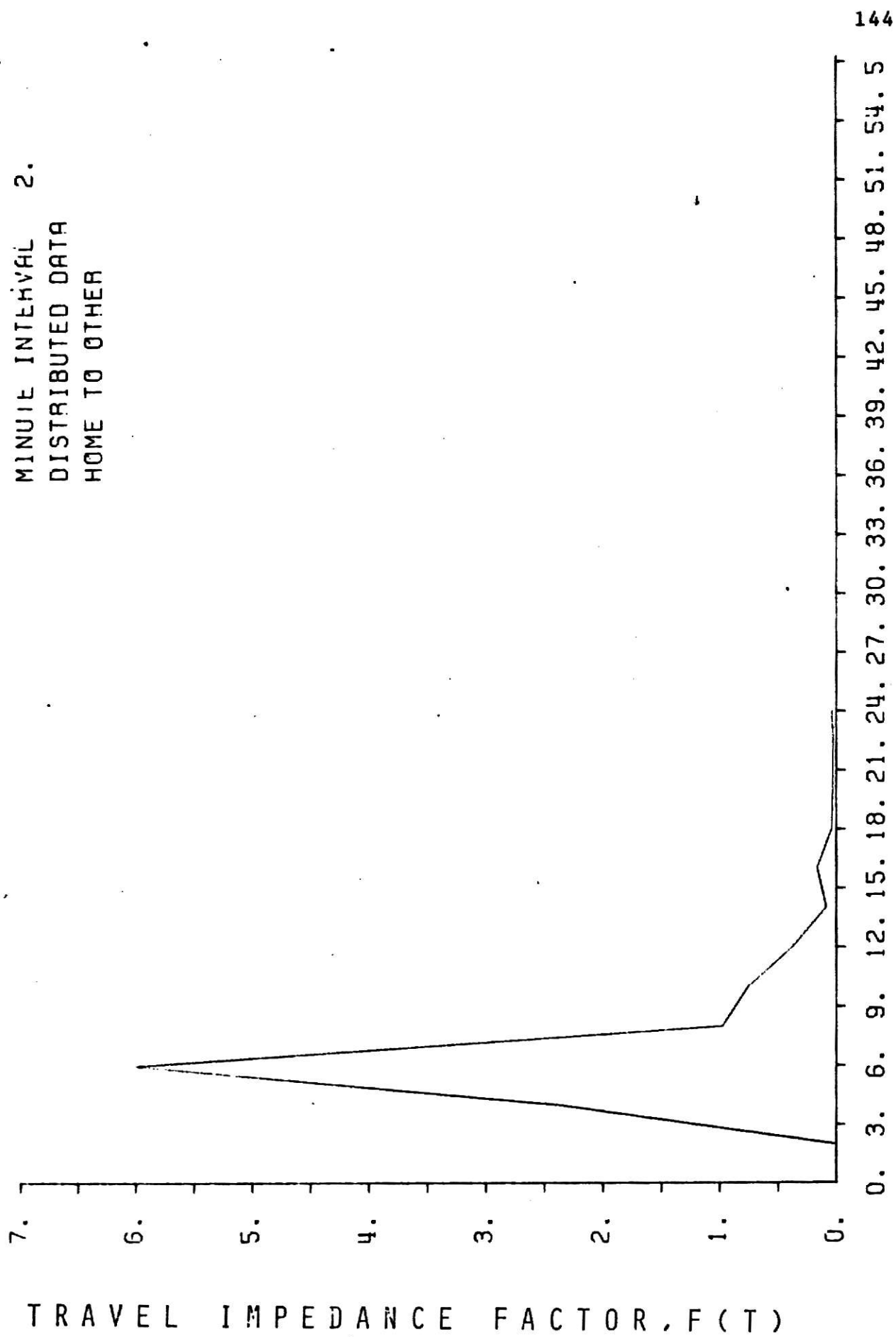
MINUTE INTERVAL 2.
FINAL F(T) VALUES
NON-HOME BASED



MINUTE INTERVAL 2.
DISTRIBUTED DATA
HOME TO WORK

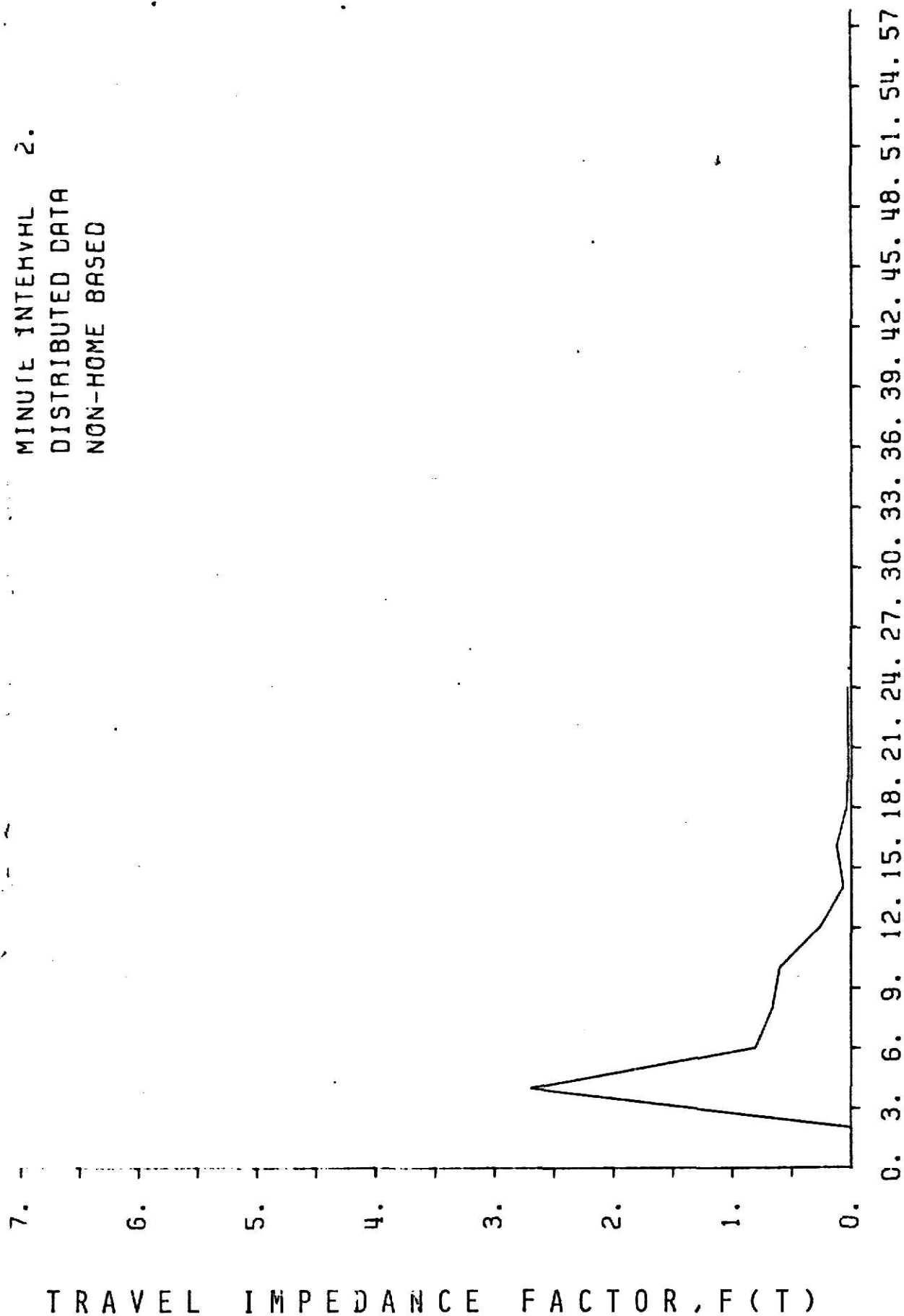


MINUTE INTERVAL 2.
DISTRIBUTED DATA
HOME TO OTHER



TRAVEL TIME

MINUTE INTERVAL 2.
DISTRIBUTED DATA
NON-HOME BASED

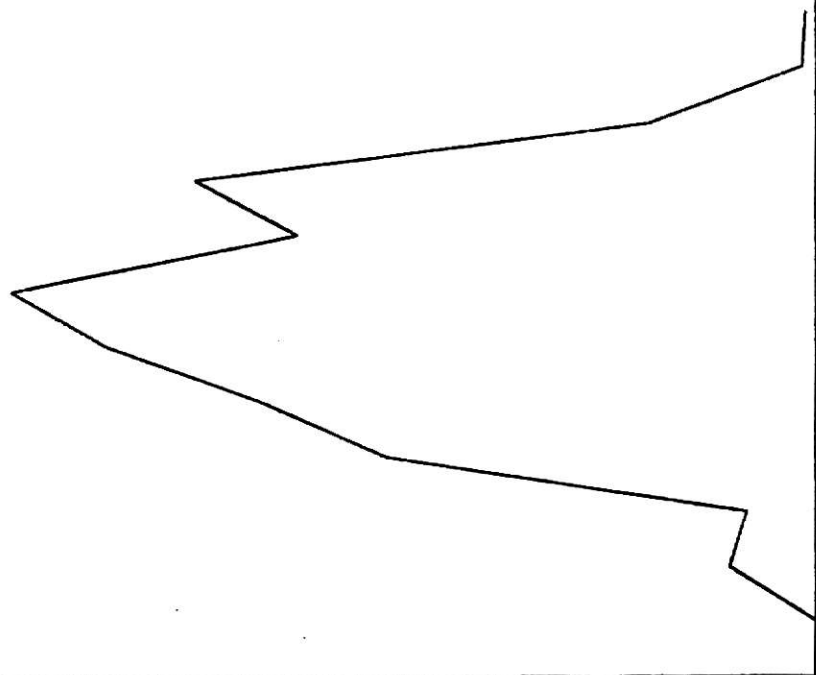


TRAVEL TIME

28.
26.
24.
22.
20.
18.
16.
14.
12.
10.
8.
6.
4.
2.
0.

PERCENT OF TOTAL TRIPS

TOTAL TRIPS 34442.
VEHICLE-MINUTES 414503.
AVERAGE TRIP TIME 12.04
MINUTE INTERVAL 2.
DISTRIBUTED DATA
HOME TO WORK



TRAVEL TIME

PERCENT OF TOTAL TRIPS

28.
26.
24.
22.
20.
18.
16.
14.
12.
10.
8.
6.
4.
2.
0.

TOTAL TRIPS

VEHICLE-MINUTES

AVERAGE TRIP TIME

MINUTE INTERVAL

DISTRIBUITED DATA

HOME TO OTHER

61033.

521589.

8.43

2.

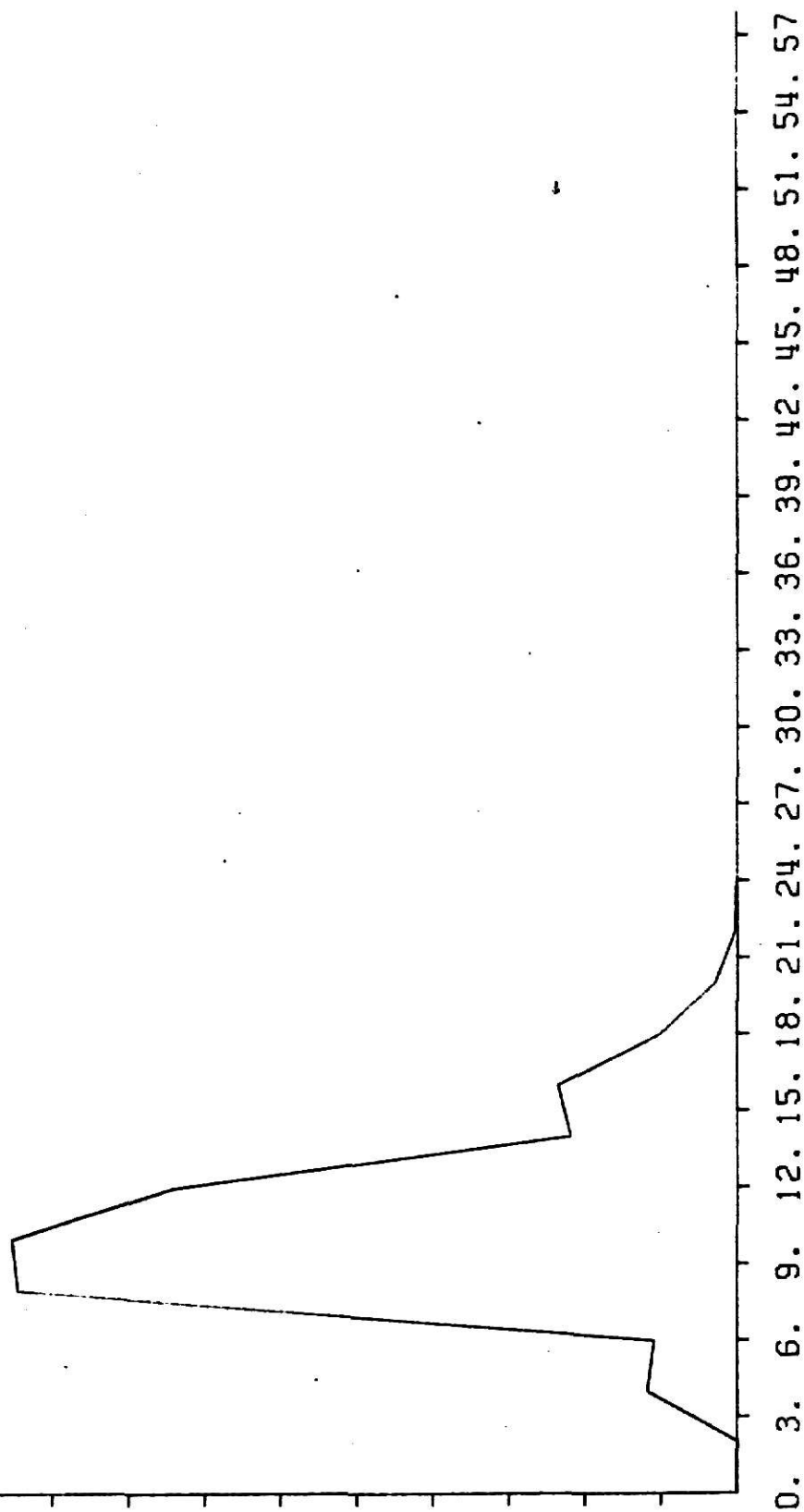
TRAVEL TIME

0. 3. 6. 9. 12. 15. 18. 21. 24. 27. 30. 33. 36. 39. 42. 45. 48. 51. 54. 5

PERCENT OF TOTAL TRIPS

28.
26.
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18.
16.
14.
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8.
6.
4.
2.
0.

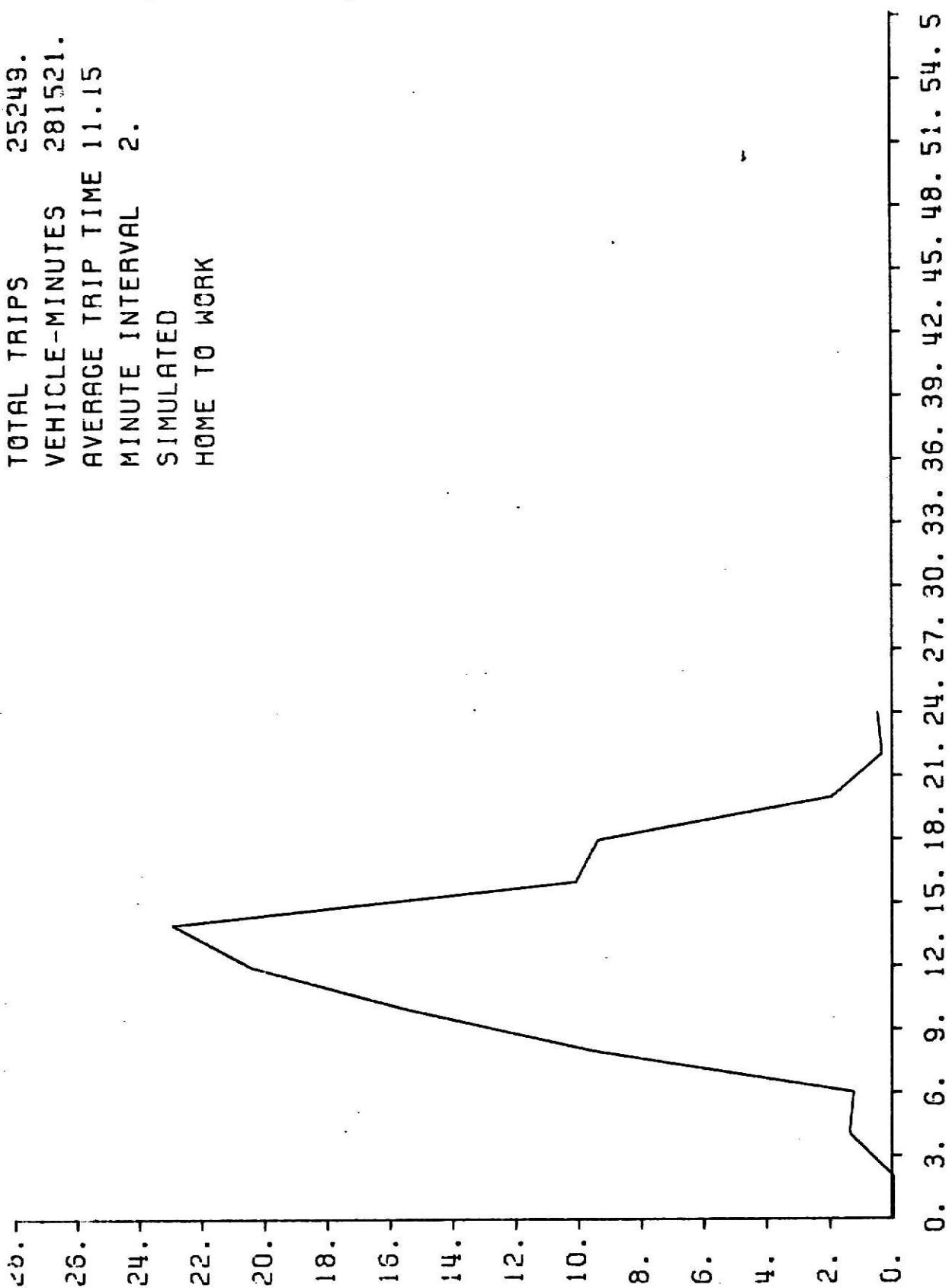
TOTAL TRIPS 49120.
VEHICLE-MINUTES 331583.
AVERAGE TRIP TIME 6.75
MINUTE INTERVAL 2.
DISTRIBUTED DATA
NON-HOME BASED



TRAVEL TIME

OPPRTY OUTPUT
FOR SKOKIE AREA

TOTAL TRIPS 25249.
 VEHICLE-MINUTES 281521.
 AVERAGE TRIP TIME 11.15
 MINUTE INTERVAL 2.
 SIMULATED
 HOME TO WORK

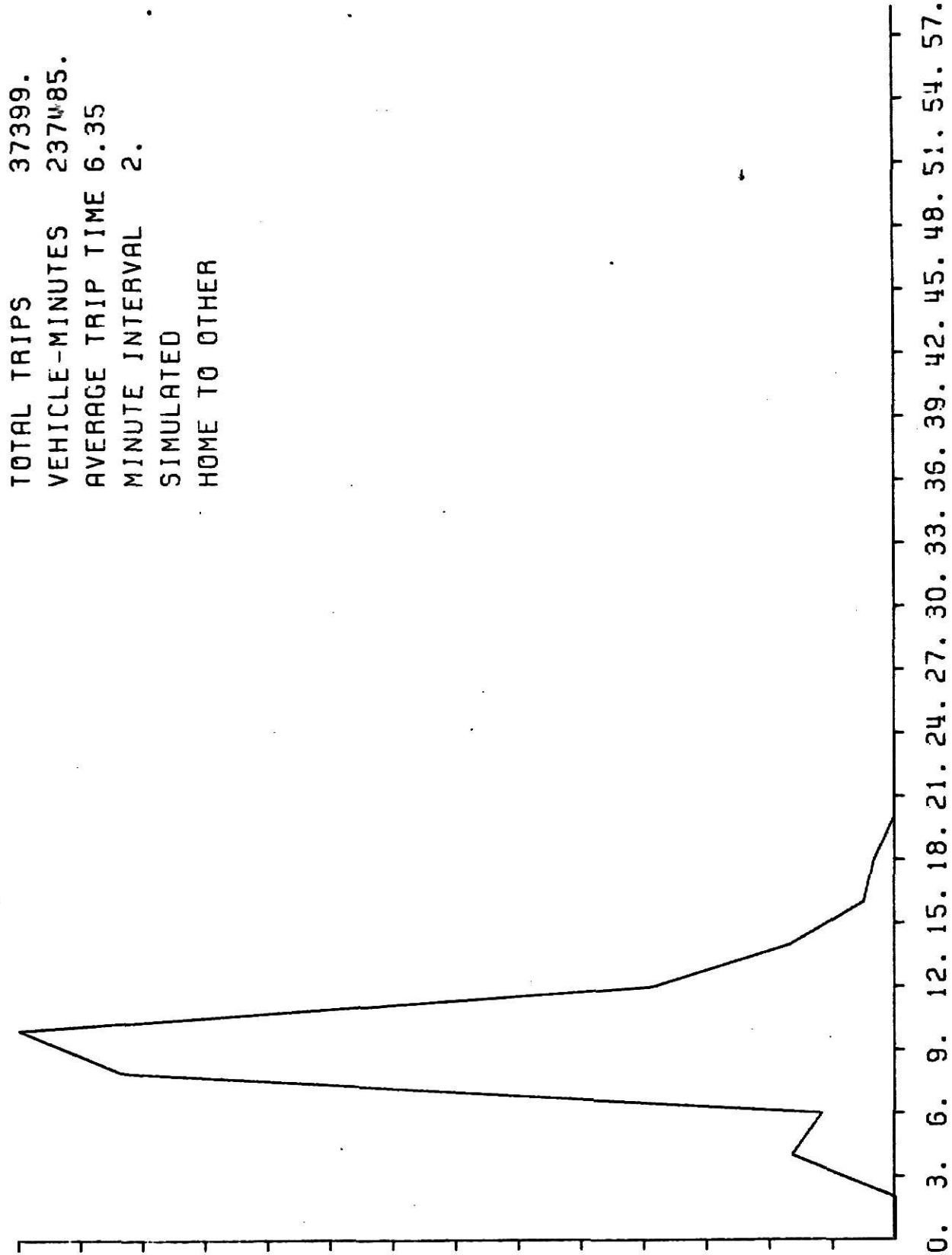


TRAVEL TIME

PERCENT OF TOTAL TRIPS

PERCENT OF TOTAL TRIPS

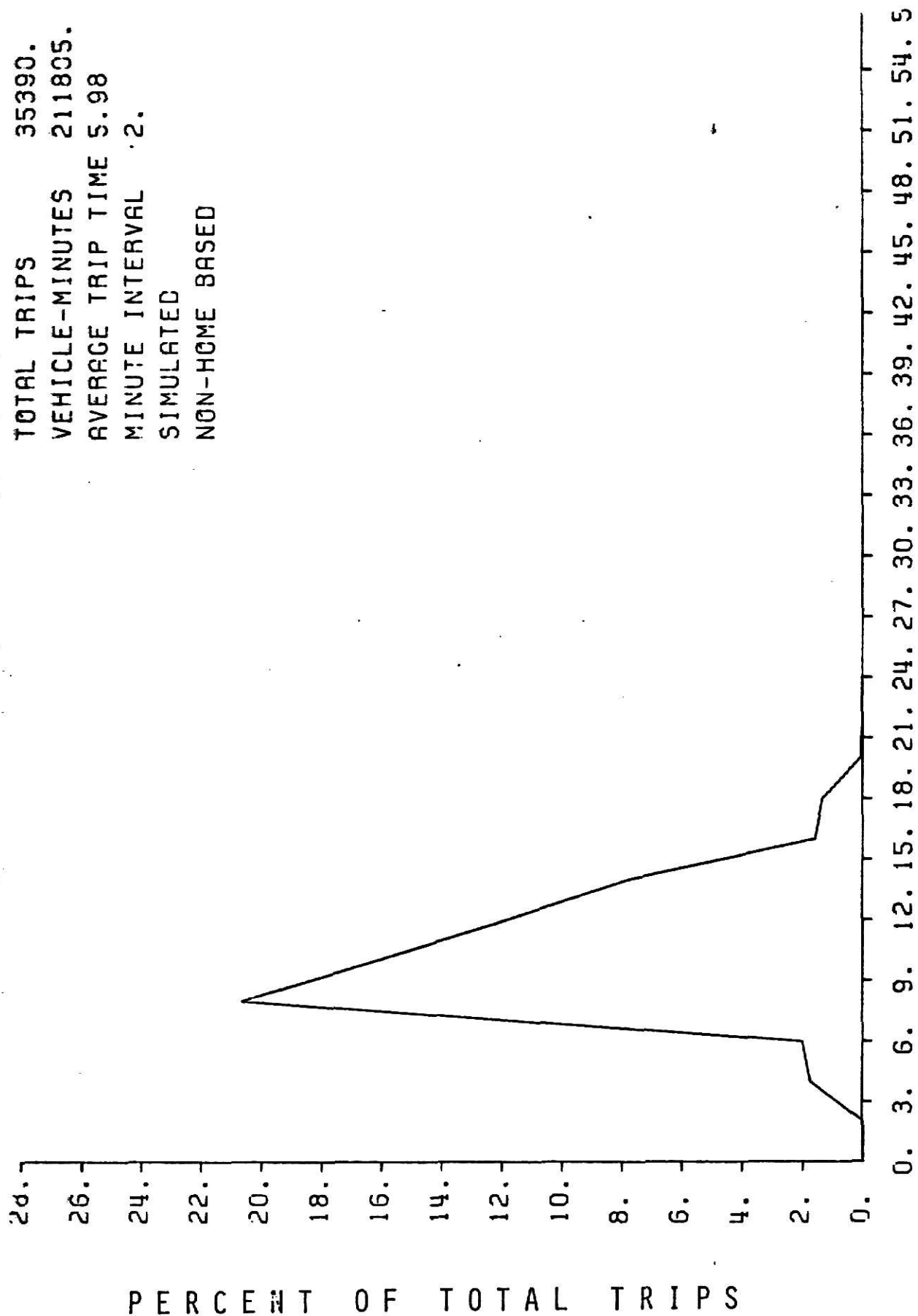
28.
26.
24.
22.
20.
18.
16.
14.
12.
10.
8.
6.
4.
2.
0.



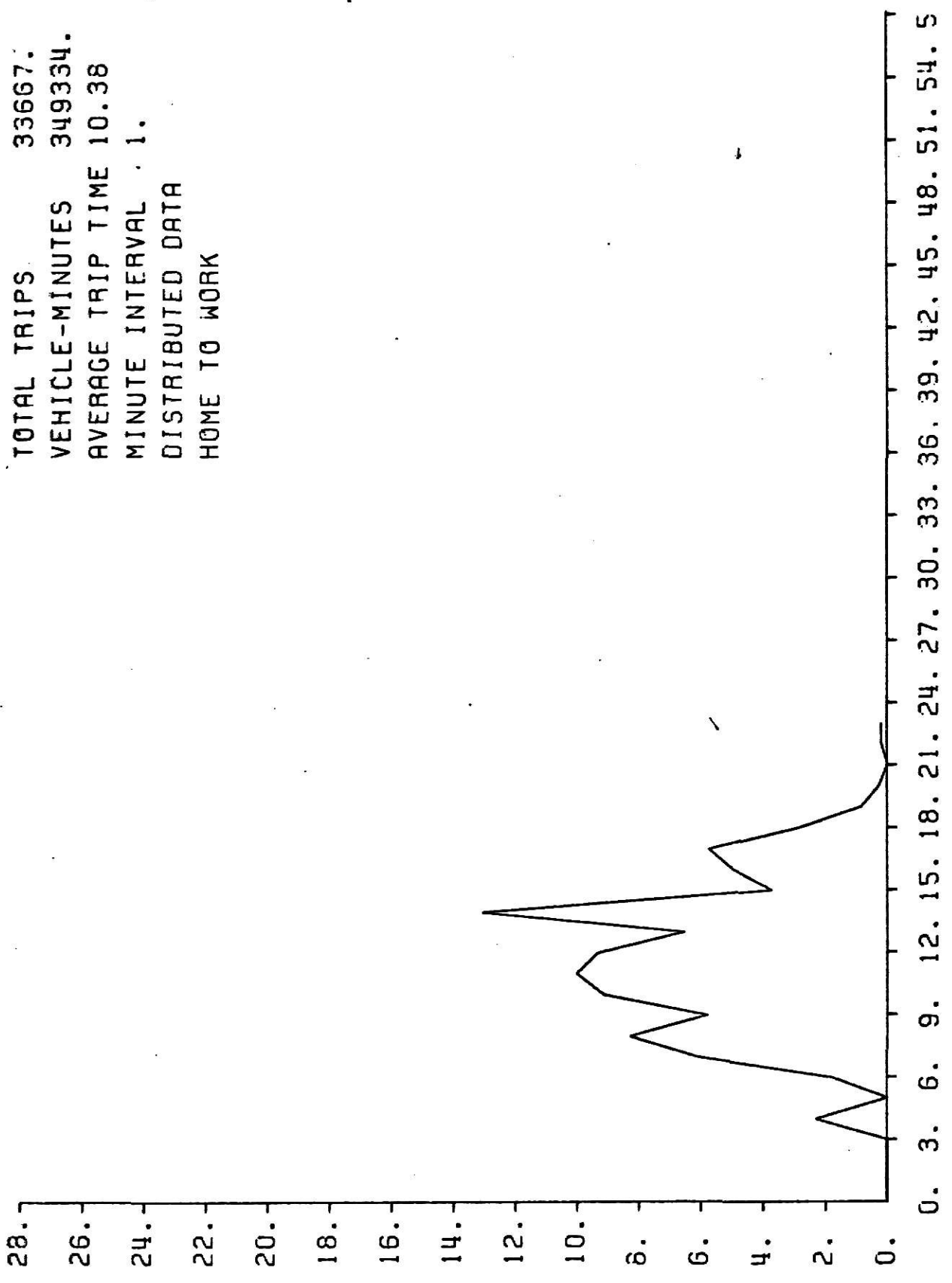
TRAVEL TIME

TOTAL TRIPS 37399.
VEHICLE-MINUTES 237485.
AVERAGE TRIP TIME 6.35
MINUTE INTERVAL 2.
SIMULATED
HOME TO OTHER

TOTAL TRIPS 35390.
 VEHICLE-MINUTES 211805.
 AVERAGE TRIP TIME 5.98
 MINUTE INTERVAL .2.
 SIMULATED
 NON-HOME BASED



PERCENT OF TOTAL TRIPS

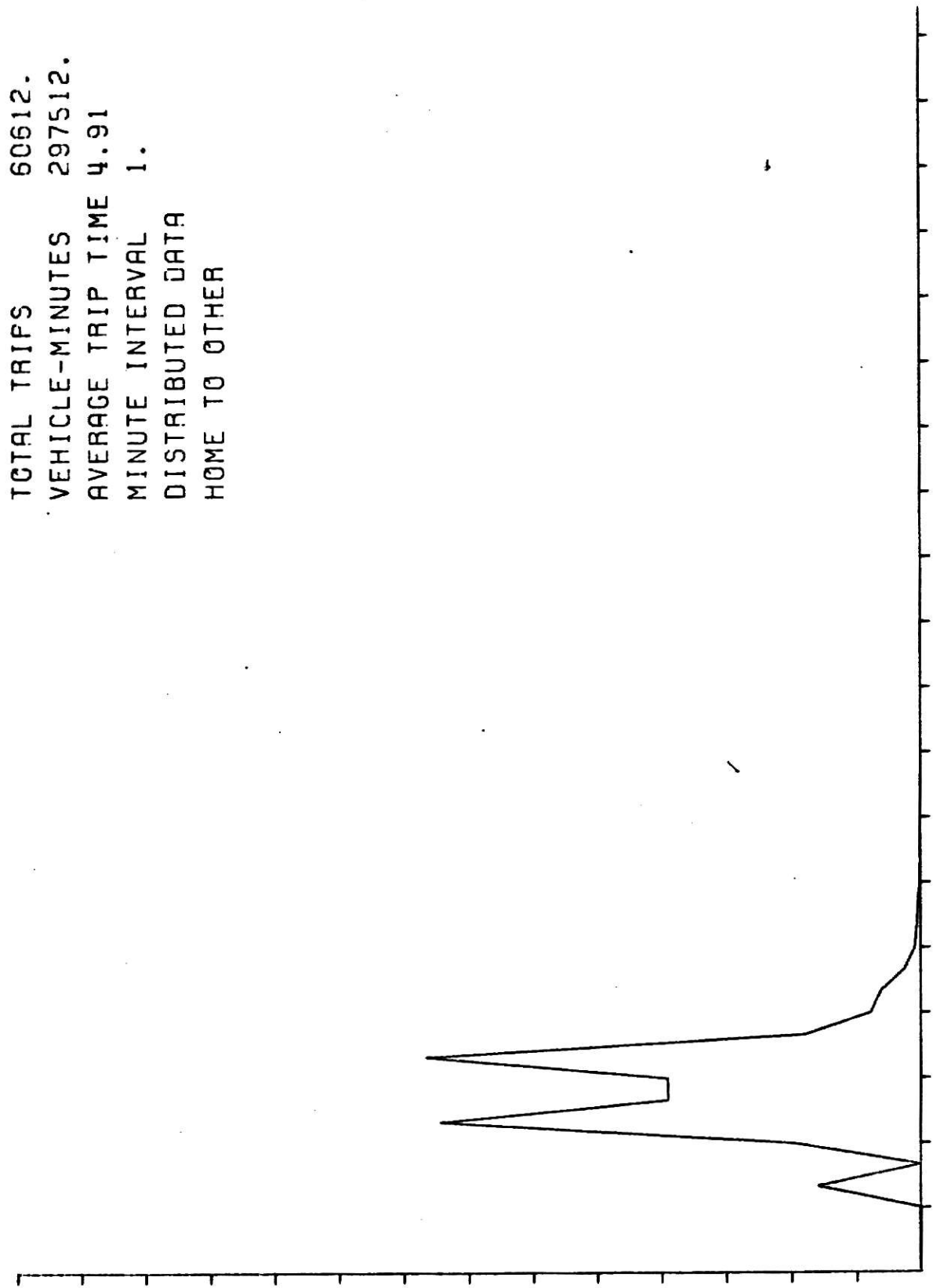


TRAVEL TIME

TOTAL TRIPS 33667.
VEHICLE-MINUTES 349334.
AVERAGE TRIP TIME 10.38
MINUTE INTERVAL 1.
DISTRIBUTED DATA
HOME TO WORK

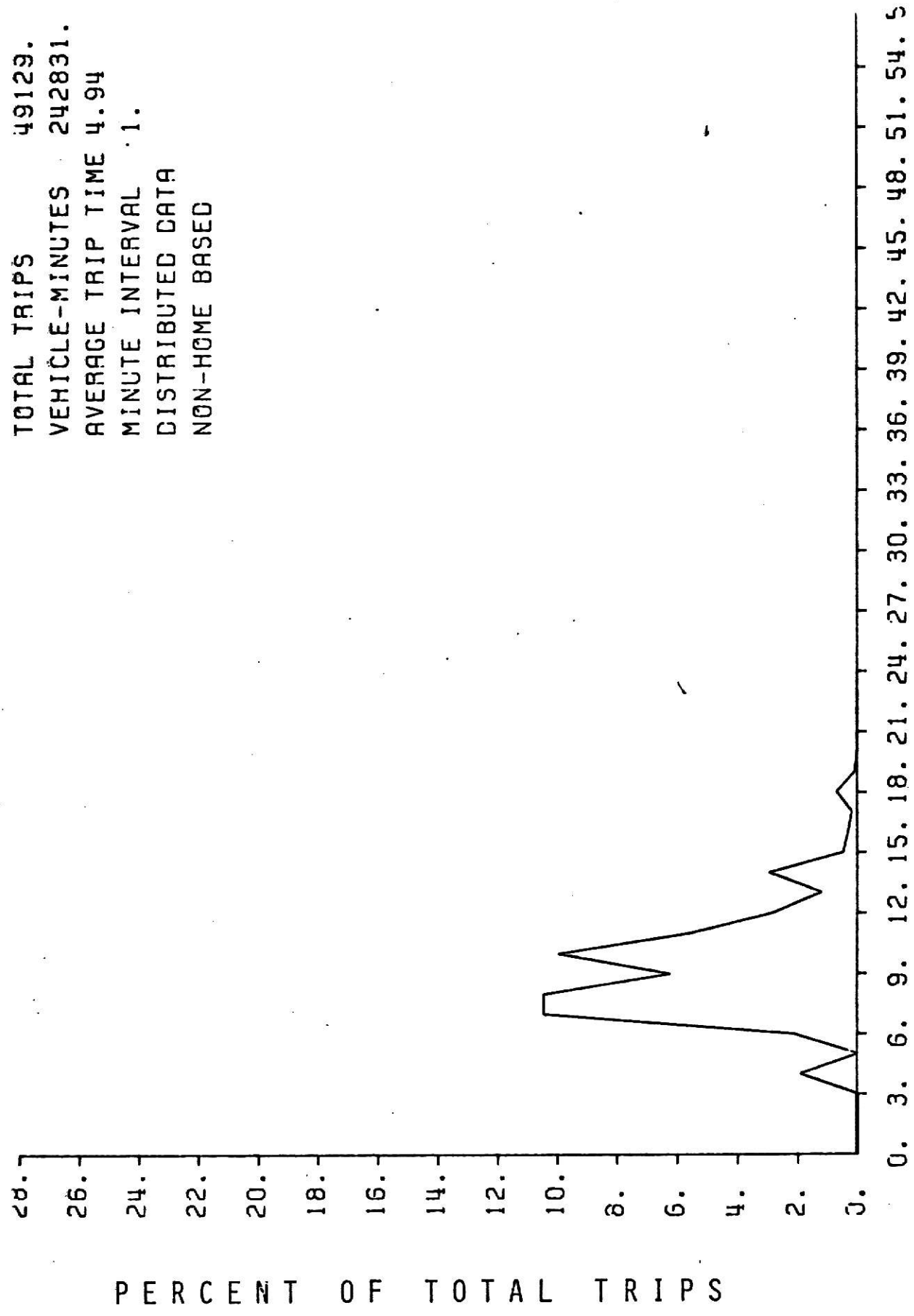
PERCENT OF TOTAL TRIPS

28.
26.
24.
22.
20.
18.
16.
14.
12.
10.
8.
6.
4.
2.
0.



TRAVEL TIME

TOTAL TRIPS 49129.
 VEHICLE-MINUTES 242831.
 AVERAGE TRIP TIME 4.94
 MINUTE INTERVAL .1.
 DISTRIBUTED DATA
 NON-HOME BASED



TRAVEL TIME

APPENDIX F

**SKOKIE AREA URBAN
TRANSPORTATION STUDY**

PLAN FORMULATION

PRESENT NETWORK

Figure 1

157

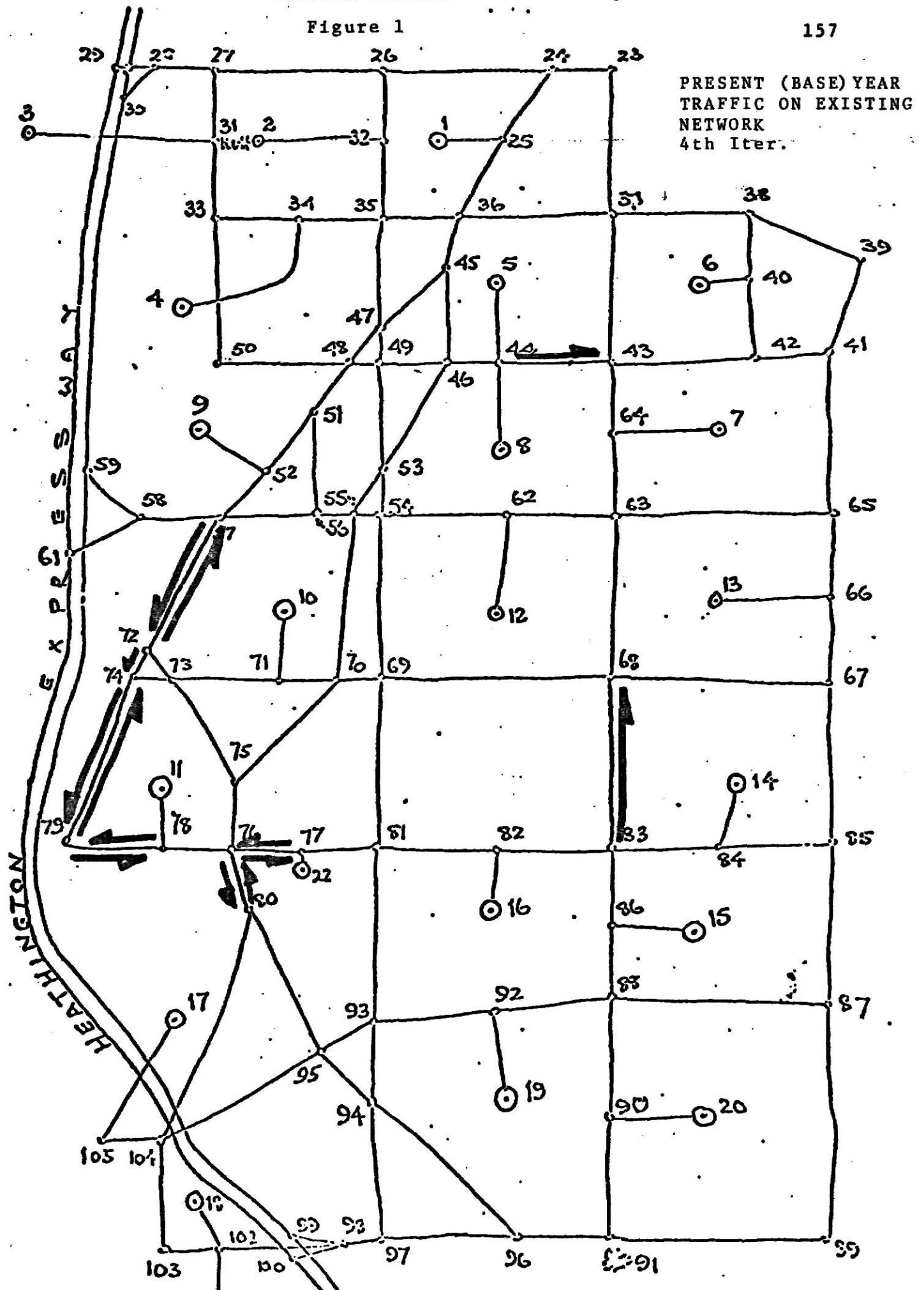


Figure 2

DESIGN YEAR TRAFFIC
ON EXISTING NETWORK
4th Iter.

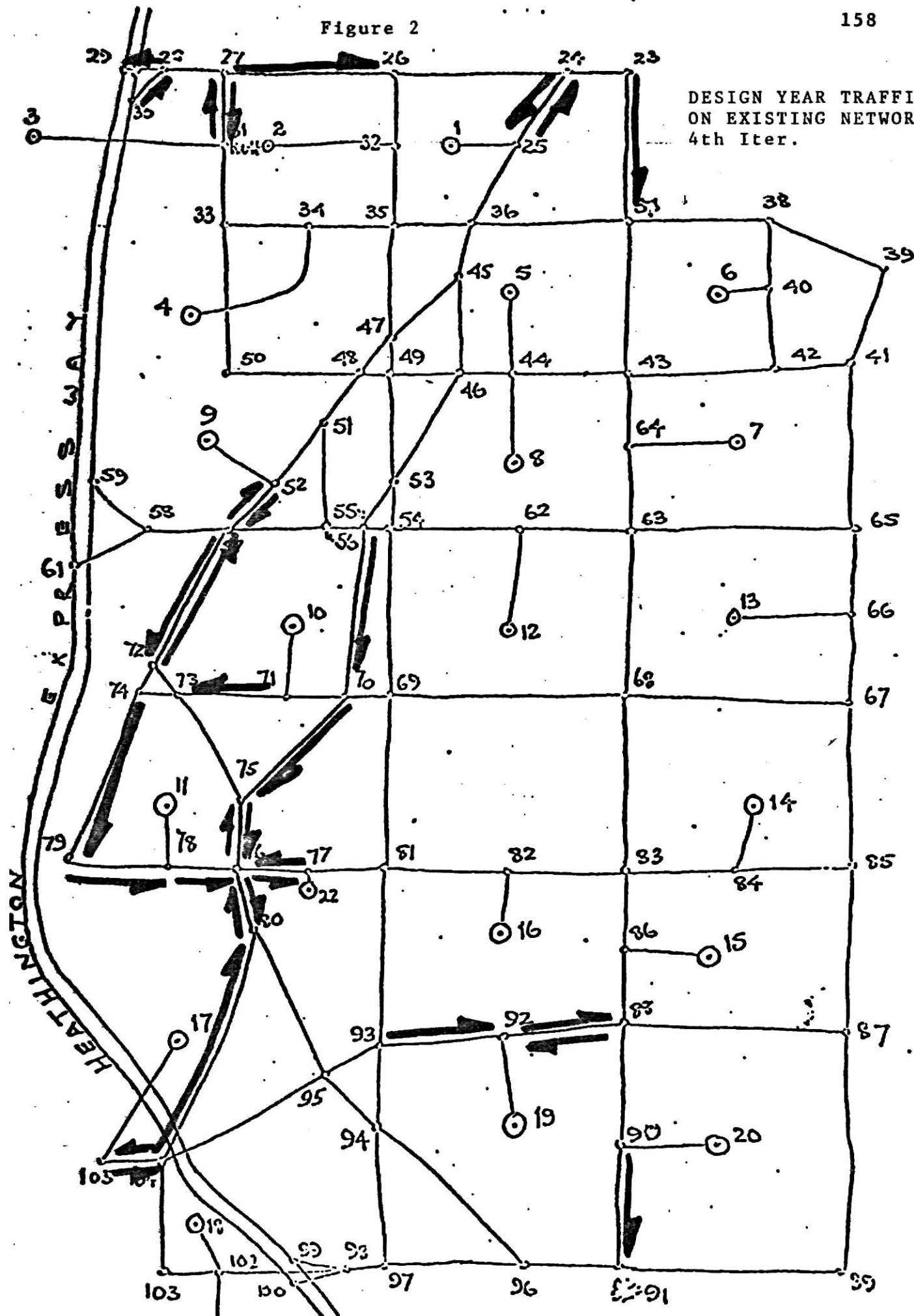
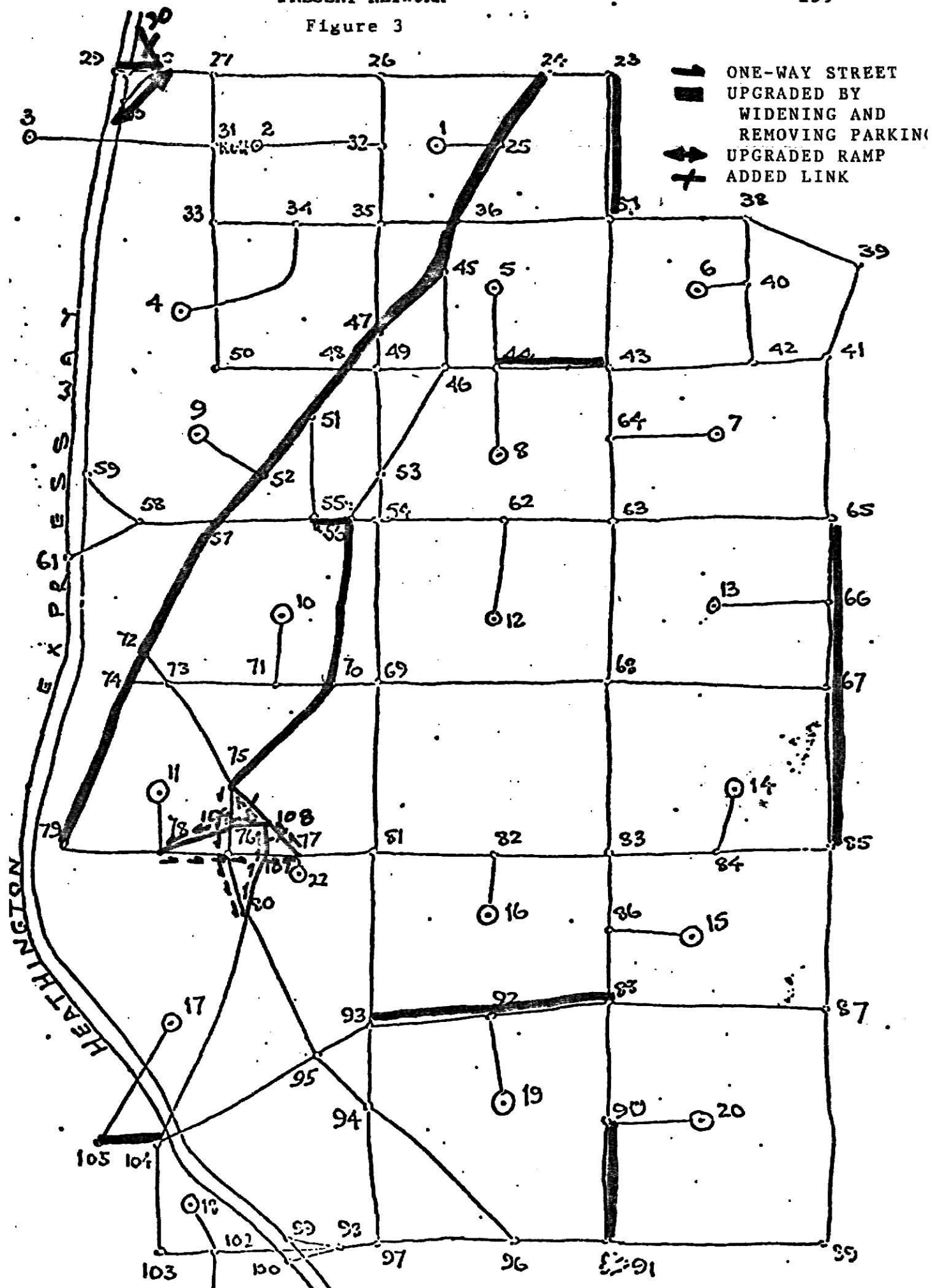


Figure 3



COMPUTER SOLUTIONS TO THE URBAN
TRANSPORTATION PLANNING PROCESS

by

CHRIS E. COVERT

B. S., Kansas State University, 1973

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

Kansas State University
Manhattan, Kansas

1975

ABSTRACT

This report provides a summary of the urban transportation planning process and examines four computer programs used to produce these plans. There were two types of computer programs examined, teaching packages and large scale urban transportation planning programs. The Purdue Teaching Package which was originally written for the CDC 6500 computer, was revised and rewritten for utilization on the Kansas State University IBM 360 system. A users' documentation manual for this program is provided in the appendix of this report. The reference manual and sample test runs for the Urban Mass Transportation Administration program battery is also submitted with this report. All other source decks and data decks utilized this semester are also submitted for future use in urban transportation planning courses at Kansas State University.