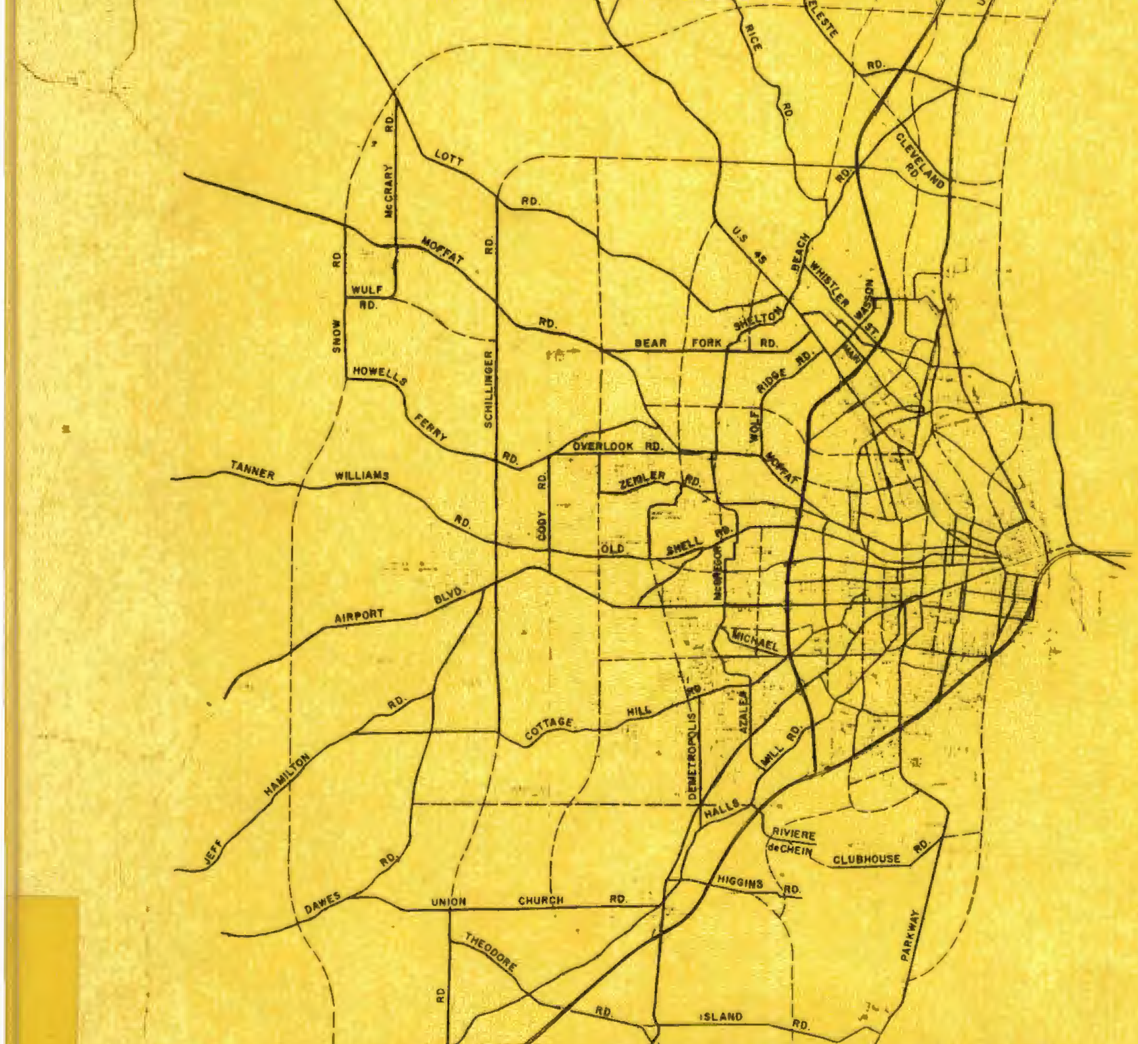
Urban Transportation Planning

General Information



U.S. DEPARTMENT OF TRANSPORTATION

Federal Highway Administration

March 1972

URBAN TRANSPORTATION PLANNING

General Information

and Introduction to System 360

U.S. DEPARTMENT OF TRANSPORTATION

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PREFACE

This document provides the necessary background information to facilitate the use of the Urban Planning System 360 program battery available through the Federal Highway Administration. A companion document, "Urban Planning System 360 - Program Documentation" contains the required information for utilizing each program in the battery. Although the programs have been developed for use in urban study work, they are extremely useful in statewide transportation study.

This document is intended to meet the needs of those already familiar with the urban planning process but requiring information related to computer applications. Every effort has been made to include current information. However, changes in the program battery, planning techniques and IBM System 360 may invalidate some portions of this document. When these changes become significant, it is anticipated that revised documents will be distributed.

Eight chapters are included herein which relate the various planning techniques to the Urban Planning Program Battery.

Chapter I describes the interrelation between the various planning processes.

Chapter II contains descriptions of data requirements for traffic assignment, trip distribution, trip generation and modal split.

Chapters III - VI contain details on traffic assignment, trip distribution, trip generation and modal split techniques respectively.

Chapter VII describes special analysis capabilities of the program battery. This includes selected link analysis, capacity computation, spiderweb networks and small area analysis.

Chapter VIII contains hardware and software requirements, and introduction to System 360 operating system including Job Control Language (JCL), programming conventions, standard data set formats and urban planning utility programs.

Chapter IX, Appendix, contains a Glossary and a Bibliography.

The material contained in this document basically represents a compilation from existing literature in urban planning and related computer technology. As such, it should be considered a review of the "state-of-the-art".

While considerable effort has been made to achieve accuracy and completeness in the programs and supporting documents, the Federal Highway Administration cannot guarantee the proper operation of this system by any user nor can it assume liability for any damage, loss or inconvenience resulting from the operation of these programs or the results obtained thereby. The Urban Planning Division, Office of Planning, Federal Highway Administration will aid any public agency in the installation and use of the battery if contacted through a local division office.

To obtain the IBM 360 battery, send a magnetic tape(s) of 2400 feet to:

Mr. W. L. Mertz
Chief, Urban Planning Division
Federal Highway Administration
Washington, D.C. 20590

The battery (in unloaded executable form) will be copied onto your 9-track tape(s) and the tape and program documentation returned to you. Please specify whether you desire 800 or 1600 bpi. The battery has become so large that the source decks must be copied onto a separate tape. If you do not require the source decks then only one tape need be sent.

There is no charge for this service for State highway departments, transportation study groups, or other governmental bodies. Due to administrative policy, all others, including universities and foreign bodies, must pay a $40 labor and computer time charge to reimburse the Government for copying each tape. If both tapes are required, then the charge is $80.

The check or money order, payable to the "Federal Highway Administration," must accompany the tape.

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CHAPTER I

URBAN TRANSPORTATION PLANNING PROCESS

A. BACKGROUND

At the present time, about 70 percent of our population and most of the industrial capacity of the Nation are concentrated in urban areas, and the trend toward urbanization is continuing. One of the greatest domestic challenges of our time is to create cities that are economically healthy and thriving, and at the same time attractive and satisfying places for living and working.

The efficient movement of both people and goods is essential to the economic health of any urban area, particularly a growing one. Comprehensive community planning gives consideration to the interaction of land development and transportation facilities and promotes the most desirable pattern and character of urban growth.

The passage of the Federal-Aid Highway Act of 1944 first provided regular Federal-aid highway funds for use in urban areas, and the Bureau of Public Roads(now the Federal Highway Administration) has actively promoted urban transportation planning since that time. This was followed by Section 9 of the Federal-Aid Highway Act of 1962, which amended Chapter I of Title 23, United States Code, by adding Section 134. This section requires that programs for Federal-aid highway projects approved after July 1, 1965, in urban areas of more than 50,000 population must be based on a continuing, comprehensive transportation planning process carried on cooperatively by States and local communities.

Urban transportation planning is designed to develop and continuously evaluate short- and long-range highway and transportation plans which are soundly conceived to meet the goals and standards of the State and urban communities.

The comprehensive character of the planning process requires that the economic, population, and land use elements be included; that estimates be made of the future demands for all modes of transportation, both public and private, for both persons and goods; that terminal and transfer facilities and traffic control systems be included in the inventories and analyses; and that the entire area within which the forces of development are interrelated, and which is expected to be urbanized within the forecast period, be included. Basic elements for which inventories and analyses are required are as follows:

a. Economic factors affecting development
b. Population
c. Land use
d. Transportation facilities, including those for mass transportation
e. Travel patterns
f. Terminal and transfer facilities
g. Traffic control features
h. Zoning ordinances, subdivision regulations, building codes, etc.
i. Financial resources
j. Social and community-value factors.

The scope of the inventories and the extent to which the various analyses need be carried will, of course, vary depending upon such factors as city size, age, proximity to other centers of population, and growth potential.

A diagram of the overall transportation planning process is shown in Figure I-1.

THE URBAN TRANSPORTATION PLANNING PROCESS

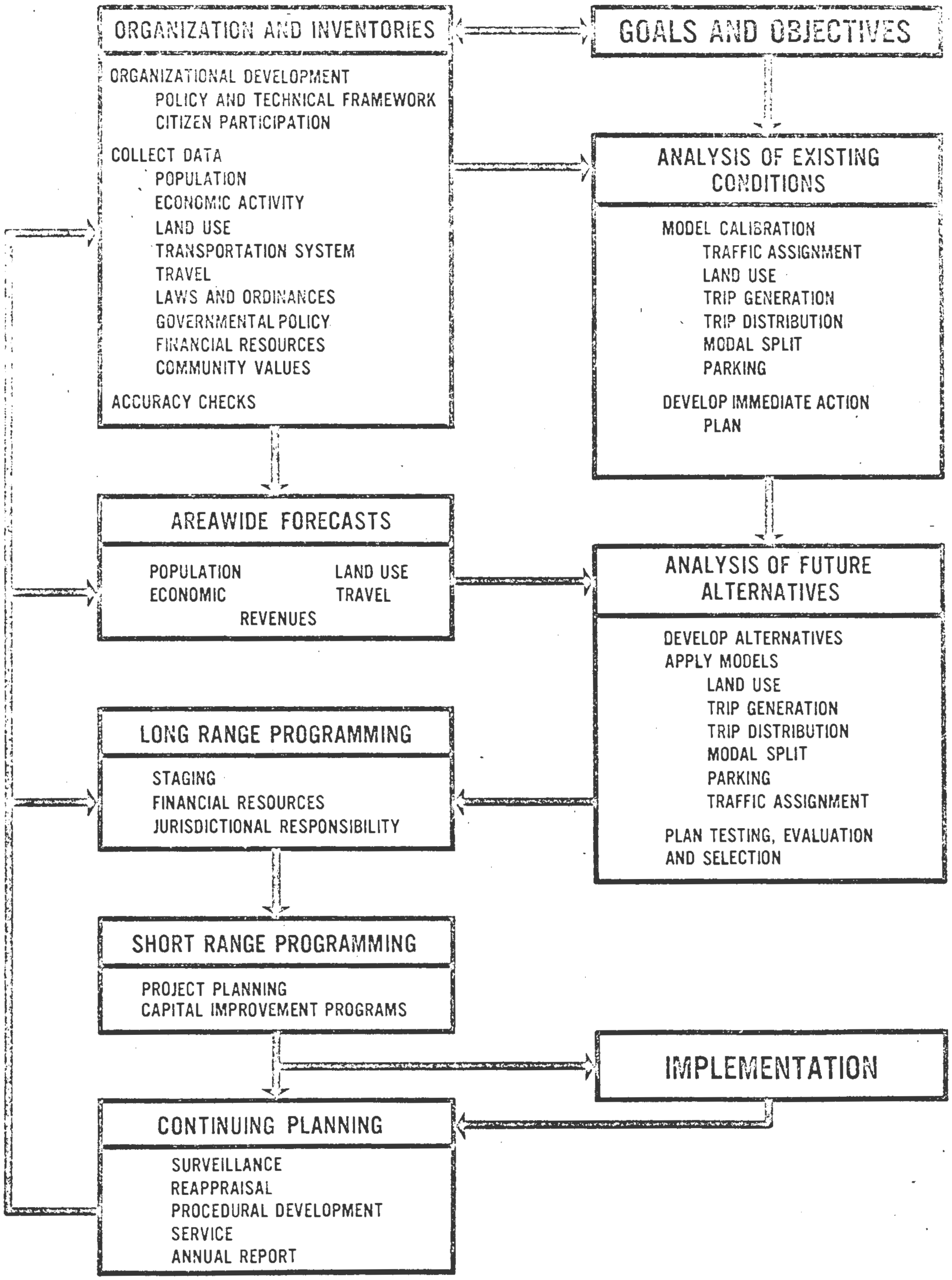


FIGURE I-1

B. URBAN TRAVEL FORECASTING

The development and improvement of travel forecasting procedures, as well as the overall transportation study philosophy and methods of analyses, have greatly contributed to a better understanding of the urban transportation problem. Urban traffic patterns now and in the future are a function of:

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.

These relationships are utilized in the transportation planning process to provide quantitative information on the travel demands generated by alternate land use patterns and transportation systems. The process has matured within the last several years until at present it is a comprehensive and, in certain respects, sophisticated process. The planning process may be characterized in four general phases:

(1) Inventories, (2) analysis of existing conditions and the calibration of forecasting techniques, (3) the forecasting of future conditions, and (4) an analysis of future transportation systems which also provides for the essential feedbacks between the transportation and land use elements. Figure I-2 illustrates the various elements which comprise the four technical phases of the urban transportation planning process.

The inventories provide the base upon which the transportation planning process rests and include surveys of economic activity and population, measures of land use, basic travel characteristics, and the existing transportation facilities. In the analysis and calibration phase, the data resources of the inventory phase are analyzed and forecasting techniques are developed. The primary forecasts are the estimate of the future population and the level of economic activity (usually expressed in terms of

URBAN TRAVEL FORECASTING PROCESS

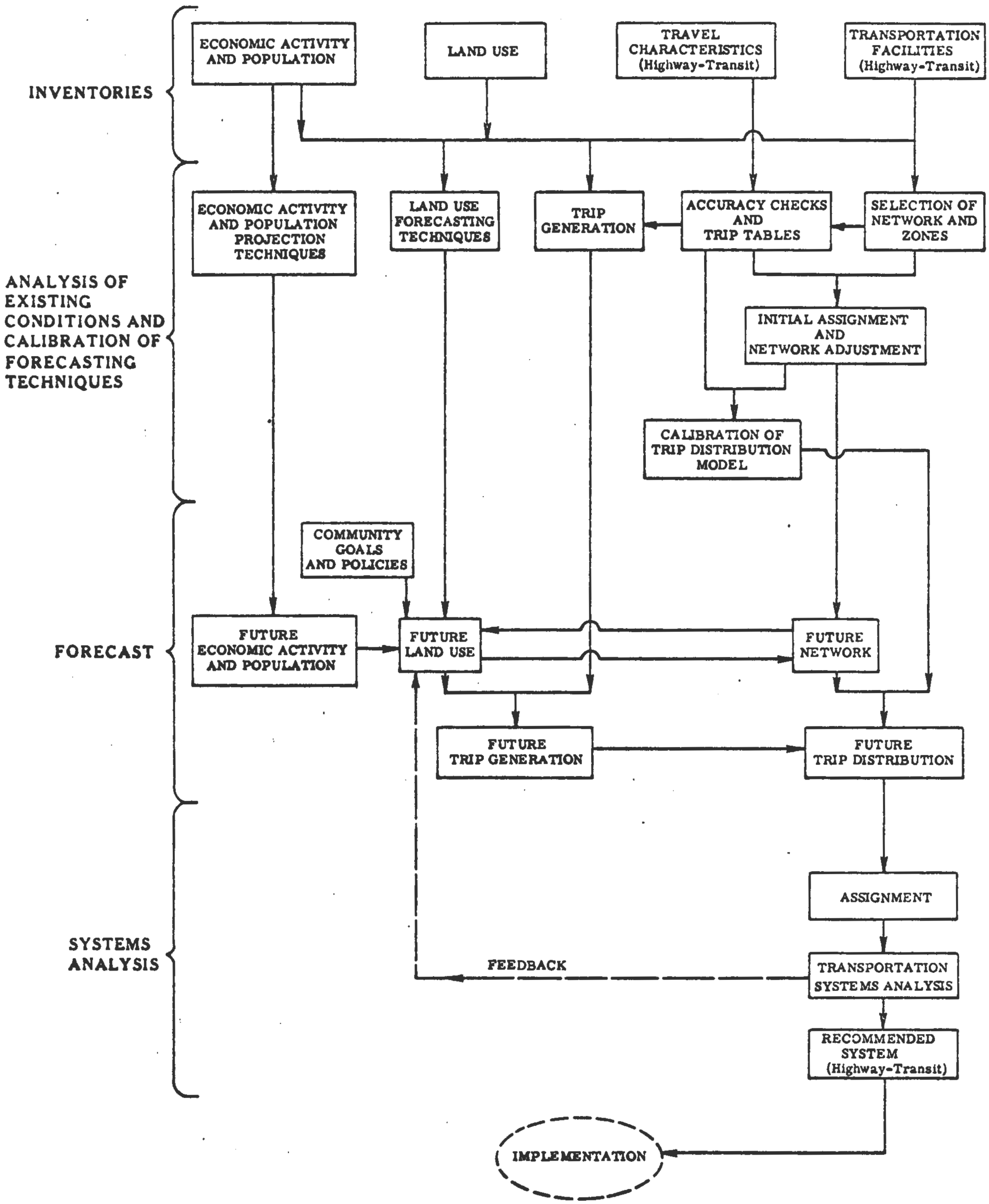


Figure I-2

employment and income) for the study area. The land use phase translates population and employment increases into land requirements and allocates them to the individual analysis units. Trip generation bridges the gap between land use and travel by providing the means with which the number of trips that begin or end in a given analysis unit can be related to the land use or socio-economic characteristics of that unit. The generated trip ends form the measures of trip "production" and trip "attraction" (or origins and destinations) that are used in trip distribution, along with measures of spatial separation developed from the highway and transit networks, to estimate travel patterns. These travel patterns are then assigned to the highway or transit network in the traffic assignment element.

In the transportation systems analysis phase, many alternatives of both land use plans and transportation systems can be evaluated. The objective of the transportation planning process is to provide the information necessary for making decisions on when and where improvements should be made in transportation systems, thus, satisfying travel demands and promoting land development patterns that are in keeping with community goals and objectives.

Perhaps a clearer picture of the logical sequence of the technical elements may be obtained if the questions which each attempts to answer are expressed:

1. Population and Economic Studies - what will be the magnitude of the activities?

2. Land Use - where will the activities be located?

3. Generation - how many trips will these activities generate?

4. Distribution - where will these trips go?

5. Modal split - by which mode?

6. Assignment - which route will these trips take?

7. System Analysis - what is the best transportation system?

This, of course, is a gross oversimplification of the transportation planning process. It does, however, establish the functional relationships of the major elements of the process. It is particularly important to look upon the several elements of the transportation planning process as integrated components. Often trip generation, distribution, assignment and the other elements of the process tend to take on an air of individuality as though the results of each constitute an end product. From a behavioral point of view, however, it is difficult to separate decisions to travel from the choice of destination. Nor can decisions about residential location and the length, number, and mode of trips be arrived at individually.

This approach will ultimately lead to the development of models more sophisticated and complex than most of those in use today.

C. USE OF COMPUTERS

The electronic computer has made possible the degree of depth and refinement to which urban transportation planning is now being conducted. Efforts in the adaptation of computers to urban transportation planning began in 1955 almost simultaneously with the introduction of computers to commercial uses. Since that time, hundreds of programs have been written for the various phases of the transportation planning process. The current urban planning 360 Battery, described in this document and in the "Urban Planning System 360 - Program Documentation" manual, has programs which are pertinent to most, if not all, phases of the technical planning process.

As in many other fields of endeavor, the application of computers to transportation planning has been an evolutionary process that has paralleled, indeed permitted, the development of the profession itself. Even in the early years of the profession, it became apparent that travel characteristics are related not only to the existing transportation system but also to a variety of social-economic indicators of the population served by the system. As transportation planners began to collect and utilize all of these data, it was not long before they got bogged down with manual calculations. The advent of origin and destination ("O and D") surveys of travel patterns materially increased the quantity of data that analysts had to process, and they turned first to EAM equipment and later to computers for assistance. 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 generation IBM 704 in 1958.

Shortly after the transition from first to second generation machines (1961-1962), it was decided to incorporate the major programs available for the IBM 7090/7094 computers into a system or library of programs. Inasmuch as a substantial part of the program development was accomplished on the Bureau of Standards computer which used the BELL MONITOR for control of the program flow through the machine, one system used the BELL MONITOR as a foundation and provided some additions and modifications. The program system was called BELMN and includes about 60 individual programs.

Another system of programs was begun at Texas A&M University and is called the Texas system. Both systems contain about the same number of programs, and most of the programs in both sets are essentially duplicates. There are, however, a few programs in both sets that are unique to that set such as the selected link analysis on the Texas system and the capacity diversion analysis on the BELMN. In addition, there are several programs that are independent of both systems such as the set for computer coding of origins and destinations. The Texas and BELMN program batteries have been used extensively throughout the United States, in Europe, the Orient and the Southern hemisphere.

In 1964 it became apparent that the third generation of computers was on its way. The Bureau of Public Roads decided to prepare a battery of transportation planning programs for some third generation machine (personnel and financial limitations, as well as program efficiency requirements prohibited development of a battery for more than one machine). The computer chosen was the IBM 360. This was mainly because the majority of the State highway departments, the actual "users" of the battery, would use the IBM 360 for their own computer installation. The second major decision was the selection of the monitor or operating system under which the battery would run. The (full) Operating System was selected. Chapter VIII describes more fully the hardware and software specifications for the 360 system of programs.

The considerable experience gained in the development and use of previous program packages for transportation planners has formed the basis for the current System 360 battery. The programs have incorporated new theoretically based features as well as taking advantage of additional third generation computer capabilities. In addition to the basic program sets for traffic assignment and trip distribution, the current battery includes special analysis programs, such as for capacity calculations, parking studies and cross tabulations.

D. SYSTEMS FLOW CHARTS

The following chapters of this document describe the processes of traffic assignment, trip distribution, trip generation and modal split as well as some special analyses. The description provides a basis for the use of the program documentation contained in "Urban Planning System 360 - Program Documentation."

The flow charts that follow are intended to provide the user of this battery with a general picture of overall logic of program flow. It should be emphasized that this systems flow between individual programs is only illustrative in an effort to more fully document software interrelationships. At several points in the systems flow, alternative methodology might be employed. Included in the flow charts are only those programs in the battery at the present time, and which form a definable process of interrelated programs such as traffic assignment and trip distribution. Special analyses programs such as for capacity calculations are not shown. Updates to the charts will be made to reflect additions or modifications to the battery as they become available.

FIGURE I-3

TYPICAL SYSTEMS FLOW CHART FOR BUILDING BASE YEAR TRIPTABLES

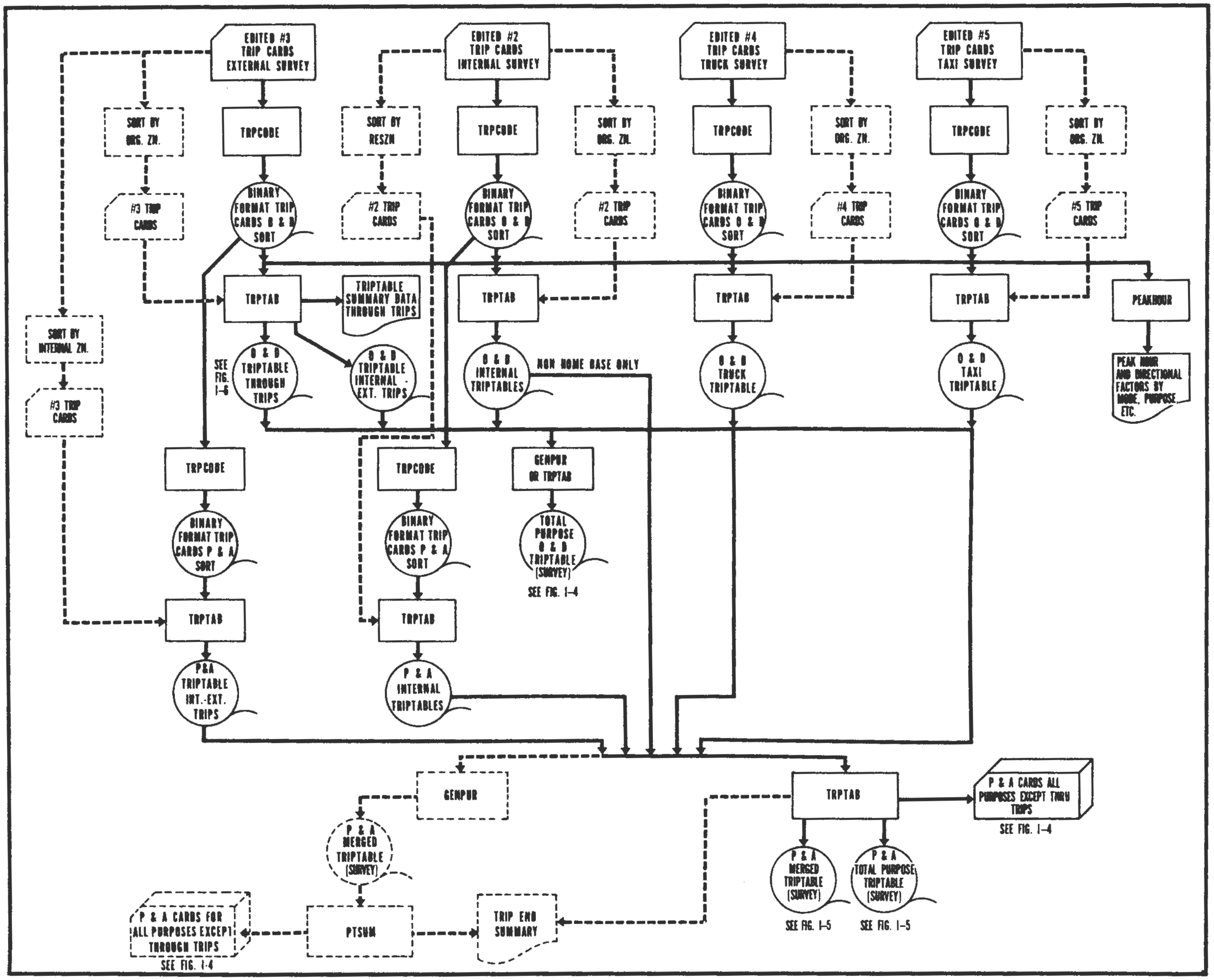


FIGURE I-4

POSSIBLE BASE YEAR SYSTEM FLOW CHART

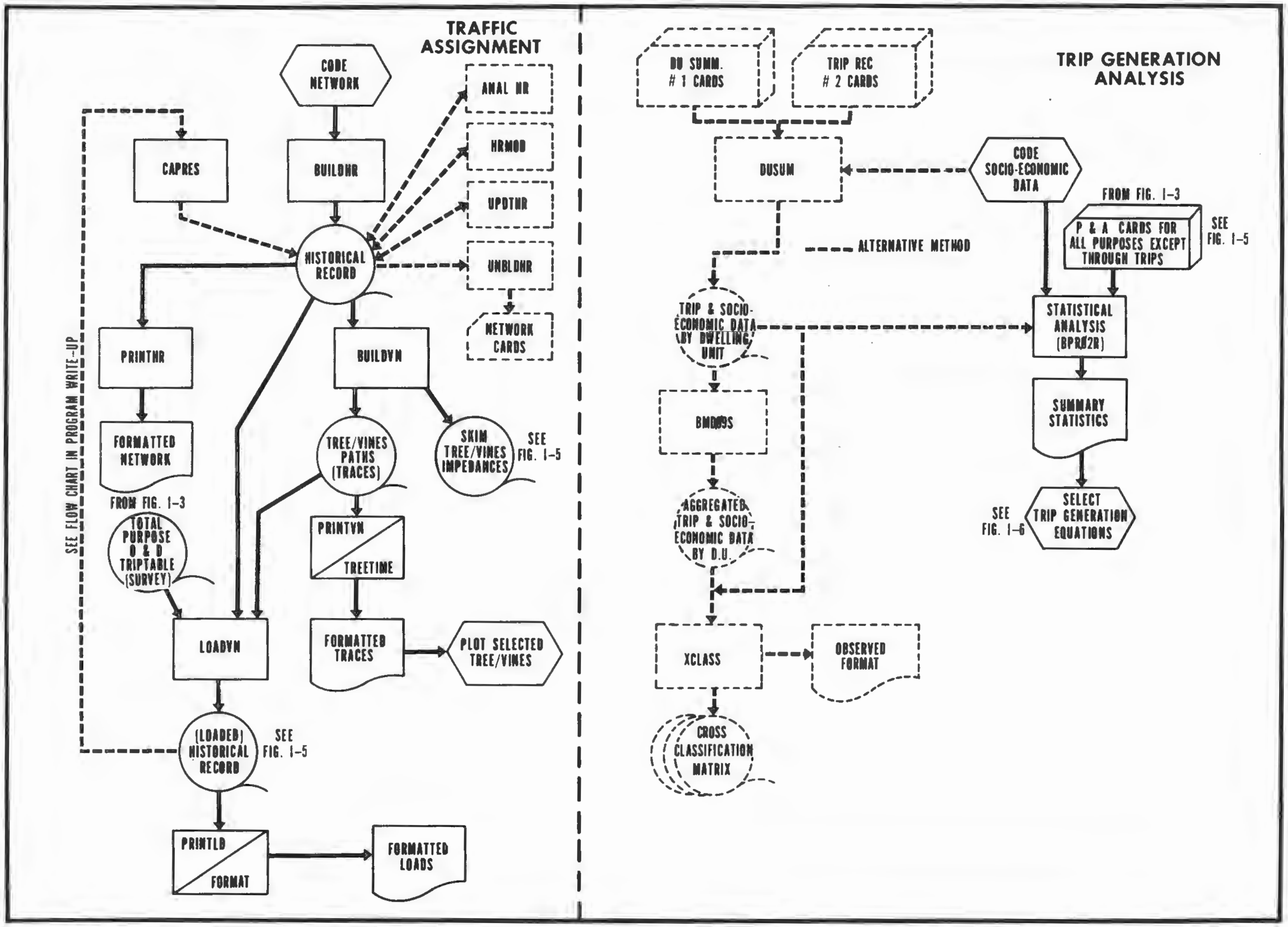


FIGURE I-5

POSSIBLE BASE YEAR SYSTEM FLOW CHART

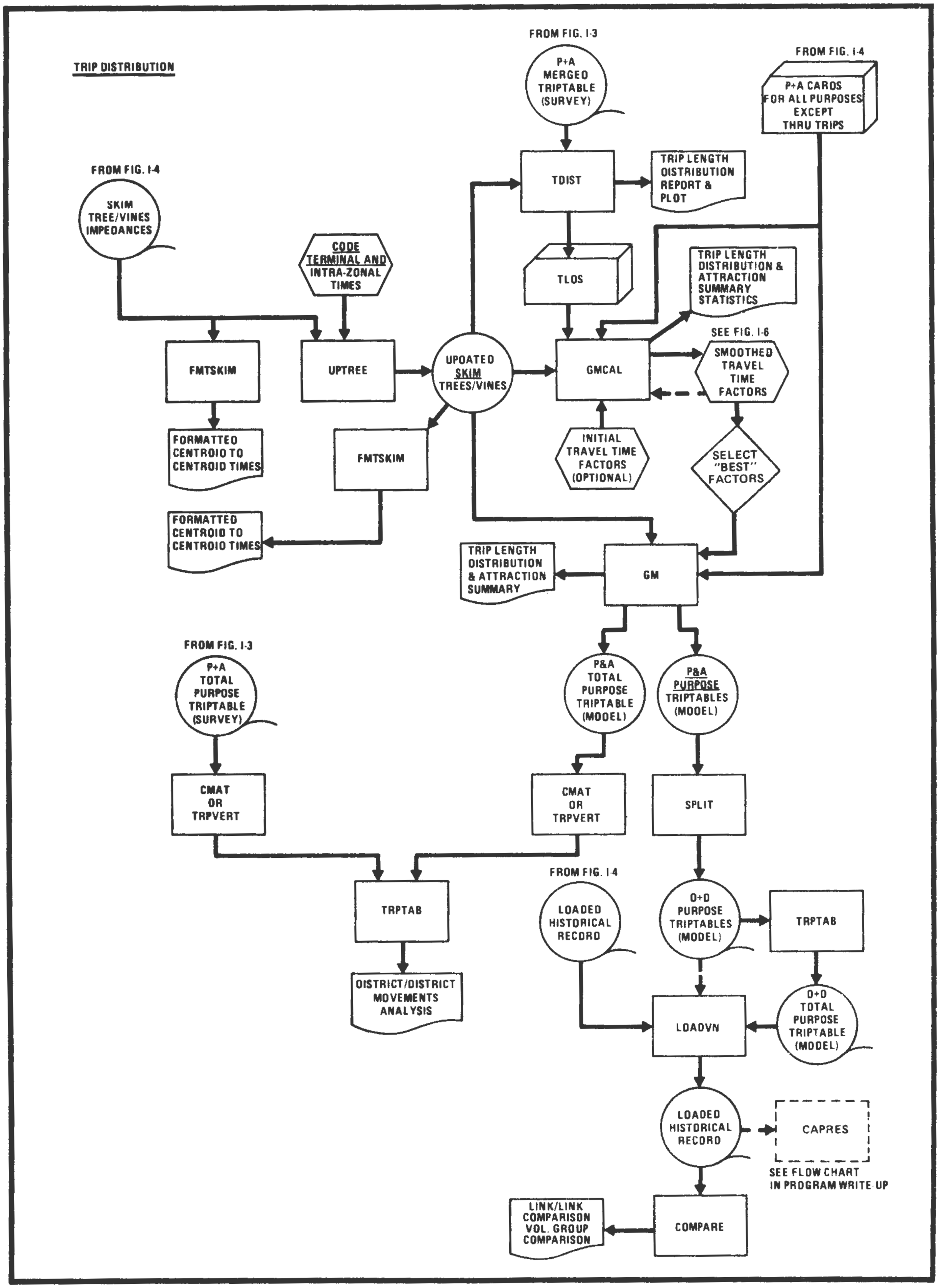


FIGURE I-6

POSSIBLE FORECAST YEAR SYSTEM FLOW CHART

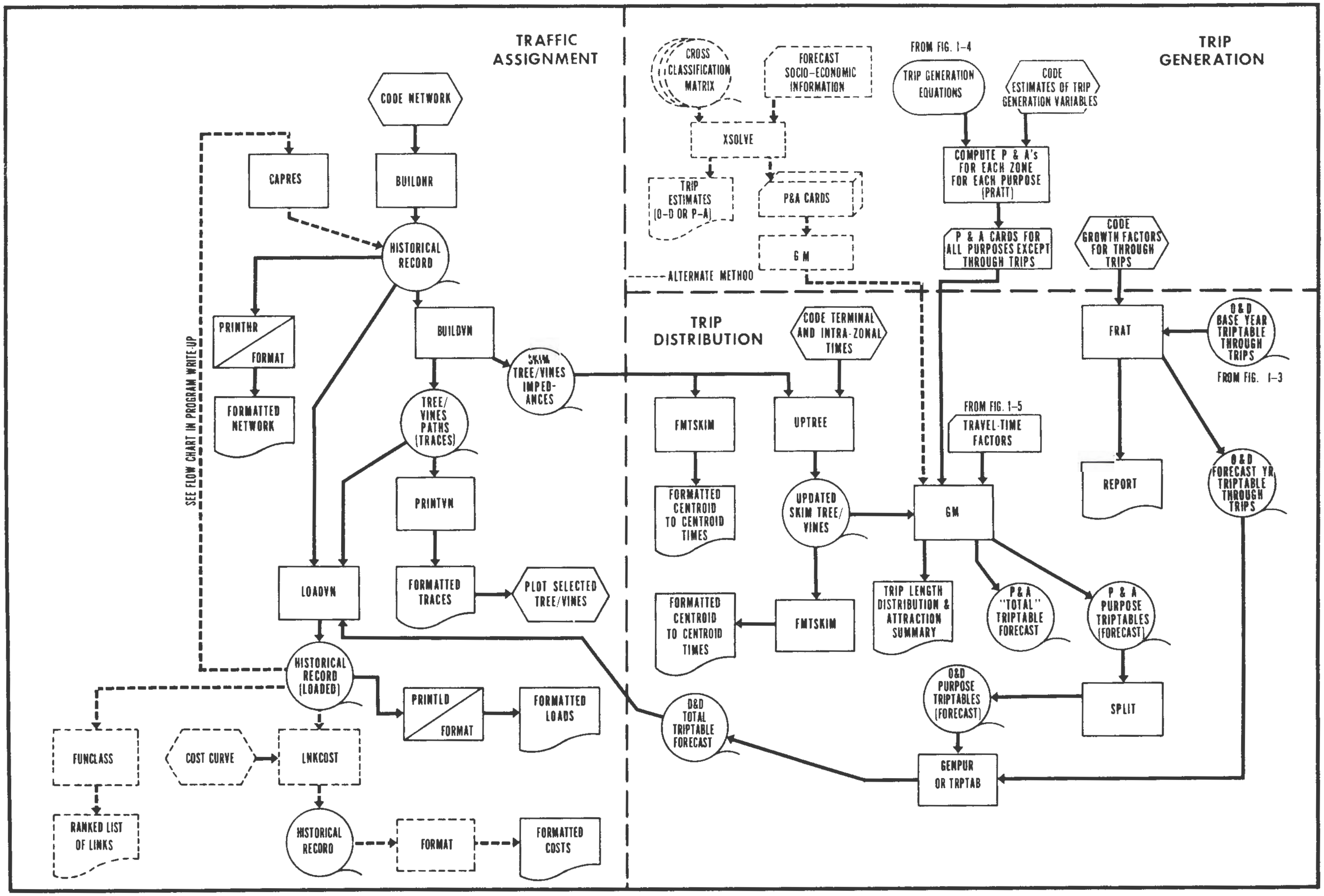


FIGURE I–7

POSSIBLE BASE-YEAR / FORECAST YEAR SYSTEM FLOW CHART

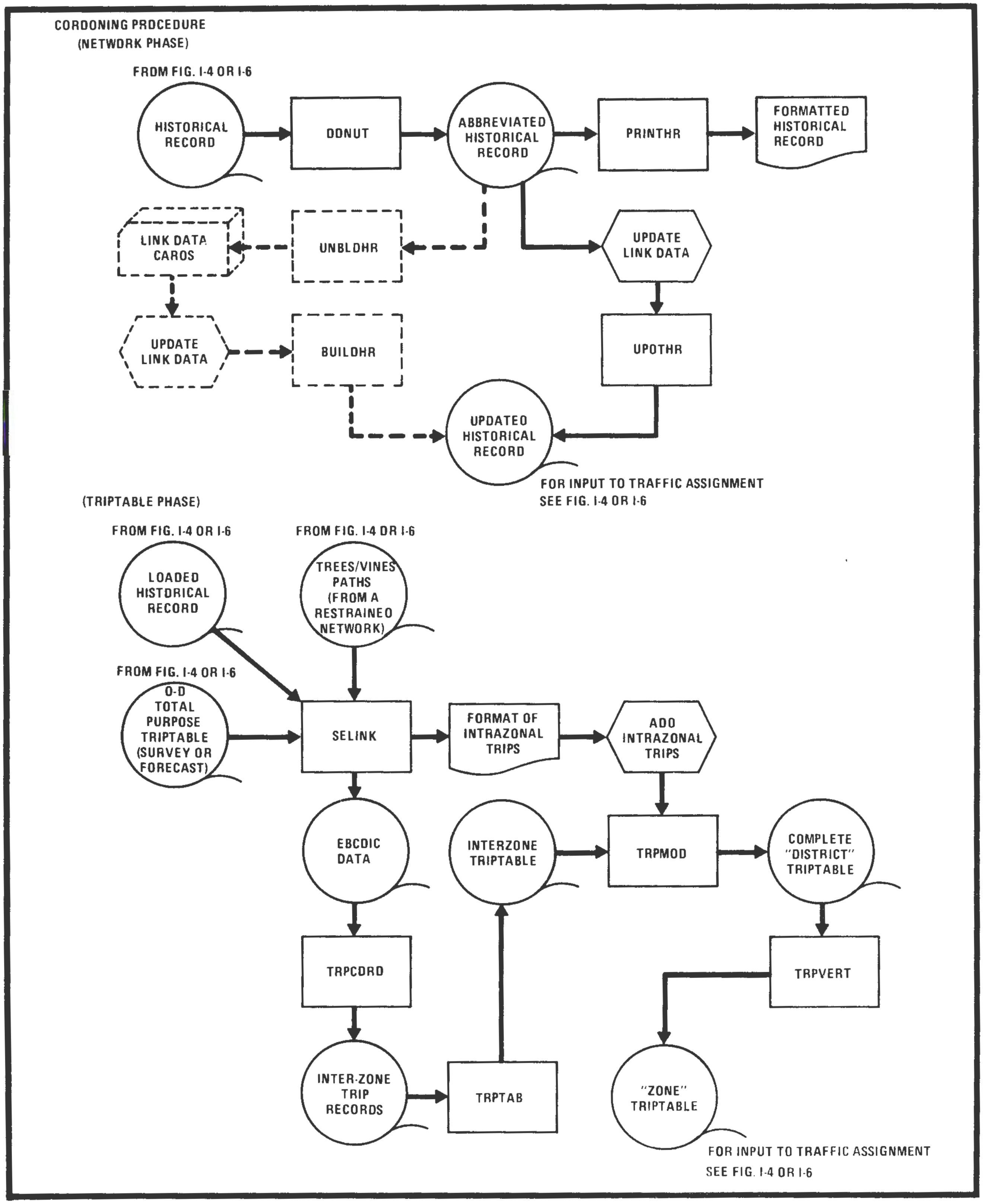


FIGURE I-8

SYSTEMS FLOW CHART FOR ANALYZING SPIDERWEB NETWORKS

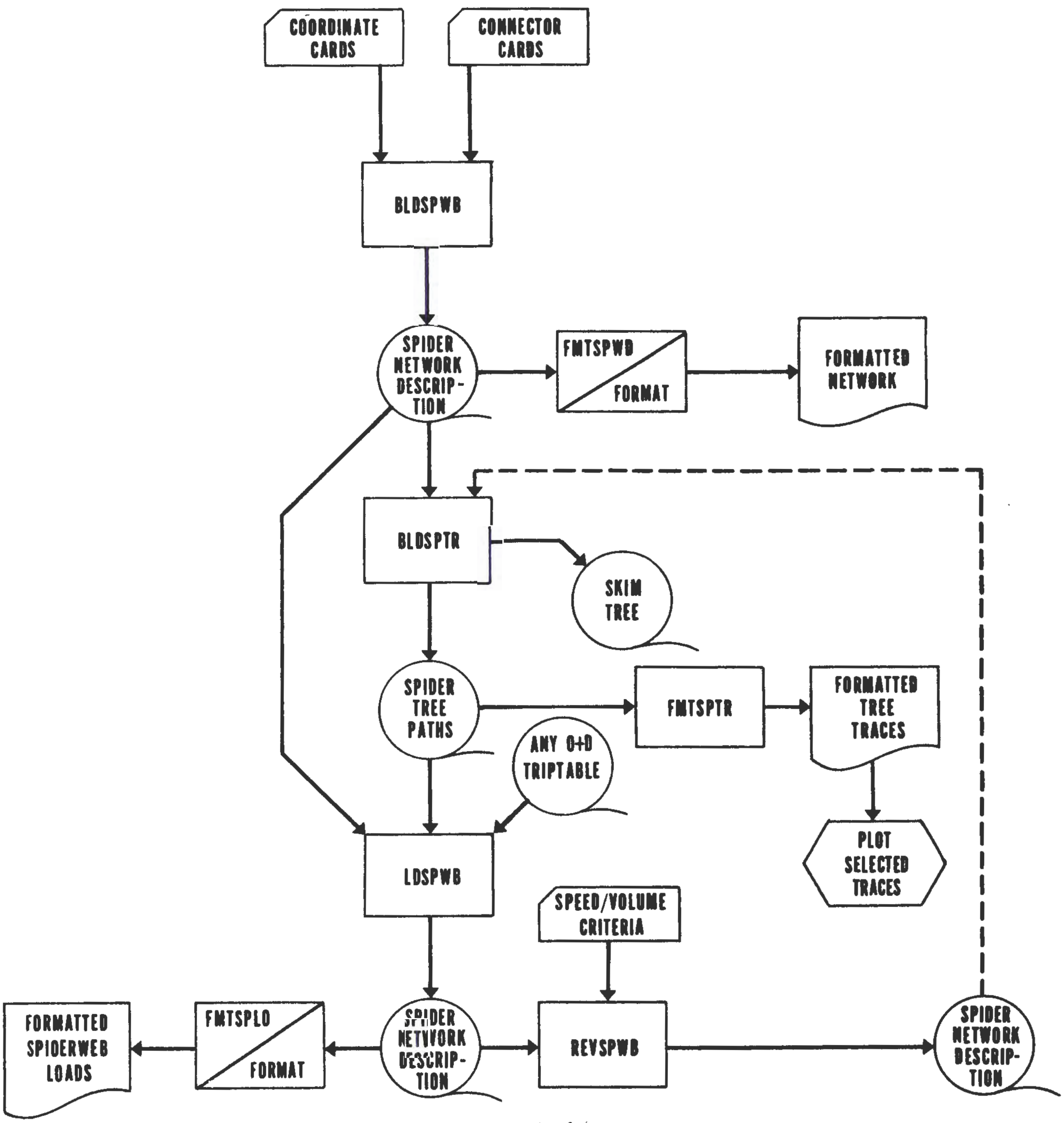


Figure I-9

SYSTEMS FLOW CHART FOR GENERATING MACHINE PLOT TAPES

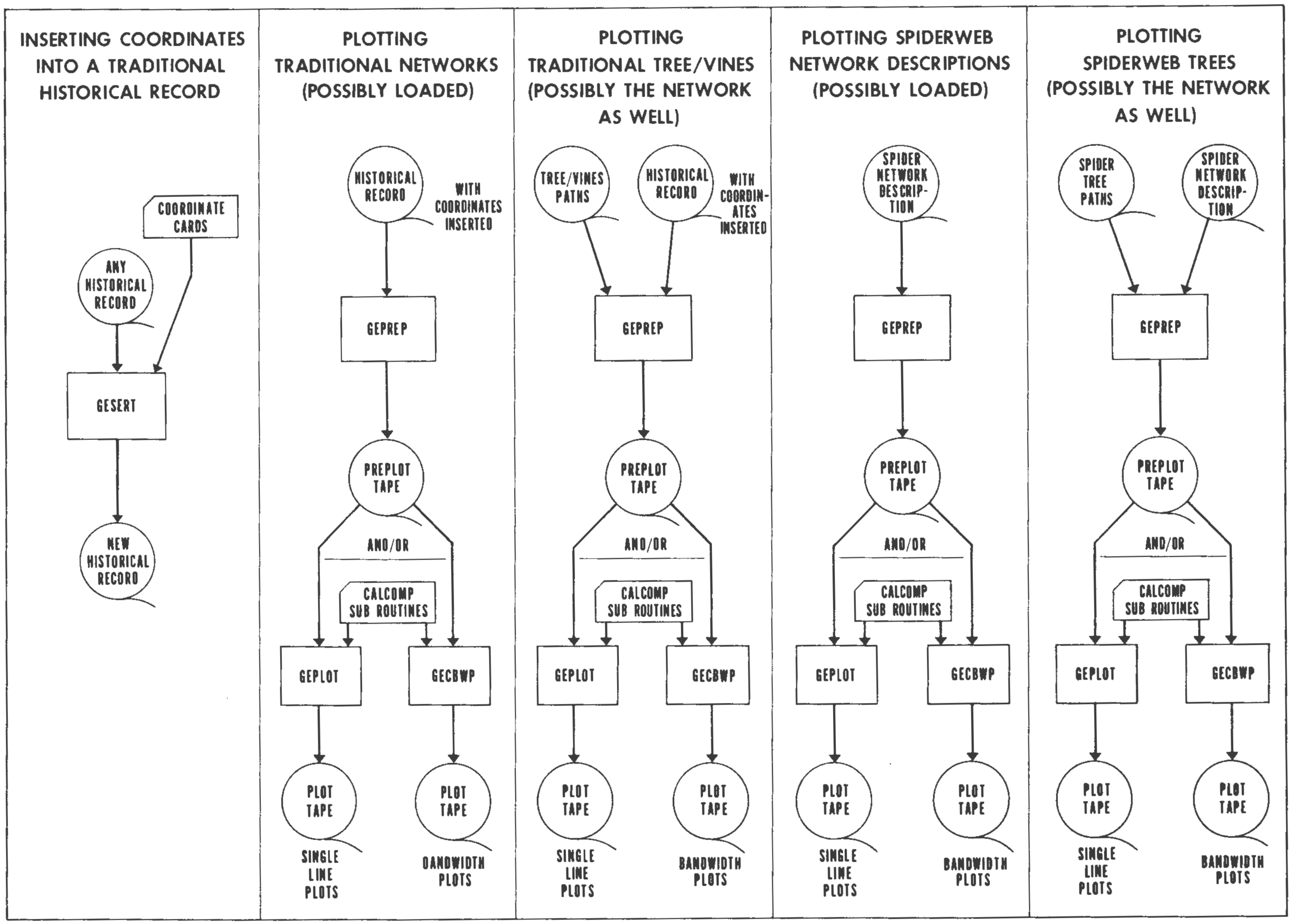
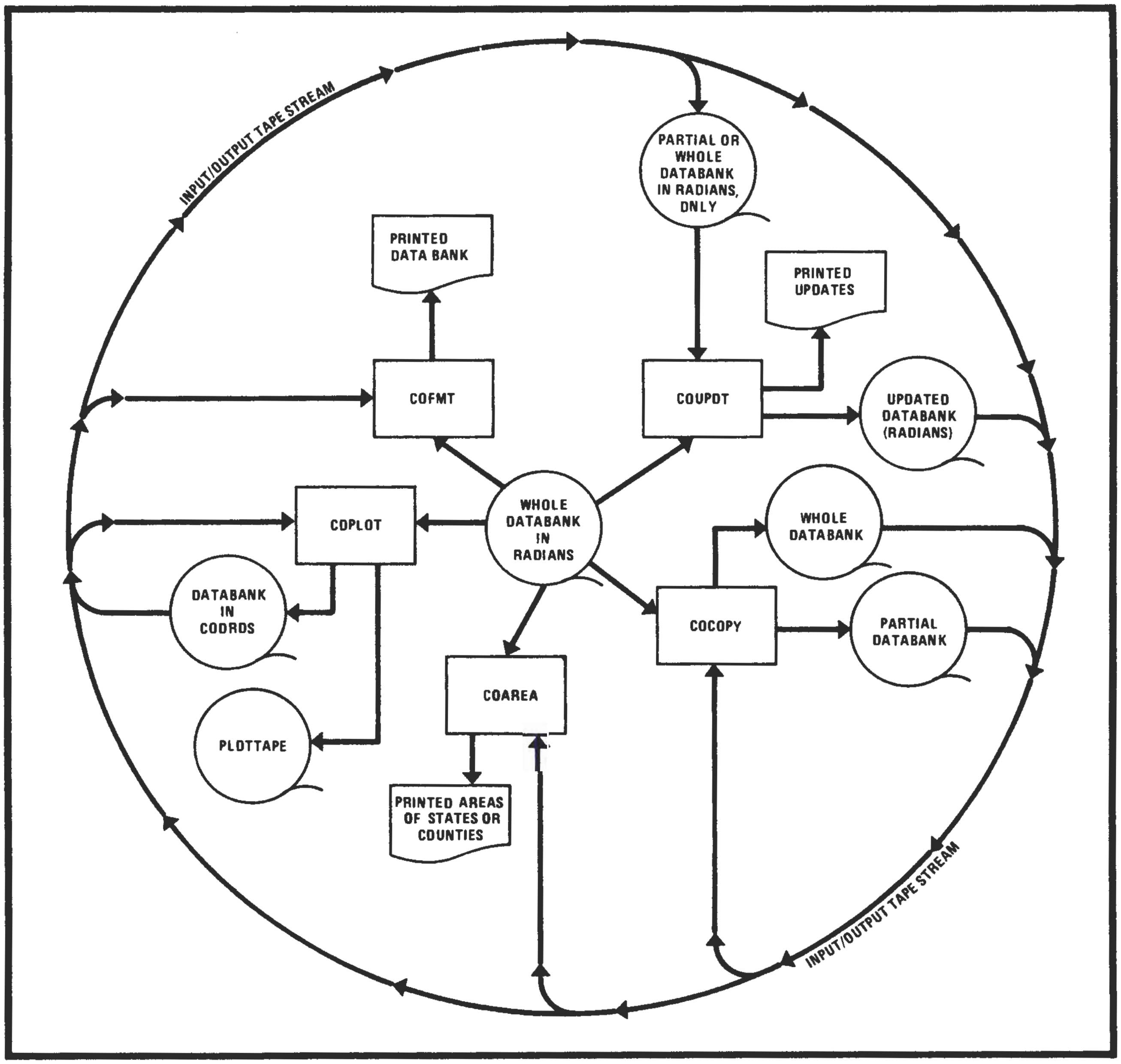


FIGURE I-10

STATE / COUNTY BOUNDARY



CHAPTER II

DATA REQUIREMENTS

A. INVENTORIES - GENERAL

The transportation planning process relies heavily upon measureable and observed characteristics within an urban area. These base year conditions are the basis for forecasting future system requirements. The inventories made to obtain information on the current situation include:

- Land use
- Population
- Economic Factors
- Transportation Facilities
- Travel Patterns (O-D surveys)
- Legislation
- Financial Resources

The data collected is expanded, summarized and processed for analysis purposes to develop trends and basic relationships between existing conditions. These data form the basis for developing models for trip generation, trip distribution, modal choice and traffic assignment.

The inventories most pertinent in the use of the Urban Planning System 360 are for transportation facilities and travel patterns.

B. TRANSPORTATION SYSTEMS INVENTORIES

Transportation facility inventories include those for highway, transit and terminals. These inventories (particularly highway and transit) provide the basis for traffic assignment networks.

1. Highway system.

An initial step in highway system inventories is the functional classification of streets and highways into 1) the principal arterial system, 2) the major arterial street system, 3) the minor arterial street system, 4) the collector system and 5) the local system. The classification criteria generally includes:

a) Trips served

(1) trip length
(2) traffic volume

b) Service provided to urban activity centers

c) Systems characteristics

(1) system continuity
(2) facility spacing
(3) access control
(4) level of service-speed
(5) transit service
(6) mileage guidelines for system limits
(7) travel guidelines for system limits

The physical features of the highway inventory include 1) roadway features such as number of lanes, pavement and approach widths; 2) traffic and engineering features such as signals and channelization, and 3) traffic and parking regulations such as signs and pedestrian controls.

The existing traffic service studies provide data necessary to measure the existing level of service. These data are necessary for traffic assignment purposes.

a. Street and highway capacity. The performance of the the arterial and collector streets, insofar as their traffic-carrying is concerned, reflects the capacities of the major street intersections. Thus, the major street intersections have an important role in the evaluation of the present level of service provided by the existing system, as well as estimating its future adequacy. In measuring the capacity of intersections, three factors are involved--geometrics, traffic characteristics, and the traffic controls at the intersection and on its approaches.

Since the ability of an intersection to function during peak hour conditions is of primary concern, the traffic volume counts and turning movements should be taken during these hours. The traffic data and information concerning geometrics and traffic controls are then used to determine the intersection capacity. The procedures for computing the capacity of an intersection are described in the new "Highway Capacity Manual" issued by the Highway Research Board. Capacity studies should be made at all major and problem intersections, as well as on other facilities where intersections are not the controlling factor (e.g., urban freeways). Chapter VII, Section J describes computer programs for capacity calculations. Capacity is used in the assignment process for capacity restraint purposes (see Chapter III).

b. Traffic volumes. Traffic volume data is needed in several phases of the urban planning process which deal with the verification and/or development of transportation models. Traffic counts which yield independent estimates of travel patterns and growth are used to evaluate the ability of the entire traffic forecasting process to simulate actual travel. In the period between the model development and/or reevaluation phases, there is a need to monitor change. The surveillance of traffic volumes allows the identification of travel growth trends for the total as well as subareas. The cost of obtaining complete accuracy in measuring average daily volumes for the entire network would be prohibitive. Therefore, sampling methods are used to gather traffic volume data with a degree of accuracy sufficient for the needs of the study.

In designing a traffic counting program for an urban transportation study, it is important to obtain traffic volumes which are representative of the conditions existing during the time that the trip information is being obtained in the O-D studies, so that reasonable comparisons can be made between ground counts and the O-D trips assigned to the transportation network.

Generally speaking, the traffic counting program may be divided into the following phases:

a. Continuous counts
b. Seasonal counts
c. Coverage counts
d. Turning movement and classification counts

Continuous and seasonal counts are taken to determine patterns of seasonal, daily, and hourly variations in traffic volumes which are typical of roads and streets in the study area. Adjustment factors developed from these counts are applied to short-term sample counts to obtain estimates of average daily volumes. The need for these two types of control stations depends on the degree of accuracy desired.

Coverage counts are taken to obtain traffic volume information at sufficient locations to be representative of each section of city street in the transportation study network. These counts may be taken either manually or by machine and should be taken on each leg of an intersection. Coverage counts need to be made only at alternate intersections and may be farther apart depending upon the desired accuracy of the resulting estimates of average daily traffic. Machine counts should be of 24-hour duration on weekdays, while manual short counts should be a minimum of 6-minute duration and repeated every hour for 8 hours. To estimate the total volume of traffic during the 8-hour period of count, the traffic volume for the eight 6-minute periods should be added and the sum multiplied by 10. To estimate the 24-hour volume of traffic, it is necessary to have one 24-hour machine count located along the route where 6-minute counts are taken. Coverage counts are adjusted to estimates of average daily volume by the use of monthly, weekly, or daily factors developed at appropriate continuous and seasonal count stations. Estimates of peak hour volumes at coverage stations may also be obtained by applying factors from appropriate continuous and seasonal count stations. In general, approximately 100 coverage count stations will be required for each 50 miles of city streets.

When required in the planning process, classification and directional distribution data should be collected at each continuous count station and at a sufficient number of other volume counting stations to be representative of all significant variations in the study area. When it is necessary to determine turning movements and classification of traffic by vehicle type during the peak hour, short manual counts of two to four hours may be made which include the peak period.

For additional information on traffic volumes see the manual "Traffic Volume Counting Manual", published March 1970, and available from the Federal Highway Administration.

c. Traveltime. A primary consideration of the vehicle operator in selecting a route of travel is the total time required to reach his destination. For that reason traveltime is an important measurement of traffic service. Traveltime studies provide a measure of congestion which can be utilized in developing vehicle operating costs. Further, traveltime is extremely useful in estimating usage of a new facility as well as the benefits to be derived from its construction. These data are also necessary in the traffic forecasting phase of an urban transportation study in assignment and trip distribution.

Traveltime studies are usually limited to the arterial street system. Determination of peak hour volumes and predominate flow is necessary prior to initiating this study. Equipment and personnel for the operations include an automobile, driver, observer, stop watch, and recording forms. Since peak hour volumes are considered to be the most critical data, the runs should be made during evening and morning peaks; runs should also be made during normal (off-peak) daytime hours to obtain reasonable traveltimes for ADT analysis. Some studies have used the following formula for determining ADT traveltime, since approximately two-thirds of the traffic occurs in the off-peak hours:

$$\text{ADT Traveltime} = \frac{2\ (\text{off peak traveltime}) + 1\ (\text{peak traveltime})}{3}$$

Pavements should be dry during these runs. As many traveltime runs as needed to obtain a reasonable (and stable) estimate of time on a route (usually two during the a.m. peak, two during the p.m. peak, and two during the off peak hours) should be made. Most major routes of the system should be covered; a table of representative speeds for different types of facilities in specific areas of the urban area (CBD, fringe, suburban, etc., see Figure III-4) can be set up and used to assign speeds to those routes not inventoried. This table is illustrative and does not pertain to any specific urban area. Isochronal charts may be used for graphic presentation of the data after the analysis work is completed.

An alternative to collecting traveltime in a car (e.g. floating car technique) would be through the use of license plate recording. The recording would be accomplished at both ends of a link and matched to obtain the elapsed traveltime. A tape recorder can be used to record the license numbers (the speed of the tape can be utilized to obtain a good estimate of the recording time from some established base). Photographic recording is also a possibility. These methods allow the gathering of a larger sample than is usually obtained from a car pacing method. The results of the recording would be keypunched and computer matched to obtain the traveltimes. A program LICMATCH has been developed for these purposes. Refer to Chapter VII, Section L for additional information.

See the link data coding format in Chapter III, Section 3 for the highway inventory items to be coded for assignment purposes.

2. Transit System

Data which describes the transit system and usage can usually be obtained from the company or agency operating in the study area. In many of our urban areas, much of the data needed in a transit inventory is a matter of public record. Any data which cannot be collected directly from the transit company should be requested through the state and local regulatory agencies, city governments, or the agency granting operating authority to the transit company.

a. Service area. The area served by the transit system should be defined by collecting the following data:

-Map of the study area indicating the following:

(1) Transit routes by type of service
(2) Location of transfer points, terminal and parking facilities
(3) Area within ¼ mile of transit route
(4) Potential areas for transit

-Population of the study area and within ¼ mile of transit route.

-List of transit companies and/or operating agencies by service area.

b. System data. The following data should be collected on each transit company or agency providing service within the study area.

-Total number and miles of routes by type of service and company.

-Total number of transit vehicles by type, age, seating capacity, and number of vehicles air-conditioned for each company.

-Transit vehicle maintenance procedures.

-Restrictions under which each company operates including franchise limitations, prescribed loading standards, and union agreements.

-Description of terminal facilities including type of facility, passenger and transit vehicle capacity; type of parking facilities and number of spaces provided.

-Financial condition of each company.

-Fare structure including parking cost information for parking facilities established in conjunction with transit service.

-Organizational structure.

-Method of financing including source and amount of any subsidies.

c. Revenue data. The following data should be collected on each transit company or agency operating in the study area.

-Total annual and average weekday revenue by class (i.e., regular route, charter, other).

-Average weekday Saturday, and Sunday revenue for each route.

-Revenue per vehicle mile for the system and individual route.

d. Cost data. The cost of providing transit service in the study area should be determined by obtaining the following data:

-Annual and weekday total system costs

-Weekday, Saturday, and Sunday costs by route

-System costs per vehicle mile

-Annual capital costs

e. Operating Statistics. The following items of data should be collected for each company and summarized to describe the operating characteristics of the entire system.

-Total annual and weekday vehicle miles and hours of operation.

-Individual route data including:

(1) Route number, streets traversed, and terminal to terminal mileage
(2) Daily hours of operation
(3) Number of one-way vehicle trips
(4) Minimum, maximum and average headway (frequency between vehicles) by time period (i.e., AM peak, PM peak, midday, night)
(5) Running time by route segment, terminal to terminal and round trip total for peak and off peak hours
(6) Average trip turn-around time (layover) by time period
(7) Number of vehicles required to operate schedule by time period
(8) Operating speeds by time period
(9) Location of transit stops, average spacing, and points of transfer
(10) Schedule adherence - percent of vehicles on time, late or early
(11) Type of vehicles assigned
(12) Accidents by type of service

f. Passenger volume. Data which will describe the usage of the transit system should consist of the following:

-Total annual and average weekday system passengers by classification (e.g., revenue, transfer and school)

-Maximum load point passenger counts by direction to develop occupancy ratios

-Total annual and average weekday passengers by route

-On and off passenger counts at terminals and major loading points

-Passengers per mile by route and total system

g. Transit origin - destination surveys. There are two types of origin - destination surveys which are generally used to develop transit travel patterns in an urban area. These are the home interview survey and the on-vehicle transit survey.

The home interview survey is a measure of the total trips made in the study area. This type of survey covers all modes of travel including private and public transporation. For a transit study, the number of transit trips surveyed during the home interview may be too small in many cases. After the data is stratified, it may be too thin to develop a stable model for predicting future transit travel. Also, the data on travel habits collected during the home interview survey may be too old for use in a transit study. Many changes may have taken place in the transportation system as well as variations in land use and growth characteristics which would affect the choice of mode as well as bring about revised travel patterns. Up-to-date transit travel data may be needed when a survey of all travel is not warranted. In many cases the traditional home interview may not fill the transit travel data needs.

The on-vehicle transit survey is a survey of transit trips only and it can be made on the same day the trip is made. Through this type of survey, a large sample of transit trips can be obtained which will result in a more stable model for predicating future transit travel. The transit survey is an in-depth study of transit travel patterns and can be conducted in the following ways:

-Direct on-vehicle interviews by trained personnel

-Post card questionnaires distributed to passengers on transit vehicles

C. TRAVEL SURVEYS

The purpose of the travel inventories is to obtain a complete picture of present travel within an urban area. This information is then used to make future estimates of travel and allow the location and design of new transportation facitities.

There are three basic types of inventories which cover vehicle and person travel throughout an urban area:

1. Home interview survey
2. Truck and taxi surveys
3. External or cordon line survey

The home interview survey obtains a measure of the total trips made by residents of an urban area. The trips obtained account for 80-90 percent of the total trips in a study area. The unit of observation for the selection of a sample is the dwelling unit. Usually a sample size of 12½ percent is recommended for a population of 50,000 - 150,000 ranging down to 4 percent for 1,000,000+ population to obtain a stable sample. The details for accomplishing a travel survey can be found in the Home Interview Survey manual prepared by the Federal Highway Administration.

In order to conduct an efficient survey, one which is complete and accurate, it is imperative that a comprehensive quality control program be initiated to insure the acceptability and reliability of the collected data. The Urban Planning System 360 contains the program QUALCON (Quality Control and Progress Report Program for the Standard Home Interview). This program has been written to compare the work submitted by each interviewer to all the interviewers in the study area for households which have similar tripmaking characteristics. After making this comparison, the interviewer whose work is significantly different from all other interviewers will be identified. A second feature, the progress report program, has been written to provide an efficient means for reporting weekly and cumulative study progress.

The truck survey is designed to obtain a current picture of truck travel in the survey area. To accomplish this, the technique of selecting and interviewing a sample of all trucks garaged within the survey area is utilized in a manner similar to the sampling of dwelling units previously described. Experience indicates that a percent sample approximately double of that for the dwelling unit survey, will provide adequate results.

The cordon survey should intercept 95 percent of travel crossing the study area boundary. Also, 25-50 percent of the traffic should be interviewed. This survey is used to obtain travel for persons not living in the survey area and for trucks registered outside the area, and supplements the internal survey data.

D. EVALUATION OF TRAVEL SURVEY DATA

An important phase of the transportation planning process begins after the travel survey data have been collected, keypunched, and edited. At this point, there are five basic survey cards available that supposedly give a clear picture of travel characteristics in the study area. They are:

Card No. 1 - Dwelling unit summary
Card No. 2 - Internal trip report
Card No. 3 - External trip report
Card No. 4 - Truck trip report
Card No. 5 - Taxi trip report

The unanswered question at this point is "How good are these data?"

1. Dwelling Unit Summary Comparisons

The simplest test of the survey accuracy is a comparison of the dwelling unit summary information to similar data from other independent sources; e.g., census, motor registry, utility company, and school board records. In addition, broad indicators such as trips per dwelling unit and trips per person can be developed and checked against nationwide summaries. If good quality control is maintained during the survey, an overall study area check of 95 percent or better should be obtained. In any case, no census tract should have less than an 85 percent check.

It should be recognized, however, that an acceptable check of the dwelling unit summary data does not necessarily mean that the corresponding trip data are also acceptable. It merely indicates that the more easily obtained dwelling unit data (population, autos, dwelling units) have been collected and expanded correctly.

The program PRKTAB can be utilized to obtain tabulations of survey data (see CHAPTER VII, Section I).

2. Trip Data Comparisons - Screenline

The most widely used method of checking the accuracy of the expanded trip data is the screenline comparison. A screenline is an imaginary line dividing the study area into two parts. Its purpose is to check the completeness and accuracy of the reported trip data. This is done by making manual classification counts of all vehicles crossing the screenline and comparing these counts, by hours, to the number of trips having an origin on one side and a destination on the other as determined from the expanded interview data.

In order for a screenline to operate properly, it must be located correctly. When locating a screenline, it is important that it:

a. Extends entirely across the internal area

b. Minimizes opportunities for multiple crossings

c. Intercepts large volumes of internal travel and a minimum number of external trips

d. Follows, not cuts, traffic zone boundaries

Before proceeding to the preparation of tables and charts comparing survey and ground count volumes at the screenline, a judgment should be made concerning the impact of multiple crossings. In some areas, multiple crossings may not be significant in determining the adequacy of the reported trip data; e.g., the screenline is a natural barrier such as a river with a limited number of crossings. In this instance, a determination that multiple crossings do not affect the accuracy comparisons is probably justified.

In other areas, the location of a perfect screenline is impossible; i.e., multiple crossings do occur. In these instances, a reduction in the ground count to account for multiple crossings prior to making the screenline comparisons is reasonable.

Any reduction in the ground count greater than 5 percent should be justified. One method of accomplishing this is by conducting screenline interviews. Another method is to conduct a license plate survey at the screenline crossings. A third method available to give insight into the magnitude of the problem is to use SELINK. See CHAPTER VII, Section B for a description of this program and its use.

After analyzing the multiple crossing problem and making appropriate adjustments, the actual screenline comparisons may proceed. The tables and charts to be prepared are adequately described in the home interview manual.

The home interview manual states that an 85 percent screenline check is adequate and further analysis can proceed immediately. Although adequate in the precomputer era, recent experience has shown that better assignment results are obtained if the screenline is adjusted upward to about 97 percent. It is strongly recommended that this suggestion be considered.

3. Trip Data Comparisons - Assignment

Another valuable tool that can be used in evaluating the adequacy of the reported trip data is traffic assignment. By assigning unadjusted trips to the present network, it is possible to get an areawide feel for the adequacy of the trip data. Such indicators as total trips assigned vs. total counted volume, corridor checks, vehicle-miles of travel, etc., can be used to further substantiate the adequacy of the trip data. Furthermore, these checks should be made if there are any doubts about the screenline analyses (See CHAPTER III).

4. Cordon Check

Travel data obtained during the external roadside survey include trips crossing the cordon line made by residents of the study area as well as by people not living within the study area. Travel data on trips crossing the cordon made by study area residents are also obtained during the home interview survey. It is, therefore, possible to compare these data as an additional indication of the accuracy of the travel data. Since the external survey is made using a high sample rate, the external data are assumed to be more accurate than the internal home interview data and are used as the basis for comparison.

Trips crossing the cordon are long in nature and are usually well reported in the home interview. For this reason, this accuracy check normally gives better results than the other travel checks and is, therefore, used only as a guide in factoring the internal data.

5. Screenline Adjustment

After a determination has been made that the trip data are under-reported, there are several methods that may be used to develop adjustment factors.

Method 1 - If the reported trip data are under-reported by a fairly constant amount for <u>each</u> hour of the day, a uniform factor may be applied to all trips. This condition, however, is extremely unlikely.

Method 2 - If the reported trip data indicate that peak hour trips compare favorably, thereby establishing the completeness of the work trip data, and the off-peak comparisons vary by a <u>constant</u> amount, a uniform factor may be applied to all nonwork trips. Past experience has shown, however, that the greatest under-reporting of trips usually occurs during the period 10 a.m. to 3 p.m.

Method 3 - A third method is to adjust by purpose. This method is recommended since:

a. Although adjustment by purpose is relatively quick and easy, it does require that the adjustor examine the data carefully. Previously undetected inconsistencies, such as the largest block of trips being for the purpose of serve passenger, may be discovered simply by tabulating the data.

b. This is the only method whereby the total percentage comparison and the comparison by hours can both be adjusted satisfactorily.

c. Common sense dictates that some trips are not as fully reported as others. For example, it is a lot easier for an interviewee to remember that he or she went to work than it is to remember that on the way home from the grocery store a stop was made to pay a bill.

In adjusting screenline comparison data either by the uniform factor methods or by purpose, the general procedure is to apply the adjustment factor only to <u>internal</u> trips. The reasoning is that the external trips <u>are fully</u> reported because of the higher sample rate. It should be recognized, therefore, that the screenline adjustment factor developed is <u>not</u> the percentage difference between the screenline <u>ground</u> count and the trips crossing the screenline as determined from the reported trip data, but some larger factor depending on the extent of external trips crossing the screenline. For example, to adjust an 80 percent screenline check comprised of 50 percent external trips to 100 percent, the adjustment factor would need to be 1.5 times the internal trips.

Furthermore, as the percentage comparison decreases and/or the percent external increases, the adjustment factor increases. This point is discussed because it is well to remember that even with a good screenline check (85 percent), it might be that 25 or 30 percent is being added to the total universe of trips.

To aid in the determination of the number and type of reported trips crossing the screenline, the Federal Highway Administration has a program available to summarize screenline crossings. Program SCREEN reads trip data cards and prepares summaries by purpose, time and mode for those trips crossing a user defined screenline.

In addition a summary of trips not crossing the screenline is compiled. This compilation is important since the breakdown by purpose of trips not crossing the screenline may not be equal to the breakdown of trips crossing the screenline by purpose. For example, 50 percent of trips crossing the screenline may be for the purpose of work, while only 40 percent of all trips made throughout the study area are for a work purpose.

To adjust a screenline by purpose, the following procedure is recommended. The procedure considers only internal auto driver trips. It should be remembered, however, that the internal auto passenger trips must be factored by the developed internal auto driver adjustment factors, and that truck, taxi, and transit trips may require adjustment. A similar procedure would be employed to factor these trips.

a. Obtain a tabulation of total auto driver trips crossing and not crossing the screenline by hour period and purpose. In making this tabulation, the travel survey cards are processed by the screenline program. "Gravity model" type trip purposes should be used in making those tabulations; i.e., trips from or to "home" are considered to be home based and trips with neither end at "home" are considered to be nonhome based.

b. Determine the amount of underreporting that exists in the internal auto driver trip data for trips crossing the screenline (U_{ic}). A value of U_{ic} is obtained as follows:

$$U_{ic} = \frac{(T_{gc}) - (T_{ic} + T_{ec})}{T_{ic}}$$

Where: T_{gc} = Total number of autos manually counted crossing the screenline.

T_{ic} = Total number of internal autos crossing the screenline as determined from the expanded trip inventories.

T_{ec} = Total number of external autos crossing the screenline as determined from the expanded trip inventories.

c. Examine the screenline comparison graphs (plots of trips by purpose and hour period and ground count data by hour period to get a "feel" for what trips are underreported. Develop adjustment factors for these trip purposes such that a plot of screenline ground counts and adjusted survey data compare favorable by hour and the overall comparison is about 97 percent. This is a "trial and error" operation.

d. Apply the adjustment factors to total internal auto driver trips crossing and not crossing the screenline. Set the adjusted total equal to T_{ia}.

e. Determine the amount of underreporting that exists in the internal auto driver trip data (U_i). A value of U_i is obtained as follows:

$$U_i = \frac{T_{ia} - T_{ir}}{T_{ir}}$$

Where: T_{ir} = Total number of internal auto driver trips reported.

T_{ia} = Total number of internal auto driver trips after adjustment.

NOTE: The amount of underreporting of internal trips crossing the screenline (U_{ic}) will be different than the total underreporting of internal trips (U_i). This is due to the difference between the screenline and total internal area with respect to the proportion of total trips made for each specific trip purpose. The total amount of underreporting of internal trips (U_i) will not be used in adjusting the data, but it is good to know the magnitude of underreporting.

E. PREPARATION OF TRIP TABLES

1. General Information

A trip table is an area to area matrix of trips. The use of a computer in the urban transportation planning process requires that trip data be summarized to areal units which are called traffic analysis zones. All trips to (or from) these areas are assumed to end (or begin) at the center of activity of these zones. The trip table is actually a binary representation of this matrix of trips.

A trip table does not contain specific routings, only interchanges of trips throughout an urban area. The table is generally a square matrix with a cell for each one-way interchange: thus, there would be a cell containing trips from zone 1 to zone 2 and also a cell for trips from zone 2 to zone 1.

There are two basic types of trip tables used in transportation planning--origin-destination (O-D) and production-attraction (P-A). Trip tables are in sort by origin zone for an O-D table or production zone in case of a P-A table. The O-D trip table consists of a matrix of trips from each zone (the origin) to each other zone (the destination). An assignment trip table consists of a combination of all types of trips by vehicles throughout an urban area. This includes automobile, truck, and taxi vehicle trips for all trip purposes. It includes trips which have one end outside the urban area and one end within the area. This type of trip table is used as a supplemental check of survey data and for calibration of a traffic assignment network. After future traffic projections are made, a trip table of this type is used to load trips on various facilities for plan development purposes.

Program TRPTAB (alone or in combination with program TRPCODE) is used to build trip tables. The preferable approach is to utilize TRPCODE to produce a standard format survey record tape file. This file can be in sort by origin zone (TRPTAB will build standard O-D trip tables) or by production zone (TRPCODE will examine residence, origin and destination zones and assign production and attraction zones from which TRPTAB will build P-A trip tables). Non-home-based trips will be handled properly by this method.

An alternative, but less desirable, method for building P-A trip tables is through the use of TRPTAB alone. Non-home based trips are separated from home-based trips and sorted by residence zone. TRPTAB is then utilized to build the trip tables. The residence zone of the home-based trip becomes the production zone (must be the same as the origin or destination zone) and the attraction zone is taken as either the non-residence origin or destination zone.

An O-D trip table can also consist of only a portion of the trips mentioned above. This type of trip table usually is used for a special purpose traffic assignment to test the effect of a certain type of trip on the transportation system. It is sometimes desired to determine the effect of external trips, CBD orientated trips, or trips from or to a particular employment site on a transportation system. In these cases, a specialized O-D trip table would be built using only those trips which meet the specific criteria.

A P-A trip table consists of a zone-to-zone matrix of trips which is used in calibration of mathematical models; it is necessary to generate and distribute future trips throughout an urban area when the gravity model is used for trip distribution. Each trip has a production and attraction. For trips which have an end at the home, and this type usually accounts for over 80 percent of the trips throughout an urban area, the home end of the trip is considered to be the production and the other end of the trip the attraction. Thus, a worker would generally have two home-based work trips each day, one to work and one from work. Trips have a more stable relationship with the home and, thus, a trip distribution model can be calibrated with more accuracy when this convention is used. See CHAPTER IV for further information on production and attraction.

Some of the home-based trip purposes used are work, shopping, social-recreational, eat-meal, medical-dental and other. Data must be available from the origin-destination survey to stratify the trips to a fine level. Some smaller studies have combined some of these purposes for their model development, while larger ones have stratified them further such as white collar work, and other work trips. This purpose stratification is necessarily dependent on the desired stratification of the models. The remaining internal trips, those without either end at the home, are called nonhome-based trips, and a regular origin-destination type table is built with them, for use in model calibration.

The general usage of P-A trip tables is in the development of trip distribution and generation models for each trip purpose with survey data. A separate production-attraction trip table is developed for each trip purpose. These are generally internal auto driver or total person trip tables. After the trip generation and trip distribution models yield forecasted trips (i.e., future P-A trip tables), they are factored and converted to O-D trip tables. They are then combined with truck, taxi, and externally orientated trips to produce a total vehicle O-D trip table, which is assigned to a highway network.

The data collected in typical transportation inventories (home interviews, external interviews, truck and taxi interviews) include information concerning the trip and tripmaker. This is coded onto cards which represent dwelling unit information (No. 1 cards), data concerning each person trip from the home interview (No. 2 cards), data concerning external trips (No. 3 cards), and truck and taxi trip data (No. 4 and No. 5 cards). Since a sample was taken in the various surveys, each trip card represents several trips. An expansion factor is generally calculated and punched on each card. This factor is used during the building of the trip tables to expand the trips to represent the total universe of travel data.

The processing usually begins with editing all the cards to insure the logic of the information punched on them such as valid codes in all columns and logical trip information. The No. 2 cards are then prepared for processing by separation of the internal-internal trip cards from the cards with one or both ends with an external origin or destination. The information concerning these external trips is usually obtained from the external survey (No. 3 cards).

After the editing and separating of the cards, the internal trips may be linked. Linking is the process of giving trips their true desired origins and destinations. Some of the trip distribution procedures used (see Chapter IV) are based upon linked trips.

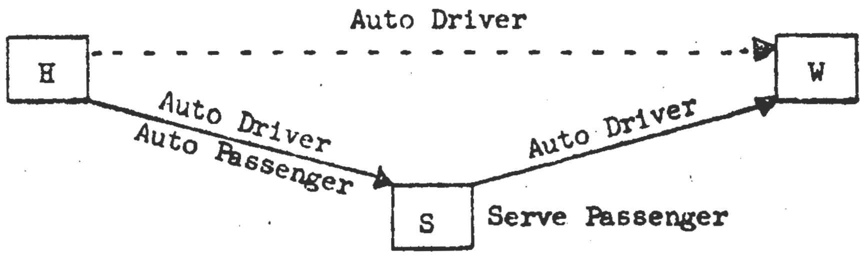
The linking process requires the No. 2 trip cards or trip records to be in a sample number, person number, and trip number sort. The sample number is the primary sort, person number is the secondary sort, and trip number the tertiary sort. This sort is necessary to sequence the trip pattern of each tripmaker in the order in which the trips were made on a particular day.

Because of the standard origin-destination survey definition of a trip, many journeys made by a tripmaker have to be represented by two or more trip records even though only one journey is involved. In an origin-destination survey, one trip ends and another begins every time a person changes his mode of travel, or an auto-driver stops to serve a passenger, or when the tripmaker reaches his ultimate destination. There are two types of trips which may be linked--change mode and serve passenger trips. If each of these trips are analyzed separately, the relationships between the actual starting point, the ultimate destination, and the purpose of trip would be lost. Some analysts find it more convenient to relate the type and intensity of the linked trip to the type and intensity of the land use. Consequently, it is usually desirable to combine or link those trips with a purpose to or purpose from of either change mode of travel or serve passenger so that the relationship between the purpose and the ultimate destination of the trip is preserved.

Some examples of those trips which might be combined or linked are shown in Figures II-1, II-2, II-3.

Figure II-1 illustrates an auto driver driving his car from home to a transit station, where he boards a transit vehicle and rides to work. In an origin-destination survey, this journey would be recorded as two separate trips. The first trip would be recorded as an auto driver trip from home to change mode of travel. The second trip would be recorded as a transit passenger trip from change mode of travel to work.

Since the ultimate purpose of this journey was to get from home to work, it is desirable, for some analytical purposes, to link these two trip records into one which covers the entire journey. In this particular case, the linked trip would become a home-to-work trip since this was the ultimate purpose of the trip. The mode of travel would be transit, the assumption being that, if satisfactory transit service was available at the tripmakers' home, he would have used it. Mode of travel is assigned according to a priority listing which in this case ranks transit over the automobile. Regardless of the phase of the journey, that mode used which is of highest priority on the list is assigned to the linked trip. The analyst should decide on the priority listing of modes for his own specific case.



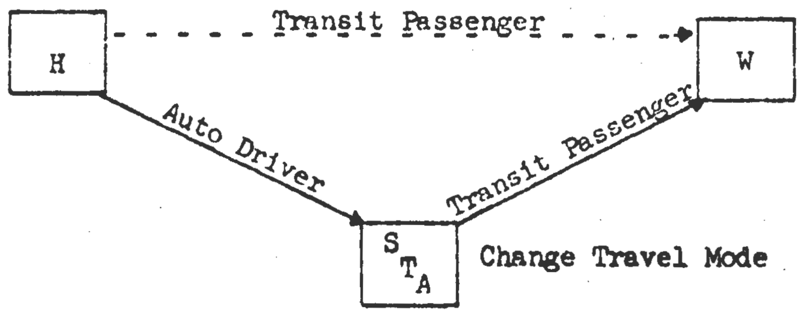
O-D TRIPS

1. From home to serve passenger (auto driver)
2. From serve passenger to work (auto driver)
3. From home to school (auto passenger)

LINKED TRIPS

1. From home to work (auto driver)
2. From home to school (auto passenger)

Figure II-1



O-D TRIPS

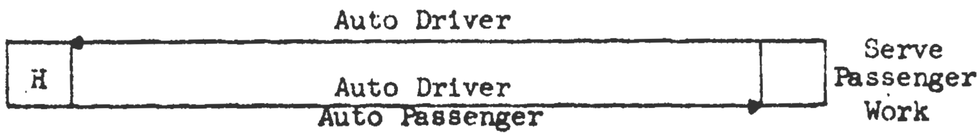
-- From home to change travel mode (auto driver)

-- From change travel mode to work
(transit passenger)

LINKED TRIP

-- From home to work (transit passenger)

Figure II-2



O-D TRIPS

A. From home to serve passenger (auto driver)

B. From serve passenger to home (auto driver)

C. From home to work (auto passenger)

LINKED TRIPS

A. From home to personal business (auto driver)

B. From personal business to home (auto driver)

C. From home to work (auto passenger)

NOTE: Home to home trips are not allowable

Figure II-3

Figure II-2 illustrates a similar situation. An auto driver driving to work first stops at a school where he leaves his child. There are three trips recorded in the home interview: An auto driver trip to serve passenger, an auto driver trip from serve passenger to work, and an auto passenger, home to school trip. Since the ultimate purpose of the auto driver's trips was to get to work, his two trips are linked into one auto driver trip from home to work. The child's ultimate purpose was to school; thus, his trip remains home to school, auto passenger trip.

There are two additional cases in the recording of trips. An example of one of these types occurs when a wife drives her husband to work and then returns home (see Figure II-3). These two trips would be coded as home to serve passenger and serve passenger to home. The linked card for these trips would show an invalid home-to-home trip for the wife, provided the normal logic was followed. Instead, the serve passenger code for each trip is usually changed to personal business. The normal process is then followed.

The second type concerns those trips which have only one trip record in the journey. For example, a trip by a person who changes mode of travel at an airport or railroad station and leaves the city and does not return that day would be recorded in an origin-destination survey as only one trip with a purpose to of change mode of travel. The one trip record is used as the linked trip record after changing change mode of travel code to personal business code.

Trip linking is not necessary in all studies. For example, in urban areas where change mode trips may be small in number because of the lack of transit facilities and where serve passenger trips may also be small in number because of the absence of car pooling, trip linking may not be necessary. For analysis purposes, trips of this type can often be combined with the other trip purposes with no significant loss in accuracy. However, in larger urban areas, it may be desirable to link trips. The analyst should evaluate the need for trip linking and the rules to be followed if linking appears desirable for his specific case.

The trip linking process may be done on the IBM 1401 computer using a trip linking program, written for the Federal Highway Administration. However, many transportation studies have developed their own linking programs for their specific purposes. The trip linking process causes a decrease in both the absolute number of trips taking place and in the total vehicle (or person) miles of travel in the urban area. The loss in vehicle-miles results from the more direct routing of some linked trips. The exact amount of the decrease in the number of trips can be determined by simple subtraction of the number of trips in the linked records from those in the unlinked records. The slight decrease in vehicle-miles of travel can be obtained by assigning both the linked and the unlinked trip records to a comprehensive highway network and subtracting the two resulting vehicle-miles of travel. From analysis of past studies, it appears that the decrease in trips and in vehicle-miles of travel is of little consequence.

Although the text has been confined to ADT or 24-hour auto driver trip tables by purpose of trip, several other types of trip tables are sometimes needed in the transportation study. It is possible to build a trip table of trips having a specific purpose, mode, land use, or time of day by specifying the proper criteria in the trip table program.

2. S 360 Programs

Figure I-3 shows a typical system flow chart for building base year trip tables (O-D as well as P-A) as well as providing trip end (P-A) cards for trip generation and distribution purposes. The pertinent programs utilized will be described here.

TRPCODE - The purpose of this program is to edit a file of trip cards and write a survey record tape file in a standard format. The binary format output is acceptable by the trip table builder program TRPTAB. TRPCODE will recode information based upon a list of equivalents or ranges. The editing is limited to checking fields against acceptable ranges. The trip records created contain up to 84 bytes of information about the trip which includes fields of information such as origin, destination, production, attraction, by purposes, land uses, auto occupancy, etc. Figure II-4 shows the standard dictionary of data on the record, although any of these may be changed by the user. With the trip records in this format, it is possible to build binary origin-destination trip tables providing the records are in sort by origin of the trip. It is also possible to build binary production-attraction trip tables by purpose by sorting the trip records by the production field. Both home based and non-home based trips will be handled properly.

TRPTAB - This program is used to:

(a) build binary trip tables from edited trip cards or binary trip records from TRPCODE. If trip cards are input, the program can be used to produce a file of trip cards that met table building criteria instead of producing the actual trip tables.

(b) arithmetically manipulate, copy, merge and unmerge trip tables. As an option, the user can also output a trip card file corresponding to the output trip tables. This is useful for converting between systems or for creating input for statistical programs, etc.

Optionally, TRPTAB will print (and/or punch) trip end summaries for all or selected tables. TRPTAB will also optionally format zone-zone movements for all or selected origin zones and/or tables.

A diagram showing how a trip table looks on tape is shown in Figure II-5. The trip tape can consist of one trip table or several "merged" trip tables. The merging produces a tape with the first logical record containing the first origin zone followed by the trips to all destinations for Table 1. This is followed by a logical record containing the same origin zone and the trips to all destinations for Table 2 and so on. The number of logical records for each physical tape record is a function of the blocksize assigned to the trip table. Normally, the logical record length (LRECL) is large enough to permit one origin zone to be contained in a single logical record for each table. If the LRECL is not large enough, "chopped" trip tables may occur. This means that more than one logical record is required to store a given origin zone for a given table. All programs in the battery handle this situation correctly.

In addition to the efficiencies gained from storing trip tables in a merged format, trip tables contain only those interchanges with non-zero trips. This provides a great storage and time savings, especially for survey trip tables where many interchanges are zero.

Trip table files should begin with "* records" containing comments and descriptions regarding the file. Programs that produce trip tables provide for the inclusion of these comment records while programs that input trip tables read and print the "* records".

GENPUR - This program is capable of arithmetical manipulation, copying and merging trip tables. Both input and output files may consist of single or merged trip tables residing on single or multiple data sets. The program will also optionally accumulate and print trip end summaries for selected output trip tables.

STANDARD DICTIONARY FOR BINARY TRIP RECORDS IN RECODE

ZONE ORIGIN
ZONE DESTINATION
ZONE RESIDENCE
ZONE PRODUCTION
ZONE ATTRACTION
STATION INTERVIEW
STATION ENTER
STATION EXIT
SCREENLINE SEGMENT ORIGIN
SCREENLINE SEGMENT DESTINATION
CARD NUMBER (2, 3, 4, 5)
MODE
DIRECTION
PURPOSE FROM
PURPOSE TO
GENERAL PURPOSE
FACTOR
FACTOR (HOURLY-EXTERNAL)

LAND USE ORIGIN
LAND USE DESTINATION
LAND USE PRODUCTION
LAND USE ATTRACTION
TIME START
TIME ARRIVE
TIME MIDPOINT
STATE ORIGIN
STATE DESTINATION
COUNTY ORIGIN
COUNTY DESTINATION
CITY ORIGIN
CITY DESTINATION
CENSUS TRACT ORIGIN
CENSUS TRACT DESTINATION
CENSUS BLOCK NUMBER, ORIGIN
CENSUS BLOCK NUMBER, DESTINATION
GROUP CODE (A, B, C, & D)

SAMPLE NUMBER
PERSON NUMBER
TRIP NUMBER
SEX AND/OR RACE
INDUSTRY
OCCUPATION
RELATIONSHIP TO HEAD OF HOUSEHOLD
VEHICLE TYPE
CAR AVAILABILITY
PARKING TYPE
PARKING COST
GARAGED
FLEET/NONFLEET
COMMUNITY
WEIGHT CLASS
MONTH
DATE
DAY

FIGURE II-4

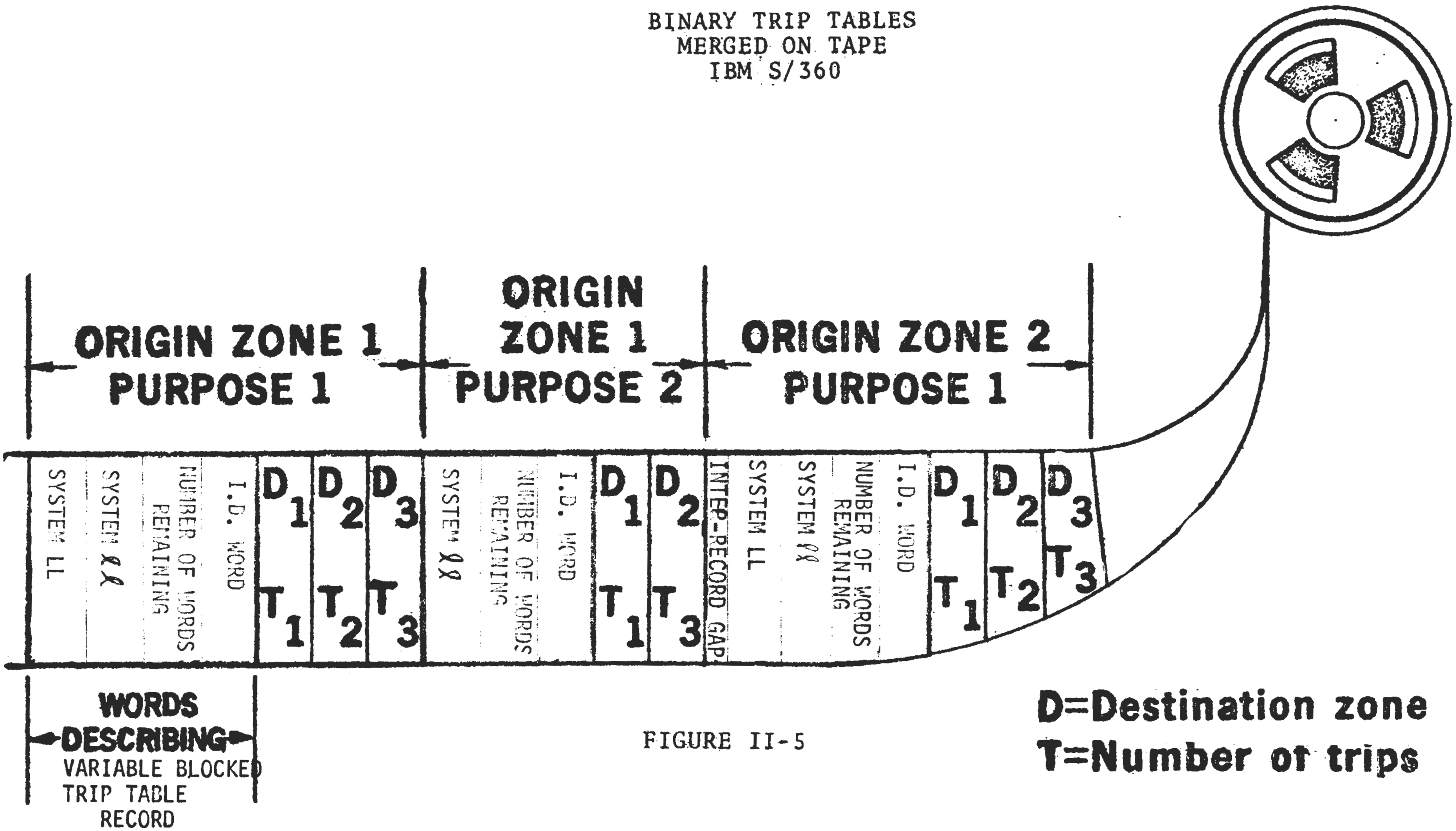

BINARY TRIP TABLES
MERGED ON TAPE
IBM S/360
ORIGIN ZONE 1
PURPOSE 1
ORIGIN
ZONE 1
PURPOSE 2
ORIGIN ZONE 2
PURPOSE 1
SYSTEM LL
SYSTEM ℓℓ
NUMBER OF WORDS
REMAINING
I.D. WORD
D_1 T_1 D_2 T_2 D_3 T_3
SYSTEM ℓℓ
NUMBER OF WORDS
REMAINING
I.D. WORD
D_1 T_1 D_2 T_3
INTER-RECORD GAP
SYSTEM LL
SYSTEM ℓℓ
NUMBER OF WORDS
REMAINING
I.D. WORD
D_1 T_1 D_2 T_2 D_3 T_3
WORDS
DESCRIBING
VARIABLE BLOCKED
TRIP TABLE
RECORD
D=Destination zone
T=Number of trips

FIGURE II-5

FMTTRP - This program may be used to format all or a portion of one specified trip table (which may be one of several trip tables comprising a merged trip table data set. An option allows scanning the entire data set and then printing a summary of the physical sequence of the trip tables within the data set together with the highest destination and origin zone numbers for each.

PTSUM - This program creates printed reports from trip tables (summarizing trip ends for each zone) as well as providing optional card output of this data which can be used for trip distribution and generation model development.

TRIPLEN -This program produces trip tables on the basis of trip length. Input to the program are trip tables and skimmed trees. In addition, the program will copy existing trip tables, accumulate and print trip end total for each selected output trip table and accumulate and print the number of trips, allocated to each selected output trip table, broken down by origin.

3. 7094-S 360 Data Conversion Programs.

Since many users will be converting from the IBM 7094 traffic assignment and trip distribution systems to the Urban Planning System 360, some programs have been developed to aid in an orderly transition where data is already available in 7094 format. The following programs are available:

AVTCON - This program will perform data set conversion and/or merging from or to formats for the S 360 to or from the IBM 7094 battery of programs. The data sets can be zone to zone trip tables or skim trees. In addition conversion can be made to or from the HUD Transit Planning Programs format. This program allows compatibility between the IBM 7094 and S 360 computer programs.

TRPCON - This program reads an IBM 7090/94 format binary trip table from a 7-track tape drive, alters the format to that required by the IBM 360 battery, and outputs the resulting records.

TIMCON - This program reads IBM 7090/94 format binary skim trees from a 7 track tape drive, alters the format to that required by the IBM 360 battery and outputs the converted skim trees.

F. INFORMATION SYSTEM

1. General Information

The continuing transporation planning process has three major functions: (1) planning, (2) monitoring and (3)service. The types of activities necessary to support these functions are data collection, data management, analysis and research. Information systems include the computer program that provides and manages data throughout the functional responsibilities of a planning agency. The Urban Transportation Planning System 360 program battery now contains programs to aid transportation planning agencies fulfill their information system-related functions.

Almost from the inception of computers, the speed of reading and writing and the computational efficiency of these machines has made them attractive for processing large amounts of data. Over a period of years a number of programs have been written to process and accumulate these data into "DATA BANK" or "INFORMATION SYSTEMS". In general the amount and attributes of the data and the results desired have been so diverse that searching for an established procedure is in itself a major undertaking. The programs provided under this section are those which may prove useful in transportation planning.

There are currently two programs in the Information System subsystem of the Urban Transportation Planning System 360 program battery. These are:

STRTWRK	To prepare an information system file.
WRKHORSE	To process data in an information system.

Other additions are being considered, and in the future the following programs are contemplated for inclusion in the systems:

MODWORK	To modify the data in an information system.
PLOTWORK	To plot data in an information system.

2. Common System Elements

The Information System has been designed to include elements that are common to each of the programs in the subsystem. These are:

READING PARAMETER CARDS - In general the programs use a read parameter macro (RPMAC) and subroutine (RDPAR). In this subroutine the following characters have special significance as follows:

Comma (,)	Field delimiter
Semicolon (;)	Get another card
Period (.)	End of data
Dash (-)	From previous to subsequent

The subroutine tests each field. If all characters are numeric the value is converted to binary and stored in a table called PARSET. If any character is non-numeric the entire field is moved into the table without conversion. The maximum length of a field is 8 characters.

IDENTIFICATION OF FILE - The file is identified by a suitable parameter card. The identification consists of :

Number of logical records in file
Max. = 32,768

Number of words in each logical record.
Max. = 32,768

Number of logical records to make one physical record. Max. = 255

Number of words in each physical record.
Max. = 32,768

Blocksize Max. = 32,768

ASTERISK RECORDS - In any information system one of the problems is to precisely identify each of the items of data particularly after a period of time has elapsed. This is resolved by having a set of asterisk records at the beginning of the file. Each record begins with an asterisk (*) and identifies the content of the entire file and each item in the file. The asterisk in each record is followed by a sequence number of up to 5 characters. This provides for any future modification of the asterisk record. The sequence number is followed by a word number of this data item (if applicable) followed by a description of the data item. Example:

```
*001  FILE OF SIOUX FALLS, SOUTH DAKOTA
      DATA
*002  WORD 1 1956 SEQUENCE ZONE NUMBER
*003  WORD 2 1956 NUMBER OF DWELLING UNITS
```

PRINT LENGTH RECORD- To eliminate the problem of scale (at some future time) and to reduce the parameter card requirements to print data from the file, a print length record follows the asterisk record. This record keeps track of the print length for each item in the file.

DECIMAL POINT RECORD - For the same reasons as noted for the print length record, the next record on the file is one which keeps track of the decimal places (units, tenths, hundredth, etc.) for each item in the file.

DATA - The decimal point record is followed by the data.

3. Subsystem Programs

The programs now available in the Information System are more fully described in the document "Program Documentation - Urban Transportation System-System 360." The general characteristics of programs STRTWRK and WRKHORSE are as follows:

STRTWRK This program accepts raw input data from the card reader, from tape or from a disk. The format can be under several different options. The program inserts the asterisk records, the print length record and the decimal record on the output tape and coverts the raw data into an output format as specified and places it on the output tape as DATAO.

For a more complete description of the program, see the program STRTWRK in the Program Documentation Manual.

<u>WRKHORSE</u> This program accepts a standard DATAI tape (previously created by another program as DATAO) and permits the following applications:

a. Print the asterisk, print length and decimal point records. This information is needed to describe in detail the content of the file.

b. Print any portion of the file by a single simple parameter card together with title and headings provided by the user.

c. Write out a new file of EBCD information suitable for the BIMD package of statistical programs or any other purpose including any or all of the variables in the file.

d. Read any portion of <u>each</u> record in the input file into memory so that each of the fields may be used to develop new variables by mathematical transformations.

e. Read a selected set of constants into memory for checking, mathematical transformations or controlling the operation of the program.

f. Perform the following operations in

any of the fields read into memory:

(1) Load a variable or constant
(2) Add another variable or constant
(3) Subtract another variable or constant
(4) Multiply by another variable or constant
(5) Divide by another variable or constant
(6) Store the result in memory
(7) Raise a value to an integer value
(8) Take the square root of a value
(9) Compare to another value or constant

(10) As the result of a compare, branch to an appropriate operation
(11) Convert value from an integer to floating point and vice versa

(12) Perform floating point arithmetic
(13) Move a value or constant into 1 of 16 index markers
(14) Replace previous input value
(15) Take the log of the value
(16) Get the antilog of the value

g. Describe the print length and number of decimal points for any of the new values generated under (f) above.

h. Print any of the input or generated values in memory by a single parameter card together with user title and headings.

i. Write out a new file of EBCD

information suitable for BIMD programs from any of the input or generated values in memory.

j. Write out a new DATAO file which contains all of the information in the original DATAI file plus any of the values created by operations under section (f).

k. Read any portion of all records in the input file into a memory matrix so that the mathematical transformations can be performed on the entire matrix.

l. Describe any of the operations described in section (f) on any of the values in the matrix.

m. Describe the print length and number of decimal points for any of the new values generated under section (1).

n. Print any of the input or generated values in the matrix by a single parameter card together with user title and headings. Multiple prints can be obtained from the matrix if needed.

o. Write out a new file of EBCD information suitable for BIMD programs from any of the input or generated values in the matrix.

p. Write a new DATAO file which contains all of the information in the origianl DATAI file plus any of the values created by operations under section (1).

CHAPTER III

TRAFFIC ASSIGNMENT

Traffic assignment may be defined as the process of allocating a given set of trip interchanges to a specific transportation system. The process may be used to estimate the traffic load on the various sections of a system for a future year or for the simulation of present conditions. For a reproduction of the existing traffic loads, the origin and destination survey or present-day synthesized traffic movements are used for the traffic assignment. For the future year a forecast of area-to-area movements must be made.

Input to the traffic assignment process are: 1) a complete description of the transportation system, and 2) a trip volume matrix of the interzonal traffic movements. The techniques outlined in this manual will provide estimates of the traffic volumes on each link of the system, by direction, with directional turning movements at intersections.

A. HISTORY OF TRAFFIC ASSIGNMENT

Highway system planning might be dated from the introduction of the origin and destination survey. The O-D survey produces "trip tables" which measure the trips people make independently of the routes that they select. Historically, origin-destination trip movements have been illustrated by some form of "desire lines" showing the magnitude of the trips on the shortest airline distance between the terminal points of the trips. The problem facing the highway planner, then, is the routing of these trips over the existing and/or the proposed facilities. This routing problem was the impetus for the development of the traffic assignment techniques. A compendium of correspondence, published in 1950 by the Highway Research Board, summarized the practices of several States in assigning traffic to routes. Considerable difficulty was expressed in the evaluation of the driver's choice of route to complete his interzonal trip. Quantitative route choice decisions were based on traveltime, distance, and user cost as comparison parameters. Some States based their decision on the engineer's personal experience and judgment. At that time no empirical formula had been devised and the analytical approaches that were suggested were based only on theory.

Mr. Earl Campbell of the Highway Research Board proposed an 'S' curve, based on theoretical considerations, relating the percent usage of a particular facility to a traveltime ratio. Apparently, the primary concern at this time was with the diversion of traffic from an existing street network to a proposed freeway or expressway facility. The traveltime ratio was expressed as the traveltime via the expressway divided by the traveltime via the existing street system.

To evaluate these theories, studies were undertaken which attempted to relate the choice of route to time and distance factors. As a result, empirical studies of street and freeway usage were made in some half-dozen cities in the United States. Tabulations of basic data were obtained from the studies of diversion to the following expressways: 1) Shirley Highway in Arlington, 2) Gulf Freeway in Houston, 3) Willow Run Expressway in Detroit, 4) Alvarado and Cabrillo Freeways in San Diego, and 5) Central Expressway in Dallas. From this information, AASHO developed a standard traffic diversion curve as recommended policy for predicting usage of urban freeways. The curve was based on the traveltime ratio as the most important parameter. Other organizations and State highway departments developed diversion curves using such parameters as time and distance, speed and distance, time saved and lost, and distance saved and lost.

Studies using these methods dealt, in general, with a single freeway and parallel existing routes. As the capability to handle single facilities improved, the need for techniques of analysis for entire highway systems was realized. The manpower and time requirements to perform the tedious calculations seemed to prohibit such extensive approaches to urban highway planning.

At first, traffic assignment was done manually; the mechanical techniques, as we now know them, were not available. The automation of traffic assignment procedures began with the advent of the punch card tabulating equipment, and some very sophisticated techniques were developed. As electronic computers came into general use in the highway field, traffic assignment computer programs were also developed, but they were only modest improvements on earlier punched card tabulating procedures. They were, for the most part, tabulating programs that summarized the data that the engineer prepared. The route selections for each interzonal movement were still made by the engineer based on his personal knowledge and judgment. Given the interzonal movements and the routing that was selected by the engineer, the computer merely aggregated to the final result.

Attempts to develop a complete traffic assignment program were always blocked by the route selection problem. Fortunately, others working in a field quite unrelated to highways had a similar problem. The telephone companies were faced with the problem of route selection for the direct dialing of long distance telephone calls.

The most significant development in the field of traffic assignment came in 1957 with the presentation of two research papers. One was by Mr. E. F. Moore, titled "The Shortest Path Through a Maze", presented at the International Symposium on the Theory of Switching at Harvard University. The other was by Mr. George B. Dantzig, titled "The Shortest Route Problem" in Operations Research 5:270-3, 1957.

About this time, Dr. J. Douglas Carroll, Jr., was searching for a solution to the problem of traffic assignment for the Chicago Area Transportation Study. The services of the Armour Research Foundation were retained and Mr. J. G. Haynes and Mr. F. C. Bock were assigned to perform the research. This investigation resulted in an electronic computer program developed for an intermediate-size computer. It had been designed to find the minimum time (or distance) paths through networks. The program was something of a laboratory novelty as it used a large portion of the computer storage and, as a result, could accommodate only a very small network. It was, however, quite valuable as a basis for further development.

Concurrently with the work of the Chicago staff, engineers in Washington, D.C., were also searching for a solution to their assignment problems. A joint project was undertaken involving the Bureau of Public Roads, the Washington Regional Highway Planning Committee, and the General Electric Computer Department of Phoenix, Arizona. This project produced a battery of high-speed computer programs that would assign the nondirectional interzonal traffic movements, including a provision for specifying time penalties for turns. In addition, it incorporated the option of using a diversion or an all-or-nothing assignment.

Independently, Dr. Albert Mayer and his staff of the Detroit Area Transportation Study began the development with a slightly different approach. The California State Division of Highways, having developed their assignment techniques before the Moore Algorithm then applied their unique diversion curve to the minimum path techniques in their version of the assignment program.

The Washington system was further refined by the Minnesota Department of Highways, the Bureau of Public Roads, and the General Electric Computer Department to provide greater flexibility by permitting traffic assignments by direction of travel. In 1960, General Electric in cooperation with the District of Columbia Highway Department, added a refinement that prohibited selected turns in the calculation of the minimum time paths. Another modification, developed first by the staff of the Chicago study, and later by the Traffic Research Corporation and the Bureau of Public Roads, was the addition of techniques to calibrate an assignment by capacity restraint.

The initial BPR traffic assignment battery was written for the IBM 704 Computer. These programs were later modified for processing on the IBM 7090/7094 systems (early 1960's). This chapter describes the traffic assignment process as it relates to the programs developed for the IBM S 360 series of computers.

B. PURPOSES OF TRAFFIC ASSIGNMENT

The purposes of traffic assignment may be listed as follows:

1. To determine the deficiencies in the existing system.

2. To assist in the development of a future transportation system through an evaluation of the effects of improvements and additions to the existing system.

3. To develop construction priorities by assigning the trips forecasted for intermediate years to their corresponding systems.

4. To provide systematic and reproducible tests for alternate system proposals.

5. To provide the highway designer with the design-hour traffic volumes.

C. THE GENERAL PROCESS OF TRAFFIC ASSIGNMENT

1. Traffic Assignment in the Transportation Planning Process.

As conceived today, a transportation planning study should be a cooperative, comprehensive, and continuing process. The principal objective of this transportation planning process is to determine the future form of the transportation network and the volume of vehicles or persons using any portion of this network.

There are four phases in any planning process: (1) organizing for the study; (2) collecting and analyzing the data; (3) forecasting, formulating, testing, and evaluating the plan or plans; and (4) plan implementation. The first technical phase of the transportation planning process is the inventory of the existing conditions. Analysis of the data collected in these inventories provides the source information upon which the estimates of the future growth of the area are based. After estimates of the future travel have been made, the trips are then assigned to an assumed transportation network. The results are evaluated with reference to the desired level of service plus the social and economic consequences of the assumed system. Inevitably some revision will be necessary. The information obtained during this assignment is then used to modify the system, and another future travel assignment is made to the adjusted transportation network. This process is repeated until satisfactory results have been achieved.

The traffic assignment techniques developed for use on a high speed computer provide engineers and planners the necessary tools for testing alternate networks for adequacy under estimated transportation loads. The efficiency of a network depends primarily on its location and its ability to carry this load. Various possibilities, therefore, must be evaluated.

It should be understood that traffic assignment does not take the place of planning. It merely enables the planner to uncover the areas of greatest needs, and to test the consequences of various possible plans.

Analysis of the assignment results, while not considered part of the process by some, is extremely important. Traffic assignment analysis should be designed and carried out with the following applications in mind: (1) establishing the validity of the assignment results; (2) systematically producing workable data for evaluation (including economic evaluations, further general planning, design volumes); (3) permitting evaluations of internal system performance (identifying good and weak points in the system, delineating deficiencies, etc.); (4) establishing comparative evaluations with other parameters to aid in the planning and design toward an "optimum" system; and (5) permitting the evaluation and interpretation of results for use by highway engineers.

2. A General Description of the Procedure

The traffic assignment procedure is based essentially on the selection by an electronic computer of a minimum impedance-path between zones. To accomplish this task, a description of the network is coded, key punched, and stored in the memory of the computer. After selecting the minimum impedance-path between zones, the computer proceeds to assign the trips to these routes. Traffic volumes are thus accumulated for each route section.

For coding purposes, the route sections are considered to be the one-way part of a route lying between two intersections. They are referred to as "links." Intersections are points at which two or more route sections meet, allowing the possibility of a change in the travel direction. The intersections are referred to as "nodes." The nodes at which trips are generated are called "centroids." There is one centroid for each traffic assignment zone and external station in the study area. There may be only four links connected to a node.

Each node in the system is identified by a unique number. The lowest node numbers are reserved for centroid nodes. The numbers may be as large as 16,000. In addition to the node number at the end of each link, information concerning the travel speed and distance on the link is necessary. The capacity and existing volume on the link should also be coded. There is provision for many other types of data. Suggested items are: functional classification, administrative jurisdiction, facility type, surface type, route number, land use, parking and condition. Of course, other items may be included, but none are mandatory. The more items recorded the more meaningful the results can be.

After the coding is complete, the data are key punched into standard tabulating cards and later used as input to the computer. These cards are subjected to detailed manual or machine contingency checks. Such checks guarantee that the network is continuous, i.e., that there are no missing links; that there are no dead ends; that each node has the correct number of links associated with it; that there are no duplicate numbers used for coding; that information coded for each link falls within certain specified ranges; and that there are no invalid data items in the cards. These checks try to insure that the computer processing will not fail because of coding inconsistencies, inaccuracies, or the incompleteness of a network.

These coded link data cards are then read by a computer program called BUILDHR, which performs many edit checks along with many of the consistency network checks mentioned above. The program then writes a sorted file of link and intersection description records, which is called the historical record. The historical record shall be referred to as the HRO when it is being written out by a program, or HRI when it is being read by a program. It may be examined for detail by use of the program PRINTHR, or alternatively, FORMAT. The historical record is the basic work file of the assignment programs.

The next step, the selection of the minimum impedance routes, is the key to the assignment procedure. The minimum impedance route is the shortest route from one node (usually a centroid) to another. All the routes from one centroid to all others are referred to as a "tree" or a "vine." The term "path" or "route" may be used in general discussion to eliminate confusion as to whether the path is a tree or a vine. A tree records the routings in such a manner that there is only one entrance link to a node. A vine records the routings in such a manner that all four links connected to a node may be traversed if necessary to ensure the minimum path. A vine is more accurate than a tree, but requires two to three times as much computer time to determine. If many intersections have prohibited turning movements, or large turning penalties associated with them, vines should be used. Otherwise, trees are recommended.

Whereas the tree is calculated to each node, the vine calculates to each of the legs of a node. This is a rather significant difference as shown in Figure III-1. Suppose the minimum path between centroid A and centroid B is desired and the left turn on link 107-104 is prohibited. Suppose further that the minimum path to node 104 is via node 107 rather than via node 106. Under the tree option, the back node from node 104 is node 107, and since the left turn at node 104 is prohibited, the only available path from A to B is via nodes 107, 104, 103, 102, 101, and 105.

Under the vine option the program will calculate the traveltime to the beginning of leg 3 at node 104 as coming from node 106. Therefore, under the new procedures, the minimum path from A to B is via nodes 106, 104, and 105 - a much more realistic path.

The paths may be selected on travel time, (the most common criteria), or any associated link impedance such as distance or cost. The program BUILDVN reads the historical record and computes the minimum paths. The paths are written on a magnetic tape or disk file called PATHSO. When the file is read by subsequent programs, it is referred to as PATHSI. The paths may be examined for logical accuracy by use of the program PRINTVN.

Next, a program called LOADVN reads the PATHSI file and the TRIPSI (zone-to-zone trip matrix) file, and routes the zone-to-zone trips along their minimum path. As it does, it accumulates the link usage and the turning movements at each node. The program repeats this process for all selected zone-to-zone movements. When all routings are completed, the program reads in the HRI (historical record) file and merges the link volumes and turning movements with it, and writes out a

Portion of Transportation Network

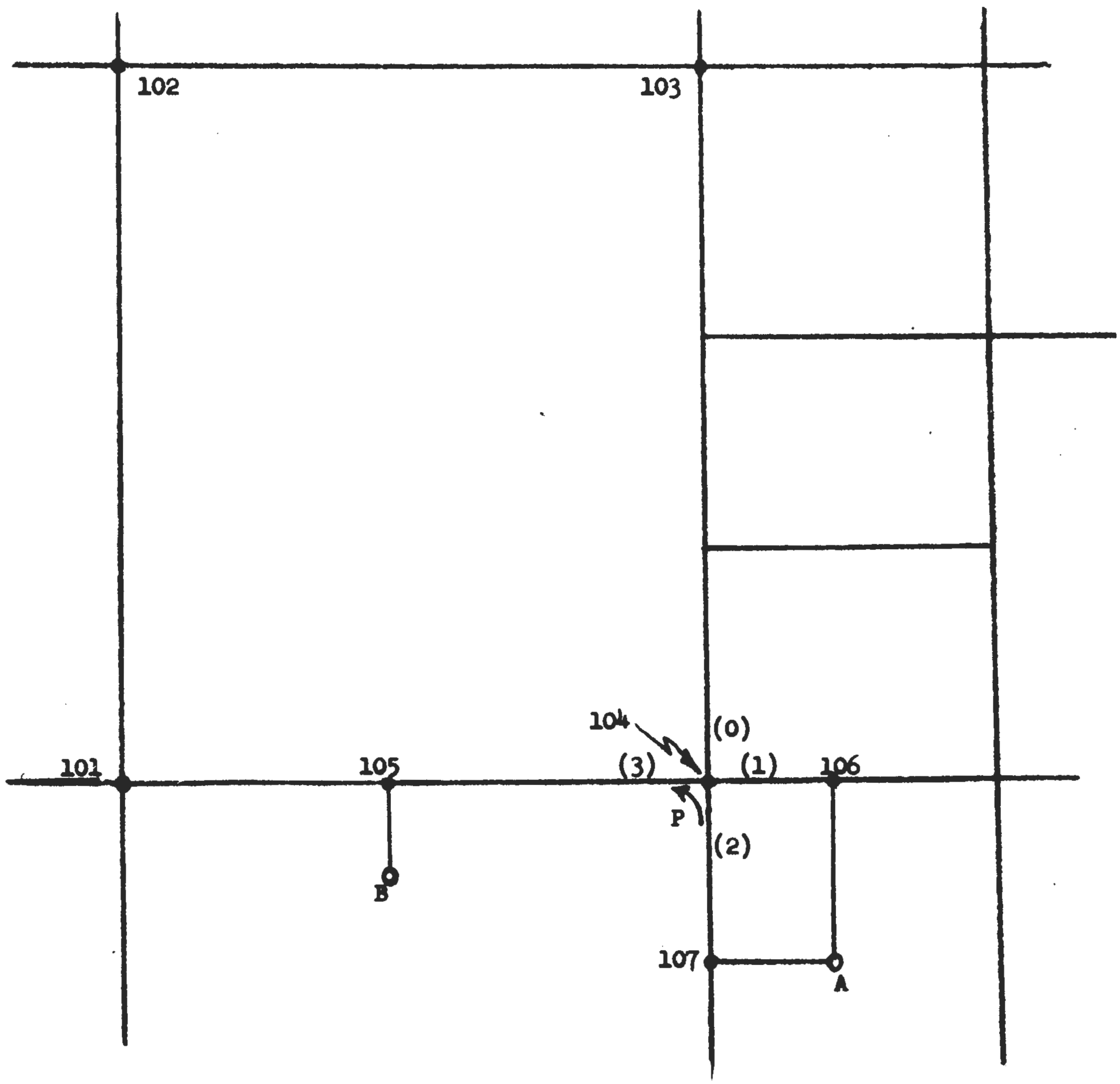


Figure III-1

new, more detailed HRO file. The program PRINTLD may be used to read this HRO file (only now it will be referred to as the HRI file), and prepares readable printed summaries of the link loads and turning movements. Program FORMAT is a more complex, but more useful program for examining the historical record in detail.

Some of the loads on the individual links may approach or exceed the capacity of the transportation facilities, thus affecting the traveltime or other criteria that were used to determine the minimum paths. In this situation, the computer program sequence may be interrupted by the engineer, and new minimum paths computed using a set of adjusted traveltimes. The automatic method for making these adjustments to the original network is called capacity restraint.

If the capacity restraint process is to be performed through the use of a computer program (the more logical approach), the program CAPRES is invoked. It reads the HRI file that contains the link speeds, travel impedance, volume and capacity for each link (where capacity is available) and adjusts the traveltime according to a predetermined relationship. The CAPRES program adjusts link traveltime in accordance with a relation between assigned volume and link capacity. Thus, the speed necessary to travel the route section may be lowered much in the same way as increasing congestion causes speeds to be lowered in real situations. The use of capacity restraint to modify assigned traffic provides a more realistic distribution of traffic in the system. It is improbable for one route to be heavily overloaded if its neighboring streets are lightly used.

The program CAPRES writes a new HRO file which can be read by the BUILDVN program, and the entire process is repeated until satisfactory overall loadings are achieved.

3. The Alternatives in Traffic Assignment

Traffic assignment, in simple terms then, is the process of determining the amount of usage on segments of a highway network. The process is accomplished by first determining the most reasonable route, or path, through the network to be used while traveling from one point on the network to another. Once the path has been determined, the number of trips that desire to travel from the origin point to the destination point are routed along the path and the highway segment usage is accumulated. The process is completed for all points in the network where trips originate or terminate. In effect, traffic assignment, then, is a simulation of link volumes in a highway network.

The analyst who wishes to use traffic assignment techniques for traditional networks has several considerations before beginning the detailed work associated with the process:

(a) - All-or-nothing or Diversional Routing (not available in S 360 package).

(b) - Directional or Non-directional Assignment

(c) - Capacity Restraint

(d) - Peak Hour or Daily Traffic

Each of these items will be discussed in detail in the following paragraphs.

The term "traditional" is used simply because this type of network has been used for many years. Its counterpart is the "spiderweb" network. A traditional network is employed when greater detail is desired. All freeways, expressways, parkways and major arterials are included, along with a majority of collector-type facilities and a minimum of local streets. Higher-level type facilities such as freeways may have opposing lanes and access ramps detailed individually. In the highly congested areas, such as the CBD, all streets and intersections are used.

a. <u>All-or-nothing or diversional routing</u>--As discussed earlier, problems in determining the proper path between two points in the network will be quite prevalent when two or more higher-level type facilities are competitive through major portions of the network. The most direct approach is to simply choose the facility that will result in the minimum delay or impedance between the points of decision. All the traffic between the considered points of origin and destination will then be routed along that path. This procedure is the easier to use and is known as the "all-or-nothing assignment" technique. The alternative method is to allow several routings between the considered points of origin and destination. Then, the traffic is distributed by some criteria so that different portions will use the alternative routes. This method is known as "diversion assignment". Capacity restraint essentially provides for diversion to many routes based upon an averaging process between successive assignments.

The all-or-nothing technique is the more widely used since it is easier, less expensive, more comprehensible, and less prone to errors than diversion assignment. At the time of this manual preparation, the FHWA battery of transportation programs for use on the IBM System 360 does not include a diversion technique. The all-or-nothing techniques are offered in such a manner that the user can select the spatial parameter for selecting the optimum route. Variables such as time (the most commonly used), distance, cost, etc., or a combination of these may be selected at the user's discretion.

b. <u>Directional or non-directional assignment</u>--Directional assignment allows the user to examine the segments of highway on a "directional" basis; i.e., he can analyze the usage in a north-to-south direction separately from the usage in the south-to-north direction. This means, of course, that he must prepare the network with more detail than if he is interested only in the total (non-directional) usage on the segment of highway. The non-directional usage can obviously be obtained through the use of directional assignments by simply adding the directional volumes for both directions of the link.

Non-directional assignment involves more than this simple concept, however; one-way links are not utilized, which precludes the detailed use of ramps for freeways. The route from origin to destination will be same as the route from the destination to the origin. This will not necessarily be true in directional assignments. The direction of trips have no meaning in non-directional assignments as the trips from origin to destination will result in the same link loads as if they were in the opposite direction. Turning movements through intersections have somewhat different meanings. Assignment of production-attraction, directional, or triangular trip tables will result in the same link loads. Directional trip tables only should be used for directional assignments. Since there is insignificant cost and time difference in the preparation of a directional network, it is the recommended procedure. The computer programs in the package are aligned to directional analysis.

c. Capacity restraint--Capacity restraint is the method whereby the link volumes resulting from a traffic assignment are compared to the vehicular capacity of the link, and travel times on the link are adjusted in a pre-described manner to reflect more realistic operating characteristics. This comparison can be on a directional or a non-directional basis. The ratio of assigned volume to capacity is referred to as the "volume-capacity ratio," or simply as "V/C". If only a relatively few segments in the highway network are over-loaded, and most traffic appears to be operating near legal speeds, then capacity restraint techniques need not be considered.

Traffic can realistically be assigned to a highway network by considering the practical capacity of each link (or as many links as possible) in the network. The capacity of the links comprising the existing highway network can be computed, and an estimate of the future highway capacities can be made. However, it is difficult to estimate the speed at which future traffic will travel without knowing the volume which will be carried on a particular link. A speed (or traveltime) must be given for each link on the system, since this is the parameter which determines the minimum path to be selected by the tree-vine building program.

Capacity restraint, as the FHWA computer programs function, is an iterative process. As the user prepares the highway network for computer simulation, one of the additional parameters that he provides is the capacity for as many segments of highway as possible. The paths for origin-destination movements are calculated and traffic assigned to them. The resultant "loaded network" is then examined automatically on a link-by-link basis to determine the V/C ratio. The adjusted link speed and/or its associated travel impedance is computed by use of the following equation:

$$T = To \left[1 + 0.15\ (V/C)^4\right]$$

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

To= free-flow travel time; observed traveltime (at practical capacity) times 0.87

Figure III-2 graphically illustrates this relationship.

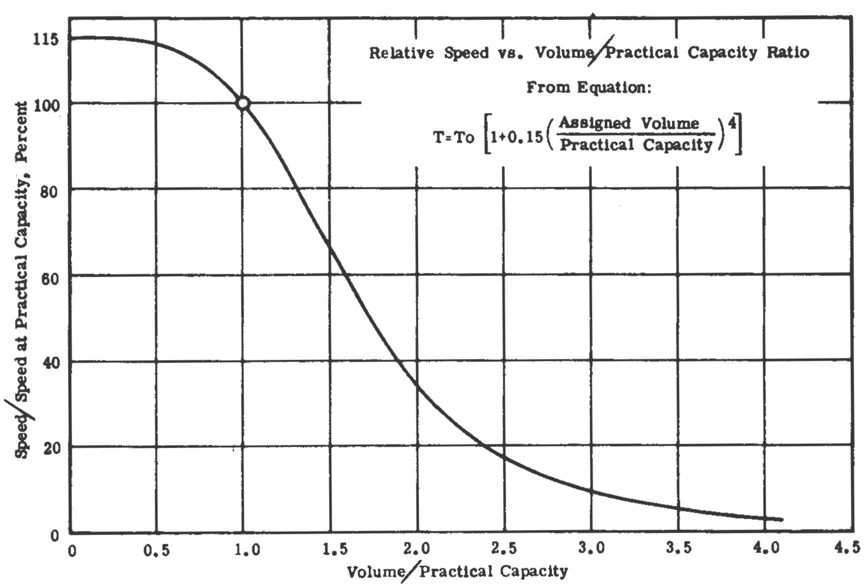


Figure III-2 - - - Capacity restraint relationship

Direct use of the balance travel impedance for a successive traffic assignment tends to result in an extreme oscillation in the link volumes. To offset this, a different link travel impedance is obtained by combining the balance travel impedance (T) with a base travel impedance. The assignment travel time is normally used as the base time. The combination is usually weighted so that the new impedance is one-fourth the difference between the base time and the balance time, or expressed mathematically:

$$Ta = 0.75T_{base} + 0.25T$$

where Ta = assignment link travel impedance for use in next assignment.

The user may find that he wishes to change this weighting factor. The computer program CAPRES allows this.

An example of capacity restraint for a given highway link may clarify the process. Assume a link one mile long has a practical capacity of 32,000 vehicles per day, and a speed at that capacity of 60 mph. The travel time at zero volume (To) is computed to be 0.87 minutes. The first assignment produces a volume on the link of 40,000 vpd, or a V/C of 1.25. Applying the above equation $T = To\,[1 + o.15\,(V/C)^4]$: the balance travel time (T) is computed to be $T = 0.87\,[1 + o.15\,(1.25)^4] = 1.19$ minutes, or a speed of 50.4 mph, which would allow for a capacity of 40,000 vpd. The assignment travel time or speed would be computed as:

$$0.75\ (1.00) + 0.25\ (1.19) = 1.05 \text{ minutes,}$$
or 57.3 mph.

The next traffic assignment would then use a travel impedance of 1.05 minutes for the link when determining the minimum path routes. The subsequent assignment then would be adjusted in the above manner, and the process repeated. This process may be continued for as many iterations as desired, but experience has shown that after four iterations the accuracy of the assignments does not improve appreciably. Current practice based upon considerable experience suggests the averaging of the capacity restrained assignments rather than the use of any single assignment results. This averaging is available in the CAPRES program.

d. Peak hour or daily traffic--Peak-period traffic assignments are used primarily to determine design volumes. They usually consist of three separate assignments using three different trip volume files. An abbreviated analysis would include only one peak-period movement, but it is suggested that the assigned volumes be investigated for both morning and evening peak periods, in addition to the offpeak period. A more stable trip volume file for each peak period usually results if a 2-hour peak period is isolated and a proportion of this 2-hour peak later factored to represent the design-hour traffic. Both 2-hour and 1-hour peak assignments have been made.

To assign the forecasted peak-hour movement, the percentage of the total trips occuring during the peak periods by purpose of trip is analyzed for the survey data. These factors may then be applied for each trip purpose to the forecasted information and a trip file produced which represents the peak-period traffic movement.

For a Fratar analysis, separate growth factors may be applied for the three existing trip files and the forecasted peak-period trip movements obtained directly.

A disadvantage of using peak-hour traffic assignments is the greater cost. Part of this cost is due to the additional data collection involved. For example, traveltimes must be determined for three periods and capacity may vary by time of day (due to different parking conditions, use of reversible lanes, different signal cycling, turning movements, and percentage of trucks, as well as the important difference in ability and incentive of drivers in motion at different periods of the day). However, these factors are also those that make peak-hour assignments desirable.

Peak-hour traffic assignments are also more expensive in computer running time. Forecasting is more time-consuming, and the path building and loading must be accomplished three times. A peak-hour assignment is approximately three times as expensive in computer time, and probably twice as costly in time for coding the system.

Despite the higher cost, peak-hour traffic assignment is a useful procedure and employs a time period short enough to yield realistic volumes for comparison with capacities. Experience has shown, however, that a peak-period traffic assignment may yield some unrealistic results. There should be justification for those results which vary excessively from the normal factors and splits. Some loadings have resulted in directional splits of 80-20, and these certainly must be substantiated by a thorough examination of the movements in question.

D. RECOMMENDED NUMBER AND TYPES OF ASSIGNMENTS

Now that the uses of traffic assignment and the several different types of assignments have been discussed, the application of the assignment technique to a transportation study will be described.

There are three basic categories of assignments which should be made in any transportation study. These are:

1. Existing trips to the existing network.

2. Future trips to the existing plus committed network.

3. Future trips to the existing plus committed plus proposed network.

The amount of detail used and the number of assignments made in each category for any city is dependent upon size, the ultimate goals of the study, and the financial resources available.

1. Existing Trips to the Existing Network

An assignment of the total number of present trips, computed by expanding the origin-destination survey data to the total universe, or by application of a mathematical model, to the present transportation network should be made first. This assignment should be made only after a proper screenline check has been made on the expanded trip data. The purpose of this assignment is to check the adequacy of the assignment procedure by testing its ability to mechanically reproduce the existing travel patterns within the study area as accurately as possible.

This initial assignment is usually made by loading traffic on the minimum time-paths computed between zones by the computer. An analysis of this assignment may reveal that many links have been assigned volumes which greatly exceed or are considerably less than the actual counted volumes on these links. Thus, the capacity restraint technique should be used to adjust the assigned volumes automatically, thereby simulating the existing travel patterns more closely.

2. Future Trips to the Existing Plus Committed Network

The future trips may be assigned to the existing plus committed network to determine the deficiencies in the existing system and to provide the framework for developing the necessary improvements and additions to this system. Again, this assignment should consist of an assignment to the computed minimum time paths, and an adjustment by the use of the capacity restraint technique. If it can be shown that an unrestrained assignment demonstrates a reasonable picture of true desires, it should be used.

3. Future Trips to the Future System

In determining the structure of the future transportation system, the mutual effect of land use and the transportation system must be analyzed carefully. In the optimum situation, several alternate land use plans and their accompanying transportation systems should be investigated. For each land use plan, alternate transportation systems can be designed and loaded with future trips. Again, capacity restraint should be used in the loading process to obtain the most accurate results. Finally, the best land use and transportation plan can be determined which is consistent with the needs and desires of the community.

The determination of construction priorities for the chosen plan can be made next by partial network assignments, using capacity restraint. This analysis will allow a comparison of the benefits to be obtained from following a certain construction priority.

Assignments may also be made by, say, 5-year increments to allow for future adjustments in the forecasting and assignment procedure to more nearly fit actual travel patterns. This technique will allow the evaluation of procedures within a relatively short period instead of waiting 20 years for the forecast year to arrive.

The assignments outlined above have been assumed to be for ADT, or daily volumes. The assignment procedure has an optional feature which allows the assignment of peak-hour traffic to the system. It may be desirable to make this type of analysis for determining design-hour volumes on the network. These assignments should be made in addition to the ones already described.

E. MAJOR DECISIONS

In addition to deciding which of the available computer programs he must use, the engineer must resolve the following questions before attempting any traffic assignment.

1. How will future trips and their distribution be estimated?

2. What will be the forecast year or years?

3. How many alternate networks should be tested and how many land use plans should be evaluated?

4. What is the availability of computer equipment?

5. Should the trip information be linked?

6. Should traffic zones or districts be used?

7. How should the external station movements be treated in the assignment?

F. SELECTING AND CODING THE ASSIGNMENT NETWORK

1. Obtaining and Recording Physical Data

a. Review of inventories and summaries--An inventory of the existing street and highway network is one of the first studies to be undertaken in the comprehensive planning process. The results of this inventory provide the information for defining the street and highway system to the computer. The information that is required for each link used in the traffic assignment highway system includes the link speed or traveltime, the link distance, the existing traffic volume, and the practical capacity. Each item will be discussed individually in the following paragraphs.

b. Map preparation--Two base maps are required to define the existing street and highway system. A map showing the traffic survey zones and their numbers must be available to locate the zone centroids. Appropriately scaled street and highway maps must also be available. It is desirable, but not necessary, that the zone maps and the street and highway maps be of the same scale. The zone map for a sample network is shown as Figure III-3. The network map is shown as Figure III-5.

The scale (or scales) of the street and highway maps will, of course, vary with the size of the study area. The Washington Metropolitan Area Transportation Study used maps of three different scales. The 1" = 2000' map of the area was used for the outlying area of Maryland and Virginia, the 1" = 1000' scale for the 10-mile square of the District of Columbia, and a 1" = 400' map for the downtown area. As a rule, a scale should be chosen so that very few major links on the traffic assignment network are less than one inch long.

As in Washington, several maps may be used for defining the street and highway network. In this case, match lines between the maps are mandatory. The physical size of the map is usually limited to the size of the reproducing equipment. A map larger than 4' x 5', however, may prove to be too cumbersome for efficient use. It may be advisable to obtain reproducible copies of these base maps on Cronar film. These are the master tracings from which the prints are made that are later used as worksheets during the analysis of assignments.

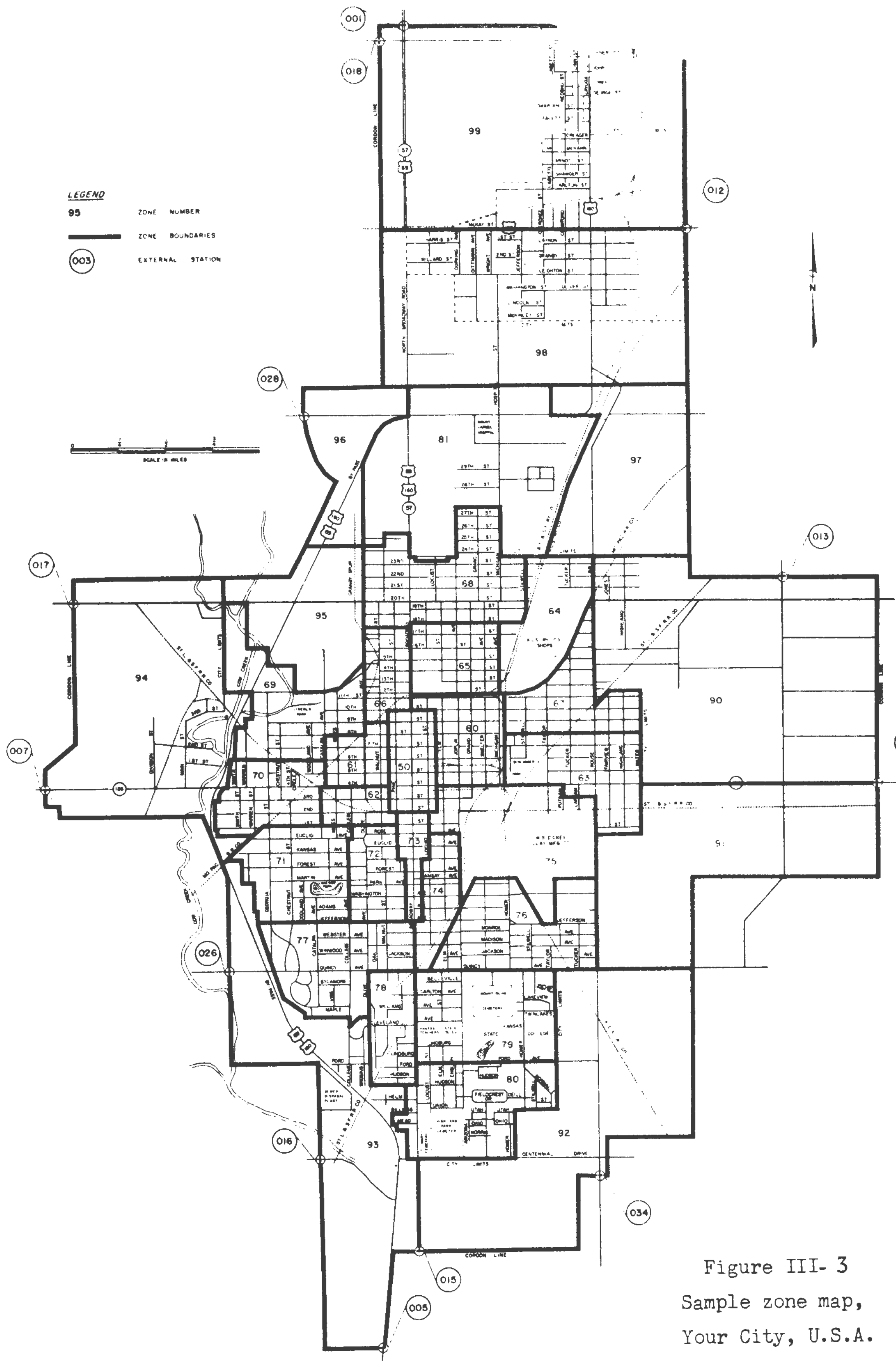


Figure III- 3
Sample zone map,
Your City, U.S.A.

c. Speed and traveltime data--One of the major inputs to the traffic assignment process is a value for speed or traveltime on each link in the traffic network. These values are used in the computation of the minimum time path routings between traffic zones, which are eventually loaded with vehicular movements between these zones.

Speed or traveltime runs are usually made during both the peak and offpeak hours in urban areas. If peak-period traffic assignments are to be made, the corresponding peak speed or time should be recorded and used. For ADT traffic assignments, peak and offpeak speeds or times may be combined to represent average daily values. One method currently being used assumes that approximately two-thirds of the daily traffic occurs in the offpeak hours, and the value of

$$\text{ADT Traveltime} = \frac{2\ (\text{offpeak traveltime}) + 1\ (\text{peak traveltime})}{3}$$

In large transportation studies it may be impossible to obtain the speed or traveltime on every link in the network. Typical values of speed or time obtained for the major links may be used on links having similar uses and characteristics when it is not feasible to collect these data in the field. However, caution must be used when resorting to this procedure, since the accuracy of the assignment process is dependent upon these values. Methods for measuring these parameters can be obtained in other documents. The reader is also referred to Chapter VII, Section L, for a description of a license matching technique for gathering traveltime data.

d. Traffic volume data--The total traffic volume (either directional or nondirectional) on as many streets and highways as possible, except the local streets, should be obtained during the survey. Although this information is not considered an integral part of the network description, it does permit the evaluation of the results of an initial traffic assignment. The capacity restraint program adjusts volumes by changing link traveltimes on the system. It also compares the measured with the assigned volumes for each link having this information coded.

e. Street capacity data--Data concerning the practical capacity of each link in the street and highway network are mandatory if the capacity restraint option is to be utilized, The inventory of the physical characteristics of the network should record such information as curb-to curb width, parking regulations, and the type of control devices including the signal timings. Programs for calculating street capacity are described in CHAPTER VII, Special Analysis.

f. Selection of speed and traveltime data for future traffic network--The selection of speed or traveltime for each link in the traffic network should be made with care, since these values are used to build the minimum time path routes which will eventually be loaded with vehicular trips. As explained previously, speed or traveltime runs are made to find the existing values on the present network. Judgment must be used to determine the values of speed or time on the future network.

The speeds to use on different categories of facilities may be determined on the basis of the desired highway or street capacity standards. The desired capacity on a particular facility is dependent upon the "level of service" to be rendered by that facility. For a more detailed discussion of the "level of service" concept, refer to the 1965 edition of the Highway Capacity Manual. Based on a desired level of service and the corresponding highway or street capacity, the speed on a certain type of proposed facility may be determined. Speeds may be obtained for freeways, expressways, arterials, collectors, and locals which are located in the CBD, intermediate, suburban, and rural areas. Figure III-4 illustrates the arrangement for a table of speeds by facility type and location within the urban area. This table would include speeds expected under the conditions shown. The table is for illustrative purposes and might vary by area.

Figure III-4--Sample table of average running speeds to be used on future traffic network. Speeds, in MPH, are based on design capacity at level of service "C"[1]

Facility classification	Location			
	CBD	Intermediate	Suburban	Rural
Freeways	40	40	50	55
Expressways	30	30	35	40
Arterials	20	25	30	35
Collectors	15	20	25	35
Locals	10	15	20	25

[1]Level of Service "C" is defined as the middle range of stable flow, but speeds and maneuverability are more closely controlled by the higher volumes expected in this range. Most of the drivers are restricted in their freedom to select their own speed, change lanes, or pass. A relatively satisfactory operating speed is still obtained, with service volumes perhaps suitable for urban design capacity.

The speeds recorded in Figure III-4 have been determined for one particular level of service. There are six levels of service which have been defined by the Committee on Highway Capacity, Highway Research Board. A definition of these levels of service can be found in the 1965 edition of the Highway Capacity Manual. Each city or study must determine its own desired level of service standards, and develop a table of speeds based on the capacities corresponding to that level of service.

The traffic volume data should be recorded on the base maps along with the practical capacity of each link. With these data, the process of describing the network to the computer may begin.

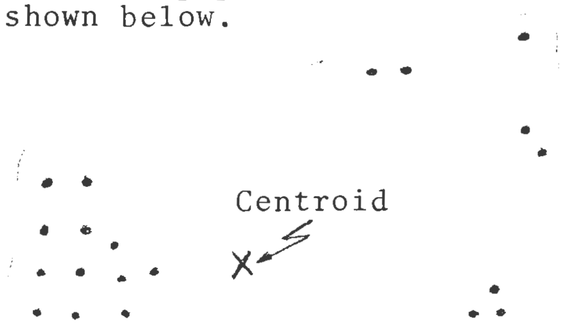
2. Preparation of Computer Required Network Data

After all the physical data mentioned above is accumulated in a logical manner, the next step is to place it in a format suitable for input to the computer programs. It is suggested the various items be prepared in the following order:

a - Locate and number the centroids
b - Define the basic transportation network
c - Connect the centroids to the arterial street system
d - Locate and define the nodes
e - Prepare a node numbering table
f - Assign the node numbers
g - Code the turn penalties and prohibitors (use of leg codes)
h - Define the link parameters
i - Special treatment for external stations
j - Identifying and storing the maps and tabulations.

a. Locate and number the centroids--The establishment of traffic zones should consider the requirements of the traffic assignment procedure as well as the requirements for data collection. In addition, planning areas, census tracts, and the requirements with regard to traffic forecasting areas should also be recognized.

In a traffic assignment, all trips are assumed to be loaded on the highway network from a single point established for each zone. The point of loading for each zone, defined as a centroid or loading point, should be located at the center of activity for the zone. For a completely residential zone, the center of activity would be the center of gravity of the zone's population. For example, consider the typical zone shown below.



Assuming each spot represents 100 persons, the center of population or centroid, would be established approximately as shown.

For mixed land use zones, such as residential and commercial, the location of the centroid is determined to a large extent by judgment based on expected trip ends. There is one centroid for each survey zone and external station. They are numbered in a consecutive unbroken sequence beginning with number 1.

A transparent overlay is then placed on the street and highway maps and the centroids with their corresponding numbers are transferred to this overlay.

b. Define the network--Judgment is the major criterion for the selection of a network for traffic assignment purposes. The necessary information required for selecting the network is the street classification map, traffic volumes, street capacities, and a general knowledge of the area. All streets that carry a substantial volume of traffic should be included. Naturally, a substantial volume means something different in each city. In a large city, it may mean 5,000 vehicles per day. In smaller cities, the number might be 1,000. As a general rule, all expressways and all arterials should be included, as well as a portion of the collector streets. The local streets are not included, but are simulated by connections between zone centroids and arterials. For State or regional networks, the interstate, primary, and portions of the secondary systems should be defined.

The assignment procedure does not assign intrazonal trips since all trips are loaded to and from a single point, that point being the zone centroid. Therefore, if all streets are included in the system, the assigned volume would tend to be lower than the actual volume counts. On the other hand, if too few streets are included in a network, they would tend to be overloaded.

In any size city, a general rule is to include all streets that are protected by a signal or a stop sign. Again, judgment is the major criterion as to which facility is to be included in a network. On the average, there is about one two-way link for every 100 persons in the study area. When the inclusion of a facility is questionable, it is better to include it than to reject it.

Each facility that is selected for use in the network is traced from the base map on the overlay that contains the centroid locations. There should be no dead-end links in the system. Refer to the sample network (Figure III-5) and the base map (Figure III-6).

c. Connect the centroids--Each loading point or centroid must be connected to the arterial street system. Because of computer program restrictions, a centroid can have no more than four connections to the system. As these are hypothetical links that represent the local street system, they are drawn as dashed lines at an angle to the arterial street. Centroids are not normally located directly on a link of the system. If they should fall on a link, they must be relocated adjacent to it and connected by a link of zero traveltime and distance.

It is recommended that a centroid be given as many connections as possible, consistent with reality (with a maximum of 4 allowed). This tends to smooth the traffic on the adjacent links. If only one connection is given to the centroid, the point at which it connects to the arterial street system will show abrupt changes in traffic volume at that point. This should be avoided where possible. For those centroids that represent only a few trips, it may be sufficient to connect them with only one or two links. This, again, is a judgment decision. When in doubt, the maximum number of local link connectors should be used. It is easier to delete a link that is not needed than to add a new link at a later time.

The centroid connections are illustrated in Figure III-5.

d. Locate and define the nodes--Now, a circle or small dot is placed at each intersection in the system. These will be the nodes. A node is also inserted where ever a link crosses the match line between maps or jurisdictions, even though there is no actual highway intersection. One of the limitations imposed by the computer program is that there may be no more than four links connected to a node. When intersections of more than four links are encountered,

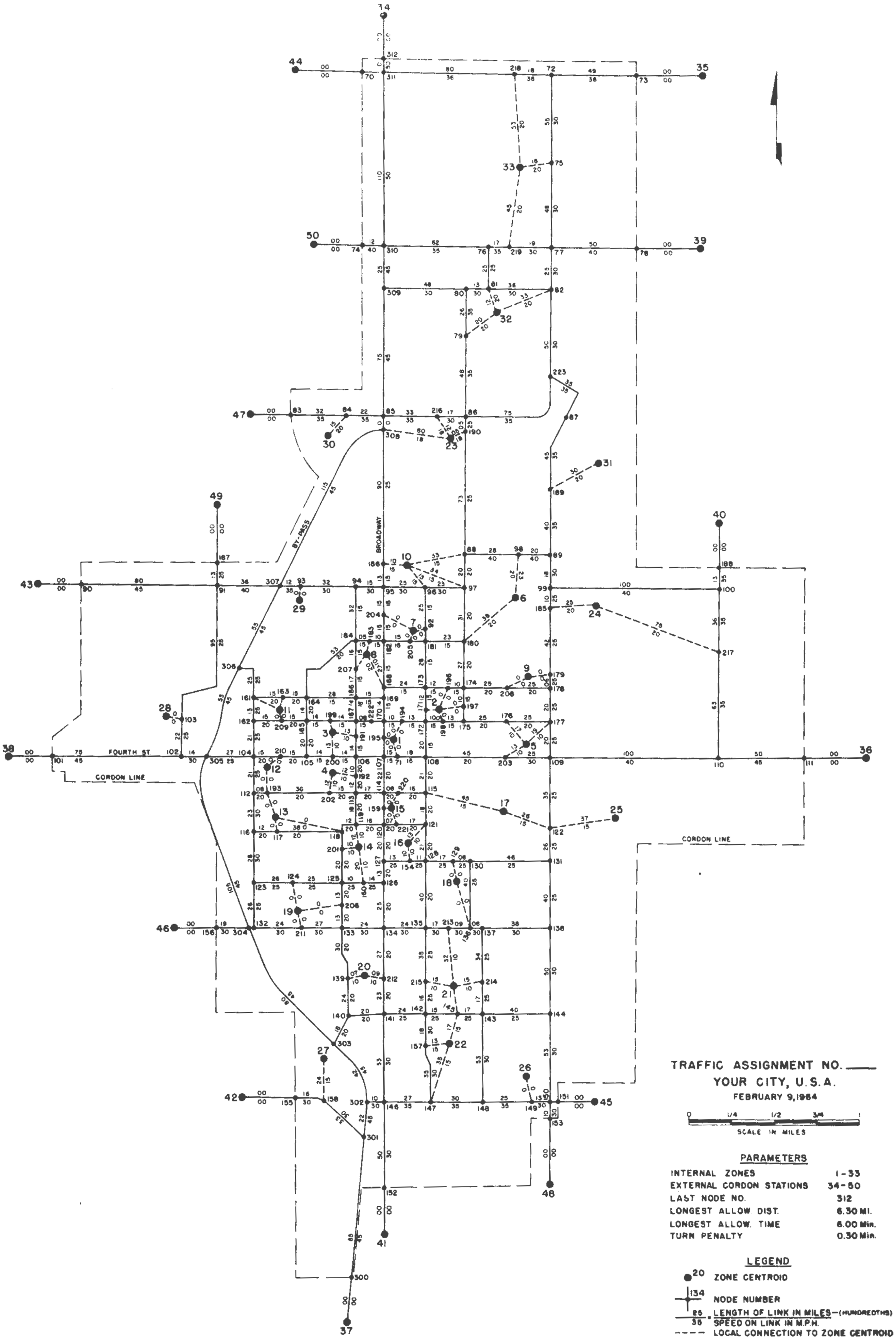


Figure III-5 .--Sample network map, Your City, U.S.A.

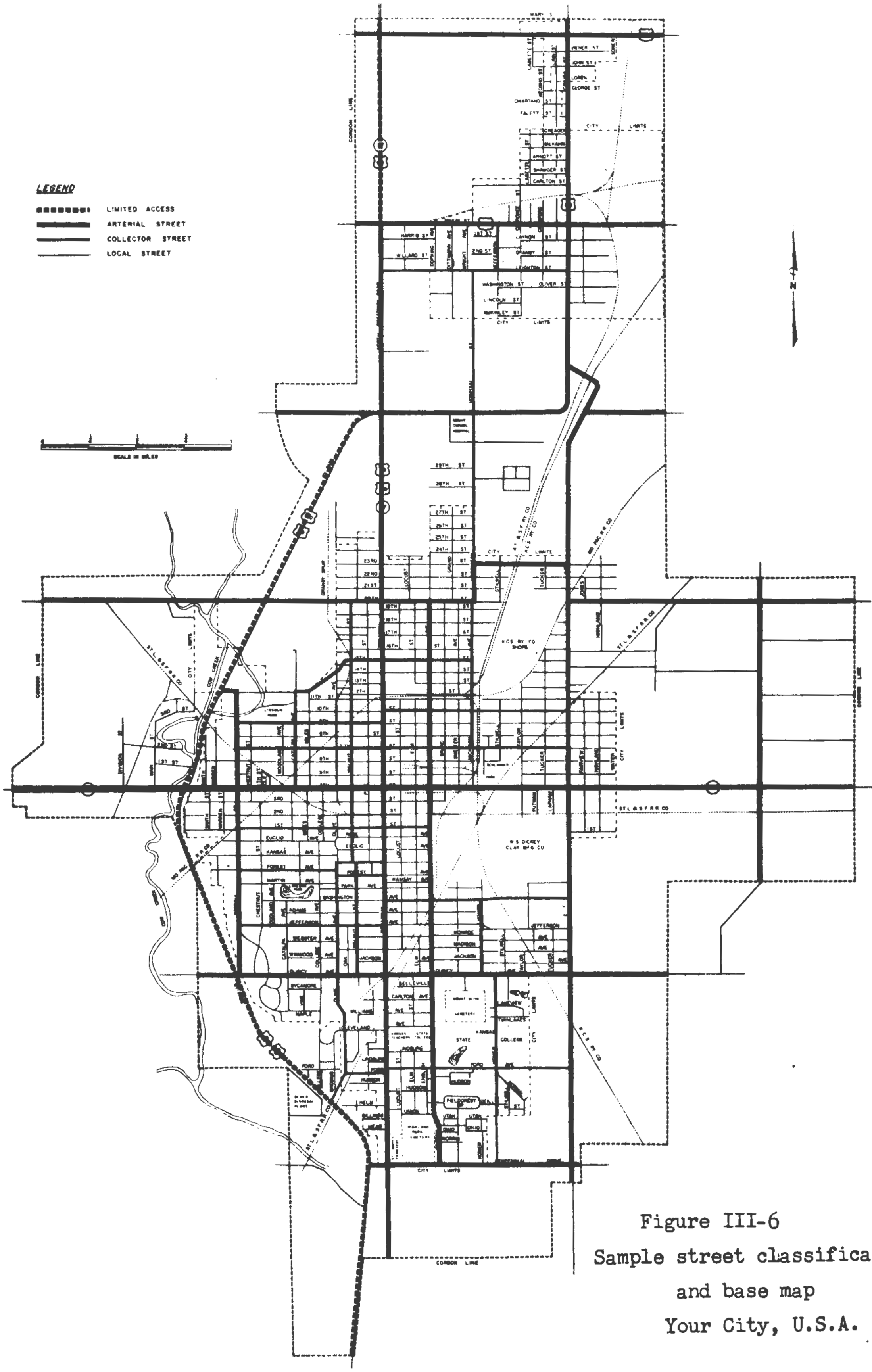
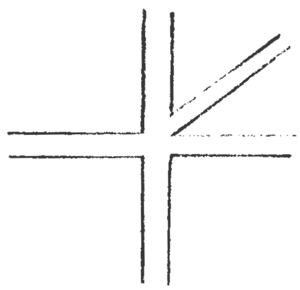


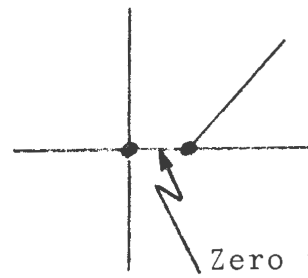
Figure III-6
Sample street classification
and base map
Your City, U.S.A.

it is necessary to add extra nodes at the intersection in such a way that none of them has more than four connecting links. The following example shows how this may be done:

DESIGN



SIMULATION



Zero time and distance link.

The distance of a link must be such that it will not yield a travel time in excess of 32767 units (usually meaning 327.67 minutes). A more reasonable limit of 999 units should probably be kept as a maximum.

At this point, all one-way streets should be marked with arrows in the direction of travel and, if space is available, some of the major geographical landmarks should be identified such as bridges, major streets, etc.

If the system that is being coded contains some high type facilities, such as freeways, their interchanges may be coded directionally. In directional coding, turning movements and weaving movements may be specified as links in the system. Thus, the longer distance and traveltime inherent in the loops of a cloverleaf interchange may be simulated in a network by directional coding. Some examples of directional coding are illustrated in Figure III-7.

e. Prepare a node numbering table--As stated earlier, the centroid numbering must begin at 1 and form a monotonic string until all centroids are numbered. It is suggested that other node numbers begin after a reasonable gap in numbers has been left for centroid expansion. A gap of approximately 20 percent of the number of centroids is a suggested guide. For example, if there are 300 centroids in the system, non-centroid nodes should not begin at less than 360. This will allow for later zonal refinement, if necessary. In areas where large growth is expected, and

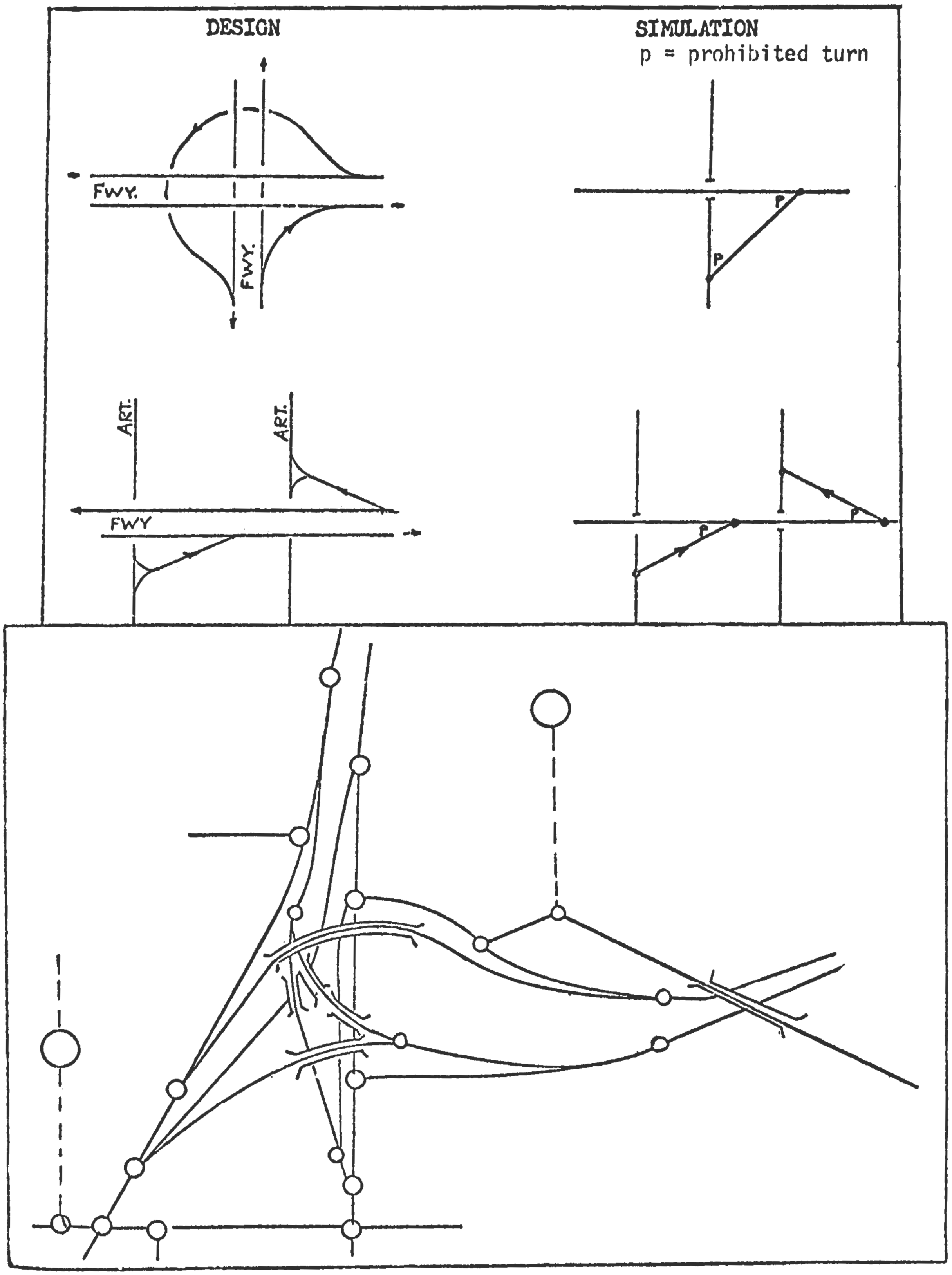


Figure III-7 --Examples of directional coding.

revisions in zonal structure are anticipated, the gap should possibly be larger than this. The number of zones has been known to double in some studies. If sufficient gaps are maintained, future networks will involve only additions to the existing network, eliminating the need for a complete re-numbering scheme. As opposed to past computer programs, the numbering logic need not be associated with a type of facility other than the centroid connector limitations.

A list of numbers to be used should be prepared. As a number is used, a notation is placed beside it. Notes indicating the map number on which the node was used can be very helpful. This list always provides the next node number(s) that are available for use. It also helps prevent the duplication of node numbers, which is illegal.

f. Assign the node numbers--Many advantages accrue from adopting a systematic method of assigning node numbers. In general, it has been found best to proceed along the main radial highways, from the center of the urban area outward, and to complete the numbering in the sector between two radials before proceeding to the next. Then the nodes in the same numerical range are grouped together. This facilitates the process of plotting the trip volumes and other tabulated data during the analysis of the computer run.

The node numbers may be written either beside the dots representing the nodes or, if preferred, they may replace the dots. Legible writing is critical, as this is the master tracing that will be used throughout the traffic assignment. After completing the numbering, the maps should be reviewed to be sure that every node has been assigned a number.

g. Assign turn penalties and prohibitors (use of leg codes)--As each node is numbered each link connecting to it may be assigned a unique number, 0-3. This number shall be called the leg number, and should be printed on the map adjacent to the node number along the link that it refers to. The number should be placed within parenthesis to avoid confusion with other posted link values. A placement system should be consistent, i.e., always place the leg code on the top of horizontal links, and to the right of vertical links, or perhaps always on the counter-clock-wise side of the link. Leg numbers are not an essential item, but must be included at nodes (intersections) where turning movements are to be penalized (delayed) or prohibited in the process of determining the minimum paths. It is not recommended that turning penalties be applied at selected sections of the study area and omitted at the surrounding areas, since this may cause the routings to completely (and unrealistically) by-pass the area. At nodes where leg numbers are included, be sure to include numbers for all connecting links.

During the routing process, as the path traverses a node, a penalty is levied depending upon certain parameters. The parameters are evaluated by determining which "in" leg was used, and which "out" leg was used when exiting from the node. If a penalty code is associated with that combination of leg movements, the penalty assigned to the code is added to the accumulation of elapsed impedances along the route. The penalty codes may range from 0 to 5, with zero having no associated penalty and 5 meaning the movement is prohibited and can not take place. The user can specify the penalty values for codes 1-4.

Generally, certain rules for selecting turn codes should be followed: a code should be used for normal type left turns, one for normal type right turns, and the remaining two codes for other turn penalties.

If there is room on the work map the penalty code desired for a given turn can be printed directly. If there is not room, then a method should be devised so that a recording of all turn codes can be kept. Once the link data are all recorded on punch cards, the formatting programs, PRINTHR or FORMAT, will provide a listing of which codes were assigned. The maps in the figures in this chapter do not illustrate leg codes or turn codes due to amount of detail in small reproductions.

Leg codes may be coded in the same sequence as the connecting node numbers. This is strictly for ease of reading reported outputs of some of the programs: sometimes the summaries are by leg code sort, and other times by connecting node sort. Another approach commonly used is to number the leg codes in a clockwise order from 12 o'clock. For program efficiencies, certain little tricks can be employed in the numbering scheme, but the insignificant savings (perhaps a maximum of 5%) of computer time in a few selected programs do not warrant considerable man-power to worry about it. Successive numbering beginning at leg 0 eliminates confusion when coding the link data cards.

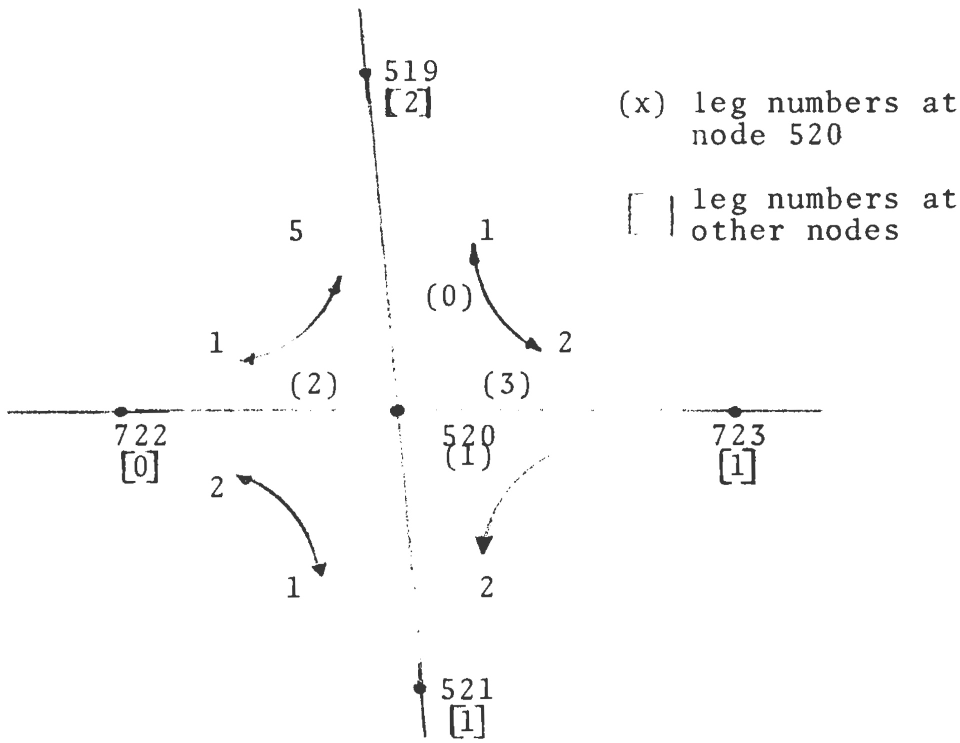


Figure III-8 -- Sample leg codes and turn penalties

In Figure III-8 the movement from 722-520-519 [520(2)-520(0)] is prohibited with a turn code of 5. All other left turns are assigned a turn code of 2, and all right turns except 521-520-723 [520(1)-520(3)] are assigned a turn code of 1. All thru movements and the [520(1)-520(3)] movement have no assigned codes, or zero turn penalties.

h. Define the link parameters--At this point, the overlays of the network showing the links, nodes, centroids, street names, signs, etc., are complete. All further work is done on transparent (reproducible) prints or opaque ozalid prints of these maps.

On a print, each link must be defined by its two main parameters--the link distance and speed or traveltime. Measuring tapes are prepared from strips of tracing paper (about 8" x 1") and marked off in hundredths of a mile. A separate tape is made for each map scale. The title of the map with which it is to be used is clearly marked on the measuring tapes. As each link is measured, the distance is written along the link, e.g., 57. No decimal point is used, thus 57 means 0.57 miles.

The length of each link should be limited to a maximum of 99.99 miles. Any links that exceed the maximum distance must be divided into two or more smaller links by the insertion of additional "dummy" nodes.

For each link, either speed or traveltime is written under the link, e.g., 525. No decimal point is used, thus, 525 means 5.25 minutes or 52.5 m.p.h. The following example shows how distance and speed or traveltime are coded on the network map.

57

525

If peak-hour systems are to be coded in addition to the average daily traffic system, the appropriate speeds or traveltimes will also be written adjacent to the link.

i. Special treatment for external stations--Some engineers prefer to code the external stations as centroids lying right on the cordon line connected directly to the major facility crossing the cordon. This places the station in a location competitive with internal zones. and can cause some difficulties in trip distribution models and assignments.

Other engineers prefer to treat the external stations very elaborately by increasing the size of the study area. They remove the external station and extend the network through to the outlying zones, each of which contains a centroid or loading node. This, of course, requires special handling in the building of trip tables and in the preparation of the network. It does permit a "diversion" of the trips approaching the external station, as it gives them a choice of alternate routes to enter the study area.

j. <u>Identifying and storing the maps and tabulations</u>--Each traffic assignment is given an identification number. Some engineers have used the following two-digit system: The first digit refers to the year which the network represents, and the second digit represents the individual assignment or revision thereof. For instance, the number "1-5" would represent the existing system, revision of assignment number 5; the number "3-7" would represent a 1985 network, trial number 7. All maps and tabulations pertaining to the individual assignment are given this number.

All of the tracings and prints for a particular system or assignment are kept together in a roll in pigeon-hole files or any other suitable filing device. Copies of the following tabulations (usually the top copy) are bound in hard covers and preserved for reference:

(1) A tabulation of the link data cards used in building the network.

(2) The printed historical record as built by the computer.

(3) The tabulation of volumes as assigned by the computer.

(4) If printed, a tabulation of zone-to-zone trips as used by the computer.

(5) Tabulations of selected trees, and other information.

3. Coding the Link Data

Figure III-9 is a format diagram of the link data card. The notes beneath the column designations describe the specifications for the fields:

Columns	Contents
1	Unused (perhaps identification)
2-6	A-node number
7	A-node leg number (0-3)
8-12	B-node number
13	B-node leg number (0-3)
14-17	Distance (XX.XX)
18	T or S for time or speed (A-B)
19-21	Time or speed (A-B) (X.XX/XX.X)
22-24	Turn penalty codes at node B
25-28	Hourly capacity (A-B)
29-31	Conversion factor (VPH/ADT), (A-B)
32-36	Directional count (A-B)
37-38	Street width (A-B)
39	Parking (A-B)
40	Unused (A-B)
41	T or S for time or speed (B-A)
42-44	Time or speed (B-A) (X.XX/XX.X)
45-47	Turn penalty codes at node A
48-51	Hourly capacity (B-A)
52-54	Conversion factor (VPH/ADT), (B-A)
55-59	Directional count (B-A)
60-61	Street width (B-A)
62	Parking (B-A)
63	Unused (B-A)
64	Administrative classification
65	Functional classification
66	Type facility
67	Surface type
68	Type area
69-70	Predominant land use
71-74	Link location
75-78	Route number
79	Condition
80	Unused

NOTES: Columns 2-6, 8-12, 14-17, 19-21, 25-38, 42-44, and 48-61 must be right justified numeric characters with leading blanks permissible. Columns 7, 13, 22-24, and 45-47 may be numeric or blank. Column 18 must be "T" or "S"; 41 must contain "T", "S", "X", or "blank" (for one-way links); columns 40, 63, and 80 are undesignated but may be used. Other columns may contain any EBCDIC characters. If an "X" is coded in column 41, the A-B values for count, capacity, and street width are halved, and together with the other items in columns 18-40 are moved to columns 41-63 of the card.

Figure III-9 -- Link Data Card Format

An inspection of the link data card shows that the data are of three types.

1. Intersection data

    a. Node and leg numbers
    b. Turn penalty codes

2. Directional link data

    a. Columns 18-21, 25-40, 41-44, 48-63

3. Nondirectional link data

    a. Distance
    b. Columns 1, 64-80

If it is found that because of differing alinements or for other reasons the distance (B-A) should be different from the distance (A-B), this can be accomplished by using two one-way link data cards. However, if the items in columns 1 or 64-80 need to be different by direction, it will be necessary to be more elaborate in coding with the critical streets represented by parallel links of differing node numbers in the same way that freeways are often coded.

The capabilities which must be considered while coding link data are two: (1) the provision to permit turn penalties and/or turn prohibitors, and (2) the ability to summarize traffic assignment outputs by many classifications (such as functional class, surface type, etc.). Program ANALHR provides for analysis and tabulation using these classifications.

If a user does not intend to do anything further than make an all-or-nothing loading, he could code the following minimum number of items: A-node, B-node, distance, and speed. On the other hand, he might elect to code all of the items if he intends to make a comprehensive analysis of traffic.

Program SUMLINK may be used to read the link data cards and produce summaries such as road-miles, count-miles, capacity hours and road surface area broken down by one-way and two-way links.

The "BUILDHR" program will carry along all of the data from the link data cards, even if the items (other than the minimum) are all blank, thus the Historical Record file will be of the same size regardless of the number of items coded. In other words, the user should not forego coding certain items to save running time, but only if he is sure he will not find these items of value at any time during his analyses.

a. Turn penalty/prohibitor considerations--There are several items involved in the use of turn penalties or turn prohibitors. There are six graduations of turn penalties ranging from no penalty (code of zero or blank) to complete prohibition* (code of 5). The values to be represented by the other four codes (1-4) are not needed until run time; however, they should be decided upon at the beginning so that the coding will be on a uniform basis, particularly if the coding process is carried out by more than one person.

The philosophy of coding turns may be either to code like turns in a like manner (i.e., all left turns with a common code) or to estimate the delay time for each turn and to code accordingly (all turns which involve a like delay get the same code). The latter process will be more accurate but will take longer to accomplish.

In regard to thoroughness of coding, it is feasible to code turn penalty/prohibitors only at a few problem intersections (assuming, in effect, that all other turns involve no delay). However, the decision to move in this direction should not be made without considering the consequences. For example, coding turn penalties only in the central business district area may cause the assignment process to divert trips around the central business district. This may seem desirable, but, of course, should not be permitted if this is not what is really going to happen on the ground.

Having decided which intersections to code and the codes to apply to each movement, this information is furnished to the programs by following the following rules:

1. Turn penalties/prohibitors are coded on the link from which the movement enters an intersection.

2. Turn penalties/prohibitors are indicated by specific codes which are related by means of leg numbers: therefore all leg numbers should be

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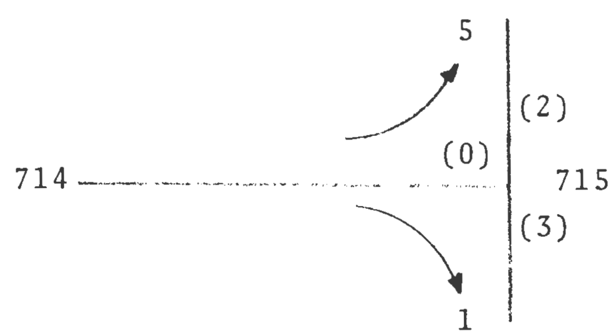
*It is not necessary to employ turn prohibitors to prevent traversing one-way links in both directions.

coded on intersections requiring turn penalties/ prohibitors. The "BUILDHR" program assigns leg numbers where they are not coded, and it may not assign them in the order expected.

3. Turn penalties/prohibitors may be coded in either one-way link cards or in two-way link cards. In the first case, columns 22-24 are employed; in the second case, columns 22-24 and 45-47. Columns 22-24 are for the three potential turning movements leaving the link at the B-node end, columns 45-47 for the A-node end.

To choose the column in which to punch a turn code, follow this rule: place the code for the lowest leg number (not counting the leg number of this link) in the first column; the second column is for the next highest leg; and the third column for the highest. Thus, for turn codes for a link with leg number zero, the progression is movements to leg numbers 1, 2, and 3; for a link with leg number 1, the columns are for movements to leg numbers 0, 2, 3; for leg 2: 0, 1, 3; and for leg 3: 0, 1, and 2. This order of use is mandatory--for example, when coding turns from leg zero for an intersection having no leg 1--but only legs 2 and 3, the first column would be left blank and penalty codes entered for movements to leg numbers 2 and 3.



For example, to enter the turn penalty and prohibitor shown above for the intersection represented by node 715, the turn penalties would be coded either in a one-way link card (714-715.0) in columns 22-24 or in a two-way link card (columns 22-24 if A-node is 714 or columns 45-47 if A-node is 715). The appropriate three columns would be coded as follows: "blank," 5, 1, for leg numbers 1 (nonexistent), 2, and 3, respectively.

b. "Classification" coding considerations--The major use of classifications such as Functional Class, Administrative Class, type of parking etc., is to permit summaries by these classes. For example, total vehicle miles could be printed by functional class by street width.

The critical points to be considered are

1. The classification should be fine enough that the needed information can be broken out, but

2. not so detailed that many of the summary values need be manually summed,

3. remember that all uncoded items will appear to the program as classification of "blank" (or zero for numeric-only fields such as street width),

4. that like items must be coded like, e.g., First Street should not be coded both as "FRST" and "1ST" as they will appear completely different to the computer, and a summary would list them separately.

Certainly, the detail employed in these items will depend on the expense in time or dollars involved in getting and interpreting necessary data. This cost should be balanced against the benefit resulting from having this information in the file.

In transferring network data from the various possible sources to the link data card, the usual process is to first put it on a map of suitable scale. The minimum data to be put on the map will vary with the user but should include node numbers, distances, speeds, and where required, leg numbers, and turn codes. Centroids, local links, and one-way links should be so indicated. Such items as count, capacity, route or street name, and parking type may be considered desirable as well.

It is expected that with the higher number of coded items the map scale may have to be increased. It may be desirable to denote functional class by some means such as dashed lines, and it may be well to show coordinate grids.

G. EDITING AND CALIBRATING THE NETWORK

1. Initial Edits of the Link Data

When all link data cards are coded, key punched and key verified, they are ready to be input to the computer. There will most likely be initial coding errors in the network so listings of the link data cards in both A node and B node sorts are advisable. If off-line sorting and listing capabilities are available, they should be utilized to aid in the process. If they are not available, a series of simple programs available in Urban Planning System 360 can easily be used along with the first BUILDHR run. The series includes:

1. BPRCOPY to place the cards onto a tape or disk,
2. SORT to sort the cards (now on tape or disk) on B node,
3. BPRDUMP to list the sorted file,
4. SORT again but this time on A node - B node, and
5. BPRDUMP to list that sorted file.

If the link data deck is relatively large, the final output of the A node - B node sort should be saved on tape or disk.

The link data cards on tape or disk can be input directly to the BUILDHR program (see LNKCDI option) and also can be updated by use of the PRKUPDT program if the records are in sort. Some users prefer changing the initial link card deck each time to retain a complete updated network in card form.

The control card inputs to the BUILDHR program set certain parameters about the network. These parameters are normally kept in effect for the duration of analysis on that particular network. The program documentation states all the options available, so only a few of the more important ones will be discussed here. The user should definitely specify LASTZN (number of zone centroids) and LASTND (highest node number). The turn penalty information TPCD1-TPCD4 and TPEN1-TPEN4 and TSTAST are highly recommended for inclusion. Probably the next most important parameters are the speed checks for links within specified classifications. The other items have a great usefulness but are not necessary for most network editing.

The BUILDHR program will print messages about any link data cards with errors if error weights are included. When it is finished it will have written a data set called HRO (historical record) which contains label records that explain what is on the data set, intersection detail records that contain information about each node in the network and link detail records that contain information about each link in the network. The HRO data set is written in the binary mode and therefore cannot be read directly by the analyst. The PRINTHR program will prepare a printed report detailing the link information. The report lists by A node sort, the leg numbers, the turn penalty codes associated with the A node, the link distance, speed, count, capacity, and the data from columns 37-40 and 60-80 of the link data cards.

If there are network errors, the output of the formatted historical record is then examined, along with the link card listing and output of the BUILDHR program. The sources of errors are determined to be either in the original network map, or on the link data card, or both. When the map is correct, revisions are made to the link data deck. The revisions may be manually completed by altering or modifying the actual link data card deck, or by following the methods outlined in the following section.

2. Correcting Network Errors-Updating the Historical Record

The program UPDTHR will update the historical record data set by allowing the user to specify link additions, deletions, or changes. There are considerable advantages to using UPDTHR to update the historical record as opposed to manually correcting the link data.

1. There are less data cards to handle, eliminating a potential source of error.

2. Updating may be faster than having to go through BUILDHR again.

3. The program setup (JCL) is easier and less intermediate work space is needed.

The UPDTHR can also be used in place of BUILDHR to build the original historical record from link data cards.

However, it is not capable of building all size networks; so BUILDHR is referred to as the universal building program. If the network being considered fits within the limitations of UPDTHR build option (see program writeup for details), then it should be used in place of BUILDHR; it is less expensive to operate.

If the UPDTHR program is used to update the historical record, the user should, when all errors are corrected, use the program UNBLDHR to convert the historical record back to link data cards. This is done so that he will always be able to recreate the network in case of loss or damage to the historical record data set. It also provides a "hard copy" of base data used in the transportation study.

An alternative to updating the historical record to make revisions is to update the original link data deck and proceed through the building phases again. The program PRKUPDT can be used to update (in link data card format) the data set that was used as LNKCDI to the BUILDHR program (recall that it is in sort by Anode-Bnode, or possibly by Anode and leg). In PRKUPDT several parameters are important:

```
PAR,INPUT=CARDS
SORTKEY,A,B
DEFINE,A=2-6,B=8-12
```

The user can then change items on specific links, delete links or even add new ones. The only strict requirement is that the input link data file (called TRPCDI) and the update cards be in the same sequenced order on A-B.

3. Checking for Network Logic Errors--Building and Tracing Paths and Plotting

When all directly noticeable errors are corrected, the network must then be checked for logic errors. The types of errors that must be checked for are:

1. Miscoded data items such as speed and distance
2. Wrong assignments of turn codes or prohibitors
3. Missing links
4. One-way links coded as two-way, and vice-versa
5. Tunnel links (those links that connect to the wrong nodes)

a. <u>Building and tracing selected paths</u>--The above errors can be located in several different ways. One method is to have the program BUILDVN compute selected routes throughout the network, and program PRINTVN format the zone-to-zone paths. By hand tracing the paths printed by PRINTVN on the network map, most of the above errors will be quite obvious. The paths to be computed should be selected from varied centroid locations in the network. As a usual practice 6 to 10 origin point centroids are selected. All trees are not built because the computer time can become quite large. It is advisable to build at least one tree from a CBD centroid, and several from scattered points around the peripheral area.

The PRINTVN program reads the PATHSI data set containing the paths created by BUILDVN (PATHSO) and prints the nodes in the order that they were traversed in arriving at the destination. Actually, the trace is printed in reverse order. The first number printed for a trace is the destination centroid for that particular O-D movement. The number to the right of that node is the node number for the node that was traversed prior to the node on the left. A series of node numbers follows until the node number at the origin point is printed. The analyst, in using the printed output, will normally use a red pencil and trace along the network map the route as designated by the string of numbers. He then examines the path in entirety for logic at which time network errors will be obvious.

It is not imperative to trace the paths to all centroids on the network; selected destinations will give a fairly good coverage. A destructive trace option is available in the PRINTVN program that eliminates a considerable amount of output. When the option (DSTRAGN) is used a given printed destination trace may not terminate at the origin point. When this occurs the user simply scans the traces prior to the current one until he finds one which contains the node number that is the same as the one where the current trace terminated. The trace may be continued from that point. If that path had already been traced on the map, there is no further need to continue the tracing. It is recommended that the destructive trace option be used, but set it at a reasonable number, say 5-10, so that considerable frustration is not involved in trying to find the remainder of the trace.

The program TREETIME may be used to print nondestructive traces for selected origins. In addition to the tree traces this program lists the cumulative time from the origin to each node of the trace. TREETIME reads a PATHSI (tree option only) data set and a corresponding historical record and prints nondestructive traces.

b. Plotting networks and paths--An alternative and less manpower-consuming method of checking for many network errors can be accomplished by using programs which prepare input tapes for automatic digital plotters. Initially more work is involved in the preparation of node coordinates and in obtaining computer systems support to be able to combine the correct program decks that actually write the tapes for the local plotter. At the current time, the plotting series of programs are geared to a CALCOMP off-line plotter; with slight programming work other plotters can conceivably be employed. Section F of CHAPTER VII describes the plotting programs in greater detail.

c. Network routing errors--The plotting (manually or mechanically) of selected paths may reveal that, in some instances, the true minimum time path has not been determined. This condition is usually caused by the addition of turn penalties and turn prohibitors to the network. This does not mean that turn penalties and prohibitors always force the computer to build a tree this way. However, the computed minimum time paths should be examined for illogical routings, and the turn penalties and prohibitors adjusted (added or removed) when necessary. The use of vines in the path building phase will eliminate this type of error.

Illogical routings involving high speed or low speed links may be discovered. If the minimum time path criterion is used alone and a particular freeway is coded with a speed of 50 to 60 m.p.h., it may attract circuitious routings which are unlikely in reality. Thus, the freeway speed should be reduced to, say, 40 to 50 m.p.h.

Conversely, traveltime runs may indicate speeds of 10 m.p.h. or less in the central business district. If this speed is coded on CBD links, the computed minimim time path routings may unrealistically avoid the CBD. In this case, the very low speed links may have to be coded at a somewhat higher value to obtain realistic routes.

It should be noted that route selection is based on elapsed time, i.e., minutes per mile. This may be illustrated in the following manner:

Speed (m.p.h.)	Minutes/mile
60	1.0
40	1.5
30	2.0
24	2.5
20	3.0
15	4.0
12	5.0
10	6.0
9	7.0
8	8.0

Note that a difference of 1 minute/mile results in a change in speed of 30 m.p.h. at the upper range of the table, and only 1 to 2 m.p.h. at the lower range.

If there are no noticeable network errors, the network is ready to be tested to determine its ability to simulate existing conditions. If there are errors, a return to network editing as outlined in Sections 1 and 2 above is necessary.

4. Loading the Network and Capacity Restraint

a. Loading the network--The next step in calibrating or checking the network is to assign the current trip table to the links in the network. Program LOADVN reads in the trip tables (TRIPSI) and the paths (PATHSI). The paths from origin to destination are examined to determine which links are used; the trips from O to D are accumulated on those links. During the process, the turning movements of vehicles at nodes are accumulated, if desired. The user may specify the origin zones to be considered, the destination zones to be considered and the trips to be considered. In checking the network at this phase, all vehicle trips between all zone pairs should be loaded.

When the program is finished with the assignment it reads in the historical record (HRI) and merges the new link volumes and turning movements with it and writes out an expanded historical record (HRO). It also prints a summary of vehicle-miles and vehicle-hours.

b. Formatting the link volumes and turning movements --A companion program PRINTLD is used to put the link volumes and turns in a readable format. The program FORMAT is extremely useful in obtaining economic factors about the link loads. It will also print the link volumes. FORMAT is somewhat complex to use, but its flexibility warrants the time required to determine the proper setup criteria. Once the type of setup is satisfactory the same control deck should be kept intact for further use.

c. Plotting an analysis of loaded networks--If this is the initial loading of a network, the output is generally a "free" or "desire" type assignment. There has been no adjustment to the network other than the correction of coding errors, and the trees have been built strictly on the basis of the traveltime as prescribed by the coder of the network. No attempt has been made to account for other parameters that may affect the route choice decisions between two points such as congestion, pedestrian interference, pavement condition, etc. Because of this, the assigned volumes may be considerably in excess of the ground counts or the capacity of the links. Of course, some links may also be considerably underloaded.

The loading is analyzed by transferring the assigned volumes from the output of program FORMAT to a print of the network maps. This is a rather time-consuming procedure and, in practice, only the assigned volumes on the major facilities are investigated initially. If the assignment has been of existing traffic to the existing network, the assigned volumes may be compared with the ground counts. If not, the assigned volumes are compared to the capacities of the facilities.

Of course, if mechanical plotting of the network has been provided for, considerable time can be saved by using the plotting programs to post the volumes. Color band widths can be used to aid in visual comparisons of overloaded or underloaded links or facilities.

If any large discrepencies show up at this time, the analyst must try to decide where the base of the problem lies. It could be improper trip tables, unrealistic travel speeds, or still some network errors. These problems should be remedied before continuing.

For a more complete discussion of the plot programs available see Chapter VII, Section F,Graphical Display.

d. Restraining assignments--Capacity restraint is utilized in this phase of the work to change link speeds in response to loaded volumes, which should provide realistic assignments. The aim of the speed changes is to put load and speed in "balance" on each link. After this is accomplished the network can be further reviewed to determine its adequacy for assignment purposes. When the network finally is considered acceptable for present year assignments, it is recommended that the restrained speeds obtained should not be used for future trip assignments. Rather, the original link data speeds and/or desired speeds on new routes should be used.

An assignment restraint may be done by either of two methods: manually or automatically by capacity restraint. The manual process of restraining assignments will be discussed first, and then the automatic capacity restraint as performed by the computer will be illustrated.

The manual restraint of a traffic assignment is simply a process of deciding what link adjustments are necessary, coding and keypunching the necessary update cards, and revising the network description. The process of revising the network is continued until the traffic assignment is satisfactory. It is evident that this manual restraining procedure may be very time-consuming and costly. If capacities are available for the links in the system, it is advisable to avoid these manual adjustments and allow the computer to make these adjustments automatically.

The capacity restraint procedure for adjusting a traffic assignment is a completely automated method of adjusting the network parameters. The theory of capacity restraint analysis is described in detail in Section C.3.b of this chapter. Details concerning the output summaries of the CAPRES program are contained in the program writeup.

5. Analytical and Utility Programs

Various programs have been developed which allow for analysis of traffic assignment operations. CHAPTER VII describes several of these programs. It is advantageous to use these programs and become quite familiar with them; they can many times (with a little imagination)be used for more purposes than their originally intended use.

6. Summary of Traffic Assignment Computer Programs

ANALHR - This program accepts as input any output of the assignment program. The program automatically stores the standard portion of each historical record (the first 17 words) into a preset area of the program. In addition it permits acquiring any loads or other information from the remainder of the input record and stores the information in the program area.

The program has the option of doing any or all of the following options:

- GNWV Generate new variables from the input variables. For example: Multiply the volume by the count to obtain vehicle miles, divide the volume by the capacity to get V/C ratio.
- PRNT Print any of the input or generated variables.
- BM2R Prepare a BCD output of any or all input or generated variables that among other purposes may be used as input to regression analysis.
- REWR Rewrite the historical record with generated variables added to the record.
- CLAS Classify the data into a three dimentional matrix and print the resulting accumulations.

Each of the options listed above have a control feature. For example, if you wish to divide the volume by the capacity, you must first check that the capacity is not zero (or unreported). The control permits comparing the capacity field with a constant (or with another field) and based on whether the comparison results in less than, equal to, or greater than; do one of the following: skip the operation; handle the operation; check the next control field.

BUILDHR - Build Traditional Historical Record. This program reads link data cards, edits them, and, unless errors are too numerous, prepares a historical record containing (1) descriptive print records, (2) a parameter record, and (3) one historical record for each node in the network described.

BUILDVN - Build Minimum-Impedance Paths. This program reads the HRI (Historical record data set) created by BUILDHR (or as modified by other programs) and prepares designated outputs (PATHSO = trees or vines; IMPEDO = skimmed trees).

CAPRES - Apply Capacity Restraint. This program reads in link capacities and loadings from a traditional historical record and then adjusts link traveltimes according to a predetermined relationship of volume to capacity on the links. The objective is to achieve a balanced and realistic traffic assignment.

FORMAT - Variable formats of historical record. This program formats traditional or spiderweb historical records. By use of appropriate control cards, the program can be instructed to (1) print detailed information on a link by link basis or (2) accumulate selected values from the network. The latter includes totals, means, and standard error measurements.

LNKCOST - Compute Link Travel Cost. This program reads speed-cost curve data cards, edits them in relation to other control information, and, unless errors are present, updates a historical record by the addition of link cost words for each curve present or for those curves which fall within that link's classification, depending on which option is being used.

LOADVN - Load trips on network links. This program reads the PATHSI dataset created by BUILDVN and loads specified trips from a TRIPSI (trip table) dataset. An HRI dataset is read and updated by either link loads or turning movements and output in an HRO dataset.

PRINTHR - Rigid Format of Historical Record. This program prepares a printout of selected data from the traditional network historical record file. Although the program can format a variety of data, the program FORMAT is preferred for flexible formatting.

PRINTLD - Format historical record link volumes (rigid format). This program prepares a printout of data from a loaded traditional record. Among the data which can be printed are counts, capacities, and turning movements (each optional) and link loads.

PRINTVN - Format zone - to zone paths. This program formats for printing, traces to selected destination zones from selected origin zones. Traces may be nondestructive or iteratively destructive.

SUMLINK - Reads link data cards in the standard 360 format and prepares summaries such as road-miles, count-miles, capacity hours, and road surface area broken down by one-way and two-way links.

TREETIME - Prints nondestructive traces for selected origins and the cumulative time from the origin for each node of the trace. This program will not read vines (only trees).

UNBLDHR - Extract link data records from historical record. This is a general purpose program capable of converting the Traditional Historical Record Dataset data to standard S 360 link card format. In addition, or alternately, it will punch x - y coordinates file.

UPDTHR - Update Historical Record. This program is a dual purpose program for either building or updating Traditional Historical Record Files. When used in update mode it will add/delete/change links and data in existing Historical Record Files. In the build mode it may advantageously be used as an alternative to the BUILDHR program under certain circumstances.

VEHMILE - Obtain vehicle miles of travel. This is a general purpose program capable of reading single or merged trip tables on one TRIPSI dataset and up to eight IMPEDI datasets, and preparing single or merged vehicle-mile trip tables on one TRIPSO dataset. Optionally, the user may request printout of total vehicle miles, total trip and average trip length by zone for each table produced.

WTLOAD - Will calculate weighted volumes, weighted turning movements and standard or weighted V/C ratios from an historical record.

BLDSPTR	Build Spiderweb network*
COMPARE	Compare Network Assignments**
FMTSPLD	Format Spiderweb Link Loads*
FMTSPTR	Format Spiderweb Trees*
FMTSPWB	Format Spiderweb Network*
GEALPHA	Annotate Nodes for Plotting*
GECBWP	Plot Colored Link Bank Widths*
GEPLOT	Plot Selected Network Areas*

* See CHAPTER VII
** See CHAPTER IV

GEPREP	Prepare Network on Paths for Plotting*
GESERT	Insert Node Coordinates in Historical Record*
LDSPWB	Load Spiderweb Network*
REVSPWB	Revise Spiderweb Network*
SELINK	Determine trips using selected links*
TRPTAB	Obtain vehicle miles of travel (see VEHMILE on preceeding page). In addition, zone-zone VMT for selected origin zones and/or tables can be printed (see Chapters IV and VII).

* See CHAPTER VII

7. Analysis and Presentation of Results

When the traffic assignment computer operations have been completed and the assigned volumes transferred to network maps, it is good practice to prepare a short writeup about the traffic assignment. This discussion, which would accompany each traffic assignment, should contain the number of the traffic assignment and additional explanatory information about the trips and the network.

The notes about the trips that were loaded to the network should record the following:

1. Are they existing or forecasted trips?
2. For which year?
3. Total daily or peak period movements.
4. The type of trips--total vehicles, work trips only, transit trips, etc.,
5. For which land use plan?
6. Other identifications.

Concerning the network, the following information should be included:

1. Is it an existing or forecasted network?
2. Representing which year?
3. How was the loading performed--all-or-nothing, restrained, etc.,?
4. A total daily or peak hour system
5. Any specific links that were tested
6. "System" numbers--It has been found useful to distinguish different transportation networks used in the assignment process by successive "system" numbers, even though the differences between networks may be small. The system number can then be used to identify link data cards, computer output, network maps, and traffic volume maps. The differences between systems should be clearly identified.
7. Other details.

It may also be advisable to include some of the results of a preliminary analysis of the network or, at least, indicate if the assignment was considered successful. Any computer program malfunction should also be noted in this brief writeup. If the facilities are available and the system is not excessively large, the assignment map could be photographed, reduced, and a print inserted with the text.

The necessity for maintaining accurate and detailed records concerning the traffic assignments will become obvious after several systems have been run.

The results of a traffic assignment may be illustrated in many ways. It may only be necessary to record the assigned volumes adjacent to the street segment on a copy of the assignment map. Some engineers prefer to illustrate the assigned volumes by flow bands on the street segments. The width of the flow band represents the assigned traffic volume.

Perhaps a more useful illustration would be to compare the assigned traffic volume to the capacity of the segment and record the percent usage of the capacity. To avoid a misrepresentation, however, either the capacity or the assigned volume must also be shown.

The title block for all illustrations should contain at least the system number, date, scale, and the network parameters.

CHAPTER IV

TRIP DISTRIBUTION

A. INTRODUCTION

Trip distribution analysis is the process by which trips originating in one zone are distributed to the other zones in the study area. Trip distribution methods are constantly evolving, shifting in the last decade from a total reliance on growth factor techniques to the wide use of mathematical travel models.

Growth factor techniques are used to project into the future the existing travel pattern as determined by the home-interview survey. The growth factors are developed for each zone and by trip purpose within the zone. The projection is carried out in a series of successive approximations. In the Fratar method, the most widely used of the growth factor techniques, a forecast of the future trips between any pair of zones is obtained by multiplying the current trips by the product of the growth factors for the two zones with an adjustment for the relative attractiveness of other competing zones.

When growth factor techniques are used, it is necessary to make adjustments to account for zones now vacant but which are expected to be developed, as well as for the zones in which future land uses will be materially different from the existing land uses. When an urban area is expected to experience significant growth, the adjustments to the present trip pattern become difficult and, to a considerable extent, speculative.

The greatest advantage of the growth factor techniques is that they reflect the many unique travel relationships that exist in any urban area. They are most applicable in slowly growing areas. However, many cities are experiencing rapid growth in the form of significant suburban development coupled with extensive downtown redevelopment. These land use changes make extensive adjustments to the procedure necessary. For this reason, many of the major urban studies are turning to mathematical travel models. These models synthesize travel patterns by relating them to characteristics of the land use pattern and of the transportation system. The Fratar method is used extensively to factor external trip tables.

All of the synthetic distribution models have the following factors in common. The producing or attracting power of the activities in any given zone is measured in trip ends. The trip interchange is a function of the producing and attracting powers of the zones and the spatial separation between them.

Spatial separation may be measured in traveltime, distance, or cost via the specified transportation systems. All of the models must be "calibrated" or adjusted so that the theoretical relationships fit the existing travel characteristics of the particular urban area being studied. The calibrated model is then subjected to a comprehensive test of its ability to reproduce the existing travel pattern. If the test is satisfactory, the model may then be used to predict the distribution of the trips estimated to be generated in a future year over a transportation system or systems assumed to be then in existence.

The mathmatical model techniques present interesting contrasts in their approach to the trip distribution problem. The most widely used and best documented of the procedures is the gravity model. This approach, loosely paralleling Newton's gravitational law, is based upon the assumption that all trips starting from a given zone are attracted by the various traffic generators and that this attraction is in direct proportion to the size of the attractor and in inverse proportion to the spatial separation between the areas.

In the gravity model the measure of spatial separation has generally been accepted as the zone-to-zone traveltime via the specified transportation system. Because people as social beings do not order their lives according to exact physical laws, it is necessary to adjust the gravitational concept to fit the travel characteristics of the urban area being studied. Typically, models are developed for from three to six trip purposes depending upon city size, with the larger number in the larger and more complex areas. The procedure is an iterative process which, for each trip purpose, develops a set of traveltime factors. The classical gravitational formula containing an inverse exponential function of spatial separation is ordinarily restructured for use in computer programs. A table of factors representing the effect of spatial separation for each one minute time increment is used in place of a single time exponent. This allows more complex mathematical functions to be easily represented. A further modification in the basic gravitational formulation is made to eliminate the need for a proportionality constant.

A second widely used travel model is the Chicago, or intervening opportunities, model developed by the Chicago Area Transportation Study. This model utilizes a probability concept which in essence requires that a trip remain as short as possible, lengthening only as it fails to find an acceptable destination. Initially an equal areawide probability of acceptance is defined for all trips in a given category. All trip opportunities or destinations are considered in sequence by traveltime from the zone of origin. The first opportunity considered is the one closest to the origin, and it has the stated areawide probability of acceptance. The next opportunity has the same basic probability of acceptance; however, the actual probability is decreased by the fact the trip being distributed has a chance of already having accepted the first opportunity. The procedure continues with each successive opportunity having a decreased probability of being accepted.

This model is calibrated by varying the probability value until the simulated trip distribution produces the same vehicle-miles of travel by major geographic subareas as the surveyed trip distributions.

Typically, the quality of any given model is measured by the accuracy with which the synthetic trip distribution reproduces the surveyed distribution. Remembering that in each model the effect of spatial separation was the same areawide for a given trip purpose category--one traveltime factor for a given trip length in the gravity model, single probability in the Chicago model--there is the possibility that a unique travel situation may not be properly accounted for. For example, a given residential area may have very strong ties to a given employment site. This may have resulted from the timing of the development, the wage scale of the plant, and the average rents of the residential areas or other factors. The model must be checked to guarantee such conditions have been adequately met. In several model applications, it has been necessary to apply adjustment factors to modify the basic model relationships. However, before applying such factors, it is essential that the factors be quantitatively related to land use or socio-economic characteristics of the area. The relationship to specific socio-economic characteristics is required so that the adjustment factors may be properly forecast as a function of characteristics of the anticipated future land use plan.

The wide use of mathematical trip distribution models has raised questions on the need for large sample home-interview surveys. Stable zone-to-zone trip movements are a prerequisite for the use of growth factor techniques. The calibration of trip distribution models, however, requires only certain of the parameters developed from the travel survey. Most important is a measure of the trip length characteristics of travel in the area, by trip purpose and a knowledge of trip generation. Areawide trip length characteristics and trip generation values may be established from fairly small random samples, but the development of generation values for small zones, in the absence of a comprehensive survey, must rely on secondary data sources. For example, total areawide work trip ends may be allocated to the zones in proportion to the resident labor force in the residential zones and to the employment in nonresidential zones, although the treatment of other trip purposes is more difficult. The validity of the synthetic trip distribution may be checked through a comprehensive series of screenlines rather than against the home-interview trips. The most critical problem is, however, the establishment of the socio-economic factors needed to eliminate error or bias which may occur in the synthetic distribution.

In the interest of time and cost of surveys, certain studies are reducing sample rates to a limited degree, although the Federal Highway Administration still recommends the full sample rates. Considering the magnitude of decisions resulting from the urban transportation process, the investment in an accurate data base is considered to be money well spent.

B. THE FRATAR METHOD

The Fratar method is the oldest of the three trip distribution techniques contained in the package. The procedure was presented by Thomas J. Fratar to the Highway Research Board in 1954. It is based on the assumption that the change in trips in an interchange is directly proportional to the change in trips in the origin and destination zones contributing to the interchange. It is felt by many to be the most satisfactory way to deal with certain types of trips such as external, external to internal and, in some cases, peak hour.

1. Method Theory

The Fratar method differs from the two other models included in the trip distribution package in that it requires a trip table as one of its inputs. The user must also supply a growth factor for each origin zone. He may, if he wishes, specify a growth factor for each destination zone as well. If he fails to exercise the latter option, destination growth factors are assumed to be the same as origin growth factors.

Origin and destination growth factors are applied to each interchange in the trip table supplied. Factoring is done in such a way that the proper number of origins is always present. After any one pass, however, actual destination totals may not agree with those desired. An iterative capability is included in the program which refines the correspondence between actual and desired destination totals. It is the user's responsibility to see that iteration continues until a sufficient degree of accuracy has been obtained. Experience has shown that four iterations will usually suffice. Several statistical tests have been included in the program to help with this decision.

The program is capable of applying the Fratar technique to more than one trip table at a time. This feature is particularly convenient when trips are divided into several types or purposes. The limit on the number of trip tables which the program can handle at one time is a function of the quantity of core available for data storage. A problem requiring more storage than available will be rejected.

The technique employed may be represented mathematically as follows:

$$T_{ij(k+1)} = (T_{ijk}F_{jk})F_{ik} \qquad (1)$$

where

$$F_{jk} = \frac{T_j}{\sum_{i=1}^{n} T_{ijk}} \qquad (2)$$

$$F_{ik} = \frac{T_i}{\sum_{j=1}^{n} (T_{ijk}F_{jk})} \qquad (3)$$

and where

T_{ijk} = trips between i and j for iteration k (represents given trips when k=1);

F_{jk} = destination (column) factor j;

F_{ik} = origin (row) factor i;

T_j = final desired total for destination j;

T_i = final desired total for origin;

i = origin zone number, i=1,2,...,n;

j = destination zone number, j=1,2,...,n;

n = number of zones;

k = iteration number, $k=1, 2, \ldots, m$;

m = number of iterations.

It is evident that the calculation

$$T_{ijk} F_{jk}, \quad j=1,\ldots,n$$

must occur before F_{ik} can be obtained. Formula (1) above, therefore, represents a two-step programming process. The application of this process to all origin zones represents one iteration. The diagram in Figure IV-1 shows the logic-flow for the Fratar program.

2. Method Example

As an example of how the Fratar technique is applied in the program, suppose that Figure IV-2 is a 3 x 3 trip table containing a total of 25 trips. Suppose also that the factors in Figure IV-3 are to be applied to the origin and destination zones in order to generate a 3 x 3 trip table containing a total of 75 trips.

Final column and row totals should equal those in Figure IV-4. To supply the missing ij values is the main purpose of the Fratar method.

In the first iteration, F_{jk} factors would be applied to each column in the given trip table yielding the results in Figure IV-6. F_{ik} factors would then be derived as in Figure IV-7. These factors would be applied to the column-factored table above to yield the output from Iteration 1 found in Figure IV-8.

It is important to understand that the column-factored table never exists as an entity. The program operates upon one row of the input at a time and generates, in each case, one row of output. It does have a logical existence just as shown, however.

The second iteration operates upon the output of the first iteration. First, F_{jk} is calculated for each column as in Figure IV-9. A column-factored table as in Figure IV-10 is then produced row by row. F_{ik} is calculated

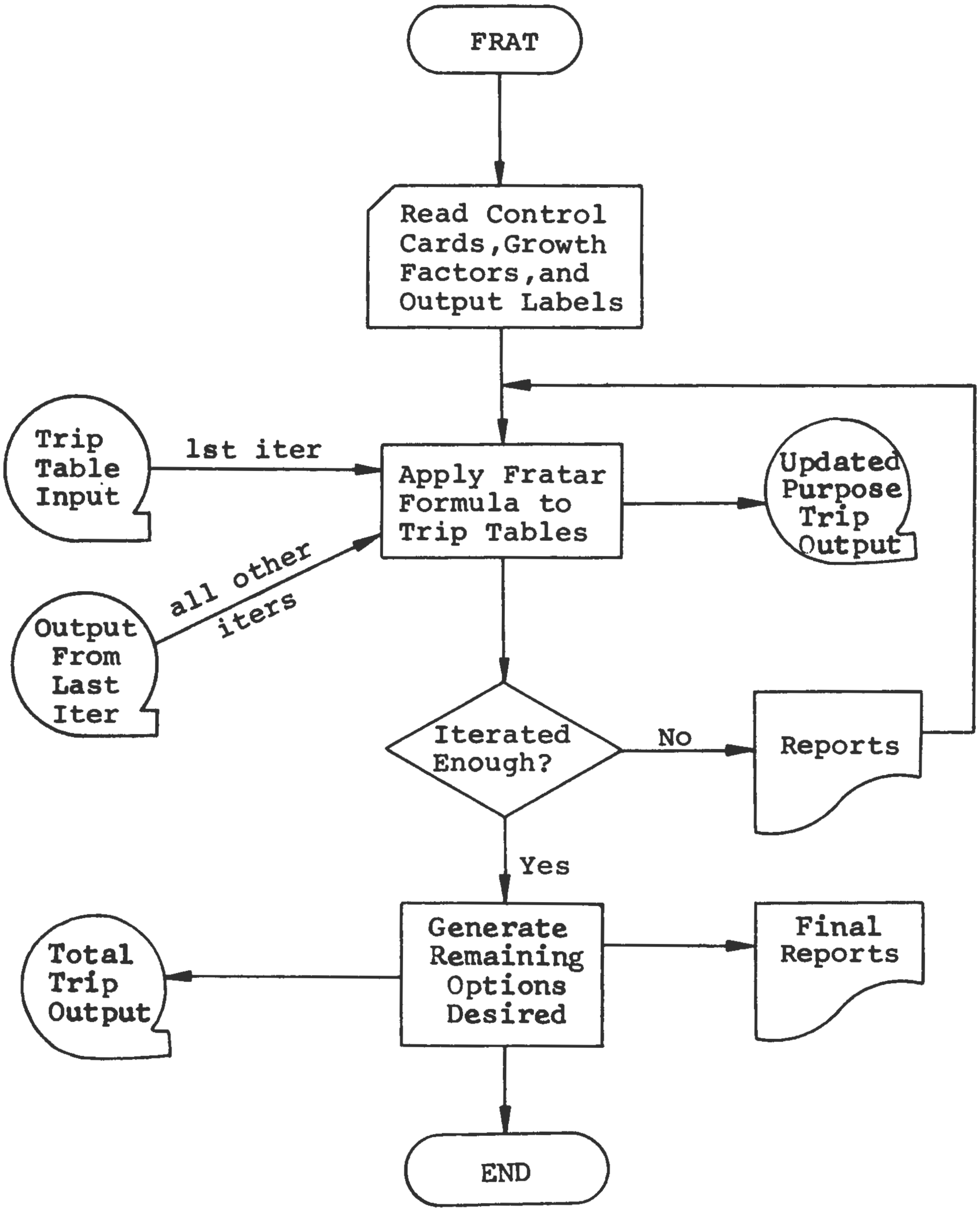


Figure IV-1
Fratar Logic-Flow

Orig \ Dest	1	2	3	Total
1	1	4	2	7
2	6	2	3	11
3	4	1	2	7
Total	11	7	7	25

Figure IV-2
Sample 3 x 3 Trip Table

Zone	1	2	3
Origin Factor	2.0	3.0	4.0
Destination Factor	3.0	4.0	2.0

Figure IV-3
Factors

Orig \ Dest	1	2	3	Total
1	x	x	x	14
2	x	x	x	33
3	x	x	x	28
Total	33	28	14	75

Figure IV-4
Desired Results

Destination Zone	1	2	3
T_j = desired column total	33	28	14
$\sum T_{ijk}$ = actual column total	11	7	7
F_{jk} = column factor	3.00	4.00	2.00

Figure IV-5
Iteration 1
Calculate F_{jk}

Orig \ Dest	1	2	3	Total
1	3.00	16.00	4.00	23.00
2	18.00	8.00	6.00	32.00
3	12.00	4.00	4.00	20.00
Total	33.00	28.00	14.00	75.00

Figure IV-6
Iteration 1
Column-Factored Table

Origin Zone	1	2	3
T_i = desired row total	14	33	28
$\sum(T_{ijk}F_{jk})$ = actual row total	23.00	32.00	20.00
F_{ik} = row factor	0.61	1.03	1.40

Figure IV-7
Iteration 1
Calculate F_{ik}

Orig \ Dest	1	2	3	Total
1	2	10	2	14
2	19	8	6	33
3	16	6	6	28
Total	37	24	14	75

Figure IV-8
Iteration 1
Output

Destination Zone	1	2	3
T_j = desired column total	33	28	14
$\sum T_{ijk}$ = actual column total	37	24	14
F_{jk} = column factor	0.89	1.17	1.00

Figure IV-9
Iteration 2
Calculate F_{jk}

Orig \ Dest	1	2	3	Total
1	1.78	11.70	2.00	15.48
2	16.90	9.36	6.00	32.26
3	14.24	7.02	6.00	27.26
Total	32.92	28.08	14.00	75.00

Figure IV-10
Iteration 2
Column-Factored Table

as in Figure IV-11 for each origin as its row is generated in the column-factored table. Finally, F_{ik} is applied to each row to adjust it to the desired number of origins, and the resultant rows are output as in Figure IV-12.

Origin Zone	1	2	3
T_i = desired row total	14	33	28
$\sum(T_{ijk}F_{jk})$ = actual row total	15.48	32.26	27.26
F_{ik} = row factor	0.90	1.02	1.03

Figure IV-11
Iteration 2
Calculate F_{ik}

Orig \ Dest	1	2	3	Total
1	2	10	2	14
2	17	10	6	33
3	15	7	6	28
Total	34	27	14	75

Figure IV-12
Iteration 2
Output

The third iteration operates upon the output of the second iteration. First, F_{jk} is calculated for each column as in Figure IV-13. A column-factored table like Figure IV-14 is then produced row by row. F_{ik} is calculated for each origin as its row is generated in the column factored table as shown in Figure IV-15. Finally, F_{ik} is applied to each row as in Figure IV-16 to adjust it to the desired number of origins, and the resultant rows are output.

Destination Zone	1	2	3
T_j = desired column total	33	28	14
$\sum T_{ijk}$ = actual column total	34	27	14
F_{jk} = column factor	0.97	1.04	1.00

Figure IV-13
Iteration 3
Calculate F_{jk}

Orig \ Dest	1	2	3	Total
1	1.94	10.40	2.00	14.34
2	16.43	10.40	6.00	32.83
3	14.55	7.28	6.00	27.83
Total	32.92	28.08	14.00	75.00

Figure IV-14
Iteration 3
Column-Factored Table

Origin Zone	1	2	3
T_i = desired row total	14	33	28
$\sum(T_{ij}F_{jk})$ = actual row total	14.34	32.83	27.83
F_{ik} = row factor	0.98	1.01	1.01

Figure IV-15
Iteration 3
Calculate F_{ik}

Orig \ Dest	1	2	3	Total
1	2	10	2	14
2	16	11	6	33
3	15	7	6	28
Total	33	28	14	75

Figure IV-16
Iteration 3
Output

The user may continue iteration until he is satisfied that the calculated destinations nearly enough approach the desired destination. In this case, further iteration would not be necessary since calculated destinations from Iteration 3 output exactly equal the desired results. Such a situation is very unlikely in practice, however.

C. THE GRAVITY MODEL

The gravity model is one of the most widely used trip distribution techniques. It does not require base year trips as input, and it is able to produce non-zero interchanges where, in the base year, there were no trips. The gravity model requires calibration, however.

1. Model Theory

The gravity model formulation is based upon the hypothesis that the trips produced at an origin and attracted to a destination are directly proportional to the total trip production at the origin, the total trip attraction at the destination, a calibrating term, and possibly a socio-economic adjustment factor. This relationship may be expressed as follows:

$$T_{ij} \propto P_i A_j F_{ij} K_{ij} \qquad (1)$$

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_{ij} = calibration term for interchange ij;

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

i = an origin zone number, i=1,2,...,n;

and

n = number of zones.

These terms will be further amplified below since they are basic to much of what follows.

From the gravity model formulation four separate parameters are required before the trip interchanges (T_{ij}) can be computed. Two of the basic parameters, the number of trips "produced" (P_i) and the number of trips "attracted" (A_j) by each traffic zone in the study area, are related to the use of the land and to the socio-economic characteristics of the people who make trips.

The gravity model distributes trips from production zone to attraction zone, while the other travel models in use distribute trips from origin zone to destination zone. To demonstrate the production and attraction definition, it is first necessary to class all trips as home based or nonhome based. Home based trips always have one end at the residence of the trip maker. Nonhome based trips have neither end at the residence of the trip maker.

Home based trips are always produced by the zone of residence of the trip maker whether the trip begins or ends in that zone. Home based trips are always attracted at the nonresidential end of the trip.

Nonhome based trips are always produced by the zone of origin and attracted by the zone of destination.

The spatial separation between zones can be measured by one of several parameters. To date, the most effective measure seems to be traveltime.

The total traveltime between zones is the sum of the minimum path driving time between zones plus the terminal times at both ends of the trip. Terminal times are added in order to allow for differences in parking and walking times in these zones, as caused by differences in congestion and parking facilities. This provides a more realistic measure of the actual spatial separation (in time) between zones as it is likely to influence automobile drivers in their decisions as to places to work, shop, etc.

The minimum path driving time between each pair of zones is obtained by the traffic assignment process. The traffic assignment process works with data showing the distance and travel speed over major routes of the transportation system. These data are used in preference to the trip times reported in the O-D home interview survey because people tend to report traveltime to the nearest 15 minutes even when asked to specify time to the nearest minute.

Terminal times on the other hand, can be obtained from data on average walking distances, which are generally available from parking surveys. They can also be estimated by personal judgment. A reasonable estimate of the terminal time is better than omitting it completely.

Intrazonal driving times, the average driving times of those trips that start and end within the same zone, must also be estimated. Terminal times are added to intrazonal driving time to arrive at intrazonal traveltime.

Traveltime factors (F_{ij}) express the effect that spatial separation exerts on trip interchange. They indicate the impedance to interzonal travel due to spatial separation between zones. In effect, these factors measure the probability of tripmaking at each one-minute increment of traveltime.

Today's traveltime factors are usually assumed to remain the same into the future. The validity of this assumption has never been definitely proven, but evidence from studies of work trip travel patterns in Baltimore for the time period between 1926, 1946, and 1958, indicates that there is some basis for making this assumption. In addition, Pyers and Bouchard have shown that the traveltime factors for Washington, D.C., remained constant from 1948 to 1955.

Whitmore, however, in his analysis of traveltime factors from many cities suggests that traveltime factors may vary over time. This research only utilized data for single points in time and this premise must be verified. Whitmore suggests that the introduction of an expressway system could have an effect on traveltime factors.

The Puget Sound Transportation Study has varied their base year traveltime factors when making forecasts. This application had certain unique aspects. For example, the level of service offered by the transportation system varied significantly from the base year to the forecast conditions. CBD speeds reflecting heavy congestion on the arterial streets in the base year plan were drastically improved with the addition of a freeway with an assumed minimum speed of 45 miles per hour. This large increase in system speeds allows trips to go much farther in a fixed time. For example, at a speed of 15 miles per hour a 10-minute trip is a 2.5-mile trip. At 45 miles per hour a 10-minute trip is a 7.5-mile trip. In such situations it may be desirable to develop travel cost factors (i.e., weight in distance on the minimum time path) rather than travel-time factors.

The remaining input to the gravity model formula reflects the effect on travel patterns of social and economic characteristics of particular zones or portions of the study area. These are represented by the zone-to-zone adjustment factor (K_{ij}). These factors reflect the effects on travel patterns of social and economic characteristics which are not otherwise accounted for in the use of the model. If found to be necessary, they must be quantitatively related to socio-economic characteristics of the particular zones to which they apply. It is necessary to relate the adjustment factors to characteristics of the zones so that they may be forecast as a function of the socio-economic conditions estimated for the future land use plan. Although the gravity model provides for these adjustments very few cities have found it necessary to use them.

Relationship (1) may be written as an equation by introducing a constant term, C, as follows:

$$T_{ij} = CP_iA_jF_{ij}K_{ij} \qquad (2)$$

A value for constant C for any origin zone i, C_i, may be established when it is specified that the sum of all T_{ij}s for origin i must be equal to P_i:

$$P_i = \sum_{j=1}^{n} T_{ij} = \sum_{j=1}^{n} \left(C_i P_i A_j F_{ij} K_{ij} \right)$$

$$= C_i P_i \sum_{j=1}^{n} \left(A_j F_{ij} K_{ij} \right), \quad i=1,2,\ldots,n$$

therefore,

$$C_i = \frac{1}{\sum_{j=1}^{n} \left(A_j F_{ij} K_{ij} \right)}, \quad i=1,2,\ldots,n$$

and (2) becomes

$$T_{ij} = \frac{P_i A_j F_{ij} K_{ij}}{\sum_{j=1}^{n} \left(A_j F_{ij} K_{ij} \right)}, \quad i=1,2,\ldots,n \quad (3)$$

which is the standard gravity model formula.

The calibrating term, F_{ij}, is generally found to be an inverse exponential function of impedance. However, it is not obligated to take that particular form. This elasticity is, perhaps, one of the major strengths of the model.

When all trip interchanges have been computed according to equation (3), production (row) totals will be correct due to the structure of equation (3), the gravity model formula. However, attraction (column) totals will not necessarily match their desired values. An iterative procedure is employed to refine calculated interchanges until actual attraction totals closely match the desired results.

After each iteration, adjusted attraction factors are calculated according to the following formula:

$$A_{jk} = \frac{A_j}{C_{j(k-1)}} A_{j(k-1)} \qquad (4)$$

where

A_{jk} = adjusted attraction factor for attraction zone (column) j, iteration k.

$A_{jk} = A_j$ when k=1;

C_{jk} = actual attraction (column) total for zone j, iteration k;

A_j = desired attraction total for attraction zone (column) j;

j = attraction zone number, j=1,2,...,n;

n = number of zones;

k = iteration number, k=1,2,...,m;

m = number of iterations.

In each iteration, the gravity model formula is applied to calculate zonal trip interchanges using the adjusted attraction factors obtained from the preceding iteration. In practice, the gravity model formula thus becomes:

$$\left[T_{ijk} = \frac{P_i A_{jk} F_{ij} K_{ij}}{\sum_{j=1}^{n} (A_{jk} F_{ij} K_{ij})}\right]_p \qquad (5)$$

where T_{ijk} is the trip interchange between i and j for iteration k and $A_{jk} = A_j$ when k=1. Subscript j goes through one complete cycle every time k changes, and i goes through one complete cycle every time j changes. Formula (5) is enclosed in brackets which are subscripted p to indicate that the complete process is completed for each trip purpose. It is equivalent to placing a subscript p on every variable in equation (5).

The calibration term, F_{ij}, is usually a function of trip time. Its usage is generalized, however, by using a table rather than a formula to obtain values for F_{ij}. The user thus supplies a table of F-factors (friction factors) for each trip purpose. Individual values are related to increments of trip time. Skim trees are supplied by the user to indicate interzonal travel times. The F-factor chosen for each interchange is thus a function of the trip time for that interchange.

It is quite evident, however, that the F-table supplied by the user for a particular trip purpose could easily represent something other than a continuous inverse exponential function. It is equally evident that the contents of the skim trees supplied by the user could reflect some other measures of impedance than time alone. This feature of the model makes it a very general technique.

The usual procedure, having chosen an appropriate measure of impedance, is to calibrate to base year data. An assumed set of F-factors is adjusted until a satisfactory approximation results. A detailed discussion of the calibration procedure will be found in Section C.3.

The adjustment term, K_{ij}, unlike the F-factor, is applied only to interchange ij. If none is supplied by the user, $K_{ij} = 1$ is assumed by the program. K-factors should be resorted to only when a few extreme socio-economic variations can be distinguished. They are usually developed and applied to the aggregate. The diagram in Figure IV-17 shows the logic-flow in the gravity model program.

2. Gravity Model Example

As an example of how the gravity model functions, the table in Figure IV-18 contains forecast productions for a small three zone system. Assume also the F-factors shown in Figure IV-19, a specially constructed table which does not represent a base year calibration. These F-factors are

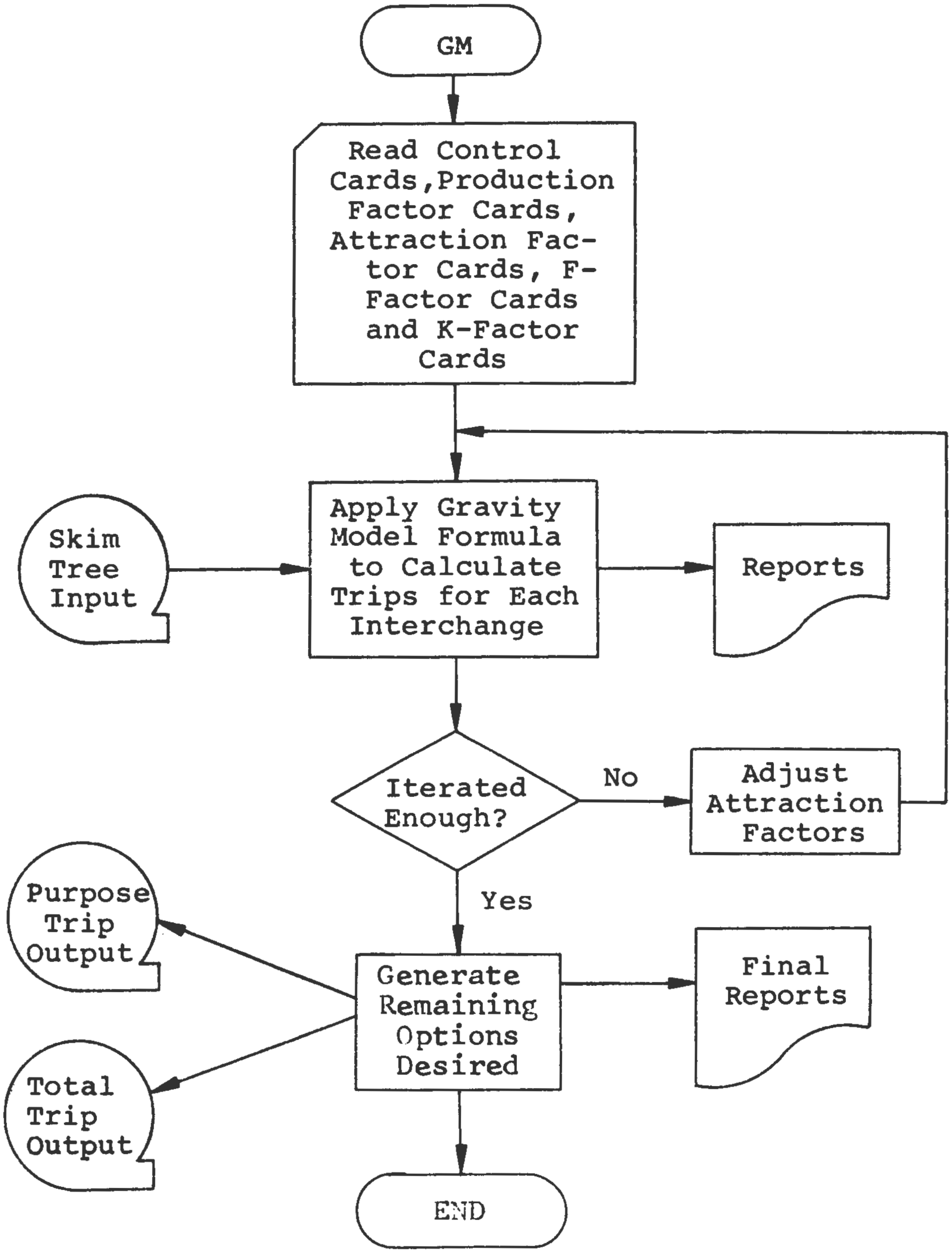


Figure IV-17
Gravity Model Logic-Flow

Zone	1	2	3
Production	14	33	28
Attraction	33	28	14

Figure IV-18
Forecast
Productions and Attractions

Impedance Units	F-Factor
1	82
2	52
3	50
4	41
5	39
6	26
7	20
8	13

Figure IV-19
F-Factors

Zone	1	2	3
1	8	1	4
2	3	6	5
3	2	7	4

Figure IV-20
Skim Trees

to be used according to values in the artificial skim trees shown in Figure IV-20.

Using values from the above figures, the first iteration of the gravity model will produce the results as shown in Figure IV-21. Adjusted attraction totals for Iteration 2 are calculated according to equation (4). The table in Figure IV-22 contains the values used in these calculations.

Att / pro	1	2	3	Total
1	2	10	2	14
2	19	8	6	33
3	17	5	6	28
Total	38	23	14	75

Figure IV-21

Iteration 1

Output

Zone	1	2	3
A_j, Desired Attraction Total	33	28	14
C_{jk}, Actual Attraction Total	38	23	14
A_{jk}, Adjusted Attraction Factor, this Iteration	33	28	14
$A_{j(k+1)}$, Adjusted Attraction Factor next Iteration	28	33	14

Figure IV-22
Iteration 1
Calculate Adjusted Attractions

The gravity model formula is applied again using the adjusted attractions calculated above (Figure IV-22). The second iteration of the gravity model produces the results shown in Figure IV-23

Pro \ Att	1	2	3	Total
1	2	10	2	14
2	17	10	6	33
3	15	7	6	28
Total	34	27	14	75

Figure IV-23
Iteration 2
Output

Adjusted attraction totals for Iteration 3 are calculated according to equation (4). Figure IV-24contains the values used in these calculations.

The gravity model formula is again applied using the adjusted attractions calculated above. The third iteration of the gravity model produces the results shown in Figure IV-25.

Zone	1	2	3
A_j, Desired Attraction Total	33	28	14
C_{jk}, Actual Attraction Total	34	27	14
A_{jk}, Adjusted Attraction Factor This Iteration	28	33	14
$A_{j(k+1)}$, Adjusted Attraction Factor Next Iteration	27	34	14

Figure IV-24
Iteration 2
Calculate Adjusted Attractions

Pro \ Att	1	2	3	Total
1	1	11	2	14
2	17	10	6	33
3	15	7	6	28
Total	33	28	14	75

Figure IV-25
Iteration 3
Output

Since the actual attractions from Iteration 3 exactly equal the desired totals, further iteration is pointless and will not affect the result. When real data are used, however, a perfect match for all zones is seldom or never achieved. The program supplies the user with statistical measures of the quality of the current results to help him determine when to end iteration.

3. Gravity Model Calibration

The advent of the gravity model added a new dimension to the problem of trip distribution. It became necessary to calibrate the model as well as to forecast zonal trip growth.

The problem of calibration has been approached from several points of view. The most satisfactory solution involves the repeated application of the model to base year data. This technique is the one used in GMCAL, the gravity model calibration program.

The program represents a substantial improvement in the trip distribution process. Until recently, most gravity model calibration was performed very laboriously by a combination of hand and computer techniques. GMCAL assumes the hand portion of the calibration, thereby rendering the process completely automatic. Moreover, the computation methods employed parallel those hand techniques found, through experience, to be satisfactory.

Gravity model calibration depends upon the repeated adjustment of a set of friction factors. Adjustment is continued until friction factors are obtained which result in a near-enough approximation of base year data when the gravity model is applied to base year productions and attractions. The decision as to when the approximation is near enough is left to the user who is supplied with several statistical tests as aids.

The friction factor adjustment technique mentioned above may be represented mathematically as follows:

$$F'_{rk} = F_{r(k-1)} \frac{T_r}{\sum_r T_{ij(k-1)}} \qquad (1)$$

and then

If $F'_{rk(min)} \geq 1$ $\qquad F_{rk} = \left(F'_{rk} \right)$ integer

$$F_{rk} = \left(\frac{F'_{rk}}{F'_{rk(min)}} \right) \text{integer} \qquad \text{If } F'_{rk(min)} < 1 \tag{2}$$

where

F_{rk} = the friction factor associated with interchange group r in calibration k of the calibration program. F_{rk} = supplied or assumed starting value when k=1.

T_r = the desired given total trips for interchange group r.

T_{ijk} = the total trips derived for interchange group r, calibration k of the calibration program, by means of the gravity model formula using F_{rk}.

$F'_{rk(min)}$ = the smallest value generated in equation (1).

r = a set of zonal interchanges, which, by virtue of having a similar impedance, all have the same F-factor(F_{rk}) applied to them, r=1,2,...,f.

f = the number of sets of zonal interchanges for which friction factors are to be derived. Each and every interchange must be included in one and only one such set. There are a total of n^2 interchanges.

k = the calibration number, k=1,2,...,m.

m = the number of calibrations.

i = a production zone number, i=1,2,...,n.

j = an attraction zone number, j=1,2,...,n.

n = the number of zones.

The right hand side of equation (2) is enclosed in brackets and subscripted "integer" to indicate that F_{rk}, r=1,...,f, is a set of integer values. It is evident that $F_{rk(min)}$ will be equal to or greater than one (1). Since F-factors are relative only to each other, this conversion to a set of integer values is a usual step in the calibration process.

A further complication is introduced by the traditional insistence that the values F_{rk}, r=1,...,f, should represent the ordinates of a smooth curve. In the gravity model calibration program, this is accomplished by fitting the values derived from equation (2) to the following function by means of the least-squares technique:

$$F_{rk} = aI_r^b e^{-cI_r}, \quad r=1,2,\ldots,f \qquad (3)$$

where

a, b and c = constants peculiar to this particular set of F_{rk}, r=1,2,...,f. These constants are derived using the values obtained from equation (1) by means of the least-squares technique.

I_r = the trip length (value of impedance) associated with the set of zonal interchanges r.

e = the base of natural logarithms, the constant value 2.71828... .

It is the smoothed values of F_{rk}, r=1,...,f, derived from formula (3) which are used by the calibration program in Calibrating k and which are then employed in equation (1) to calculate friction factor values for the next calibration which in turn are smoothed, etc.

The function represented in relationship (3) is ideally suited to the purpose. As may be seen in Figure IV-26, it is very flexible and may represent a great variety of exponential shapes. In particular, its shape when $b \leq 0$ is that usually associated with a friction factor function. The diagram in Figure IV-27 shows the logic-flow of the gravity model calibration program.

As an example of how gravity model calibration works, assume that the table in Figure IV-28 contains base year productions and attractions for a small three zone system. Also, assume that the material in Figure IV-29 represents

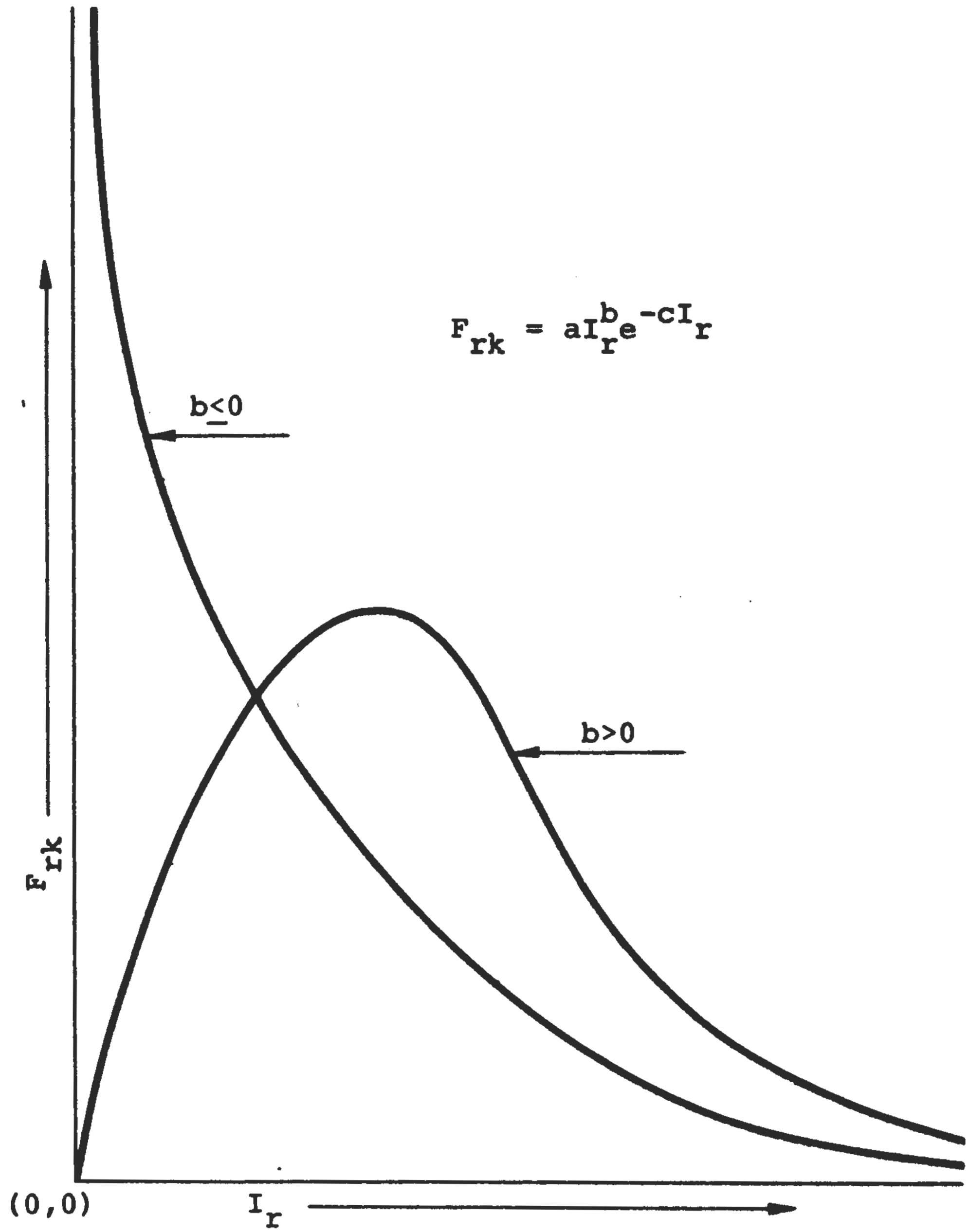


Figure IV-26
Shapes Assumed by the F-Factor
Smoothing Function

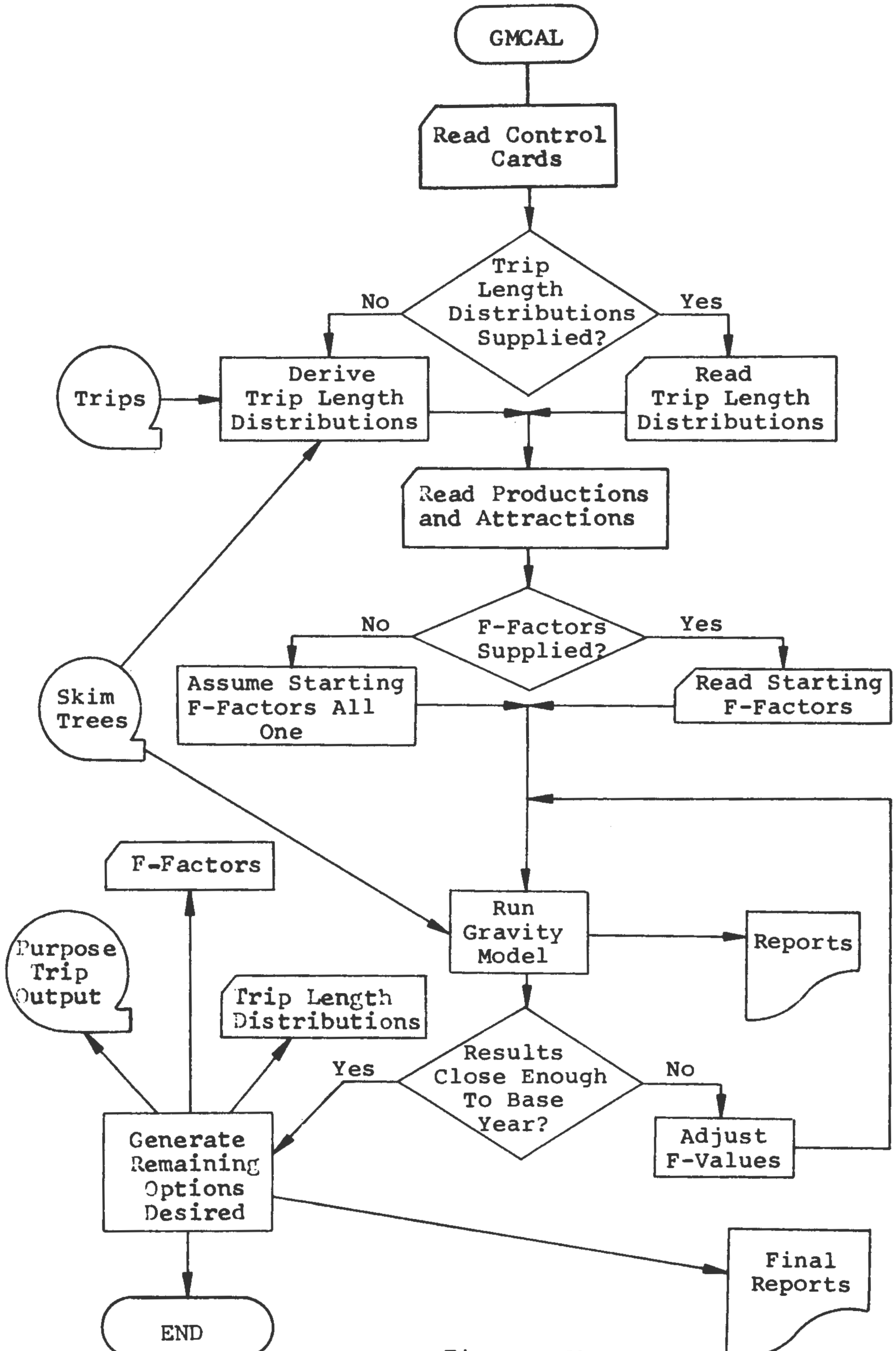


Figure IV-27
GMCAL Logic-Flow

Zone	1	2	3
Production	7	11	7
Attraction	11	7	7

Figure IV-28
Base Year Productions and Attractions

Zone	1	2	3
1	8	1	4
2	3	6	5
3	2	7	4

Figure IV-29
Impedance Matrix

an impedance matrix (skim trees) for the same system and that Figure IV-30 contains a trip impedance (i.e., trip length) distribution obtained by combining base year trips with the impedance matrix.

In this example, the option will be exercised which causes the calibration routine to assume a starting value of one (1) for all F-factors. The gravity model formula is applied to each interchange using these starting F-factors, as well as the productions and attractions in Figure IV-28 and the impedances in Figure IV-29. The trip table in Figure IV-31 will result from this procedure.

In order to compare the trip table in Figure IV-31 with the given distribution in Figure IV-30 the generated trips are summarized in a similar trip impedance distribution. This derived distribution may be found in Column

Impedance Units	Trips
1	4
2	4
3	6
4	4
5	3
6	2
7	1
8	1
Total	25

Figure IV-30
Trip Impedance Distribution

Orig \ Dest	1	2	3	Total
1	3	2	2	7
2	5	3	3	11
3	2	3	2	7
Total	10	8	7	25

Figure IV-31
Calibration 1
Gravity Model Trips

D of Figure IV-32. Adjusted F-factors for each value of impedance, found in Column E of Figure IV-32, are calculated by factoring the assumed F-factors, found in Column C, by the ratio of given trips to calculated trips, Columns B and D respectively, and adjusting to obtain integer values.

A Impedance Units	B Given Trips	C Last F-Factors	D Calc. Trips	E Adjusted F-Factors	F Smoothed F-Factors
1	4	1	2	6	7
2	4	1	2	6	5
3	6	1	5	4	4
4	4	1	4	3	3
5	3	1	3	3	2
6	2	1	3	2	2
7	1	1	3	1	1
8	1	1	3	1	1
Total	25	-	25	-	-

Figure IV-32
Calibration 1
Calculate Adjusted F-Factors

The adjusted F-factors in Column E are then smoothed and the results tabulated in Column F of Figure IV-32. In this example, smoothing is done by hand for the sake of simplicity. The calibration program itself employs equation (3). The adjusted F-factor values and the smoothing curve drawn through them are graphically represented in Figure IV-33.

In the second calibration the gravity model formula is again applied to each interchange. The smoothed F-factors from Column F of Figure IV-32 are used, along with the productions and attractions in Figure IV-28. The result is the trip table shown in Figure IV-34.

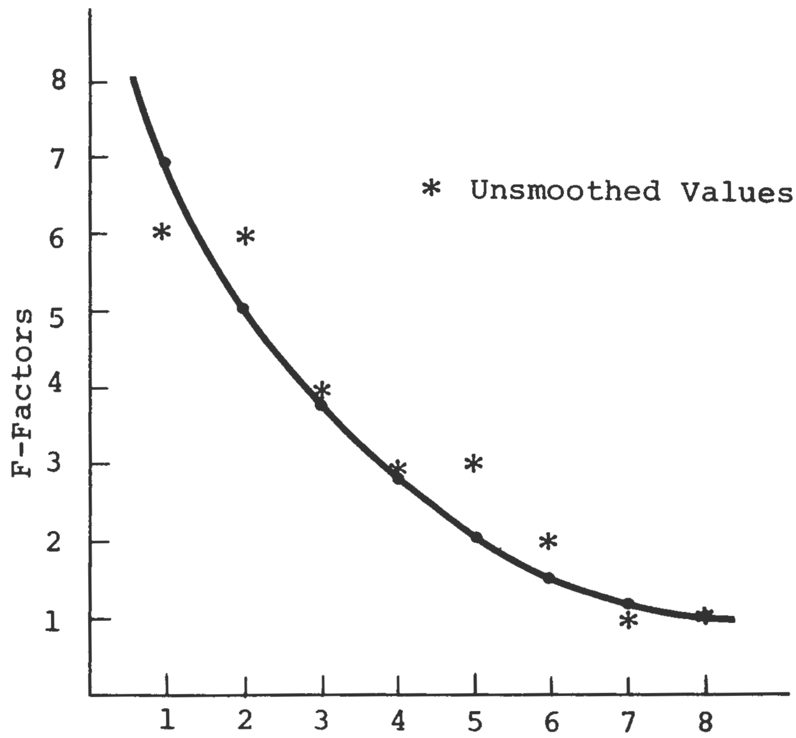


Figure IV-33
Calibration 1
Smoothed Adjusted F-Factors

Zone	1	2	3	Total
1	1	4	2	7
2	7	2	2	11
3	5	0	2	7
Total	13	6	6	25

Figure IV-34
Calibration 2
Gravity Model Trips

The generated trips in Figure IV-34 are again summarized into an impedance (trip length) distribution as found in Column D of Figure IV-35. Adjusted F-factors in Column E are again calculated as for Calibration 1.

A Impedance Units	B Given Trips	C Last F-Factors	D Calc. Trips	E Adjusted F-Factors	F Smoothed F-Factors
1	4	7	4	7	7
2	4	5	5	4	5
3	6	4	7	3	4
4	4	3	4	3	3
5	3	2	2	3	2
6	2	2	2	2	2
7	1	1	0	1	1
8	1	1	1	1	1
Total	25	-	25	-	-

Figure IV-35
Calibration 2
Calculate Adjusted F-Factors

Figure IV-36 shows the curve which is used to smooth the adjusted F-factors for Calibration 2. Calibration is terminated at this point since the ordinates of the smoothed friction factor curve for Calibration 2 are the same as those from Calibration 1. Continued calibration would result in no improvement.

When a set of friction factors is obtained which causes the derived trip length (trip impedance) distribution to approximate the given distribution nearly enough, the gravity model is said to be calibrated for that trip purpose. The calibration program, like the gravity model program, is able to handle several trip purposes at once.

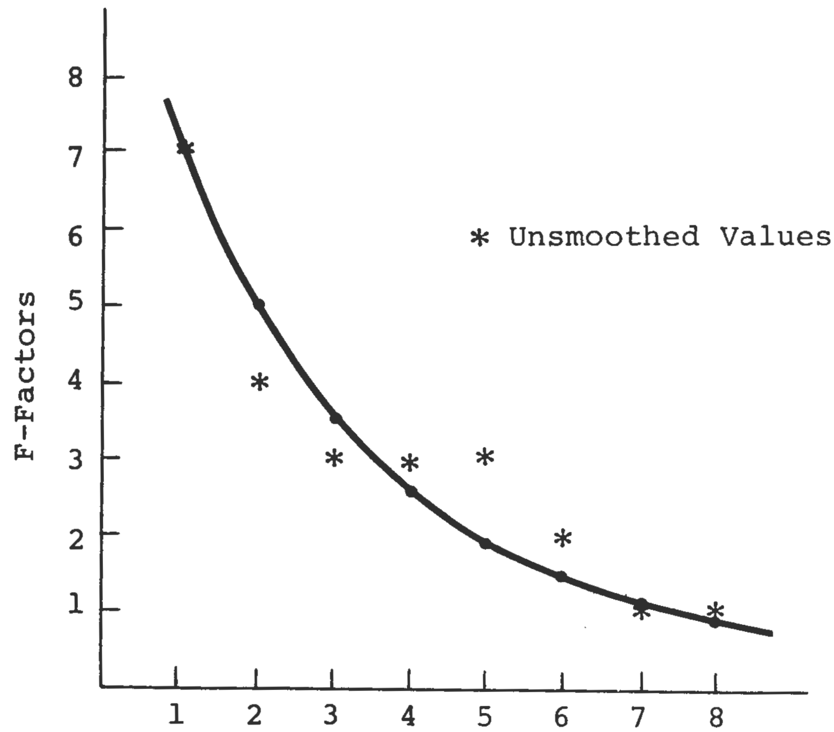


Figure IV-36
Calibration 2
Smoothed Adjusted F-Factors

The user is supplied with the means to specify when the calibration process has continued long enough, based on statistical comparisons of given and derived trip length distributions.

4. Gravity Model Application

a. Initial decisions to be made--Once a transportation study has decided on the basic type of trip distribution model to be used, in this case the gravity model, there remain a great many choices as to the manner in which this model is to be utilized to provide reasonable estimates of travel patterns.

Perhaps the first question is whether the model should distribute vehicle trips or total person trips. The answer is directly related to both the objectives and needs of the study and to the size of the area involved. The type of modal split analysis is usually the prime determinant. In most studies a vehicle trip model is utilized. The modal split is determined at the trip generation phase of the analysis and the auto driver and transit passenger trips are distributed separately via each mode.

In other studies, where a more extensive modal split analysis is being made, total person trip distributions are necessary. The modal split is then made separately for each zone-to-zone person trip movement.

A decision must also be made as to how many and what trip purpose categories will be used in the study. Gravity model trip distribution formulas have been developed using as few as one trip purpose and as many as nine or more. There is no clear agreement on this point and it is at least partially a function of the scope and objectives of the study, as well as the size of the urban area involved. As a general rule, it is desirable to take into consideration the number of trips in each category, and the trip length characteristics for each of the trip purpose categories and the ability to forecast the categories separately. The amount of data preparation time, computer time, and analysis time must also be considered.

Several studies in large urban areas have used the following trip purpose categories in their gravity model with satisfactory results:

(1) Home based work.--those trips between a person's place of residence and his place of employment for the purpose of work.

(2) <u>Home based shop</u>.--those trips between a person's place of residence and a commercial establishment for the purpose of shopping.

(3) <u>Home based social-recreation</u>.--those trips between a person's place of residence and places of cultural, social, and recreational purposes.

(4) <u>Home based school</u>.--those trips by students between the place of residence and school for the purpose of attending classes.

(5) <u>Home based miscellaneous</u>.--all other trips between a person's place of residence and some form of land use for any other trip purpose.

(6) <u>Nonhome based</u>.--any trip which has neither origin nor destination at home regardless of its purpose.

(7) <u>Truck trips</u>

(8) <u>Taxi trips</u>

In some large areas where these eight purposes have been used, it has been observed that the results could have been improved with further stratification without causing additional difficulty in forecasting. For example, in a study of travel patterns in Washington, D.C., it was observed that the gravity model results could probably have been improved if work trips had been further stratified to distinguish between government and nongovernment workers. Some studies also reported the need for further stratification of shopping trips to distinguish between convenience shopping trips (trips to grocery stores, etc.) and other shopping trips.

Most of the recent gravity model studies in small urban areas have been using three trip purpose categories, home based work, home based nonwork and nonhome based trips. Home based work trips are those defined previously in category "1." Other home based trips are those defined in categories "2" through "5" above. A study of travel patterns in Sioux Falls, South Dakota showed that the differences in the accuracy obtained when using eight trip purposes, as compared with three purposes are insignificant in small areas.

Consequently, it appears that in large urban areas an eight purpose model is desirable but in small urban areas (less than 100,000 population), a three purpose model may be sufficient.

The treatment accorded to external trips, that is, trips with one or both ends outside the cordon line, presents the transportation planner with a choice. In some studies, the external cordon stations have been considered as fictitious zones and have been assumed to produce and attract trips in a manner similar to the internal zones. Generally, it is undesirable to do this for the following reasons:

Trips made by those persons living inside the cordon may exhibit different trip length characteristics than those made by persons who live outside the area.

External-to-external trips are associated with the study area in question for only a small portion of their total journey and, therefore, exhibit distribution characteristics which have nothing at all to do with the study area.

Consequently, it is generally desirable to treat the total universe of trips as three distinct types:

Internal trips, those with both ends of trip within the cordon area.

External trips, those with one end inside the cordon and one external end.

Through trips, those with both ends outside the cordon.

For the first group of trips the gravity model can be used directly. For the second group of trips the gravity model can also be used. However, since the trip length characteristics of these trips are generally different from those in the first group, a separate gravity model analysis should be made. The external trips are normally considered as being produced at the external stations and attracted at the internal zones. For the third group of trips (through trips) a growth factor technique such as the Fratar procedure is recommended.

b. Determining traveltimes.--Spatial separation between zones appears to be more realistically approximated by traveltimes than by driving times. The zone-to-zone traveltime is the sum of the over-the-road driving time between zones and the terminal times within the origin and destination zones. Consequently, it is necessary to develop a measure of terminal time for each zone in the study area to be combined with the information on driving time in determining spatial separation between zones.

Terminal times may result from the following conditions:

(1) The time spent in looking for a parking place at the nonhome end of a trip.

(2) The time spent in walking from a parking place to the actual destination of a trip, be it an office, store, recreation facility, or home.

(3) The time spent in walking from a trip origin, be it the home, an office or other such origin, to the parking place.

(4) The time spent in getting from the parking place to the street system at the origin end of the trip.

There are no absolute rules for estimating terminal times. Several methods have been employed in various transportation studies, including (1) the subjective allocation of a terminal time to each zone based on a knowledge of the study area or upon data derived from studies such as a parking survey, (2) relating the values of terminal time to the distance from the CBD, (3) the use of an index that is a relative measure of congestion conditions in a zone.

One recent study employed a so-called subjective method in allocating terminal times to each zone for a small urban area. From the results of a central business district parking survey, it was observed that in the downtown area, an average of two minutes was spent in walking from parking space to the store or office of ultimate destination. Furthermore, it was estimated that an average of three minutes was spent in cruising for a parking space. Consequently, for all zones in the central business district, a terminal time of five minutes was used; for residential zones a terminal time of one minute was used; for zones with moderate amounts of commercial activity, intermediate values of terminal time were used.

It is next necessary to incorporate the calculated terminal times into the trees to change the driving time to traveltime. This is accomplished by using the update trees program (UPTREE). This program adds the terminal time for the respective zones to the skim trees, thereby producing a series of records containing the traveltimes between each pair of zone centroids.

Another method that has been utilized to incorporate the terminal times into the analysis is to modify the coded highway network. Using this procedure terminal times are added to "dummy" links which connect the centroid to the highway network.

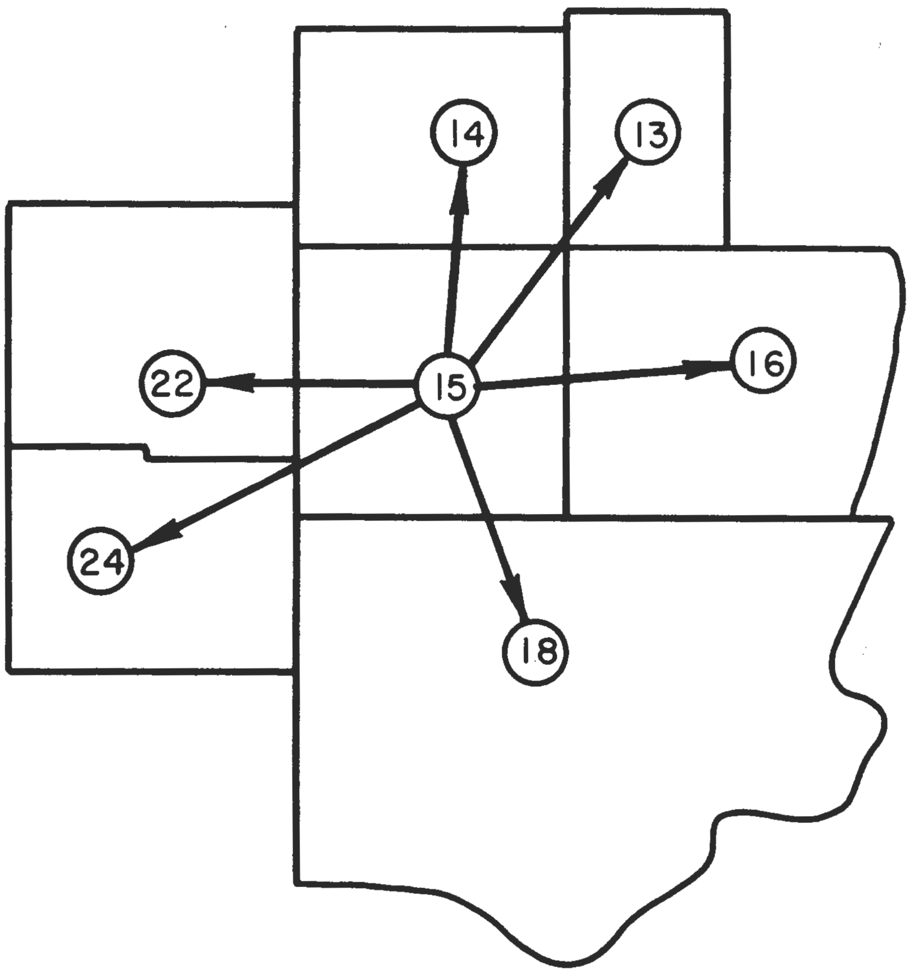
The procedures do not yield any measure of time for trips that do not leave a particular zone. This time is called intrazonal driving time and must be derived separately. One method of arriving at an estimate of intrazonel driving time is to analyze the driving times to adjacent zones. Figure IV-37 illustrates this procedure. The average of the driving times from the centroid of zone 15 to the adjoining zone centroids is 3.6 minutes.

The intrazonal driving time is taken as one-half of this average driving time, or 1.8 minutes. The rounded values would then be incorporated into the skim trees by using program (UPTREE).

c. Zone-to-zone movements.--A key step in the analysis of the basic trip data is the determination of zone-to-zone movements for each of the several trip purposes. The trip table builder and related programs perform this function through the following five operations:

(1) Convert survey zone numbers to zone centroid numbers (TRPCODE).

(2) Determination of the zone of production and the zone of attraction for each trip record (TRPCODE or TRPTAB).



CENTROIDS	TREE TIME (MINUTES)
15 → 13	4
15 → 14	2
15 → 16	4
15 → 18	3
15 → 22	4
15 → 24	5
	22

$$\frac{22}{6} = 3.63 \text{ MINUTES}$$

$$\frac{3.63}{2} = 1.8 \text{ MINUTES}$$

(USE 2 MINUTES)

Figure IV-37 --Determination of intrazonal driving time.

(3) Classification of each trip record into one of several trip purposes (TRPTAB).

(4) Determination of the number of trips between each zone of production and every zone of attraction for the several trip purposes (TRPTAB).

(5) Accumulation of the number of trips produced and attracted by each zone in the study area for each trip purpose (TRPTAB).

The first two operations process and identify data for further analysis in the remaining operations. The second two operations provide the necessary information for many of the subsequent analyses in the gravity model calibration and testing process. The trip interchanges, for example, will eventually be combined with the minimum path travel times to obtain a one-minute frequency distribution of trip occurrence for each trip category.

d. Selecting initial traveltime factors.--At the present time, a specific mathematical equation or function which can adequately express the effect of spatial separation on zonal trip interchange is not available. Consequently, it is necessary to go through a trial and adjustment (calibration) procedure, to fit the model to a particular urban travel situation. The traveltime factors developed in this manner are an empirical measure of the relationship of spatial separation and travel. This adjustment is performed automatically by program GMCAL as previously described.

The initial set of traveltime factors for each trip purpose can be determined in at least two ways. First, one can assume that each traveltime factor has a value of one, or, in other words, that the traveltime has no effect on trip interchange. It is known that this is not the case, but this method allows you to initiate the calibration procedures. The second and most expedient method of beginning the calibration process is to use a set of traveltime factors taken from a city of comparable size and use these to calculate a gravity model distribution of trip interchanges.

e. <u>Topographical Barriers</u>.--Many of the gravity model studies conducted to date have shown that topographical barriers, such as mountains, rivers, and large open spaces, may cause some bias in the gravity model trip interchange estimates. For example, a study in Washington, D.C., indicated that the Potomac River had some influence on trip distribution patterns. A study in New Orleans, Louisiana, indicated similar findings. A study in Hartford, Connecticut, indicated that the toll bridges crossing the Connecticut River also affected travel patterns.

The nature of the influence of such topographical barriers is not known. All of the above-mentioned studies have analyzed the apparent reasons why these barriers have influenced travel patterns in their own unique situation. In Washington, D.C., it was attributed to the fact that off-peak hour traveltimes did not correctly indicate the amount of congestion which was present on bridges crossing the Potomac River. An analysis of congestion patterns in the region showed that there was greater congestion in the area of the Potomac River than elsewhere in the region. From this analysis, it was reasoned that a more realistic measure of the traveltime on these bridges was required. In the Hartford study, it was attributed to the fact that tolls are collected on several bridges crossing the Connecticut River. Since travel costs can also influence travel patterns, it was concluded that this cost barrier should be reflected by increased traveltimes on those bridges where tolls were collected. In New Orleans the Mississippi River separates portions of the study area. It was concluded that traveltimes on these bridges should be increased to allow for the effect of the long traveltimes necessary in crossing the river by ferry boat.

In each of the above cases, the effects of topographical barriers were accounted for in the gravity model by inserting time penalties on portions of the transportation network. The need for these penalties is a result of the present lack of knowledge of a precise measure of spatial separation between zones.

The examination of the traveltime patterns for bias caused by topography involves an analysis of the differences between the estimated and the surveyed trips crossing the various topographical barriers in the study area. Essentially, it is a screenline analysis. The trip interchanges developed from the travel pattern survey are compared directly with those of the final gravity model calibration.

It is important to point out that when time penalties are imposed on portions of the transportation network, these penalties must be brought to bear on the trip length frequency distribution of the survey trips. This can be done by updating the network description and rebuilding the trees. The trip interchanges for each trip purpose are then rerun through the trip length frequency program.

The revised trip length frequency distributions are then used as a base against which any subsequent gravity model estimates are compared.

f. Developing zone-to-zone adjustment factors.--There may be factors, other than those related to travel-time, which could affect patterns of urban travel. Travel patterns may also be influenced by various social and economic conditions. The effect of these factors can be accounted for in the gravity model formula by the use of zone-to-zone adjustment factors (K_{ij}).

Due to the limited research on this particular point, the underlying reasons behind the need for K_{ij} factors are not well understood. However, several studies have indicated that the following may influence our ability to identify the real causes for the need to incorporate zone-to-zone adjustment factors into the gravity model formula.

1. The trip purpose stratifications used today may not be precise enough to account for all of the basic differences in travel patterns. For example, it is possible that all the work trips produced by a particular zone are those trips made by industrial workers. When distributing these trips by the gravity model, or any other traffic model for that matter, the largest proportion of these trips would be sent to the closest zones with large employment centers, regardless of the type of employment which is

available. This means that many of these industrial workers may be sent to large offices and commercial establishments, mainly because of their proximity to the residences of these workers. However, such a stratification may create problems in forecasting trips, since it would be more difficult to forecast the place of residence and the employment opportunities for blue collar and white collar workers than it would be for all workers.

2. It is customary to develop a set of traveltime factors for each trip purpose category. Since trips between all zones are used in developing these factors, they represent the average areawide effect of traveltime on trip interchange. However, there is some evidence which tends to show that traveltime factors vary by zone depending on the characteristics of the people who live in each zone. These factors may also depend upon the distribution of land uses immediately adjacent to these zones.

3. There is some evidence that factors such as income and residential density may influence the need for zone-to-zone adjustment. It is not yet clear whether these two factors may actually be a reflection of items 1 and 2 or whether they are independent factors in themselves. In Washington, D.C., for example, it was observed that low income families were not as likely to work in the central business district as were higher income families. This observation was made by direct comparison of zonal interchanges estimated by the gravity model formula and those from the origin-destination survey. However, since average areawide traveltime factors and only a six-purpose trip stratification were used, this conclusion may be somewhat weak.

Regardless of the reason for zone-to-zone adjustment factors, the need may exist for incorporating them into the gravity model formula. In some cases these adjustments (K_{ij}) may be significant and in others they may not be necessary at all. Generally, in the large urban areas where there are many types of employment, shopping, and recreation, these adjustments may be necessary. However, in the smaller urban areas, the need for K_{ij} factors is small and in most cases the factors are not necessary at all.

Even with many limitations on the understanding of the K_{ij} factor, tests to determine the extent of required adjustments and procedures for incorporating them into the model have been devised and used in several studies. The procedures require an analysis of the differences between the trip interchanges calculated in the final calibration of the gravity model and those measured in the O-D survey. This analysis is performed on data for the trip purposes where problems are suspected using procedures described below.

Limited experience has shown that it is the large traffic generators for which the gravity model trip interchanges must be adjusted. Trips between all zones and the central business district of an urban area, for example, may require adjustment. Occasionally, trips between one city of an urban complex and another city within the same complex must be adjusted. The procedure used in developing adjustment factors is to compare the trip interchanges between large traffic generators as estimated by the gravity model with those developed from the origin-destination survey. These comparisons are usually done graphically.

The first step is to combine the trip purpose categories into major groups. For example, if trips between all zones and the central business district were to be examined, it would be desirable to look at home based work trips and home based shopping trips separately, while the remainder of the trips may be combined into one major group. Work trips and shopping trips should be analyzed separately because of the importance of the central business district as a generator of these two types of trips. All remaining trip purpose categories could then be combined by using the general purpose program. This combining is done for both the gravity model interchanges and those from the origin-destination survey.

The specific movements to be examined in the "K" factor analysis may be isolated through the use of the interzonal volumes summary program.

Figure IV-38 illustrates this analysis for the central business district trips.

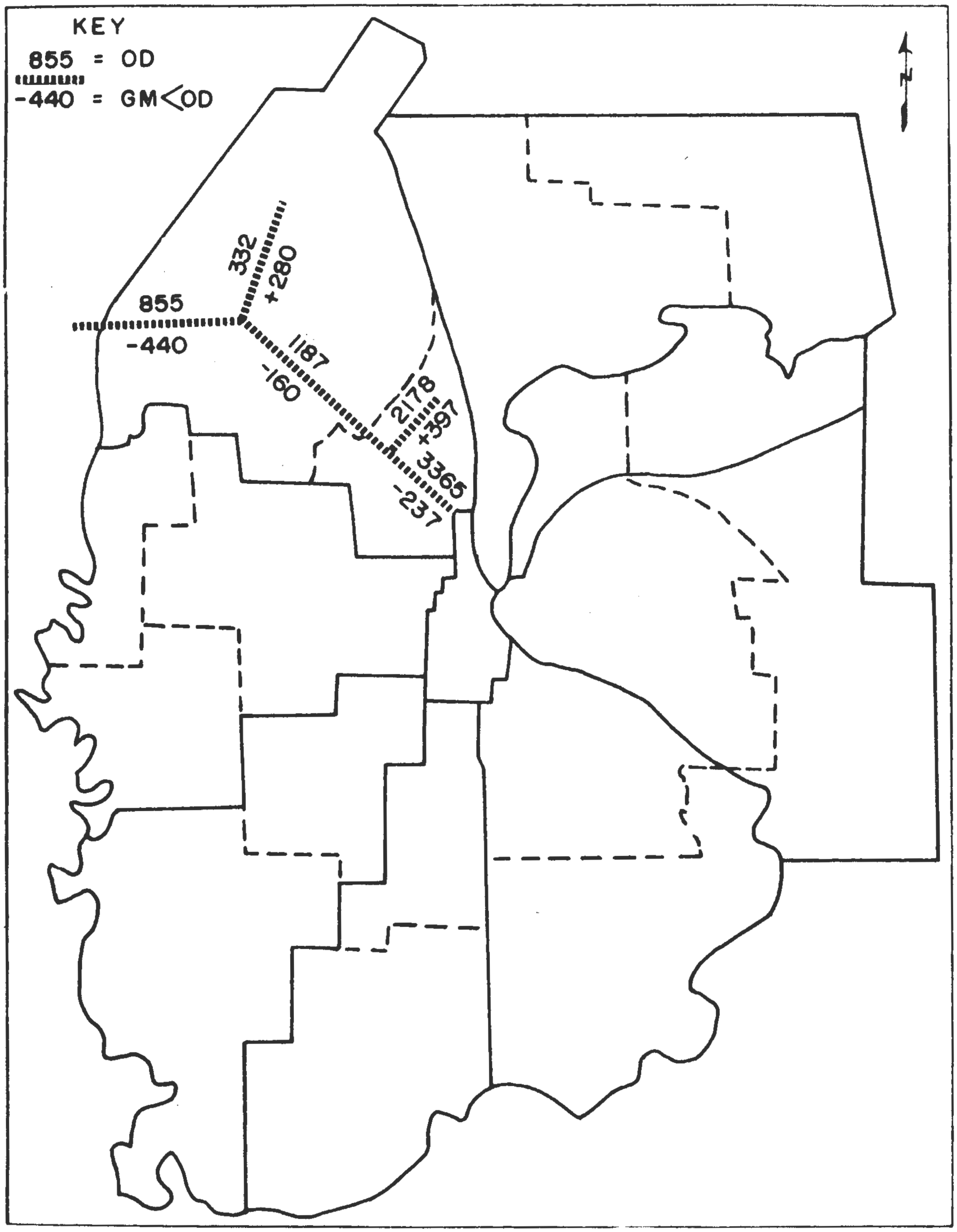


Fig. IV-38--Graphical analysis to determine the need for zone-to-zone adjustment.

A district map is used in this examination, one for each major trip purpose category examined. Sector lines are drawn to denote major traffic drainage corridors. One fictitious radial transportation route is assumed to be centered in each of these sectors. The movements between each district and the central business district are then manually "assigned" to the fictitious facility within the sector in which the district is located. These volumes are then accumulated as the fictitious route approaches the central business district. Generally, three values are shown for each corridor--the total origin-destination survey movements, the total gravity model movements, and the difference between the two. Using this procedure, any systematic errors which reflect the need for zone-to-zone adjustment factors can be easily located.

The same procedure could be repeated for any desired traffic movement. Once the analyses are completed, the need for adjustments must be determined. Generally the amount of adjustment would be dependent on the ratio of the origin-destination survey results to the gravity model results for a particular movement. But, it is also dependent to a more limited extent on the proportion of trips produced in any zone which are to be adjusted. A study in Washington, D.C., concluded that the following formula expressed the relationship between the adjustment factor required for any zonal movement and these two factors:

$$K_{ij} = R_{ij} \frac{1 - X_i}{1 - X_i R_{ij}}$$

where: K_{ij} = adjustment factor to be applied to movements between zone i and zone j (or district i and district j)

R_{ij} = ratio of origin-destination survey results to the gravity model results for the movement between zone i and zone j

X_i = ratio of OD trips from zone i to zone j to total OD trips leaving zone i

This formula modifies the initial adjustment factor (R_{ij}) to account for the fact that the final factor (K_{ij}) appears in both the numerator and the denominator of the gravity model equation, and thus its effect in the numerator is buffered. This buffering is critical if from 10-40 percent of the trips out of a zone have factors applied all in the same direction (i.e., all positive or all fractional). In this situation it is necessary to apply this formula to maintain the proper adjustments.

If over 40 or under 10 percent of the trips leaving a zone are to be adjusted, R_{ij} should be used as the K_{ij} factor.

The distribution utilizing the adjustment factor should be checked to determine if the proper adjustment has been attained. In some instances it may be necessary to modify certain of the initial K_{ij} factors and to calculate a new trip distribution in order to attain the desired accuracy.

The following example will illustrate the use of this formula. It has been determined that work trips between all districts and the central business district must be adjusted. District 100 produces 5,000 total work trips daily. The origin-destination survey reported that 1,000 of these trips went to the central business district. The gravity model, however, estimated that only 500 of these trips went to the central business district. The adjustment factor to correct the gravity model results for this condition would be calculated as follows:

$$K_{100\text{-}CBD} = \frac{1{,}000}{500} \left[\frac{1 - \frac{1{,}000}{5{,}000}}{1 - \frac{1{,}000}{5{,}000}\,\frac{1{,}000}{500}} \right] = 2.67$$

This factor would then be inserted into the gravity model formula with other calculated adjustment factors and a revised trip distribution pattern obtained.

The trip length frequency of this revised trip distribution pattern must be checked against the origin-destination survey distribution to verify its correctness.

5. Testing the Gravity Model. The gravity model program produces a synthetic trip distribution pattern which is an approximation of existing conditions. It must be realized that variations between the existing and the estimated conditions are inherent in any approximation process. Tests can be made to determine the accuracy of the procedure used in forecasting future travel patterns. Several types of tests are available to aid the transportation analyst in evaluating the procedure.

The statistical tests are generally applied only to a calibrated gravity model. The total trips from the calibrated gravity model are compared to the origin-destination survey trip interchanges after both are assigned to the same spider network. Urban areas with a population less than 100,000 may find it feasible to assign their trips to the actual network rather than to a spider network. The trip comparison program is used in making the comparisons.

This comparison program (COMPARE) accepts as input two historical records, one containing the surveyed information and the other the corresponding gravity model estimates.

The program produces a table as illustrated in Figure IV-39.

Figure IV-40 shows the frequency of occurrence of various differences between the gravity model and the origin-destination survey movements within the 8000-9999 volume group. It also shows the sum of these differences, the sum of their squares, the mean difference, the standard deviation, the root-mean-square error, the percent root-mean-square error, and the total trips from both sources, within this volume group. It can be seen that a total of 102 movements fall into this category.

The same procedure is used on all volume groups. If the relative error for each group is within the limits of accuracy the transportation planner is willing to accept, then the model is deemed statistically satisfactory. If it is not within acceptable limits, the source of the error must be located.

Fig. IV-39 Trip comparison - Link volumes

A Node	B Node	O-D Volume	G-M Volume	Difference
1	9	38,680	43,412	4,732
1	500	16,452	16,428	-24
1	509	36,412	36,180	-232
2	3	5,812	5,692	-120
2	7	3,552	3,704	152
2	500	1,704	2,040	336
2	509	10,796	11,460	664
3	2	11,428	12,440	1,012
3	4	2,820	2,180	-640
3	6	5,944	6,724	780
3	280	3,492	4,036	544
4	3	10,404	11,900	1,496
4	5	31,940	30,340	-1,600
4	284	11,664	10,556	-1,108
4	285	4,872	3,676	-1,196
5	4	8,832	7,736	-1,096
5	6	18,600	23,628	5,028
5	19	16,708	12,392	-4,316
6	3	5,352	6,012	660
6	5	3,704	4,628	924
6	7	9,128	10,416	1,288
6	22	9,944	10,756	812
7	2	2,932	2,748	-184
7	6	2,936	1,920	-1,016
7	8	8,476	8,348	-128

Figure IV-40. Trip comparison - frequency distribution and analysis of differences, volume group - 8,000 to 9,999

Difference	Frequency	Sum of Differences
-99,999 AND OVER	0	0
-75,000 TO -99,998	0	0
-50,000 TO -74,999	0	0
-25,000 TO -49,999	0	0
-20,000 TO -24,999	0	0
-15,000 TO -19,999	0	0
-10,000 TO -14,999	0	0
-8,000 TO -9,999	0	0
-6,000 TO -7,999	0	0
-5,000 TO -5,999	0	0
-4,000 TO -4,999	0	0
-3,000 TO -3,999	0	0
-2,000 TO -2,999	5	-12,612
-1,000 TO -1,999	18	-27,616
-500 TO -999	11	-8,332
0 TO -499	16	-3,260
0 TO 499	15	4,020
500 TO 999	14	11,024
1,000 TO 1,999	15	21,428
2,000 TO 2,999	5	11,824
3,000 TO 3,999	3	10,908
4,000 TO 4,999	0	0
5,000 TO 5,999	0	0
6,000 TO 7,999	0	0
8,000 TO 9,999	0	0
10,000 TO 14,999	0	0
15,000 TO 19,999	0	0
20,000 TO 24,999	0	0
25,000 TO 49,999	0	0
50,000 TO 74,999	0	0
75,000 TO 99,998	0	0
99,999 AND OVER		
TOTALS	102	7,384

SUM OF SQUARES	=	192,891,392
MEAN DIFFERENCE	=	72
RMS ERROR	=	1,375
STANDARD DEVIATION	=	1,373
TOTAL O-D TRIPS	=	909,180
TOTAL G.M. TRIPS	=	916,564
PERCENT RMS ERROR	=	15.43

The trip comparison program may also be used to compare binary trip tables. This test is somewhat more stringent than the spider network comparison as there is no chance for geographic or socio-economic bias to be averaged out in the assignment.

When evaluating the accuracy of travel models the accuracy of the origin-destination survey data should also be considered. Figure IV-41 developed by A. Sosslau and G. Brokke can be used to estimate the accuracy of survey volumes given the home interview sampling rate. For example, given a sampling rate of 5 percent, a volume of 10,000 trips estimated from the home interview survey can be expected to be accurate within ±8 percent at the two-thirds level of confidence.

It follows that if a model demonstrates an accuracy at each volume level equivalent to the accuracy of the survey data, the calibration can be considered complete. To achieve any further accuracy other sources of data would have to be used.

6. Other considerations.

a. Converting the gravity model results to directional movements--Once the gravity model trip interchanges have been shown to reproduce the travel patterns surveyed by the field inventories, it is desirable to convert the gravity model results to directional movements between origin and destination zones. The gravity model results yield movements from zones of production to zones of attraction. The converted movements may be used for directional assignment to the transportation network. Provision has been made to convert the gravity model results using the trip table splitter program (SPLIT).

Consider the following examples of the conversion to directional volumes. Zone 1 produces 100 work trips which are attracted to zone 2. This is shown schematically in figure IV-42. Each of these trips is produced in the home zone and attracted by the zone at the nonhome end of the trip.

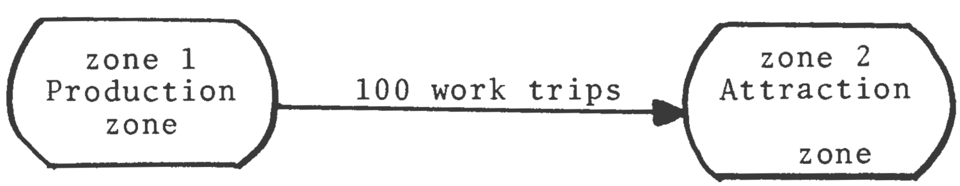


Figure IV-42.--Schematic gravity model trip interchange.

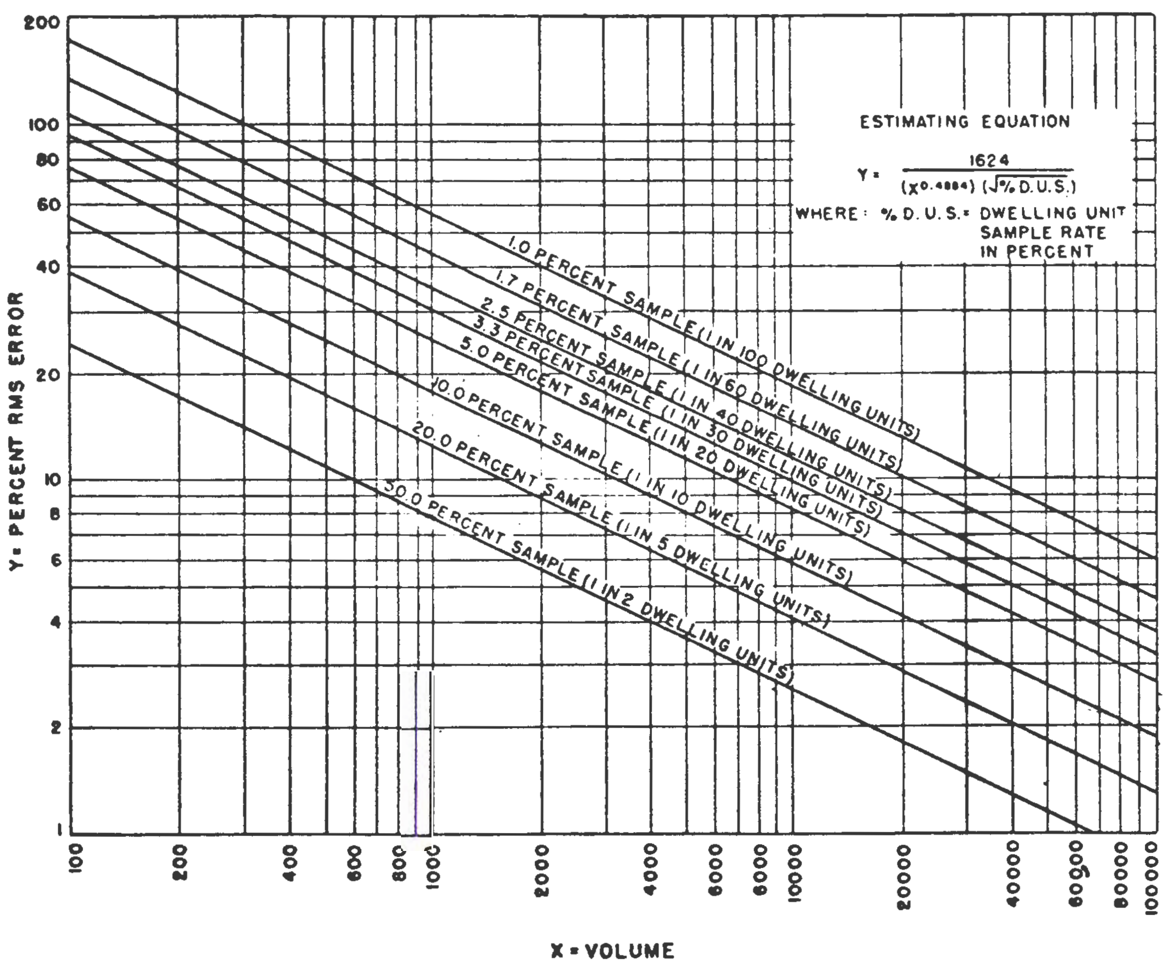


Fig. IV-41.--Relation of percent root-mean-square error and volume for various dwelling unit sample rates.

These gravity model trip interchanges converted to directional origin-destination movements are illustrated in figure IV-43.

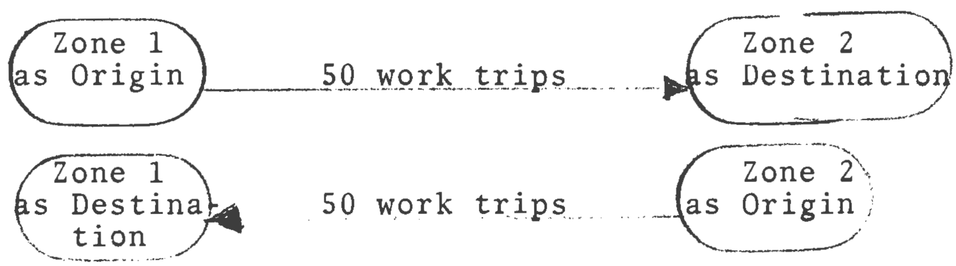


Figure IV-43.--Schematic origin to destination interchange.

In current practice a 50-50 split is usually assumed for all home based trips. Since for nonhome based trips, the zones of production and attraction remain the same as the zones of origin and destination, respectively, no splitting of these trips is required. The output from this program is a binary trip table of directional movements between all origin and destination zones. This output can then be assigned to the transportation network to obtain directional volumes.

In certain areas unique situations may exist where it might be desirable to convert on other than a 50-50 basis. The trip conversion program provides the user with this option. This same option may also be used to factor an ADT trip table (by purpose) to a directional peak hour trip table. To develop factors for peak hour directional movements, PEAKHOUR is available. This program is described in Chapter VII, Section K.

b. <u>Forecasting future travel patterns using the gravity model.</u>-- The calibrated gravity models developed from present data are used to estimate future travel patterns for any desired year or land use pattern. Many of the phases related to the process of estimating future travel patterns are outside the scope of this manual. Future trip distribution is influenced by many other elements in the forecasting process. The primary elements are the traveltime factors developed in the calibration of the model, the future network, and the future land use. Each of these elements is in turn conditioned by the basic travel characteristics, the existing network, the forecast of economic activity and population, and the community goals and policies.

Briefly the process may be described as follows:

The entire forecast is based upon the estimate of future economic activity and population. Once this estimate is available, the economic activity and population must be translated into land requirements and distributed among the various zones. The trip generation is then a direct function of land use.

Trip generation relationships are developed using the base year data. These mathematical expressions, which relate trip production and attraction to various land use and socio-economic indicators, are applied to the future land use to arrive at future generation.

A proposed transportation system is determined for the future time period. The location and extent of this system can be influenced by present points of congestion and probable changes in land development patterns. The proposed system is then coded and described to the computer in the same manner as described in chapter III for the present system. The minimum path traveltimes between all zone pairs for the proposed system are then calculated.

Traveltime factors, as developed from present data, are used for the future time period. Very limited evidence leads to the conclusion that this is a reasonable assumption to make. However, much research work is required on this point before the assumption can be accepted without reservation.

In addition, if zone-to-zone adjustment factors (K_{ij}) were found necessary for the present time period, they may also be necessary in the future. These are developed for the future based on their relationship to the same specific socio-economic characteristics. For example, a study in Washington, D.C., developed zone-to-zone adjustment factors for all home based work trips to the central business district. The factors were then related to the income level of the persons living in each zone. The socio-economic adjustment factors for the forecast period were determined by analyzing the forecast estimates of zonal income.

The essential techniques have thus been described for the calibration of a gravity model for base year data and for the application of this technique to a forecast year.

The gravity model provides the transportation planner with an effective tool to relate the characteristics of land use (as represented by generated trip ends) to the characteristics of the transportation system in order to simulate the distribution of trips. The feedback from the transportation system to the land use and vice versa is the key to the transportation system analysis.

The transportation planner has many alternate approaches to systems analysis available to him. Alternate land use configurations can be studied with respect to a single transportation plan or more likely alternate transportation systems can be studied with respect to a given land use plan. The number of combinations of land use and transportation systems requires a systematic approach to the problem.

D. THE INTERVENING OPPORTUNITIES MODEL

The theory of the intervening opportunities model was published in 1960 as an appendix prepared by Morton Schneider to an article entitled "Panel Discussion on Inter-Area Travel Formulas" in Highway Research Board Bulletin 253. Mr. Schneider, then Chief of System Research, Chicago Area Transportation Study, was primarily responsible for the development and implementation of the model. The following discussion of model theory depends very heavily on the above publication.

1. Model Theory

The intervening opportunities model assumes that the trip interchange between an origin and a destination zone is equal to the total trips emanating from the origin multiplied by the probability that each trip origin will find an acceptable terminal at the destination. This is expressed as follows:

$$T_{ij} = O_i P(D_j) \qquad (1)$$

where

T_{ij} = the trips between origin zone i and destination zone j;

O_i = the total trip origins produced at zone i;

D_j = the total trip destinations attracted to zone j;

$P(D_j)$ = the probability that each trip origin at i will find destination j an acceptable terminal.

$P(D_j)$, the probability that each trip origin at i will find destination j an acceptable terminal, is expressed as a function of D_j, which is the total trip destinations attracted to zone j. D_j is used because the model assumes that two zonal characteristics determine the probability that a destination will be acceptable. They are the size of the destination and the order in which it is encountered as trips proceed away from the origin.

$P(D_j)$ may also be expressed as the difference between the probability that the trip origins at i will find a suitable terminal in one of all destinations, ordered by closeness to i, up to and including j, and the probability that they will find a suitable terminal in all destinations up to but excluding j. Thus:

$$T_{ij} = O_i\left(P(A) - P(B)\right) \qquad (2)$$

where

A = the sum of all destinations for zones between, in terms of closeness, i and j and including j.

B = the sum of all destinations for zones between i and j but excluding j.

Note that

$$A = B+A_j \qquad (3)$$

It is then possible to formulate the function P. The probability that a trip will terminate within some volume of destination points is equal to the product of two probabilities. These are (a) the probability that this volume contains an acceptable destination and (b) the probability that an acceptable destination closer to the origin of the trip has not been found. This may be expressed in differentials as follows:

$$dP = (1-P)LdV \qquad (4)$$

where

$$P = P(V)$$

and where

V = the volume of destination points (destination trip ends) within which the probability of a successful terminal is to be calculated.

L = the probability density (probability per destination) of destination acceptability at the point of consideration.

Assuming L to be constant, the solution to equation (4) is:

$$P = 1-ke^{-LV} \qquad (5)$$

where

k = the constant of integration;

e = the constant base of natural logarithms, 2.71828... .

It can be shown that k=1 since P must be zero when V is zero. Equation (5) thus becomes:

$$P(V) = 1-e^{-LV} \qquad (6)$$

The function thus derived for P(V) may be substituted into equation (2). Thus:

$$T_{ij} = O_i\left(e^{-LB}-e^{-LA}\right) \qquad (7)$$

Equation (7) is the standard formulation of the intervening opportunities model and is the one used in this program. The formulation requires that destination zones be ordered according to their nearness in time to the origin being considered. Thus, in the program, destinations are in sequence according to the contents of the skim tree associated with the origin.

Equation (7) is also of interest in that, unlike the Fratar and gravity model formulas, it is not insisted that the full number of trip origins be utilized. It is also significant that T_{ij} represents a curvilinear function of L which may obtain a maximum value.

Since the model is based upon the distribution of trip origins, an iterative technique similar to that employed in the gravity model is used to cause calculated destination (column) totals to approach the desired values. After each iteration adjusted destination totals are calculated by the following formula:

$$D_{jk} = \frac{D_j}{C_{j(k-1)}} D_{j(k-1)} \qquad (8)$$

where

D_{jk} = the adjusted destination total for destination zone (column) j, iteration k $D_{jk} = D_j$ when k=1;

C_{jk} = the actual destination (column) total for zone j, iteration k;

k = the iteration number, k=1,2,...,m;

m = the number of iterations.

These adjusted destination totals are those to be employed in the next iteration of the model as is shown in Figure IV-44 a diagram of its logic-flow.

2. IOM Example

As an example of how the intervening opportunities model functions, the table in Figure IV-45 contains forecast origins and destinations for a small three-zone system.

Figure IV-46 contains the impedance table to be associated with the system. In this case, Figure IV-47 shows L-factors to be employed for each origin zone. However, it is important that the user recognize that this particular L-factor configuration is not a program requirement.

Using values from these figures, the first iteration of the intervening opportunities model will produce the results shown in Figure IV-48 Note that only 65 of the 75 origins are accounted for. Adjusted destination totals for Iteration 2 are calculated according to equation (8). The results may be found in Figure IV-49

The intervening opportunities model formula is again applied using the adjusted destination totals calculated in Figure IV-49 The second iteration of the model produces the trip table found in Figure IV-50 Note that the second iteration produces a gain of three trips over the former iteration.

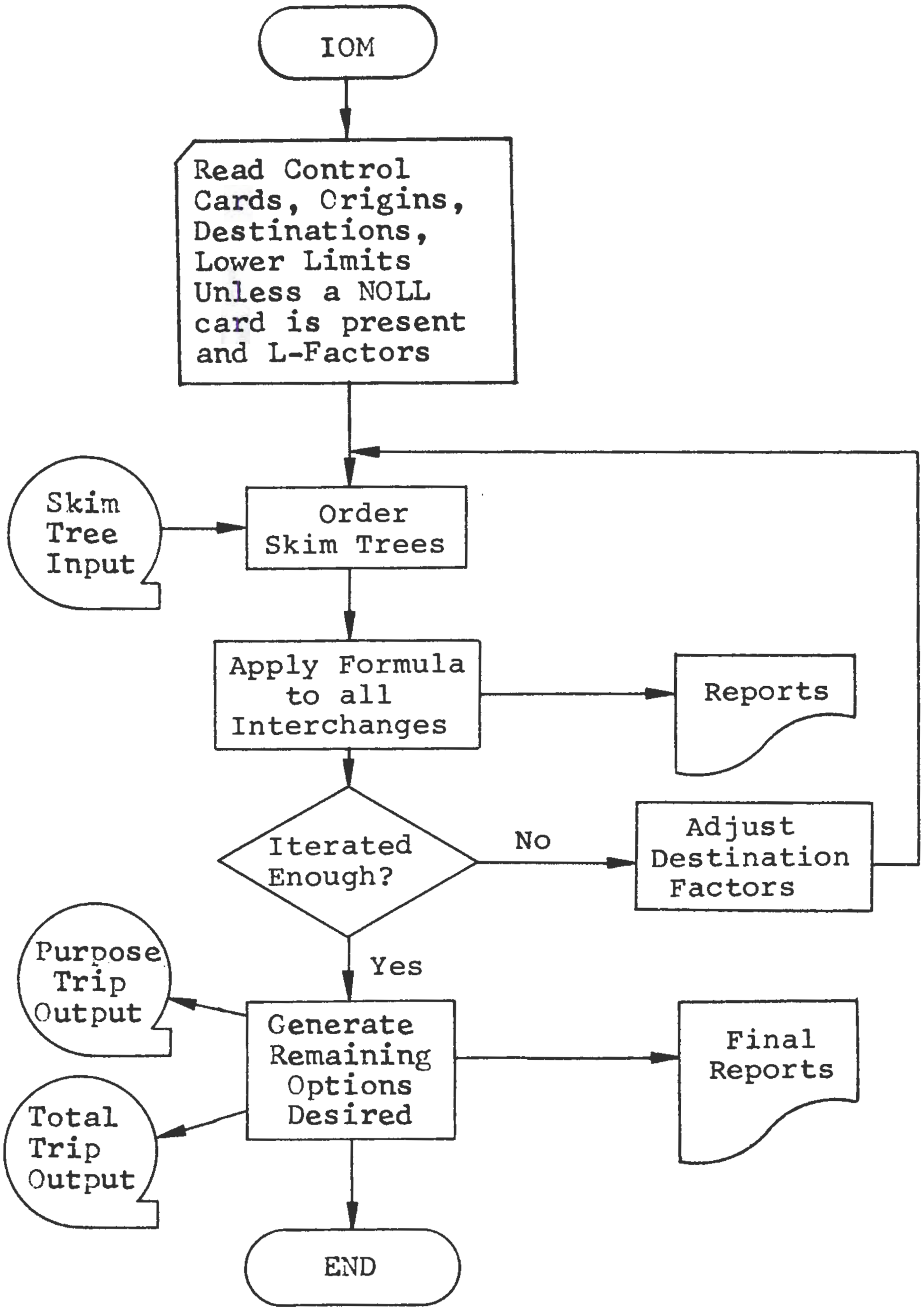


Figure IV-44
IOM Logic-Flow

Zone	1	2	3
Origins	14	33	28
Destinations	33	28	14

Figure IV-45
Forecast
Origins and Destinations

Zone	1	2	3
1	1	2	3
2	2	1	3
3	2	3	1

Figure IV-46
Impedance Table

Zone	L-Factor
1	0.04
2	0.02
3	0.04

Figure IV-47
L-Factors

D / O	1	2	3	Total
1	10	2	1	13
2	9	14	2	25
3	12	3	12	27
Total	31	19	15	65

Figure IV-48
Iteration 1
Output

Zone	1	2	3
D_j, Desired Destination Total	33	28	14
C_{jk}, Actual Destination Total	31	19	15
$D_{j(k-1)}$, Adjusted Destination Total, Preceding Iteration	33	28	14
$D_{j(k+1)}$, Adjusted Destination Total, Next Iteration	35	41	13

Figure IV-49
Iteration 2
Calculate Adjusted Destinations

O \ D	1	2	3	Total
1	11	3	0	14
2	7	18	2	27
3	13	3	11	27
Total	31	24	13	68

Figure IV-50
Iteration 2
Output

Adjusted destination totals are again calculated for Iteration 3 using the results of Iteration 2. These calculations may be found in Figure IV-51

Zone	1	2	3
D_j, Desired Destination Total	33	28	14
C_{jk}, Actual Destination Total	31	24	13
$D_{j(k-1)}$, Adjusted Destination Total Preceding Iteration	35	41	13
$D_{j(k+1)}$, Adjusted Destination Total, Next Iteration	37	48	14

Figure IV-51
Iteration 3
Calculate Adjusted Destinations

The intervening opportunities formula is again applied and the trip table in Figure IV-52 is the result. Note that another origin has now been utilized.

The above iterative process may be continued until the user is satisfied that calculated destination totals approximate their desired values. Several statistical measures are supplied to aid in making this decision. Alternately, a point may be reached where further improvement seems unlikely.

O \ D	1	2	3	Total
1	11	1	1	13
2	7	20	2	29
3	12	3	12	27
Total	30	24	15	69

Figure IV-52
Iteration 3
Output

E. PROGRAMS FOR TRIP DISTRIBUTION

The basic set of programs utilized for the trip distribution process, depending upon the model selected are summarized below.

FRAT, The Fratar Program

To adjust and output given trip tables according to the Fratar formula, providing printable summaries of the results.

GM, The Gravity Model Program

To distribute zonal productions and attractions among interchanges according to the gravity model formula, outputting resultant trip tables and printable reports summarizing total attractions and trip length distributions.

GMCAL, The Gravity Model Calibration Program

To derive traveltime factors (F-factors) for the gravity model, and output them along with printed reports and the corresponding trip length distributions.

IOM, The Intervening Opportunities Model Program

To distribute origins and destinations among zonal interchanges according to the intervening opportunities formula, outputting the required trip tables as well as printed reports of the resulting destination and trip opportunity distributions.

TDIST, The Trip Length Distribution Program

To generate trip length distributions for all purposes, given the relevant trip tables and skim trees/vines, and to output them in internal or EBCDIC format while printing and plotting the results as requested.

ODIST, The Trip Opportunity Distribution Program

To generate the trip opportunity distribution for each district, given relevant trip tables and skim trees/vines, and to output them in internal form or EBCDIC records as well as printing and plotting the results as requested.

COMPARE, Compare Volumes Program

To compare selected volumes from one or two trip tables, or one or two historical records, and print summary tables with appropriate statistical measures.

CMAT, The Matrix Compressing Program

To create a square trip matrix from a given square trip matrix of equal or larger dimension.

UPTREE, The Skim Tree/Vine Updating Program

To update one existing skim tree/vine.

PTSUM, The Trip End Summary With/Without Punch Card Program

To create printed reports concerning trip tables, summarizing trip ends for each zone, with optional card output.

FMTSKIM, The Format Skim Tree/vine Program

To create formatted tables of 1 or 2 byte skim tree/vine datasets.

ACCESS, The Accessibility Program

To provide printed reports & datasets for the accessibility indices and/or ratios.

SPLIT, The Trip Table Splitter Program

To convert a trip table in terms of productions and attractions to a trip table in terms of origins and destinations by applying user supplied factors at the production and attraction end. Peaking or expanding, as well as copying, may be accomplished.

GENPUR, A General Purpose Trip Manipulating Program

GENPUR will perform all of the following, either individually or in combination, on Trip Tables:

Addition	Factoring
Subtraction	Interpolation/Extrapolation
Multiplication	Copying
Division	

TRPTAB, Trip Table Building and Manipulating Program

TRPTAB will perform all of the following on trip tables and/or skim trees:

Addition	Factoring
Subtraction	Copying, merging, unmerging
Multiplication	Format zone-zone values
Division	Trip end summaries

TRPTAB will also produce trip end summary cards in the standard distribution program format or any user supplied format. The program will not output skim trees but will input them for summary purposes or to build vehicle-hour or vehicle-mile trip tables. Trip table output is optional so that the program can be used to only format (and manipulate) and/or summarize trip tables.

TRPVERT, Compressing, Expanding and Renumbering Program

TRPVERT will compress, expand and renumber any or all trip tables in a single dataset. The three operations can be performed simultaneously in a single run. In addition, trip table numbers may be changed or several tables added together during the run.

References should be made to the systems flow charts contained in Chapter I to determine the sequence of operations in the use of the above programs.

CHAPTER V

TRIP GENERATION[1/]

A. BACKGROUND

Trip generation may be defined as the study of the relationships between trips made in an area and characteristics of the area such as land use, population, employment and other economic activity measures. The desired end product in trip generation analysis is an accurate identification and quantification of trips beginning and ending in the various analysis units within a transportation study area. These trip end volumes are, in themselves, difficult, if not impossible, to forecast directly. Decisions made in the household with respect to travel are attributable to such diverse variables as the families' economic status, locational environment, and associated demographic characteristics. Certain data describing the characteristics of the various analysis units can be forecast more easily and efficiently than can trip ends per se.

The ultimate goal of trip generation analysis, therefore, is to establish an adequate functional relationship between trip end volumes and the land use and socio-economic characteristics of the units from which they originate or to which they are destined. In this respect, some causal relationship rather than a simple linkage is hypothesized. In effect, the analyst attempts to develop relationships which help to answer such questions as: why does a family living in a high-rise apartment close to the central business district (CBD) average 4 trips per day, while the daily average for a family living in the suburbs is 12 trips? Generally, questions of this nature can be thought of in terms of three factors which influence trip generation: (1) Intensity, (2) character, and (3) location.

1/ Detailed documentation of trip generation procedures may be found in the following publications: U. S. Bureau of Public Roads, Guidelines for Trip Generation Analysis, U. S. Government Printing Office, Washington, D. C., June 1967 and Fleet, Christopher R., and Robertson, Sydney R., "Trip Generation in the Transportation Planning Process," Highway Research Record No. 240, Highway Research Board, Washington, D. C., 1968, pp. 11-31.

B. INITIAL DECISIONS TO BE MADE

There are many initial decisions to be made prior to the trip generation phase of the urban travel forecasting process which have not yet been discussed or which have only been briefly touched upon. The adequate meshing of the various phases of the process at their interfaces is of particular importance. For example, the decision must be made as to what trip purpose stratification to use and whether to use trip productions and attractions or trip origins and destinations. Very clearly the latter choice is dependent primarily upon the distribution model to be used. Future trip end estimates must be compatible with input requirements of the particular interarea travel model formula to be used. Other considerations relate to "modal split" and the definition of trip (i.e., person trip or vehicle trip, for example).

1. Trip End Stratification

Perhaps one of the most important, yet basic, questions to be answered deals with the stratification of the dependent variable by trip purpose classifications. The degree of stratification in trip generation has been conditioned primarily by the requirements of trip distribution. The trip distribution stratification is, in turn, a function of the scope and objectives of the study as well as the size of the urban area involved. Specific considerations include the number of trips in each category and the trip length characteristics for each trip purpose, as well as the ability to forecast the categories separately in the trip generation element.

Aside from the importance of dividing trips by type for trip distribution, the stratification does much to explain the variation in total trips. Obviously, by relating work trips or shop trips to characteristics most directly associated with the reasons for making these trips, a more accurate estimate as well as more confidence in the estimate may be obtained. Much is known about a trip when its purpose is known.

Although the stratification of trips by purpose is dependent, at least partially, on the distribution phase, trip generation is much more sensitive to stratification than are the distribution models. Basic trip data that are over stratified may lead to statistically unstable relationships. Not only do data which are "cut too thin" produce mean numbers of trips of small magnitude (with correspondingly high sampling variation) but the number of observations in each analysis area may be insufficient to obtain reliable estimates.

a. Land use stratification at the trip end. Statistical stability may become even more of a problem when trips are stratified by both purpose and land use at their origin or destination. In this instance, it is particularly necessary to examine the size of the observed values of the dependent variable in each analysis area. For example, it is quite unlikely that zones in the CBD would produce many home based work trips on commercial land, while the same zones would certainly attract a substantial number of these trips. The predictive ability of estimating equations may be increased by stratification, yet this stratification should not be so fine that the number of observations is extremely small or that there is a large number of zones in which observed values of the dependent variables are zero. For these reasons, detailed stratifications of trip ends by land use are not recommended.

b. Other considerations. Additional refinement may be made by deleting from the analysis those zones not exhibiting urban characteristics. This, in fact, should be done prior to developing the trip generation relationships. Since we are attempting to describe urban travel, it would be illogical to include in the analysis such zones as those on the periphery of the study area which are largely undeveloped. Large areas of farm land, for example, will not normally contain characteristics explanative of urban travel. Similarly, zones containing no dwelling units should be excluded as observations in home based trip production equations.

Special consideration should be given to analysis areas or zones containing unique characteristics. The CBD is one example; a zone which contains a large shopping center is another. In the former case, the CBD largely comprises commercial establishments, government buildings, and office buildings and rarely contains any residential land. Here, home based trip productions would be almost nonexistent. Often the zones which comprise the CBD can be separated from the rest of the study area and a special analysis conducted on these zones. The analysis unit which contains a large shopping center, or air or railroad terminal is another example which should be considered for special handling.

Occasionally equations are developed using O-D survey data (dependent variables) and selected socio-economic data (independent variables) obtained from other sources, such as census or planning departments. While this is usually necessary in forecasting, crossing data sources in this manner in the base year trip generation analysis may prevent the development of reliable relationships and should be avoided if possible.

2. Trip Type Definition and Modal Split

The decision about the type of trips to forecast is primarily related to the objectives and requirements of the study and to the size of the area involved. Unless present transit usage is a small portion of the total areawide travel (and is expected to remain so in the future) person trips normally are used. After person trip ends have been forecast, the proportion of future travel by transit is estimated by modal split procedures either before or after the trips are distributed (figure V-1)*.

In very small study areas, the generation analysis may be designed so that base year vehicle trips and transit trips are analyzed separately. If there is no transit usage, the generation analysis can be directed toward estimating future vehicle trips only.

3. Considerations in Forecasting

The assumption of the stability of the relationships between trips and land use and socio-economic variables, over time is basic to forecasting, and the significance of this assumption cannot be overemphasized. No matter how well the estimated relationship corresponds to the observed data, considerable forecasting error may result unless the variables used can be forecast within a reasonable degree of accuracy and the relationship, in fact, does remain constant. As forecasts of independent variables generally come from other sources, it is often easy to forget that the trip generation estimating procedure is only as good as the quality of the future estimates of the independent variables. Because the assumption of time invariance is

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* Refer to Chapter VI

generally made when forecasting, it is extremely important that relationships be chosen that do exhibit stability. The analyst should not become so involved in the mechanics of data fitting that he loses sight of his intended goal--meaningful forecasts.

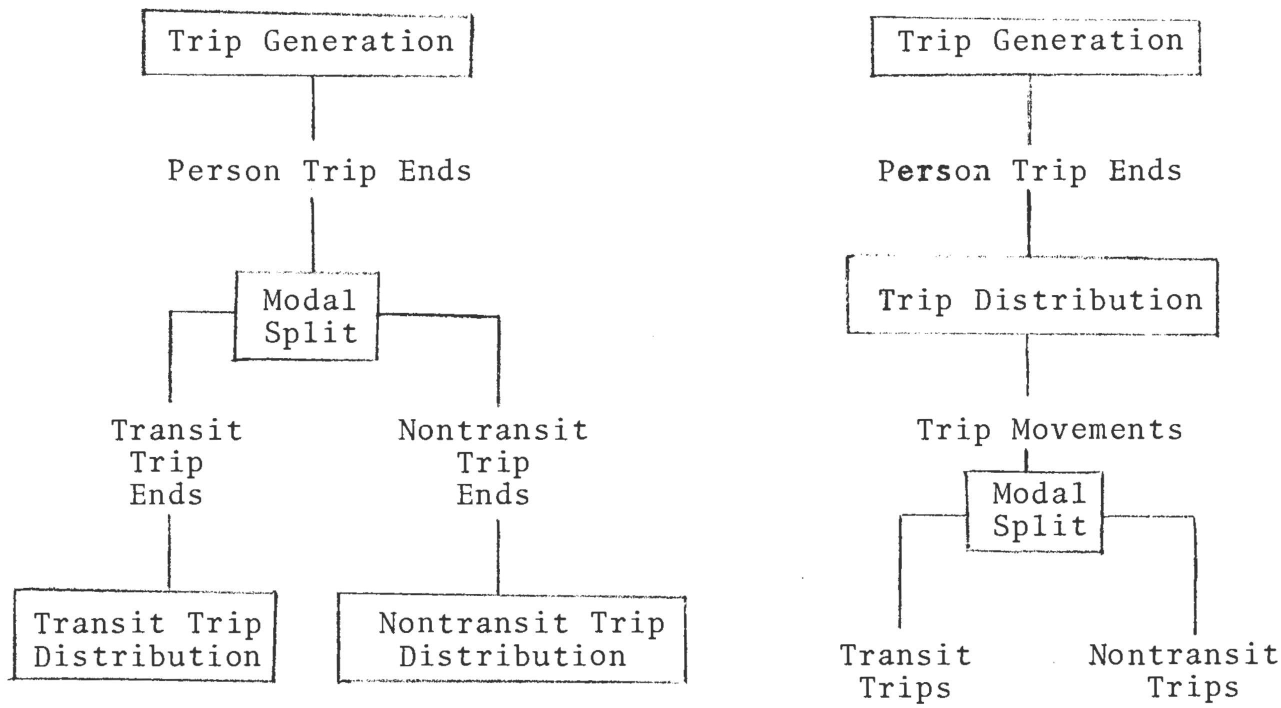


Figure V-1. Location of modal split with respect to trip generation analysis in the transportation planning process.

C. ANALYTICAL TECHNIQUES

Essentially two levels of analysis have been considered in this chapter--the basic level at which the data are obtained and the level to which these data are aggregated. Current approaches to trip generation analysis rely on the latter, usually zonal level. However, aggregation reduces the total amount of variation in trip making by the dwelling unit that can be explained. In general, geographic aggregation of the data is not as efficient as it might be. The most meaningful results, in terms of explanation of variation, should occur at the level of greatest detail. Trip making of individuals is therefore most realistically related to the characteristics of the dwelling unit. Aggregation will only cloud much of the variation and also many of the relationships which might explain this variation.

Figure V-2 shows the results of regression analyses conducted at two levels. Equation 1 was developed in the usual manner using both trip and socio-economic data from dwelling unit samples aggregated and expanded by zone prior to the analysis. The dependent variable is total home based trips per zone. Equation 2 resulted when the unexpanded 5,255 dwelling unit sample data from the home interview survey were analyzed. In this equation the dependent variable is total home based trips per dwelling unit.

Figure V-2 Results of regression analyses conducted at the zone level and dwelling unit level.

No.		N	R^2	$S_{y.x}$	$\bar{Y}$	% $S_{y.x}$	Adj. $\%S_{y.x}$
1	$\hat{Y}_1 = 36.03 + 5.09\ (\text{cars/zone})$	143	.95	296.07	1,679	17.6	
2	$\hat{Y}_2 = 0.69 + 1.39 \begin{pmatrix}\text{No. of persons} \\ \geq 5\ \text{yr./D.U.}\end{pmatrix} + 1.94\ (\text{cars/D.U.})$	5,255	.36	3.89	5.20	74.9	19.4

The relatively large value of the percent standard error of equation 2 is somewhat misleading. In order to evaluate the percent standard errors realistically, the standard error should be computed after the dwelling unit regression equations have been applied at the analysis unit level. Trip generation estimates by geographic area (analysis zone, for example) will still be required as an end product because of the other elements of the transportation process, namely, distribution and assignment.

1. Linear Regression Analysis

Regression analysis is a statistical procedure in which the relationship between two or more related items,called variables, may be expressed in an optimum mathematical form according to specified criteria. In the past few years, multiple regression programs for use on large computers have made the development of trip generation equations a relatively fast "prepackaged" process. While permitting the development of multivariable equations, these programs have often resulted in the analyst becoming more and more disassociated from the data he is analyzing. As a result, complex equations have been developed which, although often adequate when evaluated statistically, have had little or no thought given to the reasonableness of the results.

In order to facilitate analysis at the dwelling unit level, a program (DUSUM) has been added to the urban planning battery. This program is described in section D of this chapter and can be used in conjunction with linear regression or cross-classification analysis.

2. Evaluation of Multiple-Regression Trip Generation Analyses

The evaluation of multiple-regression trip generation analyses can be broken into two general areas - statistical validity and reasonableness of results. As multiple regression is a statistical analysis technique, it is important that the various standard tests of validity be considered and that the work be evaluated by this means. Multiple regression is only as accurate and as useful as the validity of the assumptions that are made and the statistical significance of the results obtained. It is, however, most important that a great deal of hard thought be applied to both the results and the statistical evaluations to determine the reality and logic of these results. It is entirely possible to produce results which meet all of the various statistical criteria and yet offer no explanation of the causative relationships affecting trip generation. In order to forecast, such a causative relationship is imperative. Many trip generation analyses have been lacking because of unreasonable results not statistical invalidity. It should be noted, however, that unreasonable results will often result in statistical unreliability.

a. Statistical Validity. "R" (multiple correlation coefficient).--In general, this statistic indicates the degree of association between the independent and dependent variables in the equation. The higher the value of "R," the greater the reliability of the association. This statistic, however, is quite often overemphasized and utilized as the only equation evaluation tool. Equations are often developed which possess a high value of "R" (very close to 1.00) and contain illogical variables or are statistically unstable. It should also be remembered that it is entirely possible to have a statistically reliable association which has little or nothing to do with the underlying functional relationships.

Standard error of estimate.--This statistic indicates the degree of variation of the data about the regression line established. Mathematically, it is a measure of the error to be expected in predicting the dependent variable from the independent variables in the equation. It is most meaningful, however, to express the standard error as a percent of the mean observed value of the dependent variable:

$$\frac{\text{Standard error of estimate}}{\text{Mean of the observed values of Y}} \times 100$$

Mean observed value.--Overstratification of the basic trip (O-D survey) data will produce a mean zonal value which is too small to permit the development of a statistically stable relationship. Overstratification generally produces excessively large coefficients of variation. Stratifications of the basic trip data are performed to obtain meaningful explanations of the variation of trip making by purpose. Trip generation is far more sensitive to stratification than is distribution. Therefore, the trip generation analysis, rather than the trip distribution model, should control the stratification of the trip data.

"t" test.--A "t" test indicates the significance or lack of significance of the regression coefficient of each independent variable in a regression equation. In general, "t" must have a value of at least 2.0 for significance. The value of "t" is calculated by dividing the regression coefficient by its standard error:

$$t = \frac{\text{regression coefficient}}{\text{standard error of coefficient}}$$

Independent variables which have a computed "t" of less than 2.0 do not have a significant relationship with the dependent variable and therefore contribute nothing to the equation. Any such independent variables should be deleted from the equation.

Simple correlation matrix.--This matrix contains the simple correlation coefficients for all combinations of variables - independent and dependent. The simple correlation coefficient expresses the degree of association between two variables. An examination of this table should be made prior to any detailed development of equations in order to determine the relationships between the various independent and dependent variables. Such an examination can impart a great deal of insight into the relationships within the data to the analyst. Strong associations between independent and dependent variables can be readily evaluated for logic.

It is also valuable to investigate the data for high intercorrelations between independent variables. Such high intercorrelations can often result in a degeneration of the least squares regression procedure and yield meaningless results.

Modifications of the basic regression equation.--If a standard regression equation (of the form Y=A+BX) containing a constant is developed, the regression line is the best fit of all of the data, passing through the mean of the dependent and independent variables. If the regression or least squares technique is applied with no constant (an equation of the form Y=BX) the regression line developed is the best fit of the data, but is now restrained to go through the origin (Y=0, X=0). This, however, is not the best least squares fit of the data. If the constant were initially large, the regression equation will have a considerable built-in error. The solution of such an equation will produce serious discrepancies between the observed and calculated zonal values. The constant must be examined for significance before permitting any equation to be forced through zero. A constant must be very small with respect to the mean zonal value in order to be considered insignificant.

When a constant is removed from an equation, the various evaluation statistics mentioned above must be recalculated, as those previously developed with the use of a constant are no longer applicable. It is misleading and statistically incorrect to present the previously developed statistics.

When trip generation equations are forced through zero, the resultant solutions will not produce the same number of total trip ends as are included in the basic data. At this point, the analyst generally decides to apply a factor to the equation to adjust for the discrepancies. Such adjustments are grossly inaccurate and result in destroying the statistical reliability obtained in the application of the least squares technique. Furthermore, the equation statistics (multiple-correlation coefficient and standard error of estimate) reported no longer apply to the factored equation. It is misleading and statistically incorrect to report the statistics obtained for the unfactored equation.

In cases where a regression equation is modified, the recalculated equations will have higher standard errors and lower multiple-correlation coefficients. This is merely an indication that the best lease squares fit is no longer obtained.

<u>Plots of observed versus estimated trip ends by zone and plots of the ratios of observed versus calculated trip ends by zone.</u>--This analytic tool has been rarely used in the past but should be used extensively. Zones which contain unique characteristics become obvious when plotted in suxh a manner. These zones may then be deleted and given special treatment. Statistically poor regression equations will result in wide scattering on such plots. This is a good method to make an overall performance evaluation of an equation.

b. <u>Reasonableness of Results</u>

<u>Ability to forecast data.</u>--Only those independent variables which can be forecasted within a reasonable degree of accuracy should be used in trip generation equations. In the past, variables which were not to be available or could not be forecasted have often been used in generation equations. As forecasts of independent variables generally

come from other sources, it is often easy to forget that the trip generation estimating procedure is only as good as the quality of the future estimates of the independent variables.

Because the assumption of stability over time is generally made when forecasting with regression equations, it is extremely important that relationships which do exhibit stability over time be chosen. The analyst should not become so involved in the mechanics of regression data fitting that he loses sight of his intended goal -- meaningful forecasts.

Logic of variables.--Only those variables which are reasonably related to the dependent variable should be permitted to enter the equations. For example, it is not realistic to have variables such as retail sales and industrial employment enter into an equation for home-based work trip productions. In this case, the trip ends produced at the home for the purpose of work should be related to the characteristics of the dwelling units and occupants. Reviews of previously completed work indicate, in some instances, that little attention has been given to the selection of independent variables. It is important that completely illogical independent variables be removed before the computerized equation development process begins. Deletion of independent variables at this stage avoids additional complications in the subsequent analysis of the equations.

Association-causation.--Some independent variables enter into an equation due to association within the data alone. Such association between independent and dependent variables may be caused merely by chance. In order to have a meaningful relationship and some reasonable degree of confidence in the forecast, the relationship should be causative. For example, it may be found that the number of acres of vacant land in a zone has a relationship to the number of work trip productions in the zone. Certainly this relationship has dubious value in the forecast of future trip ends and a more logical variable such as labor force should be used. These types of situations generally result when the analyst allows the regression procedure to mechanically sift the data for strong relationships.

Rates versus zonal aggregates.--Zonal aggregates and rates should not be intermixed in the same equation. Trips per dwelling unit and persons per acre are examples of rates which are commonly used while the number of dwelling units or cars in a zone are examples of zonal aggregates of data. Rate variables eliminate the effects of zone size while the aggregate variables do not. For example, a sparsely developed zone carries the same weight in an analysis as one which is densely developed. Mixing the rate and aggregate variables will result in a poor equation.

District level trip generation equations.--If adequately stable trip data are available and the analysis zones are not unreasonably small, trip generation equations should be developed using zonal rather than district data.

Zonal data which are aggregated to a district level will result in a reduction of variation. However, it is inaccurate to then reapply these equations at the zonal level to predict the greater zonal variations in trip making.

It may be reasonable and prudent to aggregate the data if analysis reveals that the zonal level stratification results in insurmountable variations or that the inherent sampling variation in the data is too great.

Deletion of zero trip and zones as observations.--If a transportation study area contains an extensive number of zones which presently do not contain urban characteristics, these zones should be deleted as observations in the trip generation analysis. Such marginally developed zones or fringe zones may presently be largely vacant or utilized as agricultural land. The equations being developed are for areas of an urban character. The marginal zones do not contain these characteristics.

Extensive stratification of the trip data often results in a large number of zones with no trips observed. In such cases, the reasons for these zero observations should be determined before selecting the zones to include in the analysis. A situation which often presents difficulty is the stratification of trips by both purpose and land use of origin or destination. For example, if an equation is developed for shopping trip attractions to commercial land uses, it is most likely that there will be a large number of zones, primarily of residential character, which will not attract any of these trips. This is only logical, as these zones have nothing in common with the trip stratification. They do not belong as observations in the data to be used to develop the equation for shopping trip attractions to commercial land. Because of the mixed uses of land in urban areas, the stratification of trips by land use will often result in difficulties in the trip generation phase.

Large equation constants.--A constant in a regression equation is considered large when it contributes the majority of the estimate of the dependent variable. This is indicated when the constant is large with respect to the mean observed value.

It is unsafe to make a generalization that large constants are always bad. However, the analyst should recognize the difficulty which results when there are small or zero values of the independent variables. In these cases reason may indicate that no trips should be estimated. However, the regression equation will, because of the magnitude of the constant, result in large values of the dependent variable. In such cases, examination of the relationships in the regression equation may indicate inconsistencies which should be alleviated.

Signs of independent variables.--Logic must be considered when examining the positive or negative contribution of the independent variables in a regression equation. In many instances, the contribution to the estimate of the dependent variable is illogical. For example, in equations developed for home-based vehicle trip productions, the characteristics of the dwelling units in that zone (population, car ownership, labor force, etc.) should be positively correlated to trip making. However, if this were a person trip model for transit trips, it may be logical to have car ownership enter the equation as a negative quantity. In this instance, it is logical to assume that transit trips will increase as car ownership decreases, or vice versa.

3. Cross-Classification Analysis

Cross-classification is a technique in which the change in one variable can be measured when the changes in two or more other variables are accounted for. In this sense, it is not unlike the more widely used multiple regression techniques. Cross-classification, however, does not rely so heavily on the assumed distribution of the underlying data and, as such, is sometimes referred to as a "nonparametric" or distribution-free technique. Essentially, "n" number of independent variables are stratified into two or more appropriate groups, creating an n-dimensional matrix. Observations on the dependent variable are then allocated to the various cells of the matrix, based on values of the several independent variables, and then averaged. Cross-classification analysis has been used as a research tool in trip generation analysis and is becoming more widely used by operational transportation studies.

D. PROGRAMS FOR TRIP GENERATION

The following descriptions outline general program operation and application philosophy. More detailed documentation necessary for program utilization is available in the publications "Urban Planning System 360--Program Documentation," and "BMD Biomedical Computer Programs." 1/ These tools will provide for more efficient and effective trip generation analyses. This is important for both initial studies and for studies performing serveillance activities or updating existing trip generation relationships.

1. Regression Analysis - (BPRO2R and BMDO2R)

Trip generation regression analysis techniques in current use rely almost without exception on the use of electronic computers. The regression analysis programs that have been prepared are generally sophisticated in their operation and are often extremely powerful in their analytical capacities. Many of the programs are stepwise in nature. That is, they employ a method of successively adding variables to a regression equation with the objective of obtaining the "best" final equation. In this method one variable is added at each step and statistical tests are conducted to determine the "improvement" in the equation. Variables continue to be added until the maximum step specified is reached, there are no more variables, or there are no more variables which satisfy certain statistical limitations specified by the user. This type of "buildup" program is by far the most versatile and most powerful. One such program, BPRO2R (or BMDO2R), Stepwise Regression, is part of a battery of data analysis programs developed for medical research at UCLA. These programs are extremely versatile and many are suited for use in the transportation planning process. For this reason, BPRO2R (or BMDO2R) has been included in the urban planning battery (BPRO2R is basically the BMDO2R program developed by UCLA with additional options and output information). In addition, BMDO1D, BMDO5D, BMDO9S and BMDO1V have also been included in the battery and are briefly described in item 4 of this section.

The BPRO2R (BMDO2R) program computes a sequence of multiple linear regression equations in a stepwise manner by adding one variable to the regression equation in each step.

1/ BMD Biomedical Computer Programs, W. J. Dixon, editor. Available at a cost of $6 from the University of California Press, 2223 Fulton, Berkeley, Calif. 94720.

The variable added is the one which makes the greatest reduction in the error sum of squares. In addition, variables can be forced into the regression equation. Non-forced variables are automatically removed when their F values become too low. Equations with or without regression intercept may be selected.

2. Dwelling Unit Regression Analysis (DUSUM)

DUSUM is designed to merge relevant data from dwelling unit summary records (No. 1 cards) and trip records (No. 2 cards). The resulting output is a dwelling unit record summarizing by sampled dwelling unit any trip and socio-economic information desired. This data set is suitable as direct input for dwelling unit regression analysis, utilizing, for example, the multiple regression program (BPRO2R or BMDO2R) or the cross-classification analysis program (XCLASS).

The program assumes that both input data sets (dwelling unit and trip cards) are in sort by sample number. Edits are made, however, in both sets for proper sort and the user is warned (1) if either data set is out of sort or (2) if there is no dwelling unit record for a particular trip record.

The user specifies the "from" and "to" purpose codes and the "mode" codes of the trip purposes and modes desired in the dwelling unit summary output. Trips may be summarized by purpose in either origin-destination or production-attraction format, and the output data set may be in either binary (normal) or EBCDIC format, at the option of the user. If combined purposes are desired, then the output of DUSUM may be used with any transgeneration program, such as BMDO9S, which is in the planning battery. Subsequent modifications of this program will allow purpose combination.

Although this program is designed to merge No. 1 and No. 2 cards, other socio-economic and trip data sets may be merged so long as certain constraints are met in describing these data.

3. Cross-Classification Analysis (XCLASS and XSOLVE)

XCLASS forms the core of the cross-classification analysis procedures. It provides cross-tabulations, in various forms, of input data based on stratifications of up to three independent variables. Observations in the input data set are assigned to calls of a matrix created by user-specified categories of the two or three independent variables. Cell totals, row and column totals, and a grand total of the number of observations are printed out. If requested by the user, a dependent variable is summed and averaged by cell and printed with row and column totals and averages. Cell standard deviations are also provided. The cell means of the dependent variable can be output for future use in the XSOLVE program (see below) if specified by the user. In the present interim version, only a one-purpose matrix can be created in each run of the program.

The usefulness of XCLASS is paramount in the area of dwelling unit data stratification for developing trip rates by dwelling unit types. It should be emphasized, however, that variables from any data set may be cross-classified using this program.

The XSOLVE program will provide estimates of trip ends by trip purpose and geographic area designation (e.g., zone) suitable as input for trip distribution programs. Input data consist of a cross-classification matrix for each trip purpose (from XCLASS or in punched cards) and socio-economic data (e.g., forecasts) on cards. The socio-economic data are matched with the appropriate cell of the desired trip purpose cross-classification matrix, based on the value of the independent variables in the input data. The program will interpolate between cells if necessary. Trip ends are calculated either from the particular cell value found or from interpolation. If trip end estimates are desired for small geographic areas based on a dwelling unit cross-classification matrix, for example, the total number of dwelling units per area and the proportion of those dwelling units for which the input socio-economic data are representative must be specified. If desired, an average value for the independent variables for each geographic area may be used and a proportional representation of 100 percent would be specified. Output consists of total trips sent and received for all purposes by each geographic area in either production attraction or origin-destination format.

4. Biomedical (BMD) Statistical Programs

a. BMD01D - Simple Data Description. This program computes simple averages and measures of dispersion of variables, omitting those values which the user specifies for exclusion from the computations.

b. BMD05D - General Plot Including Histogram. This program produces graphs and histograms.

c. BMD09S - Transgeneration. This program performs selected transgenerations on specified variables in the data. Input may be from punched cards, from BCD tape, or from binary tape.

d. BMD01V - Analysis of Variance for One-Way Design This program computes an analysis-of-variance table for one variable of classification, with unequal group sample sizes. Data may be input from punched cards, from BCD tape, or from binary tape.

e. BPR02R - Stepwise Regression Analysis. This program is an expanded version of BMD02R (see Section D-1). It provides additional statistics and plots plus extended capability for selecting observations. Better run identification is also available through user supplied ID cards.

E. TRIP GENERATION ANALYSIS IN THE CONTINUING PLANNING PROCESS

1. Updating

The requirement that transportation planning be a "continuing" process emphasizes the need for adequate methods of "updating" trip volume estimates in light of changing land use and socio-economic characteristics in the study area. The maintenance of study data on a current basis should be one objective in this continuing process. Thus, at any time after the base year, updates or comprehensive evaluations of the original forecasts should be possible. A general reappraisal, in which the forecasts are checked against current development, should be made periodically. If the forecast is found to require updating, current land use and socio-economic data must be available.

The need for updating, of course, is primarily a function of the age and growth pattern of the metropolitan area. In older cities actual updating and model redesign may not be as critical as in rapidly growing urban areas. This does not, however, obviate the need for adequate and timely evaluations. To stay abreast of travel demands and changing land use activity in a dynamic and rapidly growing area, evaluation of the forecast annually may not be too often.

2. Emerging Concepts in Trip Generation Analysis in the Continuing Planning Process

Emerging from recent research are new techniques and concepts regarding methods of trip generation analysis. In addition to providing for a better base year analysis and forecast, these techniques offer many advantages in updating. There are two elements to be considered. First, every variable used in the base year generation must be available for each update. The less complex the variables used, the easier they will be to obtain. Secondly, certain techniques free the analyst from geographic constraints. For example, dwelling unit analysis allows aggregation of data to any geographic area, whereas a zonal equation should always be applied at the zonal level. The fact that dwelling unit equations can be updated using small samples also makes a compelling argument for their use.

Cross-classification analysis also has certain merits from the standpoint of updating. Home interview samples could be designed to cover selected cells in the cross-classification matrix to determine if changes were being properly accounted for.

F. SELECTED VARIABLES FOUND SIGNIFICANT IN URBAN TRANSPORTATION PLANNING

Variables	Weight given for use in trip generation analysis
1. Variables found significant in zonal trip generation analysis	
a. Demographic Data	
(1) Total population	1*
(2) Age, sex, race, etc.	3
(3) No. of household units	1
(4) School enrollment	2
(5) Family life cycle	3
b. Economic Data	
(1) Total employment	1
(2) Selected employment	1
(3) Employment by industry	3
(4) Employees by residence	1
(5) Labor force	3
(6) Labor force by occupation and industry	3
(7) Median income	1
(8) Income stratified	3
(9) Automobile ownership	1
(10) Dwellings without autos	2
(11) Retail sales	2
(12) Average home value	3
c. Land Use Data	
(1) Specific activities	3
(2) Selected categories	1
2. Variables found significant in dwelling unit trip generation analysis	
(1) Car ownership	1
(2) Family size	1
(3) No. of persons 5 years old, and over in household	1

(4)	Length of residence	3
(5)	Family income	2
(6)	No. of persons 16 years old and over	2
(7)	No. of persons 16 years old and over who drive	1
(8)	Age of head of the household	2
(9)	Distance from the CBD	3
(10)	Stage in the family life cycle	1
(11)	Occupation of head of household	1
(12)	Structure type	1

* Key to weights: 1 = Essential data; 2 = Desirable data; 3 = Useful data.

CHAPTER VI
MODAL SPLIT ANALYSIS

A. BACKGROUND

A procedure to estimate potential transit usage is one of the tools required to test transit proposals. Transit estimating procedures relate transit usage to factors which affect it, generally in some mathematical form such as an equation, curve, or surface. The relationships, or models, that have been developed by urban transportation studies were based on actual observed characteristics of travel within an urban area (primarily using O-D survey data) rather than on attitudinal survey data. The BMD statistical programs described in Chapter V are valuable in this analysis.

A detailed "Documentation of Nine Methods for Estimating Transit Usage" is available for 70¢ through the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402.

A mass transit planning system for the IBM System 360 has been developed under contract with the U.S. Department of Housing and Urban Development. The system consists of programs for (1) network analysis, (2) modal split model development and application, (3) passenger loading. Documentation is available from the clearinghouse for Federal Scientific and Technical Information for $6.00 (check or money order payable to "NBS-CFSTI." Request publication PB180-490 and PB 180-491. The address is:

Clearinghouse
U.S. Department of Commerce
Springfield, Virginia 22151

The Urban Mass Transit Administration (UMTA) will provide technical assistance for this series of programs. The programs are available either from UMTA or from the Urban Planning Division, FHWA. Requests can be sent to either agency and should include the same information as for URBAN1 requests (tape density), check for $40, if applicable, etc. See front of this document for method obtaining programs.

UMTA Contact: Mr. Robert Dial
Chief, New Systems Requirements Analysis Br.
UMTA
Washington, D. C. 20590

B. USE OF TRANSIT ESTIMATING PROCEDURES

Investments in transportation facilities are very expensive. Within the urban transportation planning process, it is important to estimate as accurately as possible, within the constraints of time and cost, the probable travel on various transportation system alternatives so that sound decisions can be made on which alternate to implement.

As part of this travel forecasting process, it is necessary to estimate the probable split of travel between the two major alternate modes; private automobile and public transportation. Transit estimating techniques are developed to serve this purpose.

The various combinations of highway and transit facilities are tested using these transit estimating techniques. It is through the use of these procedures that the number of transit riders for a particular combination of transit and highway facilities can be determined. In this manner, the effectiveness of alternate transit and highway proposals can be evaluated based on the number of persons attracted to the transit system and the number reduced from the highway system, or vice versa.

C. TYPES OF ESTIMATING PROCEDURES

Transit estimating procedures which have been developed within the urban transportation planning process can be grouped into three approaches:

1. Direct generation of transit trips
2. Trip end modal split models
3. Trip interchange modal split models

1. Direct Generation. This approach has been used extensively by small urban area transportation studies. Transit trips are generated directly, generally using regression equations. An example of this type of procedure is shown in Figure VI-1

Figure VI-2 shows where this type of transit estimating procedure fits into the travel forecasting process. When this approach is used, either auto-driver or total person productions and attractions are also generated. If auto-driver trip ends are generated, there would be no interrelationship developed between automobile and transit use estimates. If total person trip ends are generated, transit trips can be subtracted from total person trip ends to produce person trip productions and attractions by automobile. These automobile person trip ends are factored using automobile occupancy rates to produce auto-driver trip ends. The auto-driver and transit productions and attractions are distributed with separate gravity models and assigned to their respective networks.

2. Modal Split Models. Modal split models estimate the proportion of total travel to be carried by public transportation and the private automobile. This division is usually expressed as the percent of total person trips by transit. This approach has the advantage of producing more stable results because the percent of transit usage is multiplied times the forecast of total person travel.

a. Trip End Modal Split Models. Trip end modal split models estimate the proportion of productions and attractions (or origins and destinations) by public transit and

FIGURE VI-1

EXAMPLE OF EQUATIONS FOR DIRECT GENERATION OF TRANSIT TRIPS

TRIP PURPOSE	EQUATION
A. PRODUCTIONS	
1. Home-based work	27.7 + 0.02 Total Labor Force - 0.18 Automobiles + 11.9 Traveltime Difference
2. Home-based other	10.6 + 0.05 Total Population - 0.02 Total Income - .68 Buses Per Day
3. Nonhome -based	2.3 + 0.02 Total Population + 0.3 Total Employment -.08 Automobiles
B. ATTRACTIONS	
1. Home-based work	2.1 + 2.4 Total Employment + 0.40 Buses Per Day
2. Home-based other	0.5 + 1.3 Total Employment + 0.3 Total Population
3. Nonhome-based	2.3 + 0.02 Total Population + 0.3 Total Employment -0.8 Automobiles

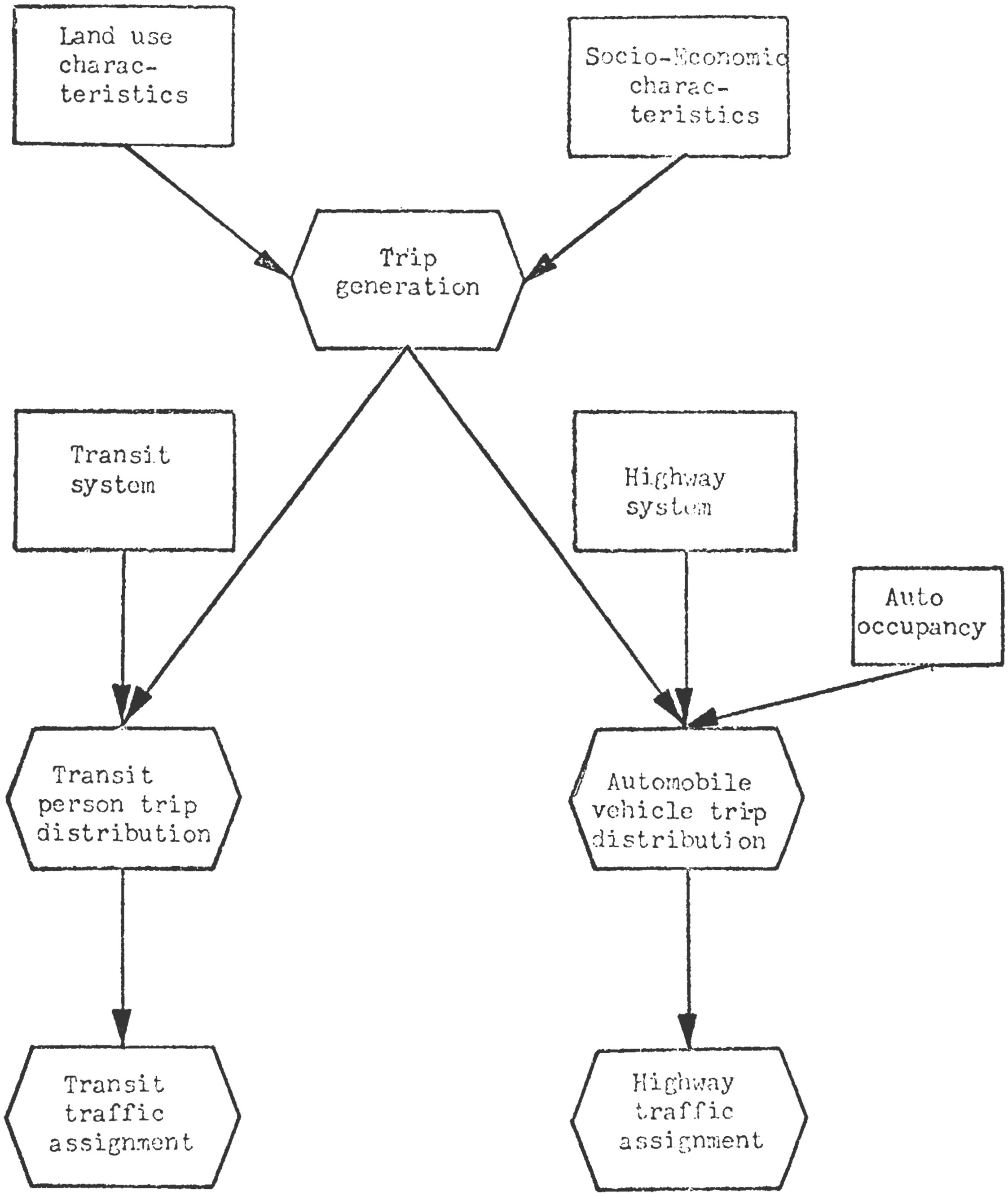


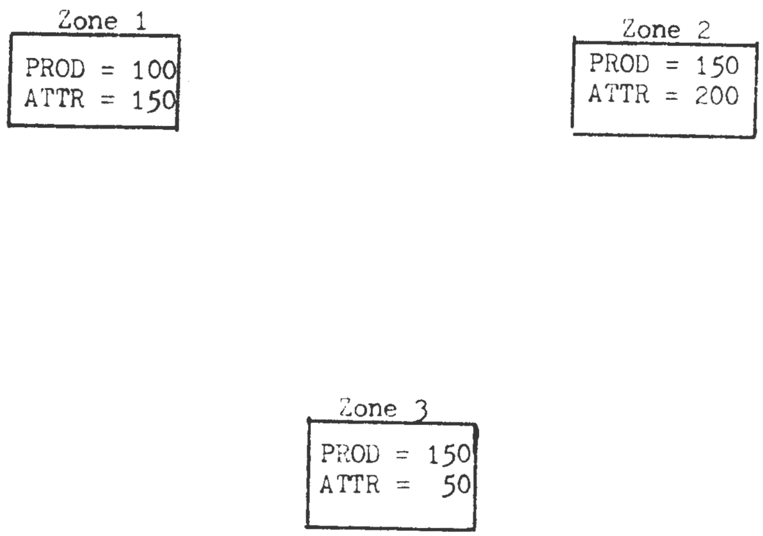
Figure VI-2 - Position of the direct generation approach in the travel forecasting process.

private automobile, prior to trip distribution. Figure VI-3 schematically illustrates how a trip end model operates. With the number of total person productions and attractions known, the trip end model calculates the percent that will be travelling by public transit and by private automobile. For example, for zone 2, the total person trip productions are 150 and attractions are 200. Six percent of the productions and 10 percent of the attractions will be on transit from the modal split model. Multiplying the values for percent transit by the total person productions, yields 9 transit productions and 141 automobile productions, and 20 transit attractions and 180 automobile attractions.

Figure VI-4 shows the position of a trip end modal split model in the travel forecasting process. First, total person trip productions and attractions are generated by purpose. Then, the proportion of productions and attractions by transit and automobile are determined from the modal split model. Automobile occupancy factors are applied to the automobile person trip productions and attractions to yield auto-driver productions and attractions. Transit and auto-driver trip ends are distributed using separate gravity models. Finally, the transit and auto-driver trip tables are assigned to their respective networks.

b. Trip interchange Modal Split Models. Trip interchange modal split models estimate the proportion of trip interchanges by public transit and private automobile. Figure VI-5 schematically illustrates how a trip interchange model operates. With the number of total person trips between zones known, the trip interchange model calculates the percent that will be travelling by public transit and private automobile. For example, from zone 2 to 3, there are 25 total person trips. Seven percent of these trips will be on transit as calculated by the modal split model. Multiplying the number of total person trips by the percent transit produces 2 trips by transit and 23 trips by automobile.

The position of trip interchange models in the travel forecasting process is shown in Figure VI-6. Using this approach, total person productions and attractions are generated by purpose, and distributed by gravity models,



ZONE	TYPE OF TRIP ENDS	NUMBER OF TOTAL PERSON TRIP ENDS	PERCENT BY TRANSIT	NUMBER OF TRIP ENDS	
				TRANSIT	AUTOMOBILE
1	PRODUCTIONS	100	8	8	92
	ATTRACTIONS	150	10	15	135
2	PRODUCTIONS	150	6	9	141
	ATTRACTIONS	200	10	20	180
3	PRODUCTIONS	150	8	12	138
	ATTRACTIONS	50	4	2	48
	TOTAL	800	9	66	734

FIGURE VI-3. Schematic illustration of a trip-end modal split model

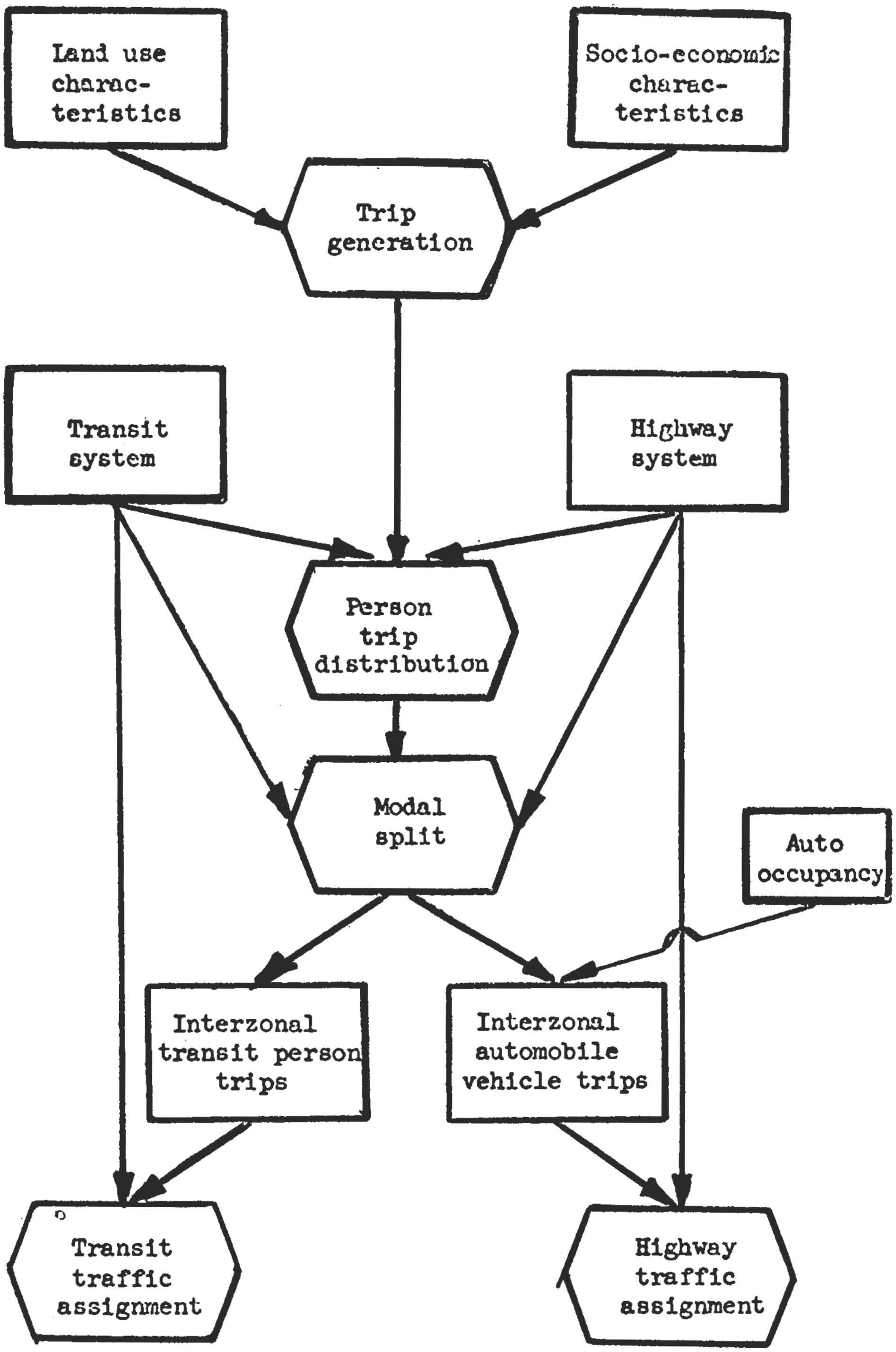
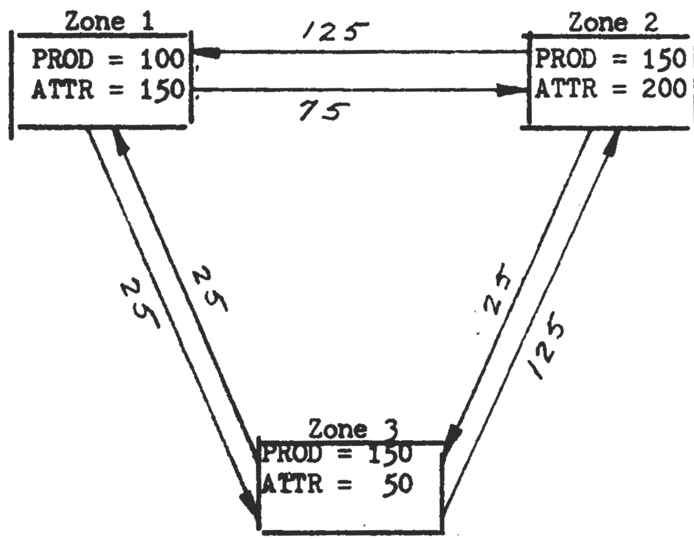


Figure VI-4.- Position of a Trip End Modal Split Model in the travel forecasting process



INTERCHANGE	NUMBER OF TOTAL PERSON TRIPS	PERCENT BY TRANSIT	NUMBER OF TRIPS	
			TRANSIT	AUTOMOBILE
1-2	75	9	7	68
1-3	25	6	2	23
2-1	125	8	10	115
2-3	25	7	2	23
3-1	25	9	2	23
3-2	125	9	11	114
TOTAL	400	9	34	366

Figure VI-5. - Schematic illustration of a trip-interchange modal split model usually using highway skim trees. The proportion of all trip interchanges by transit and automobile are calculated from the modal split model. Automobile occupancy factors are applied to the automobile person trip interchanges. The transit and auto-driver trip tables are then assigned to their respective networks.

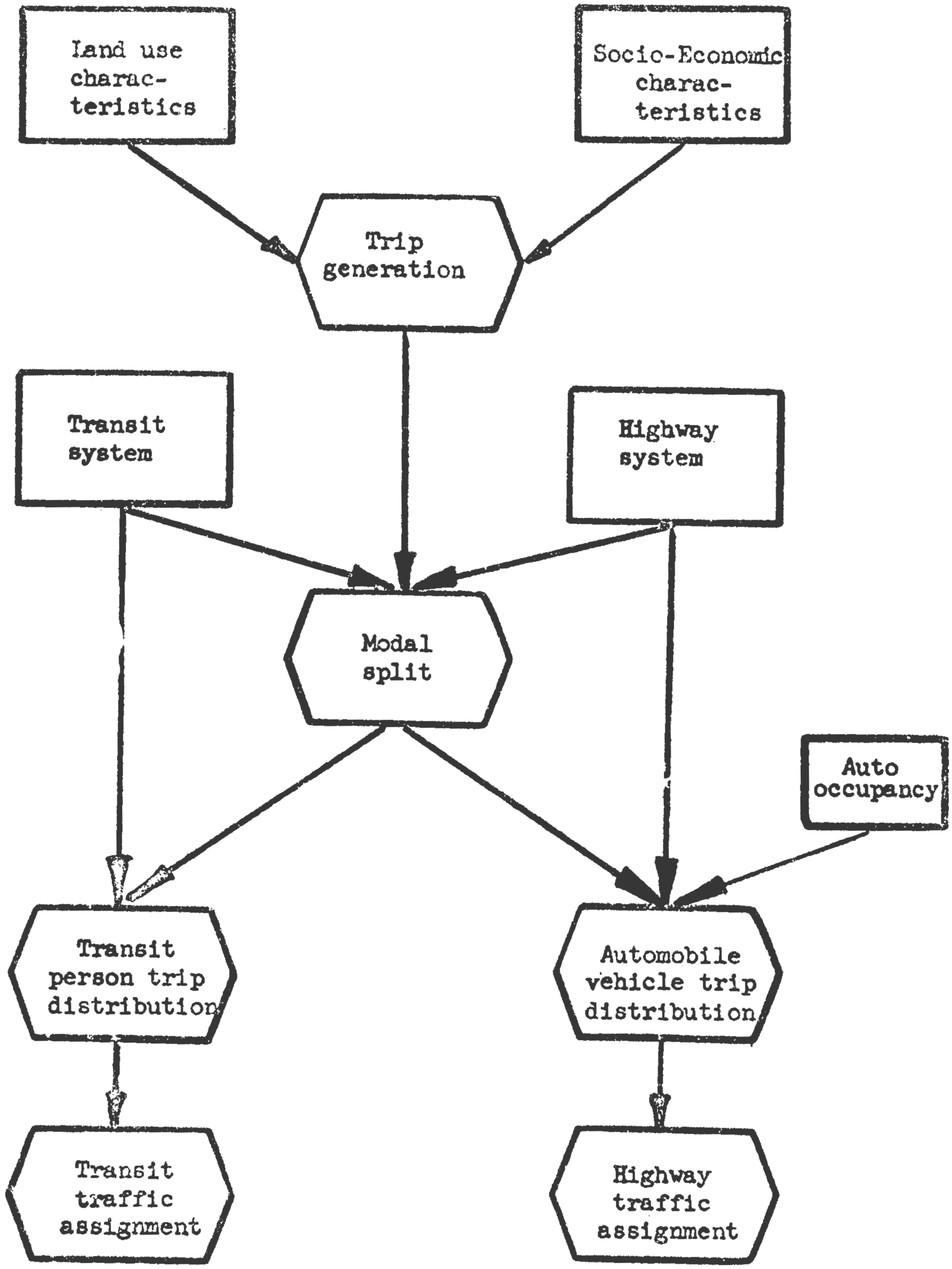


Figure VI-6 - Position of a trip interchange modal split model in the travel forecasting process.

D. VARIABLES USED IN TRANSIT ESTIMATING PROCEDURES

A large number of independent variables have been used in transit estimating procedures. These variables can be grouped into three categories:

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

Summarized in Figure VI-7 are the variables used most frequently in transit estimating procedures to describe the various characteristics of the trip, tripmaker and transportation system.

FIGURE VI-7

Variables most often used in transit estimating procedures

Trip Characteristics	Tripmaker Characteristics	Transportation System Characteristics
Trip purpose	Automobiles per household	Traveltime ratio
Orientation to CBD	Median income	Traveltime difference
Trip length	Residential density	Accessibility ratio
Time of day	Employment density	Parking cost
	Automobiles per person	Travel cost ratio
	Automobile availability	Travel cost difference
	Workers per household	Excess traveltime ratio
	Distance to CBD	Excess traveltime difference
		Accessibility index

FIGURE VI-8

General Factors Affecting Choice of Mode

University of Maryland Research Project

(Factors presented in order of importance)

Work Trip		Non-Work Trip	
Baltimore	Philadelphia	Baltimore	Philadelphia
1. Repairs	1. Reliability	1. Repairs	1. Reliability
2. Reliability	2. Travel time	2. Comfort	2. Weather
3. Speed	3. Weather	3. Cost	3. Convenience
4. Cost	4. Cost	4. Speed	4. Cost
5. Independence	5. State of vehicle	5. Independence	5. Travel time
6. Traffic	6. Unfamiliarity	6. Family & friends	6. State of vehicle
7. Age of vehicle	7. Self esteem	7. Traffic	7. Congestion
8. Family & friends	8. Diversions	8. Age of vehicle	8. Unfamiliarity
			9. Diversions
			10. Self esteem

E. VARIABLES AFFECTING TRANSIT USAGE

Transit estimating procedures as developed within the urban transportation planning process have been based on observed behavior. The largest body of data have been the origin-destination surveys conducted by all urban studies. These data have been analyzed to determine which variables had the greatest effect on transit usage in the base year and what this relationship was.

Another approach to determining the variables that affect on the use of transit is the use of attitudinal surveys. These surveys are based, not on observed behavior, but rather on persons being asked what their attitudes and opinions are concerning various subjects, in this instance, public transportation.

The University of Maryland conducted similar attitude studies in Baltimore and Philadelphia to determine what factors were important to transportation users and how each mode would be rated for each of these factors.

A factor analysis was performed to determine the general categories of factors that are important to transportation users. Figure VI-8 list these general factors based on Baltimore and Philadelphia data for work and non-work trips. The results indicate that reliability is more important than traveltime and cost for work trips, and that comfort and convenience are more important than cost and traveltime for non-work trips.

CHAPTER VII

SPECIAL ANALYSIS

A. INTRODUCTION

The Urban Planning S360 battery provides considerable special analysis capability in addition to the computer capability provided in the areas of traffic assignment, trip distribution, trip generation and modal split. The user of the system should not overlook the extensive capabilities in these special analysis areas. Capabilities are continuously added to the system. The special analysis programs conform to the hardware and software specifications described in Chapter VIII. For further information on the specifics of the programs, reference should be made to the document "Urban Planning System 360 - Program Documentation."

B. SELECTED LINK ANALYSIS

Program SELINK can examine a set of paths (PATHSO) and a trip table (TRIPSI) and determine which trips use certain links or pass through specified nodes in the network. A new trip table and/or a listing of these movements may be obtained as output. Options in the program allow for various types of analysis such as determination of:

1. trips that use certain links
2. weaving movements on specific links such as a bridge
3. trips that double or multi-cross screenlines
4. trips that enter, leave, or pass through selected areas such as a CBD
5. trips that use certain facilities such as a segment of freeway.

Several trip table data sets may be created from those trip movements that meet the selected criteria or pass through a specified number of links and/or nodes. A data set called EBCDIC can be created; it contains information about each trip movement that crosses each of the selected links and/or nodes. EBCDIC could be processed by special peripheral programs that could summarize various useful bits of information. An example would be a program that reads EBCDIC, along with a list of selected area zone numbers, and creates a new trip table for a sub-area. Links that cordon the sub-area could be recoded to act as external stations to the area.

An interesting application is to obtain a trip table of movements that use a certain facility under consideration and then load those trips onto a network without the facility. The loading results would show what effect the facility has upon the system. Loaded network summaries from assignments of these trips to both networks would reveal the savings in vehicle miles and hours, and through the use of an other program (LNKCOST), the actual cost savings.

Program LNKCOST allows the user to compute travel cost(s) for each link based upon the speed on the link, with the option of also considering the link's classification. There are two options available:

1 - Based upon a link's classification, the indicated cost curve is entered to obtain a word (cost value) for the A-B direction and a word for the B-A direction.

2 - Each curve is entered to obtain words (link costs) for the A-B and B-A direction. If five cost curves are present (maximum allowable), five words are obtained for each direction.

In either case, the cost obtained from the curve is multiplied by the link distance before the resultant value is inserted into the historical link record and a new historical record (HRO) is written out.

C. FUNCTIONAL ANALYSIS

To determine priorities for improvements, it is often necessary to analyze the network in many different ways. A relatively new approach has been to functionally classify network segments by their relative utility. One approach to this involves several steps as described in this section. Currently S 360 programs are available for all the steps. These steps are:

1. Obtain zone-to-zone travel distance along the minimum impedance path (use program SUMPED).

2. Multiply zone-to-zone distance table by the zone-to-zone trip table, resulting in zone-to-zone vehicle miles of travel (use program VEHMILE or TRPTAB).

3. Assign zone-to-zone VMT to network (use program LOADVN).

4. Run functional classification program FUNCLASS to create summaries of reports presented by different sort controls:

    a. Anode-Bnode
    b. Link distance
    c. Average length of trip on the link
    d. Link volume
    e. Vehicle trip length index (vehicle miles of travel crossing the link)
    f. Vehicle miles of travel (product of volume times distance)
    g. Any optional link parameter.

Each line will contain all the above items plus accumulative sums of some of the items and percentage of system total for certain other items. The reports will clearly depict which links are serving what type of traffic and should aid in setting priority schedules.

D. <u>SMALL AREA STUDIES</u>

It is often desireable to study, in detail, selected areas within a regional network. The selected area can be a CBD in a small or medium-sized study area or perhaps an entire community within a large regional study. The selected area usually will not have the network or trip detail that is desirable for the study.

Two possible approaches to this problem are described below. The first approach involves detailing the trips and network within the selected area, consolidating (compressing) the trips in the outlying areas, leaving the trips intact in the intermediate area and performing the analysis with this modified data. The second approach involves isolating the selected area with a cordon and detailing the trips and network for this area only. All trips outside the selected area are treated as "external" trips.

1. Approach 1

a. Detailing the Network

The entire regional network is retained intact except for the selected area. Within this area, the network is updated to provide the necessary detail. Retaining the entire network allows the planner to evaluate the effects of regional network changes on the selected area. The consolidation of trips in the outlying areas should greatly reduce the number of zones to be considered in the assignment step.

b. Modifying the Trip Table

The zonal system within the detail study area is usually not refined enough for detailed small area analysis. Therefore, the zones should be subdivided into smaller zones. The first step is to decide upon the boundaries of the new subzones. When this is accomplished, the steps involved in the trip generation process must be reviewed. The subzones are proportioned from the original zones based upon the major trip generation variables. When the subzones and their final proportion factors are determined the trip breakdown process can take place.

By the same reasoning, zones that are far removed from the study area are usually too detailed for small area analysis. For processing efficiency, they should be combined (compressed) into larger super-zones (districts). Zones in the intermediate area directly surrounding the detail area should be left intact.

Program TRPVERT is used to subdivide the zones in the small area, compress the outlying zones and leave the intermediate zones intact. The program will accomplish this task in one step and also insure that trips are not gained or lost. If the super-zones are selected properly, no network adjustment in the outlying areas will be necessary.

c. Assigning Trips to the Modified Network

This process follows the same patterns that are used on total study area networks. The basic difference lies in the level of detail that is used. Certain routing problems may arise due to the fineness in the network, but they are usually corrected by manual adjustments.

2. Approach 2

a. Isolating the Network

The usual process is to code a detailed network from scratch for the area. Program DONUT is available to extract a portion of a network from the study area network. This program reads a historical record data-set and a list of nodes which divides the input network into two parts, and prepares a new historical record composed of only the nodes in the specified portion. This extracted network can then be updated to provide additional detail.

A cordon line is drawn around the small area in such a way that it crosses all the network links that will allow access to or egress from the area. The outer nodes of the links that cross the cordon are renumbered to act as external stations. The network recoding allows for refinements of turning codes and the addition of more nodes and links to the study area. Of course, the zone centroids will also change. When the network is in proper shape, it is time to consider the trip matrix that will be used in the study. Since considerable work has gone into developing a study-wide forecasted trip matrix, that matrix should be used to the extent possible. The following steps are recommended to utilize it.

b. Obtaining Internal-External and Thru Trip

The next step is to prepare for a selected link run that will "trap" all the trips that pass through the selected links crossing the small area cordon line mentioned above. Care must be exercised so that all such links are used. Selected nodes - centroids in the CBD area - should also be specified. The program SELINK is then run using the total study trips and network. The EBCDIC option (option 1 on the OUTPUT control card) must be specified to obtain the data records of O-D movements that cross the cordon line. The EBCDIC data set will contain information showing the origin zone, destination zone and selected link (node) used for each movement. The SELINK O/P should have 2 EBCDIC records for each movement. If a movement passes through 3 or more selected links, the cordon is placed incorrectly.

A special program TRPCORD must be employed to process the EBCDIC file. The program outputs individual trip records for each necessary trip movement except intrazonal movements. (If required, TRPMOD can be used before going to step c.) The determination of the trip type (thru, int-ext, int-int, etc.) is made by examining the EBCDIC records. A selected link is an external station. A selected node is an internal zone. The dataset produced by TRPCORD can be processed by program TRPTAB to build small area trip tables.

c. Creating Subzones

Program TRPVERT is used to expand the "internal" zones of the small area trip table. The "external" zones remain intact. The criteria for determining proportion factors was discussed previously in section 1-b.

d. Assigning Trips to the Small Area Network

See previous section 1-c.

Both approaches discussed will provide meaningful results for small area analysis. The major advantage of the first technique is the ease with which regional network changes can be evaluated. The trip table must be modified(TRPVERT)only once. After that, only the network must be updated to evaluate the effect of regional improvements on the selected area. The second approach requires the selected link process (SELINK, TRPCORD, TRPTAB and TRPVERT) to develop a new small area trip table before the analysis can be performed.

E. SPIDERWEB NETWORKS

A spiderweb network is a simplified network of direct connections between centroids. It is used for analytical purposes including:

1. Preparation of trip desire line illustration. The assignment of trips to a spiderweb network results in volumes between centroid pairs that are routed on a path that is essentially a straight line. Figure VII-E-1 is an example of a spiderweb network with the volumes assigned indicated by band widths.

2. Comparison of trips across arbitrarily selected screenline. Since a spiderweb network usually contains significantly fewer links than a regular (traditional) assignment network, many assignments can be made inexpensively. In addition, the smaller number of links facilitates the addition of link volumes in determining the screenline crossings. This analysis can be utilized to load survey trips for comparison with actual ground counts in checking the accuracy of the survey volumes. Comparisons may be made of changes in screenline volumes resulting from changes in major facility locations.

3. Development of synthetic trip distribution models. The overall quality of a calibrated distribution model is often tested by assigning trips estimated by the model and trips from the origin-destination survey to the same spiderweb network and comparing the results both visually and statistically. The statistical tests are generally made with the COMPARE program which compares the loaded networks. The spiderweb network assignment is usually preferred to zone-to-zone or district-to-district trip comparisons since these trip comparisons do not allow any averaging of geographic or socio-economic bias.

4. Corridor Analysis. The spiderweb program for S360 was originally written for use in nationwide traffic assignments where counties are used as zones and the network connects centroids representing this zonal system. Assignments to such a network represent major corridor movements throughout the United States. Likewise, major corridor studies in urban areas can be accomplished.

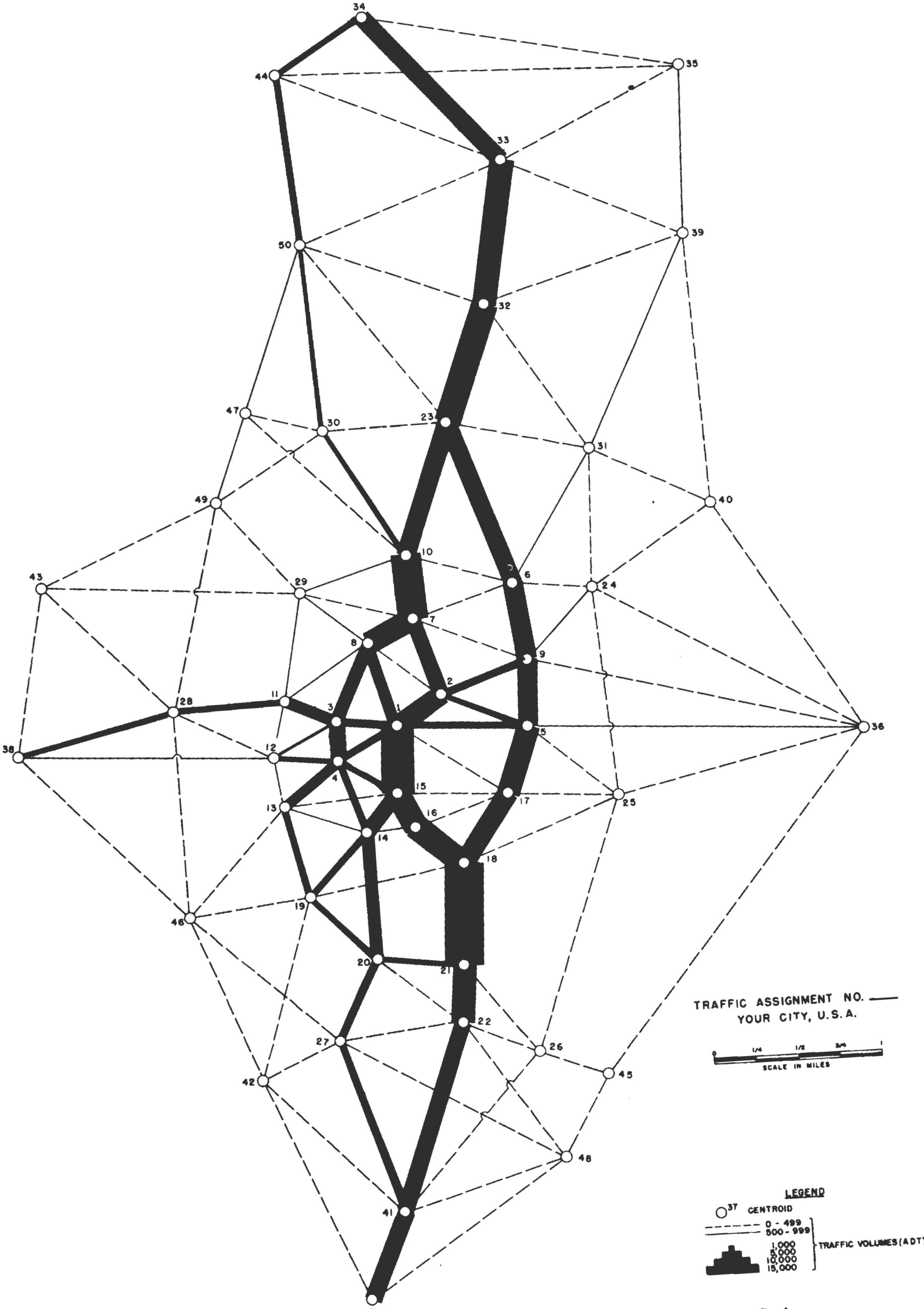


Figure VII-E-1 .--Loaded spider network map, Your City, U.S.A.

The programs used for spiderweb analyses include:

BLDSWB - Build Spiderweb Network Description
FMTSPWB - Format Spiderweb Network Description
BLDSPTR - Build Spiderweb Trees
FMTSPTR - Format Spiderweb Trees
LDSPWB - Load Spiderweb Network
FMTSPLD - Format Spiderweb Loads
REVSPWB - Revise Spiderweb Impedances

The interrelations between these programs in accomplishing spiderweb analysis are shown in Figure I-6. A short description of the purpose of each program follows:

<u>Build network record - spiderweb</u> (BLDSPWB)

This program was originally written to use in nationwide traffic assignment but appears to have equal merit in urban areas.

The input for this program requires the coordinates for each centroid in the area plus such additional description as desired by the user. In addition, an input of connector cards is required stating which centroids should be connected to each centroid. To minimize coding, only centroids connected to higher numbered centroids need be recorded. The program permits either a maximum of four connectors or eight connectors at each centroid.

From the coordinates and connectors, this program prepares a network and writes it out together with such additional information as included in the coordinate file as a network record very similar to a historical record.

<u>Build trees - spiderweb</u> (BLDSPTR)

This program uses the network record described above, as input and produces a tree file and/or a tree time file under user option. Since this is a spiderweb network with up to eight connectors, turn penalties and turning volumes are not provided. Due to the absence of turn requirements, the tree is basically one-fourth as long as the tree described in item 2, but due to the eight connectors, three bits are used to designate the leg number.

Load trees - spiderweb (LDSPWB)

This program requires as input the network record, the tree file, and a trip table. The output is an updated network record which includes the link volumes found in this program. The program is flexible as to zones that may be loaded. Options are provided for loading all zone-to-zone movements, selected origins to selected destinations, all origins to selected destinations or selected origins to all destinations.

Revise network impedances (REVSWB)

A spiderweb network inherently represents the desires of travel rather than the actual location on specific physical facilities. At the same time, the heterogeneous pattern of travel desires has a tendency to load all links with a somewhat uniform volume. Actual observations have repeatedly shown that travel is highly attracted to superior physical facilities - whether the improvement is due to alinement, grades, surface type, control of access, grade separations, safety features, capacity, design speed or operating speed. Many of these improvements, of course, are interrelated and in total form the design standards for the transportation system. Each of the improvements likewise involve substantial expenditures of limited public funds. The problem then resolves into one of deciding where the limited funds can be spent to accomplish the most good.

The basic algorithm of the assignment process selects the best route. Whether this best route is one that reflects one variable, such as time, or a summation of all variables is immaterial so long as all variables can be related to a common base. This program uses the concept that all of the variables are combined into a common base called impedance.

Starting at the beginning, it follows that the greatest single improvement in a transportation system can be made by reducing the impedance on the most heavily traveled route. However, there is a practical limit to the amount of improvement that is feasible for a particular traffic volume. Therefore, for the particular area under consideration, an impedance standard can be set for various traffic volume levels. To discourage abnormally high volumes, the impedances can also be raised progressively for volumes over a specified level. The relationship is assumed to be continuous over the full range of volumes.

This program revises the impedance on each link commensurate with user criteria established. These impedances are used by the other spiderweb programs to establish new routings and loads until stability is established. This procedure has the inherent quality of maximum effectiveness based on the criteria used.

Format spiderweb network description (FMTSPWB)

This program provides a standard format of a spiderweb network description as initially built by BLDSPWB or subsequently updated by REVSPWB.

Format spiderweb trees (FMTSPTR)

This program provides a standard format of spiderweb trees.

Format spiderweb loads (FMTSPLD)

This program provides a standard format of spiderweb loads.

F. GRAPHICAL DISPLAY

Traditionally, a tremendous expenditure of man-power has been necessary to prepare a network for analysis purposes. This time has been spent manually reviewing network print-outs and maps. Further time has been spent manually plotting minimum path trees to establish the reasonableness of the coding. This "hand" approach, although cumbersome and error prone, has proven satisfactory within the size constraints imposed by second generation hardware and software.

The introduction of urban planning system 360 has raised the limitations on network size to a point where manual methods of displaying networks, paths and assignment results may become prohibitive. A series of programs are included in the battery to produce plots on a CALCOMP drum or flatbed plotter. These programs are quite flexible, allowing the user to specify scale, physical plotter size, number of plates to be plotted and the manner in which the information is plotted. The programs can also be used on other digital plotters providing their software is compatable with that of CALCOMP.

1. Initial Considerations

The potential user should decide early in the study development whether he will utilize the automatic plotting features of the battery. Although x-y coordinates can be coded and inserted into the historical record at any point in the process, considerable time and cost savings will result if coordinates are obtained during the network coding phase. The programs that generate the off-line input to a CALCOMP plotter require special CALCOMP subroutines (PLOT, SYMBOL, NUMBER). The user should be sure he will have access to these subroutines at the computer installation he is utilizing. They are not included in the planning battery since they vary depending on both computer system and plotter model and because they are proprietary. Usually, an installation that has a CALCOMP plotter will also have the necessary CALCOMP subroutines.

2. Use of the Plotting Programs

Data plotting within the urban planning battery is accomplished in three phases:

a. Insertion of coordinates in the historical record (GESERT) - The main function of GESERT is to insert or update coordinates in a traditional historical record. This is accomplished by providing a deck of coordinate cards for each node in the historical record. Coordinate card format is at the user's discretion. Output of this program consists of an updated historical record and a node coordinate listing. This phase is not necessary for spider networks since coordinates are initially part of the network coding.

b. Preparation program (GEPREP) - GEPREP is an intermediate program in the plotting system. It accepts networks or trees/vines and arranges links in an efficient manner for plotting. Many options are available to the user at this point such as: plotting of range values in different colors; annotation of plotted links with one or two variable data fields, such as volume, speed, distance, etc. The standard format dataset (PREPO) produced by GEPREP is the input for programs GECBWP or GEPLOT which generate the actual tape to drive the CALCOMP plotter.

c. Generation of plot tape (GEPLOT or GECBWP)GEPLOT reads the PREPO dataset from GEPREP and produces single line graphic displays of the information contained therein. The study area or portion thereof may be plotted on as many plates as required based on desired scale and plotter size limitations. The data on a GEPLOT or GECBWP output tape is arranged in sequentially numbered blocks. Multi-color plots will result in more than 1 block per plate so that individual passes of the plotter can be made with the specified colors.

GECBWP is the companion program to GEPLOT. It operates basically the same as GEPLOT but has the ability to generate bandwidth displays. These displays are especially useful where traffic flow maps are needed.

GEALPHA is also used to generate CALCOMP plots. This program plots specified symbols at a given point with alphanumeric annotation. Input to this program is a deck of fixed format data cards describing points, symbols and annotations to be plotted. Multiple plates can be generated in a single running of the program. A useful application of GEALPHA is to plot zone centroids preparatory to coding a spiderweb network.

G. STATE/COUNTY DATABANK

The State/County Databank is a set of coordinates describing the outline of all states and counties in the Continental United States (Alaska and Hawaii are not yet digitized). However, the District of Columbia is also included, resulting in 49 "states". The purpose of the Databank is to allow complete or selective plotting of state and/or county boundaries for the 48 continental states and the District of Columbia. Programs are available to allow plotting of these data on CALCOMP plotting equipment.

1. Plotting Programs

At present there are five programs which manipulate these data. They are:

COPLOT: the plotting program which is capable of plotting any combination of states and/or counties either in Albers Equal Area or Lambert Conformal projections. This program must be link-edited (as GEPLOT is) in order to obtain the necessary CALCOMP plotting routines.

COAREA: to calculate any county or state area in square miles either in Albers Equal Area or Lambert Conformal projections.

COUPDT: to update (add, delete, or change) databank points for greater accuracy.

COFMT: to format databank points for any point, line, county, or state (or any combination) in order to inspect and/or update the values. Also to punch the coordinates.

COCOPY: to copy the databank or any portion for more efficient local use. Also to merge multiple data files (useful after updating).

The programs are in PLANPAC and the documentation is included in the Documentation Manual. The State/County Databank is available on request. The same instructions apply as for obtaining a tape copy of the PLANPAC battery. (See page ii) However, the tape length required is 300 feet or more.

If the Databank and the program source decks are required (assuming the user has not already obtained or does not plan to obtain the urban planning battery), then this should be pointed out in the requesting letter. The source decks will be copied to file 2 of your tape.

It is requested that when a state or some other agency updates the databank, and the results more accurately define a state or any of its counties, a copy of the update be sent to the Federal Highway Administration for possible inclusion in the FHWA master file.

It should be noted that adjacent states may not always arrive at the same coordinate values for points lying along the state line. Each state now contains identical points along the adjacent state lines. Should one state be changed, and the adjacent state left alone, then a plot of both states together would show errors (double lines) in the changed areas. We suggest contacting the pertinent office(s) in the adjoining state to see if any updating of a particular portion of this databank has already been done. Coordination of effort is highly recommended.

Figure VII-G-1 shows a plot of all of the data in the databank. It was done using COPLOT with the ALBERS projection parameter as noted in the documentation. The actual size plotted was 5.5" in the vertical (y) direction as the control rather than an actual scale.

When using the databank all coordinate pairs should be multiplied by 57.2958 to obtain latitudes and longitudes since coordinate values are in radian units. Also, because of the great importance of positional pointers in the databank, extreme care should be taken not to expand or contract any of the arrays, except with program COUPDT which would result in a useless databank.

2. Databank Organization

The points in the databank are divided into three classifications. The first is the internal county inter-

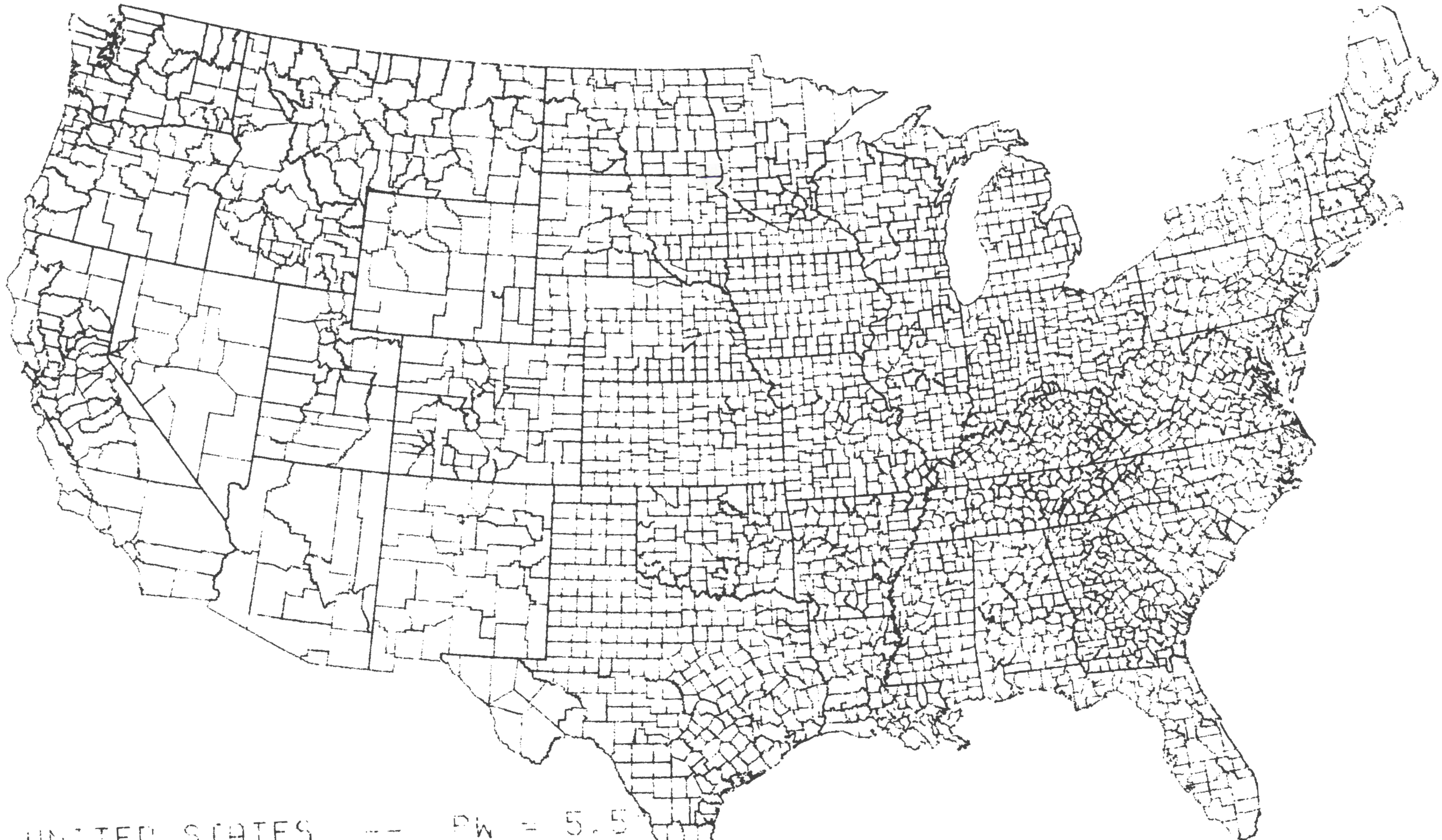


Figure VII - G-1

section points which define intersections of three or more county lines. This grouping does not include any points which lie on state boundaries, even though there may be places where county lines meet.

The second classification is the state boundary points. These points trace the outline of the state, and may also serve as county line segment end points for counties lying on the state border.

The last grouping is the intermediate points between internal intersection points and/or state boundary points. Since most county lines are not straight, points were digitized along the county lines and/or state boundaries between intersection points in order to preserve the county or state border shape.

The latitude and longitude coordinates of the points are contained in the X and Y arrays. The first NST entries in the arrays are the internal intersection points. The next NBD entries are the state boundary points. The remaining entries are the intermediate points, arranged in sequential strings in such a way as to define a county line or state boundary segment.

The point strings are accessed by means of arrays A and B. The arrays provide pointers for locating, in the X and Y arrays, the intermediate sequences for any pair of line segment end points.

The databank also contains arrays COUNTY and NSQ which, for every county in the state, give the sequence of internal intersection points and state boundary points needed to outline that county.

3. Description of Arrays

The following discussion of the logical organization of the databank references the sample state/county map shown in Figure VII-G-2. Words in upper case letters are data element or array names, and are defined in CHAPTER VIII Section D (Part 9) under the heading "Array or Variable Name". This section also describes the format of the databank.

State Number K

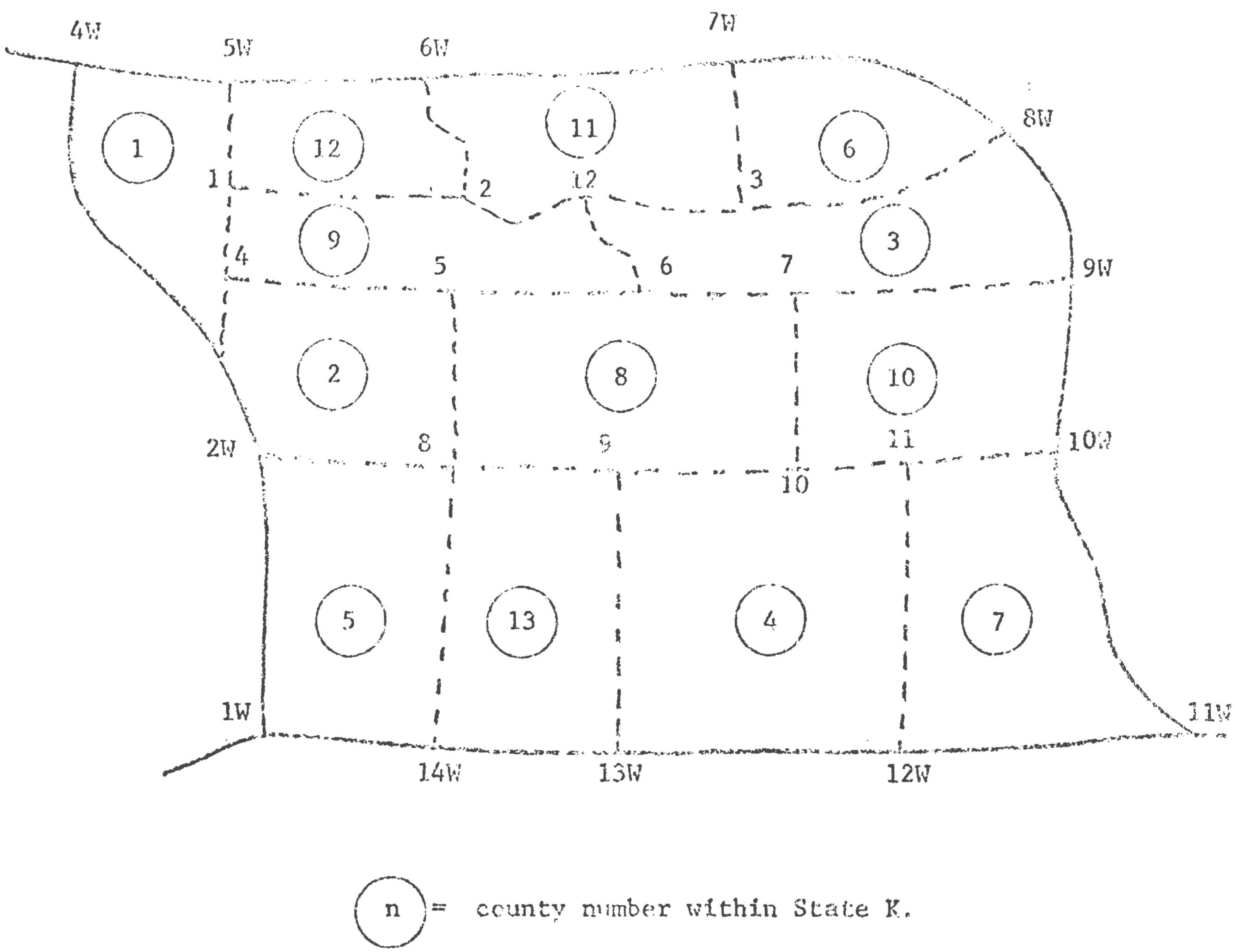


Figure VII-C-2

Arrays X and Y, the latitudes and longitudes.

These arrays contain the coordinates, in radians, for all digitized points in the state. The sample state K has 12 internal intersection points, designated by numeric values 1 through 12. The coordinates of these points are contained in entries X(1),Y(1) through X(12),Y(12) of the arrays.

The state boundary points were designated on the 12 submaps from which the digitizing was done by alphanumeric names. For inclusion in the databank, the names were converted to a purely numeric numbering sequence. In the example, the state boundary is outlined by 14 points, 1W through 14W. These were entered into the databank as coordinate pairs X(13), Y(13) through X(26),Y(26). The array subscript has become the databank point number for the digitized point name.

The remaining entries, X(27),Y(27) through X(LXY),Y(LXY), are the coordinates for the sequential point strings which define irregular county or state boundary segments. The strings are accessible through arrays A and B, to be described below.

Arrays COUNTY and NSQ provide information for selection of appropriate internal intersection and state boundary points to outline the counties.

The COUNTY array contains three values for each county in a state. The ordering of the counties within the array is determined by the aforementioned national county sequencing scheme (see word 10, Logical Record 1). Counties are numbered by a non-unique, individual state numbering system, i.e., they are sequenced from one to NCT, the number of counties. The national sequence designates every county with a unique number, so that any county can be identified without regard to its state. The national sequence is arbitrary, and does not reflect the individual state's ordering of counties.

For example, if the highest national county number for state K-1 was 1100, in state K county number 5 might have been designated as national county 1101. Furthermore, a county's position in the COUNTY array implicity defines its national sequence number, i.e., County 5 would be the first entry in array COUNTY.

The three word grouping for array COUNTY is as follows:

COUNTY(I,1) = State county number; the national county number is defined as LAST+I.

COUNTY(I,2) = Pointer for entrance into the NSQ array which gives the location (NSQ(COUNTY(I,2))) of the first county or state border intersection point needed to outline this county.

COUNTY(I,3) = Number of consecutive NSQ entries needed to outline this county, beginning with NSQ(COUNTY (I,2)).

As an example, consider County 12 of state K and the following hypothetical array segments:

COUNTY (5,1) = 12	NSQ (12) = 1
COUNTY (5,2) = 12	NSQ (13) = 17
COUNTY (5,3) = 4	NSQ (14) = 18
	NSQ (15) = 2

Data element LAST, the highest national county number for state number K-1, was defined as 1100. Since the fifth entry in the COUNTY array, I=5, is being dealt with, this county is national county LAST+5=1105. From COUNTY (5,1)=12, the county is also designated as state county number 12.

The second word, COUNTY (5,2) =12, points to entry number 12 in the NSQ array and the value NSQ (12)=1 gives the first internal intersection or state boundary point needed to outline this county.

Finally, COUNTY (5,3)=4 denotes that four sequential NSQ entries, beginning with NSQ (12) are needed to outline this county. The entries NSQ (12) thru NSQ (15) are databank points 1, 17, 18, and 2, representing digitized points 1, 5W, 6W, and 2 respectively. Hence, the intersection point coordinates needed for this county are:

X(1),Y(1)
X(17),Y(17)
X(18),Y(18)
X(2),Y(2)

If these intersection points were simply connected with straight lines a distortion of the actual shape of county 12 would occur since not all the actual lines are straight. To eliminate this problem, intermediate points were digitized along irregular county lines and state boundaries. The A and B arrays are used to identify these cases, and they will be discussed in the next section.

When tracing the state boundary only, it is important to note that the state boundary points are so arranged in the databank as to outline the state in a clockwise direction beginning, usually, in the lower left hand corner of the state. In the example, entries X(13),Y(13) through X(26), Y(26) give the coordinates of the state boundary points in the proper sequence. The boundary segment end point pairs must be examined by means of arrays A and B to determine whether intermediate points were digitized. However, the COUNTY array need not be used for state outline purposes, thus saving processing time.

Arrays A and B

The function of these arrays will be described by using the irregular line segment between digitized points 6W and 2 as an example. All line-segment end point pairs are always dealt with as low-high pairs. Since digitized point 6W is databank point 18, i.e., the 18th point by position, this pair is considered from points 2 to 18. The low point number is used as a pointer into array A. In order to determine whether a string of intermediate points was coded for this segment, the value of A(2) must be examined. If such a string exists, it is in the order of progression along the line from low to high numbered end point.

The simplest case would be if A(2) equaled minus one. A code of minus one means that no intermediate points were coded between point two and any other intersection point (although the user would be required to check any end point pair where two is the high number), and the points would be joined by a straight line.

For the second case, consider these sample values,

A(2)=78	B(78,1)12;B(78,2)=100
A(3)=-1	B(79,1)=18;B(79,2)=109
A(4)=80	B(80,1)=16;B(80,2)= 113

Since A(2) does not equal minus one, point two is connected to at least one other internal intersection or state boundary point by means of intermediate points. It remains to be determined whether point 18 is such a point.

The exact number of points connected to point 2 in this manner is determined from the A array by taking the difference between the A entry in question and the next non-zero entry. As given above, A(2) equals 78 and a search of the array gives A(4)=80 as the next non-zero entry. Thus the difference A(4)-A(2)=80-78=2 determines that point two is connected to two other intersection points by intermediate points.

The number of points (2) also tells us the number of consecutive entries in the B array which must be examined for point numbers. The B array contains, for any entry I, two values: B(I,1) which equals the first point number in the intermediate string. The number of points in the string equals B(I+1,2)-B(I,2).

The value of A(2), namely 78, gives the first of the string of B entries related to point two, B(78,1). Since two consecutive B entries are related to point two, B(79,1) must also be considered.

Examining B(78,1) and B(79,1), 12 and 18 respectively, it is determined that two and 18 are indeed joined by intermediate coordinates.

Since B(79,2) equals 109, the first coordinate pair in the intermediate string is X(109),Y(109). To determine the number of intermediate points in the string, take the difference B(80,2)-B(79,2)=113-109=4. The intermediate string is composed of coordinates X(109),Y(109) through X(112),Y(112), and the county line segment may now to traced by joining points X(2),Y(2),X(109),Y(109) through X(112),Y(112) and X(18),Y(18) in that order.

In the same way, all other pairs of intersection points are examined when a county is being outlined. The method is also used for connections between state boundary points. For example, intermediate points between points 9W and 10W could be obtained by examining the low-high pair 21-22.

H. PARKING ANALYSIS

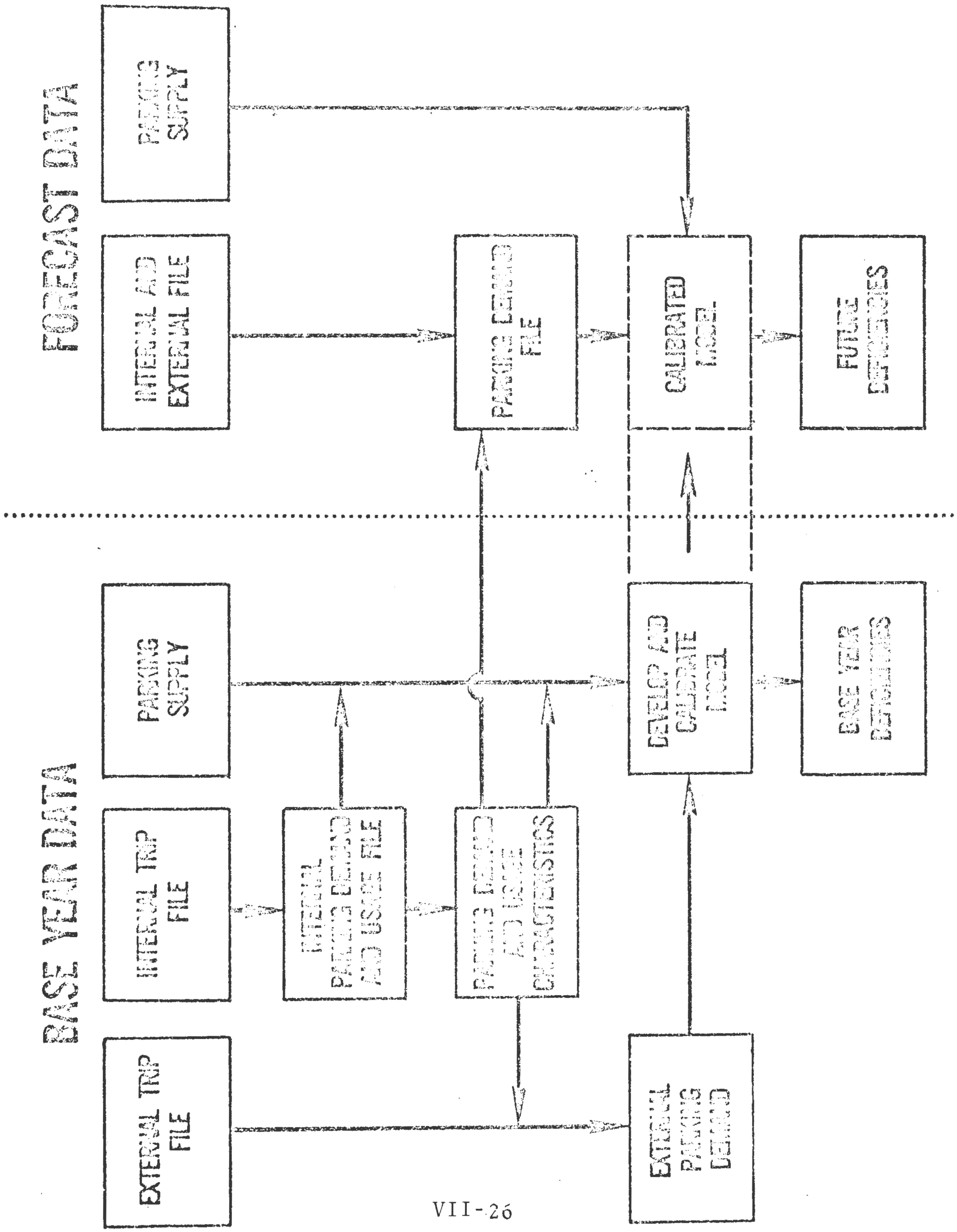
1. Background. The Urban Planning System 360 contains a series of programs for analyzing and forecasting parking demand in urban areas utilizing origin-destination survey data. The programs link consecutive trips to create a parking demand file containing information similar to that obtained by a parking interview procedure. The file is then used to create tables of parking characteristics. The level of geographic and other stratification of the tables is quite flexible within the limitations of the data set used.

A complete parking supply inventory is required. It is quite possible, however, that this is the only information that must be collected on the street. Some cities collect and maintain parking supply information on a continuing basis. In any event, the collection of supply information is a minor item compared to the cost of parking interviews, accumulation counts, turnover studies, and cordon surveys which can be eliminated by the use of O-D data.

While the parking programs have specifically provided for the use of O-D data, they are flexible and can readily be used to process conventional parking study information in non-standard formats.

As with conventional parking studies, the new analysis involves utilization of two basic data sets--the base year data and the forecast data. Figure VII-H-1 briefly outlines the steps in processing the data. The analysis begins with the three base year data files--the external trip file, the internal trip file (home interview survey) and the parking supply file. The internal trip file is the data set that contains most of the parking data, therefore, it is processed first. The trip cards are sorted and processed through a linking routine, thereby creating the internal parking demand file. This file is summarized, creating tables which define the internal parking demand and parking characteristics. These characteristics are then used to transform the external trip file into an external parking demand file. The merging of these two files results in the base year parking demand data set.

FIGURE VII-H-1



Having defined the parking demand file, the next step involves the distribution of this demand to the available supply. This involves use of a special distribution model which has been developed for this purpose. However, as with other transportation models, this distribution model first must be defined and calibrated. Once the model has been calibrated, the base year data can be analyzed and existing deficiencies noted using program ALOCAT.

One of the major objectives in the development of this new procedure was to provide reports that would be more useful to those individuals who make the decisions concerning development of parking programs. Therefore, the reporting function of the distribution model is such that it will indicate the general location of the deficiency, the magnitude of the deficiency, whether the deficiency results from the need for additional long or short duration parking, and the time that the deficiency occurs. Having this detailed information, a short range or immediate action parking program can be developed.

Next, the forecast data is analyzed. This data consists of the forecasted trip-ends and parking supply. This may be the existing supply or an estimate of the future parking supply. The forecasted trip-ends are transformed into a future parking demand file through use of the characteristics developed for the base year. The parking demand and supply are then analyzed using the calibrated distribution model. A report similar to that of the base year is created and the long range parking program developed.

2. Elements of the Program System.

To analyze the O-D data as previously described, a system of eight special programs have been developed to process and analyze the data sets. These programs are:

PRKLINK - edits and links successive person trips TO and FROM a given area.

PRKUPDT - allows corrections of errors in the basic trip files.

PRKTAB - summarizes and tabulates data in a matrix form. (Samples of output of PRKTAB appear later in the text.)

EXPAND - formats data for regression analysis or tabulation.

MODPARK -merges and factors data sets.

PRKPRIN - formats records produced by PRKLINK and TRPCODE

ALOCAT - distributes parking demand to supply based on input parameters

In general the program system operates as shown in Figure VII-H-2.

<u>Preliminary process</u> (not shown on Figure VII-H-2)

The sorted internal trip file is obtained by using TRPCODE to: recode alphabetics (none of the programs described below accept alphabetics), recode other numberic survey codes and sort the data. The use of TRPCODE is strongly recommended for the following reasons: (1) items in the "standard" output file can be referenced by name only (i.e. ORGZN, DESTZN, PURP), thus relieving the user from the task of specifying column definitions; (2) invalid data (alphabetics) is not present to cause errors in subsequent programs; (3) processing efficiency is increased in other programs.

<u>Step 1</u>

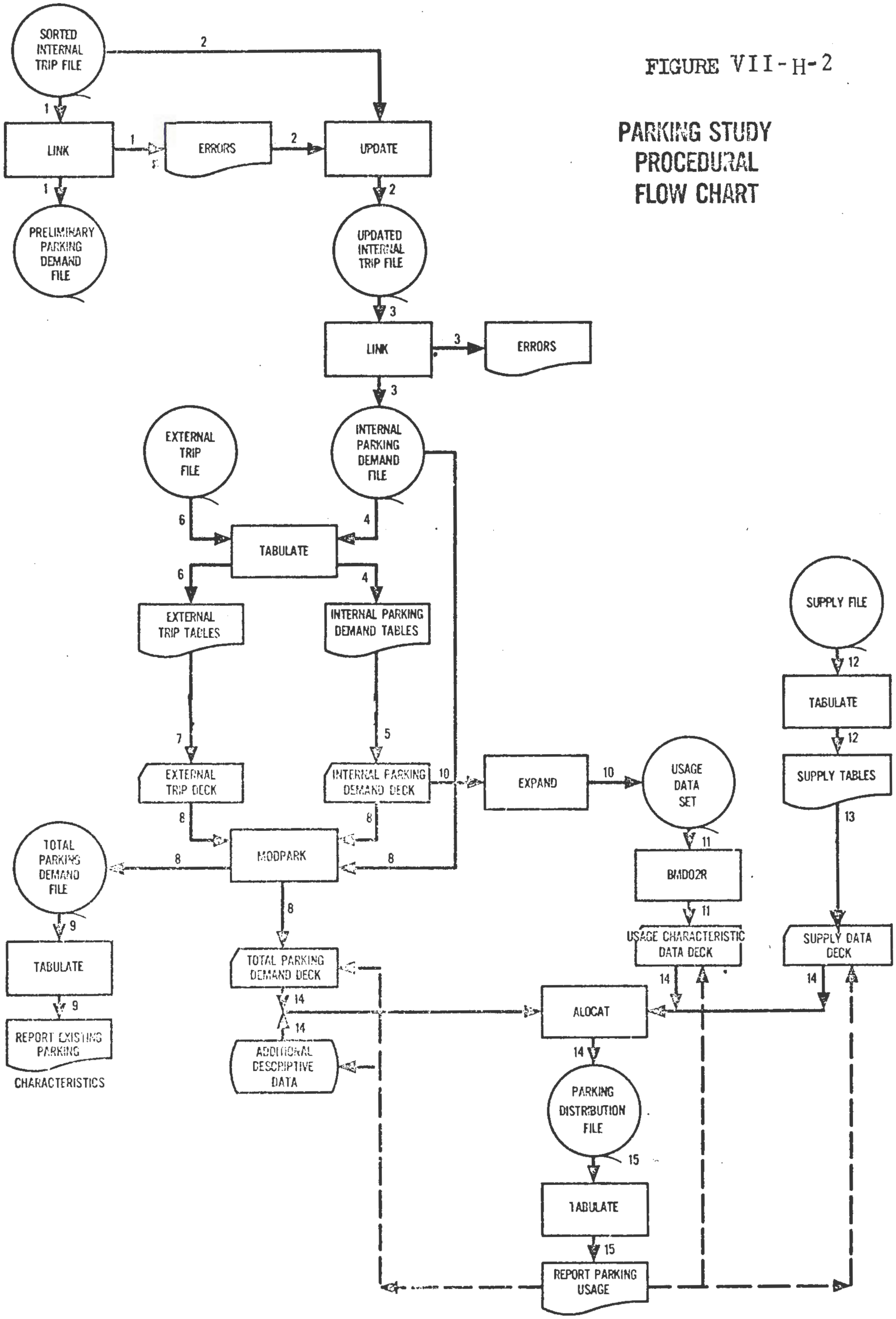
The sorted internal trip file is processed through the PRKLINK program, creating the preliminary parking record file and a list of data errors. Inputs to this program include definition of the input data, definition of the variables which identify the trips and the tripmaker, and definition of the CBD zones. The error listing indicates data collection, coding or punching errors observed in the input file which prohibit the linking of certain records.

<u>Step 2 - 3</u>

Errors in the input data are resolved through use of program PRKUPDT. The corrections are appropriately coded on operation cards and processed with the original tape through the program. An updated internal trip file is produced which is then processed through the PRKLINK program, producing the final internal parking record file.

FIGURE VII-H-2

PARKING STUDY PROCEDURAL FLOW CHART



Step 4 - 5

The parking demand file is processed through the PRKTAB program which summarizes the internal parking data in the form required to process the external trip file. A data deck is produced which is used for further processing.

Step 6 - 7

The external trip file is processed through PRKTAB which summarizes the external trip file in the form needed for adding the external trips to the internal parking demand file. A data deck is produced which is used for further processing.

Step 8

The internal parking demand deck produced in Step 5 and the external trip deck produced in Step 7 are processed through the MODPARK program which merges the decks and produces a total parking demand data deck needed for further processing. Simultaneously, the internal parking demand file tape can also be processed and an updated total parking demand file tape produced.

Step 9

The parking demand file produced in Step 8 can be processed through PRKTAB to produce all desired summaries of parking characteristics.

Step 10

One of the data sets produced by Steps 4 and 5 contains information on those variables which reflect the trade-off between walking distance or time and parking cost. This data set is processed through the EXPAND program which produces a data file needed to further process the trade-off relationships.

Step 11

The data file produced in Step 10 is processed through the biomedical Computer program--Multiple Linear Regression (BMDO2R)--which develops the statistical relationships between time and cost which are utilized in the distribution model.

Step 12 - 13

The base year supply data is processed through PRKTAB which summarized the data as needed. A data deck required for further processing is produced.

Step 14

The demand data (Step 8), the time-cost relationship (Step 11), the supply data (Step 13), and other necessary input data are processed through the ALOCAT program which distributes the demand to the supply. The additional input data includes parking costs, parking time restriction, time separation between generators and parking facilities, and other facility characteristics such as queueing time, attendent parking, etc.

Step 15

The output tape from Step 14 is processed through PRKTAB, producing the desired tabular summaries. The initial tables produced would be those for comparison of the synthesized data and the base year data. Based on these comparisons appropriate revisions are made in the input parameters to Step 14 and ALOCAT rerun. This iterative procedure continues until satisfactory calibration is achieved. At this point PRKTAB produces the final reports.

3. The ALOCAT Model

Program ALOCAT will provide one of the major innovations in the parking technology. In previous parking studies, supply and demand were analyzed by block through comparison of total parking activity for the study period (usually 8 or

10 hours) and total supply available in that period, or through comparison of total parking activity for the peak hour and total supply available in that hour. This analysis results in a block-by-block determination of parking surplus or deficiencies. To account for the known fact that parkers do not necessarily park in the block of trip destination, the individual deficiencies are arbitrarily assigned by hand to surplus in adjacent blocks. The report which results contains information on the total number of spaces required to satisfy the deficiency in the block.

ALOCAT is designed to provide a dynamic, iterative distribution procedure which distributes an increment of parking demand to the available supply based on the characteristics of the parking demand, the user, and available parking facilities. Possible user and demand characteristics include origin of trip, destination of the trip, arrival time, purpose, duration and socio-economic level of the trip maker. Possible supply characteristics include location with respect to demand generators, number of spaces, time restrictions and fee structure.

I. CROSS TABULATION

The ability to summarize survey data in a meaningful fashion is extremely important, especially early in the analysis phase of a transportation study. Information obtained from these tabulations can be used to determine: trip purpose relationships (trip distribution & generation), travel by mode (modal split), travel by time of day (peak hour analysis), travel by area (CBD-non-CBD) or land use (land use models).

The tabulation program included in the urban planning battery (PRKTAB) can generate up to 20 tables in a single pass of the data. It accepts numerical data (in any order) in the standard binary format produced by programs TRPCODE or PRKLINK or EBCDIC data in any format. The user has almost complete freedom to define the types of tabulations he desires. If the program is used for parking data analysis, provision is made for automatically producing parking accumulation summaries.

The user has the following options available when using PRKTAB for general tabulations:

(1) specification of the field to be tabulated or a frequency count.

(2) specification of the scaling to be performed on the input data and the number of decimal places to be printed on the output.

(3) Specification of criteria which a record must meet before it can be considered for inclusion in any table.

(4) specification of up to 5 row variables and up to 2 column variables within the constraints of a print line.

(5) inclusion of individual table headings

(6) generation of the following for each table specified

(a) a table of the percentage of each item to its row total.

(b) percentage of each item to its column total.

(c) percentage of each item to its table total.

(d) weighted average for each row.

(e) weighted average for each column.

The exact number and size of the tables that can be produced is governed by the amount of core storage available at execution time.

The following example shows the type of tabulation that can be produced by PRKTAB

YOUR CITY TRIP CHARACTERISTICS CBD-NON-CBD
PURPOSE BY MODE

	CBD			NON			
	MODE			MODE			TOTAL
PURPOSE	1	2	3	1	2	3	
1-1							
2-2							
3-3							
4-7							
8-9							
TOTAL							

Alternately, numeric codes and ranges can be replaced by alpha names

	CBD			NON			
	MODE			MODE			TOTAL
PURPOSE	AUTO	TRAN	WALK	AUTO	TRAN	WALK	
WORK							
SHOP							
SCHL							
OTHR							
NHB							
TOTAL							

J. CAPACITY ANALYSIS

The Urban Planning System 360 battery contains a series of programs for performing capacity analysis. All calculations are based upon the 1965 Highway Capacity Manual. The programs are:

CAPFREE - Performs a capacity analysis of freeways, undivided multi-lane rural highways, and two lane highways. The program can be used to calculate service volume, number of lanes, or level of service.

CAPINT - Performs a capacity calculation for signalized intersections. The program computes either service volume, approach width, load factor or G/C ratio.

CAPINTR - This program computes service volumes only for the signalized intersection approaches at both ends of a link

CAPRAMP - This program will solve for either ramp service volume or level of service for an individual single lane ramp. One of the two methods for solving for ramp capacity presented in the 1965 highway capacity manual is used depending upon level of service. Provision is made for handling an upstream and/or downstream ramp where the existence of such additional ramps would affect the operation of the ramps under study. No provisions are made for directly handling truck input data, left side ramps, 2-lane ramps or varying numbers of freeway lanes (except for auxiliary lanes.)

CAPTURN - This program determines service volume, approach width, greentimes, cycle length, G/C ratio, and in some cases, level of service for left and right turning lanes with and without exclusive signal phasing.

CAPWEAVE - This program may be used in analyzing simple and multiple weaving sections on freeways, multilane, and connecting collector-distributor roads. For simple and multiple weaving sections, the program may be used to solve for level of service versus number of lanes for each weaving section. In addition, the program may be used to solve for numbers of lanes and length of section versus level of service.

The above programs have input data prepared on forms specially designed for each capacity program. The output is on a printer page. The results of these programs can be used for operational and design capacity analysis as well as for the preparation of input to the capacity restraint (CAPRES) program for planning analysis purposes. There is currently no direct computer linkage between the capacity calculation programs and the historical record used for capacity restraint. The printed output from the capacity calculation must be recoded into link data cards. All of the capacity calculation programs provide for a title field which may contain node numbers or other desired description. The CAPINTR program specifically calls for the coding of A node and B node numbers.

K. PEAK HOUR ANALYSIS FOR ASSIGNMENT

1. Background

In the past, urban transportation planners have concentrated most heavily on developing survey procedures and models for use in macro planning efforts; e.g., regional transportation networks, major corridor studies, transit patronage models, etc. In these type analyses, the unit most often used to measure traffic is Average Daily Traffic (ADT).

In addition to providing ADT estimates for macro planning, the urban transportation planner is also responsible for providing peak hour traffic estimates for design purposes. This function is becoming increasingly more important as more planning agencies enter the continuing phase of the transportation planning process and concentrate more on the service function and on performing special or micro studies such as airport access, central business district circulation, etc. Some leading professionals have indicated up to ninety percent of all requests for traffic estimates are for purposes of design.

Considering the preceding, the importance of providing realistic peak hour traffic estimates should be apparent. The method of obtaining the factors needed to convert average daily traffic to peak hour traffic may not, however, be as readily apparent.

2. Conversion of Average-Daily to Peak Hour Traffic

The conversion of average-daily to peak hour traffic requires the development of two basic factors: i.e., the percentage of average-daily traffic occurring in the peak hour and the directional imbalance of traffic associated with this travel. Following is a discussion of several methods currently employed to perform this conversion.

a. One method is to simply apply factors developed from traffic count information to average-daily traffic estimates. This method is, of course, very precise for today's conditions. The validity of using similar relationships for developing future peak hour traffic estimates is, however, somewhat questionable since the procedure contains an inherent assumption that the composition of traffic (work, shop, school, etc.) will remain constant over time on a particular facility. In addition, many traffic counts are necessary to perform the conversion for an entire study area and, the procedure is essentially a manual one (after each traffic assignment, convert ADT link volumes to peak hour link volumes). Furthermore, the procedure does not allow for special analyses since the composition of peak hour volume is unknown. In other words, it is impossible with these data to perform a peak hour shopping trip analysis, and this does not even consider the fact that shopping trips peak during a different period than do total trips.

b. A second method is to convert average-daily non-directional trip matrices to directional peak hour matrices by applying reasonable estimates of 1). The percentage of travel occurring during the peak period and 2) the directional imbalance associated with this travel. The application of this type factoring (say 10 percent of average-daily traffic occurs in peak period with a directional imbalance equal to 60/40) is illustrated in Figure VII-K-1.

Figure VII-K-1 shows for a simple three zone problem the A.M. peak hour volumes that would result from the application of a 10 percent peak hour factor (step 2) and a 60/40 directional factor (step 3) to a total non-directional average-daily trip matrix from a gravity model (step 1).

Shown in Figure VII-K-2 is a second estimate of A.M. peak hour volumes - the only difference being the factors used. These factors were actually determined (not estimated) for a typical, medium-sized midwestern city. As can be seen, there is a great difference in the peak hour directional volumes estimated. On the basis of the preceding, it would probably not be unreasonable to expect at least a three percent error in a peak hour volume derived from estimates of

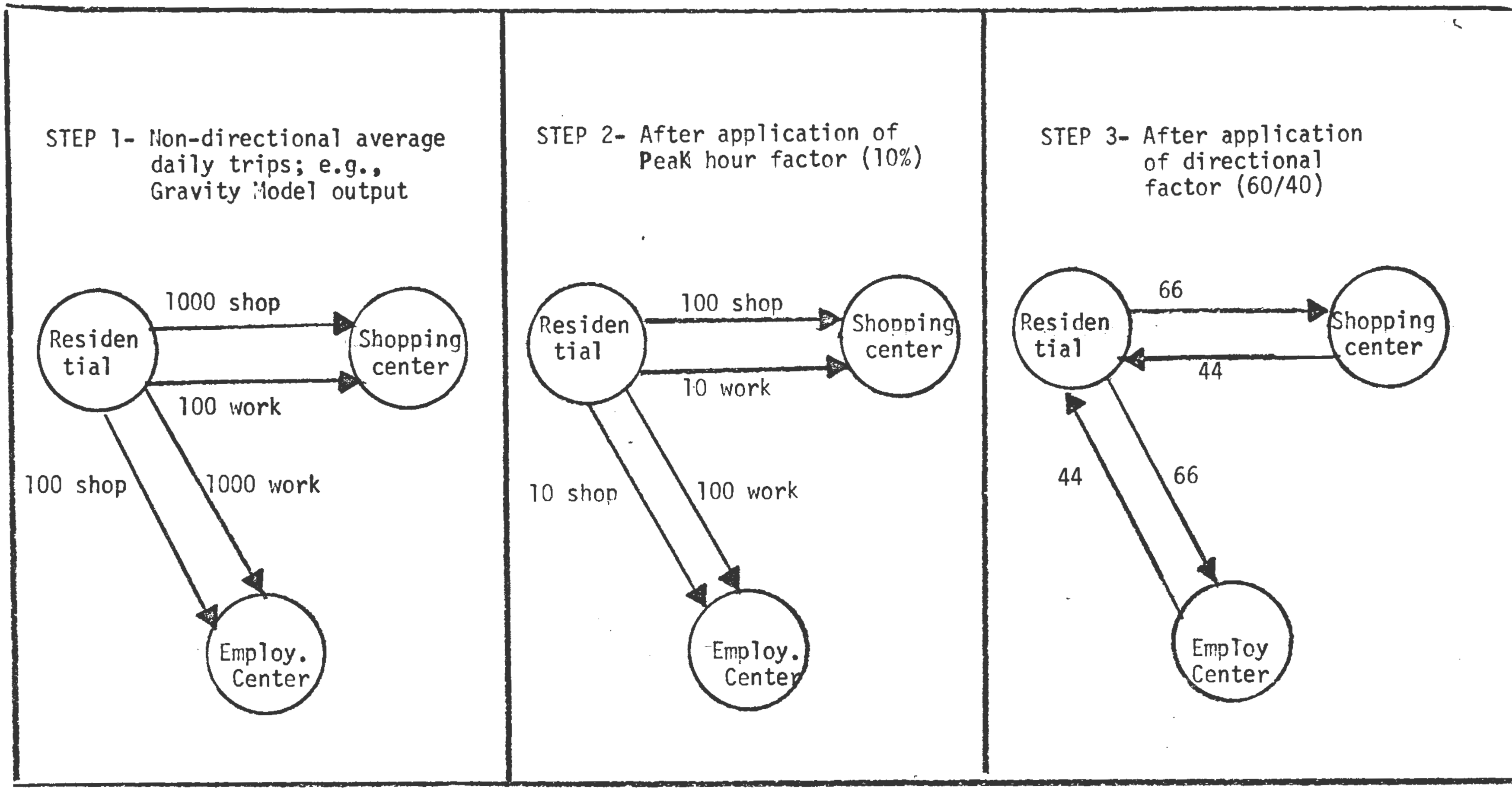


FIGURE VII-K-1

Application of reasonable peak hour and directional factors to non-directional ADT trip movements

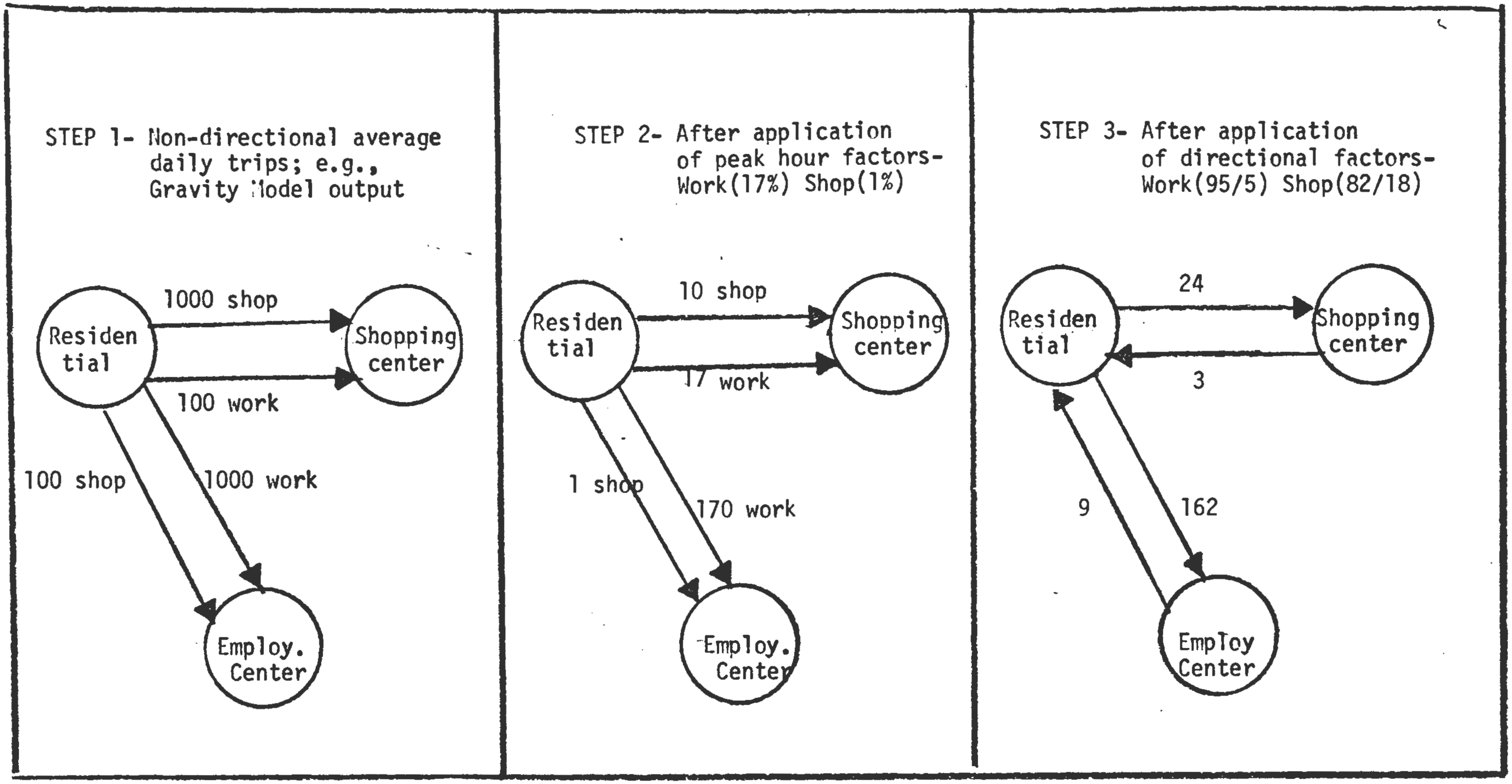


FIGURE VII-K-2

Application of actual peak hour and directional factors to non-directional ADT trip movements peak hour factors (percentage and directional). Although a three percent error may seem insignificant, an error of three percent when applied to a link carrying 60,000 vehicles per day is roughly equal to about one lane of freeway.

c. A third method of converting average-daily non-directional traffic volumes to peak hour volumes is to precisely determine the exact hour during which traffic peaks and the peak percentage and directional imbalance for each type trip occuring during this period (work, shop, social-recreation, etc.). This procedure has the advantages of being-

- Automatic and reproducible - One peak hour trip matrix can be produced and subsequently used for testing many network alternatives.
- Responsive to land-use changes in the area - For example, as shopping patterns change, the shifting patterns are reflected in peak hour estimates.
- Well suited for special analyses - For example, that hour period during which shopping trips to the central business district peak can be isolated and studied in detail.

3. Determination of Peak Hour Factors

The determination of peak hour factors begins with the determination of when the peak hour occurs, however, before the peak hour can be determined several additional questions must be answered; i.e.,

a. What constitutes the peak hour? Is it that hour period during which a maximum number of trips have say started, ended or reached the mid-point of their trip or, is it that hour period during which the maximum number of trips are in motion?

b. What trip unit should be used to measure the peak hour - person, vehicle or, perhaps, some other trip unit?

To answer these questions program PEAKHOUR was developed to determine not only the peak hour but any peak period; i.e., peak two hours, peak fifteen minutes, as well as determining the peak period for any trip unit. The highway planner is primarily interested in the vehicle peak hour, the transit planner in the person peak hour, the airport planner in both the vehicle and the person peak hours but only to a specific destination, etc. The trips-in-motion concept is used to define the peak periods because of its greater precision achieved as a result of the manner in which the trips are tabulated. For example, a trip analysis uses either a start-time, mid-point time or end-time of a trip and assumes that the trip occurs wholly within that hour period. A table is then constructed by time interval (usually six minutes) and the trip is placed in its appropriate time interval. After all trips have been tabulated, the ten consecutive six minute intervals that produce the greatest number of trips is designated as the peak hour. A trips-in-motion concept uses a slightly different approach; i.e., both the start-time and the end-time of the trip are interrogated to determine not only the time but also the duration of the trip. The trip is then placed in one or more time intervals. For example, if a trip begins at 8:00 A.M. and ends at 8:30 A.M., it would be added to the one-tenth hour (6 minute) time intervals indicated below:

8.0 - 8.1
8.1 - 8.2
8.2 - 8.3
8.3 - 8.4
8.4 - 8.5

On the average, a trip will only be in motion for one-half the beginning interval and one-half the ending interval. To adjust for this, trips are half-factored in the two terminal intervals. The peak hour is taken as the ten consecutive six-minute intervals containing the greatest number of trips. The trips-in-motion concept insures that the peak hour is the actual period when the maximum number of trips are on the system or "in-motion."

The trips-in-motion concept utilizes trip length as well as start-end time. This produces a more accurate peak period determination as well as a more realistic description of the nature of the peak period (i.e. short - highly congested vs. long - moderately congested).

4. The Peakhour Program

As previously mentioned, the PEAKHOUR program uses the trips-in-motion concept. As such, each trip record selected for processing is interrogated to ascertain its start-time and end-time. It is then placed into its proper time intervals. Those records to be selected for processing are controlled by the user through the use of a SELECT control card. For example, if Mode 1 equals auto-driver, Mode 2 equals auto-passenger, Purpose 0 equals home and Purpose 1 equals work -

```
SELECT,CARDNØ=2,MØDE=1,2,PURPØSE=0,1
```

would select for processing all home based work auto-driver and auto-passenger trip records from the Number "2" card trip record file. In this example, the sum of auto-driver and auto-passenger trips would be considered as the daily total.

In addition, the user has the additional capability of specifying those reports desired. This is accomplished through the use of SET control cards. For example,

```
SET,AUTO-DRIVER HOME BASED WORK TRIPS
CONTINUE,MODE=1

SET,AUTO-PASSENGER HOME BASED WORK TRIPS
CONTINUE, MODE=2
```

would effectively provide two printed reports from those records selected; i.e., one for auto-driver home based work trips and one for auto-passenger home based work trips. These printed reports will show by time period selected (say one-tenth hour although the time period is user controlled) the number of home-to-work trips, the number of work-to-home trips, the number of non-home based work trips (in this example zero), the set total (either auto-driver or auto-passenger) and the daily total (in this example the sum of auto-driver plus auto-passenger trips).

Furthermore, a printer plot showing the profile of both trips-in-motion and trips is also displayed. The scale and symbols used in these plots are controlled by the user. Finally, the program produces those factors necessary for converting the average-daily non-directional trip matricies to directional peak hour trip matricies; i.e., peak hour (for example 7:36 - 8:36), number of trips in peak hour by trip category, percent of trips in peak hour and directional imbalance.

Due to the nature of travel surveys, the trips in motion tabulation will not show a smooth variation from one time period to the next. To adjust for this inherent variation, the program utilizes harmonic analysis to fit a curve <u>exactly</u> through each of 24 observations (average hourly value). This curve can be readily differentiated to obtain maximums (peaks) and minimums. It can also be integrated to obtain number or percent of trips on the system between specified time limits.

5. Application of PEAKHOUR Program

The PEAKHOUR program is a very flexible planning tool. The analysis that can be accomplished with the program is extensive. Some suggestions for consideration are -

a. Select total auto-driver and auto-passenger trips. Process auto-driver as SET 1 and auto-passenger as SET 2, yielding for each SET from home, to home and non-home based trips by hour period; a set total by hour period (from home plus to home plus non-home) and a daily total (auto-driver plus auto-passenger). Readily available at this point are auto occupancy factors by hour period (daily total/set total).

b. Select as in Number 1 but for a specific trip purpose (say shop). Again, auto occupancy factors by hour period are now readily available for a specific trip purpose. In addition, the period during which shop trips peak region-wide is now known.

c. Select as in Number 2 but for specific zones; e.g., ORGZN=ALL,DESTZN=100. If Zone 100 is a major regional shopping center, the period during which shopping trips to the center peak will become apparent. Extension of this logic could yield peak hour traffic estimates for specific parts of the study area; e.g., estimates of peak hour CBD oriented trips, estimates of peak hour suburban trips, etc.

d. Select to isolate the peak hour for total vehicle trips for the entire region. This information is directly applicable for highway design purposes.

e. Select to isolate the peak hour for total person trips. The results of this run will be directly applicable in transportation planning efforts (satisfying travel demand irrespective of mode). Once again, extension of this logic could produce total person peak hour information in selected corridors for use in evaluating rapid transit proposals.

L. LICENSE PLATE MATCHING - Travel Time Study

1. Background

Travel time data is a necessary input to many of the transportation planning techniques described previously. It is a key variable for trip distribution, modal split analysis and traffic assignment. Likewise travel time changes over a period of years is one element in the monitoring of system changes that is part of the continuing transportation planning function.

Field collection of travel time between points in a network has generally been accomplished utilizing the "floating-car" technique. Although generally inexpensive, it has quality limitations based upon the number of runs which can be made and the driver's ability to reflect an average condition.

Work has been completed in the development and application of procedures utilizing tape recorders in gathering travel time data. Basically, the technique consists of recording license plate numbers (and/or alphabetic characters) at the ends of the section(s) under study, coding these into forms in the office, timing the tape recorded license entries, keypunching the data and processing this utilizing program LICMATCH.

2. Field Collection - Tape Recorders

The procedures developed allow obtaining license plate designations at any number of points along a facility and matching the results to obtain an O-D matrix and corresponding travel times between all the points in question.

Field collection consists of a number of personnel, reading plate designations into a tape recorder at each station between which travel times are desired. For example, if O-D movements and travel times between 5 intersections along a street were desired, 5 stations would be established. The number of personnel at each station would depend upon the number of lanes on the facility and the type of operation. On city streets, for example, one person can obtain two lanes of information for light to medium traffic conditions. On freeways, however, one person per lane is required for medium to heavy traffic conditions.

In addition to obtaining license designations, information on lane, turning movements and vehicle classification can be recorded to allow a determination of differences in travel times resulting. Four characters (the right-most) are usually sufficient license recording to eliminate duplicate readings. If some duplicates can be tolerated (these merely reduce sample rate) three characters are usually acceptable.

No time information is recorded in the field. An entry must be read into the recorder to allow synchronization between stations. This can be done in a number of ways. The best is to have a "test" car pass through the section under study to start each station's field operation. As the test car passes each station, the recorders say "test," "start" or some other word which starts the operation. The test car driver times (with a stop watch) the elapsed time between stations. Another synchronization procedure involves each crew member synchronizing a watch to some standard, and saying "start" at some predetermined time.

A large sample of field data can be collected in short periods of time with this technique. For example, on a 2,000 vehicles per hour facility, a ten-minute recording will catch 333 vehicles. If only a match rate of 50% is obtained between stations, a sample of 176 vehicles is obtained for travel time calculation. This is considerably more representative of actual conditions than found by passing a test car through the section a few times.

A few words about tape recorders may be of value. For some studies undertaken, $20.00 cassette tape recorders were used with good success. Two hints may prove valuable. First, new tapes should be run through the recorder before field collection since there is some initial tape stretching which might affect the results. Secondly, high quality batteries such as Alkaline batteries should be used to insure a constant tape speed.

Once field collection is complete, the license characters as well as lane and turning designations are coded by replaying the tape recorders. At this point the elapsed time from the "start" entry on the tape to each recorded license designation is also coded. The license designation and time coding is usually a two-phased operation with each tape being played back twice.

3. Program LICMATCH

A program, described in more detail in the Program Documentation Manual, LICMATCH is available to handle the tape recorder data. This program determines vehicle densities along a facility, weaving movements, elapsed time (including standard deviations and distributions based upon user specifications of ranges) and volumes, from data describing the vehicles passing recording stations along the facility. The data is normally obtained by voice tape recording of license plates coded to a specified format. However, data collected by other means such as photography, can be coded to utilize the program. The required data is the license plate, the time of recording and optionally, an indication as to entrance, exit or through lane occupied (or turns made).

The program LICMATCH reads data records containing the license plate number, the time of recording, the lane and status (enter, exit, thru) of individual vehicles passing recording stations. When all records for all stations are read and edited, they are then sorted by license number, time, and station. The sorted records allow the program to determine the path taken by each individual vehicle. As it examines the path, the program accumulates the movements, speed distributions and vehicle hours of travel.

TABLE VII-K-1

SAMPLE RESULTS FROM LICMATCH PROGRAM

START TIME	LOCATION	LENGTH (miles)	COUNT A	COUNT B	#OF MATCHES	Percent Match	STD. DEV.	VPM	VPH
7:30 A	B-W PARKWAY	3.40	423	497	212	55.6	4.5	50	2767
9:00 A	Northbound Routes 197 to 198	3.40	180	214	125	62.3	6.8	19	1194
11:45 A		3.40	205	243	115	63.0	5.2	22	1374
2:45 P		3.40	244	253	120	65.9	6.2	23	1496
5:30 P		3.40	352	327	200	59.8	8.7	34	2044
8:15 A	U.S. 1 Southbound Cherry Lane to Lindendale Street	0.60	118	141	75	38.9	5.9	20	782
11:00 A		0.60	91	89	37	37.6	5.6	16	589
2:15 P		0.60	136	129	72	40.5	7.4	20	800
4:45 P		0.60	130	130	71	20.7	3.8	22	780
9:45 A	ROUTE 198 Westbound Brockbridge Rd. to Route 197	0.95	68	75	44	36.5	5.3	12	438
12:30 P		0.95	90	85	54	34.3	7.0	16	535
3:45		0.95	118	121	71	43.1	6.3	17	730
7:30 A	GEORGIA AVE. Southbound, Seminary Place to Route 391	0.07	*518	*411	232	25.4	10.6	77	1948
8:45 A		0.07	459	445	264	26.4	14.1	103	2721
11:45A		0.07	264	245	162	17.6	14.1	87	1575
1:00 P		0.07	269	251	177	18.1	12.7	87	1575
4:00 P		0.07	*350	*340	155	8.4	6.4	173	1454
8:15 A	I495 Westbound Colesville Road to Georgia Avenue	1.35	681	507	196	22.4	3.4	160	3581
9:20 A		1.35	368	422	192	58.2	8.1	41	2382
12:15 P		1.35	319	340	184	59.2	9.9	33	1977
4:45 P		1.35	544	517	192	59.0	9.0	54	3201

CHAPTER VIII

HARDWARE & SOFTWARE REQUIREMENTS

A. IBM SYSTEM/360 HARDWARE

The System/360 is IBM's third generation computer. In actuality, it is not a single computer but a family of computers, currently called Models 20 through 91, designed to meet the whole range of computer needs. When originally announced, the 360 line was "fully compatible," meaning that a given program could be written for any of the machines and run on any of the others, subject only to the availability of sufficient core and the presence of the required input/output devices. Since the original announcement, several additional models (Models 25, 44, and 67, for example) have been added to the 360 family which are not fully compatible with the rest of the family.

To a large extent, the 360 is disk oriented. This is particularly true under the Operating System monitor. In addition, bulk storage devices such as drums and data cells are available.

The table below summarizes some of the basic differences between the 7090/94 and the 360. The two character sets referred to are the Binary Coded Decimal (BCD) consisting of 64 characters and the Extended Binary Coded Decimal Interchange Code (EBCDIC) consisting of 256 characters. The number representation referred to is that used in core dumps, patch cards, etc.

	7090/94	360
Number of words	32,768	Variable
Binary bits per word	36	32
Bits per character	6(BCD)	8(EBCDIC)
Characters per word	6	4
Number representation	Octal (base 8)	Hexadecimal(base 16)
Tape drives	7-track	9-track
Tape drive densities (bpi)	200/556/800	800/1600

On the 360, each group of eight bits, the equivalent of one EBCDIC character, is called a "byte". While the 7090/94 could be described as a word machine, the 360 is basically a byte machine. Core storage on the 360 is normally referred to as so many thousands (k) of bytes. Since it takes four bytes to form a word, a 128K 360 is supposedly equivalent in storage to a 7090/94 (however, each of the 360 words is 11 percent - four bits - shorter). In terms of operating power (overall efficiency and speed of computation), it takes a Model 65 360 to equal a 7094.

1. Minimum Hardware Configuration

The complete urban transportation planning battery of programs requires at least a Model 30 of at least 64K equipped with the universal instruction set feature. "Two disk drives are required together with six additional, comparable disk and/or tape drives." Either a 1052 console or a composite console (card reader-printer) is necessary.

With the eight I/O storage devices referred to above, a user should be able to run <u>all</u> of the programs in the battery. Actually, few of the programs require nearly that many devices (five are all that are presently required to execute the entire set of traffic assignment programs).

Direct access devices, such as a 2311 disk drive, may be used providing that there is sufficient space on the volume and that the physical block size of the data records does not exceed that of the device.

With one exception, 7-track tape drives with data conversion (an optional hardware feature) are compatible to disks and 9-track tapes, but without this feature they are not compatible. Almost all of the data sets used by the urban planning battery are binary, and binary data can only be written (and later read) successfully onto those 7-track tapes that have the data conversion feature. The exception noted above is that 7-track tapes, even with the data converstion feature, cannot be used as intermediate work units while running the IBM supplied sort/merge program. Only 9-track tapes <u>or</u> direct access space may be used. This could be a critical problem at some installations as the urban planning battery uses the IBM sort/merge program (it is an integral part of the Build Historical Record - BUILDHR - program, for example).

It should be emphasized that the configuration specified above is the minimum configuration with which the programs can be successfully run. For efficient operation with a reasonable size network, a Model 40 of at least 128K is required. Two disk drives should be on a selector channel, and the console would be an IBM 1052. In order to avoid unnecessary tape (or disk) mounting and dismounting, additional tape and/or disk drives should be available. It is believed that the program battery cannot be run on a Model 44 (IBM's special purpose scientific machine) but can be run on a Model 67 (IBM's real-time machine).

Individual installations may desire to maintain all or a portion of the Federal Highway Administration "urban planning disk" on one of their disk packs. Although it is a relatively easy operation to "dump" the contents of a disk onto a tape and later "restore" the contents to a disk, frequent use of the programs comprising the battery will justify permanently maintaining the program battery (and perhaps the other components of the Federal Highway Administration disk) on one of the installation's disk packs.

2. Hardware Features

There are many features of the third generation machines that are advantageous. One of the major elements is the wide variety of size (and cost) variations. Small urban areas and many of the programs for large areas can be run on relatively inexpensive machines which are readily available. At the same time, there are scattered locations where computers with seven times the capacity (core memory) of the 7090-94 are available.

Perhaps more important is the reduction in cost of comparable runs. Third generation computer costs can be less than half or even one-fourth of the cost of second generation machine runs. For example, the third generation computer computer installed by the Federal Highway Administration replaced three second generation machines at roughly the same cost. The three machines replaced were unable to handle any of the basic programs used in urban transportation planning, but were used in a number of peripheral applications.

The new machine accommodates all of the programs needed for urban transportation planning (including the peripheral programs at a significant increase in speed and efficiency). The new machine handles a problem almost twice as large as could be handled on the 7090-94 at almost the same speed and at about one-third the rental cost.

3. Core Storage Requirements

Preliminary estimates for the critical programs of the urban planning package are given in the tables below:

Maximum Possible Last Centroid Number

Machine size	Number purposes	GM	IOM	GMCAL
64K	1	170	230	---
	2	115	155	---
	3	85	115	---
	4	65	90	---
128K	1	2,450	2,450	2,250
	2	1,700	1,650	1,650
	3	1,300	1,200	1,350
	4	1,050	950	1,100
256K	1	7,000	6,900	7,500
	2	4,900	4,650	5,700
	3	3,700	3,450	4,500
	4	3,100	2,750	3,800

Highest Allowable Node Number

Machine size	Traditional Networks		Spiderweb	
	Trees/Vines	Load	4-way	8-way
64K	1,250	1,550	1,230	730
128K	3,250	4,200	4,000	2,430
256K	7,450	9,400	9,250	5,650
512K	16,150	16,383*	16,383*	12,000

* Maximum allowable node number

These core storage estimates are based on the following assumptions:

1. The hardware configuration is typical, or at most slightly on the modest side, for the particular core size referenced.

2. The primary control program (PCP) is used with few, if any, software options.

It cannot be overemphasized that these core storage estimates, although carefully prepared, are, in fact, <u>only</u> estimates and should be used solely as a guide.

4. Standard Tape Labels

The use of standard labeled tapes with the urban planning battery is strongly recommended. The Operating System will automatically position tapes so labeled to the specified file (thus greatly simplifying the stacking of several files on a single tape) and give a positive check on both the six-digit (maximum) alpha-numeric volume serial number and the alpha-numeric file identification (DSNAME). The system will also automatically handle reel switching for files (now called data sets) split over two or more reels. At the time a data set is generated (written), either a retention period or an expiration date for the data set can be specified. In either case, if at a later date someone attempts to write over the data set in question before the end of the retention period, the system will issue a retention check message to the operator who can either cancel the job or tell the system to disregard the retention check.

Schematic drawings of two data sets residing on standard labeled tapes are shown in Figure VIII-1 and VIII-2. Fig. VIII-1 shows the case where both data sets are contained on one tape reel, while Fig. VIII-2 shows the case where the second data set is split between two tape reels. All standard labels (VOL1,HDR1, etc.) are actually unblocked 80 byte card images.

STANDARD LABELED TAPES

Two Data Files on One Reel

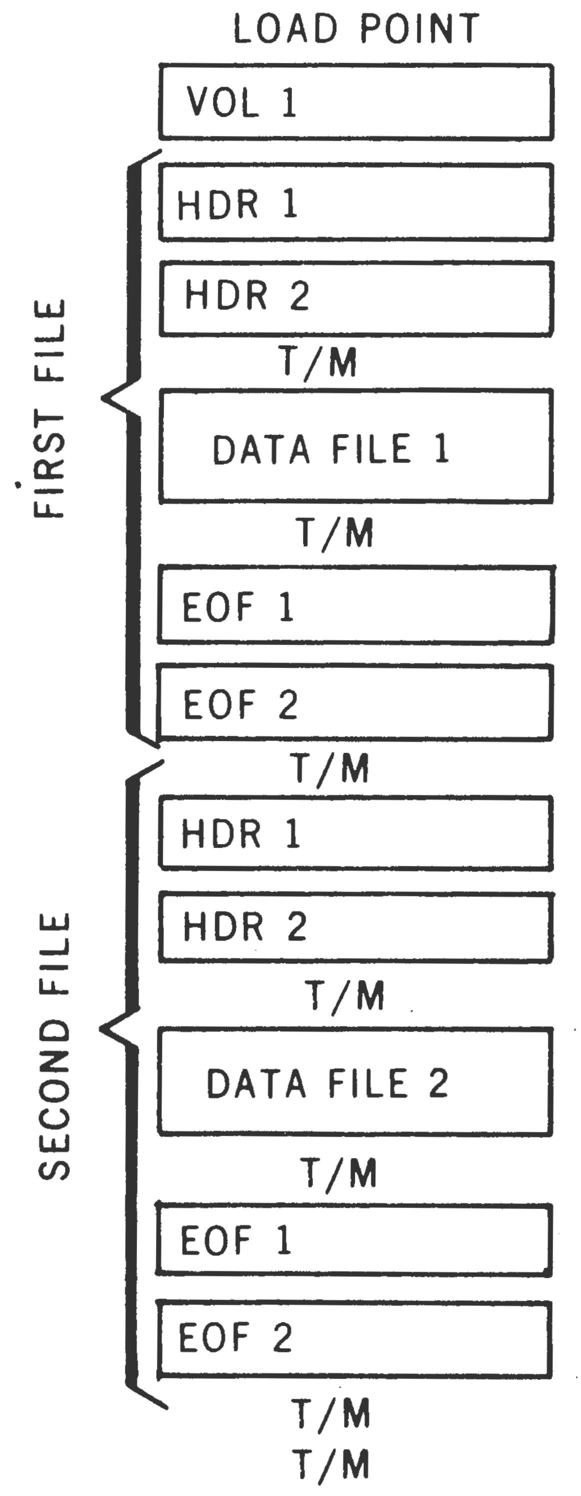


FIGURE VIII-1

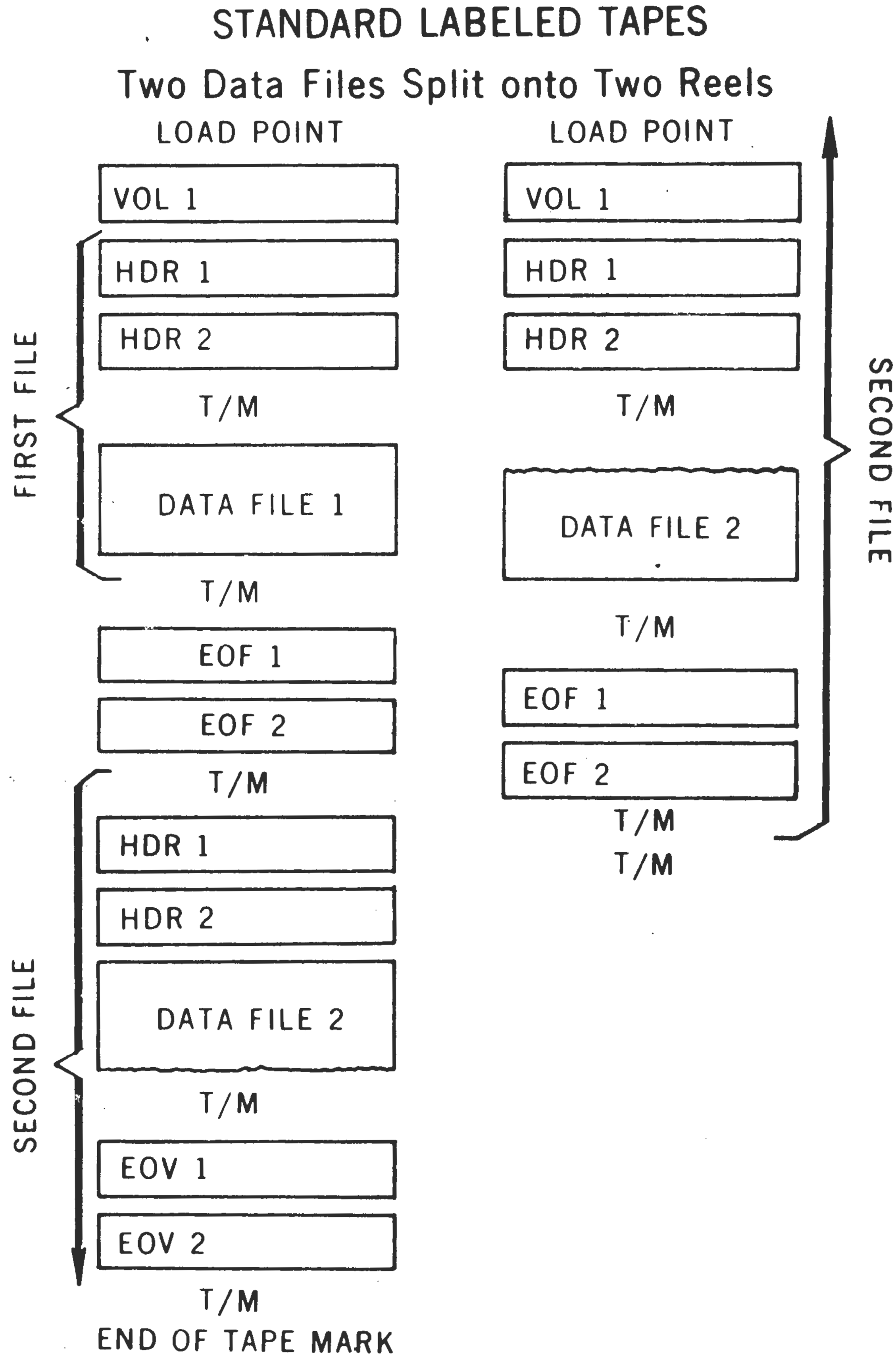


FIGURE VIII-2

B. IBM SYSTEM 360 SOFTWARE

1. Software Requirements

The urban transportation planning battery will only run under IBM's (full) Operating System (O.S.). The full Operating System should be the primary monitor normally used at the majority of the installations at which the urban planning battery will be run. Therefore, the installation's own personnel (programers and machine operators) will be able to furnish maximum assistance in running the programs. In addition, this means that, within certain limitations, the battery programs can be submitted through the regular job stream and not require a special setup.

A given installation may be unable to run some or all of the programs in the urban planning battery for one or more of the following reasons:

1. The installation has elected to use some other monitor than the (full) Operating System.

2. The installation has included many options in its version of the Operating System, thus using up additional core for the resident monitor that is needed in order to process a network of a given size.

3. The necessary sort/merge routines have been excluded from the system.

4. Necessary data management routines (BDAM, BSAM, and QSAM) - have been excluded from the installation's system.

5. Certain problems, mainly stemming from an insufficient number of disk drives or from severe limitations on available disk space, may develop at a few installations. Most of these operational problems can be

overcome by a good systems programer. Inadequate system programing support may prohibit the use of the battery under the installation's monitor.

2. Operating System

The IBM/360 operating system (OS) consists of a control program and a number of processing programs. In the urban planning package, the programs are written in FORTRAN, COBOL, and/or ALC. This package is designed specifically to run in partnership with the OS control program which resides in core with this package at all times.

The control program's function in this partnership is to initiate the problem program, to assimilate input and to process output, and to assume full control after the problem program is finished. These control program functions are invoked by the user and directed by means of distinctive control cards which are fed into the mechanism.

The correct method for using the urban planning package is discussed in the following subject sequence on the next pages:

BASIC ORGANIZATION OF DATA

- Jobs and Job Steps
- Data Sets

JOB CONTROL LANGUAGE (JCL)

- The Name Field of Control Cards
- The Operation Field of Control Cards
- The Operand Field of Control Cards
  - Positional Parameters
  - Keyword Parameters
- The Comments Field of Control Cards
- Continuation

CODING JOB CONTROL LANGUAGE STATEMENTS

- The JOB Statement (Card)
  - The JOB Card Name Field
  - The JOB Card Operand Field
- The EXEC Statement (Card)
  - The EXEC Card Name Field
  - The EXEC Card Operand Field
- The DD Statement (Card)
  - The DD Card Name Field
  - The DD Card Operand Field
  - Creating Data Sets
  - Retrieving Data Sets
- The Delimiter Statement
- The JOBLIB Card
- Data Set Concatenation

Under these headings in the text will be found definitions of terms and detailed descriptions of all materials which the user will encounter, as well as step-by-step instructions for their correct systematic use. For easy reference, important terms are capitalized in the text, essential procedures are distinguished by MUST and important exceptions to rules and procedures by EXCEPT.

Certain methods of notation have been adopted for use throughout these instructions. The rules concerning their use are:

- The hyphen (-), brackets ( ), and ellipses (...) are used in format specifications to clarify their meanings. These MUST NEVER be coded in control statements.

- The hyphen is used to conjoin words which represent a single variable in job control language. For example: programmer-name.

- The brackets enclose optional items.

- Ellipses represent indefinite repetition. For example: Option, option, ...

- Capital letters and digits should be coded into control statements exactly as shown.

The following symbols also are coded as shown:

'	apostrophe
*	asterisk
,	comma
=	equal sign
()	parentheses
.	period
/	slash

An underscore (___) indicates a default option. If the underscored option is chosen, it need not be coded because it will be assumed by OS.

The word "field", as used in job control language, means that area on a control card where distinctive categories of facts are punched. For example: The word "namefield" refers to that space on a control card provided for designating the JCL name for the information which is being communicated to OS.

a. Basic Organization of Data

(1) Jobs and Job Steps

Basically, the control cards are grouped in jobs and, within jobs, in job steps. Usually, the steps within the same job are related to each other. Thus, a job is a group of one or more job steps. A job step, in its simplest form, merely initiates and controls one of the program elements in the overall problem program or package. Under certain circumstances, these job steps themselves are divided into sub-steps or procedure steps. It is important for the user to distinguish between the procedures to initiate job steps and those for defining the data sets which are produced by the steps.

(2) Data Sets

A data set is a collection of information which is retained in one or more data storage devices, such as tape files, card decks, etc., which may be kept in a library connected with the IBM/360. They are labeled, usually as part of the data itself, but sometimes only in the mind of the user.

In OS, all input and output is performed in the context of data sets. Control cards allow the user to dictate many of the identifying characteristics of the data sets which will be used by his program at run time. These defining characteristics which the user can control are:

- The name of the data set;
- The unit on which the volume or volumes containing the data set are to be mounted;
- The serial number or numbers of the volume or volumes containing the data set;
- The record format;
- The block size; and
- The logical length of the record.

b. Job Control Language (JCL)

Job Control Language (JCL) properly punched into control cards is the user's only means of communication with OS during program execution, and through OS with the computer. OS understands only JCL. Statements and directions are punched into control cards:

- to invoke the problem program or job step;
- to dictate the conditions under which it will proceed; and
- to communicate variable defining data to OS.

In JCL not only the exact sequence of symbols but also their location and spacing on the card is important.

Statements and directions in JCL are signaled to OS by a double slash (//) in card columns 1 and 2. Beginning in column 3, these statements and directions are classified in four fields (or card areas) as follows:

- the name field;
- the operation field;
- the operand field; and
- the comments field;

each field calling for more detailed classification, identification and disposition statements and directions.

Although the user should meet the requirements of these four fields in the same order, all fields are not always included in each job step. All statements and directions may be spaced in free-form except those in the name field, which MUST begin in column 3 and MUST be preceded by a // placed in columns 1 and 2. Information MUST NOT be punched beyond column 71, EXCEPT in the procedure described under <u>Continuation</u>.

The fields MUST be separated by one or more blanks on the card. The first blank which the machine encounters in any field terminates that field, EXCEPT (a) when blanks are encountered in the comments field, (b) when the operand field is continued from one card to another, and (c) when any field contains alphabetic expressions which are enclosed in quotes.

(1) The Name Field of Control Cards

The name field is used:

- to designate the specific job, job step or data set;
- to enable OS to distinguish between JCL statements with the same operation field;
- to permit referencing previous JCL statements in the operand field; and
- to relate DD (data definition) statements to input/output statements in the problem program.

When the name field is used, it can contain from one to eight alphanumeric characters, the first of which MUST be alphabetic (non-numeric). This field is required on the JOB and all but one type of the DD card (see Data Set Concatenation), and in certain tests described under The Operand Field of the EXEC Statement. It may be omitted in EXEC cards, when the particular step is not referred to in later steps of the same JOB. It MUST NOT be included in continuation cards.

The name field MUST begin in column 3 and MUST be preceded by // in columns 1 and 2. It is ended by one or more blanks to separate it from the next field. Column 3 MUST be blank if the name field is omitted.

(2) The Operation Field of Control Cards

The three so-called "verbs" of job control language are the three codes of the operation field. These are:

- JOB (job);
- EXEC (execute); and
- DD (data definition).

Each of these is a unique type of statement (or card). Instructions for their use are given in the sections entitled The JOB Card and Statement, The EXEC Card and Statement, and The DD Card and Statement.

All JCL statements EXCEPT the delimiter statement, MUST be defined in the operation field by one of these three verbs. As in the case of the name field, the operation field MUST NOT be repeated in continuation cards.

The operation field must begin and end with one or more blanks to separate it from the other fields. Although this field MUST NEVER begin before column 4, it may begin anywhere thereafter.

(3) The Operand Field of Control Cards

Parameters can be called "computer shorthand" for certain defining and limiting statements. They may be positional (i.e., positioned in a certain way), or keyword, i.e., keyed to certain sequences of alphanumeric characters which OS recognizes.

The operand field consists of required and optional parameters. This field MUST be used in all JCL statements with the exception of the delimiter statement and one special case of the DD statement. It MUST begin and end with one or more blanks to separate it from the other fields. It may be continued from one card to another. (See Continuation.)

Parameters in the operand field are either positional or keyword. Positional parameters in this field MUST be placed before keyword parameters and MUST appear in the order specified. If there are more than one positional parameters in a sequence, the omission of any one of them MUST be indicated by a comma if others are to follow.

Keyword parameters in this field may be placed in any order but they MUST COME AFTER POSITIONAL PARAMETERS. They are coded as follows:

KEYWORD=value, or

KEYWORD=(subparameter-list)

These subparameters in the subparameter list may themselves be either positional or keyword. When they are keyword, they are formed as follows:

SUBPARAMETER=value

(4) The Comments Field of Control Cards

In this field the user can make clarifying remarks. The comments field, when used, comes after the operand field and MUST be separated from it by one or more blanks. The comments field is:

- always optional;
- may contain blanks; and
- may be continued to another card.

(5) Continuation

The operand and comments field may be continued from card to card by means of the following procedure:

- The operand field may be interrupted at any point up to and including column 71 after a comma following a parameter. The comments field also may be interrupted at any point up to and including column 71.
- A non-blank character is then punched in column 72.
- A // is placed in columns 1 and 2 of the next card.
- Columns 3 through 15 of this next card are left blank.
- The operand field is continued beginning in column 16. Column 16 MUST NOT be left blank if the operand field is being continued. A comment may be continued anywhere in columns 16 through 71 and column 16 may be left blank.

Although this process may be repeated as many times as necessary, excessive quanitities of continuation cards reduce the efficiency of OS.

c. Coding JCL Operation Statements

(1) The JOB Statement (Card)

(a) The Name Field of the JOB Card

A control card bearing the operation symbol JOB MUST be first in every job. Its name field is coded:

jobname

and consists of one to eight alphanumerica characters, of which the first MUST be alphabetic. It MUST begin in column 3 and MUST be preceded by // in columns 1 and 2. It MUST be followed by one or more blanks to separate it from the next field.

(b) The Operand Field of the JOB Card

The operand field of the JOB card contains four parameters of particular interest to the user of the urban planning package. There are two positional parameters and two keyword parameters.

The two positional parameters are

(account-number ,accounting-information) , and

,programmer-name

The first positional parameter should contain in its first field, account-number, the installation account number. In its second field, accounting-information, it should contain any other parameters required by the installation.

```
//THISJOB   JOB   (360-006-07,02-03-67),JOHN-DOE
```

The mechanics for handling this information are inserted into OS when it is generated. Thus, the exact content of this first positional parameter of the operand field of the JOB statement has been pre-specified and MUST be adapted by the user in accordance with specific installation requirements.

The second positional parameter of the operand field of the JOB statement is programmer-name. If this contains (1) commas, (2) parentheses, (3) apostrophes, or (4) blanks, it MUST be enclosed in single apostrophes.
Those apostrophes which are included within the parameter MUST be coded as double apostrophes ('') to distinguish them from the enclosing single apostrophes ('). The maximum number of characters allowed in programmer-name is 20 between apostrophes.

```
//THISJOB   JOB   360-006-07,'JOHN DOE'
```

or

```
//THISJOB   JOB   360-006-07,'JOHN DOE''S BROTHER'
```

The two keyword parameters in the operand field of the JOB card are:

MSGLEVEL=0
MSGLEVEL=1

and

COND=((code,operator) ,(code,operator) ...)

The MSGLEVEL parameter provides a means for the user to designate the type of OS control card printout he wishes to receive. MSGLEVEL=0 calls for printing out only diagnostic messages and those control cards which are in error. MSGLEVEL=0 is usually a default option as shown by the underline.

MSGLEVEL=1 calls for printing out all control statements as well as those in error and diagnostics.MSGLEVEL=1 is recommended.

```
//THISJOB   JOB   360-006-07,JOHN-DOE,MSGLEVEL=1
```

The second keyword, or COND parameter shown in the format above allows the user to designate the conditions under which a job will be ended. When jobs are ended by using this parameter, any remaining steps are bypassed and control is given to the next job in the input data stream. This parameter can be employed by the user to instruct OS what termination action to take in as many as eight situations. It must be designated if the user wishes the job to terminate under any specific circumstances.

The variable in the COND parameter format is composed of two elements: code and operator. The variable code in the COND parameter format above may be any number from 0 to 4095. The variable operator in the format represents the mathematical relationship between the code specified by the user in JCL and the return code issued by OS after the job step. The mathematical expression evaluated by OS is:

code · operator · return-code

which, if it is true, will cause the job to be ended. The relative values which the operator mechanism can understand are:

Operator Code	Meaning
GT	greater than;
GE	greater than or equal to;
EQ	equal to;
NE	not equal to;
LT	less than; and
LE	less than or equal to.

If more than one condition is specified by the user, the job will terminate if any of these conditions are found to be true. The outermost pair of parentheses indicated in the COND parameter format may be omitted if only one condition is specified.

In the example below, the user has specified that the job will terminate if a return code of 5 or greater is issued.

```
//THISJOB    JOB    360-006-07,JOHN-DOE,MSGLEVEL=0,COND=(5,LT)
```

(2) <u>The EXEC Statement (Card)</u>

Just as a JOB control card must be first in every job, a control card bearing the operation EXEC MUST be first in every job step. There may be only one for each step. At times, when a cataloged procedure is invoked, a step is divided into one or more substeps, called procedure steps. In such cases, each substep MUST also begin with an EXEC card.

The information in the EXEC card is used by OS to identify the job step or substep and to supply required and optional information as to what problem program will be processed.

(a) The Name Field of the EXEC Card

An EXEC card must have a name field if the step which it introduced is to be referenced in subsequent steps. It is coded:

stepname

which consists of one to eight non-blank alphanumeric characters, the first of which MUST be alphabetic. It MUST begin in column 3 of the card and be preceded by // in columns 1 and 2. It MUST be followed by one or more blanks to separate it from the operation field code EXEC.

(b) The Operand Field of the EXEC Card

The operand field of the EXEC card contains three parameters of interest to the user of the urban planning package. There is a positional parameter selected from the following three formats:

PROC=cataloged-procedure-name

cataloged-procedure-name

PGM=program-name

This parameter specifies either the cataloged procedure to be invoked or the load module to be executed. One of the three MUST be specified.

A cataloged procedure is a set of precoded control statements which are stored in a special system library which can be invoked by the user. When a cataloged procedure is invoked, the control statements of the appropriate cataloged procedure become part of the user's control card input. The user can invoke any number of these precoded control cards by use of a single EXEC card.

A load module is a problem program which has been prepared previously by the user for execution by OS. It MUST have been stored in advance in a library connected with the IBM/360. This library is defined by means of a JOBLIB Data Definition (DD) card, if the user exercises the option PGM=program name in the format above. (See The JOBLIB Card.)

The examples below show how (a) or (b) a catalogued procedure (PTSUM) can be invoked and (c) how a program load module (GM) would be executed:

(a) //STEPXX EXEC PROC=PTSUM

or

(b) //STEPXX EXEC PTSUM

(c) //STEPXX EXEC PGM=GM

In addition to the positional parameter just discussed, the operand field of the EXEC statement has an optional keyword parameter which may be utilized:

```
COND=((code,operator  ,stepname.GO  ),
        ,(code,operator  , stepname.GO)  ...)
```

The COND parameter of the EXEC card is used to make the execution of any step dependent upon the completion code returned by OS after a previous step. The user MUST distinguish between the COND parameter of the EXEC and of the JOB cards. The COND parameter of the EXEC card refers ONLY to the STEP initiated by the EXEC card in which it appears, NOT to all steps, as does the COND parameter of the JOB card.

In this COND parameter, the variables code and operator are used in the same way as they were in the COND parameter of the JOB card. The variable stepname is the contents of the name field of a previous EXEC card in the same job.

In addition, EVEN and ONLY subparmeters may be utilized. If the EVEN subparameter is used, the job step will be executed even though one or more of the preceding job steps has ended abnormally. Use of the ONLY subparameter causes the step to execute only if one or more of the preceding job steps has ended abnormally.

The examples below show how the outcome of a previous step can be tested. Note that when the previous step is that one which is being tested, it is not necessary to specify a stepname. In these examples, execution of STEPXX will be deleted by OS if the specified step generated a completion code of 5 or greater. Note also that the outermost parentheses are deleted when only one test is specified.

```
//STEPXX  EXEC  PTSUM,COND=(5,LT)

//STEPXX  EXEC  PTSUM,COND=((5,LT,MODEL.GO),(5,LT.COMPRESS.GO))
```

(3) The DD Statement (Card)

The control card with the operation code DD (data definition) MUST be supplied for every data set involved in a job step. When a PGM=program-name parameter has been specified in the EXEC card, the user MUST code and include all DD cards required by the problem program. When either a PROC=cataloged-procedure-name or a cataloged-procedure-name positional parameter has been specified in the EXEC card, the cataloged procedure which has been invoked usually supplies most of the DD cards required by OS. In such instances, the user needs only to supply that data definition (DD) information which cannot be anticipated by the cataloged procedure.

(a) The Name Field of the DD Card

In all but one case (see Data Set Concatenation), the DD card MUST have a name field. This field enables OS to associate the parametric information supplied in the DD card with the correct input-output (I/O) operations in the problem program. This name is coded:

ddname

The form GO.ddname is used sparingly and generally only in cases such as: LKEDG: COMPILE, LKEDG. As an example, reference should be made to the GEPLOT sample set-up in the "Documentation" manual.

These ddname codes consist of one to eight alphanumeric characters, the first of which MUST be alphabetic.

Both begin in column 3 and MUST be preceded by // in columns 1 and 2. Both MUST be followed by one or more blanks to separate them from the operation symbol DD.

The ddname form employed by the user MUST be the same as the one expected by the problem program, in order that OS may make the correct association. The ddname form is used when the problem program has been invoked by means of a PGM=program-name positional parameter of the EXEC card.

```
//STEPXX   EXEC    PGM=PTSUM
//TRIPSI   DD    Parameter-list
```

The GO.ddname form is used when the problem program has been invoked by means of a PROC=cataloged-procedure-name or a cataloged-procedure-name positional parameter in the EXEC card. GO in this case refers to a specific step name in the catalogued procedure.

```
//STEPXX   EXEC   PTSUM
//TRIPSI   DD   (Parameter-list)
```

(b) The Operand Field of the DD Card

The operand field of the DD card has one positional parameter which may assume either of two mutually exclusive values. They are:

* , or

DUMMY

The * parameter signals that a data set will follow immediately after the DD card into which * has been punched. This form of the parameter usually is associated with the GO.SYSIN DD name card and is followed by a problem program parameter and appropriate data cards.

```
//STEPXX   EXEC   PTSUM,COND=(5,LT)
...
...    (PTSUM DD CARDS)
...
//SYSIN   DD  *
...
...    (PTSUM PARAMETER CARDS)
...
```

The DUMMY form of the parameter indicates to OS that the data set described is to be treated as a dummy. In the urban planning package, input data sets MUST NEVER be defined as DUMMY, but output data sets may be so defined. If either form of the positional parameter in the operand field of the DD card is specified, keyword parameters MUST NOT also be specified.

If no positional parameter has been specified on the DD card, there are eight keyword parameters which may be used. They are:

(1) DSNAME=dsname

(2) UNIT=(name,,DEFER)

(3) DCB=(subparameter-list)

(4) VOLUME=(PRIVATE ,RETAIN

,,volume-count ,SER=(volume-

serial-number ,volume-serial-number

...))

(5) SPACE=(average-record-length,(primary-

quantity ,secondary-quantity),RLSE)

(6) LABEL=(data-set-sequence-number ,NL)

LABEL=(data-set-sequence-number ,SL)

(7) DISP=(type ,status)

(8) SYSOUT=A

The DSNAME parameter allows the user to specify the data set name. This parameter is a group of one to 44 non-blank alphanumeric characters, the first of which MUST be alphabetic. The user of the urban planning package should always specify a DSNAME when the positional parameter is not used, although it is not strictly required for output. If none is supplied, a system-generated DSNAME will be used, but such data sets are difficult to recover at the end of a job.

```
//STEPXX   EXEC   PTSUM
//TRIPSI   DD   DSNAME=WASHDC.TRIPS,...
```

The UNIT parameter is used to specify the type or address of the unit to be associated with the data set which is being described. Unit type name and unit addresses may vary from installation to installation, but those which are common to most installations are:

Code	Data Device
SYSSQ	tape or disk
SYSDA	disk
2311 or 2314	disk
2400	9-track tape
2400-1	7-track compatibility
2400-2	7-track compatibility and data conversion

The following are examples of the use of the UNIT parameter. Figure (a) shows the use of a type name and (b) the use of an actual address. When a type name is used, OS assigns an appropriate device from among those available and issues a mounting instruction to the computer operator. The DEFER subparameter causes volume mounting to be deferred until required by the problem program. Its use is recommended when appropriate.

```
(a) //STEPXX   EXEC   PTSUM
    //TRIPSI   DD   DSNAME=TRIPS,UNIT=(2400,,DEFER),...

(b) //STEPXX   EXEC   PTSUM
    //TRIPSI   DD   DSNAME=TRIPS,UNIT=(281,,DEFER),...
```

The DCB parameter is associated with a subparameter list, some of which are used with the urban planning package. All are keyword:

```
(DEN=0)
(DEN=1)
(DEN=2)
(DEN=3)
(TRTCH=C)
(TRTCH=E)
(TRTCH=T)
(TRTCH=ET)
(RECFM=F(A) (,BLKSIZE=xxxx)
(RECFM=U(A) (,BLKSIZE=xxxx)
(RECFM=V(A),LRECL=xxxx,BLKSIZE=xxxx)
(RECFM=FB(A),LRECL=xxxx,BLKSIZE=xxxx)
(RECFM=VB(A),LRECL=xxxx,BLKSIZE=xxxx)
```

The DEN subparameter of the DCB parameter is specified only for data sets on magnetic tape volumes. It is required only for 7-track tapes or 9-track tapes mounted on dual density tape drives. The meanings of the DEN values are:

- 0 200 BPI
- 1 556 BPI
- 2 800 BPI
- 3 1600 BPI

The TRTCH subparameter of the DCB parameter is specified only for data sets residing on 7-track magnetic tape volumes. The meanings of the TRTCH values are:

- C the data conversion feature is to be used;
- E even parity is to be used;
- T translation from BCD to EBCDIC is desired; and
- ET even parity is used and translation from BCD to EBCDIC is desired.

In the data conversion feature (C above); 48 6-bit bytes from the 7-track tape are fitted into 36 8-bit bytes in core. No other conversion occurs. This hardware feature, however, is not universally available.

AVTCON, TIMCON & TRPCON, the only programs in the Urban Planning System 360 Battery which are designed to convert 7-track binary tapes to 9-track, uses the translation rather than the conversion feature. TRTCH=T should be specified in the DCB field when using these programs.

The RECFM, LRECL, and BLKSIZE keyword subparameters of the DCB parameter specify record characteristics which are volume independent. The meanings of the RECFM values are as follows:

.F means fixed record format.

Each record is the same number of bytes long and data are contained in all bytes. BLKSIZE MUST be set equal to the number of bytes in each record if a value is not assumed. This option applies only to data sets intended for the card reader or the card punch in the urban planning package.

.U means undefined record format.

Each record may not exceed an assumed number of bytes of that number fixed by BLKSIZE. Data are contained in all bytes. Data sets intended for the printer employ this option in the urban planning package.

.V means variable record format.

Each record is of variable length and is preceded by 2 words (8 bytes) of ID. LRECL MUST be specified and is set equal to the maximum number of bytes of data plus (+) four. BLKSIZE

MUST be specified and is set equal to LRECL plus four (the maximum number of bytes plus (+) eight). Trips and trees are in the variable record format in the urban planning package.

.FB means fixed-length block record format.

Each record is a block of fixed-length logical records. All bytes contain data. LRECL MUST be specified and is set equal to the length of one logical record in bytes. BLKSIZE is a multiple of LRECL.

.VB means variable-length blocked record format.

Each record has a 4-byte (1 word) ID and is a block of variable-length records. LRECL MUST be specified and represents the maximum number of bytes in each logical record plus (+) four. BLKSIZE MUST be specified and MUST be a multiple of LRECL plus four. Trips and trees may be in the variable blocked format in the trip distribution package.

.A means carriage control.

The character A may be appended to any of the above RECFM specifications. It indicates that the first byte in each logical record contains the standard FORTRAN carriage control.

Because all data sets MUST have the RECFM and BLKSIZE subparameters of the DCB parameter, if the user does not assign them a DD card, FORTRAN I/O will make the following assumptions:

SYSIN..........RECFM=F,BLKSIZE=80
DPNTAPE........RECFM=UA,BLKSIZE=133
All others.....RECFM=U,BLKSIZE=800

If the program has the subroutine DCBPAR included and the user does not assign the RECFM, LRECL, and BLKSIZE subparameters of the DCB parameter (or it is not a standard labeled input data set) and the I/O ddnames are IMPEDI, IMPEDO, TRIPSI, or TRIPSO, the following assumptions are made:

TRIPSI and TRIPSO

```
RECFM=VB
LRECL=4(LCN+3)
BLKSIZE=LRECL+4
```

IMPEDI and IMPEDO

```
RECFM=VB
LRECL=LCN+8 (1-byte)
LRECL=2LCN+8 (2-bytes)
BLKSIZE=LRECL+4
```

The following shows sample DD cards which might be associated with an execution of program TRPCON. The input on TRIPSI is a set of 7090 format trips with a last centroid number of 500. The output on TRIPSO is a set of 360 format trips. This is also the first example of continued JCL control statements.

```
//STEPXX EXEC TRPCON
//TRIPSI DD DSNAME=OLD.TRIPS,UNIT=2400-1,
            DCB=(DEN=1,TRTCH=T,RECFM=F,BLKSIZE=3006),...
//TRIPSO DD DSNAME=NEW.TRIPS,UNIT=2400,
            DCB=(RECFM=VB,LRECL=2012,BLKSIZE=2016),...
```

The fourth keyword parameter, VOLUME, is associated with the subparameters shown below. The first three of these are positional and the last is keyword.

(1)	positional	(PRIVATE)
(2)	positional	(,RETAIN)
(3)	positional	(,,volume-count)
(4)	keyword	(SER=(volume-serial-number (,volume-serial number)....))

The PRIVATE subparameter of the VOLUME parameter is used to refer to direct access volumes only. Tape volumes are assumed to be PRIVATE. This subparameter instructs OS to assign only the data set defined in this DD card to the volume specified.

The RETAIN subparameter of the VOLUME parameter informs OS that the volume specified is to remain mounted after completion of the job step. This is desirable when the data set defined in the DD card is required for use in a subsequent step. A RETAIN MUST be issued in each step if a data set is to remain mounted. (For an alternate method; see the DISP parameter.)

The volume-count subparameter of the VOLUME parameter specifies the number of volumes required by the data set. It MUST be specified for both input and output if more than one volume is required; unless the volume serial numbers (see the SER subparameter) of all involved volumes are specified.

Note that the volume-count subparameter, if used, must be preceded by two instead of one comma, to indicate the omission of a subparameter rarely used in the urban planning package.

The SER subparameter of the VOLUME parameter is used to specify the serial number or numbers of the volume or volumes associated with the data set which is being defined in the DD card. These serial numbers MUST be specified on input data sets, even when the volumes involved are unlabeled.

The variable volume-serial-number is composed of one to six non-blank alphanumeric characters, the first of which may be numeric. It should correspond to the installation's external volume identification. It is used as part of the computer operator's mounting instructions.

The parentheses enclosing the list of serial numbers may be deleted when:

·only one volume-serial-number is specified; and

·only one volume-serial-number is specified; and

SER is the only subparameter of the VOLUME parameter being used.

Thus, the simplest form of the VOLUME parameter is:

VOLUME=SER=volume-serial-number

```
//STEPXX  EXEC  PTSUM
//TRIPSI DD DSNAME=TRIPS,UNIT=2400,VOLUME=(,RETAIN,SER=
  PML067), ...
//STEPXX EXEC PTSUM
//TRIPSI DD DSNAME=TRIPS,UNIT=181,VOLUME=SER=PML067,...
```

The space parameter applies only to output on direct access volumes. Although in terms of tape volumes, this parameter has no meaning, it should be specified when the type of volume which a data set will occupy cannot be determined in advance, i.e., when it is specified that UNIT=SYSSQ.

This SPACE parameter has three positional subparameters which are used with the urban planning package:

average-record-length

,(primary-quantity

(,secondary-quantity))

The average-record-length subparameter of the SPACE parameter is an estimate of the average length in bytes of records to be written in this volume. The primary-quantity subparameter is an estimate of the number of records of average-record-length to be written. The secondary-quantity subparameter, which is optional, is the number of additional records of average-record-length to be written, if the primary quantity is exceeded. OS will allocate space for secondary-quantity records as many as 15 times.

```
//STEPXX  EXEC TRPCON
//TRIPSO DD DSNAME=TRIPS.OUTPUT,UNIT=SYSSQ,                  X
//          DCB=(RECFM=VB,LRECL=2012,BLKSIZE=2016),          X
//          VOLUME=(PRIVATE,RETAIN),SPACE=(1500,(500,10)),...
```

The LABEL parameter has two subparameters which may be utilized in the urban planning package. It MUST be specified for non-labeled volumes and for data sets which will occupy files other than the first file in tape volumes.

The data-set-sequence-number parameter of the LABEL format identifies the location of a data set in relation to the first data set on a tape volume. For example, the third data set on a tape would have the data-set-sequence-number of 3. This position MUST be specified. If the position is not specified, OS assumes that the position is 1.

The second positional subparameter of the LABEL parameter indicates whether labels are standard (SL) or non-existent (NL). If neither is specified, SL is assumed.

```
//STEPXX EXEC PTSUM
//TRIPSI DD DSNAME=TRIPS, UNIT=281,VOLUME=SER=0514, X
             DCB=(RECFM=VB,LRECL=2012,BLKSIZE=2016),
             LABEL=(3,NL),...
```

The DISP parameter is an important one. It has two positional subparameters. The first, type, may assume the following values which are used in the trip distribution package:

NEW
OLD
SHR
MOD

NEW means that the data set defined will be created in the current job step. A NEW data set cannot be input first: it MUST be output first. If the volume upon which it is to be written is direct access, it MUST not already contain any other data set of the same dsname. OLD means that the data set defined has been previously created. OLD data sets MUST exist on the volume specified. NEW is assumed, if neither NEW or OLD is specified.

The second positional subparameter of the DISP parameter is status, which is optional. It may assume the following values:

DELETE

KEEP

PASS

DELETE causes the data set defined to be deleted at the end of the current job step. In a direct access volume, such a deletion is fatal and the data set becomes irrecoverable. KEEP instructs OS not to DELETE the data set in question. The computer operator is instructed to save the volume which contains the data set. PASS instructs OS not to dismount the volume which contains the data set at the end of the current step. PASS has the same effect as RETAIN in the VOLUME parameter. Data sets which are passed out of a job are:

- DELETED if they were first specified as NEW: and

- KEPT if they were first specified as OLD.

Failure to specify a status subparameter will cause a data set to be:

- KEPT if it was OLD; and

- DELETED if it was NEW.

Enclosing parentheses may be deleted if the status subparameter is omitted.

```
//STEPXX EXEC PTSUM
//TRIPSI DD DSNAME=TRIPS,UNIT=2400,VOLUME=SER=PML073,
//             DISP=(OLD,KEEP)
```

The SYSOUT=A parameter specifies that the ultimate destination of the data set is the printer. This parameter and DCB information are all that are required to define a data set which is destined for the printer.

(c) Creating Data Sets

When the user of the urban planning package is defining a data set which is to be created, he will use the following DD parameters:

- DSNAME

- UNIT

- DCB

- VOLUME

- SPACE
- LABEL
- DISP

If the data set which is being created will have standard labels, it is not necessary to specify the LABEL parameter unless the data-set-sequence-number is some number other than 1. Sequence is not meaningful on labeled direct access volumes where standard labels are the rule. The data-set-sequence-number need be specified only for stacked data sets on tape volumes.

The SPACE parameter need not be specified when a data set is destined for a tape volume. In the DCB parameter, the DEN and the TRTCH subparameters need not be specified if the data set is destined for a direct access or for a 9-track tape volume. The following example shows samples of data sets destined for (1) a direct access, (2) a labeled 9-track tape, and (3) an unlabeled 7-track tape, in that order. It is assumed that alphanumeric data are being written on the 7-track tape.

```
//TRIPSO DD DSNAME=OUTPUT,UNIT=2311,VOLUME=SER=0067,
//      DCB=(RECFM=VB,LRECL=54,BLKSIZE=544),
//      SPACE=(544,(100)),DISP=(NEW,PASS)
//TDIST01 DD DSNAME=OUTPUT,UNIT=2400,VOLUME=SER=TP013,
//      DCB=(RECFM=VB,LRECL=54,BLKSIZE=544),DISP=(NEW,KEEP)
//FFACO DD DSNAME=OUTPUT,UNIT=2400-1,VOLUME=SER=TP7013,
//      DCB=(DEN=1,TRTCH=T,RECFM=VB,LRECL=54,BLKSIZE=544),
//      LABEL=(,NL),DISP=(,PASS)
```

(d) Retrieving Data Sets

To retrieve a labeled data set only the following DD parameters are required:

- DSNAME
- UNIT
- VOLUME

·LABEL

·DISP

The LABEL parameter may be omitted unless the data set being retrieved is stacked on a tape volume. DCB and SPACE information becomes part of the data set label and need not be repeated.

To retrieve unlabeled data sets, all DD parameters used to create the data set MUST be repeated. The following example shows how each of the data sets created in the previous example could be retrieved.

```
//TRIPSI  DD DSNAME=OUTPUT,UNIT=2311,VOLUME=SER=0067,
         DISP=OLD
//TDISTI DD DSNAME=OUTPUT,UNIT=2400,VOLUME=SER=TP013,
          DISP=OLD
//FFACI DD DSNAME=OUTPUT,UNIT=2400-1,VOLUME=SER=TP7013,

          DCB=(DEN=1,TRTCH=T,RECFM=VB,LRECL=54,BLKSIZE=544),

          LABEL=(,NL),DISP=(OLD,KEEP)
```

(4) The Delimiter Statement (Card)

The delimiter statement is unique in that it has no name, operation or operand field. It is defined by a /* in columns 1 and 2. Column 3 MUST be blank. A comments field may begin in column 4. This statement cannot be continued from one card to another.

It is used to signal the termination of data cards inserted into the input data stream by means of a

//SYSIN DD *

card. It MUST be placed in this location.

(5) The JOBLIB Card

The user may insert a special DD card between the JOB card and the first EXEC card when he wishes to execute programs directly from a library. The purpose of this DD card is to define a program library for OS.

The ddname in the JOBLIB card must be JOBLIB. The parameters in the operand field are those which are used to retrieve a labeled data set from a direct access volume. The disposition MUST be:

DISP=(OLD,PASS) or DISP=(SHR,PASS) in a multi-programming environment.

(6) The STEPLIB Card

The user may insert a special DD card immediately after an EXEC card when he wishes to execute the program directly from a library.

The ddname in the STEPLIB card must be STEPLIB. The parameters in the operand field are identical to those for a JOBLIB card. The STEPLIB is only in effect for the specific step in which it appears.

(7) Data Set Concatenation

OS can be instructed to treat two data sets as though they were one. This is done by placing the DD cards for the two together and leaving the ddname field of the second card blank. Data sets with different record formats should not be concatenated.

C. URBAN PLANNING BATTERY PROGRAMING CONVENTIONS

The Federal Highway Administration has implemented a number of programing conventions in the preparation of the IBM 360 urban transportation battery. Although certain exceptions have been made in isolated cases (due to particular circumstances), the vast majority of the programs either do, or will, conform to these conventions.

Perhaps even more important than the detailed conventions are the "guiding principles" used in the development of the battery. These principles, which should be fully understood by anyone preparing programs for the battery, are:

1. Efficiency of operation is a must. This is particularly true of those programs which will be used frequently. For example, it is totally unacceptable for a program performing a straightforward format operation to operate at a speed slower than the fastest printers currently available.

2. The same program must work for a large network in a large machine and a small network in a small machine (i.e., dynamic storage allocation must be used).

3. There must be an absolute minimum of hardware and software limitations imposed by the individual programs.

4. The fact that the majority of the users will not be computer oriented must be kept in mind at all times. One implication of this is that no user error should cause a program to "blowup" (e.g., generate a system OCx ABEND). Also, input data coding formats should be consistent (between programs), and the output formats should be similar.

The detailed programing conventions are:

1. Program Names

Names are seven or fewer characters in length, can be alphanumeric (the first character must be alpha, however), and are descriptive of the task performed by the program (e.g., BUILDHR is the program which builds a historical record).

Subject to the above restrictions, the programer may choose the name for his own program, assuming, of course, that it does not conflict with an existing program.

2. Hardware Requirements

The programs are device independent and do not require optional hardware features, such as the data conversion feature for 7-track tape drives. Also, the programs run satisfactorily in a machine configuration no larger than a 64K Model 30 with at most two disk drives and six additional disk and/or tape drives. It is assumed that the universal instruction set feature is installed on the subject machine and the printer has 132 printable positions.

3. Software Requirements

The programs run in an optionless version of the (full) Operating System in any of the three environments (P.C.P., M.F.T. and M.V.T.), as well as under a system in which the store and fetch protection feature is implemented. Successful program operation is not dependent on installation modifications to the IBM-distributed SVCLIB and LINKLIB.

Where advantageous, full use has been made of Operating System facilities such as planned overlay structure and dynamic storage allocation. Any program requiring a large quantity of core for data storage where the amount is dependent on the problem parameters (last node number, etc.) uses the dynamic storage allocation feature.

4. Data Definition Names (DDNAMES)

The following DDNAME conventions have been adopted so that a user with reasonable familiarity with the Urban Planning Battery can code the necessary JCL cards with a minimum of reference to Urban Planning System 360-Program Documentation. These conventions are followed with almost no exceptions:

a. SYSIN - card input in the standard job stream

b. DPNTAPE - standard printed output destined for the printer.

c. SYSABEND or SYSUDUMP - dataset on which system or program requested core dumps will be written (this card is not required but is strongly recommended).

Certain other datasets, such as historical records, triptables and trees have DDNAMES of the following form:

xxxxdn

"xxxx" represents a series (1-6) of alphameric characters which are descriptive of the data set in question. "d" indicates whether the dataset is input or output from the program ("I" or "O") respectively.

With the exception of temporary (scratch) datasets, the "d" digit is always used. The third portion of the DDNAME "n", is only used by those programs which have the capability of accepting (or generating) more than one dataset of the type in question. For example, a program which could possibly input two historical records and output a third would use the DDNAMEs HRI1, HRI2, and HRO.

DDNAME	Dataset
TEMPn	Temporary (scratch) files
TRPCDdn	Trip cards
LNKCDdn	Link data cards
HRdn	Regular historical record
NWRCDdn	Spiderweb historical record
TRIPSdn	Trip tables
IMPEDdn	Tree records containing only impedances (skim trees)
PATHSdn	Tree records containing only path information
XYIDdn	Coordinate cards for spiderweb programs
CONCTdn	Connecter cards for spiderweb programs
TAPEdn	Data-independent datasets (such as the input to a tape copy program)

The trip distribution programs which provide the capability of generating a merged-by-purpose trip table and a separate total purpose trip table use TRIPSO1 and TRIPSO2, respectively, as DDNAMEs. All programs, including those using FORTRAN I/O routines, should follow these DDNAME conventions.

5. Program Control Cards

Once a program gets into execution, it will generally read two types of cards--program control cards and data cards. Program control cards are used for such things as stating page headings for output, defining needed parameters (such as the last node number), and specifying program options. Data cards include, but are not limited to, cards containing numeric data used in computations. Program control cards precede any data cards in the deck setup.

The general format of program control cards shall be an identifying keyword (PAR, RANGE, etc.) followed by a comma followed by individual parameter values (usually numeric) separated by commas, where necessary. The operation keyword must start in column 1, and there cannot be any imbedded blanks. The remainder of the card, after the first blank, may be used for alphanumeric comments. Rules exist for continuation cards. Keywords (defining types of program control cards) do not exceed eight characters in length.

Program control cards can occur in any order, but a GO card (the characters "GO " in columns 1-3) will usually be the last such card. Where applicable, the page heading for output is defined by columns 4-80 of the ID card (identified by the characters "ID," in columns 1-3).

6. Messages and Printouts

All messages and printouts are written on the DPNTAPE dataset, using carriage control and, if needed, 132 positions of print. The use of the typewriter is generally reserved for program termination messages.

At program termination time (successful or otherwise), an appropriate message is printed on both the DPNTAPE dataset and on the typewriter. This message is brief, concise, and incorporates both the program name and last compilation date (MM/DD/YY). The first eight characters of the message printed on the typewriter is the jobname (from the TIOT system control block). Where advantageous, numeric "abort codes" may be printed in lieu of word messages in case of apparent malfunction.

All program control cards are printed on the DPNTAPE dataset.

FORTRAN programs use one of the following two alternative conventions for dataset reference numbers:

Dataset	Convention No. 1	Convention No. 2
SYSIN	1	5
DPNTAPE	3	6
(Punch)	2	7
(Maximum allowable)	25	25

7. Return Codes

All programs issue an appropriate return code to the system when returning control to the monitor at the conclusion of program execution. This is done by "placing" the desired value in general purpose register 15 immediately prior to issuing the "BR 14" instruction.

The urban planning battery follows the standard IBM conventions for return codes. A code of 0 indicates successful completion of the program, 16 denotes that the program was aborted during execution, and intermediate codes, if needed, indicate errors of some sort were detected (the relative severity of which are related to the magnitude of the code--4, 8, or 12) but the program continued to completion.

8. General Considerations

All programs conform to accepted programing standards. These include, but are not limited to, the following:

1. Standard Operating System linkages are used.

2. Unnecessary use of temporary (scratch) datasets is avoided, as is unnecessary repeated reading of input datasets.

3. Modular program design is used but not to the point where program efficiency is impaired by excessive transfers between individual modules.

4. Appropriate comments are liberally interspersed with instructions in source decks.

5. Needless proliferation of programs was prevented by combining similar functions in a single program, wherever feasible.

6. Repetitious coding was avoided by defining macros and using appropriate standard routines (either separate subroutines or sections of coding which may be inserted into a program). The Federal Highway Administration has developed a macro library and a subroutine library to facilitate its own programing effort in the development of the urban transportation planning battery.

7. End-of-data exits are provided for all input datasets, and appropriate program action taken if the end of data is unexpectedly encountered. FORTRAN programs do this by utilizing the END parameter in the READ statement.

8. Assembly language programs check to make sure that the user provided the needed DD card before doing I/O on that dataset. An expedient method of doing this is by use of the ZOPEN macro.

9. The size of the executable load module, together with the amount of core storage which is obtained dynamically is minimal.

10. The programs require the user to furnish only a minimal amount of DCB information (i.e., RECFM, BLKSIZE, and LRECL) to the system on JCL cards. To implement this, the use of standard labels is strongly encouraged (in fact, assumed). Also, the user never has to compute LRECL and BLKSIZE based on some formula (i.e., the program performs the computation and utilizes a DCB exit, if necessary, to inform the system of these parameters).

11. Input/output error exits are provided for all datasets and appropriate program action is taken if this condition is encountered. FORTRAN programs do this by utilizing the ERR parameter in the READ and WRITE statements. ALP programs use the ZSYN macro.

12. Any given process is usually accomplished by executing a single program rather than a series of two or more programs. For example, the process of building a traditional historical record involves three separate steps (editing the input cards, executing the IBM sort/merge program, and outputting the final historical record), yet all three are incorporated in the one BUILDHR program (the program "links" to the sort/merge program during the second step).

13. During execution, a program usually does not require the dynamic "loading" of modules into higher core. Exceptions would be access method routines, SVC routines, the standard sort/merge programs, etc., but not user coded routines or subroutine library routines (such as PL/I library routines).

14. ALP compiles include a TITLE card so that the compile listing has an appropriate title line and columns 73-76 of the generated object decks contain identifying characters.

15. Several of the binary datasets used in the battery (e.g., triptables, historical records, etc.) incorporate user-provided EBCDIC identification (comment) information. Any program inputting such a dataset prints this information in a standard format, and any program outputting the dataset provides the user with the capability of specifying such information.

9. Available Programing Aids

To aid in the preparation of the battery, the Federal Highway Administration has developed a number of macros and subroutines.

These fall in the following general categories:

1. A modified FORTRAN subroutine library together with the corresponding FORTRAN G and H compilers. These modifications permit the user to specify non-FORTRAN DDNAMEs, print job termination messages of the type described herein, etc.

2. Standard subroutines to permit a FORTRAN program to read and interpret parameter cards of the required type, read and write skim trees, read and write trip-tables, etc.

3. Assembly language macros to substantially reduce redundant coding and provide the necessary linkage to certain user subroutines.

4. User subroutines for ALP programs to perform such tasks as opening datasets (ZOPEN), handling input/output errors (ZSYNAD), interpreting parameter cards (PARAM), dynamically obtaining core (GMAINS), etc.

Programs developed under contract to the Federal Highway Administration must use the above subroutines and macros. Other parties developing programs which might be incorporated into the battery are strongly urged to use these subroutines and macros. By so doing, it will be possible to:

1. Minimize programing effort.

2. Easily maintain compatibility in data coding formats, etc.

3. Maintain similarity of actual programing instructions and techniques, thus making it easier for other programers to familiarize themselves with the program and make any desired modifications.

Documentation on these subroutines and macros, as well as the decks themselves, will be available on request to the Federal Highway Administration.

D. URBAN PLANNING BATTERY - STANDARD DATASET FORMATS

1. Triptable Dataset Format

An IBM 360 triptable dataset contains a record of all interchanges between each origin-destination pair for one or more "purposes," optionally preceded by comment records. The same basic format is used for origin-destination triptables, production-attraction triptables, and vehicle-mile tables. The dataset is in variable blocked record format, and all logical records can be read with the following FORTRAN statement:

```
21   FORMAT (33(255A4))
     READ (12,21) N,ID,(A(I),I=2,N)
```

The format of the optional comment records is:

Word	Contents
0	System word (11)
1	Binary 20_{10}
2-21	Comment card image (The first byte contains an asterisk.)

Every program that outputs triptables has the capability of inserting these comment records which are actually provided by the user in the form of comment cards (denoted by an asterisk in column one).

One (or more, as described later)logical record is used for each row in the matrix:

Word	Bits	Contents
0		System word (11)
1		N-number of words remaining in the record, in binary
2	Identification	(ID) word
	0-7	Binary flag (see page VIII-46)
	8-15	Table number, in binary
	16-31	Origin zone number, in binary
2+i	i=1,.....,n	where n is the number of nonzero volumes associated with the origin zone in question.
	0-13	Destination zone number, in binary
	14-31	Interchange value, in binary

All zero interchange volumes are left out of the record. If there are no interchanges to any destination zone from a given origin zone, a 16-byte logical record is written consisting of the system word, a binary 2_{10}, the ID word, and a binary zero. Negative interchanges are not allowed, and therefore all 18 bits are used for the positive value. If a given interchange exceeds 262,143 more than one word is used for that particular interchange.

The user may specify a table, or purpose, number for each triptable created. Legitimate table numbers are greater than zero and less than 256. Table number zero is legitimate for input but not for output. This table number occupies the second byte of the ID word.

Since the user may optionally express a maximum record length when creating triptables, more than one logical record may be used for a given origin zone. Each of these records will have the same ID word. This maximum record length option gives the user the capability of minimizing the block size, and thus the buffer size, required in all programs which input triptables. The minimum size which can be specified is 88 bytes (the size required for comment records). Any value (multiple of 4) greater than 87 bytes (and less than 32,760) is acceptable, regardless of the number of zones. Normal LRECL is 12 + 4LCN; normal BLKSIZE is 16 + 4LCN. If LRECL is bigger than about 4,000, then it cannot be read into LOADVN directly.

When a given origin zone-triptable is written out in more than one logical record, a binary 255 is placed in the flag byte of the ID word of all but the last such logical record. The flag byte of the last, and usually only, logical record for a given origin zone-triptable will always contain a binary zero.

2. TRPCODE Output Dataset Format

The following is output on the output tape (TRPCDO).

A. The first output record is a label which contains a word count in the first word, an asterisk and three blanks in the second word and the following in words 3-19: "CONTROL CARD FOLLOWS - EACH CARD BEGINS WITH THE WORD COUNT AND A STAR."

B. Control cards - Each control card is written on the output tape. The first word of each record contains a word count, the fifth byte contains an asterisk and the control card is in bytes 6-84.

C. Standard dictionary - Each dictionary record contains the word count in word 1 and an asterisk, D and 2 blanks (*Dbb) in the second word. Except for the first and last dictionary records, words 3 and 5 contain the name of a variable right justified followed by the input, output and limits definitions in the next 6 words. The first record of the dictionary contains the following starting in words 3-18: "THE STANDARD OUTPUT DICTIONARY FOLLOWS - NUMBER OF RECORDS IS" and a count of the dictionary records (70) in word 19 (in binary). The last record of the dictionary is an end record for the dictionary and a x 'FF' in the first byte of the name field.

STANDARD DICTIONARY:

Note that the input positions must be defined with a DEFINE control card.

NAME	OUTPUT	NAME	OUTPUT
ORGZN	1-2	DESTCO	47-48
DESTZN	3-4	ORGCITY	49-50
RESZN	5-6	DESTCITY	51-52
PRODZN	7-8	ORGCEN	53-54
ATTRZN	9-10	DESTCEN	55-56
INTVWSTA	11-12	ORGCTB	57-58
ENTRYSTA	13-14	DESTCTB	59-60
EXITSTA	15-16	SAMPNO	61-62
SCRNORG	17	PERSNO	63
SCRNDEST	18	TRIPNO	64

NAME	OUTPUT	NAME	OUTPUT
CARDNO	19	SEX-RACE	65
MODE	20	INDUSTRY	66
DIRECTN	21	OCCUPTN	67
FROMPURP	22	RELATN	68
TOPURP	23	VEHTYPE	69
GENPURP	24	AVAIL	70
FACTOR	25-26	PARKTYPE	71
HRFACTOR	27-28	PARKCOST	72
LUORG	29-30	GARAGE	73
LUDEST	31-32	FLEET	74
LUPROD	33-34	COMMDTY	75-76
LUATTR	35-36	WEIGHT	77
STTIME	37-38	MONTH	78
ARRTIME	39-40	DATE	79
MIDTIME	41-42	DAY	80
ORGST	43	GROUPA	81
DESTST	44	GROUPB	82
ORGCO	45-46	GROUPC	83
		GROUPD	84

3. Impedance (Skim Trees) Dataset Format

The record format of this dataset is variable unblocked and consists of a single binary record for each origin zone included in the dataset. There does not have to be a record for every zone in the network(i.e., selected trees/vines were built), but all records must be in sort by origin zone number. There are two optional formats for skimmed trees, a 1-byte and a 2-byte format. Respectively, the individual impedance values are contained within one and two bytes. If a computed impedance exceeds the maximum allowable for the particular format, the impedance is set equal to the maximum.

The format of the 1-byte skim trees is as follows:

Word	Byte	Contents
0		System word ($\ell\ell$)
1	0-1	Binary 1
	2-3	Origin zone number (binary)

Each subsequent byte contains the binary impedance to that destination zone.

The format of the 2-byte skim trees is as follows:

Word	Byte	Contents
0		System word ($\ell\ell$)
1	0-1	Binary zero
	2-3	Origin zone number (binary)

Each subsequent halfword contains the binary impedance to that destination zone.

4. TRADITIONAL NETWORK HISTORICAL RECORD FORMAT

OVERALL DATASET LAYOUT

```
1 STANDARD TAPE LABELS          ------------

2 TAPEMARK

3 DESCRIPTIVE LABEL RECORDS     *--------------
    90 BYTES EACH, AT LEAST     *------------
      ONE PER H.R. WORD         *-------------

4 PARAMETER RECORD              ---------------
    ABOUT 192 BYTES

5 HISTORICAL RECORDS            ---------------
    2 TO 5 LOGICAL              --------------
      RECORDS PER NODE          --------------

6 TAPEMARK

7 STANDARD TRAILER LABELS       ------------

8 TAPEMARK


*   ITEMS 3-5 ARE VARIABLE-BLOCKED RECORDS.
```

PARAMETER RECORD FORMAT

WORD NUMBER	CONTENTS
-	TWO OPERATING SYSTEM WORDS CONTAINING RECORD LENGTH.
1	ITERATION NUMBER.
2	LAST CENTROID NUMBER - OR ZERO IF PARTITIONING - SEE WORD 35.
3	LAST NODE NUMBER. SEE WORD 35.
4	LONGEST DISTANCE PERMISSIBLE - ZERO IF DISTANCE NOT CHECKED.
5	DESIGN HOURLY VOLUME/AVERAGE DAILY TRAFFIC RATIO.*
	* THIS VALUE USED IF NOT FURNISHED IN LINK DATA CARD.
6-9	INDICATORS OF VALIDITY OF TURN PENALTY CODES 1-4. ZERO IF INVALID.
10-13	TURN PENALTIES -MINUTES, HUNDREDTHS- CORRESPONDING TO CODES 1-4.
14	LINK CARD-COLUMN OF CLASSIFICATION FOR SPEED TESTS.
15	FIRST NONZERO CODE UNDER THIS CLASSIFICATION TO BE CHECKED.
16-17	MINIMUM, MAXIMUM SPEED FOR LINKS OF THIS CODE.
18	SECOND NONZERO CODE UNDER THIS CLASSIFICATION TO BE CHECKED.
19-20	MINIMUM, MAXIMUM SPEED FOR LINKS OF THIS CODE.
21-23	THIRD CODE, MINIMUM AND MAXIMUM SPEEDS.
24-26	FOURTH CODE, MINIMUM AND MAXIMUM SPEEDS.
27-29	FIFTH CODE, MINIMUM AND MAXIMUM SPEEDS.
30,31	MINIMUM AND MAXIMUM SPEED FOR ALL OTHER CODES.
32	INDICATOR DESCRIBING FIRST ASSIGNMENT SPEED OPTION.*
	* 0 MEANS NO FIRST ASSIGNMENT SPEED WAS PREPARED.
	* 1 MEANS OBSERVED SPEED WAS USED.
	* 2 MEANS THAT THIS SPEED WAS CALCULATED.
33	RATIO OF LOAD/CAPACITY FOR WHICH SPEED WAS CALCULATED(SEE WORD 32).
34	COORDINATE SCALE FACTOR.
35	NUMBER OF SUBNETS IF PARTITIONED NETWORK(OR 'OZZZ', OTHERWISE).
36	FIRST CENTROID NUMBER FOR SUBNET 1(ZERO IF UNPARTITIONED).
37	LAST CENTROID NUMBER FOR SUBNET 1(ZERO IF UNPARTITIONED).
38	LAST NODE NUMBER FOR SUBNET 1(ZERO IF UNPARTITIONED).
39-41	DATA CORRESPONDING TO WORDS 36-38, BUT FOR SUBNET 2.
42-44	DATA CORRESPONDING TO WORDS 36-38, BUT FOR SUBNET 3.
45-47	DATA CORRESPONDING TO WORDS 36-38, BUT FOR SUBNET 4.

FORMAT OF HISTORICAL RECORD (INTERSECTION PORTION)

WORD NO	BYTE NO	ITEM LENGTH	OFF-SET	CONTENTS
-	-	4	-	OPERATING SYSTEM WORD CONTAINING RECORD LENGTH.
1	0	1	0	LINK PRESENCE INDICATOR BITS.
	2	2	2	A-NODE OF INTERSECTION (NORMALIZED)
2	0	2	4	B-NODE CONNECTED TO A0 (MAP-NODE NUMBER)
	2	2	6	B-NODE CONNECTED TO A1 (MAP-NODE NUMBER)
3	0	2	8	B-NODE CONNECTED TO A2 (MAP-NODE NUMBER)
	2	2	10	B-NODE CONNECTED TO A3 (MAP-NODE NUMBER)
4	0	1	12	TURN PENALTY CODE-BYTE FOR A0
	1	1	13	TURN PENALTY CODE-BYTE FOR A1
	2	1	14	TURN PENALTY CODE-BYTE FOR A2
	3	1	15	TURN PENALTY CODE-BYTE FOR A3
5	0	2	16	A-NODE OF INTERSECTION (MAP-NODE NUMBER)
	2	3	18	A-NODE X-COORDINATE
6	1	3	21	A-NODE Y-COORDINATE
7				WORDS MAY BE ADDED BY USER WITH SPECIAL PROGRAMS.

FORMAT OF HISTORICAL RECORD (LINK PORTION)

WORD NO	BYTE NO	ITEM LENGTH	OFF-SET	CONTENTS
-	-	4	-	OPERATING SYSTEM WORD CONTAINING RECORD LENGTH.
1	0	2	0	A-NODE AND LEG (NORMALIZED NUMBER)
	2	3	2	B-NODE X-COORDINATE
2	1	3	5	B-NODE Y-COORDINATE
3	0	2	8	B-NODE AND LEG (NORMALIZED NUMBER)
	2	1	10	CONDITION, COLUMN 79
	3	1	11	COLUMN 80, (STATE CODE IN NATIONWIDE USE)
4	0	1	12	COLUMN 1, (PARTITION INDICATOR IN NATIONWIDE USE)
	1	1	13	COLUMN 64, ADMINISTRATIVE CLASS
	2	1	14	COLUMN 65, FUNCTIONAL CLASS
	3	1	15	COLUMN 66, TYPE FACILITY (LINK LEVEL IN N-W USE)
5	0	1	16	COLUMN 67, SURFACE TYPE
	1	1	17	COLUMN 68, TYPE AREA
	2	2	18	COLUMNS 69-70, PREDOMINANT LAND USE* *(UN-NORMALIZED EQUATED PARTITION NODE NO. IF P IN COL 1)
6	-	4	20	COLUMNS 71-74, GEOGRAPHIC LINK LOCATION
7	-	4	24	COLUMNS 75-78, ROUTE NUMBER OR STREET NAME
8	1	3	29	COUNT, A-TO-B, FROM COLUMNS 32-36 OR 55-59
9	1	3	33	COUNT, B-TO-A, FROM COLUMNS 55-59 OR 32-36
10	0	2	36	DVH/ADT RATIO, A-TO-B FROM COLUMNS 29-31 OR 52-54
	2	2	38	HOURLY CAPACITY, A-TO-B, FROM COLUMNS 25-28 OR 48-51
11	0	2	40	DVH/ADT RATIO, B-TO-A, FROM COLUMNS 52-54 OR 29-31
	2	2	42	HOURLY CAPACITY, B-TO-A, FROM COLUMNS 48-51 OR 25-28
12	1	1	45	COLUMN 40, UNASSIGNED A-TO-B DATA
	2	1	46	PARKING, A-TO-B
	3	1	47	STREET WIDTH, A-TO-B
13	1	1	49	COLUMN 63, UNASSIGNED B-TO-A DATA
	2	1	50	PARKING, B-TO-A
	3	1	51	STREET WIDTH, B-TO-A
14	0	2	52	UNLOADED TRAVELTIME, A-TO-B
	2	2	54	DISTANCE, A-TO-B

FORMAT OF HISTORICAL RECORD (LINK PORTION, CONTINUED)

WORD NO	BYTE NO	ITEM LENGTH	OFF-SET	CONTENTS
15	0	2	56	UNLOADED TRAVELTIME, B-TO-A
	2	2	58	DISTANCE, B-TO-A
16	0	2	60	OBSERVED SPEED, A-TO-B
	2	2	62	OBSERVED TRAVELTIME, A-TO-B
17	0	2	64	OBSERVED SPEED, B-TO-A
	2	2	66	OBSERVED TRAVELTIME, B-TO-A
18	0	2	68	FIRST ASSIGNMENT SPEED, A-TO-B (OPTIONAL)
	2	2	70	FIRST ASSIGNMENT TRAVELTIME, A-TO-B (OPTIONAL)
19	0	2	72	FIRST ASSIGNMENT SPEED, B-TO-A (OPTIONAL)
	2	2	74	FIRST ASSIGNMENT TRAVELTIME, B-TO-A (OPTIONAL)

(THE REMAINDER OF THE HISTORICAL RECORD VARIES WITH ORDER OF PROCESSING)
(A TYPICAL PORTION, CONTAINING LOADS AND CAPACITY RESTRAINT RESULTS, FOLLOWS)

N	2	2	4N-2	TREE/VINE-BUILDING IMPEDANCE, A-TO-B
N+1	2	2	4N+2	TREE/VINE-BUILDING IMPEDANCE, B-TO-A
N+2	0	4	4N+4	TURN VOLUME, A0-TO-A1(ALL 1'S IF LINK-LOAD OPTION)
N+3	0	4	4N+8	TURN VOLUME, A0-TO-A2(OR LINK-LOAD A-TO-B)
N+4	0	4	4N+12	TURN VOLUME, A0-TO-A3(OR LINK-LOAD B-TO-A)
N+5	0	2	4N+16	BALANCE SPEED, A-TO-B
	2	2	4N+18	BALANCE TRAVELTIME, A-TO-B
N+6	0	2	4N+20	BALANCE SPEED, B-TO-A
	2	2	4N+22	BALANCE TRAVELTIME, B-TO-A
N+7	0	2	4N+24	ASSIGNMENT SPEED, A-TO-B
	2	2	4N+26	ASSIGNMENT TRAVELTIME, A-TO-B
N+8	0	2	4N+28	ASSIGNMENT SPEED, B-TO-A
	2	2	4N+30	ASSIGNMENT TRAVELTIME, B-TO-A
N+9	0	2	4N+32	CALCULATED DELAY, A-TO-B
	2	2	4N+34	TOTAL NEXT ASSIGNMENT TRAVELTIME, A-TO-B
N+10	0	2	4N+36	CALCULATED DELAY, B-TO-A
	2	2	4N+38	TOTAL NEXT ASSIGNMENT TRAVELTIME, B-TO-A

5. TRADITIONAL NETWORK VINE AND TREE FORMATS

OVERALL DATASET LAYOUT

```
1 STANDARD TAPE LABELS         ------------

2 TAPEMARK

3 DESCRIPTIVE LABEL RECORDS    *--------------
    90 BYTES EACH, AT LEAST    *------------
      ONE PER H.R. WORD        *-------------
      PLUS ADDED ID CARDS      *-------------

4 PARAMETER RECORD             ---------------
    ABOUT 208 BYTES

5 NETWORK DESCRIPTION          --------------
    RECORDS                    --------------
    ( 8 FOR VINES)             --------------
    (16 FOR TREES)             --------------

6 VINE OR TREE RECORDS         --------------
    AS SPECIFIED IN            --------------
    BUILDVN RUN                --------------

7 IMPEDANCE RECORDS            --------------
    (16 FOR VINES)             --------------
    (32 FOR TREES)             --------------

8 TAPEMARK

9 STANDARD TRAILER LABELS      ------------

10TAPEMARK


*   ITEMS 3-7 ARE VARIABLE UNBLOCKED RECORDS.
```

PARAMETER RECORD FORMAT

WORD NUMBER	CONTENTS
-	TWO OPERATING SYSTEM WORDS CONTAINING RECORD LENGTH.
1	ITERATION NUMBER.
2	LAST CENTROID NUMBER - OR ZERO IF PARTITIONING - SEE WORD 35.
3	LAST NODE NUMBER. SEE WORD 35.
4	LONGEST DISTANCE PERMISSIBLE - ZERO IF DISTANCE NOT CHECKED.
5	DESIGN HOURLY VOLUME/AVERAGE DAILY TRAFFIC RATIO.*
	* THIS VALUE USED IF NOT FURNISHED IN LINK DATA CARD.
6-9	INDICATORS OF VALIDITY OF TURN PENALTY CODES 1-4. ZERO IF INVALID.
10-13	TURN PENALTIES -MINUTES, HUNDREDTHS- CORRESPONDING TO CODES 1-4.
14	LINK CARD-COLUMN OF CLASSIFICATION FOR SPEED TESTS.
15	FIRST NONZERO CODE UNDER THIS CLASSIFICATION TO BE CHECKED.
16-17	MINIMUM, MAXIMUM SPEED FOR LINKS OF THIS CODE.
18	SECOND NONZERO CODE UNDER THIS CLASSIFICATION TO BE CHECKED.
19-20	MINIMUM, MAXIMUM SPEED FOR LINKS OF THIS CODE.
21-23	THIRD CODE, MINIMUM AND MAXIMUM SPEEDS.
24-26	FOURTH CODE, MINIMUM AND MAXIMUM SPEEDS.
27-29	FIFTH CODE, MINIMUM AND MAXIMUM SPEEDS.
30,31	MINIMUM AND MAXIMUM SPEED FOR ALL OTHER CODES.
32	INDICATOR DESCRIBING FIRST ASSIGNMENT SPEED OPTION.*
	* 0 MEANS NO FIRST ASSIGNMENT SPEED WAS PREPARED.
	* 1 MEANS OBSERVED SPEED WAS USED.
	* 2 MEANS THAT THIS SPEED WAS CALCULATED.
33	RATIO OF LOAD/CAPACITY FOR WHICH SPEED WAS CALCULATED(SEE WORD 32).
34	COORDINATE SCALE FACTOR.
35	NUMBER OF SUBNETS IF PARTITIONED NETWORK(OR 'OZZZ', OTHERWISE).
36	FIRST CENTROID NUMBER FOR SUBNET 1(ZERO IF UNPARTITIONED).
37	LAST CENTROID NUMBER FOR SUBNET 1(ZERO IF UNPARTITIONED).
38	LAST NODE NUMBER FOR SUBNET 1(ZERO IF UNPARTITIONED).
39-41	DATA CORRESPONDING TO WORDS 36-38, BUT FOR SUBNET 2.
42-44	DATA CORRESPONDING TO WORDS 36-38, BUT FOR SUBNET 3.
45-47	DATA CORRESPONDING TO WORDS 36-38, BUT FOR SUBNET 4.
48	LAST TREE TO BE FOUND IN THE DATASET.
	* FIRST BYTE ZERO FOR VINES, NON-ZERO FOR TREES.
49	LOCATION IN HISTORICAL(LINK) RECORD FROM WHICH IMPEDANCE CAME.

FORMAT OF NETWORK DESCRIPTION(B-NODE) RECORDS

WORD NO	BYTE NO	ITEM LENGTH	OFF-SET	CONTENTS
-	-	4	-	OPERATING SYSTEM WORD CONTAINING RECORD LENGTH.
1	-	4	-	FULL-WORD OF ZERO.
				* REMAINDER OF RECORD TO BE (LAST NODE MODULO 32) BYTES LONG FOR VINES OR HALF THAT FOR TREES.
2	0	2	0	B-NODE, LEG CONNECTED TO LEG 0 OF FIRST A-NODE.
2	2	2	2	B-NODE, LEG CONNECTED TO LEG 1 OF FIRST A-NODE.
3	0	2	4	B-NODE, LEG CONNECTED TO LEG 2 OF FIRST A-NODE.
3	2	2	6	B-NODE, LEG CONNECTED TO LEG 3 OF FIRST A-NODE.
4	0	2	8	B-NODE, LEG CONNECTED TO LEG 0 OF SECOND A-NODE.
4	2	2	10	B-NODE, LEG CONNECTED TO LEG 1 OF SECOND A-NODE.
5	0	2	12	B-NODE, LEG CONNECTED TO LEG 2 OF SECOND A-NODE.

* REMAINDER OF RECORD CONTINUES IN THE SAME FASHION.

* REMAINDER OF RECORDS ARE LAID OUT IN THE SAME FASHION WITH THE UN-USED AREA FILLED WITH ZEROS IN THE LAST RECORD(S).

FORMAT OF VINE OR TREE RECORDS

WORD NO	BYTE NO	ITEM LENGTH	OFF-SET	CONTENTS
-	-	4	-	OPERATING SYSTEM WORD CONTAINING RECORD LENGTH.
1	0	1	0	ZERO FOR VINES, NON-ZERO FOR TREES.
1	2	2	2	VINE OR TREE NUMBER.
				* REMAINDER OF RECORD TO BE (LAST NODE MODULO 32) BYTES LONG FOR VINES OR HALF THAT FOR TREES.
				* VINES ARE LAID OUT AS FOLLOWS:
2	0	1	4	PATH-BYTE FOR NODE 1.
2	1	1	5	PATH-BYTE FOR NODE 2.
2	2	1	6	PATH-BYTE FOR NODE 3.

* REMAINDER OF RECORD CONTINUES IN THE SAME FASHION.

PATH-BYTES FOR CENTROIDS - FIRST TWO BITS INDICATE THE LEG WHICH ENDS THE TRACE TO THIS CENTROID, REMAINDER OF BYTE WILL BE 'XX011011'. HOME NODE PATH-BYTE WILL BE '00011011'. UNREACHABLE CENTROID PATH-BYTE WILL BE '11111111'.

PATH-BYTES FOR OTHER NODES - FIRST 2 BITS SHOW ENTERING LEG ON TRACE EXITING ON LEG 0, SECOND 2 BITS SHOW ENTERING LEG ON TRACE EXITING ON LEG 1, ETC. LEGS WHICH CAN'T BE REACHED OR DON'T EXIST WILL HAVE THE LEG NUMBER ITSELF IN THE APPROPRIATE 2 BITS. UNUSED OR UNREACHABLE NODES WILL HAVE PATH-BYTES OF '00011011'.

				* TREES ARE LAID OUT AS FOLLOWS:
2	0	1	4	PATH-BYTE FOR NODES 1 AND 2.
2	1	1	5	PATH-BYTE FOR NODES 3 AND 4.
2	2	1	6	PATH-BYTE FOR NODES 5 AND 6.

* REMAINDER OF RECORD CONTINUES IN THE SAME FASHION.

FOUR-BIT HALF-BYTES ARE EMPLOYED FOR EACH NODE.
PATH-HALF-BYTE FOR HOME NODE WILL BE '1111'.
PATH-HALF-BYTE FOR UNUSED OR UNREACHABLE NODES WILL BE '1000'.
PATH-HALF-BYTE FOR OTHER NODES: '0000', '0001', '0010', OR '0011';
(THE COMBINATION OF BITS INDICATING THE BACK-LEG NUMBER.)

FORMAT OF IMPEDANCE RECORDS

WORD NO	BYTE NO	ITEM LENGTH	OFF-SET	CONTENTS
-	-	4	-	OPERATING SYSTEM WORD CONTAINING RECORD LENGTH.
1	0	1	0	BINARY '01000000' = HEX '40'.
1	1	1	1	ZERO.
1	2	2	2	NODE AND LEG NUMBER OF FIRST A-NODE WHOSE IMPEDANCE DATA APPEARS IN THIS RECORD.
				* REMAINDER OF RECORD TO BE (LAST NODE MODULO 32) BYTES LONG FOR VINES OR HALF THAT FOR TREES.
2	0	2	4	IMPEDANCE FOR OUTBOUND LINK FROM NODE A, LEG 0.
2	2	2	6	IMPEDANCE FOR INBOUND LINK TO NODE A, LEG 0.
3	0	2	8	IMPEDANCE FOR OUTBOUND LINK FROM NODE A, LEG 1.
3	2	2	10	IMPEDANCE FOR INBOUND LINK TO NODE A, LEG 1.
4	0	4	12	IMPEDANCES FOR OUT-, INBND LINKS FOR NODE A, LEG 2.
5	0	4	16	IMPEDANCES FOR OUT-, INBND LINKS FOR NODE A, LEG 3.
6	0	16	20	IMPEDANCES FOR ALL LINKS CONNECTED TO NODE A+1.

* REMAINDER OF RECORD CONTINUES IN THE SAME FASHION.

6. Preplot Dataset Format

The output from program GEPREP consists of a dataset containing one or more groups of information. The number of groups is dependent upon the type of plots to be plotted. A network plot (with or without annotation) will require one group of information. A color group plot will, as the name implies, require a group for each color range. The specification of 'TREE' on the GEPREP run card will result in the production of one group of information for each tree to be plotted.

Each physical record within the group is one hundred and thirty two (132) characters long. The first record of the group is the label record and contains the following information:

(1) Char. 1-72: 72 character title from the GEPREP label card.

(2) Char. 73-80: This field contains a number which informs GEPLOT programs of the type of plot to be made.

a. If the number is greater than zero, the group contains information for a tree plot and the number is the tree number.

b. If the number is equal to zero, a network plot has been requested.

c. If the number is less than zero, a color group plot has been requested and the absolute value of the number specifies which range from the GEPREP colors card this group represents.

(3) Char. 81-96: The values in these two fields vary according to the type of plots to be prepared.

a. If color groups are to be plotted, the first field contains the lower limit and the second field the upper limit of the range to be plotted.

b. If trees are to be plotted, the first field contains the X coordinate and the second field contains the Y coordinate of the home node.

c. In all other cases, each field contains blanks.

(4) Char. 97-132: Blank.

The remaining records in the group consist of three logical forty-four character records within the basic one hundred and thirty-two character physical records. It should be noted that these records were written as fixed length and unblocked, that is, the unblocking of these logical records will have to be handled by the programmer, not by the operating system. Each logical record contains the following information:

(1) Char. 1-8: Node number

(2) Char. 9-17: X coordinate of the node

(3) Char. 18-26: Y coordinate of the node

(4) Char. 27-35: Information to be annotated onto the link defined by the node from the current logical record (B node). If this information is of a directional nature, it would pertain to the A to B direction.

(5) Char. 36-44: Information to be annotated onto the link defined by the node from the previous logical record (A node) and the node from the current logical record (B node). If this information is of a directional nature, it would pertain to the B to A direction.

In the following discussion several references are made to the 'network.' It should be understood that the term 'network' as used also refers to any subset of the full network such as a tree or the links within any one color group.

The network is plotted by drawing the link A-B defined by using the node from the previous logical record as the A node and the node from the current logical record as the B node. The current node then becomes the A node and the next logical record is read to get the next B node. This string of logical records is developed by program GEPREP and has no fixed length. The string moves from node to node until a node is encountered from which there is no exit. When a 'no exit' condition is found, program GEPREP will write a logical record in which the node number has the value of zero and the contents of the rest of the record is zero, this comprising an 'end of string' logical record. If another string is to be developed, a new logical record is formed as described above. If the preceding string was the last in a range, an additional physical record, identical to the 'end of string' record but containing a minus one in the node field is prepared. At this point, the physical record containing this last logical record is written, being filled out to 132 characters as required, with 'end of string' records. Following this the 'end of group' record would be the label record for the next group or an end-of-file if this were the last group.

7. Spiderweb Network Description Format

The spiderweb network description dataset is in variable blocked record format and consists of the following groups of logical records:

1. Several groups of EBCDIC comment records. These are, in order of occurrence, "I," "N," and parameter record format descriptions. All are denoted by an asterisk in the fifth byte of the logical record, and all are 88 bytes long.

    a. Identification records (type I) are denoted by an "I" in the sixth byte of the record.

    b. Network description records (type N) are denoted by an "N" in the sixth byte and describe the format of the individual historical records.

c. Records having neither an "I" nor an "N" in the sixth byte describe the format and contents of the parameter record. The sixth byte should be used as carriage control for these records.

2. A 180 byte binary parameter record denoted by a "P" in the fifth byte. The parameter record contains the location and length of each field in the individual historical records. The format of the parameter - as offset from the "P" in the sixth byte of the record - is given below.

3. Individual binary historical records, one for each centroid in the network. The format of these is given below.

Any program which inputs a spiderweb network description should print the comment records on the DPNTAPE dataset. Any program which updates the network description should make the appropriate changes in the parameter record and provide the user the capability of updating the EBCDIC comment records.

SPIDERWEB PARAMETER RECORD FORMAT AND CONTENTS

NAME	OFFSET	LNG	DATA
LSTNODE	0	4	LAST NODE NUMBER
LSTZONE	4	4	LAST ZONE NUMBER
NOCON	8	2	NUMBER OF CONNECTORS
SCDIST	10	2	SCALE OF DISTANCE
SCTIME	12	2	SCALE OF TIME
SCSPEED	14	2	SCALE OF SPEED
FSTLNKD	16	2	OFFSET FOR FIRST LINK DATA
LENLNKD	18	2	LENGTH LINK DATA
LOCASTNO	20	2	LOC. OF NODE A DIST. (STATE) NO.
LNGASTNO	22	2	LEN. OF NODE A DIST. (STATE) NO.
LOCANAM	24	2	LOC. OF NODE A DIST. (STATE) NM.
LNGANAM	26	2	LEN. OF NODE A DIST. (STATE) NM.
LOCCONM	28	2	LOC. OF NODE A ZONE (COUNTY) NM.
LOCCONM	30	2	LEN. OF NODE A ZONE (COUNTY) NM.
LOCXCOR	32	2	LOCATION OF X COORDINATE
LNGXCOR	34	2	LENGTH OF X COORDINATE
LOCYCOR	36	2	LOCATION OF Y COORDINATE
LNGYCOR	38	2	LENGTH OF Y COORDINATE
RESERVE	40	40	10 WORDS RESERVED FOR FUTURE USE
LOCANOD	80	2	LOCATION OF NODE A + LEG NUMBER
LOCBSTA	82	2	LOC. OF NODE B DIST. (STATE) NO.
LOCBNOD	84	2	LOCATION OF NODE B + LEG NUMBER
LOCIMPD	86	2	LOCATION OF IMPEDANCE
LOCDIST	88	2	LOCATION OF DISTANCE
LOCSPED	90	2	LOCATION OF SPEED
RESERVE	92	80	20 WORDS RESERVED FOR FUTURE USE

FORMAT OF SPIDERWEB NETWORK HISTORICAL RECORD

Word	Bytes	Offset (bytes)	Length (bytes)	Information
-	1-2		2	System word - length of blocked record
	3-4		2	System word - blanks
0	1-2	0	2	System word - length of logical record
	3-4	2	2	System word - blanks
1	1	4	1	Number of links from this A node
	2	5	1	Offset for node A data
	3	6	1	Length of each link data record
	4	7	1	Reserved
2	1	8	1	State number - node A
	2-4	9	3	State abbreviation (EBCDIC)
3-5	1-12	12	12	County name (EBCDIC)
6	1-2	24	2	X-coordinate
	3-4	26	2	Y-coordinate
7	1-2	28	2	Node A, including leg number
	3-4	30	2	State number - node B
8	1-2	32	2	Node B, including leg number
	3-4	34	2	Impedance on link
9	1-2	36	2	Distance on link
	3-4	38	2	Speed on link
10	1-4	40	4	A-B link volume (if network loaded)
11	1-4	44	4	B-A link volume (if network loaded)
12-16				Next link
17-41				Links 3 through 7 as needed
42-46				Link 8, if needed (maximum)

8. Spiderweb Paths Dataset Format

The spiderweb paths dataset is written in fixed unblocked record format, and it consists of (1) a series of path-length records containing the network description followed by (2) the path records themselves in sequence by origin. Records for all zones may be present, or there may only be records for selected zones.

The length of the path record is equal to (6 + (Last Node Number +2)/2) bytes. The network description records, of which there are normally 32 in number for 8-connector networks and 16 for 4-connector networks, consist of the following:

```
Word 0 - Bytes 0 and 1 - Record Length in Bytes
         Bytes 2 and 3 - Zeros
Word 1 - Bytes 0 and 1 - B-node and leg for Node 1-Leg 0
         Bytes 2 and 3 - B-node and leg for Node 1-leg 1
Word 2 - Bytes 0 and 1 - B-node and leg for Node 1-leg 2

 ...      ...                         ......
 ...      ...                         ......

Word 4 - Bytes 2 and 3 - B-node and leg for Node 1-leg 7
```

The B-nodes and legs for each of remaining A-nodes then follow in succession. This format is continued into the following records with Word 0 of each record containing the Record Length in bytes in the first halfword and zeros in the the second halfword.

Following the description of the final node, the last network description record is filled out with zeros.

Note: When a maximum of four connections has been specified in building the network, room in the network description is only provided to accommodate four B-nodes and legs for each A-node.

The format of the path records themselves is as follows:

```
Word 0 - Bytes 0 and 1 - Record Length in Bytes
         Bytes 2 and 3 - Zeros
Word 1 - Bytes 0 and 1 - Origin zone
         Byte 2        - Back legs for Nodes 0 (normally 0)
                                                     and 1
```

	Byte 3	- Back legs for Nodes 2 and 3
Word 2 -	Byte 0	- Back legs for Nodes 4 and 5
	Byte 1	- Back legs for Nodes 6 and 7
...	....	......
---	------	Back leg for last node

Thus one half-byte (4 bits) is used to contain the back leg number for each node. A hexadecimal 'F' in the back leg position denotes the home node. A hexadecimal '8' is used for those nodes which are not included in the network or which cannot be reached.

9. State/County Databank Record Formats

The databank tape is written for S/360 (OS) in unformatted Fortran binary at 800 BPI with default record length. This produces variable block records with a maximum length of 200 words, including the two system words. Arrays of more than 198 words will generate multiple records. These considerations present no problem if unformatted "reads" are used when processing. The entire databank is contained in one file, with the states ordered as given in Table VIII-D-1. A list of the county sequence within each state, which also contains a cross-reference to the national county numbering sequence, can be obtained from the Urban Planning Division at the same address as for the URBAN1.

1. Logical Record 1

Word	Array or Variable Name	Contents
0		System word
1		BPR state number, See Appendix 3.
2-7		State name (alphanumeric)
8	NCT	Number of counties in this state.
9		Sub-map number (1-12) from which the machine digitizing was done by the Electronic Business Services Corporation (EBS).

Word	Array or Variable Name	Contents
10	LAST	BPR sequence number of the last county of the preceding state (all counties in the U.S. are ordered in a national numbering scheme from 1 to 3076).
11	NST	Number of internal intersection points of county boundaries not including state boundary points.
12	NBD	Number of state boundary points.
13	LA	Length of A array
14	LB	Length of B array
15	LXY	Length of X and Y arrays
16	LSEQ	Length of NSQ array
17	RECA	Number of logical records for array A
18	RECB	Number of logical records for array B
19	RECXY	Number of logical records for arrays X and Y
20	RECTY	Number of logical records for array COUNTY
21	RECSO	Number of logical records for array NSQ.
22		Minimum latitude for this state (radians)
23		Maximum latitude for this state (radians)

Word	Array or Variable Name	Contents
24		Minimum longitude for this state (radians)
25		Maximum longitude for this state (radians)

2. Logical Record(s) Two thru RECA=1

Array A - used to identify state boundary and/or county lines which have intermediate points between intersection points; an integer array; A(I),I=1,LA.

3. Logical Record(s) RECA+2 thru NTOT=RECA+2+RECB

Array B - used in conjunction with array A to designate intermediate points; B(I,1),B(I,2),I=1,LB.

4. Logical Record(s) NTOT+1 thru NTOT1=NTOT+1+RECXY

Arrays X and Y - contain the coordinate pairs in radians; X's are latitudes and Y's logitudes; floating point arrays; X(I),Y(I),I=1,LXY.

5. Logical Record(s) NTOT1+1 thru NTOT2=NTOT1+1+RECTY

Array COUNTY - provides information as to intersection points needed to outline all counties; interger array; COUNTY(I,1),COUNTY(I,2),COUNTY(I,3),I=1,NCT.

6. Logical Record(s) NTOT2+1 thru NTOT2+1+RECSQ

Array NSQ - used with array COUNTY to give sequences of intersection points for county outlines; interger array; NSQ(I),I=1,LSEQ.

The above sequence, consisting of six types of logical records, is repeated for each state in the databank.

TABLE VIII-D-1

BPR State Sequence in Databank

BPR State No.	State Name	BPR State No.	State Name
1	Maine	26	Michigan
2	New Hampshire	27	Wisconsin
3	Vermont	28	Minnesota
4	Massachusetts	29	North Dakota
5	Rhode Island	30	South Dakota
6	Connecticut	31	Nebraska
7	New York	32	Iowa
8	New Jersey	33	Missouri
9	Pennsylvania	34	Kansas
10	Delaware	35	Oklahoma
11	Maryland	36	Arkansas
12	District of Columbia	37	Louisiana
13	Virginia	38	Texas
14	West Virginia	39	New Mexico
15	North Carolina	40	Colorado
16	South Carolina	41	Arizona
17	Georgia	42	Utah
18	Florida	43	Nevada
19	Alabama	44	California
20	Mississippi	45	Oregon
21	Tennessee	46	Washington
22	Kentucky	47	Idaho
23	Ohio	48	Montana
24	Indiana	49	Wyoming
25	Illinois		

E. URBAN PLANNING SYSTEM 360 - UTILITY PROGRAMS

The following utility programs are included in the urban planning battery as a supplement to IBM System 360 - Utility Programs. Although they were designed for urban planning work, they have general utility application.

1. BPRCOPY (COPY SEQUENTIAL DATASETS)

BPRCOPY reads fixed, variable, or undefined logical records and writes out identical records. The logical record length and basic record format (fixed, variable, or undefined) cannot be changed, but the output physical block size may be different, thus allowing the reblocking of fixed or variable records.

2. BPRDUMP

BPRDUMP is a multipurpose Operating System dump program for physical sequential data sets on tape or disk. The program can handle blocked or unblocked, fixed, variable, or undefined records of any size up to 32,000 bytes. It will dump complete records or the first so-many bytes, complete files or specified groups of records. Either nine-track or seven-track tapes (written in any density or parity) can be handled as well as tapes without labels, with standard labels, or with nonstandard labels. The output can be in hexadecimal, octal, or EBCDIC, up to 124 characters to the line, with the record size always printed and a byte count and record count available on option.

3. BPRMOVE

The BPRMOVE utility program copies an unloaded partitioned data set (or selected members) onto a direct access device.

4. REFORM (REFORMAT RECORDS BY SHIFTING FIELDS AND INSERTING CHARACTERS)

REFORM reads fixed length records, blocked or unblocked, and on the basis of control card-specified instructions, fills the output record with specified characters, moves in data fields from the input record, inserts individual characters in the output record, and writes the record out in fixed length format, blocked or unblocked.

5. PRKUPDT (File Maintenance)

The purpose of this program is to add, delete or change individual records or parts of records of either binary or EBCDIC numeric files. The only requirements other than that data must be numeric are: (1) records must be fixed length, (2) the file must be in sort such that each record can be uniquely identified. Input to this program is either a standard binary dataset (produced by PRKLINK or TRPCODE programs) or an EBCDIC dataset in any format.

The following options are available to the user in any combination or order:

DELETE - deletion of a single record or a series of records.

COPY - duplication of any number of records.

CHANGE - alteration of specific fields on a specific record (if a given field on all records is to be changed, see REFORM program previously described).

INSERT - insertion of a record containing specified variables into output file.

INSERT-CARDS - insertion of card images from input stream into output file. This option is only used when input records are 80 character card images.

6. SYMDKS

SYMDKS is used to build, access, update, and maintain sequential datasets of individually retrievable members. Members consist of related groups of either card images (source decks, object decks, data cards, etc.) or print images, and these types can be readily intermixed within a given SYMDKS dataset. There is no theoretical limit to the number of members in a SYMDKS dataset, but each must have a unique name. In a given SYMDKS run, as many as nine existing SYMDKS datasets may be input together with as many as nine additional datasets (in addition to the SYSIN dataset) while outputting one new SYMDKS dataset. Input members may be copied, printed, and (if appropriate) punched depending on the user's requests.

7. ZSCRATCH

ZSCRATCH automatically "scratches" an unlimited number of unwanted datasets from as many as 99 different disk packs (either 2311 or 2314 compatible). The list of datasets to be saved is largely defined in the program itself, but provision is made for the execute-time specification of as many as 200 additional datasets to be saved. All datasets other than those "to be saved" are scratched.

CHAPTER IX

APPENDIX

A. GLOSSARY

ACCESS TIME: (1) The time between the instant at which information is called for from storage and the instant at which it is delivered. (2) The time between the instant at which information is ready for storage and the instant at which it is stored.

ACCESSIBILITY - ACCESSIBILITY INDEX: Potential of opportunities for interaction. The denominator of the gravity model formula.

ADDRESS: A label, name, or number which designates a register, a location, or a device where information is located.

ALL-OR-NOTHING ASSIGNMENT: The process of allocating the total number of trips between two zones to the path or route with the minimum traveltime.

ALPHANUMERIC: Characters which may be either letters of the alphabet, numerals, or special symbols. See Extended Binary Coded Decimal Interchange Code.

ANALOG COMPUTER: A computer in which numbers are represented by physical magnitudes such as the amount of rotation of a shaft or a quantity of electrical voltage or current.

ANALYSIS AREA: Any group of zones that are combined for the purpose of making an analysis.

ARITHMETIC UNIT: That part of the computer which performs the arithmetic operation.

ARTERIAL: A general term denoting a highway primarily for through traffic, usually on a continuous route.

ASSEMBLY: Process whereby instructions written in a symbolic form by the programer are changed by the machine to a machine language.

ASSIGNMENT: See Traffic Assignment.

AUTOMATIC PROGRAMING: Technique whereby the computer, itself, will translate a program written in a pseudo-language into a machine-sensible language which the computer may use efficiently. Example: FORTRAN, COBOL, PL/1.

BINARY: A number system using the base of two. There are only two symbols: one or zero ("on" or "off"). Digit values reading from right to left are: 1, 2, 4, 8, 16, 32, etc.

BIT: (1) An abbreviation of "binary digit." (2) A single character of a language employing exactly two distinct kinds of characters.

BLOCK DIAGRAM: A schematic representation of a sequence of steps designed to solve a problem using symbols to represent an operation such as read, write, compare, switch, etc.

BYTE: (1) The smallest addressable unit of core storage in IBM S/360 consisting of two hex digits (see HEXADECIMAL) or eight bits. (2) A unit of storage capacity.

CAPACITY: The maximum number of vehicles that can pass over a given section of a lane or roadway in one direction (or in both directions for a two-lane or three-lane highway) during a given time period under prevailing roadway and traffic conditions. It is the maximum rate of flow that has a reasonable expectation of occurring. The terms "capacity" and "possible" capacity are synonymous. In the absence of a time modifier, capacity is an hourly volume. The capacity would not normally be exceeded without changing one or more of the conditions that prevail. In expressing capacity, it is essential to state the prevailing roadway and traffic conditions under which the capacity is applicable. Refer to the revised edition of the "Highway Capacity Manual" for more detail.

CAPACITY RESTRAINT: The process by which the assigned volume on a link is compared with the practical capacity of that link and the speed of the link adjusted to reflect the relationship between speed, volume, and capacity. The procedure is iterative until a realistic balance is achieved.

CATALOGED PROCEDURE: A group of system control cards (JCL) which can be referenced by an EXEC card. This is normally done to minimize the amount of JCL coding that the user must provide at run time.

CENTROID: An assumed point in a zone that represents the origin or destination of all trips to or from the zone. Generally, it is the center of trip ends rather than a geometrical center of zonal area.

CENTRAL PROCESSING UNIT (C.P.U.): That portion of the hardware of a computer which directs a sequence of automatic operations, interprets the coded instructions, and initiates the proper signals to the computer circuits to execute the instructions.

CHARACTER: A decimal digit, alphabetic letter, or special symbol such as $, %, etc. See Extended Binary Coded Decimal Interchange Code (EBCDIC).

CHECK: AUTOMATIC CHECK - Provision, constructed in the computer, for verifying information transmitted, manipulated, or stored by an unit or device of the computer.

PARITY CHECK - One type of redundancy check.

REDUNDANCY CHECK - Use of summation of bits and redundant bits (check digits) to insure accuracy.

CHOICE, POINT OF: The points at which two routes diverge or converge. Between these points a traveltime ratio can be computed.

COLLECTOR - DISTRIBUTOR STREET: An auxiliary roadway, separated laterally from but generally parallel to the expressway, or thru roadway, which serves to collect and distribute traffic from several access connections between selected points of ingress to and egress from the through traffic lanes.

COMPATIBILITY (SIMULATOR): A set of computer instructions which permit the operation of a program designed for a particular machine on another type machine.

COMPUTER: Any device capable of accepting information, processing the information, and providing the results of these processes in acceptable form.

CONSOLE: A piece of computer hardware which an operator may use to control the machine manually; correct errors; determine the status of machine circuits, registers, and counters; determine the contents or memory; and revise the contents of memory.

CONTROL CARD: A data card which usually controls program operation by supplying user parameters and options.

CORDON LINE: An imaginary line enclosing a study area.

COUNT: The traffic volume counted on a street or highway.

DATA SET: A distinct group of records on an external data storage device (tape or direct access).

DEBUGGING: A procedure to establish program accuracy by running the program with selective data to find logical or clerical "bugs" or errors.

DESIRE LINE: A straight line connecting the origin and destination of a trip. A desire-line map is made up of many such desire lines, the width or density of which represents the volume of trips moving between the origins and destinations.

DESTINATION: The zone in which a trip terminates.

DIGITAL COMPUTER: The data processed by a digital computer consists of clearly defined numbers as opposed to physical quantities which are processed in an analog computer.

DIRECT ACCESS DEVICE: A physical data storage device which permits random (i.e., nonsequential) storage and retrieval. The most common examples are an IBM 2311 disk drive and an IBM 2314 direct access storage facility.

DISTRIBUTION: The process by which the movement of trips between zones is estimated. The distribution may be measured or be estimated by a growth factor process, or by a synthetic model.

DISTRICT: A grouping of contiguous zones that are aggregated to larger areas.

DIVERSION ASSIGNMENT: The process of allocating trips between two possible routes on the basis of measurable parameters.

DRIVING TIME: The time to traverse the distance between zones, not including terminal time at each end of the trip.

EDIT: To rearrange information: for instance, editing may involve the deletion of unwanted data, the selection of pertinent data, etc.; also tests for validity and reasonableness of information.

EXPRESSWAY: A divided arterial highway for through traffic with full or partial control of access and generally with grade separations at intersections.

EXECUTABLE LOAD MODULE: A completely self-sufficient load module (i.e., a program in final, ready to execute form). Must be on a direct access device.

EXTENDED BINARY CODED DECIMAL INTERCHANGE CODE (EBCDIC): A system of representing decimal numbers, letters, and characters in eight binary bits (byte).

FIELD: (1) Punchcard machines: A set of one or more columns in each of a number of punchcards which is regularly used to report a standard item of information. For example: if columns 16 through 19 are regularly used to report weekly rate of pay, then these columns would constitute a field. (2) Computers: A set of one or more characters which is treated as a whole.

FILE: See data set.

FIXED WORD LENGTH: Refers to computers in which data is treated in units containing a set number of characters.

FORMAT: The predetermined arrangement of characters, fields, lines, punctuation marks, etc.; refers to input and output. To print in an orderly and readable manner.

FORTRAN: (FORmula TRANslation) a programming language which is written in terms very similar to algebraic equations. Its use does not require a detailed knowledge of computers, and it is especially useful in solving mathematical problems.

FRATAR DISTRIBUTION: A method of distributing trip ends based on the growth factor of the origin and destination and on the given trip interchanges. Named for Mr. Thomas J. Fratar.

FREEWAY: An expressway with full control of access.

GRAVITY MODEL: A mathematical model of trip distribution based on the premise that trips produced in any given area will distribute themselves in accordance with the accessibility of other areas and the opportunities they offer.

GROWTH FACTOR: A ratio of future trip ends divided by present trip ends.

HARDWARE: The mechanical, magnetic, electrical, and electronic devices from which a computer is constructed.

HARMONIC ANALYSIS: As used in planning, the determination and use of a mathematical equation which passes through 24 hourly traffic volumes.

HEXADECIMAL (HEX): A number system using the base of sixteen. There are sixteen symbols, 0-9, A, B, C, D, E, F. S/360 operates in hexadecimal, where a hexadecimal digit contains four bits.

HISTORICAL RECORD: A binary tape record used in traffic assignment programs to provide link distance, traveltime, speed, capacity and/or count, and other descriptive information. It may also carry information about previous loadings. The output of program BUILDHR, UPDTHR, LOADVN, CAPRES, etc.

IEHMOVE: An Operating System utility support program supplied by IBM and documented in IBM manual C28-6586. Can be used to unload datasets onto a magnetic tape and vice versa.

IEHPROGM: An Operating System utility support program supplied by IBM and documented in IBM manual C28-6586. Can be used to "scratch" data from a direct access device.

INPUT: This is information (instructions or data) to be transferred from external storage (usually tape or cards) to the internal storage of the machine.

INSTRUCTION: An order to the machine to perform a particular operation.

INTERACTANCE MODEL: A variation of the gravity model utilizing a series of curves to represent trip interaction between land uses of varying intensity.

INTER-RECORD GAP: A space which occurs between records on tape. These are produced by the acceleration and deceleration of the tape in a write status.

INTERZONAL TRAVELTIME: The total traveltime between zones consisting of the terminal times at each end of the trip plus the driving time.

INTERZONAL TRIP: A trip traveling between two different zones.

INTRAZONAL TRAVELTIME: The average traveltime for trips beginning and ending in the same zone, including the terminal time at each end of the trip.

INTRAZONAL TRIP: A trip with both its origin and destination in the same zone.

JOB LIBRARY: See program library.

JOBLIB: Common abbreviation for job library. See program library for definition.

LEG NUMBER: A means of identifying outbound links from a node to facilitate turn prohibition and multiple turn penalties. The inclusion of leg numbers also speeds up the tree building process (see Minimum Path).

LEVEL OF SERVICE: The term used to indicate the quality of service provided by a facility under a given set of operating conditions. Refer to the revised edition of the "Highway Capacity Manual" for more detail.

LIBRARY TAPE: The tape containing the urban transportation planning battery as distributed by the Bureau of Public Roads. Created by using IEHMOVE to unload the dataset(s) from the direct access devices upon which they are permanently maintained.

LINK: In traffic assignment, a section of the highway network defined by a node at each end.

LINK EDITOR: See linkage editor.

LINKAGE EDITOR: An IBM supplied program that produces load module(s) from input object module(s) (the output of language translators, such as FORTRAN).

LINK LOAD: The assigned volume on a link.

LOADING: The process of determining the link loads by selecting routes of travel and accumulating the trip volumes on each link that is traversed.

LOAD MODULE: A link edited module of coding suitable for loading into core and executing. Must be located on a direct access device. Not necessarily self-sufficient (i.e., certain subroutines may be missing).

LOCAL STREET: A street intended only to provide access to residence, business, or other abutting properties.

MACHINE LANGUAGE CODING: The form of coding in which instructions are executed by the computer; contrasted to relative, symbolic, and other nonmachine language coding.

MAGNETIC TAPE: A flat ribbon of plastic which is coated on one side with a material which can be magnetized. Information is stored on the tape by a combination of magnetized spots in certain patterns.

MAJOR STREET OR HIGHWAY: An arterial highway with intersections at grade and direct access to abutting property, and on which geometric design and traffic control measures are used to expedite the safe movement of through traffic.

MEMBER: A uniquely defined portion of a library on a direct access device (i.e., a single program in a program library containing several programs).

MINIMUM PATH: That route of travel between two points which has the least accumulation of time, distance, or other parameter to traverse. This path is found by the build trees program (BUILDVN).

MODAL SPLIT: The term applied to the division of person trips between public and private transportation. The process of separating person trips by the mode of travel.

MODE OF TRAVEL: Means of travel such as auto driver, vehicle passenger, mass transit passenger, or walking.

MODEL: A mathematical formula that expresses the actions and interactions of the elements of a system in such a manner that the system may be evaluated under any given set of conditions. See Various Models listed herein.

MULTIPLE CORRELATION: Correlation involving one dependent variable and two or more independent variables.

NODE: A numbered point representing an intersection or zone centroid. Up to four links may be connected to each node.

OFF-LINE: Operation of input/output and other devices not under direct computer control; most commonly used to designate the transfer of information between magnetic tapes and other input/output media.

ON-LINE: Operation of an input/output device as a component of the computer under programed control.

ORIGIN: The zone in which a trip begins.

OUTPUT: Information transferred from the internal storage of a computer to output devices or external storage.

OUTPUT DEVICE: Part of a machine which receives the electrical impulses processed by the machine.

1. Printed forms.
2. Punched cards.
3. Magnetic "writing" on magnetic tape or direct access device.

PARAMETER: An item of information which is usually furnished by the user to make a general routine workable for a particular operation or condition.

PEAK HOUR: That one-hour period during which the maximum amount of travel occurs. Generally, there is a morning peak and an afternoon peak and traffic assignments may be made for each period, if desired.

PERIPHERAL: See Off-line.

PRINTER: Unit of the machine which prints the results obtained from processing some data. Numbers, letters, or symbols may be printed, depending on the device.

PROGRAM: A precise sequence of machine coded instructions for a digital computer to use to solve a problem.

PROGRAM LIBRARY: One or more executable load modules (i.e., programs) in a single dataset. Must be on a direct access device.

READ: To copy, usually from one form of storage to another, particularly from external or secondary storage to internal storage.

RECORD: A group of related facts placed either on a card or tape and then read into memory. See Inter-record Gap.

ROUTE: That combination of street and freeway sections connecting an origin and destination. In traffic assignment, a continuous group of links connecting two centroids that normally requires the minimum time to traverse.

ROUTINE: A set of computer instructions which carries out some well defined function. See Subroutine.

RUN: One routine or several routines automatically linked so that they form an operating unit, during which manual interruptions are not normally required of the computer operator.

SCHNEIDER MODEL: A mathematical model for distributing trips based on the assumption that the trips originating in any zone will distribute themselves to other zones in proportion to the probability that the trips have not found a prior destination and they will be as short as possible. (Intervening Opportunities Model).

SCREENLINE: An imaginary line, usually along physical barriers such as rivers or railroad tracks splitting the study area into two parts. Traffic classification counts - and possibly interviews - are conducted along this line, and the crossings are compared to those calculated from the interview data as a check of the survey accuracy.

SEQUENCED ZONE: To distribute trips or to assign traffic to a network, it is necessary that all zones be numbered in an unbroken sequence beginning with zone 1. This sequenced zone number designates the zone to the computer programs.

SKIMMED TREES: A series of binary records containing the traveltimes only between each pair of zones. The data is obtained during the tree building process.

SOFTWARE: A computer program.

SORT: To sequence records according to a certain key field or fields contained in the records.

SPIDERWEB (SIMPLIFIED) NETWORK: A simulated highway system for a given area composed only of connections between zone centroids without respect to the physical street layout. This network is usually used for corridor type analysis.

SQUARE TRIP TABLE: A table of zone-to-zone trips showing trips by direction between each pair of zones. See Triangular Table.

STATION: A location at the external cordon line where driver interviews are conducted.

STORAGE: A general term for the equipment that retains information.

SUBROUTINE: A routine which is arranged so that control may be transferred to it from a Master Routine and so that, at the conclusion of the subroutine, control reverts to the Master Routine. This avoids repeating the same sequence of instructions in different places in the Master Routine.

SYMBOLIC PROGRAMING: Coding a program in a language other than that which is accepted directly by the machine itself. This type of program, which lessens the chance of clerical errors, must be converted to machine language before it can be executed by the machine.

TAPE: See Magnetic Tape.

TERMINAL TIME: The traveltime required to unpark or to park and the additional walking time required to begin or complete the trip.

TRACE (TREE): That sequence of nodes which defines the links comprising the minimum path between two centroids. See Minimum Path.

TRAFFIC ASSIGNMENT: The process of determining route or routes of travel and allocating the zone-to-zone trips to these routes.

TRAVELTIME: The time required to travel between two points, including the terminal time at both ends of the trip.

TRAVELTIME RATIO (DIVERSION ASSIGNMENT): Traveltime between points of choice by a freeway route divided by the traveltime between the same points by a nonfreeway route.

TREE: A record showing the shortest routes from a given zone to all nodes in the highway network. See VINE.

TRIANGULAR TRIP TABLE: A table of zone-to-zone trips between each pair of zones nondirectionally, normally in the low-to-high direction only. See Square Trip Table.

TRIP: A one-direction movement which begins at the origin at the start time, ends at the destination at the arrival time, and is conducted for a specific purpose.

TRIP CARDS: Data cards containing survey-derived trip information and related information. The data for each surveyed trip is punched in one trip card. See Trip.

Comprehensive surveys will produce the following types of trip cards:

No. 1 card - Dwelling Unit Summary
A summary of trips and related information regarding the occupants of one dwelling unit.

No. 2 card - Internal Trip Report
Contains information describing one trip by a resident of the survey area, and also contains certain information regarding the person making the trip.

No. 3 card - External Trip Report
Contains the information describing one trip by a vehicle which has crossed the external cordon line.

No. 4 card - Truck Report
Contains the information describing one trip by a truck registered or garaged in the survey area.

No. 5 card - Taxi Report
Describes one trip by a taxi registered or garaged in the survey area. In some studies taxi trips are included in the No. 4 cards.

TRIP END: Either a trip origin or a trip destination.

TRIP FACTOR: The number of trips represented by the trip card in which the trip factor appears. Basically it is the ratio of dwelling units to the interviewed dwelling units or a similar ratio of vehicles. It may be modified to offset a poor screenline check.

TRIP LENGTH FREQUENCY DISTRIBUTION: The array which relates the trips or the percentage of trips made at various trip time or distance intervals.

TURN: In the traffic assignment loading process, a movement from a link to another link, which is identified by the node numbers comprising the two links.

TURN PENALTY: The traveltime added to the total traveltime of a trip when a turn is made in the network. Four different penalty values may be coded with a fifth used for a prohibited turn.

UNLOADED DATASET: A single dataset (such as a program library) unloaded onto a magnetic tape by program IEHMOVE.

UPDATE (verb): To modify a master file according to current information, which is often contained in a transaction field, according to a procedure specified as part of a data processing activity.

VARIABLE WORD LENGTH: A term applied to computers in which the number of characters to be operated on by an instruction is almost completely under control by the programer; contrasted to fixed word length.

WORD: An ordered set of characters which is the normal unit in which information may be stored, transmitted, or operated upon within the machine. (Four bytes in S/360).

WRITE: To copy information usually from internal to external storage--to transfer information to an output medium.

VINE: Same as TREE with the additional provision that a node may be traversed more than once from a given zone. This permits realistic paths where turn penalties and/or prohibitors are involved.

ZONE: A portion of the study area, delineated as such for particular land use and traffic analysis purposes. There may be two types of zones used in the traffic assignment process:

1. Survey Zone - A subdivision of the study area which is used during the data collection phase of the study.

2. Traffic Assignment Zone - A subdivision of the study area.

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