TEXAS TRAFFIC ASSIGNMENT PRACTICE

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INTRODUCTION

The decentralized organization of the Texas Highway Department with its several districts and urban areas, requires that a large number of engineers in various locations be familiar with the data produced by the traffic assignment process. This manual is intended to provide the Highway Design Engineer with a guide for the use of computer traffic assignment data as developed in Texas in the geometric design of proposed highway facilities.

Traffic assignment might be defined as the process of allocating a matrix of trip movements to a transportation network in order to estimate the probable traffic volumes on each component of the network. This is accomplished by resolving traffic movement into trip origins and destinations, finding the best path through the network for the movement between each possible origin and destination, and accumulating the traffic flow on each segment of the network.

It is most important to note that the network to which the "traffic is assigned" is not identical to either the existing or any proposed future street and highway system. In other words, since all streets are not shown on the network, a link in the network often represents more than one street segment on the ground.

The various steps in the traffic assignment process were developed by the Transportation Engineer-Planner to assist in the planning of future facilities. Two principal purposes are:

(1) to identify corridors in which additional streets and highways can be expected to be needed.

(2) to obtain an estimate of the future volume through these corridors. For this purpose, there is no need for concern with small scale changes in traffic volume.

The Design Engineer, on the other hand, desires information with respect to hourly (design) volumes and turning movements. Unfortunately, the output from computerized traffic assignments gives an appearance of precision and accuracy which may be misleading. These volumes should not be used directly for design without analysis.

This manual is intended to provide the reader with a basic review of the printouts provided by the several traffic assignment programs. It is not intended to provide the user with a complete understanding of the transportation planning process nor the assumptions and techniques involved in developing a traffic assignment. It is hoped that this background will then assist the highway designer in the application of traffic assignment information to design problems. The reader is referred to the LIST OF SELECTED REFERENCES FOR FURTHER READING for information on the mechanics of conducting a comprehensive study and the details of operation concerning the several computer programs involved.

SOME LIMITATIONS ON THE TRAFFIC ASSIGNMENT

Traffic assignment techniques were initially developed in the planning for larger urban areas. More recently they have been applied to smaller urban areas with considerable benefit. However, it is appropriate to realize that there is some minimum size area for which their use is reasonable; this is probably in the vicinity of about 50,000 population.

It is most important to note that the various phases of the transportation study leading up to the future traffic assignment(s) were developed as a transportation planning tool. Principally, the intent was to develop quantitative means of identifying future corridors of travel and the approximate volume within each corridor given different spatial relationships of land use. As such, the techniques have proven most successful.

The use of the traffic assignment output for design purposes is considerably different from its use in planning. The print out is to the nearest whole number giving an impression of great precision. Actually the process involves certain assumptions and there are a variety of possible sources of error. The values should be considered guides for reasonable design values.

Computer Representation of Street Networks

The actual street and highway system as it exists on the ground is not, of course, represented in the computer. Rather, a "skeleton network" is delineated, coded, and input to the computer. For convenience, the delineated and coded network will follow individual facilities in the existing or a future network and for ease of orientation will be so labeled. These coded links, therefore, not only represent themselves but some streets on either side as well.

Further, the computer utilizes the parameters of distance and time to describe each link. It is Texas practice to actually code distance and speed into the link data cards; the computer then calculates the link travel time for internal use.

Under the TEXAS-BIGSYS programs now being used by the Texas Highway Department, the parameters of distance, speed, and time are not rounded off.

Computerized Traffic Assignment

There are three basic categories of assignments which are made for transportation studies in Texas; these are:

1. Existing trips to the existing network.

2. Future trips to the existing network or the existing plus committed network.

3. Future trips to the proposed future network.

The purpose of the first category of assignments, existing trips to the existing network, is to check the adequacy of the assignment procedure by testing its ability to reproduce the existing travel volumes.

The last two categories are aimed at the overall function of the assignment process-simulation of future traffic flows on the street system to aid the transportation planner to determine the nature and location of needed future transportation facilities.

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 sequence of events followed by the Texas Highway Department in building a network and making an assignment to it is shown in Figure 1.

Directional and Non-Directional Assignments

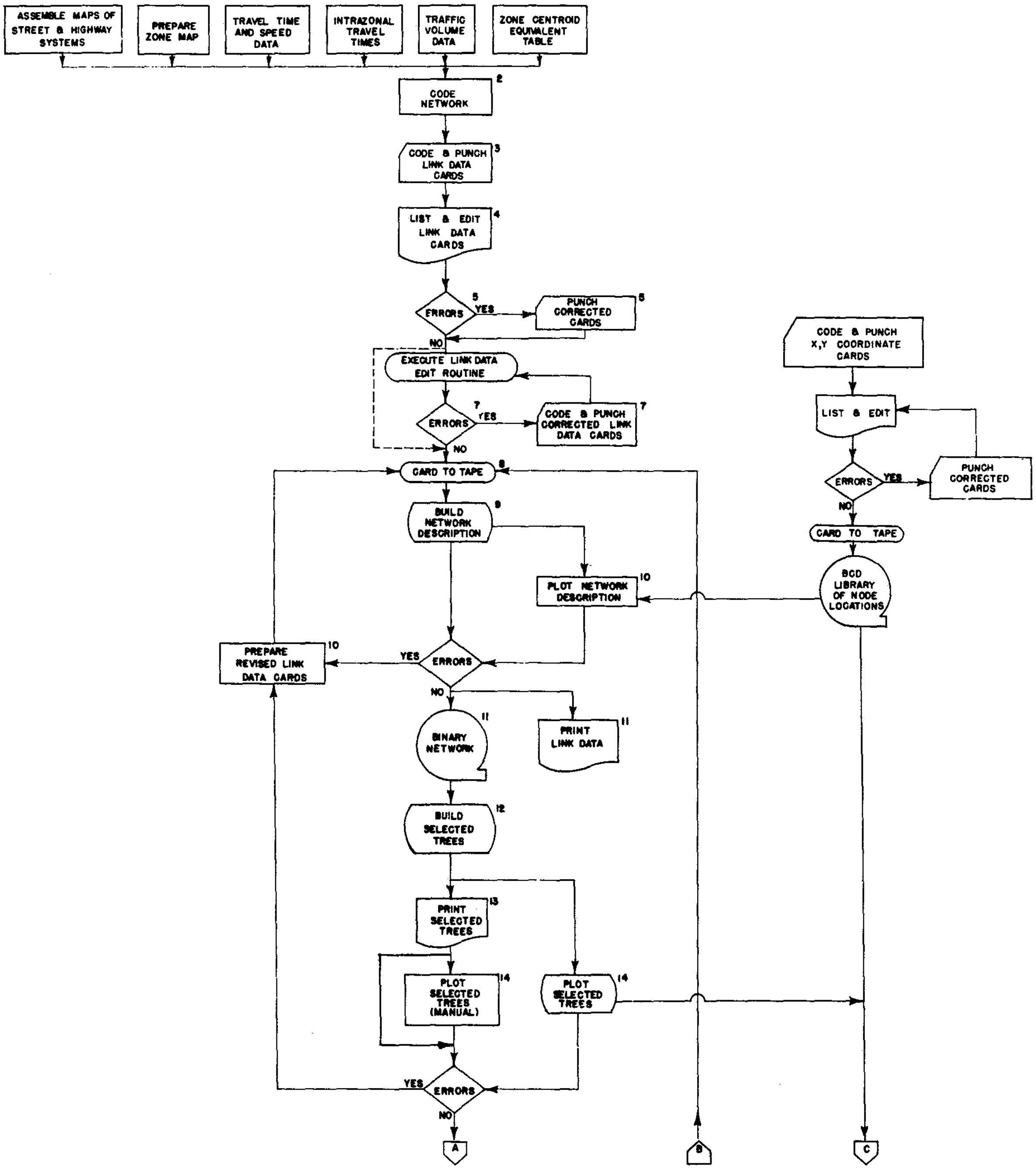
When a trip table for origins and destinations (also referred to as a "square table" or a "from-to-table") is assigned to a network, directional assigned volumes are obtained. In this case the number of trips from zone 'X' to zone 'Y' is given separately from the trips from zone 'Y' to zone 'X'; hence, the assigned link volumes can be accumulated by direction (i. e. from node 'a' to node 'b' on a link is maintained separate from that to node 'b' to node 'a'). The growth factor and "pattern trip" procedure used in Texas, by its nature, provides the information for directional assignments.

A non-directional assignment does not provide directional volumes on individual links; rather the assigned volume is the total for both directions and a directional split must be assumed if directional volumes are desired. Further, the turn volumes are for a quadrant movement rather than for individual turns as indicated in the example shown in Figure 2.

Peak Hour and Twenty-Four Hour Assignments

It is general practice in Texas to assign both the existing (survey year) 24-hour trips as well as peak hour trips. The existing 24-hour trips, of course, are the expanded total number of trips obtained from the internal (dwelling unit), external, truck, and taxi surveys.

Peak hour assigned volumes might be obtained by either of two methods: One is to multiply the assigned 24-hour assignments by a peak hour ratio. The other is an assignment developed from trip data for the peak period, morning or afternoon.



COMPUTERIZED TRAFFIC ASSIGNMENT PRACTICE

FIGURE 1

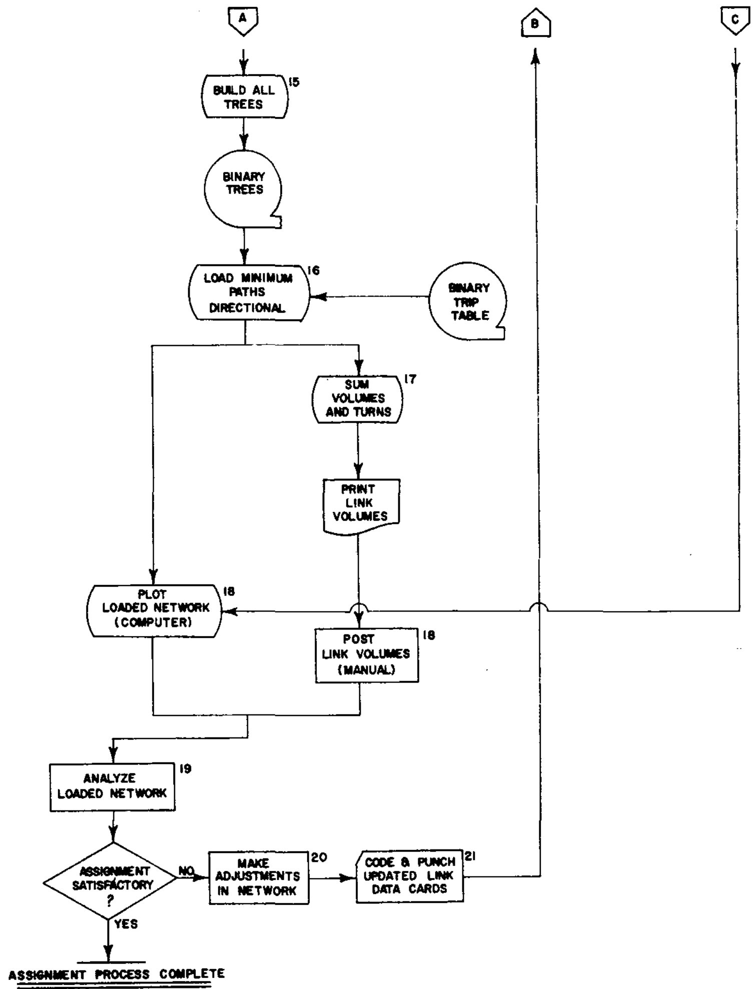
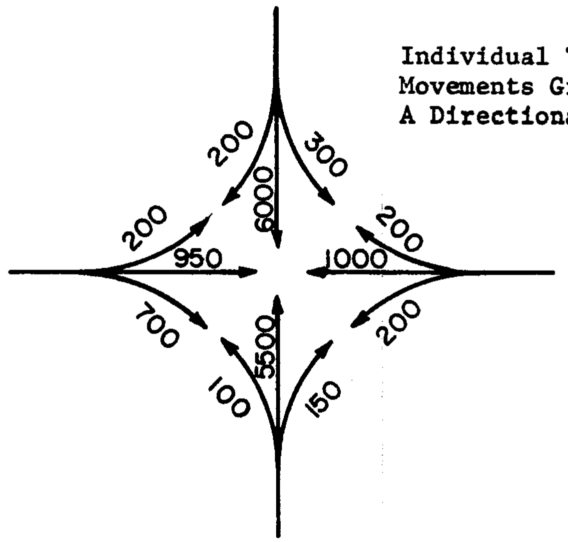
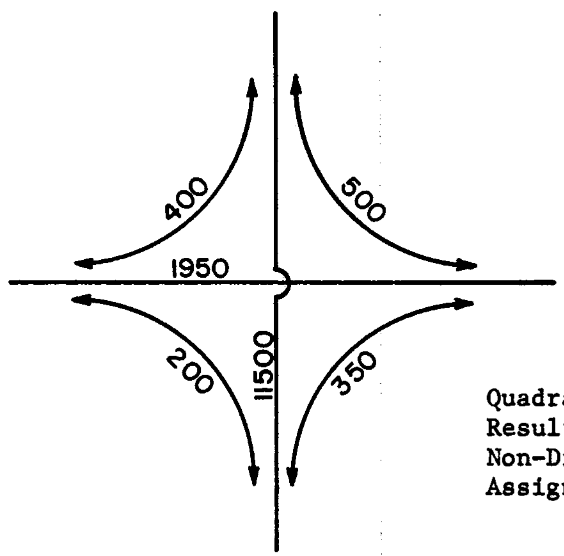


FIGURE 1 (continued)



Individual Turning Movements Given By A Directional Assignment



Quadrant Movements Resulting With A Non-Directional Assignment

DIRECTIONAL AND NON-DIRECTIONAL TURN VOLUMES

FIGURE 2

In order to develop assignments for future years, trip ends are estimated from trip generation characteristics observed in the O-D survey together with projected socio-economic and land use activity data. Estimates of 24-hour trips are, of course, made using 24-hour trip generation characteristics.

DHV assignments can be obtained by multiplying the 24-hour trips by a peak hour factor. In the more recent transportation studies, a DHV assignment run has usually been made after an agreed-upon system has been selected. This assignment run is made taking into consideration the projections mentioned above and utilizing trip data available from the O-D survey. The DHV assignments represent the volumes anticipated for the highest 60-minute period with a factor added to make the DHV's appropriate for a shorter design period.

All-or-Nothing Assignments

At the present time, Texas traffic assignment practice involves finding the minimum time path from each zone to all other zones and assigning all trips between zone pairs to this path only. Hence, the name all-or-nothing is used to denote this process.

More than one path is possible between any zone pair. Indeed, for most street systems simulated in the computer there may be several paths between various zone pairs that differ by only a few hundredths or tenths of a minute. This is especially true when the street system is a gridiron pattern. The analyst can satisfy his curiosity as to this fact by "selecting" different routes between two points on the node map and manually adding the link travel time (from the network description) via each route. Different routes as used here means that the paths are substantially different but may have several links in common.

Furthermore, it is highly unlikely that all the trip makers between any pair of zones all select the same route.

There are three principal reasons for this:

(1) the time differences between the several possible routes may be very small,

(2) trip makers probably are not sufficiently aware of small differences in time,

(3) there are indications that drivers consider other factors than time alone in selecting a route.

These conditions, of course, indicate that judgment must be executed by professional personnel experienced in the art (science) of traffic assignment. Conversely, it means that the assigned link volumes and/or turn movements should not (must not) be blindly used as they come from the computer.

On the brighter side: it is pertinent to note that the Texas Highway Department, in cooperation with the Texas Transportation Institute is currently developing a capability to assign traffic (zone to zone interchanges) to more than a single route. It is believed that this will more realistically simulate the real world and eliminate many of the shortcomings of the all-or-nothing assignment.

It should be realized that traffic forecasting and assignment by electronic computer is only as reliable as the input data used. This information consisting of existing trip data, forecasts, and network descriptions etc., is considered the best and most reliable input data presently available for such assignments. However, persons using the output should have an understanding of the capabilities and limitations of the traffic assignment process in order to utilize the output.

Traffic assignment was developed for and is generally applied to system planning for wide areas. Traffic volumes assigned in a particular area must be studied and related to those assigned to adjacent areas to assure balance volumes.

Traffic assignment can provide information which is valid and adequate for the preliminary design phase where different basic geometric designs are being considered; for example, the evaluation of alternate interchange locations or the comparison of different basic interchange designs

The Design Engineer is usually interested in the assignment in a particular area, such as a specific length of street or highway or a particular ramp. Good engineering judgement must be exercised in applying results at such isolated points.

The following sections of this chapter attempt to explain certain of the traffic assignment network adjustments that the Design Engineer should understand in order to exercise appropriate professional judgement; it also points out certain applications for design problems.

Network Analysis

Several steps are taken to insure that an assignment is as realistic as possible and that the output is valid. Such checks are made throughout the transportation study process; the ones that are of concern here are relative to the coded network description.

The first procedure is to "test and adjust" the existing link network so that it adequately represents the real world conditions; this in itself involves a series of steps. The Prepare Network Description program makes a number of validity checks on the link data cards. Appropriate error messages are printed to aid in making the necessary corrections. Selected test trees are plotted (manually or by the CAL-COMP Plot System) and visually reviewed for illogical routings.

The assigned volumes across selected screen lines are compared with the ground count. These comparisons provide the analyst with a gross means of checking the expanded origin-destination survey data; the approximate correctiveness of the number and distribution of trips. Those screen lines which often follow natural barriers, such as a river, are most valuable for this since ground counts are not influenced by circulating vehicles (such as in the C. B. D.) and double crossings due to circuitive travel. Figure 3 shows a copy of the Waco existing network indicating the position of various selected screen lines with the appropirate counted and assigned volumes.

The assigned volumes are also compared to the ground count for the "more significant" links. Figure 4 shows the Waco existing network on which volumes are given for selected links (the remaining link volumes are not shown for simplicity).

As is indicated in Figure 4, the assigned and counted volumes on all three river crossings are in close agreement. This, together with selected tree traces, is an indication that the routings between zones on opposite sides of the river are reasonalbe and correct.

It may also be noted that the assigned and counted volumes do differ on links at the fringe of the study area network. Adjustments in the network will not, of course, affect these assigned volumes as they represent only trips through an external station.

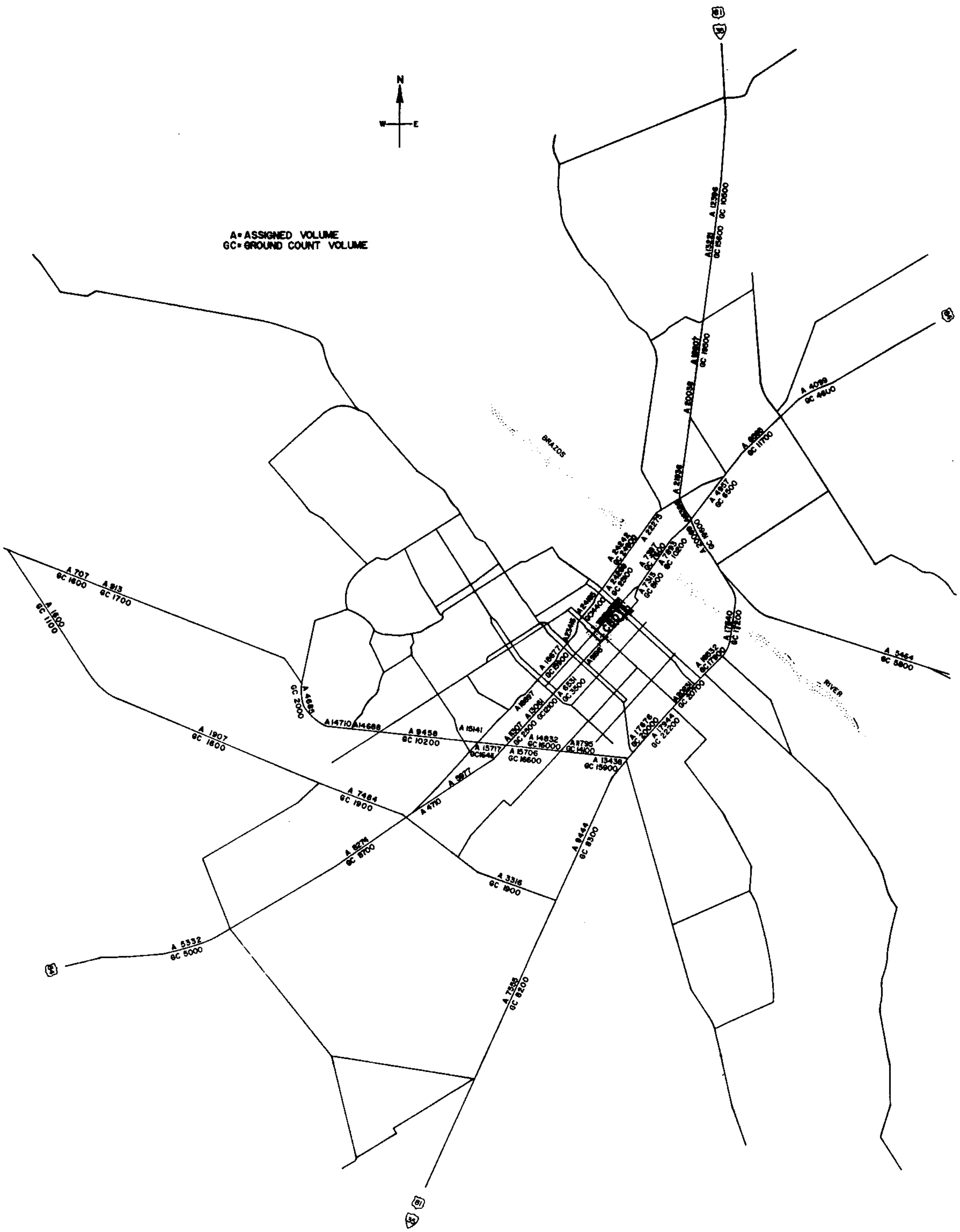
Speed-Volume Relationships

As previously indicated, the first assignment made for all studies is the existing traffic developed from the O-D data to the existing system. The various screen line and individual link assigned volumes are compared with the ground counts. When unacceptable differences exist, the level of service (speed) on selected links is adjusted. This is in effect a manual form of volume restraint.

Experience has shown that it is better to make these speed adjustments on relatively few links each time and to "creep" towards an acceptable assignment rather than make wholesale adjustments. The links on which a change is made are selected after a careful review of the entire assigned network. Speeds are then decreased on certain "over" assigned links and/or increased on certain "under" assigned links. In this process, judgement is exercised in order to anticipate the possible (probable) affect on all links in the network - those on which no speeds were adjusted as well as those on which adjustments were made.

EXAMPLE OF SCREENLINE COMPARISONS

FIGURE 3



EXAMPLE OF ASSIGNED VOLUMES VERSUS GROUND COUNTS ON SELECTED LINKS

FIGURE 4

The Texas Transportation Institute is currently developing a computerized procedure that will "duplicate" the manual procedure now employed to adjust the network. The availability of this program will, of course, greatly facilitate the process.

Directional Volumes

The assignment of directional zone-to-zone trips (square trip table) to a coded network, as is Texas practice, will yield directional assigned link volumes and turn movements. Thus, traffic loads on one-way streets, ramps, and individual turn movements might be obtained.

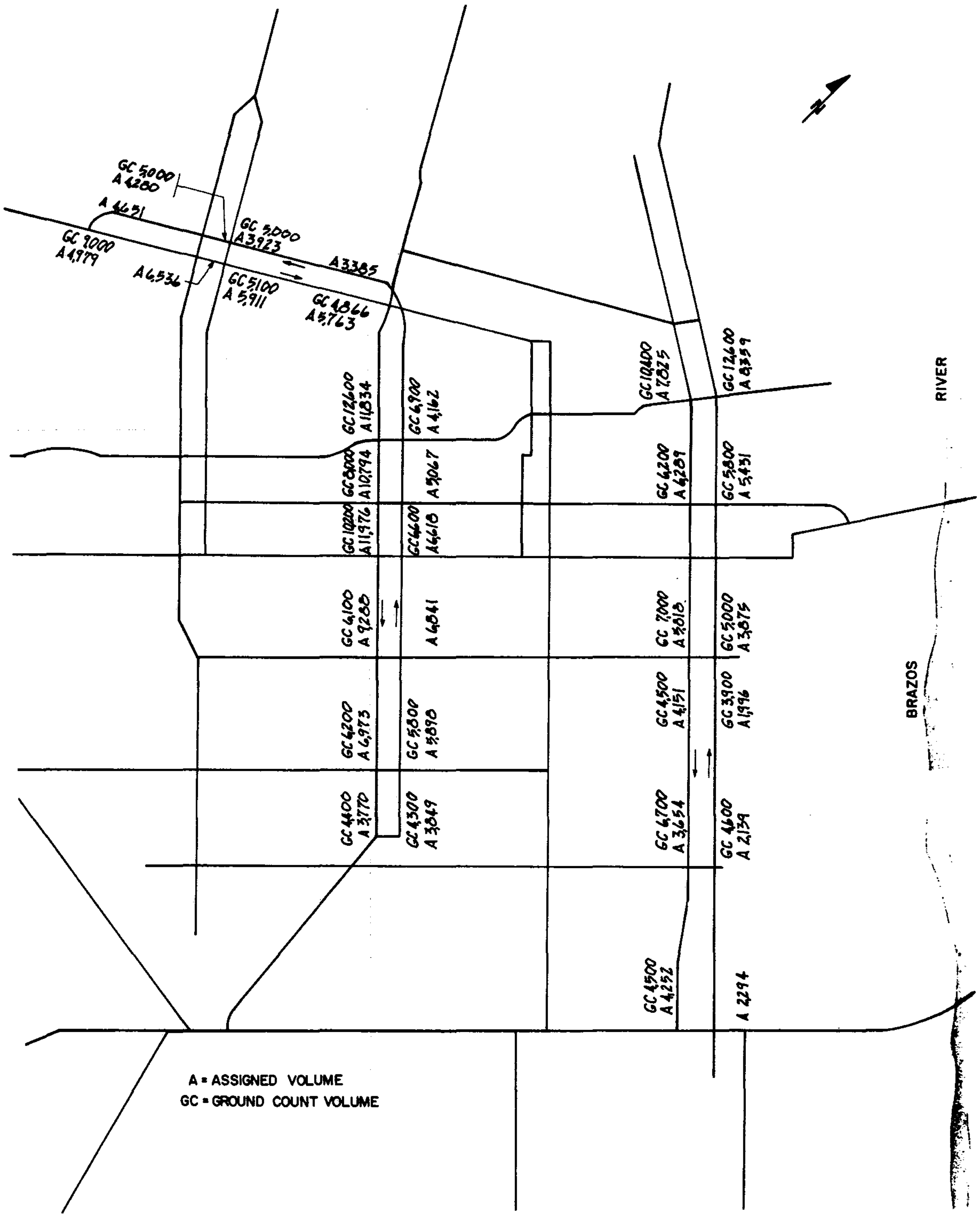
For a 24-hour assignment the directional volumes on the various links should be approximately equal. Similarly, the assigned volumes on links of a coded one-way pair should also be nearly equal. However, in various instances this is not the case as is in the Waco network shown in Figure 5.

The use of traffic assignment results for design purposes - to determine the volume expected to use a specific street segment or ramp must, therefore be tempered with a certain amount of professional engineering experience and judgement which is a quality that is most difficult to explain. The adjustment of the raw data (computer assigned volumes) may have been made before the Design Engineer receives the map with posted link volumes. Analysis resulting in revised volumes may be made by the Planning Engineer in the Urban Study Office or other engineers in the District. File D-10 often furnishes corridor analyses on request. The assignment process often results in unrealistic "jumps" in assigned volumes on consecutive links. This situation is due to the fact that trips from a centroid are "loaded" onto the network at a single point. A manual redistribution of traffic in the localized area is sometimes warranted and desirable in order to provide a more reasonable approximation of the "on-the-ground" traffic flow on various street segments.

Turn Movements

Expected turn movements at interchanges and principal at-grade intersections are of major concern to the Design Engineer. Traffic assignment can provide information that should be adequate for the comparison and evaluation of alternate designs for a particular location - such as the comparison of different interchange configurations.

If a corridor analysis has not been made and the Design Engineer is working from a posted volume map of the area, it is advisable for him to consult with the Planning Engineer before using the turning volumes in design.



EXAMPLE OF ASSIGNED VOLUMES VERSUS GROUND COUNTS ON SELECTED ONE-WAY LINKS

FIGURE 5

Design Application

The computer output for design application will generally have been checked by File D-10 and the Planning Engineer for reasonableness.

Adjustments based on professional judgement, experience, and knowledge of the area may have been found necessary in posting volumes.

However, in addition to the posted volume map the Design Engineer can usually obtain, if he so desires, a copy of the computer output. In the more recent studies, both ADT assignment and DHV assignments have been available.

Alternate Route Locations

At the present state-of-the-art, any traffic assignment represents an assignment to a traffic corridor. However, a freeway or expressway can in some cases represent a corridor by itself. Thus, freeway and expressway assignments may be expected to estimate traffic volumes with a greater degree of reality than for lower type streets.

The "accuracy" of assigned volumes on major arterials will depend on the density and configuration of the coded network. If there are several facilities paralleling a major arterial that are not themselves represented by a corresponding link or links on the network map, all these facilities will be part of the corridor represented by the major arterial on the network map. If the parallel facilities carry substantial volumes, the computer assignment to the links on the network map may (will) be much higher than the volume that would (will) be counted on the on-the-ground arterial.

When assigning trips to the primary network the use of 24-hour trips is meaningful because the ratio of 24-hour and peak hour volumes for these facilities is fairly uniform.

Computer assigned volumes for a future year can be compared with capacities for individual sections of the present or planned network. In this manner any anticipated deficiencies in the network can readily be identified and the cost of improving the network to provide the assumed level of service can be estimated.

Generally what has been said about network studies also applies to location studies for individual sections of freeway or expressway routes.

For the purpose of manual adjustment there is a selected links program available as part of TEXAS-BIGSYS that can facilitate the determination of which trips are fully using a loop. The selected links program will, for any link, give the origin and destination zone as well as the number of trips between them for all trees that have one branch common with the selected link. To find the total volume using a loop between points of decision it will be necessary to request selected link data for both the first and the last link of the loop and count only those trip interchanges that are common for both links. These adjustments will generally be done by the Planning Engineer.

The Planning Engineer furnishes the Design Engineer with an estimate of traffic desire for given routes or highway networks. If the Design Engineer concludes that a planned facility cannot be economically designed to carry the estimated future volume, it is his responsibility to propose additional/alternate routes so as to keep traffic demand in line with the design capacity for an individual facility.

Alternate Interchange Location and Design

Traffic assignment can be a valuable tool in determining the merits of alternate freeway locations and in selecting the most efficient and economical interchange pattern.

In planning the location of freeway to freeway interchanges, the route location may be fixed for one freeway or it may not be fixed for either. Generally, careful study should be given to the selection of the interchange location utilizing whatever flexibility in freeway locations is available. Another major consideration is the compatability of the proposed interchange with the existing or proposed street pattern in the area.

When planning interchanges between freeways and cross streets, the locations of these streets are usually fixed and generally any adjustment of the interchange location must be accomplished by shifting the planned freeway location. In interchange design, some of the problems are to determine which individual turning movements warrant ramps, the proper location of these ramps and the layout of these connections to provide adequate capacities for movements between the freeway and the cross street.

The Design Engineer normally will be furnished a diagram of a preliminary layout with posted directional and through movements at each proposed intersection. If analysis of the traffic assignment indicates that the preliminary scheme will not handle the traffic or is otherwise infeasible, modification of the scheme must be considered.

Interchanges in most cases (especially in large urban areas with extensive freeway networks) serve relatively small areas having specific land uses or combinations of land uses with trip patterns considerably different from those for the general areas. This means that preferably the design hour volumes should not be developed as a percent of the assigned 24-hour volumes, because the peak hour ratio for the individual area which might be used for design of a ramp will not necessarily be the same ratio as for the urban area in general. For interchanges serving areas with certain land uses, this difference may be of considerable magnitude.

Thus, the interchange design should be based on the anticipated DHV's rather than the 24-hour volumes. In many instances, DHV assignments and corridor analysis showing DHV's have been made or can be secured. When either of these are available, they should be used in preference to 24-hour assigned volumes. When they are not available and it is necessary to convert 24-hour assignments to DHV assignments, great care should be taken in determining the factor to be used so that it is applicable to the area in question.

There are generally two (2) basic types of interchanges: freeway to freeway interchanges and interchanges for freeway to streets (or highways). Freeway to freeway interchange location is a function of the freeway route location and it is unusual that a freeway crosses another freeway without it being interconnected. However, at times the freeway location is affected by the requirements of the freeway to freeway interchange to ensure good operational characteristics. In some instances, where the freeway system is dense or where the ideal (from a route location viewpoint) location would result in excessively costly and/or poorly operating interchanges, some adjustment in the location of the freeway may be indicated.

It is a known fact that corridor assignments and total trips assigned between larger areas are much more reliable than assignments to individual links or turning movements.

The Design Engineer should take advantage of this fact and verify that the total design capacity matches the total anticipated traffic demand (i.e. the total assigned volumes) for a series of interchanges, intersections, or a corridor.

Assuming the problem is to check the adequacy of the total capacity of the off-ramps for a section of a freeway in the design stage, the following technique can be used.

Group an appropriate number of consecutive interchanges and find the sum of single turning movements assigned for each interchange for the selected series of interchanges. The total design capacity and the corresponding turning movements should match the total assigned volumes.

Figure 6 is an example of how to go about applying this technique. First a group (A) of four consecutive interchanges are selected. The sum of assigned turning movements (east bound turning north) of interchange group A (interchanges 1, 2, 3, and 4) must not exceed the design capacity of the corresponding turn movements for the same interchange group. Whenever a series of four interchanges has been analyzed for all four turn movements, the next step is to move up (east)one interchange and analyze the following four interchanges (group B). In this manner there will be an overlap of three interchanges for each consecutive group being analyzed and any interchange will be included four times. The desirable overlap and number of interchanges to be included in each group is a function of interchange spacing and location and will vary for each individual section of freeway. The Design Engineer has to rely on his best judgement for grouping interchanges and selecting the extent of overlap.

A similar technique may also be applied for at-grade intersection turning movements.

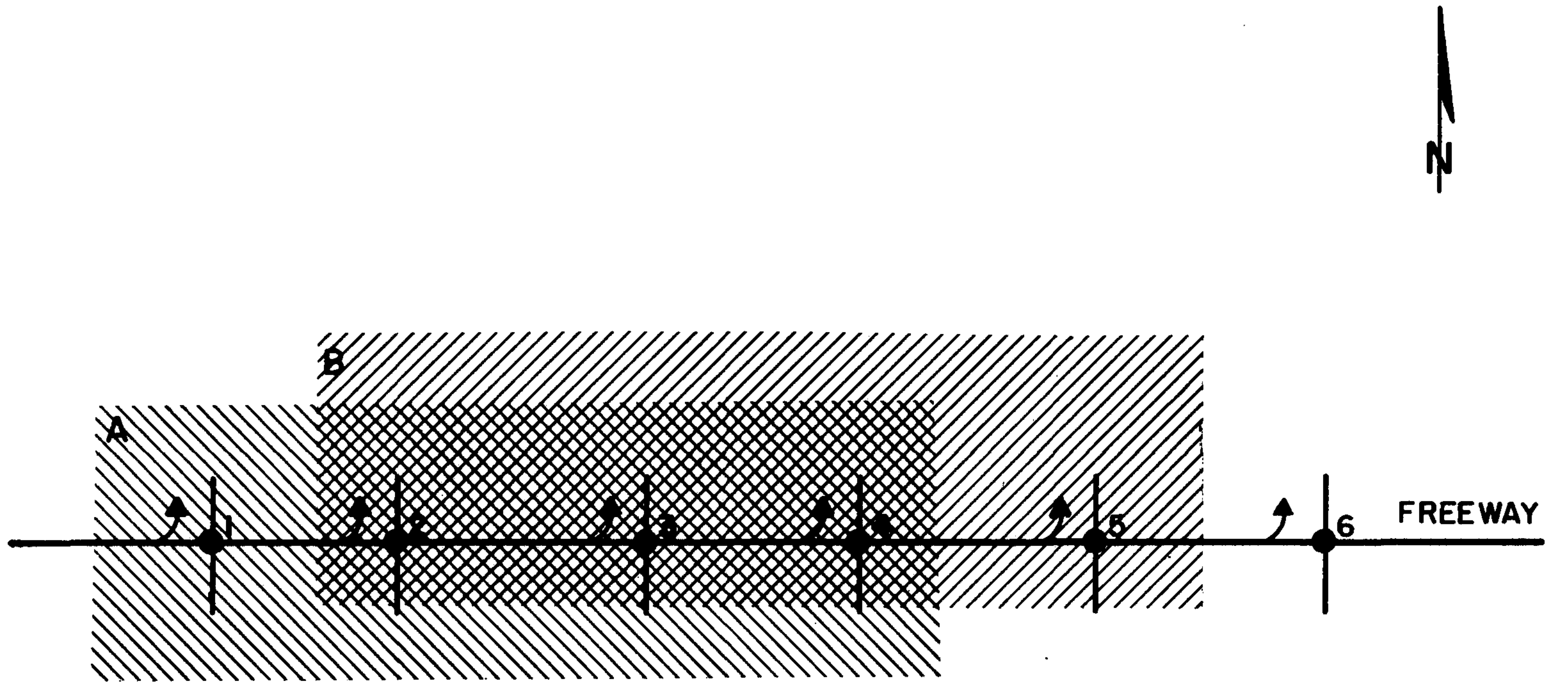
At-Grade Intersection Design

The assigned turning and through volumes, as previously stated, represent corridor movements rather than the expected load on the facility representing that corridor on the link-node map. Thus, most "intersection" nodes shown on the node map generally represent several at-grade street intersections. Also, the zone size (number of trip ends) and the manner in which the centroid is connected to the coded network will have great influence on the "accuracy" of assigned turn movements. The all-or-nothing assignment procedures presently being used cannot duplicate all the surface street routes actually selected and turns made by drivers going between any pair of origins and destination and the assigned volumes should be used as guides.

Summary of Design Application of Computer Traffic Assignment

1. Minimum size urban area for which the use of computer traffic assignment is reasonable is in the vicinity of 50,000 population.

2. Computer assignment at best can be no better than the trip table but is the best guide presently available.



CHECKING DESIGN CAPACITY BY GROUPING INTERCHANGES

FIGURE 6

3. There is only one path (the minimum) selected for assignment between any pair of zones; all trips between this pair of zones is assigned to this path.

4. Directional volumes on 2-way link should be approximately equal for 24-hour assignments.

5. Any computer traffic assignment represents an assignment to a traffic corridor (i.e. there is not necessarily a one-to-one correspondence between a link in the network description and a segment of a specific street on the ground) and should be so considered.

6. The analysis of traffic data may indicate the necessity to consider alternate routes or modification of interchange schematics.

7. The posted through and turning volumes provided to the Design Engineer are adjusted computer assigned volumes. The adjustments are made by the Planning Engineer and are based on professional judgement, experience, and knowledge of the area being analyzed.

8. Turn volumes for at-grade intersections must be "interpreted" and used with reasonable judgement by the Design Engineer.

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APPENDIX A

Definition of Terms

ADT

Average Daily Traffic or, more properly Annual Average Daily Traffic. Such a figure would result if the traffic past a point on a roadway were counted 24 hours per day every day of the year and the total thus obtained was divided by 365 (days per year).

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.

ARTERIAL

A general term denoting a highway primarily for through traffic usually on a continuous route. In traffic assignment, a link connecting two arterial nodes.

AIR STATION

Automatic Traffic Recording Station. A location at which traffic volumes are computed and recorded by a permanently installed and maintained device; such device is in continuous operation 365 days per year. The data from these stations are used to factor counts made at other locations for periods of less than one full year (usually only a few days) to an ADT.

ATTRACTION(S)

The destination end of a trip which began in the trip maker's zone of residence; also the origin end of a trip that has its destination end in the trip maker's zone of residence. For trips which do not have either end (origin or destination) in the trip maker's home zone, the destination zone is the zone of attraction.

BACK NODE

The last preceding node on a trace.

BINARY

A number system using the base of two. There are only two symbols: one or zero ("on" or "off").

BIT

(1) An abbreviation of "binary digit."

(2) A single character of a language employing two and only two distinct kinds of characters.

CAL-COMP PLOTTER

An automatic x-y coordinate plot device. In traffic assignment practice it is used to plot the minimum path trees for selected centroids and the assignment network (with or without assigned volumes).

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 highway) during a given time period under prevailing roadway and traffic conditions. Refer to the revised edition of the "Highway Capacity Manual" for more detail.

CAPACITY RESTRAINT ASSIGNMENT

The process by which the assigned volume on a link is compared with the capacity of that link and the speed of the link adjusted to reflect the relationship between speed, volume, and capacity.

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 gravity of the trip ends rather than a geometrical center of the zonal area. Each such point is identified by a unique number.

CENTROID TIE OR CENTROID CONNECTOR

A link which connects a centroid to the coded street and highway network. In most coded networks this connector or tie represents the local streets by which a trip travels from an individual parcel of land to the higher classification of streets coded in the network, it has no physical facility representation but serves only to get trips from the centroid on the coded network.

CORDON

(1) Cordon Line: An imaginary line enclosing an area.

(2) External Cordon: An imaginary line enclosing the transportation study area. Such a cordon around an urban center includes that area which is currently developed plus that which is expected to be developed within the study period -- normally 20 years.

COUNT

The traffic volume counted on a street or highway.

DESIRE LINE

A straight line connecting the origin and destination of a trip. Also the aggregation (summation) of such individual lines of which the origins and the destinations are the same. A desire-line map is made up of many such desire lines, the width of density of which represents the volume of trips moving between the origin and destination.

DESTINATION

The zone in which a trip terminates.

DISTRICT

A grouping of contiguous zones that are aggregated to a larger area.

DRIVING TIME

The time to traverse the distance between zones, not including terminal time at each end of the trip.

DWELLING UNIT

A house, apartment, or other group of rooms, or a single room which is suitable for occupancy as separate living quarters by a family, person, or persons and having direct access from the outside or from a common hall and equipped with cooking facilities for the exclusive use of the occupants of the unit. A dwelling unit may be occupied or vacant.

EDIT

Test for correctness or validity and reasonableness of information: also, deletion of unwanted data or the selection of pertinent data.

EXPRESSWAY

A divided arterial highway for through traffic with full or partial control of access and generally with grade separations at intersections.

EXTERNAL-LOCAL TRIP

A trip which has its origin outside the study area (outside the external cordon) and its destination inside; also, a trip originating inside the study area and having a destination outside.

EXTERNAL - EXTERNAL TRIP

A trip which passes through the study area and does not have either an origin or a destination inside the area delineated by the external cordon.

EXTERNAL STATION

An interview or traffic count location on any highway at the external cordon.

EXTERNAL SURVEY

A study or survey in which vehicles on all or selected highways crossing the external cordon are stopped and the driver interviewed in order to determine the origin, destination, trip purpose, and other information relating to the trip.

FIELD

(1) 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 22 and 23 are used to record speed in mph, hence, these columns constitute a field.

(2) A set of one or more characters which is treated as a whole.

FLAG

A code (on the link data card) to indicate whether the sign of the link at the "B" node differs from the sign at the "A" node; part of the network coding necessary if turn penalties are to be used.

FORMAT

The predetermined arrangement of characters, fields, lines, punctuation marks, etc.; refers to input and output. To print in an orderly and readable manner.

FRATAR DISTRIBUTION

A method of distributing trip ends based on the growth factor of the origin and destination and on the given (observed) trip interchanges. Named for Mr. Thomas J Fratar.

FREEWAY

An expressway with full control of access. In traffic assignment, a link connecting two freeway nodes.

FRONTAGE ROAD

In Texas terminology, an auxiliary roadway separated laterally from but generally parallel to the main (thru) lanes of the freeway or expressway. Access to the main traffic lanes of the freeway or expressway is provided by slip ramp; abutting properties generally have direct ingress/egress to/from it.

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.

HOME BASED TRIP

A trip which either begins or ends at home.

HOME INTERVIEW SURVEY

The study or survey in which a sample number of dwelling units are contacted in person by an interviewer for the purpose of obtaining selected dwelling unit data and origin, destination, purpose at each end of the trip and other data for any or all trips made by occupants of a dwelling unit.

INPUT

Information (instructions or data) to be transferred from external storage (tape or cards) to the internal storage of the machine.

INTERNAL SURVEY

The study, or studies, which obtain data concerning trips made by residents of the study area together with selected characteristics of a trip maker. It is generally composed of three separate surveys: home interview, truck, and taxi.

INTERNAL TRIP

A trip having both points of origin and destination inside the study area cordon.

INTERZONAL TRAVELTIME

The total traveltime between zones consisting of the driving time between the zones plus time (if used) at each end of the trip.

INTERZONAL TRIP

A trip traveling between two different traffic 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 traffic zone.

JURISDICTION

This item if coded in the link card, defines the political subdivision of the study area in which the link is located. Alternately, it can identify a portion of the network.

LEVEL OF SERVICE

The variable(s) used to indicate the quality of service provided by a facility under a given set of operating conditions. In traffic assignment practice, speed (mph) is used to represent the level of service of each link.

LINK

In traffic assignment, a section of the highway network defined by a node at each end.

LINK LOAD

The assigned volume on a link.

LOAD NETWORK

The process of determining the link loads by tracing the minimum path route between all zone pairs and accumulating the trip volumes on each link that is traversed.

LOAD MINIMUM PATHS

The same as Load Network.

LOCAL STREET

A street intended only to provide access to residence, business or other abutting properties. In traffic assignment, any link having a centroid as one node.

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.

MINIMUM PATH

That route of travel between two points which has the least accumulation of time, distance, or other specified pre-coded parameter to traverse. This path is found by the Search Minimum Paths Program.

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.

MULTIPLE CORRELATION

Correlation involving one dependent variable and two or more independent variables.

NETWORK DESCRIPTION

The binary records which describe the coded street and highway system within the computer in terms of distance and time and include turn indications and turn prohibitors.

NODE

A numbered point representing an intersection or zone centroid. Up to four links may be connected to each node.

A Node - The node identifying the "tail" end of a specific link. The A Node of a link is the B Node for the preceding link.

B Node - The node identifying the forward end of a specific link. The B Node of one link is the A Node for the succeeding link.

NODE MAP

The map on which the assignment network is coded by representing and identifying each intersection and centroid by a unique number.

NON-HOME BASED TRIP

A trip for which neither the origin zone nor the destination zone is the same as the zone of residence of the trip maker.

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 programmed control.

ORIGIN

The zone in which a trip begins.

OUTPUT

Information transferred from the internal storage of a computer to output devices for printing.

PATTERN TRIP PROCEDURE

The analysis process of matching an undeveloped zone having no, or very few trips, in the survey year to a developed zone which is similar to the projected future development of the zone in question. The present (observed O-D) trip pattern of the developed zone is then substituted as the present trip pattern for the undeveloped zone in question. Growth factors are then calculated from the ratio of this "pattern" number of trip ends; a Fratar distribution is then used in the conventional manner to develop the future trip table.

PARAMETER

An item of information which is usually furnished by the programmer to make a general routine workable for a particular operation or condition.

PARTITIONED NETWORK

A network which has been divided into two, three, or four subnets in order to permit traffic assignment to a network which, in order to be represented internally in a computer as a single unit, requires more core capacity than is available.

PARTITION LINE

A line, or lines, by which a large network is divided into two, three, or four subnets (sections) when utilizing the Large Systems Traffic Assignment Package.

PEAK HOUR

That one-hour period during which the maximum amount of travel occurs. Traffic assignments may be made for each peak period, if desired.

PERIPHERAL

See: Off-line.

PRODUCTION(S)

When either the origin or the destination of a trip is the residence of the trip maker, the trip is said to be produced by the zone of residence. Hence, the origin end of a trip which began at the trip maker's residence and the destination end of a trip which ends at the trip maker's residence are called productions. When neither the origin nor the destination is the trip maker's residence, the origin end is the production.

PORTABLE RECORDING COUNTER or RECORDING COUNTER

A traffic counter which is small enough to be easily moved from place-to-place by a single person, and which is easily set up and readied for operation, and automatically records a measure of the traffic past a point.

RAMP

A turning roadway at an interchange for travel between intersection legs. In traffic assignment, a link between a freeway node and an arterial node.

READ

To transfer information from external storage (tape) to internal storage (core).

REVISED TEXAS TRAFFIC ASSIGNMENT PACKAGE

A group of computer programs written by the Texas Transportation Institute for use on the IBM 7094 Computer.

ROOT-MEAN-SQUARE (RMS) ERROR

A statistical measure of error between two series.

$$\text{RMS ERROR} = \sqrt{\frac{\sum_{i=1}^{n} (x - y)^2}{n-1}}$$

where: x = the estimated value of an observation

y = the true value of the observation

n = the number of observations

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 require the minimum time to traverse.

RUN

One routing or several routines automatically linked so that they form an operating unit, during which manual interruptions are not normally required of the computer operator.

SCREENLINE

An imaginary line, usually along physical barriers such as rivers or railroad tracks splitting the study area into two parts. Traffic classification counts are conducted along this line, and the crossings are compared to those calculated from the interview data as a check of the survey accuracy.

SERIAL ZONE

Computer programs for distributing trips and assigning traffic to a network require that all zones be numbered in an unbroken sequence beginning with zone 1. This sequenced zone number designates the zone to the computer programs.

SIGN

Part of the coding necessary when turn penalties are to be used. If a movement from one link to another is made without a change in sign, no turn penalty is imposed; the turn penalty is applied if a change is involved.

SKIMMED TREES

A series of binary records containing the total traveltime between each pair of zones. The data are obtained from the binary tree records.

SORT

To sequence records according to a certain key field of fields contained in the records.

SPIDER 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 analysis.

SUBNET

Part of an assignment network which has been partitioned in order to represent it in a computer.

SQUARE TABLE

A table of zone-to-zone trips showing trips be direction between each pair of zones. See Triangular Table.

STATION

A location at the external cordon line where driver interviews are conducted. Also a point on the street system at which a traffic volume count is made.

STORAGE

A general term for the computer equipment that retains information.

STUDY AREA

That area inside of the external cordon. The area which is the subject area of a transportation study; it includes all that area which can be reasonably expected to be developed (urbanized) in a specified period, generally 20 years.

TABLE OF EQUALS

A table which gives the correspondence between geographical areas of the same delineation but numbered differently (such as, traffic analysis zones which may be numbered in any manner and assignment zones which must be numbered sequentially); or, the correspondence between small survey (data collection) zones and larger analysis or assignment zones.

TERMINAL TIME

The traveltime required to unpark or to park and the additional walking time required to begin or complete the trip.

TRACE

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.

TREE

A record showing the shortest routes and time of travel from a given zone to all nodes in the highway network.

TRIANGULAR TABLE

A table of the nondirectional trip interchanges between each pair of zones. (Also, see Square 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 END

Either a single trip origin or a single trip destination.

TRIP END ESTIMATION

The process or procedure of estimating the number of trip ends (origins and destinations or productions and attractions) in a zone or zones.

TRIP DISTRIBUTION MODEL

A mathematical model or a procedure for estimating the zone-to-zone interchanges given the number of trip ends in each zone and other constraints.

TRIP EXPANSION FACTOR

The factor to expand the sample trip information to the population (universe). Basically, it is the ratio of total dwelling units to the interviewed dwelling units, for the home interview survey the ratio of interviewed vehicles to total vehicles in the external, truck, and taxi surveys.

TRIP GENERATION

The propensity of a zone, residence, commercial establishment, shopping center, or developed area to cause trips to be made to or from it, origins, destinations, productions, and attractions are all measures of trip generation.

TRIP REPORT

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 TABLE

The tabular table indicating the zone-to-zone trip volumes; also the binary zone-to-zone trip volume records.

TRIP LENGTH FREQUENCY DISTRIBUTION

The array or plot (graph) of the percentage of trips (or number of trips) made by time intervals; also by various distance intervals.

TURN

In the traffic assignment loading process, a movement from a link to another link, which is identified by the node numbers defining the links. In tree building, a movement between links of differing signs. See Turn Penalty.

TURN PENALTY

The traveltime added to the total traveltime of a trip when a turn is made in the network.

TURN PROHIBITOR

A data card, similar to a link card, which instructs the tree building program to prohibit a particular movement through the network.

TRUCK-TAXI SURVEY

The survey (actually two surveys - one of trucks and one of taxis) is to obtain information on the origin, destination and other data concerning trips made by trucks and taxis garaged within the study area.

UPDATE

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.

UPDATE NETWORK

The process in Texas Practice of making changes in the link data cards to:

(1) Change the speed on selected links.

(2) Remove links from or add links to the network.

(3) Correct improperly specified link data information.

WRITE

To transfer information from internal (core) to external storage (tape).

ZONE

A portion of the study area, delineated as such for particular land use and analysis and traffic assignment purposes.

Survey Zone: A subdivision of the study area which is used during the data collection phase of the study. It is the smallest geographical area to which data are coded.

Serial Zone: The same geographical area as the Traffic Zone. Computer programs for trip distribution and traffic assignment require that all zone centroids be numbered or renumbered in an unbroken sequence beginning with number 1.

Traffic Zone: That geographical area used for purposes of trip end estimation, trip distribution, and traffic assignment. A traffic zone may be composed of one or several survey zones. In the event that there are two or more survey zones in a traffic zone, a table of equals is utilized to aggregate the survey zone data to a traffic zone.

Assignment Zone: Same as serial zone.

ZONE INTERCHANGE DISTRIBUTION

An array or plot of the percentage of zones with which interchanges are made by zones of various size (number of trip ends) intervals. Data to develop this distribution are provided by the BIGSYS Trip End Summary Program.

APPENDIX B

APPENDIX B

DEVELOPMENT OF A TRAFFIC ASSIGNMENT

The process of developing a traffic assignment is a complex sequence of procedures, each of which involves certain assumptions or approximations. This appendix very briefly outlines the major sections which lead to the development of a traffic assignment according to the procedure followed by the Texas Highway Department. Figure B-1 shows a generalized chart which indicates the principal technical steps involved in the conduct of a comprehensive transportation study. The following sections are presented as an overview of these steps in the hope that the Design Engineer will find it of interest and that it might serve as a basis in the use and interpretation of traffic assignment output for design purposes.

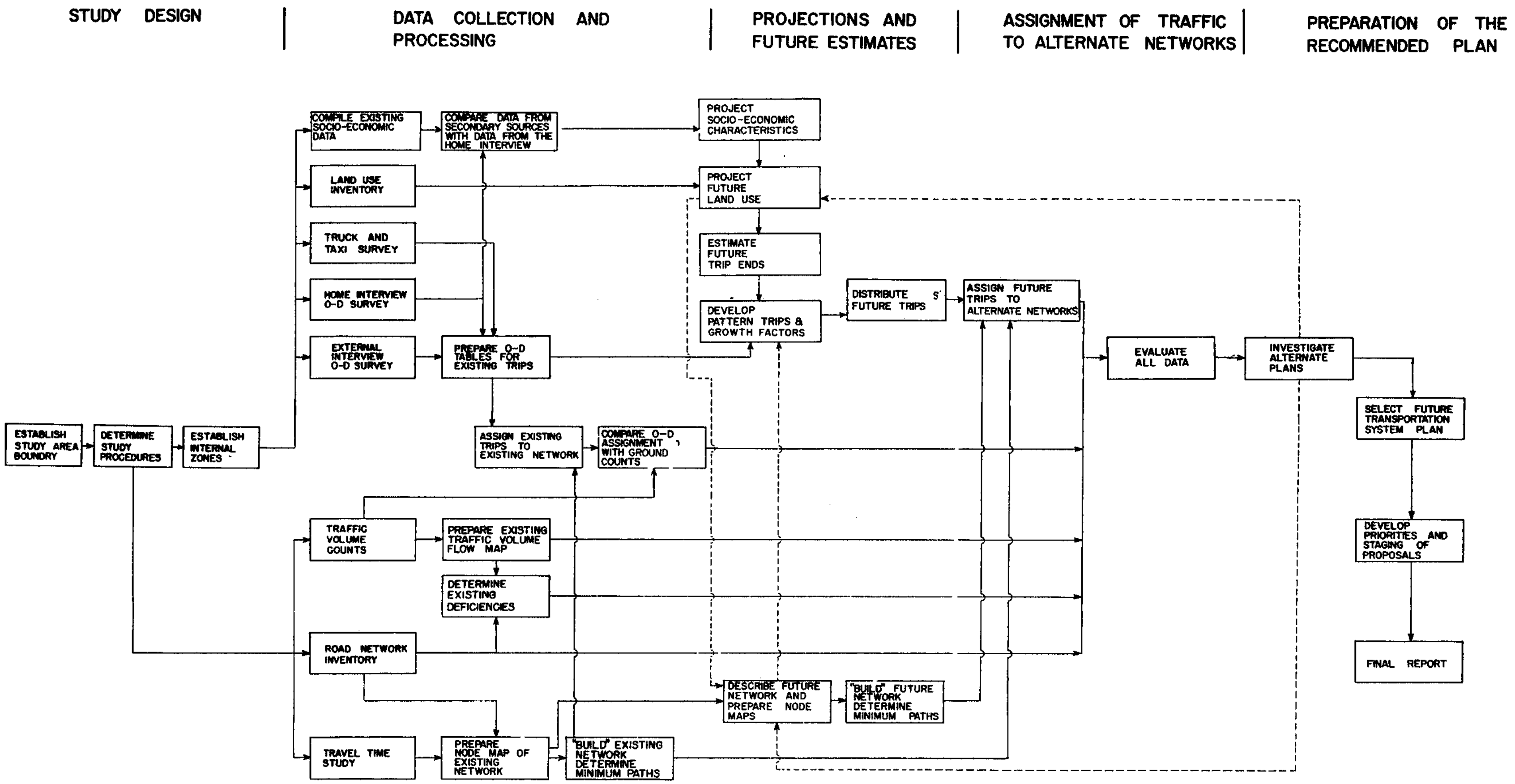
Study Design

The study design phase involves the identification of the specific geographical area to be studied. The name of the most prominent city usually identifies the general area of the study. However, considerable effort goes into the definition of the exact study area as delineated by the external cordon. All those areas which are developed and are expected to be developed within the horizon (design) period, normally 20 years, are included within this boundary. Extraterritorial jurisdiction of the city, or cities, involved is, of course, considered in defining the study area.

The nominal diameter of the external cordon obviously affects the size of the study area. It should also be noted that its location will affect the number of external-local trips and the number of internal trips. These two types of trips are projected separately and by different methods. Hence, the location of the external cordon is the first of several important decisions that will affect the final traffic assignment.

A second step in the design of the study is to decide on the general procedures that will be followed in the data collection and processing phases. These procedures will in large measure be dependent on the nature and depth of the study in order to meet the objectives of the transportation plan.

In urban areas of over 50,000 population, normal procedure calls for a home interview at a sample number of dwelling units. In cities under 50,000



FLOW CHART SHOWING THE PRINCIPAL ELEMENTS IN AN URBAN TRANSPORTATION STUDY

FIGURE B-1

Once the study area has been fixed, it is necessary to subdivide it into numerous smaller areas or survey zones for the purpose of data collection. For the purposes of traffic assignment, these are aggregated of grouped to form serial zones. Ideally, each zone should be homogenous (i.e., be of the same nature and type of development).

The delineation of these zones has substantial effect on the subsequent traffic assignments. One of the principal results is the relationship between interzonal trips and intrazonal trips. Since only interzonal trips are assigned to the network, the zone size will affect the assigned volumes. Taking an extreme condition for example: If the entire study area was considered as a single zone, there would be no interzonal trips and hence, the assigned interzonal volumes would be zero. Fortunately, most intrazonal trips probably take place on the local street system where they do not present a problem from the standpoint of either design or operation.

Traffic zones are hypothetically reduced to a single point, defined as a centroid, from which the traffic is loaded onto the highway network. The centroid should be located in the center of the trip activity for the particular zones. For example, in a completely residential zone the center of activity is taken as the center of gravity of the dwelling units in the zone. In zones of mixed land uses, such as a combination of residential and commercial functions, the problem is far more complex and difficult. In many cases, it is, of course, necessary to exercise a large amount of judgement.

Data Collection

The data required in a transportation study are obtained through the conduct of a number of independent surveys, the principal ones are indicated in Figure B-1. Analysis of data collected in the inventory of the existing conditions provides the source information upon which the estimates of the future growth of the area are based.

Each of the individual surveys involve substantial amounts of data which constitute a considerable data processing task. The masses of data also give rise to problems relating to the correctness of the data; strict quality control measures are exercised in order to minimize mistakes in the information resulting from or in data collection, coding, and keypunching.

The specific steps followed so as to assure correctness of the data are beyond the scope of this manual; the reader need only be aware that adequate quality control procedures are followed in both the field and office phase of each individual survey.

Traffic Volume Counts

Volume counts utilizing portable recording counters, are usually the first data collection to get underway. The counts at the external stations are used to make estimates of personnel needs for interviewing and controlling traffic, and hours of operation. Numerous machine counts are taken at various locations on all arterial streets, at all screenline crossing points and on all routes crossing the external cordon.

The external cordon volumes are factored to ADT volumes; this is of course, accomplished through the use of the permanent ATR station(s) in the vicinity of the study area. Counts taken on the internal street system are not expanded to ADT in as much as the traffic volumes on the majority of urban streets do not show substantial seasonal variation and it generally is assumed that the counted volumes reflect ADT volumes.

It is important that any analyst who uses the results of portable mechanical recording counters realize that these devices are subject to some error. Experienced personnel are able to detect these errors and schedule recounts where necessary. The commonly employed recording counter which uses a pneumatic road tube actually counts axles, not vehicles, and two activations are recorded as a vehicle. Experience and limited analysis show that the resulting counts are within plus or minus ten percent.

Road Network Inventory and Travel Time Study

An inventory of the street and highway system is made to obtain the necessary information to describe the physical characteristics of the existing network and to evaluate deficiencies in it.

The travel time study provides the time or speed information that, in conjunction with distance, defines the parameters of a link. Normal procedure in Texas is to conduct a conventional travel time study on all arterial streets using the average car techniques; a minimum of three runs in each direction are commonly made.

External O-D Survey

Vehicles are stopped and interviewed as they cross the external cordon on one or more days. In Texas, external interviews are made during the following hours depending upon the traffic volumes.

24-Hour Traffic Volume	Hours of Operation
over 1,000 vpd	24 hours
500 - 1,000	6:00 A.M. to 10:00 P.M.
300 - 500	10:00 A.M. to 6:00 P.M.
under 300	usually not interviewed

The sampling rate at any point in time is a function of traffic volume. At lower hourly volumes, practice is to interview all vehicles (i.e., 100% sampling). At those stations at which there is a sizable fluxuation in traffic volumes, the sampling rate may change from hour to hour or by 10 or 15 minute intervals. During peak periods the sampling rate may be reduced to a minimum of about 50 percent. However, for heavy trucks, general practice is to maintain a sampling rate of nearly 100% even during peak traffic flows. For added detail as to the type and form of the data collected, the reader is referred to the External Interview Manual prepared by the Texas Highway Department.

Home Interview O-D Survey

The home interview survey is the largest and most expensive single survey in a transportation study. Its purpose, of course, is to obtain information from which to identify existing trip generation characteristics and trip distribution patterns. The first step in the home interview survey is to identify all dwelling units (DU's). The practice followed in Texas is to field-list the DU's; that is, survey personnel drive each street and record the location of each sample DU.* This practice is generally considered to be the most reliable procedure. The detailed procedure followed is outlined in Procedure Manual 2B, "Conducting a Home Interview Origin-Destination Survey."

A factor to expand the trips made by the residents of DU's at which trip data were obtained to the total trips "made" by all residents in a small geographical area is calculated from the following:

(1) total number of DU's in the area

(2) the number selected for interviewing

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*Other methods include the use of meter listings (water, electricity, and/or gas), Sanborn maps, city directory, and telephone directory. A combination of these may be used and cross-checked against each other.

(3) the number of DU's in the sample that were found to be vacant

(4) the number of incomplete interviews (due to no contact, etc.).

The exact procedure is given in Manual 2B cited above.

Truck-Taxi Survey

The purpose of the truck-taxi survey is to obtain information relative to the number and pattern of trips made by trucks and taxis registered within the study area. In both cases, the vehicle is the unit of observation.

In order to select a sample of trucks and of taxis, it is first necessary to obtain a listing of all such vehicles registered in the study area. Every 'n'th vehicle is then selected for interviewing. For example: in a 50 percent sample, every other vehicle on the list would be selected. An interview is then made to determine the desired information for each trip made by each selected vehicle on a particular day.

Land Use and Space Use Inventory

In those instances where adequate land use - space use information is not available, an inventory is made to determine the amount (acres) of land in each survey zone according to generalized land use categories.

The reader is referred to the Standard Land Use Coding Manual, first edition, January, 1965, prepared jointly by the Urban Renewal Administration and the Bureau of Public Roads. This manual presents an identification and coding standard that can be used in varying degrees of detail through a one, two, three, or four digit code.

At this point, it may be well to define the difference between land use and space use as well as the difference between land use and land use activities. Land use refers to that two dimensional ground surface as would be identified by a routine plane survey. Space use, on the other hand, involves the third dimension (i.e., height); for example: a one story building having the dimensions of 100 feet by 200 feet would constitute 20,000 square feet of land use and 20,000 square feet of space use. However, a similar building having the same base dimensions but with four stories would constitute the same 20,000 square feet of land use but would have 80,000 square feet of space use.

Land use information relates to physical use to which a parcel of land is put. Land use activities, on the other hand, are measures of the intensity of this use. The following are examples of land use versus land use activities:

Land Use Category	Land Use Activity
residential	population labor force automobile ownership school enrollment
commercial	employment (retail) sales
industrial	employment

Hence, the land use inventory obtains information on the area used for various use categories. The collection of land use activity data is accomplished in the Home Interview Survey and in the compilation of Socio-Economic Data. The former obtains information on the residential land use activities such as population (often by age groups), school enrollment, occupation, auto ownership, etc. in addition to trip data.

Compile Socio-Economic Data

A variety of socio-economic information is needed to understand the forces affecting the functioning and growth of the urban areas. These data are also necessary in order to develop mathematical models or calculate trip generation rates for estimating future trip ends.

Socio-economic information is often obtained from secondary sources rather than by field data collection or survey. For those areas covered by an active local planning commission, much of the information is available in the files maintained by the professional planning staff. Additional data, and all available data for those areas which do not have a continuing planning function, are obtained from a variety of sources.

Projections and Future Estimates

A transportation plan for an urban area is only as good as the projections and estimates on which it is based. Hence, considerable effort is spent in evaluating what is likely to take place within the planning area over the planning period - normally 20 years. Most often, projections are also made for shorter programming periods which are usually 5 and 10 years. The projection phase is broken into components for convenience, there are: future land use arrangement
future population and employment
future trip ends
future trip distribution

Unfortunately, there is no "sure-fire" way to project these components with complete assurance. Hence, there is a need for a continuous planning process which provides a means of determining the effect of deviation of actual from projected growth and spatial arrangement.

Projection of Population and Employment

There is obviously considerable relationship between the projection of land use and population and employment as these two land use activities are the major determinant of the magnitude and nature of land use requirements for an urbanized area. Population and population related data by small areas (traffic zones) are essential in analyzing and estimating total trip generation and the number of trips having one end at the home.

Estimate of Future Trip Ends

Future trip ends are estimated by serial zones for each major land use category. Trip generation rates are determined for the various land uses by relating the number of trip ends generated by each. Land use activity variables used should be directly related to the primary purpose for which trips to each land use are made. The analysis and estimation procedure varies from study to study depending upon data availability and reliability.

Obviously, the number of future trips are no more accurate than the projections on which they are based. These projections are the "best judgement" of informed professional planners of what is likely to happen in each zone. It is obvious that all zones will not develop exactly as projected and generate the exact number of estimated trips. At best the actual number of trips generated is similar to that projected and at worst there is no comparison.

Distribute Future Trips

After the number of trip ends in each zone has been estimated, it is necessary to develop a trip table indicating the zone-to-zone movements. Texas practice is to use a "pattern trip procedure" together with Fratar distribution. The several zones are analyzed and the growth in each zone is projected. From this, growth factors for trip ends (by purpose-"home base work," "home base nonwork," and "non-home base") are determined.

For those zones in which the projected development is substantially different from the existing development, a pattern zone-to-zone interchange is developed. This is necessary for zones which are at the fringe of the presently developed urban area and which have few trips in the survey year but which are expected to be heavily developed by the horizon year - normally 20 years in the future. Such a zone is "matched" with a nearby zone that is presently developed (i.e. generates trips) and is similar to the projected development in the zone in question. In some instances, no adjacent zone with a trip pattern anticipated for the zone in question is available and a pattern must be written. The present trip pattern of the developed zone is then substituted for the low values in the O-D trip table for the zone in question. Growth factors are then determined from the ratio of projected trips (future year) to "pattern trips" (survey year) and the future trip distribution developed by the Fratar procedure.

Summary

The previous sections briefly described the steps that lead up to the development of a trip table for some future (design) year. It is the "assignment" of this trip table to the coded network that provides the link loading (volumes) and turn movements that are of interest for design.

The Texas Transportation Institute is presently developing and programming a new trip distribution model in cooperation with the Texas Highway Department. This distribution model shows considerable promise of providing the Planning Survey Division with a computerized procedure that will be a significant improvement in trip distribution.

APPENDIX C

APPENDIX C

NETWORK SIMULATION

This appendix explains the development of the coded network and the representation and use of this network by the computer. Its purpose is to provide the Design Engineer with an understanding of the process so that he might be able to better interpret assigned traffic volumes and relate these volumes to his design needs. The following discussion relates to the TEXAS-BIGSYS programs now being used by the Texas Highway Department; this program package has replaced the Revised Texas Control programs formerly used.

Node Map Preparation

The traffic assignment procedures are based on the selection of a minimum time-path between zone pairs. To accomplish this task, a description of the network is coded, keypunched, and stored in the memory of the computer. The node map is the graphical representation of the road network and serves as the basis for the preparation of the link data cards to be input into the computer.

For network coding purposes, the route sections are considered to be the one-way part of a route between two intersections and are referred to as "links." Intersections are points at which two or more route sections meet and allow the possibility of a change in the travel direction; these intersections are referred to as "nodes." Each node is identified by a unique number. These numbers are applied systematically, and a record is kept of all numbers used.

Route sections are identified by the node number at each end of the section. The additional information that is coded for each route section or link is the length of the link, its speed, and/or travel time. The capacity of the link and the existing volume of the link may also be coded. Some other data are necessary if travel statistics are to be recorded by political jurisdiction within the study area, and if time penalties are to be applied, for turning movements.

A traffic zone is represented by node (centroid) which in effect assumes that all trips to and from the zone begin or end at a single point. It is then connected to the network by one or more hypothetical connectors which serve to represent the local streets.

It is most important to note that all streets are not represented on a node map. In an operational network, practice is to "include only the principal streets." In reality then, each route on a node map may represent a number of less important parallel streets in addition to the principal street, further, the nodes representing intersections may not have a one-to-one correspondence with intersections on the ground.

It might be believed that increased detail in the coded network's representation of the street and highway system would improve traffic assignment results. Recent research by the Texas Transportation Institute has shown that this is not true; at least not with the all-or-nothing assignment.* The results indicate that assigned volumes on individual street segments and turn movements are not any more realistic when the network (or a portion thereof) is coded block-by-block.

In theory, a greater realism in the computer simulation can be achieved by taking into account the delays to vehicles making a right or left turn at intersections. Therefore, an increment of travel time (called a turn penalty) may be imposed on turning vehicles.

In practice, however, the turn penalty is more often used to avoid minimum paths which "zig-zag" through the network from origin to destination. Only one penalty value can be used throughout the system and it applies equally to both left and right turns. Turn penalties of 0.1 to 0.3 minutes per turn have been generally utilized in Texas; however, any reasonable value may be used.

The use of turn penalties can be varied in the following ways:

a. The network can be completely coded and keypunched with signs and flags, then:

    (1) Various magnitudes to turn penalty may be used for calculation of different sets of trees for the same network to determine the most satisfactory penalty time, but the magnitude will be constant throughout the system for a particular set of trees or selected trees from a set.

    (2) The turn penalty may be eliminated by designating the turn penalty zero.

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* Work is now in progress to develop and evaluate a procedure which it is hoped will eliminate some of the problems resulting from the all-or-nothing assignment.

b. The turn penalty may be suspended at selected intersections by manipulating the sign and flag when coding the node map such that all entrances and exits of the intersection are either all plus or all minus. This will cause the penalty to be suspended only at the designated intersections.

c. The turn penalty can be dispensed with entirely in the preparation and coding of the node map for a particular system by not coding the sign and flag for any intersection. This will cause an "all plus" situation at all intersections in the system. In this case, even though a turn penalty other than zero is designated, no penalties will be applied.

The details of coding turn penalties are given in the Traffic Assignment Manual prepared by the Bureau of Public Roads.

The coded network description is stored in computer memory, and the computer accomplishes the minimum time-path selection through a systematic search and accumulation of travel time from the data stored in the memory. In effect, the network is remapped in the memory of the computer.

Minimum Path Determination

In all of the traffic assignment techniques developed to date, it is assumed that the vehicle operator uses the single "best" route between his origin and destination. The "best" route could be the one comprising the shortest distance, the shortest travel time requiring the least number of stops and turns, having the minimum amount of pedestrian interference, or any combination of these. Travel time, or a combination of travel time and turn penalties expressed in terms of time, is the most common parameter used to determine the "best" or minimum path.

Several techniques for computer calculation of the minimum path through a network are available, most of which calculate the tree for each centroid separately. The procedure developed by Edward F. Moore has been generally employed in recent highway and transportation studies. A straightforward description of the use of the Moore Algorithm in traffic assignment is given in Reference Number 25, "Minimum Path Algorithms for Transportation Planning."*

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*Edward F. Moore, "The Shortest Path Through a Maze," Proceedings of International Symposium on the Theory of Switching, Harvard University, 1957.

An example of a simple network is shown in Figure C-1. For the sake of simplicity only one of two centroid connectors have been shown for each zone. The capital letters (indicated thus: A) represent zone centroids; lower case letter identify nodes; and, the number in parentheses represents the link travel time.

For the explanation of the tree building process, the minimum path tree for centroid 'B' will be used. The process is summarized in Table 1. The sequence of events is as follows: Centroid B is identified as the home zone and all ways out (i.e. links B-d and B-j) are considered; for notation purposes this is referred to as set 1. At this point, there are no links in the tree so all outbound links are included in (added to) the tree. Next, the first forward node of set 1, node 'd', is considered; all links having 'd' as a back node are called set 2. All possible forward nodes (i.e. 'e' and 2) are checked to determine if a path to each has already been found. Since the response is no (indicated by a 'no' in column 4) the link is added to the tree and the travel time for link d-e (4 minutes) is added to the total travel time to the back node 'd' - 4 minutes - to determine the cumulative time to the forward node 'e'. The forward node '2' of link d-2 is, of course, a partition line node; links to such nodes are always included in the tree.

Continuing, nodes 'e' and 'i' in turn, are the next nodes from which the program will attempt to extend the tree. Node 'e' being a forward node in set 2 and 'i' in set 3. Nodes which are on a partition line, such as node '2' are not used as forward nodes until the search procedure moves into the next subnet.

The link i-h is included in the tree since node 'h' has not previously been reached. The link i-e, however, is not included since node 'e' has previously been reached via a different path (i.e. from node 'd') which has a shorter cumulative travel time - 8 minutes versus 10 minutes

Similarly, the links considered in sets 6, 7, 8, and 9 are considered and included in the tree if the forward node in question has not been reached via a shorter path. In set 10, however, the algorithm finds a node (node 'a') which has already been reached by a different path and the connecting link (g-a) included in the tree. The time path to node 'a via 'g' was 18 minutes as found in set number 9; the routing via node 'b' as found in set number 10 is 17 minutes. Hence, the computer deletes link 'g-a' from the tree and adds 'b-a' in set number 10.

On set 11 the portion of the tree in subnet 1 for centroid 'B' is completed. The program then moves on to consider subnet 2. Continuing with the example of tree 'B': The program "picks up" the tree at the partition line nodes

1, 2, and 3 and considers each in turn. Each partition line node is connected to one, and only one, node in each subnet. Continuation of tree 'B' in subnet 2 then, of course, gives 18 minutes to node 'r', 7 minutes to node 'w', and 6 minutes to node 'x' via partition nodes 1, 2, and 3 respectively. Set 1 (subnet 2) then considers all forward nodes from node 'r'. Since centroid 'Z' and node 's' have not been reached previously, they are included in the tree; node 'v' has, of course, been reached via partition node 2 and is therefore not added. On set 2, the path to node 'r' is found to be shorter than that via partition node 1 (12 minutes versus 18) and link "1-r' is deleted from the tree. The process is continued until the portion of tree "b" in subnet 2 is completed. Trees for all other centroids in subnet 1 are computed in a similar fashion.

The formatted tree can then be traced manually on a node map or plotted by computer. The tree for centroid 'B' is shown in Figure C-2. Solid lines indicate the minimum path to the partition line nodes; these nodes are in the centroid-partition node numbering sequence and "appear" as centroids to the computer.

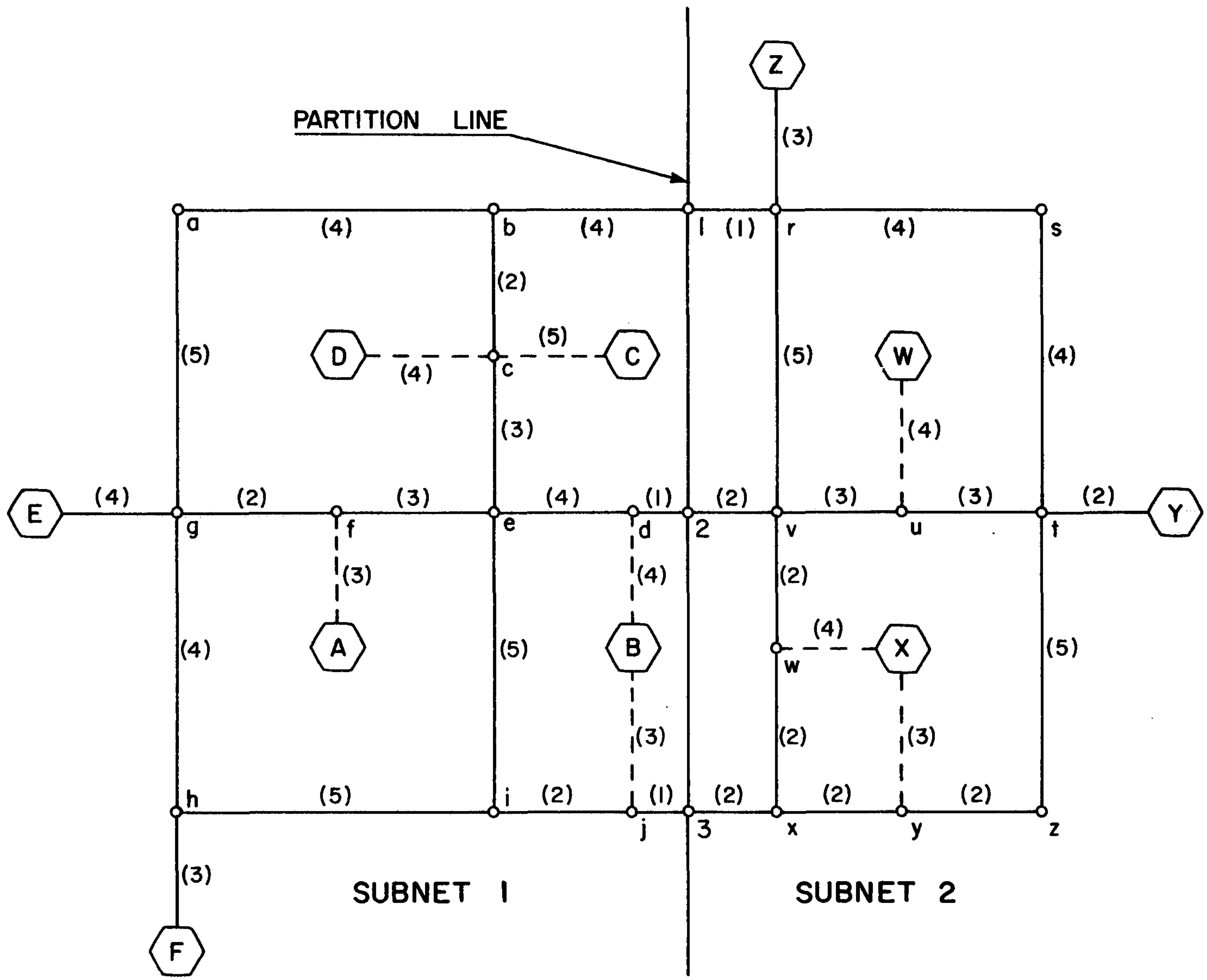


FIGURE C-1

EXAMPLE OF A SIMPLE CODED NETWORK

TABLE 1

SIMPLIFIED EXAMPLE OF THE TREE BUILDING PROCESS
FOR THE EXAMPLE NETWORK SHOWN IN FIGURE 3

Home Node = B
Home Node in Subnet 1, Searching in Subnet 1

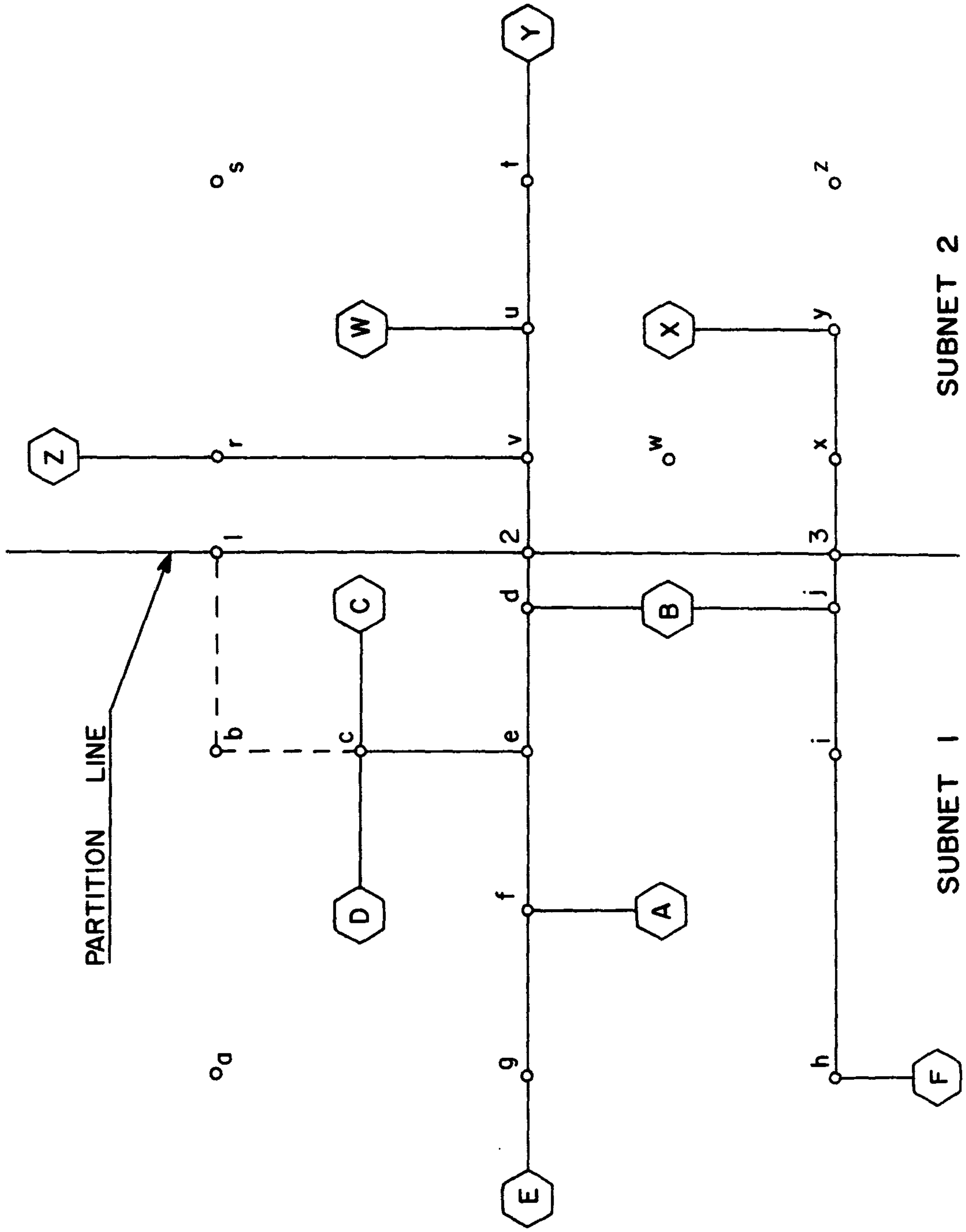
Set No.	(1) Link Back Node	(1) Link Forward Node	(2) Link Time	(3) Cumulative Time From Home Node	Previously at Forward Node via Shorter Path	Link Added To Tree	(6) Link Removed by Subsequent Set
	Set Being Considered						
1	B	d	4	4	no	yes	
	B	j	3	3	no	yes	
2	d	e	4	8	no	yes	
	d	2	1	5	no	yes	
3	j	i	2	5	no	yes	
	j	3	1	4	no	yes	
4	e	i	5	13	yes		
	e	f	3	11	no	yes	
	e	c	3	11	no	yes	
5	i	h	5	10	no	yes	
	i	e	5	10	yes		
6	f	A	3	14	no	yes	
	f	g	2	13	no	yes	
7	c	D	4	15	no	yes	
	c	b	2	13	no	yes	
	c	C	5	16	no	yes	
8	h	F	3	13	no	yes	
	h	g	4	14	yes		
9	g	h	4	17	yes		
	g	E	4	17	no	yes	
	g	a	5	18	no	yes	#10
10	b	a	4	17	no	yes	
	b	1	4	17	no	yes	
11	a	g	5	22	yes		

TABLE 1 (continued)

Home Node = B
Home Node in Subnet; Searching in Subnet 2

Set No.	(1) Link Back Node	(1) Link Forward Node	(2) Link Time	(3) Cumulative Time From Home Node*	Previously at Forward Node via Shorter Path	Link Added To Tree	Link Removed by Subsequent Set
	1	r	1	18	no	yes	#2
	2	v	2	7	no	yes	
	3	x	2	6	no	yes	
1	r	Z	3	21	no	yes	#5
	r	s	4	22	no	yes	#5
	r	v	5	23	yes		
2	v	r	5	12	no	yes	
	v	u	3	10	no	yes	
	v	w	2	9	no	yes	#3
3	x	w	2	8	no	yes	
	x	y	2	8	no	yes	
4	s	t	4	26	no	yes	#10
5	r	Z	3	15	no	yes	
	r	s	4	16	no	yes	
6	u	W	4	14	no	yes	
	u	t	3	13	no	yes	
7	w	w	2	10	yes		
	w	X	4	12	no	yes	#8
8	y	X	3	11	no	yes	
	y	z	2	10	no	yes	
9	t	u	3	29	yes		
	t	Y	2	28	no	yes	#11
	t	z	5	31	yes		
10	s	t	4	20	yes		
11	t	s	4	17	yes		
	t	Y	2	15	no	yes	
	t	z	5	18	yes		
12	3	t	5	15	yes		

*Cumulative time from home node to partition line nodes is carried over from subnet 1.



EXAMPLE OF A MINIMUM PATH TREE

FIGURE C-2

APPENDIX D

EXAMPLES OF COMPUTER PRINTOUT

This chapter attempts to familiarize the user of traffic assignment output with the format and certain limitations of the printout. It does not attempt to review the assumptions which are basic to the development of the printout nor does it attempt to develop an understanding necessary for application for planning and design purposes. All references and examples are relative to the TEXAS - Large Systems TRAFFIC ASSIGNMENT PACKAGE (i.e. TEXAS-BIGSYS or simply BIGSYS).

Network Description

The first output that the designer might be interested in is the printout from the Output Network programs. This printout is a definition of the coded network used by the computer in the assignment process. As may be seen in the example printout shown in Figure D-1, the description is output in-sort on "back node." Inasmuch as centroids are numbered first, beginning with the number '1', they are printed out first. The individual links are, of course, identified by a back node and a front node. Since each node may have as many as four ways out, there are four sets of information printed for each back node; these consist of the following:

Column Heading	Contents
BACK NODE	The node at the opposite end of the link from the back node.
SA	The sign at the back and front node respectively.
J	The jurisdiction in which the node is located.
DIST (MI)	The link distance as coded to the nearest one-hundredth (0.00) of a mile.
SPEED (MPH)	The link speed to the nearest tenth (0.0) of a mile per hour.
TIME (MIN)	The link time to the nearest one-hundredth (0.00) of a minute.

General practice in Texas is to code the link distance and link speed on the link data card; the link time is then calculated by the computer upon execution of the Prepare Network Description program. Speeds on the existing network are, of course, obtained from the travel time study and are coded to a whole mile per hour on the link data cards and increments of five miles per hour are frequently used. For assignments to future networks, levels of service that are expected at that time are assumed.

One-way links are noted by an appropriate message. For example, in Figure D-1, the link 6671 - 6670 is one-way in the direction 6670 to 6671. Hence, the various link parameter fields are blank and the message ONE WAY IN is printed. The link distance, speed, and time, etc. are given following the back node 6670 as ".03", "32.0", and ".05" respectively.

Minimum Path Trees

It is often desired to trace selected trees manually on the node map or to plot them utilizing the IBM 1401 and CAL-COMP Plotter. A printout of a tree is obtained by exercising an option in the "Search Minimum Paths" program. An example of the output is shown in Figure D-2 for tree (centroid) 760 as indicated in the upper left corner. The printout lists the nodes in numerical order beginning with node number 1 (which is, of course, a centroid) as explained below:

DESTN NODE	The node for which the following two fields apply.
ADJ NODE	The adjacent node which is the back node of the link by which the "Destination Node" was reached by the minimum path.
TIME (MIN)	The cumulative time from the home node (the centroid for which the tree was built) to the "Destination Node."

In the example shown in Figure D-2 the time from centroid 760 to centroid 1 via the minimum path is 17.61 minutes; further the path to centroid 1 was via (over) the link 3554 - 1. Similarly, the minimum path time to other selected centroids from centroid 760 is as follows:

Centroid #	Time (min.)
2	17.16
3	16.43
4	14.42
5	14.75
101	9.46
200	7.88

In order to use this output to manually plot trees, one would take each destination centroid in turn and work back toward centroid 760. For example, for centroid number 1: the link 3554 - 1 would be located in the printout, the Adjacent Node determined and this link traced on the node map; etc.

Trip End Summaries

There are two printouts of trip end summary that may be of interest to the designer from time-to-time. One is the trip table, a portion page of which is shown in Figure D-3. This figure is a reproduction of the total existing (survey year) trips from zone 22 to all zones as determined from the expanded Waco trip reports (there is one such page for each centroid). It shows, for example, that there are 164 total trips (all modes) from zone 22 to zone 8 and 170 trips from zone 22 to zone 154. These trips are one-way trips; that is, only the trips from zone 22 to any other zone. The trips in the reverse direction; for example, from zone 8 to zone 22 would be given on the page labeled:

TRIPS FROM ZONE 8 TO ALL ZONES

It also indicates that there are 48 trips which both begin and end in zone 22 (intrazonal trips) as, hence, are not assigned to the network.

For the Waco E-2 network, centroids (zones) 1 through 206 are internal zones; centroids numbered 207 and higher are external stations. Therefore, it is possible to determine the expanded number of trips that originated in zone 22 and passed through any external station; for example, 62 trips passed through station 216. The number of trips that entered the study area at any external station and destined for any internal zone or other external stations can be easily determined by reading the value off the appropriate page. By knowing the centroid numbering system for any study area, these volumes can, of course, be related to a specific highway crossing the study area boundary.

Figure D-4 shows an example of the Trip End Summary; the data shown from the existing (survey year) 24-hour vehicle trips in Waco. Proceeding

NETWORK DESCRIPTION

BACK NODE	FRONT NODE SA J	DIST (MI)	SPEED (MPH)	TIME (MIN)	FRONT NODE SA J	DIST (MI)	SPEED (MPH)	TIME (MIN)	FRONT NODE SA J	DIST (MI)	SPEED (MPH)	TIME (MIN)	FRONT NODE SA J	DIST (MI)	SPEED (MPH)	TIME (MIN)
6651	6650 ++ 2	.09	24.0	.22	4412 -- 2	.08	15.0	.32	6652 +- 2	.03	24.0	.07				
6652	6651 -+ 2	.03	24.0	.07	6648 ++ 2	.06	26.0	.13	6847 -- 2	.08	27.0	.17	6653 ++ 2	.07	26.0	.16
6653	4412 -- 2	.07	15.0	.28	6652 ++ 2	.07	26.0	.16	4448 -- 2	.03	15.0	.12	6654 ++ 2	.07	26.0	.16
6654	6653 ++ 2	.07	26.0	.16	6655 ++ 2	.04	26.0	.09	6843 -- 2	.08	15.0	.32				
6655	6654 ++ 2	.04	26.0	.09	6505 -- 2	.08	15.0	.32	6656 ++ 2	.04	26.0	.09				
6656	4413 -- 2	.07	15.0	.28	6655 ++ 2	.04	26.0	.09	4447 -- 2	.03	15.0	.12	6660 ++ 2	.04	26.0	.09
6657	4407 ++ 2	.06	15.0	.24	6658 -- 2	.03	15.0	.12								
6658	4413 ++ 2	.03	15.0	.12	6657 -- 2	.03	15.0	.12	6659 -- 2	.04	15.0	.16	6663 ++ 2	.08	15.0	.32
6659	4414 ++ 2	.06	15.0	.24	6658 -- 2	.04	15.0	.16	6660 -- 2	.04	15.0	.16				
6660	6656 ++ 2	.04	26.0	.09	6659 -- 2	.04	15.0	.16	6661 ++ 2	.03	26.0	.06				
6661	6660 ++ 2	.03	26.0	.06	6662 ++ 2	.05	26.0	.11	6838 -- 2	.08	15.0	.32				
6662	4414 -- 2	.03	15.0	.12	6661 ++ 2	.05	26.0	.11	4446 -- 2	.04	15.0	.16	6667 ++ 2	.09	26.0	.20
6663	4407 -- 2	.03	15.0	.12	6658 ++ 2	.08	15.0	.32	4414 -- 2	.04	15.0	.16	6665 ++ 2	.08	15.0	.32
6664	4407 ++ 2	.07	15.0	.28	6637 -- 2	.09	15.0	.36	4406 ++ 2	.07	15.0	.28	6665 -- 2	.03	15.0	.12
6665	6663 ++ 2	.08	15.0	.32	6664 -- 2	.03	15.0	.12	6666 -- 2	.04	15.0	.16	6669 ++ 2	.09	15.0	.36
6666	4415 ++ 2	.07	15.0	.28	4414 ++ 2	.07	15.0	.28	6665 -- 2	.04	15.0	.16	6667 -- 2	.03	15.0	.12
6667	6662 ++ 2	.09	26.0	.20	6666 -- 2	.03	15.0	.12	6668 ++ 2	.08	26.0	.18	6832 -- 2	.04	15.0	.16
6668	4415 -- 2	.03	15.0	.12	6667 ++ 2	.08	26.0	.18	6673 ++ 2	.07	26.0	.16	4445 -- 2	.03	15.0	.12
6669	4406 -- 2	.04	15.0	.16	6665 ++ 2	.09	15.0	.36	6671 ++ 2	.07	15.0	.28	4415 -- 2	.04	15.0	.16
6670	4406 ++ 2	.06	15.0	.24	6671 -- 2	.03	32.0	.05	6636 -ONE WAY IN-							
6671	6669 ++ 2	.07	15.0	.28	6672 -- 2	.05	32.0	.09	6675 ++ 2	.04	15.0	.16	6670 -ONE WAY IN-			
6672	4415 ++ 2	.06	15.0	.24	4416 ++ 2	.02	15.0	.08	6673 -- 2	.03	32.0	.05	6671 -ONE WAY IN-			
6673	6668 ++ 2	.07	26.0	.16	6826 -- 2	.05	31.0	.09	6674 ++ 2	.04	25.0	.09	6672 -ONE WAY IN-			
6674	4416 -- 2	.03	15.0	.12	6673 ++ 2	.04	25.0	.09	6679 ++ 2	.04	25.0	.09	4444 -- 2	.04	15.0	.16
6675	4405 -- 2	.03	15.0	.12	6671 ++ 2	.04	15.0	.16	6677 -- 2	.04	15.0	.16	4416 -- 2	.04	15.0	.16
6676	4404 ++ 2	.04	15.0	.16	4405 ++ 2	.03	15.0	.12	6484 -- 2	.21	29.0	.43	6677 -ONE WAY IN-			
6677	6675 -- 2	.04	15.0	.16	6676 -- 2	.04	29.0	.08	6681 ++ 2	.04	15.0	.16	6678 -ONE WAY IN-			
6678	4416 ++ 2	.04	15.0	.16	4417 ++ 2	.04	15.0	.16	6677 -- 2	.04	29.0	.08	6679 -ONE WAY IN-			
6679	6674 ++ 2	.04	25.0	.09	6680 ++ 2	.04	25.0	.09	6678 -- 2	.04	29.0	.08	7755 -ONE WAY IN-			
6680	4443 -- 2	.03	15.0	.12	6679 ++ 2	.04	25.0	.09	4417 -- 2	.04	15.0	.16	6685 ++ 2	.04	25.0	.09
6681	4417 -- 2	.04	15.0	.16	4404 -- 2	.04	15.0	.16	6677 ++ 2	.04	15.0	.16	6683 ++ 2	.04	15.0	.16
6682	4403 ++ 2	.04	15.0	.16	6635 -- 2	.08	15.0	.32	4404 ++ 2	.04	15.0	.16	6683 -- 2	.04	15.0	.16
6683	6682 -- 2	.04	15.0	.16	6681 ++ 2	.04	15.0	.16	6684 -- 2	.04	15.0	.16	6687 ++ 2	.04	15.0	.16
6684	4418 ++ 2	.04	15.0	.16	6683 -- 2	.04	15.0	.16	4417 ++ 2	.04	15.0	.16	6685 -- 2	.04	15.0	.16
6685	6684 -- 2	.04	15.0	.16	6680 ++ 2	.04	25.0	.09	6814 -- 2	.04	15.0	.16	6686 ++ 2	.04	25.0	.09
6686	4442 -- 2	.04	15.0	.16	6685 ++ 2	.04	25.0	.09	4418 -- 2	.04	15.0	.16	6691 ++ 2	.04	25.0	.09
6687	4418 -- 2	.04	15.0	.16	6683 ++ 2	.04	15.0	.16	6689 ++ 2	.04	15.0	.16	4403 -- 2	.04	15.0	.16
6688	4403 ++ 2	.04	15.0	.16	4402 ++ 2	.07	15.0	.28	6689 -- 2	.04	15.0	.16	6633 -- 2	.04	15.0	.16
6689	6687 ++ 2	.04	15.0	.16	6688 -- 2	.04	15.0	.16	6690 -- 2	.04	15.0	.16	6693 ++ 2	.08	15.0	.32
6690	4418 ++ 2	.04	15.0	.16	4419 ++ 2	.08	15.0	.32	6691 -- 2	.04	15.0	.16	6689 -- 2	.04	15.0	.16
6691	6690 -- 2	.04	15.0	.16	6692 ++ 2	.08	25.0	.19	6686 ++ 2	.04	25.0	.09	6808 -- 2	.04	15.0	.16
6692	4419 -- 2	.04	15.0	.16	6691 ++ 2	.08	25.0	.19	6697 ++ 2	.08	25.0	.19				
6693	4402 -- 2	.04	15.0	.16	6689 ++ 2	.08	15.0	.32	4419 -- 2	.04	15.0	.16	6695 ++ 2	.08	15.0	.32
6694	4402 ++ 2	.07	15.0	.28	6630 -- 2	.04	15.0	.16	4401 ++ 2	.07	15.0	.28	6695 -- 2	.04	15.0	.16
6695	6694 -- 2	.04	15.0	.16	6699 ++ 2	.04	15.0	.16	6693 ++ 2	.08	15.0	.32	6696 -- 2	.04	15.0	.16
6696	4419 ++ 2	.08	15.0	.32	4420 ++ 2	.03	15.0	.12	6695 -- 2	.04	15.0	.16	6697 -- 2	.04	15.0	.16
6697	6692 ++ 2	.08	25.0	.19	4430 -- 2	.21	15.0	.84	6696 -- 2	.04	15.0	.16	6698 ++ 2	.04	25.0	.09
6698	4420 -- 2	.03	15.0	.12	6702 ++ 2	.04	25.0	.09	6697 ++ 2	.04	25.0	.09				
6699	6695 ++ 2	.04	15.0	.16	6700 ++ 2	.04	15.0	.16	4420 -- 2	.03	15.0	.12				
6700	4401 -- 2	.03	15.0	.12	6699 ++ 2	.04	15.0	.16	6701 -- 2	.04	15.0	.16	6703 ++ 2	.04	15.0	.16

EXAMPLE OF NETWORK DESCRIPTION PRINTOUT

FIGURE D-1

TEST TREE WACO DETAILED NETWORK II TURN PENALTY 00 JUL 29, 1966

TREE NO. 760

DESTN NODE	ADJ NODE	TIME (MIN)	DESTN NODE	ADJ NODE	TIME (MIN)	DESTN NODE	ADJ NODE	TIME (MIN)	DESTN NODE	ADJ NODE	TIME (MIN)	DESTN NODE	ADJ NODE	TIME (MIN)
1	3554	17.61	2	3554	17.16	3	3553	16.43	4	3542	14.42	5	3550	14.75
6	3549	13.75	7	3540	13.96	8	3548	12.58	9	3545	11.58	10	3533	10.54
11	3534	8.26	12	3535	9.97	13	3520	8.51	14	3529	7.68	15	3515	8.30
16	3514	7.94	17	3513	7.69	18	3513	7.85	19	3524	7.51	20	3509	7.50
21	3502	9.67	22	3545	16.65	23	3753	10.63	24	3500	9.69	25	3495	10.45
26	3493	8.95	27	2729	7.73	28	2725	8.01	29	3389	8.67	30	3472	9.75
31	3471	8.45	32	3467	8.60	33	3465	8.44	34	3464	8.20	35	3459	7.73
36	3409	9.46	37	3453	6.84	38	3452	7.13	39	1204	6.93	40	3401	6.40
41	3394	6.95	42	3376	6.56	43	3399	7.77	44	3408	7.48	45	3451	6.33
46	3444	6.32	47	3437	6.24	48	3443	6.10	49	3433	5.85	50	3432	6.05
51	3431	6.63	52	3417	5.78	53	3422	5.99	54	3410	5.32	55	3414	5.79
56	1186	5.77	57	1190	6.03	58	1200	6.25	59	3475	7.19	60	3478	6.94
61	1214	7.26	62	3481	7.70	63	3481	8.06	64	1226	8.55	65	3483	9.51
66	3484	9.81	67	3486	9.78	68	1431	11.61	69	3675	11.22	70	3677	11.90
71	3704	11.94	72	3705	10.60	73	3711	9.26	74	3699	10.24	75	3679	9.01
76	3691	8.72	77	3673	11.54	78	3670	11.07	79	3671	10.75	80	3674	10.25
81	3669	11.09	82	3683	9.42	83	3680	9.35	84	3690	8.78	85	3652	8.66
86	3662	8.61	87	3683	9.46	88	3650	9.49	89	3628	8.80	90	3632	8.98
91	3643	10.01	92	3641	10.17	93	3571	8.94	94	3604	9.49	95	3634	9.17
96	3639	9.81	97	3635	9.53	98	3616	8.75	99	3616	8.83	100	3618	8.70
101	3613	9.46	102	3582	9.29	103	3567	8.92	104	3573	8.94	105	3574	8.87
106	3575	8.69	107	3577	8.58	108	3578	8.23	109	3578	8.27	110	3583	9.41
111	3619	8.16	112	3585	7.33	113	3711	8.98	114	2778	8.18	115	3698	9.03
116	3696	8.36	117	3695	7.81	118	3750	8.52	119	3695	8.01	120	3622	8.29
121	2268	7.78	122	2174	8.06	123	3592	7.42	124	2876	9.47	125	2872	8.95
126	2880	8.59	127	2881	8.43	128	3708	8.74	129	2873	8.59	130	2868	8.19
131	2865	8.03	132	2864	7.82	133	2860	7.62	134	2859	7.33	135	2858	6.94
136	2847	7.03	137	2849	6.65	138	2852	7.12	139	2853	7.40	140	2842	7.72
141	2839	7.96	142	2834	8.63	143	2766	8.85	144	2824	8.72	145	2822	8.11
146	2821	7.79	147	2820	7.59	148	2818	6.98	149	2846	6.86	150	2847	6.47
151	2807	6.81	152	2811	6.57	153	2812	6.28	154	2817	6.75	155	2782	8.00
156	2772	8.72	157	2778	8.18	158	2689	7.83	159	2691	7.82	160	2767	7.77
161	2694	7.49	162	2696	7.24	163	2786	7.48	164	2701	6.76	165	2787	7.20
166	2756	6.92	167	2791	6.77	168	2706	6.11	169	2795	6.46	170	2748	6.05
171	2708	5.88	172	2746	5.69	173	2812	6.44	174	2745	5.77	175	2800	6.61
176	2801	6.37	177	2746	5.69	178	2742	6.27	179	2716	6.03	180	2737	6.50
181	372[illegible]	6.82	182	2731	7.38	183	2643	7.31	184	2723	7.30	185	2718	6.34
186	2716	6.03	187	2653	5.61	188	2713	5.49	189	2659	5.81	190	2660	5.93
191	2623	6.49	192	2702	6.79	193	2700	7.05	194	2665	6.78	195	2666	7.10
196	2668	[illegible].08	197	2682	7.98	198	2685	7.31	199	2677	7.21	200	2671	7.88

EXAMPLE OF MINIMUM PATH TREE PRINTOUT

FIGURE D-2

WACO E-2 TRIP END SUMMARY — OCT 19, 1966

TRIPS FROM ZONE 22 TO ALL ZONES

ZONE	0	1	2	3	4	5	6	7	8	9
0		164	0	0	130	87	0	82	164	20
10	263	0	82	0	0	0	0	0	328	164
20	0	96	48	48	294	0	0	0	0	0
30	246	87	246	0	328	376	0	0	0	0
40	0	0	0	0	0	0	0	0	782	0
50	0	0	82	0	0	89	0	82	82	0
60	0	588	0	0	0	0	0	0	0	0
70	0	0	0	0	0	44	82	0	0	0
80	0	0	0	0	83	0	0	0	0	167
90	0	0	0	170	135	0	0	48	0	86
100	344	86	86	0	0	0	0	391	536	0
120	0	0	0	0	0	0	172	602	0	431
130	0	0	0	0	0	0	0	0	0	126
140	0	0	0	0	0	135	0	0	0	0
150	0	0	0	0	170	0	0	0	0	48
170	0	0	0	87	0	44	0	0	0	0
180	0	0	45	82	0	86	0	0	0	0
190	0	0	0	0	100	0	0	0	0	0
200	0	0	0	0	0	0	0	0	40	0
210	14	0	36	0	0	0	62	0	0	0

EXAMPLE OF PRINTOUT OF TRIP TABLE

FIGURE D-3

WACO DETAILED NETWORK 24 HOUR TOTAL TRIPS JUL 29, 1966

ZONE NO.	NO.TRIPS ENTERING	NO.TRIPS EXITING	NO. INTRAZONAL	NO. TRIP ENDS	NO.ZONES ENTERING	NO.ZONES EXITING
1	0	0	0	0	0	0
2	23	23	0	46	3	3
3	135	135	0	270	13	13
4	717	744	74	1609	96	98
5	43	43	0	86	5	5
6	0	0	0	0	0	0
7	6	6	0	12	2	2
8	81	81	0	162	17	20
9	316	303	8	635	55	51
10	302	302	5	614	34	32
11	115	145	0	260	15	16
12	275	275	0	550	26	26
13	127	128	0	255	11	10
14	109	95	0	204	12	12
15	235	261	0	496	15	15
16	442	431	9	891	38	34
17	427	425	0	852	37	37
18	944	930	8	1890	93	85
19	224	230	0	454	21	23
20	96	102	0	198	13	17
21	0	0	0	0	0	0
22	307	296	32	667	55	60
23	17	17	0	34	2	2
24	27	27	0	54	2	2
25	1	0	0	1	1	0
26	0	0	0	0	0	0
27	215	215	0	430	15	14
28	93	94	0	187	12	11
29	0	0	0	0	0	0
30	155	142	0	297	19	15
31	132	129	0	261	20	20
32	205	202	0	407	22	18
33	82	85	0	167	9	9
34	74	74	0	148	6	7
35	141	157	0	298	12	11
36	185	183	34	436	17	15
37	294	322	0	616	26	26
38	153	161	0	314	10	10
39	159	164	0	323	17	19
40	55	75	0	130	8	10
41	127	118	0	245	15	14
42	202	209	0	411	17	18
43	225	204	0	429	25	22
44	952	868	5	1830	76	76
45	94	101	0	195	11	11
46	59	60	5	129	8	9
47	120	117	0	237	11	12
48	20	20	0	40	4	4
49	32	31	0	63	4	3
50	199	203	9	420	25	24

EXAMPLE OF PRINTOUT OF TRIP END SUMMARY

FIGURE D-4

from left to right, the column heading and contents are:

Column Heading	Column Contents
ZONE NO.	The zone (centroid) to which the information on a link of output pertains.
NO. TRIPS ENTERING	The number of trips entering the zone from all other zones (including external stations) in the study area. When trip origins and destinations are summarized the number of destinations in each zone is given in this column.
NO TRIPS EXITING	The number of trips exiting (leaving) the zone to all other zones (including external stations) in the study area. When trip origins and destinations are summarized, the number of origins in each zone is given in this column.
NO. INTRAZONAL	The number of intrazonal trips; these trips have both ends within the same zone.
NO. TRIPS ENDS	The total number of trips ends; this is the sum of the number of trips entering plus the number of trips exiting plus twice the number of intrazonal trips.
NO. ZONES ENTERING	The number of zones from which trips came; for origins-destinations, this column gives the number of zones from which trips came to a specified zone.
NO. ZONES EXITING	The number of zones to which trips were outbound from each zone; for origins and destinations, this column gives the number of zones which were a destination for trips beginning in the specified zone.

Zone number 4 of the expanded origin-destination data for Waco shown in Figure D-4 will be used as a specific example for the following further explanation.

There were 717 trips that had destinations in zone 4; these 717 trips originated in 96 different zones.

There were 744 trips originating in zone 4 and they had destinations in 98 different zones.

There were 74 trips that had both origin and destination within zone 4.

The total number of trip ends in zone 4 was 1609, that is $717 + 744 + (2 \times 74) = 1609$.

Loaded Network

The printout with which the Design Engineer is most interested is, of course, the loaded network, an example of such a printout is shown in Figure D-5. Output information includes:

1. Directional (A Node to B Node) assigned volume for all links.

2. Non-directional (A Node to B Node plus the counter flow B Node to A Node) assigned volume for all links (except for one-way links).

3. Turn movements for the approximately 1600 highest numbered nodes in each subnet.

4. Information to assist in locating the A Node on the node maps.

The following explanation refers to the portion of the printout in Figure D-5 which is reproduced below:

LINK VOLUMES

ANODE	B NODE	VOLUME	B NODE	VOLUME	B NODE	VOLUME	B NODE	VOLUME
6900 DIR	6899	310	4473	32	6901	9	4466	0
6900 NDIR	6899	351	4473	54	6901	297	4466	0
TURNS	(4473- 6899)	22	(6901- 6899)	288	(6899- 4473)	32	(6901- 4473)	0
TURNS	(6899- 6901)	9	(6899- 4466)	0	(6901- 4466)	0	(4466- 6899)	0
TURNS	(4466- 4473)	0	(4473- 4466)	0	(4473- 6901)	0	(4466- 6901)	0

The directional volume is given in the volume column on the first line of print as indicated by the abbreviation DIR following the A Node number. The A Node is 6900. The assigned volume in the direction from node 6900 to node 6899 is 310 vehicles; from node 6900 to node 4473 it is 32 vehicles; from node 6900 to 6901 it is 9 vehicles; and from node 6900 to 4466 it is zero.

The non-directional volume is given on the second line for each A Node as indicated by the abbreviation NDIR following the A Node number. The total two-way volume on the link 6900 - 6899 is 351 vehicles; this is of course, the sum of the directional volume from node 6900 to node 6899 and from node 6899 to 6900.

The reader may satisfy himself as to this by reviewing the printout of Figure D-5. The directional volume from node 6900 to 6901 was previously determined to be 9 vehicles. The directional volumes from node 6901 to 6900 is given as 288 vehicles. Hence, the non-directive (total) assigned volume is 9 + 288 = 297; this is, of course, the figure given as the non-directional

WACO DETAILED ASSIGNMENT 6 --- TRIPS 24 HOUR TOTAL T.P.=0.00 AUG 27, 1966

LINK VOLUMES

ANODE	B NODE	VOLUME	B NODE	VOLUME	B NODE	VOLUME	B NODE	VOLUME	NAME OF INTERSECTION	
6900 DIR	6899	310	4473	32	6901	9	4466	0	6900 AT CLEVELAND	10
6900 NDIR	6899	351	4473	54	6901	297	4466	0		
TURNS	(4473- 6899)	22	(6901- 6899)	288	(6899- 4473)	32	(6901- 4473)	0		
TURNS	(6899- 6901)	9	(6899- 4466)	0	(6901- 4466)	0	(4466- 6899)	0		
TURNS	(4466- 4473)	0	(4473- 4466)	0	(4473- 6901)	0	(4466- 6901)	0		
6901 DIR	6900	288	6929	444	6902	52	6784	2207	6901 AT S 4TH	10
6901 NDIR	6900	297	6929	2916	6902	68	6784	2701		
TURNS	(6929- 6900)	263	(6902- 6900)	0	(6900- 6929)	0	(6902- 6929)	0		
TURNS	(6900- 6902)	9	(6900- 6784)	0	(6902- 6784)	16	(6784- 6900)	25		
TURNS	(6784- 6929)	444	(6929- 6784)	2191	(6929- 6902)	18	(6784- 6902)	25		
6902 DIR	6901	16	4472	0	6903	52	4467	0	6902 AT CLEVELAND	10
6902 NDIR	6901	68	4472	0	6903	68	4467	0		
TURNS	(4472- 6901)	0	(6903- 6901)	16	(6901- 4472)	0	(6903- 4472)	0		
TURNS	(6901- 6903)	52	(6901- 4467)	0	(6903- 4467)	0	(4467- 6901)	0		
TURNS	(4467- 4472)	0	(4472- 4467)	0	(4472- 6903)	0	(4467- 6903)	0		
6903 DIR	6902	16	6920	1646	6904	27	6783	1651	6903 AT S 3RD	10
6903 NDIR	6902	68	6920	3290	6904	55	6783	3267		
TURNS	(6920- 6902)	16	(6904- 6902)	0	(6902- 6920)	25	(6904- 6920)	12		
TURNS	(6902- 6904)	9	(6902- 6783)	18	(6904- 6783)	16	(6783- 6902)	0		
TURNS	(6783- 6920)	1609	(6920- 6783)	1617	(6920- 6904)	11	(6783- 6904)	7		
6904 DIR	6903	28	4471	5	6905	27	4468	0	6904 AT CLEVELAND	10
6904 NDIR	6903	55	4471	5	6905	60	4468	0		
TURNS	(4471- 6903)	0	(6905- 6903)	28	(6903- 4471)	0	(6905- 4471)	5		
TURNS	(6903- 6905)	27	(6903- 4468)	0	(6905- 4468)	0	(4468- 6903)	0		
TURNS	(4468- 4471)	0	(4471- 4468)	0	(4471- 6905)	0	(4468- 6905)	0		
6905 DIR	6782	0	6904	33	6915	0	4469	27	6905 AT S 2ND	10
6905 NDIR	6782	0	6904	60	6915	0	4469	60		
TURNS	(6904- 6782)	0	(6915- 6782)	0	(6782- 6904)	0	(6915- 6904)	0		
TURNS	(6782- 6915)	0	(6782- 4469)	0	(6915- 4469)	0	(4469- 6782)	0		
TURNS	(4469- 6904)	33	(6904- 4469)	27	(6904- 6915)	0	(4469- 6915)	0		
6906 DIR	4469	0	6781	63	6913	39	4470	0	6906 AT S 1ST	10
6906 NDIR	4469	0	6781	102	6913	102	4470	0		
TURNS	(6781- 4469)	0	(6913- 4469)	0	(4469- 6781)	0	(6913- 6781)	63		
TURNS	(4469- 6913)	0	(4469- 4470)	0	(6913- 4470)	0	(4470- 4469)	0		
TURNS	(4470- 6781)	0	(6781- 4470)	0	(6781- 6913)	39	(4470- 6913)	0		
6907 DIR	4470	16	6908	0	6912	20			6907 AT RIVER	10
6907 NDIR	4470	36	6908	0	6912	36				
TURNS	(4470- 6908)	0	(4470- 6912)	20	(6912- 6908)	0	(6908- 6912)	0		
TURNS	(6908- 4470)	0	(6912- 4470)	16						
6908 DIR	4520	0	6907	0	6909	0			6908 AT RIVER	10
6908 NDIR	4520	0	6907	0	6909	0				
TURNS	(4520- 6907)	0	(4520- 6909)	0	(6909- 6907)	0	(6907- 6909)	0		
TURNS	(6907- 4520)	0	(6909- 4520)	0						

EXAMPLE OF LOADED NETWORK PRINTOUT

FIGURE D-5

volume on link 6900 - 6901 in both cases (i.e. where 6900 is listed as the A Node and also where 6901 is listed as the A Node).

In those cases where the link is one-way, the necessary (1 WAY) is printed after the B Node on the non-directional (NDIR) line.

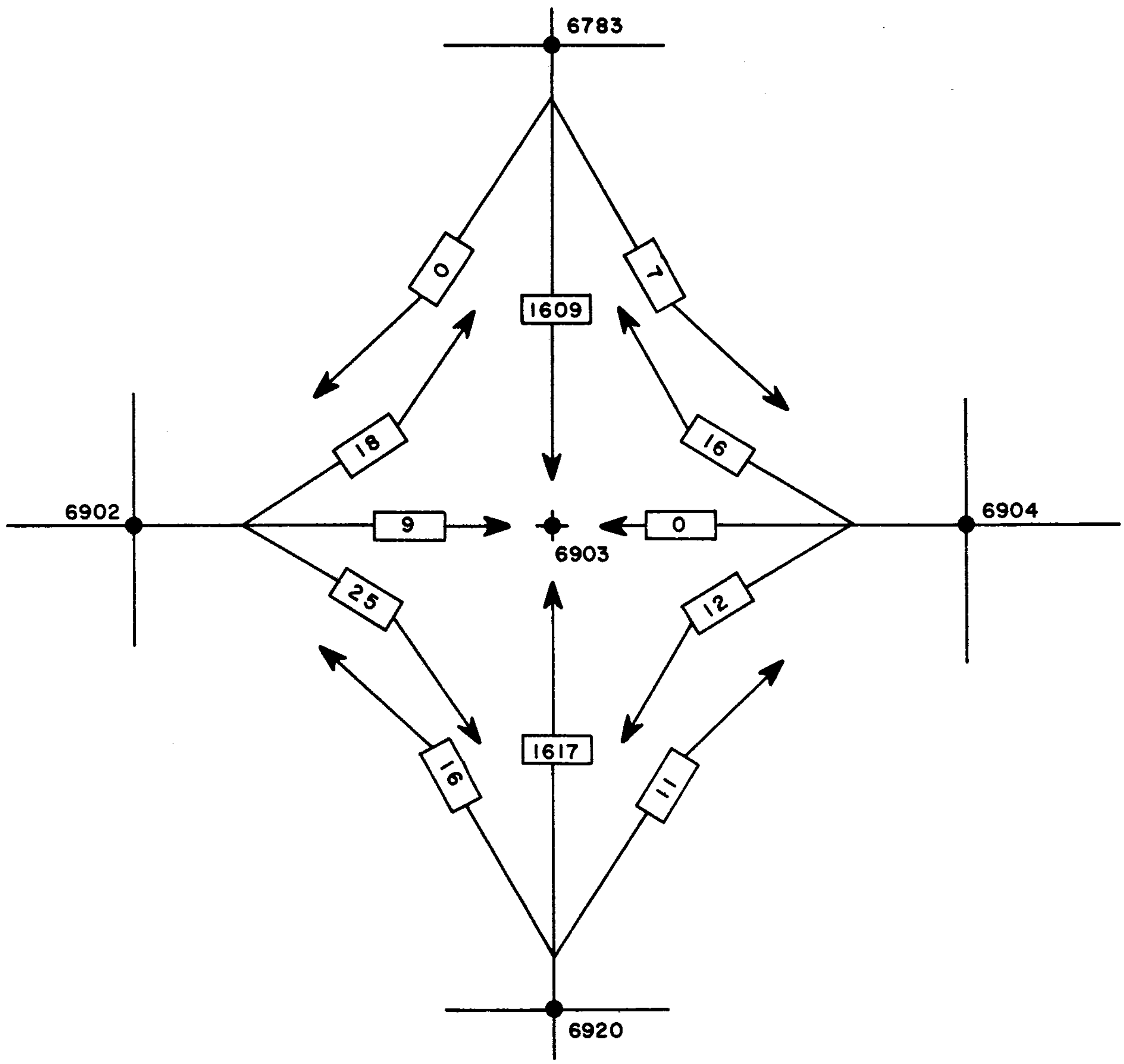
A NODE	B NODE	VOLUME	B NODE	VOLUME
6687 DIR	6673	10327	6671(1 WAY)	10370
6687 NDIR	6673 (1 WAY)	10327		
			6672(1 WAY)	10327
6688 DIR	6674	4744	(6674 - 6826)	879
6687 NDIR	6674	6911		
TURNS	(6668 - 6674)	1216		
TURNS	(6672 - 6674)	3528		

In cases where the one-way link is in the direction A Node to B Node the directional and non-directional assigned volumes are the same as may be seen for B Node 6673. When the one-way flow is in the direction B Node to A Node, there is no entry on the directional volume (DIR) line as may be seen for B Nodes 6671 and 6672.

Turn movements are given in the following format: The node number given as the A Node is the "pivot" node; the first node in the parenthesis is the "approach" node; and, the second node in the parenthesis is the "departure" node for the movement; the volume for that turn is given in the column labeled VOLUME. For example, using A NODE 6903 from Figure D-5; there are 16 vehicles that enter on link 6920 - 6903 and leave on link 6903 - 6902 or in other words make a left turn. Nine vehicles enter from node 6902, pass straight through 6903 to node 6904. These and all other movements at node 6903 are indicated on the sketch shown in Figure D-6.

Location information is provided under the caption NAME OF INTERSECTION at the right hand side of the printout of the loaded network (see Figure D-5). This information is coded in the link data cards; any convenient message may be used. In the example of Figure D-5, node 6900 has the following location information: 6900 AT CLEVELAND 10. This message indicates that the 6900 is on node map sheet number 10 and that the node is one of those defining the series of links labeled as Cleveland on the node map.

The Intersection Stringing program outputs the same information as described for the loaded network. However, the sequence of A Nodes is as specified by the analyst. This makes it possible to obtain an output in a more convenient form when working on a series of links of which the nodes are not sequentially numbered. An example of this output is shown in Figure D-7.



SKETCH SHOWING POSTED TURN VOLUMES

FIGURE D-6

WACO E-2 INTERSECTION STRINGING　　　　JUN 21, 1967

LINK VOLUMES

ANODE	B NODE	VOLUME	B NODE	VOLUME	B NODE	VOLUME	B NODE	VOLUME	NAME OF INTERSECTION
305 DIR	69	6714	154	12329	332	93639	481	85499	4
305 NDIR	69	13667	154	25316	332	186971	481	170408	
TURNS(	154- 69)	133	(332- 69)	5280	(69- 154)	181	(332- 154)	8152	
TURNS(	69- 332)	5885	(69- 481)	887	(332- 481)	79900	(481- 69)	1301	
TURNS(	481- 154)	3996	(154- 481)	4712	(154- 332)	8142	(481- 332)	79612	
332 DIR	50	3043	70	1871	305	93332	333	97212	4
332 NDIR	50	10083	70	3210	305	186971	333	190652	
TURNS(	70- 50)	48	(305- 50)	1509	(50- 70)	68	(305- 70)	551	
TURNS(	50- 305)	1339	(50- 333)	5633	(305- 333)	91579	(333- 50)	1486	
TURNS(	333- 70)	1252	(70- 333)	0	(70- 305)	1291	(333- 305)	90702	
333 DIR	332	93440	563	104337	564	12963			4
333 NDIR	332	190652	563	190545	564(1WAY)	12963	331(1WAY)	27320	
TURNS(	563- 332)	84414	(332- 563)	95266	(332- 564)	1946	(563- 564)	1794	
TURNS(	331- 332)	9026	(331- 563)	9071	(331- 564)	9223			
563 DIR	51	1389	333	86208	334	104166			4
563 NDIR	51	2516	333	190545	334	190465			
TURNS(	51- 333)	510	(51- 334)	617	(334- 333)	85698	(333- 334)	103549	
TURNS(	333- 51)	788	(334- 51)	601					
334 DIR	330	40572	335	87438	563	86299			
334 NDIR	330(1WAY)	40572	335	175456	563	190465	337(1WAY)	22125	
TURNS(	335- 330)	8197	(563- 330)	19606	(335- 563)	79821	(563- 335)	84560	
TURNS(	337- 330)	12769	(337- 335)	2878	(337- 563)	6478			
335 DIR	55	13706	61	29921	334	88018	375	92108	
335 NDIR	55	26677	61	58601	334	175456	375	186772	
TURNS(	61- 55)	1169	(334- 55)	6179	(55- 61)	630	(334- 61)	13752	
TURNS(	55- 334)	6876	(55- 375)	5465	(334- 375)	67507	(375- 55)	6358	
TURNS(	375- 61)	15539	(61- 375)	19136	(61- 334)	8375	(375- 334)	72767	
375 DIR	335	94664	373	107943	376	120146			
375 NDIR	335	186772	373(1WAY)	107943	376	236663	377(1WAY)	114128	
TURNS(	376- 335)	83266	(335- 373)	13311	(335- 376)	78797	(376- 373)	33251	
TURNS(	377- 335)	11398	(377- 373)	61381	(377- 376)	41349			
376 DIR	375	116517	378	44047	385	125969			
376 NDIR	375	236663	378(1WAY)	44047	385	241684	374(1WAY)	50672	
TURNS(	385- 375)	111216	(375- 378)	14400	(375- 385)	105746	(385- 378)	4499	
TURNS(	374- 375)	5301	(374- 378)	25148	(374- 385)	20223			
385 DIR	5	11356	65	1355	376	115715	577	122352	
385 NDIR	5	22326	65	3390	376	241684	577	234156	
TURNS(	65- 5)	0	(376- 5)	8128	(5- 65)	0	(376- 65)	0	
TURNS(	5- 376)	7477	(5- 577)	3493	(376- 577)	117841	(577- 5)	3228	
TURNS(	577- 65)	1355	(65- 577)	1018	(65- 376)	1017	(577- 376)	107221	
577 DIR	87	4305	385	111804	391	123235			4
577 NDIR	87	9155	385	234156	391	235377			
TURNS(	87- 385)	2187	(87- 391)	2663	(391- 385)	109617	(385- 391)	120572	
TURNS(	385- 87)	1780	(391- 87)	2525					

EXAMPLE OF PRINTOUT FROM INTERSECTION STRINGING PROGRAM

FIGURE D-7