F. C. BARNES

TRAFFIC ASSIGNMENT MANUAL

HISTORICAL REC

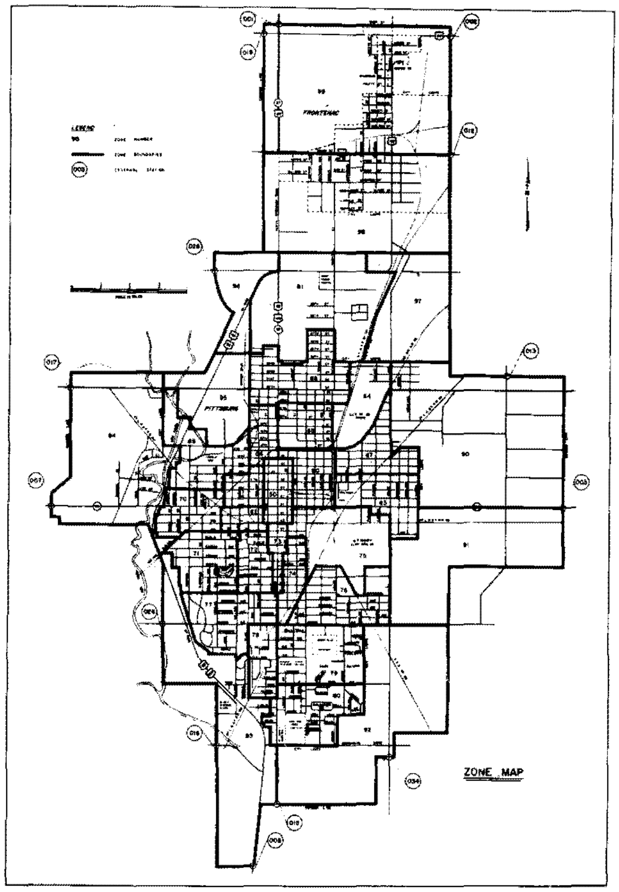
NODE A	NODE B	COUNT	CAPA																ND VOL
175	197	980	3000																568
197	175	980	3000	.08															736
175	198	2000	1500	.13	.52													15.9	444
198	175	2000	1500	.13	.52	15.0											16.9	15.9	297
176	177	1100	1500	.25	.75	20.0	208	23.0	20.5						21.4	60	23.0	21.7	97
177	176	1100	1500	.25	.75	20.0	192	23.0	20.5	60	23.0	21.1	60	23.0	21.4	60	23.0	21.7	93
177	178	1220	2000	.20	.48	25.0	1242	20.3	23.5	1536	15.5	20.6	1132	23.0	21.0	1108	23.0	21.4	1256
178	177	1225	2000	.20	.48	25.0	1300	20.3	23.5	1532	15.5	20.6	1140	23.0	21.0	1140	23.0	21.4	1278
178	179	1550	2000	.06	.14	25.0	1312	20.0	24.0	1592	15.6	21.1	1188	22.5	21.1	1160	24.0	21.1	1313
179	178	1550	2000	.06	.14	25.0	1376	20.0	24.0	1576	15.6	21.1	1184	22.5	21.1	1184	24.0	21.1	1330
178	208	1290	2000	.25	.75	20.0	92	23.0	20.5	60	23.0	21.1	60	23.0	21.4	60	23.0	21.7	68
208	178	1290	2000	.25	.75	20.0	80	23.0	20.5	72	23.0	21.1	72	23.0	21.4	68	23.0	21.7	73
179	185	1390	2000	.42	1.01	25.0	1064	24.0	24.7	1144	22.9	24.2	940	25.4	24.4	884	25.9	24.7	1008
185	179	1390	2000	.42	1.01	25.0	1084	24.0	24.7	1124	22.9	24.2	956	25.4	24.4	928	25.9	24.7	1023
180	181	1200	1000	.23	.92	15.0	200	17.2	15.5	220	17.2	15.8	208	17.2	16.2	220	17.2	16.4	212
181	180	1200	1000	.23	.92	15.0	252	17.2	15.5	212	17.2	15.8	212	17.2	16.2	200	17.2	16.4	219
181	205	1200	1000	.08	.32	15.0	200	17.1	15.4	220	17.1	16.0	208	17.1	16.0	220	17.1	16.0	212
205	181	1200	1000	.08	.32	15.0	40	17.1	15.4	52	17.1	16.0	52	17.1	16.0	40	17.1	16.0	46
182	183	1200	1000	.10	.40	15.0	764	10.9	13.6	384	16.2	14.2	436	15.7	14.6	436	15.7	15.0	505
183	182	1200	1000	.10	.40	15.0	640	10.9	13.6	404	16.2	14.2	404	15.7	14.6	432	15.7	15.0	470
182	204	12980	12900	.15	.60	15.0	1460	17.3	15.5	2494	17.3	15.7	2336	17.3	16.0	2208	17.3	16.3	2127
204	182	12980	12900	.15	.60	15.0	1280	17.3	15.5	2860	17.3	15.7	1976	17.3	16.0	1372	17.3	16.3	1872
182	205	1200	1000	.15	.60	15.0	312	16.6	15.2	284	17.3	15.7	284	14.5	15.5	312	15.0	15.2	298
205	182	1200	1000	.15	.60	15.0	416	16.6	15.2	60	17.3	15.7	792	14.5	15.5	688	15.0	15.2	489
183	184	1200	1000	.05	.20	15.0	568	15.0	15.0	624	12.5	14.2	632	13.0	13.6	676	12.0	13.0	625
184	183	1200	1000	.05	.20	15.0	440	15.0	15.0	640	12.5	14.2	596	13.0	13.6	656	12.0	13.0	583
184	207	940	2000	.16	.64	15.0	109	17.1	15.4	80	17.1	15.7	88	17.1	16.0	224	17.1	16.2	125
207	184	940	2000	.16	.64	15.0	168	17.1	15.4	196	17.1	15.7	196	17.1	16.0	224	17.1	16.2	196
186	308	9580	12900	.90	2.16	25.0	1372	28.7	25.8	1592	28.7	26.4	1204	28.7	27.0	1444	28.7	27.4	1403
308	186	9580	12900	.90	2.16	25.0	1152	28.7	25.8	980	28.7	26.4	980	28.7	27.0	980	28.7	27.4	1023
193	202	700	1500	.36	1.08	20.0	652	18.4	19.6	744	20.1	19.8	664	20.7	20.0	484	22.5	20.5	636
202	193	700	1500	.36	1.08	20.0	1052	18.4	19.6	724	20.1	19.6	704	20.7	20.0	432	22.5	20.5	728
218	311	300	3700	.90	1.33	36.0	568	41.3	37.2	568	41.3	38.0	540	41.3	38.7	540	41.3	39.3	554
311	218	300	3700	.90	1.33	36.0	540	41.3	37.2	540	41.3	38.0	540	41.3	38.7	540	41.3	39.3	540
[redacted]	170	2390	2000	.08	.32	15.0	936	17.1	15.4	704	17.1	16.0	708	17.1	16.0	708	17.1	16.0	765

[redacted]

U.S. DEPARTMENT OF COMMERCE
Bureau of Public Roads
Office of Planning
Urban Planning Division
June 1964

TRAFFIC ASSIGNMENT MANUAL

FOR APPLICATION WITH A LARGE, HIGH SPEED COMPUTER



U.S. DEPARTMENT OF COMMERCE
Bureau of Public Roads
Office of Planning
Urban Planning Division
June 1964

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402 - Price $1.50

04809

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

TRAFFIC ASSIGNMENT MANUAL

PREFACE	June 1964

Traffic assignment is one of the most important and complex phases of the transportation planning process. It provides the engineer with a systematic and reproducible technique that enables him to predict the probable traffic loads on each segment of a transportation network. The economic and operational impact of various system designs can be compared and evaluated and, after proper analysis, the results may be utilized to prescribe changes that would improve the system.

This manual documents in detail the complete process of traffic assignment as it is now defined. As automated traffic assignment techniques have only recently become available, the details involved in the various steps are continually being modified to incorporate the latest theories and techniques. Thus, it is expected that some of the descriptions that are presented in this initial writing will be changed even before it can be published. However, every attempt has been made to include the most up-to-date information available.

A companion manual was published by the Bureau of Public Roads in July 1963 --"Calibrating and Testing a Gravity Model for Any Size Urban Area." These manuals provide two basic elements needed for conducting the technical aspects of transportation planning analysis and forecasts.

This manual is divided into eight chapters, and an appendix. After the reader is introduced to the history of traffic assignment in chapter I, the general concepts of traffic assignment and the flow of data are discussed in chapter II. Chapter III is devoted to the step-by-step procedures that are involved in each phase of the process. One of the first illustrations is a block diagram or flow chart summarizing the steps in an assignment. The reader is referred to this diagram throughout the text to provide the necessary continuity. In addition, this chapter contains a sample problem which is also retained throughout the text.

Some of the data that are not strictly an integral part of the traffic assignment procedure, but which are important in the development of the planning process, are given in chapter IV. Chapter V is devoted to the theory involved in the assignment process. It is presented in a separate chapter so that the basic text will not be complicated by involved theory or explanation. Chapter VI is devoted to the detailed description of the operation of the computer programs in traffic assignment. The reader's attention is directed to chapter VII, Glossary of Traffic Assignment Terms, for an explanation of the many new terms and expressions used throughout the text. Chapter VIII contains a selected bibliography on traffic assignment.

The computer program writeups containing all the information necessary for operating the computer are described in an independent section (appendix) of the manual, and they are printed on a different color paper for easy access.

The computer programs that are described in the text are, with the exception of some peripheral IBM 1401/1410 routines, designed for use on the high speed binary IBM hardware such as the 709, 7090, and 7094. They were originally developed for the IBM 704 and, with a few exceptions, have been reprogramed for the newer equipment. The experience represented in this field by Public Roads establishes that the larger machines are definitely more economical to operate, and therefore the emphasis has been in designing for them.

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

TRAFFIC ASSIGNMENT MANUAL

TABLE OF CONTENTS	June 1964

Page

Page

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

TRAFFIC ASSIGNMENT MANUAL

CHAPTER I - INTRODUCTION	June 1964

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

The two inputs to the traffic assignment process are: 1) a complete description of the transportation system, and 2) a trip volume matrix of the interzonal traffic movements. With the techniques as they are outlined in this manual, the output of the process will be an estimate of the traffic volumes on each link of the system, by direction, complete with the directional turning movements at intersections.

A. History of Traffic Assignment

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

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

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

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

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

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

The most significant development in the field of traffic assignment came in 1957 with the presentation of two research papers. One was by Mr. E. F. Moore, titled "The Shortest Path Through a Maze" (56)[2], presented at the International Symposium on the Theory of Switching at Harvard University. The other was by Mr. George B. Dantzig, titled "The Shortest Route Problem" in Operations Research 5:270-3, 1957.

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

Mr. M. L. Schneider and others on Dr. Carroll's staff in Chicago further refined the "minimum path" techniques to the point where they were able to write a computer program for a large high-speed computer that would assign traffic to the existing and proposed street systems for the entire Chicago metropolitan area. The minimum path method differs from the previously mentioned diversion curve method of assignment because it assigns 100 percent of any particular interzonal movement to the minimum time path through the highway network. Today, this is called the "all-or-nothing" procedure of traffic assignment.

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

Independently, Dr. Albert Mayer and his staff of the Detroit Area Transportation Study began the development with a slightly different approach. The California State Division of Highways, having developed their assignment techniques before the Moore Algorithm,[1], now applied

---

[1] See Chapter V - Theory.

their unique diversion curve to the minimum path techniques in their version of the assignment program.

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

Thus, in its brief 7-year history, traffic assignment has been developed from a completely manual task to a highly automated, versatile, and powerful tool for transportation systems planning.

B. Purposes of Traffic Assignment

The purposes of traffic assignment may be listed as follows:

1. To determine the deficiencies in the existing transportation system by assigning the future trips to the existing system.

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

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

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

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

C. Advantages of this Procedure

The procedures and computer programs that are discussed in this manual offer some advantages over the other approaches to traffic assignment that are in use today. These techniques have been fully tested and complete documentation is available for each step and for each computer program. In addition, the Bureau of Public Roads offers a technical assistance program that will assist the user in performing the various operations during each of the steps. Unlike other traffic assignment procedures, the one presented in this manual permits the engineer the flexibility of performing each step as an individual procedure. This has the advantage of allowing for the various cross checks that are necessary during a traffic assignment, for the immediate recovery in case of an error, and to make adjustments between phases.

The techniques that have been used in the Chicago Area Transportation Study and others have the traffic assignment portion of the planning process incorporated with the traffic distribution procedures. Their procedures also differ in other respects, principally with the network loading operation. This can be a disadvantage, because after the traffic assignment process has been initiated on the computer, the entire process is not terminated until its completion.

The inputs and outputs to the various computer programs that are discussed in this text offer complete flexibility and compatibility with the computer programs which are available for the trip distribution process by either the gravity model method or Fratar analysis procedure. This logical flow of information between the various steps of the planning process is a unique advantage.

The computer programs that will be discussed were originally written for the IBM 704 computer. These programs have been revised for use on the IBM 709, IBM 7090, and the IBM 7094. Some traffic assignment programs are available for smaller computers, including the IBM 650, the IBM 1620, and the GE 225. The ability to handle larger transportation networks, the amount of flexibility permitted with the larger machines, and the savings in cost and time preclude the use of these slower machines for this particular phase of the transportation planning process.

The other techniques used to assign traffic to transportation systems and the use of computers other than the 700, 7000 series of IBM are discussed in other literature, (2) (5) (6) (7) (8) (12) (23) (28) (38) (39) (42) (43) (44) (45). [2]

---

[2] Numbers in parentheses identify the references listed in the Bibliography, chapter VIII.

TRAFFIC ASSIGNMENT MANUAL

A. Traffic Assignment in the Transportation Planning Process

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

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

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

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

Analysis of the assignment results, while not considered part of the process by some, is extremely important. Traffic assignment analysis should be designed and carried out with the following applications in mind: (1) establishing the validity of the assignment results;

(2) systematically producing workable data for evaluation (including economic evaluations, further general planning, design volumes); (3) permitting evaluations of internal system performance (identifying good and weak points in the system, delineating deficiencies, etc.); (4) establishing comparative evaluations with other parameters to aid in the planning and design toward an "optimum" system; and (5) permitting the evaluation and interpretation of results for use by highway engineers.

B. A General Description of the Procedure

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

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

The nodes are identified by 4-digit numbers. These numbers are applied systematically, and a complete record of all nodes and centroids is kept. 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 traveltime. The capacity of the link and the existing volume on the link may also be coded. Some other data are necessary if travel statistics are to be recorded by political jurisdictions within the study area, and if time penalties are to be applied, for turning movements.

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

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 traveltimes from the data stored in the memory. In effect, the network is remapped in the memory of the computer.

The selection of the quickest route from each zone to all others is the key to the assignment procedure. The minimum time-path is the shortest route from one centroid to another centroid. This route is determined by the computer. All minimum time-path routes from one centroid to all others are referred to as a "tree."

The computer, in selecting a minimum time-path, compares the traveltime between adjacent nodes and then sweeps successfully outward from the starting node until the quickest path to all nodes has been determined. The computer program is designed in such a way that the minimum time-path is obtained. At each node in the network, the computer records the traveltime back to the starting centroid and records the immediate previous node (called the back node) in the direction of travel to return to this centroid. Thus, the traveltime and the route between the starting node and all others are systematically recorded.

Next, with the zone-to-zone trips previously prepared and the minimum path route returned to its memory unit, the computer loads the trips on the individual route sections comprising the minimum path routes between the zones. After the trips have been assigned from one zone, the computer then selects the next zone and repeats the process. This is repeated until all of the trips from all of the centroids have been loaded on the route sections.

At this point it is possible to examine the loads on the sections by submitting the loaded network, which is now on magnetic tape, to another computer program which does some additional calculations and prints this information in a readable fashion.

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

In adjusting a network by capacity restraint, the capacity is part of the record stored in the computer memory. After the trips from all zones have been computed and added to the network, the computer calculates the ratio of the assigned volume to the capacity for each route section and adjusts the traveltime according to a predetermined relationship. This relationship says that the more the capacity of the link is used, the greater the traveltime becomes. Thus, the speed necessary to travel the route section is lowered much in the same way as increasing congestion causes speeds to be lowered in real situations. The use of capacity restraint to modify assigned traffic provides a more realistic distribution of traffic in the system It is impossible for one route to be heavily overloaded if its neighboring streets are lightly used.

The assignment procedure just described loaded all of the trips to the minimum time-path. A processing option has been made available which, instead of loading all of the trips to the quickest time-path, loads only a portion of the trips to the arterial system, and the remainder to freeway routes. This is called loading by "diversion." It simply means that two complete sets of "trees" are built for the study area, one including the freeways, and one without them. The traveltime is compared between the two trees and a traveltime ratio computed. A diversion curve previously established in the computer memory is then consulted with this time ratio, and the percentage of trips to be loaded to each tree is calculated. After the trips have been loaded on the network, the procedures are identical.

C. The Alternatives in Traffic Assignment

Some of the basic alternatives available in the procedure have already been discussed. A decision to assign traffic by the all-or-nothing procedure or the diversion procedure should be made early in the process. Similarly, as the input data requirements for a capacity restraint analysis are more involved than for a "free" assignment, this should also be considered during the early stages of preparation.

Sufficient information is given in this text so that the transportation planner will be able to distinguish the differences between the techniques (Section V - Theory). Some additional options are available within the procedure. The total daily traffic may be assigned, or any subdivision of 24 hours, such as the a.m. and p.m. peak periods. Traffic to or from a given area in a city, such as the central business district (CBD), may be assigned separately from the remainder of the volumes. Trips may also be assigned for any particular purpose or mode of travel. The traffic may be assigned directionally or nondirectionally, or it may be assigned directionally and combined for the two directions near the end of the procedure. The type of assignment that may be obtained is usually limited only by the input trip data and the amount of funds available for processing and analysis. Table II-1 summarizes the basic alternatives.

Table II-1

BASIC TRAFFIC ASSIGNMENT OPTIONS

---	ASSIGN BY THE ALL-OR-NOTHING OR DIVERSION TECHNIQUE	*
---	ASSIGN TOTAL DAILY TRAFFIC OR FOR ANY PERIOD OF THE DAY	***
---	ASSIGN BY UNRESTRAINED METHODS OR RESTRAIN THE ASSIGNMENT ACCORDING TO LINK CAPACITY	*
---	ASSIGN DIRECTIONALLY OR NONDIRECTIONALLY	**
---	ASSIGN BY VARIOUS CLASS OR TYPE OF TRIP	**
---	ASSIGN CERTAIN PORTIONS OF TOTAL TRIP INTERCHANGES	*
---	ASSIGN TRIPS OF ONLY A GIVEN TIME LENGTH INTERVAL	*

* - Program Option
** - Trip Data Input Option
*** - Trip Data and Network Input Option

Traffic assignments may be made to simulate present conditions or to represent the traffic in any future year. Current practice is to first make an average daily traffic assignment (ADT). The traffic assignments for other periods of the day are then obtained through the use of conversion factors that are determined during the origin and destination survey phase of a transportation study. Traffic may be assigned directly, however, for any period of the day. The assignment procedure and the network are generally tested for suitability by making assignments to the existing network using the origin and destination survey data. These results are compared with traffic volume counts also made during the survey.

D. Features of the Assignment Programs

Some of the unique features of the traffic assignment procedure that are discussed in detail later in this text are listed below.

1. Traffic is accumulated on the arterial street system in addition to assignment to the freeway-expressway network.

2. Turning movements may be obtained at all intersections or some specified group of intersections.

3. When the diversion method is used, the diversion ratio is computed between the points of route choice rather than between the origin and the destination.

4. The Bureau of Public Roads time-ratio curve is used in the diversion assignment program described in this manual. However, any traffic diversion curve (of one parameter) may be used.

5. A turn penalty can be applied for right and left turns (or through movements) to discourage a zigzag type of routing.

6. The minimum time routing between every origin and destination is obtained (unless certain options are prescribed).

7. The total vehicle-miles and vehicle-hours of travel are accumulated on each of the highway system components (arterials, freeways, local streets, and ramps) and for up to four political jurisdictions or sections of the study area.

8. The traffic may or may not be allowed to be routed through zone centroids.

9. A considerable increase in accuracy and consistency in results is achieved when compared to a manual assignment.

10. A savings in man-hours is obtained.

11. The program library concept with or without monitor control is available.

12. Any minimum time-path(s) may be built separately and printed for analysis.

13. Selected links in the network can be loaded separately. This feature is generally used after an assignment has been completed in situations where particular problems exist. For example, suppose that the assignment shows a particular section to be congested. The links in the congested area can be designated as selected links. The output is:

    a. An assignment to the entire network but only of the volumes that passed through the selected link(s).

    b. The origin, the destination, the link of entry, the link of exit, and the volume of every movement that passed through each selected link.

    There are many other uses such as the investigation of interchange spacing, weaving movements, etc.

14. After basic network descriptions and interzonal volume tables are established, card handling is limited to network modifications.

These procedures provide the engineer with a very flexible, systematic, and reproducible procedure for testing the suitability of future transportation networks.

E. Recommended Number and Types of Assignments

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

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

1. Existing trips to the existing network.

2. Future trips to the existing plus committed network.

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

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

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

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

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

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

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

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

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

F. Major Decisions

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

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

2. What will be the forecast year or years?

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

4. What is the availability of computer equipment?

5. Should the trip information be linked?

6. Should traffic zones or districts be used?

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

This chapter defines the step-by-step procedures that occur during a complete traffic assignment. The preparation of the input data is discussed as two phases. Phase one demonstrates the manipulation of the trip data that is required to put it into a format acceptable to the computer. It is assumed that the necessary screenline checks have been made, and the trip data are as accurate as possible. The second phase is devoted to the preparation of the network data so that the street and highway system may be properly described to the computer.

After a discussion of these two basic inputs, the detailed procedure for performing the traffic assignment will be discussed. In addition, the analysis and presentation of the results of the traffic assignment and the available diagnostic options will be illustrated in some detail.

A. Preparation of the Input Data

1. Preparation of the trip data (building a memory J).--The IBM 7090/7094 traffic assignment computer programs require that trip information be summarized into the total trips from each zone to all other zones in a predetermined binary format referred to as the "trip table" or "memory J." The trip information should be punched in tabulating cards using a standard format. Programs are available for processing and editing the internal trip record (#2) card, the external trip record (#3) card, and truck-taxi report (#4 and #5) card on the IBM 1401 if in the accompanying formats, figure III-1.

Alphabetic data is prohibited in the labeled columns, and blanks are permitted in only columns 51, 52, of the #2 card for non-auto drivers, and 36, 37, of the #3 card for non-thru trips. Occupants, where listed, include the driver; direction of travel codes are 1 for inbound and 2 for outbound; garage location codes are 1 for garaged in study area and 2 for garaged outside study area.

These standard utility programs are for operation on an IBM 1401 (8k storage) with modify address, sense switches, index registers, and two tape units. The input is expected to be in the form of 80-character records.

Card #2 - Internal trip report

Column	Contents
1	"2"
13-15	Residence
27-29	Origin
32-34	Destination
37	Mode
38-40	Start time
41-43	Arrive time
44	Purpose from
45	Purpose to
46-47	Land use, from
48-49	Land use, to
51	Occupation
52	Auto driver parking type
55-57	Trip factor (XX.X)

Card #3 - External trip report

Column	Contents
1	"3"
7-8	Station of interview
9	Direction
10-14	Serial number
17-18	Time of interview
19	Vehicle type
20-21	Number of occupants
22-24	Origin
27-29	Destination
32	Garage location
35	Trip purpose
36-37	Station of entrance/exit
51-53	Hourly trip factor (X.XX)
54-56	Daily trip factor (X.XX)

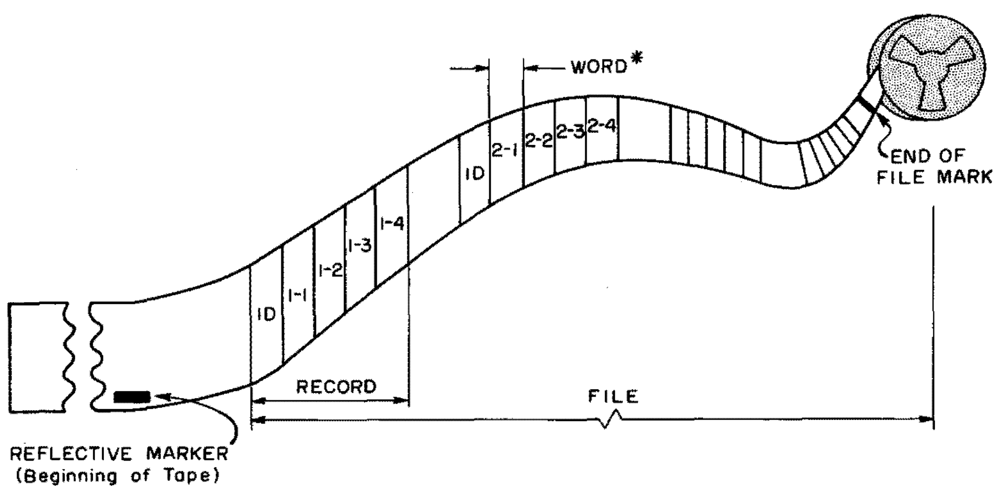
Card #4 (and #5) - Truck-taxi report

Column	Contents
1	"4" or "5"
5	Vehicle type
17-19	Origin
22-24	Destination
27-29	Start time
30-32	Arrive time
34-35	Land use, from
36-37	Land use, to
43-45	Trip factor (XX.X)

Figure III-1.--Suggested Standard Trip Data Input Card Format.

Program writeups and flow charts are available upon request from the Bureau of Public Roads. Columns not specifically labeled can be used for any information desired, e.g., the data outlined in the home interview manual. However, only the fields shown in figure III-1 are edited by the processing programs. The information concerning future trips and their distributions must, of course, be in the same format, but under ordinary circumstances the future trip data will come from sources other than the trip inventory cards. Forecasted trip information will be in the correct format for traffic assignment if either the gravity model or Fratar computer programs are used. These are described in other literature (58) (59).

The required format in the binary mode on magnetic tape for input to the traffic assignment is described in chapter VI, section D. Briefly, each record on the magnetic tape contains the trips from one centroid to all other centroids, or a square trip table. The first record contains the trips from centroid number 1 to all other centroids. The second contains the trips from centroid 2 to all others, etc. There will be as many records as there are centroids. The first word in the trip record is an identification word. This makes the length of the record N+1 words, where N is the total number of centroids. An illustration of the trip data as it appears on magnetic tape is shown in figure III-2.



SCHEMATIC DIAGRAM OF A 4-ZONE BINARY TRIP TABLE (MEM. J) ON MAGNETIC TAPE

*Each word contains the number of trips between the indicated centroids.

Figure III-2.--Trip table, as it appears in binary mode on magnetic tape.

Referring to the traffic assignment flow diagram for trip data (figure III-3), step 2 is the key punching of the trip information that has been previously recorded and coded on the interview forms using the standard format shown in figure III-1.

It is recommended that step 3, the transferring of the keypunched trip data cards to magentic tape, be executed next. Keep the various types of cards (#2, 3, 4, and 5) on separate tapes. These are written on tape with a standard card-to-tape computer program using the full 80-column reproduction.

Some of the recent transportation studies have preferred to delay the card-to-tape operation until some initial editing has been done on the trip data cards. It has been found, however, that the sorting and tabulating operations required to edit the information result in considerable damage to the cards and handicaps the later card-to-tape operation. All of the necessary contingency checks, edits, and summaries can be performed easily after the information is transferred to magnetic tape.

Step 4 in the building of the memory J is represented as one step on the flow diagram (figure III-3). This step, however, is a time-consuming and somewhat complex procedure. Some of the processes that occur in this step will depend on the techniques that are to be used in step 7, where the actual binary trip tables are produced. If the standard trip card format (figure III-1) is used, there are standard computer routines for performing some of the functions described in step 4, such as editing, recoding, reformatting, combining trips, etc. If the standard format is not used, individual computer routines must be written for performing these functions. There is a general edit routine written for the IBM 1401/1410 computer that is described in the gravity model manual (58). This routine does not perform all of the functions necessary in editing these trip data cards, but it will reformat the information and perform some edits with respect to limits on the various card fields. The process of linking the trip information is also discussed in the gravity model manual. Sorting programs for arranging the records in a low to high sort on the zone of origin are available as standard routines.

A brief discussion of each item included in step 4 follows.

a. Editing the data.--In performing contingency checks on the basic trip file, all of the information, or fields, that will be used in subsequent programs should be checked for illegal codes, illogical information, etc. If errors are found in the process, they are usually written on a separate tape, as instructed by the computer program, and printed for analysis. The trip cards that pass the edit test are written on another tape and retained for later use. The cards that contained errors should be corrected and then resubmitted to the edit routines. The procedure is repeated until all cards are free of errors.

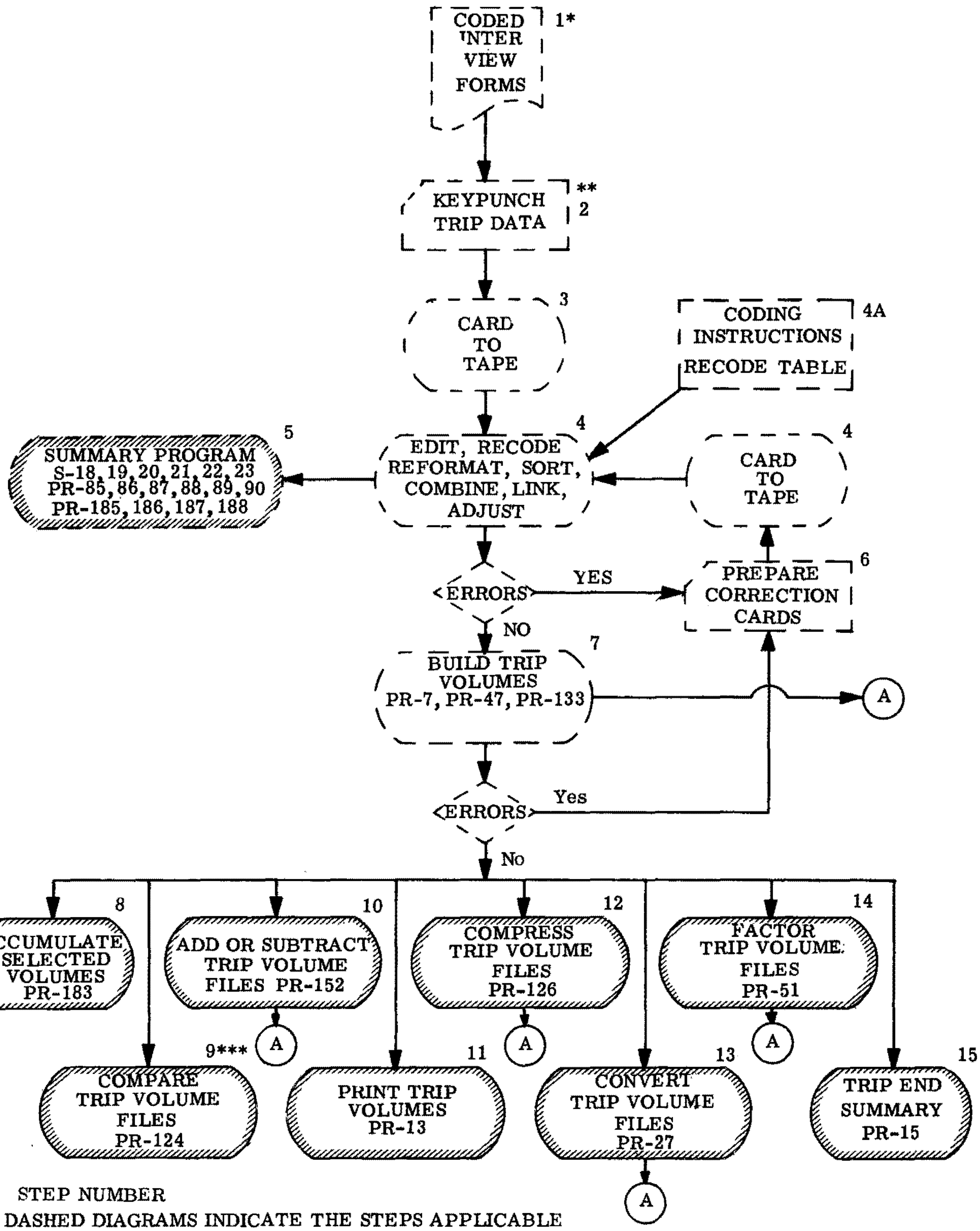
FIGURE III - 3

TRAFFIC ASSIGNMENT FLOW DIAGRAM

AS OF JUNE 1964

TRIP DATA

(BUILDING A MEMORY J)



* STEP NUMBER

** DASHED DIAGRAMS INDICATE THE STEPS APPLICABLE TO THE PROCESSING OF SURVEY YEAR DATA. SOLID DIAGRAMS REFER TO BOTH SURVEY AND FORECAST DATA.

*** SHADED DIAGRAMS INDICATE AN OPTIONAL PROCEDURE.

b. Recoding the origin and destination zones.--Step 4A may be omitted depending upon the computer program to be used in step 7. If necessary, the origin zone, the destination zone, and sometimes the zone of residence, must be recoded and replaced by the appropriate centroid number. This may be done by special routines that are tailored for the particular card type that has been used.

c. Reformatting the card files.--Reformatting is the shifting of the fields of information on the trip data card to new fields that are required in the next series of programs, if the standard format (figure III-1) is not used. (See chapter VI for the standard output format of trip data cards.) The IBM 7090/94 program, PR-133, does not require reformatting of the input data file. Program PR-47 expects to find the trip information in the standard format shown in chapter VI, and PR-7 requires the format shown in the program writeup in the Appendix.

d. Sorting.--All of the IBM 7090/7094 programs that are used in step 7 require the information to be in a low-to-high sort on the zone of origin or, in some special cases, on the zone of residence for home-based trips if the gravity model procedure is to be used.

e. Trip linking.--Linking is the process of combining those trips which have a "purpose to" or "purpose from" of either "change mode of travel" or "serve passenger" so that the relationship between the purpose of the trip and the ultimate destination of the trip is preserved. This process is described in the gravity model manual (58) in more detail. If trips are to be linked, this operation must occur prior to step 7 in the flow chart.

f. Other adjustments.--This includes the removal of the number 2 survey cards with external trip ends that are theoretically duplicated by the number 3 cards. This may also include the addition of a general purpose code if the use of the gravity model procedure is anticipated. It may also include blocking the trip file into 10, 20, or 50 card records that are required or are optional features on some of the later programs.

The flow chart indicates that some summary programs are available, if the trip card file is in the standard format as prescribed by the Bureau of Public Roads. These programs are not an integral part of the traffic assignment procedure and therefore will not be discussed in detail. Very briefly, they are written to summarize the trip files and produce listings of various types of trips by zone, land use, mode, type of parking, etc. They will also produce a table of trips in motion, which can be used to plot trips in motion by time of day.

As a result of performing the preceding operations, there is available a set of magnetic tapes with the basic trip information that is free of errors and in the prescribed format for further processing on the IBM 7090/7094.

The process of translating the survey data cards to the binary mode required by the traffic assignment process occurs in step #7. At present, there are three IBM 7090/7094 programs available to perform this function. Each program is different in its input requirements and the amount of output that can be produced in one pass on the computer. Regardless of the program that is used, the techniques are similar. Because of the time and cost involved in building trip tables, it is important that the data files be checked carefully to insure their satisfactory condition before using any of the trip table building programs.

Each program will be briefly discussed with regard to input and output in the following paragraphs. Detailed descriptions of each of these programs are included in the appendix and again in chapter VI.

Program PR-7.--This program converts the zone-to-zone trip data from summary cards to a binary tape in a format suitable for traffic assignment. (The step for obtaining summary cards is not portrayed in the flow diagram, figure III-3. There is no program available for summarizing trips; thus, this must be done using EAM equipment or by writing a special program for, say, an IBM 1401.) Since the input is a deck of summary cards, the program will not accept the detail trip cards. The program provides for only one card representing all the trips between two centroids. Three types of trip volumes may be coded on each card, and the computer is instructed, by sense switches, as to which trip table is to be built.

This program does not perform any edits on the input information, and if errors are encountered the program will print the error and halt. In addition, the origin zone and destination zone fields must contain the sequenced centroid numbers that are required for traffic assignment purposes, and not the original survey zone numbers (if the latter are in an unsequenced array). Cards in the prescribed format are transferred to tape as 80-column records, one card per record, in sort by origin zone number. Only one binary trip table is produced for each pass on the computer, and no options are provided.

Program PR-47.--This program prepares the binary trip tables from the standard output format (as shown in chapter VI) as prescribed by the Bureau of Public Roads. The input is in 10- or 20-card BCD tape records (eight words per trip card--48 columns) in sort by origin zone. By squeezing more cards into a record, the processing time is reduced and the number of input tapes required is minimized. There is essentially no limit to the number of input tapes that can be processed in one pass. All of the BCD trip records will be processed and will be included in the binary output unless the only available option is requested, which is to select only mode 1 on the detail cards. This program accepts detail cards, i.e., there may be more than one card for a given trip interchange between centroids. Only one binary trip table is written for each pass on the computer.

Program PR-133.--This program prepares up to six binary trip files from the O-D survey detail cards in one pass of the computer. It allows for complete variability of card format (and data content) and accepts the cards in blocked records of up to 50 cards per record. The program does require header and trailer records on each of the input reels (optional under the BELMN monitor). Through the use of criteria cards, the binary trip tapes may be written selecting almost any combination or category of trips. A BCD summary of trip ends is written for off-line printing. An example of this summary is shown in figure III-4.

NOTE: The reader is advised that before proceeding to build the input tapes with these programs or attempting to process the data, the program writeups should be thoroughly reviewed for the exact program requirement.

In step 7, program PR-133 performs some editing of the input data. If a card fails to pass the edits that are built into this program, it is written on tape to be printed off-line. Depending upon the type and number of these errors, their correction and resubmission to the program is at the discretion of the user. There has been a considerable investment of both time and money thus far to produce these binary trip files and, if only a few errors are encountered, they may be disregarded if desired.

Before proceeding with some of the manipulations that are possible with a binary trip file, it may be desirable to discuss some of the various types of traffic assignments that are dependent upon the characteristics of the trip information.

a. Peak hour or total daily.--The assignment procedure allows for the loading of 24-hour traffic (ADT) or peak period traffic. This alternative is essentially a function of the input trip data. If peak-hour loads are required, only those trips that occur during the peak hour are selected from the detail trip cards and loaded on the system. The transportation network, however, should reflect the network conditions which occur during this peak hour.

SUM INS OUTS AND INTRAS - SUMMARY OF TRIP ENDS -

(1) ZONE	(2) INS	(3) OUTS	(4) INTRAS	(5) TOTAL INS + OUTS (2)+(3)	(6) TOTAL TRIPS (4)+(5)	(7) TOTAL TRIP ENDS (4)+(6)
1	9,415	9,411	1,908	18,826	20,734	22,642
2	2,237	2,236	266	4,473	4,739	5,005
3	1,334	1,334	156	2,668	2,824	2,980
4	1,068	1,068	24	2,136	2,160	2,184
5	1,821	1,823	114	3,644	3,758	3,872
6	530	530	20	1,060	1,080	1,100
7	1,928	1,928	192	3,856	4,048	4,240
8	1,483	1,485	16	2,968	2,984	3,000
9	1,136	1,133	253	2,269	2,522	2,775
10	2,708	2,710	449	5,418	5,867	6,316
11	1,634	1,639	110	3,273	3,383	3,493
12	1,226	1,223	102	2,449	2,551	2,653
13	1,955	1,955	132	3,910	4,042	4,174
14	1,728	1,729	178	3,457	3,635	3,813
15	2,824	2,822	245	5,646	5,891	6,136
16	1,320	1,319	96	2,639	2,735	2,831
17	1,419	1,421	67	2,840	2,907	2,974
18	1,054	1,056	120	2,110	2,230	2,350
19	1,801	1,798	254	3,599	3,853	4,107
20	1,278	1,278	115	2,556	2,671	2,786
21	3,676	3,677	514	7,353	7,867	8,381
22	1,918	1,921	446	3,839	4,285	4,731
23	2,213	2,211	152	4,424	4,576	4,728
24	597	602	94	1,199	1,293	1,387
25	125	125	0	250	250	250
26	200	198	0	398	398	398
27	92	92	0	184	184	184
28	494	495	20	989	1,009	1,029
29	256	256	0	512	512	512
30	64	61	0	125	125	125
31	26	31	0	57	57	57
32	1,669	1,669	415	3,338	3,753	4,168
33	1,237	1,225	294	2,462	2,756	3,050
34	3,296	3,298	0	6,594	6,594	6,594
35	654	655	0	1,309	1,309	1,309
36	793	796	0	1,589	1,589	1,589
37	2,531	2,528	0	5,059	5,059	5,059
38	1,088	1,087	0	2,175	2,175	2,175
39	97	98	0	195	195	195
40	100	102	0	202	202	202
41	920	917	0	1,837	1,837	1,837
42	140	141	0	281	281	281
43	110	111	0	221	221	221
44	276	274	0	550	550	550
45	2	4	0	6	6	6
46	255	256	0	511	511	511
47	220	219	0	439	439	439
48	105	104	0	209	209	209
49	3	4	0	7	7	7
50	1	2	0	3	3	3
TOTAL	63,057	63,057	6,752	126,114	132,866	139,618

Figure III-4.--Trip end summary table.

The criteria for determining if a trip occurs during the peak hour has never been satisfactorily established. There have been several methods proposed. One method stipulates that if the midpoint time of the trip falls within the peak hour, it is to be selected. Another states that if the time of arrival at the nonhome end of the trip falls during the peak hour it is to be selected. Some engineers prefer to assign the peak 2-hour movements and manually factor the assignment to represent the peak hour. They contend that the peak 2-hour period is more stable. These decisions concerning peak hour traffic assignments are left to the user's judgment.

b. Directional or nondirectional.--A directional or nondirectional assignment is again an option that is dependent upon the input trip data. By a directional assignment, loads are obtained on each link in the system for each direction of travel. A nondirectional traffic assignment gives only the total load on each link regardless of the direction. If a "square" trip table (one which has trips from each zone to every other zone) is available, then either a directional or nondirectional assignment may be obtained. If a triangular table (one which has trips from each zone to only higher numbered zones) is available, only a nondirectional assignment may be produced. The advantage of a directional assignment is that directional turning movements are calculated at ramps and intersections and a directional split is automatically obtained. A peak-hour directional assignment, properly restrained, provides information that may be used directly by the highway designer. Square trip tables may be converted to triangular trip tables through the use of program PR-27.

Many IBM 7090/7094 computer programs have been written to manipulate these binary trip tables (memory J's) or to produce summary tabulations of trips in a readable fashion. The trip volumes may be accumulated, compared, added or subtracted, compressed, converted, factored, or printed. The next few paragraphs will contain brief descriptions of the options that are now available for manipulating the binary trip files. These are illustrated as steps 8 through 15 on the flow diagram (figure III-3).

Program PR-183 (Accumulate selected interzonal volumes).--This IBM 7090/7094 computer program is used to accumulate and print selected interzonal interchanges from the binary trip file. For instance, the program may be instructed to select and print the number of trips from centroids 317-400 to centroids 290-300. This program is especially useful in determining the total number of trips across a screenline, or to the CBD from each corridor.

Program PR-124 (Trip comparison program).--This IBM 7090/7094 computer program is used to compare the interzonal movements of two binary memory J's, or two loaded networks. The program prints a table of differences for each interzonal movement between the two binary trip files and then, if elected by the program user, produces the "difference" statistics by up to 16 volume groups and by 32 difference groups. The mean difference, the standard deviation, the sum of squares of the differences, and the number of trips for each trip file are given for each volume group. This program has traditionally been used to compare synthetic trip distributions with the survey trip volumes. Sample outputs are shown as figures III-5 and III-6.

Program PR-152 (Add or subtract trip volumes).--This IBM 7090/7094 computer program will add separate trip files and produce a new binary memory J with the results of the addition. It will subtract two trip tapes and produce a new trip file with the results of the subtraction. If the subtraction results in a negative number of trips, the answer is automatically set to zero. This program is frequently used to produce loadable trip files that are combinations of trip purposes or modes which have been built independently. The binary trip tables to be added or subtracted must have an equal number of centroids.

Program PR-26 (Trip table reduction program).--This IBM 7090/7094 computer program reads the file of binary trip volumes of N1 zones and reduces or expands them to a file of N2 zones. Any number of centroids may be combined for the new file if they are in a continuous sequence. This program has been used to compress a trip file that is on a zone basis to a new file on a district basis. It may be advisable to use this program prior to the use of program PR-124 to reduce the amount of BCD output from that program.

Program PR-27 (Trip conversion program).--This IBM 7090/7094 computer program will produce a new trip volume file which is the result of a two-day multiplication of the original trip file. The resulting matrix may be thought of as being obtained by taking two matrices identical with the original, the elements of which are some fixed percentage (say 60-40) of the element of the original. One of these matrices is then rotated through 180 degrees and superimposed on the other. The new matrix then is the result of adding together the corresponding elements of each of these matrices. This program is usually used to "square up" the trip tables that are produced by the gravity model program or, conversely, to make a square trip table triangular.

ZONE	ZONE	O-D VOLUME	G-M VOLUME	DIFFERENCE
1	1	494	654	160
1	2	69	85	16
1	3	380	444	64
1	4	78	70	-8
1	5	102	122	20
1	6	194	267	73
1	7	82	98	16
1	8	13	18	5
1	9	33	40	7
1	10	30	37	7
1	11	78	102	24
1	12	41	39	-2
1	13	39	30	-9
1	14	29	26	-3
1	15	37	34	-3
1	16	17	13	-4
1	17	8	4	-4
1	18	15	10	-5
1	19	43	37	-6
1	20	43	54	11
1	21	49	40	-9
1	22	106	95	-11
1	23	21	11	-10
1	24	59	37	-22
1	25	29	25	-4
1	26	42	33	-9
1	27	23	25	2
1	28	12	9	-3
1	29	46	58	12
1	30	27	28	1
1	31	32	39	7
1	32	69	61	-8
1	33	40	34	-6
1	34	31	30	-1
1	35	36	28	-8
1	36	27	23	-4
1	37	17	17	0
1	38	22	13	-9
1	39	59	66	7
1	40	46	74	28
1	41	37	44	7
1	42	72	85	13
1	43	38	28	-10
1	44	69	72	3
1	45	28	21	-7
1	46	6	3	-3

Figure III-5.--Sample output, PR-124 (Table 1).

TABLE 2 - FREQUENCY DISTRIBUTION AND ANALYSIS OF DIFFERENCES
VOLUME GROUP 200 TO 299

DIFFERENCE	FREQUENCY	SUM OF DIFFERENCES
-10000 AND UNDER	0	0
-7000 TO -9999	0	0
-5000 TO -6999	0	0
-4000 TO -4999	0	0
-3000 TO -3999	0	0
-2000 TO -2999	0	0
-1000 TO -1999	0	0
-800 TO -999	0	0
-600 TO -799	0	0
-500 TO -599	0	0
-400 TO -499	0	0
-300 TO -399	0	0
-200 TO -299	0	0
-100 TO -199	2	-242
-50 TO -99	17	-1,156
0 TO -49	56	-1,106
0 TO 49	42	718
50 TO 99	15	1,144
100 TO 199	5	630
200 TO 299	2	412
300 TO 399	0	0
400 TO 499	0	0
500 TO 599	0	0
600 TO 799	0	0
800 TO 999	0	0
1000 TO 1999	0	0
2000 TO 2999	0	0
3000 TO 3999	0	0
4000 TO 4999	0	0
5000 TO 6999	0	0
7000 TO 9999	0	0
10000 AND OVER	0	0
------	------	------
TOTALS	139	400

MEAN DIFFERENCE = 3

STANDARD DEVIATION = 54

SUM OF SQUARES = 420,262

TOTAL O.D. TRIPS = 34,063

TOTAL G.M. TRIPS = 34,463

Figure III-6.--Sample output, PR-124 (Table 2).

Program PR-13 (Print trip volumes).--This IBM 7090/7094 computer program produces a complete formatted trip table or tables for selected zones or for all zones in BCD suitable for printing off-line. A sample of the output is shown as figure III-7. The use of this program may be expensive, and it may yield very large outputs.

TRIPS FROM ZONE 1 TO ALL ZONES

Zone	0	1	2	3	4	5	6	7	8	9
00	-	178	81	282	78	93	142	108	68	56
10	182	227	148	73	112	330	60	---	47	90
20	213	274	289	50	110	171	270	16	--	76
30	69	127	205	55	178	19	107	49	--	154
40	154	144	211	33	140	96	---	--	78	104
50	64	78	72	12	16	--	59	13	40	--
60	29	--	12	30	147	4	327	228	207	255
70	21	120	204	188	--	347	382	32	403	310
80	924	28	400	538	90					

Figure III-7.--Sample output of PR-13 (Print trip volumes).

Program PR-51 (Factor trip volumes).--This IBM 7090/7094 computer program will factor individual entries in the binary trip table by: (a) multiplying by a constant, (b) substituting a constant, (c) adding a constant, and (d) subtracting a constant. It will produce a new binary trip table from the result. This program also permits the blocking of origins and destinations, which considerably reduces the number of input criteria cards. As an example, this program may be used to factor a total auto person trip file according to the car occupancy factors by zone.

Program PR-15 (Sum ins, outs, and intras).--This IBM 7090/7094 computer program produces a BCD summary of trip ends giving the total trips in, trips out, intrazonal trips, total trips, total trip ends, and total ins and outs for each zone, printing off-line. The output of this program was illustrated in figure III-4.

The binary output from programs PR-26, 27, 51, and 152 are in the proper format for the traffic assignment process. The length of the records on the binary tape (the number of centroids plus 1) must be compatible with the network description that is to be discussed in the next section. In each of the programs the input data are never destroyed. They are simply read by the computer which, in turn, produces a new tape file.

For traffic assignments of the forecast year, the binary trip files are produced automatically by the companion programs of the gravity model or Fratar forecast program (58) (59). If these two procedures are not utilized in the forecasting process, the binary trip files may be built by any of the programs that were discussed in step #7.

2. Preparation of the network.--Throughout the remainder of this section the reader is referred to another flow diagram (figure III-8) which illustrates the flow of information for network preparation, adjustments, loading, and analysis. When possible, the step numbers indicated in the text will refer to the corresponding steps labeled on the flow charts. The reader is advised that by continually referring to the main flow diagram the continuity of the procedures will be maintained.

a. Review of inventories and summaries.--An inventory of the existing street and highway network is one of the first studies to be undertaken in the comprehensive planning process. The results of this inventory provide the information for defining the street and highway system to the computer. The information that is required for each link used in the traffic assignment highway system is: the link speed or traveltime, the link distance, the existing traffic volume, and the practical capacity. These are indicated in step 1 of the flow diagram. Each item will be discussed individually in the following paragraphs.

1. Map preparation.--Two base maps are required to define the existing street and highway system. A map showing the traffic survey zones and their numbers must be available to locate the zone centroids. Appropriately scaled street and highway maps must also be available. It is desirable, but not necessary, that the zone maps and the street and highway maps be of the same scale. The zone map for the sample network is shown as figure III-9. The base map is shown later as figure III-11.

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

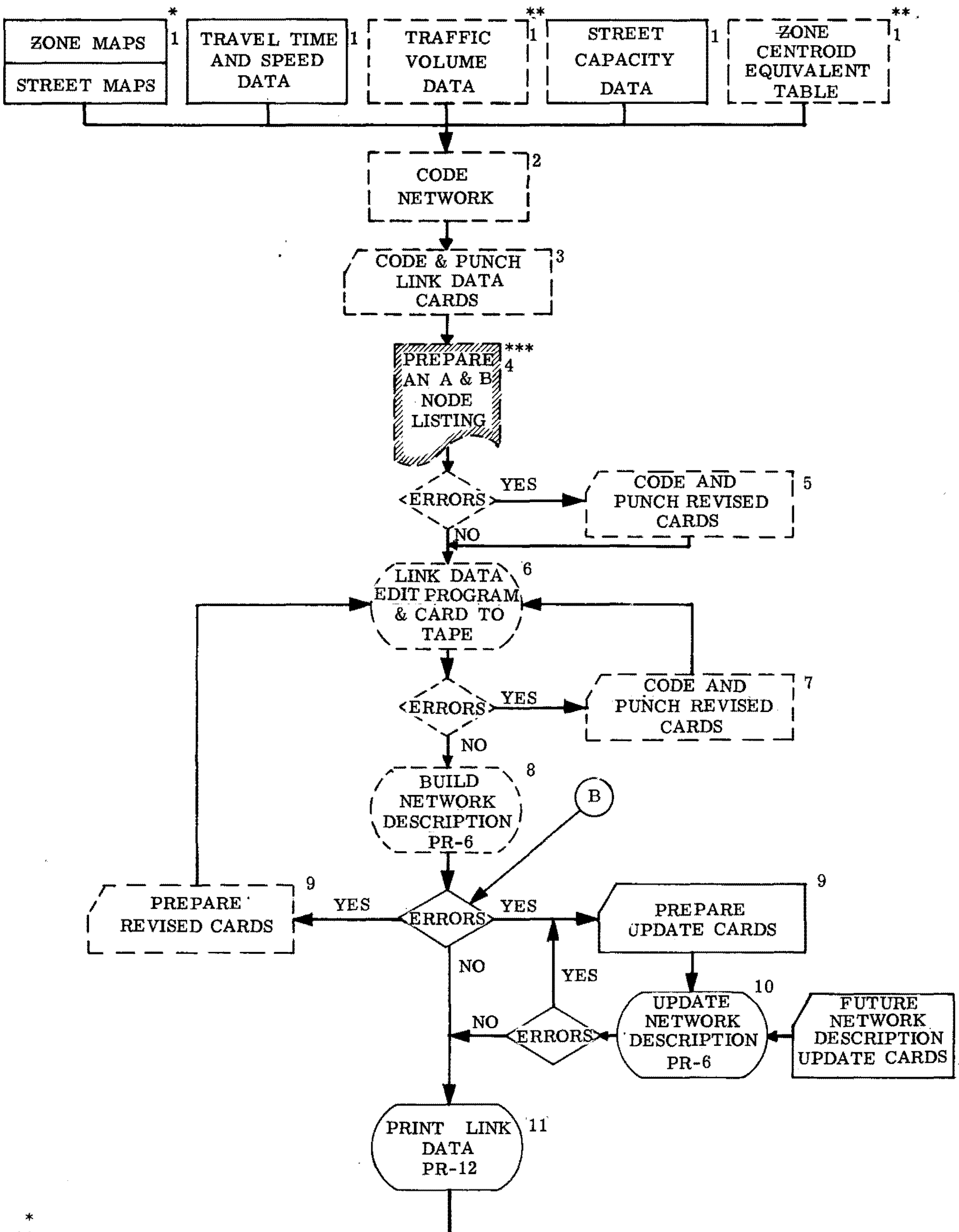
As in Washington, several maps may be used for defining the street and highway network. In this case, match lines between the maps are mandatory. The physical size of the map is usually limited to the

FIGURE III - 8

TRAFFIC ASSIGNMENT FLOW DIAGRAM

AS OF JUNE 1964

NETWORK PREPARATION, ADJUSTMENT, LOADING AND ANALYSIS



*
** SAME NOTE AS ON PAGE III-5
***

FIGURE III - 8 (CONT'D)

NETWORK DATA (CONT'D)

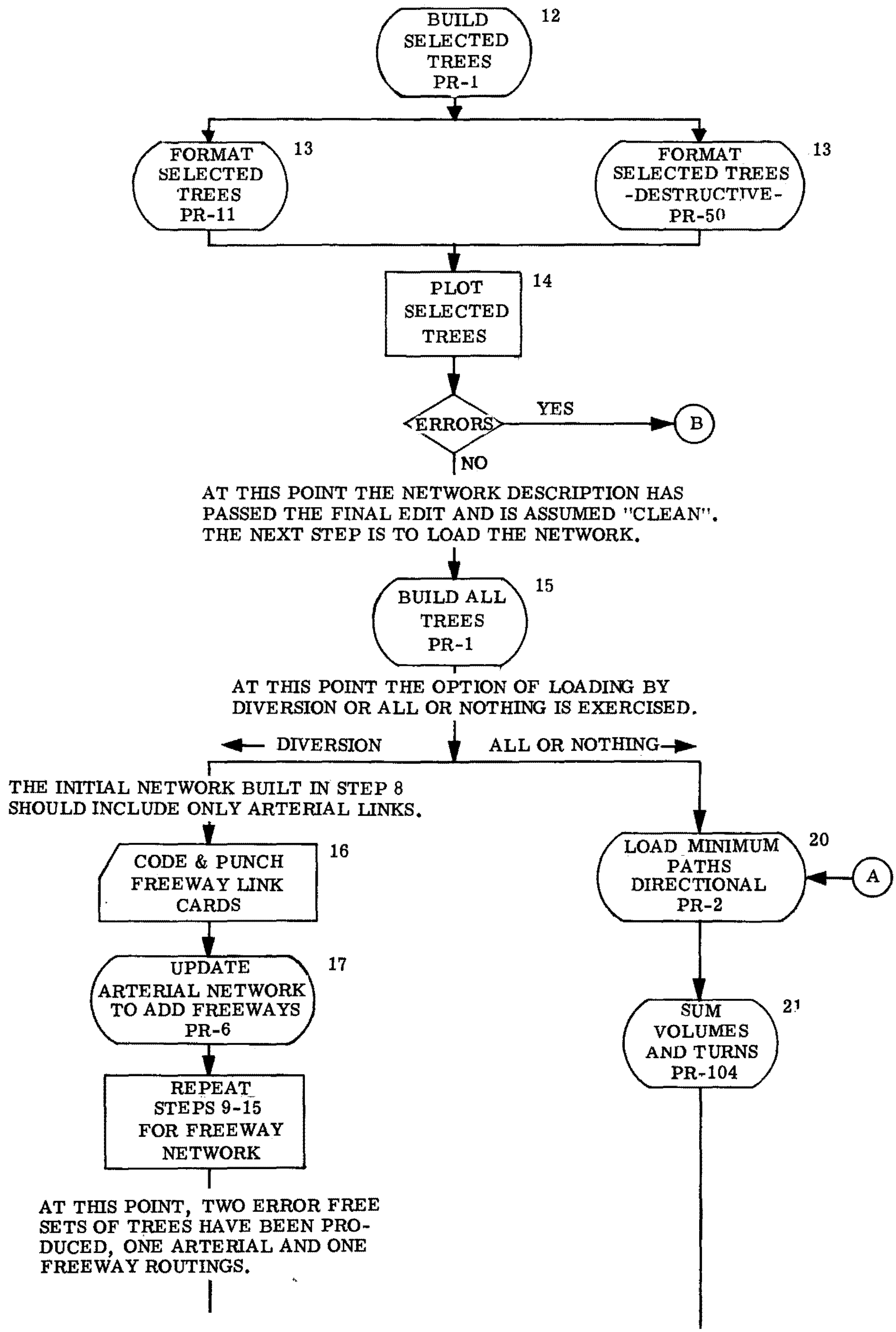
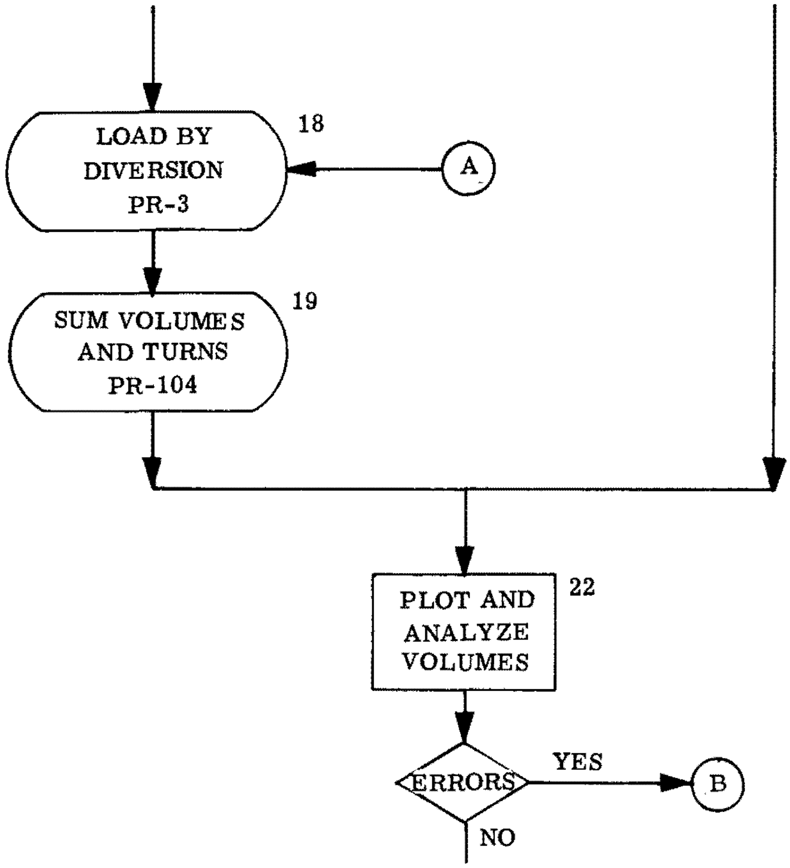


FIGURE III - 8 (CONT'D)

NETWORK DATA (CONT'D)



AT THIS POINT A "DESIRE TYPE" LOADING HAS BEEN PRODUCED IF THE NETWORK IS FREE OF ERRORS. TO CALIBRATE OR ADJUST THE NETWORK, THE OPTION OF AUTOMATIC OR MANUAL RESTRAINTS IS NOW EXERCISED.

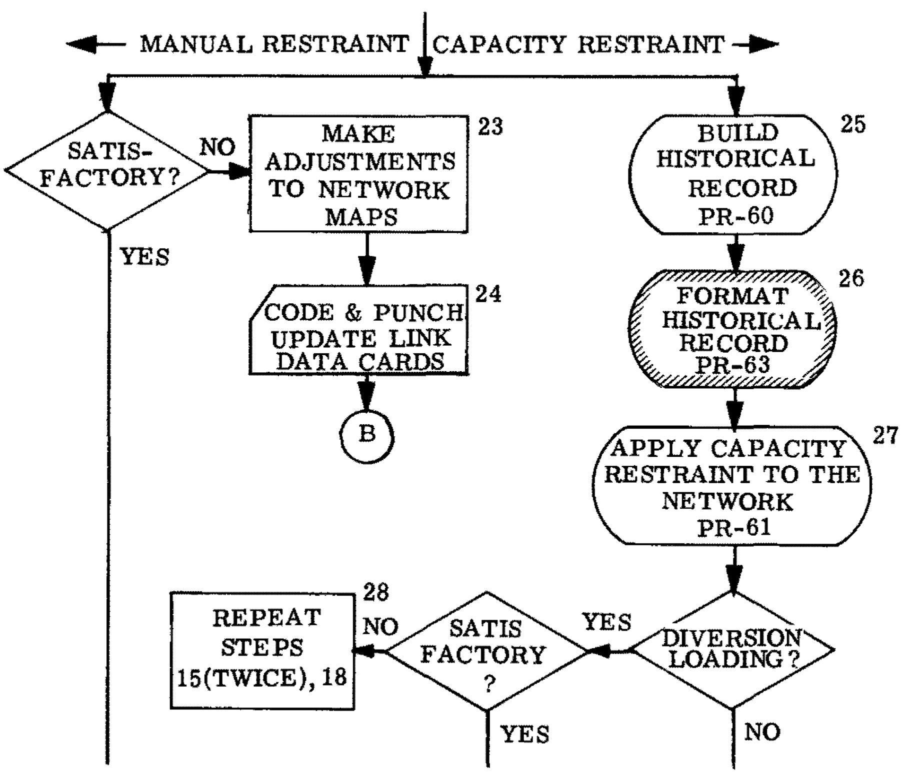
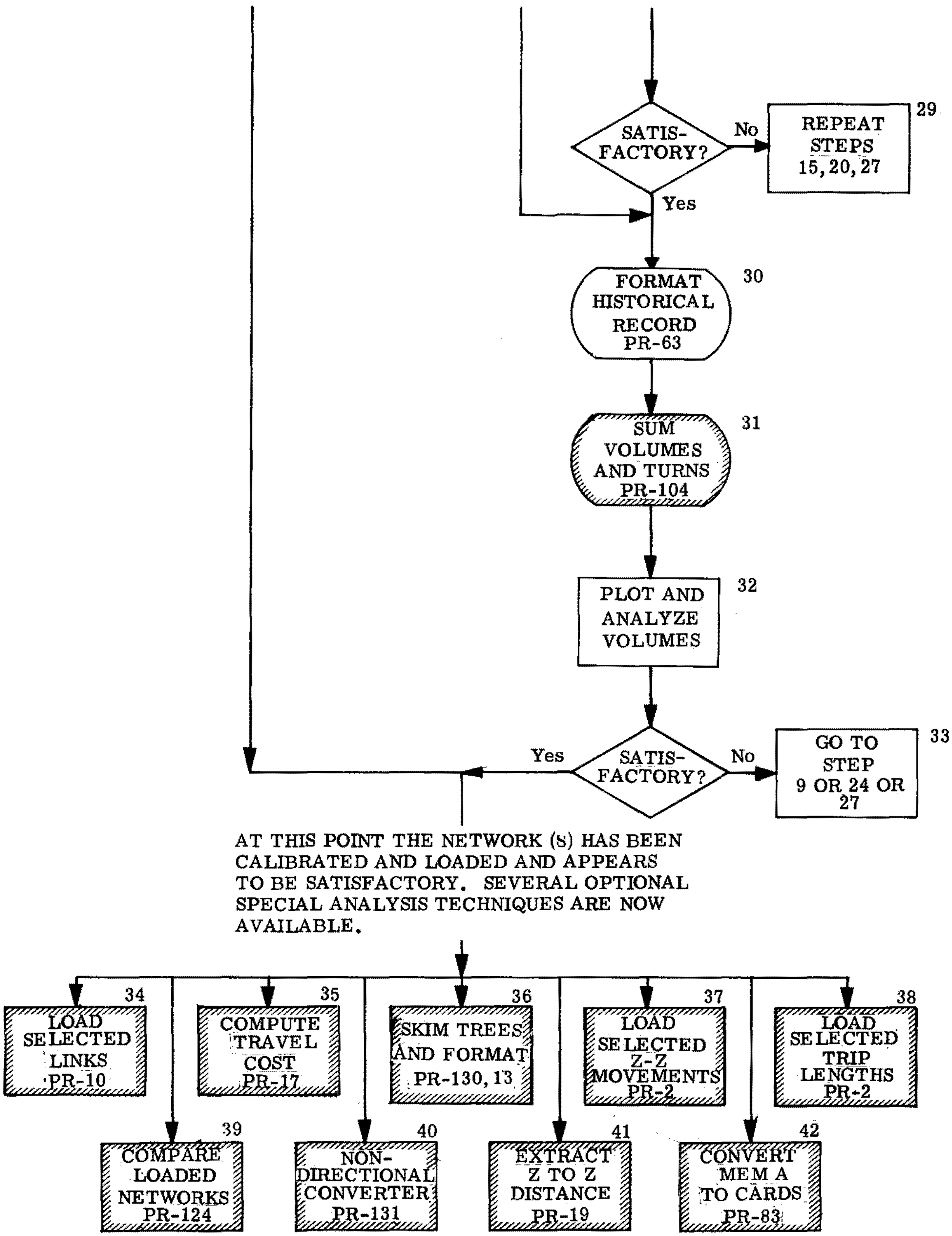


FIGURE III - 8 (CONT'D)

NETWORK DATA (CONT'D)



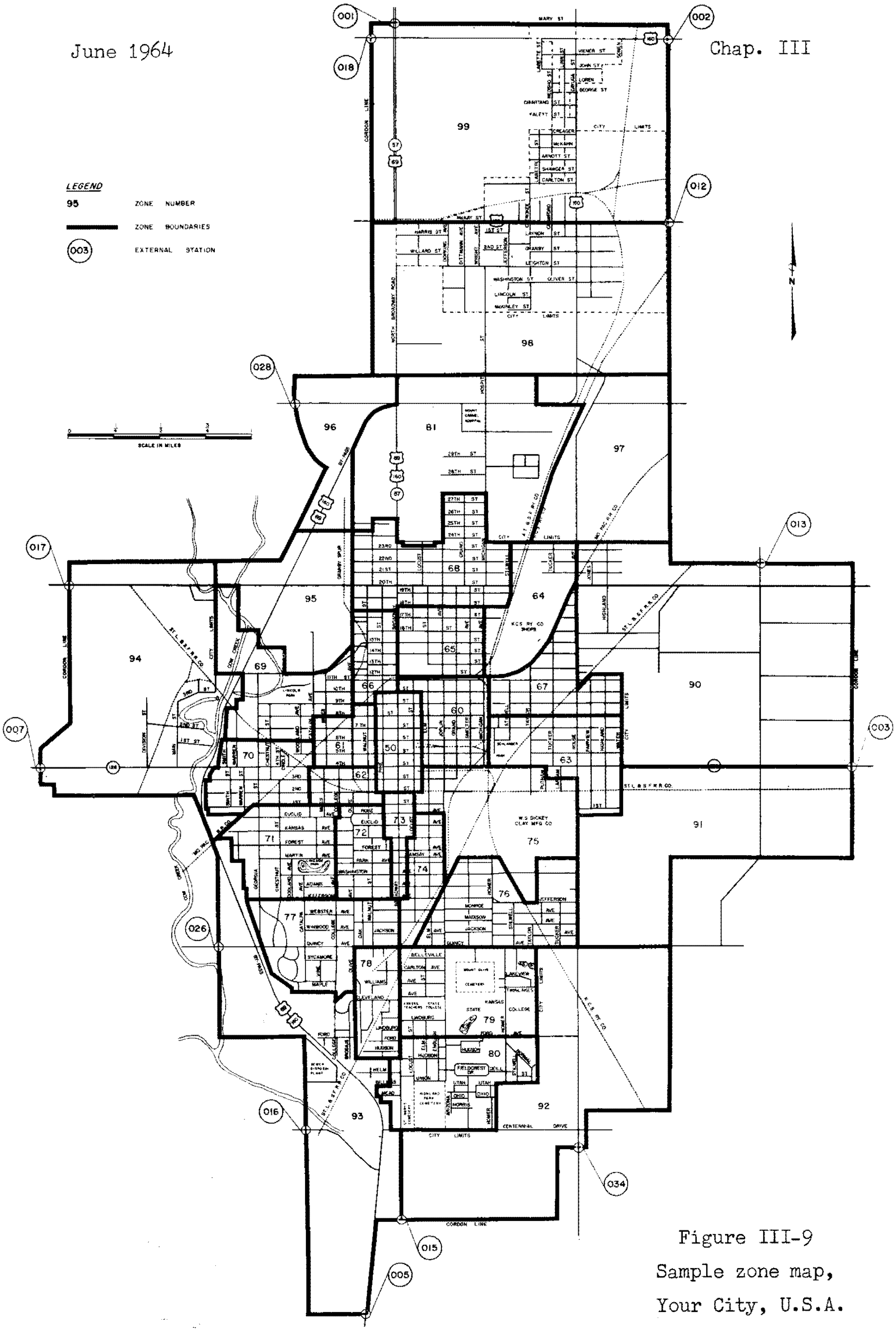


Figure III-9
Sample zone map,
Your City, U.S.A.

size of the reproducing equipment. A map larger than 4' x 5', however, may prove to be too cumbersome for efficient use. It may be advisable to obtain reproducible copies of these base maps on Cronar film. These are the master tracings from which the prints are made that are later used as worksheets during the analysis of assignments.

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

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

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

In large transportation studies it may be impossible to obtain the speed or traveltime on every link in the network. Typical values of speed or time obtained for the major links may be used on links having similar uses and characteristics when it is not feasible to collect these data in the field. However, caution must be used when resorting to this procedure, since the accuracy of the assignment process is dependent upon these values. Methods for measuring these parameters are given in other literature (17) (19) (48) (51) (52).

3. Traffic volume data.--The total traffic volume (either directional or nondirectional) on as many streets and highways as possible, except the local streets, should be obtained during the survey. Although this information is not considered an integral part of the network description, it does permit the evaluation of the results of an initial traffic assignment. The capacity restraint program adjusts volumes by changing link traveltimes on the system. It also compares the measured with the assigned volumes for each link having this information coded. If directional volumes are coded for the links, then directional capacity should also be coded. Likewise, if non-directional (total two-way) volumes are coded, total capacity should also be coded. See the section on link data card preparation, page III-36 for more detail on coding these values.

4. Street capacity data.--Data concerning the practical capacity of each link in the street and highway network are mandatory if the capacity restraint option is to be utilized. The inventory of the physical characteristics of the network should record such information as curb-to-curb width, parking regulations, and the type of control devices including the signal timings. The amount of information that is required to compute the capacity and the techniques for the calculations are prescribed in other literature (9) (10) (11) (22) (29) (34).

5. Zone centroid equivalent table.--The traffic assignment process requires the survey zone numbers to be renumbered in a continuous unbroken sequence beginning with number 1, if the zones were not numbered this way originally. The survey zone numbers are arrayed in a low to high order, placing the external stations on the high order end of the list. A listing is then prepared which is called the "zone centroid equivalent table." (See table III-1.) The listing shows the array of survey zone numbers and the corresponding centroid numbers arranged in their low to high unbroken sequence.

Table III-1.--Sample zone centroid equivalent table

Your City, U.S.A.

Internal survey zone	Centroid	Internal survey zone	Centroid	External station number	Centroid
50	1	76	18	001	34
60	2	77	19	002	35
61	3	78	20	003	36
62	4	79	21	005	37
63	5	80	22	007	38
64	6	81	23	012	39
65	7	90	24	013	40
66	8	91	25	015	41
67	9	92	26	016	42
68	10	93	27	017	43
69	11	94	28	018	44
70	12	95	29	024	45
71	13	96	30	026	46
72	14	97	31	028	47
73	15	98	32	034	48
74	16	99	33	038	49
75	17			048	50

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

The speeds to use on different categories of facilities may be determined on the basis of the desired highway or street capacity standards. The desired capacity on a particular facility is dependent upon the "level of service" to be rendered by that facility. For a more detailed discussion of the "level of service" concept, refer to the revised edition of the Highway Capacity Manual (presented at January 1964 Highway Research Board meeting). Based on a desired level of service and the corresponding highway or street capacity, the speed on a certain type of proposed facility may be determined. Speeds may be obtained for freeways, expressways, arterials, collectors, and locals which are located in the CBD, intermediate, suburban, and rural areas. Thus, a table may be set up which will allow easy coding of speed onto the proposed network links. Table III-2 illustrates the arrangement of such a table.

Table III-2.--Sample table of average running speeds to be used on future traffic network. Speeds, in MPH, are based on design capacity at level of service "C"[1]

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

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

The speeds recorded in the sample table III-2 have been determined for one particular level of service. There are six levels of service which have been defined by the Committee on Highway Capacity, Highway Research Board. A definition of these levels of service will be forthcoming in a revised edition of the Highway Capacity Manual. Each city or study must determine its own desired level of service standards, and develop a table of speeds based on the capacities corresponding to that level of service.

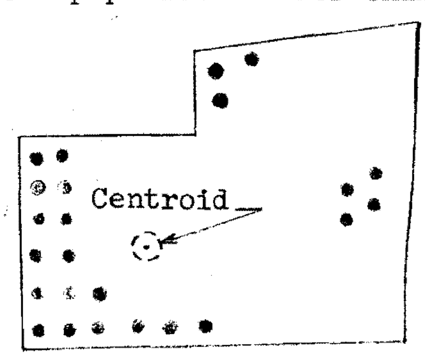
The traffic volume data should be recorded on the base maps along with the practical capacity of each link. With these data, the process of describing the network to the computer may begin.

b. Preparation of the network description map(s).--Step 2 in the flow diagram (figure III-8) for network preparation is the coding of the network. It is suggested that the various items be coded in the following order:

(1) Locate and number the centroids
(2) Define the basic transportation network
(3) Connect the centroids to the arterial street system
(4) Locate and define the nodes
(5) Prepare a node table
(6) Number the nodes
(7) Code the turn penalties (signs and flags)
(8) Code the turn prohibitors
(9) Define the link parameters

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

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



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

For mixed land use zones, such as residential and commercial, the location of the centroid is determined to a large extent by judgment.

On the copies of the zone maps that were previously prepared, the centroid of each zone is located and marked by a circle. There is one centroid for each survey zone and external station. They are numbered in a consecutive unbroken sequence beginning with number 1.

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

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

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

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

Each facility that is selected for use in the network is traced from the base map on the overlay that contains the centroid locations. There should be no dead-end links in the system. Refer to the sample network (figure III-10) and the base map (figure III-11).

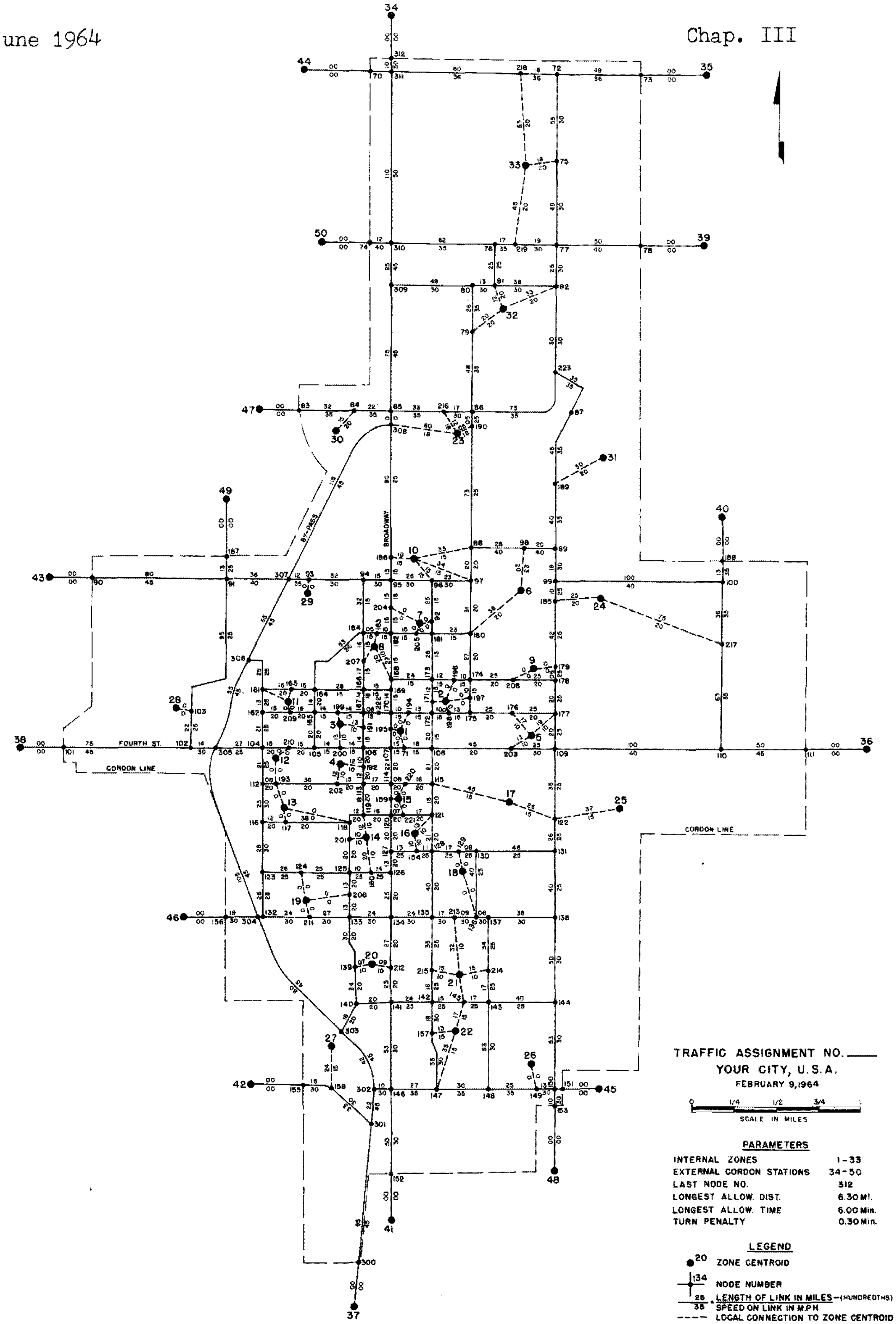


Figure III-10.--Sample network map, Your City, U.S.A.

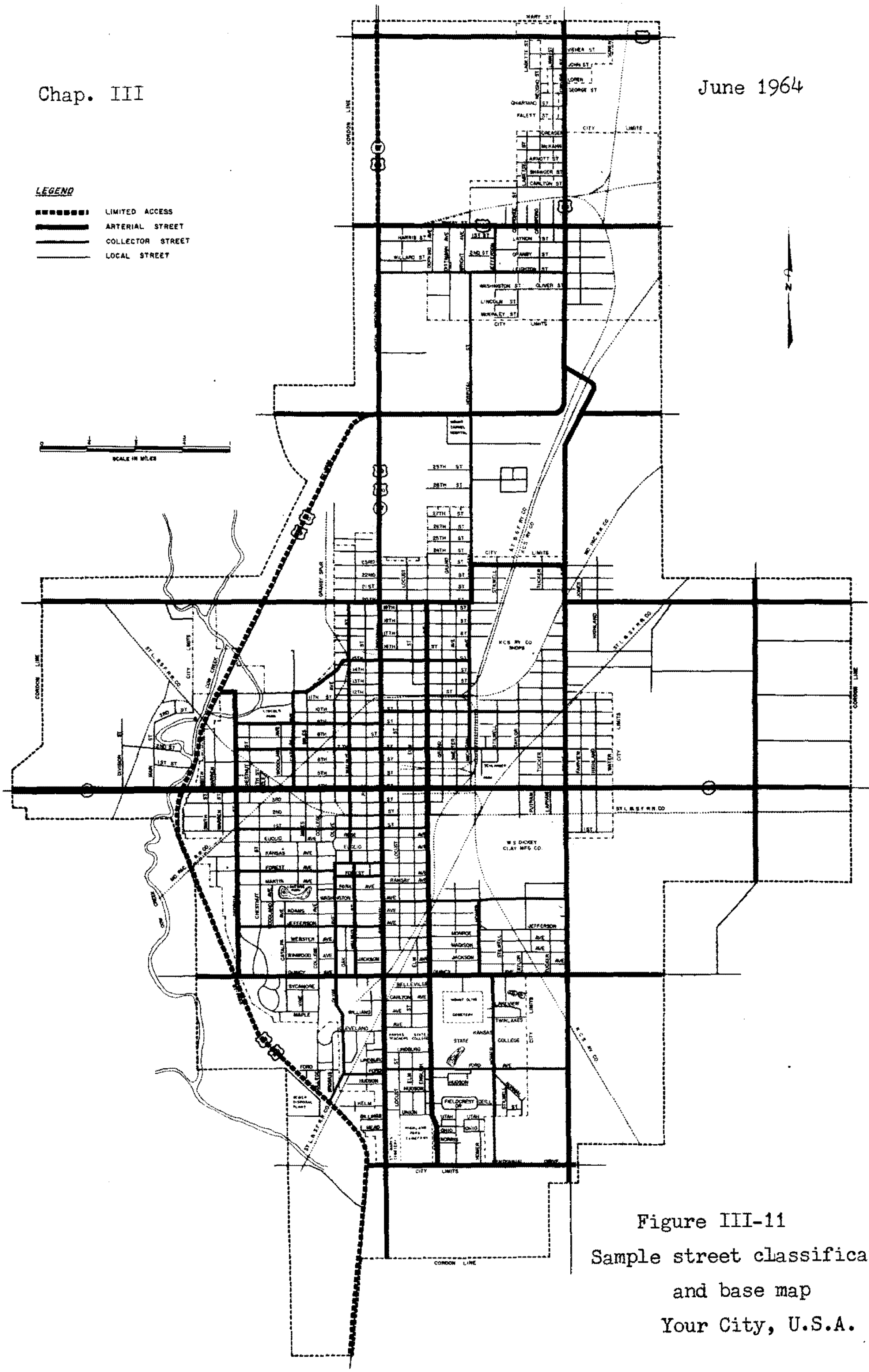


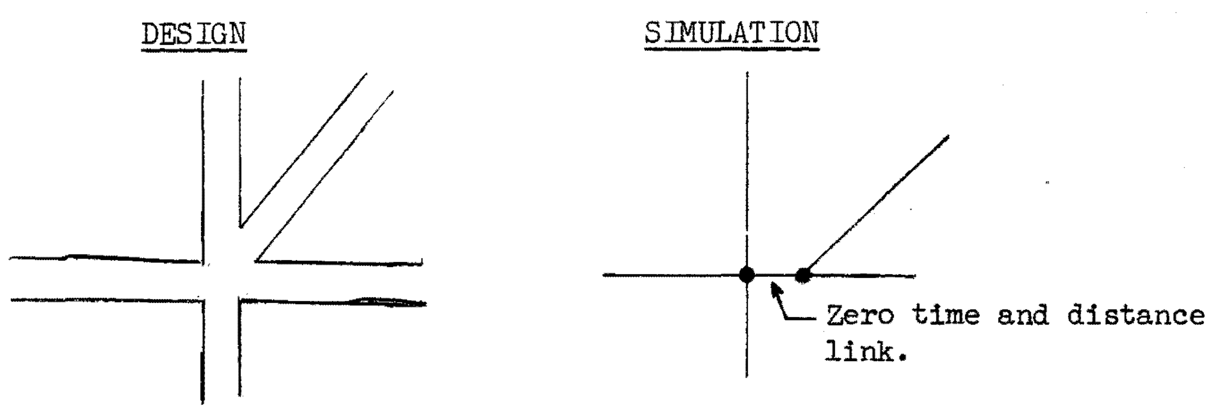
Figure III-11
Sample street classification
and base map
Your City, U.S.A.

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

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

The centroid connections are illustrated in figure III-10.

4. Locate and define the nodes.--Now, a circle or small dot is placed at each intersection in the system. These will be the nodes. A node is also inserted wherever a link crosses the match line between maps or jurisdictions, even though there is no actual highway intersection. One of the limitations imposed by the computer program is that there may be no more than four links outbound from a node. When intersections of more than four outbound links are encountered, it is necessary to add extra nodes at the intersection in such a way that none of them has more than four outbound links. The following example shows how this may be done:



If a link is longer than 9.99 miles or it is expected to have a traveltime greater than 9.99 minutes, a node or nodes must be inserted in the link so that no link will exceed this limitation. In some cases, it may be desirable to limit the length of the link to 3.15 miles and 6.30 minutes of traveltime (see chapter V, sect. D for an explanation of these parameters). Table III-3 is a convenient listing of these program restrictions.

Table III-3

RESTRICTIONS
The maximum number of nodes and centroids is 3,999
The maximum number of centroids is 999
The maximum length of a link is 9.99 miles
The maximum link time including the turn penalty cannot exceed 9.99 minutes
The maximum number of links outbound from a node is 4
Centroids cannot be located on a link of the system (under ordinary circumstances)
Centroids must be numbered starting with 1 and continue in an unbroken sequence
Each centroid must have at least one connection to the system
Duplicate node numbers are not permitted.

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

If the system that is being coded contains some high type facilities, such as freeways, their interchanges may be coded directionally. In directional coding, turning movements and weaving movements may be specified as links in the system. Thus, the longer distance and traveltime inherent in the loops of a cloverleaf interchange may be simulated in a network by directional coding. Some examples of directional coding are illustrated in figure III-12.

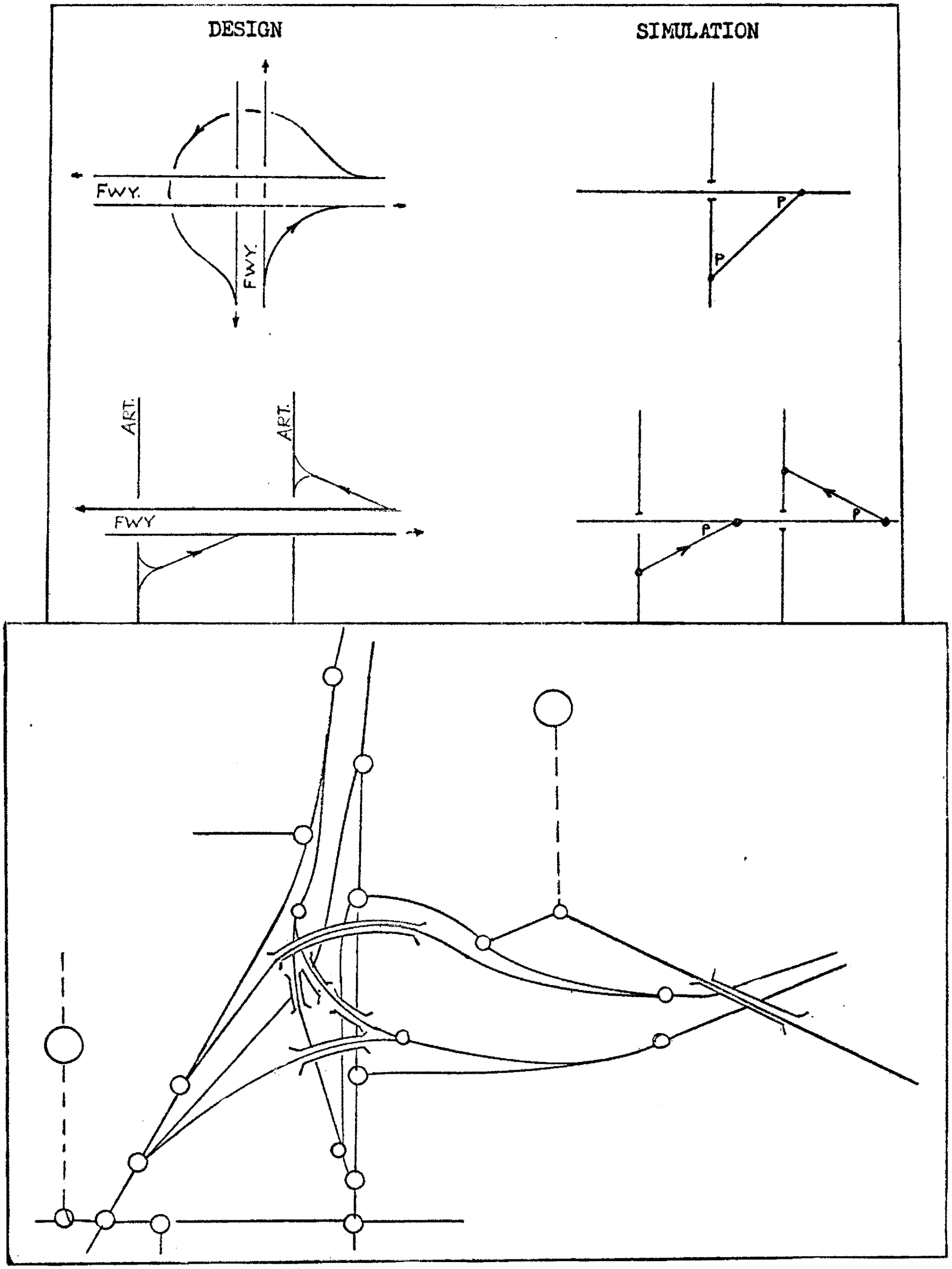


Figure III-12.--Examples of directional coding.

5. Prepare a node table.--Prior to numbering the nodes that have just been identified by circles or dots, a table of node numbers is prepared as shown in table III-4. The IBM 7090/7094 traffic assignment programs require that centroids be given the lowest range of numbers. The remaining nodes (intersections) of a highway network must be numbered according to one of two categories as follows: (1) arterial nodes, and (2) freeway nodes. The highest node number that may be used is 3,999.

Table III-4.--Node number groups

Node group	Type of node	Node number
Group A	Zone centroids	$1-n_1$
Group B	Arterial nodes	$n_2 - n_3$
Group C	Freeway nodes	$n_4 - n_5$

Where: $n_1 < n_2 < n_3 < n_4 < n_5 < 4{,}000$

Except within group A, gaps may occur in the numbering of the nodes. It is also suggested that gaps be provided between n_1 and n_2, n_3 and n_4, and n_5 and 3,999 to allow for additions and corrections to the system. For small networks, some coders prefer to use only the odd or the even numbers within the blocks for the initial coding of the network. In this manner, revisions and corrections to the network may be easily made without destroying the continuity of the numbering scheme.

The "available node" table is now prepared which simply lists all of the node numbers and their categories to be used in numbering the system. When a number is assigned to a node it is removed from the list, thus preventing any duplicate node numbers. When the node numbering has been completed, this table is retained to provide a ready source for available node numbers when making corrections or additions to the network.

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

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

7. Code the turn penalties.--At the option of the user, a time penalty can be applied to the network for right and left turns (or through movements). Only one value may be used throughout the system, and it applies equally to both left and right turns. Generally a turn penalty of 18 seconds (0.30 minute) has been applied. Any reasonable value of time may be used, however.

To inform the computer as to whether a turn is being made in any particular movement, the links must be signed. If a movement is made from one link to another without a change in sign, no turn is involved. If a movement is made from one link to another with a change in sign, a turn is involved and the time penalty will be applied. Figure III-13 and the following description illustrate the signing process.

Handle all N-S and E-W streets first. Say, for example, all N-S streets are signed (-) and all E-W streets (+). It is evident that turns between N-S and E-W streets are properly handled.

Usually, diagonals are signed opposite to that of the facility being crossed. For example, consider the diagonal street in figure III-13 proceeding in the direction 16-15-3-17-7-18. The process can be worked in the opposite direction if desired. Since links 14-15 and 15-4 are signed (-), link 16-15 must be signed (+) to inform the program of the turn. Likewise, link 15-3 must be signed (+) at the node (15) end and (-) at the node (3) end.

--The sign of link 3-17 must be (-) at the node (3) end and (+) at the node (17) end.

--Since links 2-17 and 17-8 are (-) at the node (17) end, link 17-7 must be (+) at the node (17) end. However, at the node (7) end the sign of link 17-7 should be (-).

--Link 7-18 must be signed (-) at the node (7) end because of the signs of the other links connected to node (7).

All signs are written directly on the network maps.

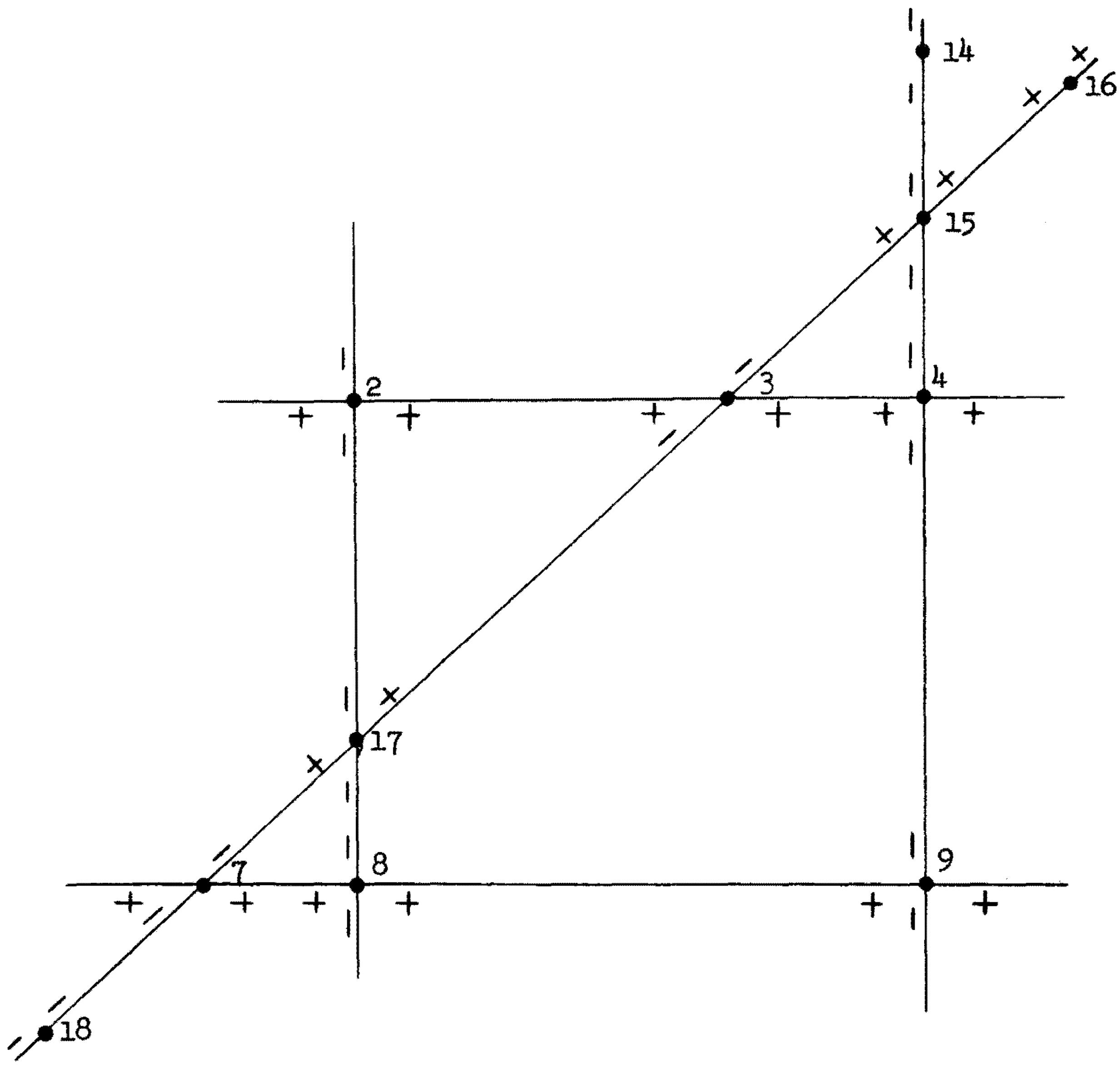
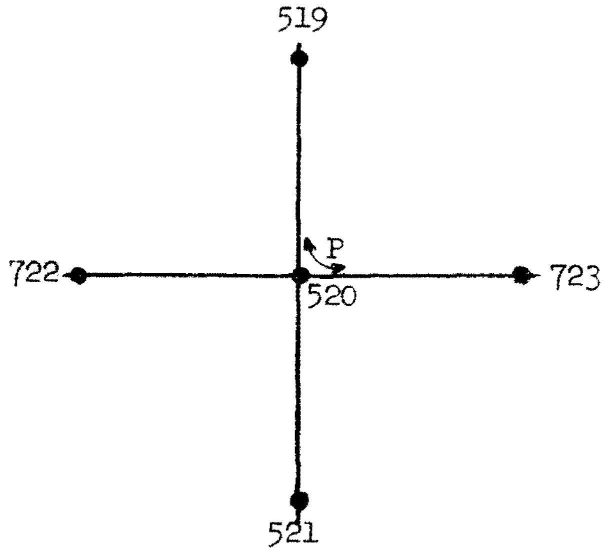


Figure III-13.--Signing the links.

8. Code the turn prohibitors.--Another optional feature of the traffic assignment programs is that any specified movement at an intersection may be prohibited. This feature has particular value in

simulating interchanges where certain turning movements are not incorporated in the design. On the map, a "P" is placed in the quadrant where the turns are to be prohibited, as shown:



See page III-41 for a description of the method used to code turn prohibitors into the network.

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

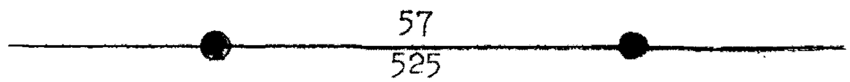
On a print, each link must be defined by its two parameters--the link distance and speed or traveltime. Measuring tapes are prepared from strips of tracing paper (about 8" x 1") and marked off in hundredths of a mile. A separate tape is made for each map scale. The title of the map with which it is to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

The length of each link has been limited to a maximum of 9.99 miles, or shorter, say 6.30 miles.[2] Any links that exceed the maximum distance must be divided into two or more smaller links by the insertion of additional "dummy" nodes.

---

[2] See chapter V, section D.

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



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

This completes the coding of the network description maps. Figure III-14 is a typical portion of a network description map that is ready for coding.

c. Special treatment for external stations.--If the preceding method was used in coding the network, the links connecting the centroids representing the external stations will be treated by the computer as local streets. As local streets, the vehicle-miles and vehicle-hours of travel on those links will be summarized in the local street category. To avoid this situation, an arterial or freeway node may be placed adjacent to the external centroid on this link. The new link connecting the new node and original centroid is assigned values of zero traveltime and distance, and the remaining link still retains its original values of time and distance.

Some engineers, however, prefer to code a traveltime for this hypothetical link which represents an average traveltime to or from that external station and the outlying zones. This will not affect the tree routing, only the summaries of vehicle-miles and vehicle-hours.

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

d. Identifying and storing the maps and tabulations.--Each traffic assignment is given an identification number. Some engineers have used the following two-digit system: The first digit refers to the year which the network represents, and the second digit represents the individual assignment or revision thereof. For instance, the

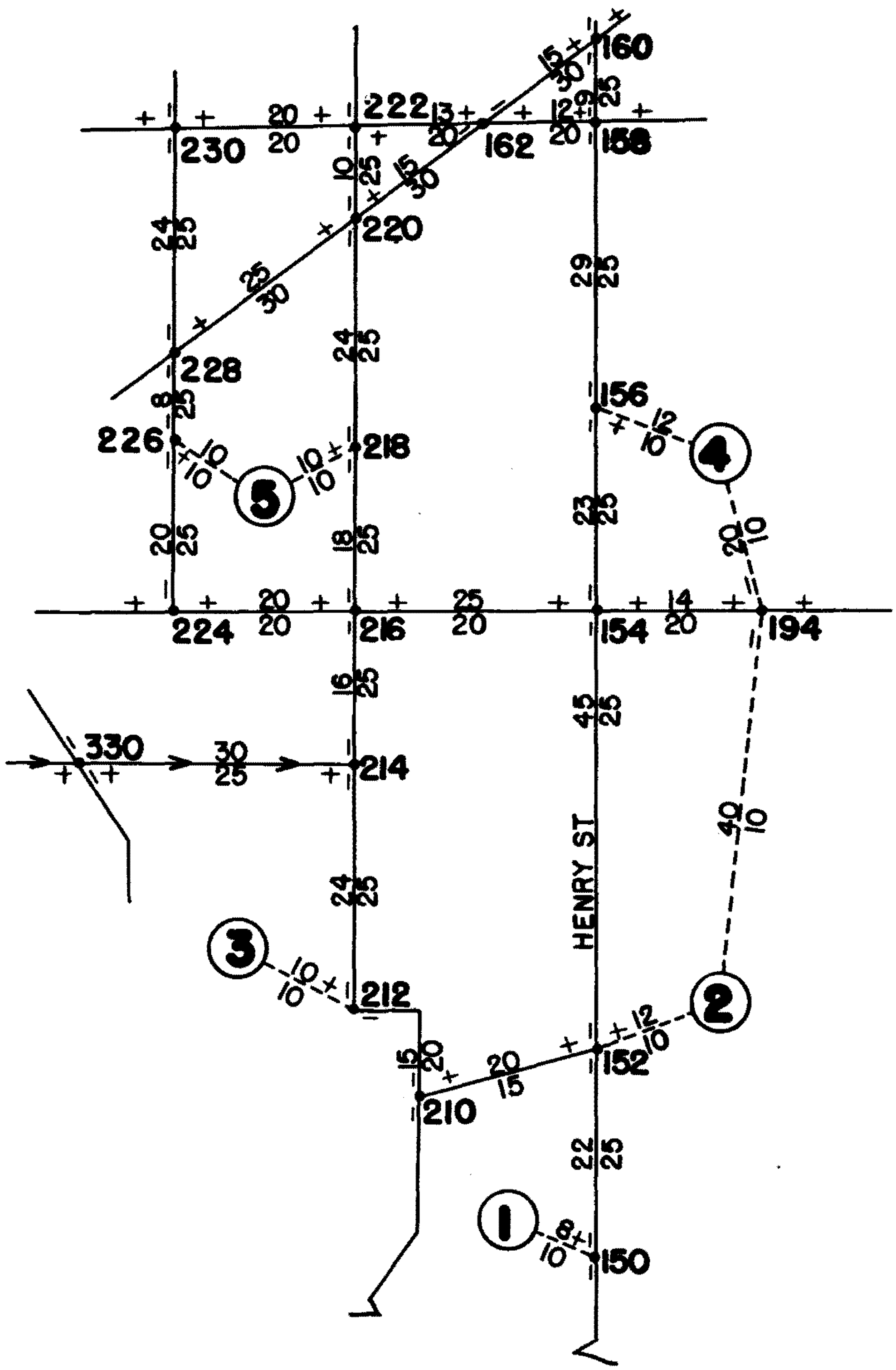


Figure III-14.--Typical section of completed network.

number "1-5" would represent the existing system, revision or assignment number 5; the number "3-7" would represent a 1985 network, trial number 7. All maps and tabulations pertaining to the individual assignment are given this number.

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

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

(2) The printed network description as built by the computer.

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

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

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

e. Link data card preparation.--Step 3 on the flow diagram for network preparation (figure III-8) involves coding the link data cards and key punching. After completing step 2 in the flow diagram, all the required information is recorded on the network maps. The data must now be transferred to the coding forms.

To prepare for coding, a transparent overlay is placed on the network map, and, as each link is coded, it is marked on this overlay. This prevents the coding of duplicate links and permits simultaneous coding by more than one person.

Figure III-14 shows a portion of a network map, ready for coding, which will be referred to in the description of network coding. A reduced print of the network coding form is shown as figure III-15. These are usually printed on sheets that are about 8½" x 14" and bound in tablets. Each line on the coding sheet represents one 80-column IBM punched card.

A link may be defined as a one-way connection between two intersections or nodes. Each line on the coding form permits the coding of two links, if the links do not represent one-way streets. For two-direction links, both directions of travel may be coded on one card. The main headings for card columns 20-33 and 35-48 indicate the direction of the links. The first field shows the link in the node A to node B direction and the second field (35-48) is for coding the link in the reverse direction. For a one-way link, card columns 35 to 48 are not used.

When coding the network, leading zeros in the fields are not necessary. Alphabetic "o's" must be distinguished from numerical zeros in a manner that is prescribed by the key punching installation. All data must be right justified in the prescribed fields.

Referring to figure III-15, the network coding form, each field from left to right on the form will be discussed in detail in the following paragraphs:

Column 1 (Optional) - This is the jurisdiction code. A summary of vehicle-miles and vehicle-hours is obtained in the assignment process for each jurisdiction of the study area. Provisions have been made for four jurisdictional codes.

The jurisdiction usually refers to a political subdivision within the study area. It may be used, however, to identify various types of facilities. Only a 0, 1, 2, or 3 may be coded. If left blank, the computer will assume zero for the code. If jurisdiction is used, it is recommended that a zero be coded into column 1 for any section of the highway system that is on the National System of Interstate and Defense Highways.

Columns 3-6 - This is the A node. Either end of a two-directional link may be designated as the A node. Consider link 152 to 154 on Henry Street in figure III-14. Either node 152 or 154 may be considered as node A because the link is two-directional. For a one-way street, the A node must be the intersection from which the movement is made. The B node is the intersection to which the movement is made. Examine link 330 to 214 in figure III-14. Since this is a one-way link from 330 to 214, node 330 must be coded as the A node and 214 as the B node.

Some experienced coders prefer to always code in the low to high direction on the two-directional links. This is not a requirement, but it facilitates the manual editing of the link data cards after they have been sorted on the A node. It insures that all of the centroid connecting links fall at the beginning of an A node card listing.

Columns 8-11 - This is the B node. The end of the link opposite node A is declared node B.

TRAFFIC ASSIGNMENT

AREA TRANSPORTATION STUDY — NODE - LINK - DATA — DATE ______ CODER ______

		LINK									A → B							B → A															
JURISDICTION		NODE A		NODE B		SIGN	FLAG		DISTANCE MILES		"T" OR "S"		FIELD 1	FIELD 2	AVG. MIN. 0.00 OR SPEED 00.0			"S" OR BL'NK		FIELD 1	FIELD 2	AVG. MIN. 0.00 OR SPEED 00.0			NODE B OF LINK TO BE CHANGED		CAPACITY	COUNT					
1	2	3 4 5 6	7	8 9 10 11	12	13	14	15	16 17 18	19	20	21	22 23 24	25 26 27	28 29 30 31	32 33	34	35	36	37 38 39	40 41 42	43 44 45 46	47 48	49	50 51 52 53	54	55 56 57 58 59 60	61 62 63 64 65 66	67 68	69 70 71	72	73 74 75 76	77 78 79 80
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		
																															4		

COL. 1 (JURISDICTION)
1
2
3
0 ______

NODE NUMBER RANGES
INTERNAL CENTROIDS ______
STATION CENTROIDS ______
ARTERIAL ______
FREEWAY ______

COL. 35
BLANK INDICATES A ONE-WAY LINK

PUNCHED ______

Figure III-15.--Network coding form.

Column 13 (Optional) - The data coded into this column is the sign of the link if turn penalties are to be used in the assignment. It is the sign of the link at the A node end. For example, the sign of the link between nodes 220 and 162 in figure III-14 is (+) if node 220 is coded as the A node. However, if node 162 is considered as node A, the sign of the link would then be (-).

If the sign of the link is (+), a zero (0) is coded into column 13. If the sign of the link is (-) a one (1) is coded in column 13. Turn penalties may be coded in the system, and if it is determined later that they should not be used, a zero time penalty can be assessed.

Column 14 (Optional) - This if the flag. The data coded into this column indicates whether the sign of the link at node B differs from the sign at the A node end of the link. If the sign at node B is the same as the sign at node A, a zero (0) is coded in column 14. If the signs differ, a (1) is coded in column 14. If column 13 is coded, column 14 must also be coded.

In the previous example, link 220 to 162 would have a (1) in column 14, as the sign changes from plus to minus.

Columns 16-18 - The length of the link in miles and hundredths of a mile is coded here. If the limit of 9.99 miles is exceeded, the link must be divided into two or more sections by the addition of extra nodes. The link distance must always be coded.

Column 20 - (T or S) - The coding of a T indicates to the computer that time is being reported in columns 28-30 (and 25-27 and 22-24, if needed). An S in this column would indicate that speed is being reported. Speed or time codes may be interchanged throughout the coding at will. Either a T or an S must always be coded in column 20.

Columns 28-30 (Field 3-Speed or Time) - If a T or an S is coded in column 20, the appropriate time or speed is coded in columns 28-30. If traveltime is coded, it is reported in minutes and hundredths of a minute. The maximum time that may be coded is 9.99 minutes. However, since the computer internally scales all time values to 63rds (see chapter V), it is desirable to limit reported times to a maximum of 6.30 minutes minus the turn penalty time. If a particular highway section has a traveltime longer than the maximum (or 6.30 minutes minus the turn penalty time), it should be divided into two or more links by the addition of extra nodes.

If speed is coded rather than traveltime, it is reported in miles per hour to tenths. Speeds should not be coded on the links that would convert to a traveltime in excess of the maximum.

If only one network is to be coded, columns 28-30 are used. If traffic is to be assigned for two time periods or modes of travel at different speeds, or time values for each link, columns 25-27 are also used. If three assignments are required, they may be simultaneously coded by using all three fields.

Column 35 (T,S, or blank) - If the link being coded represents a one-way street, this column is left blank. If both directions are to be coded on a two-directional link, either a T or an S is coded in this column to identify the information that is being coded in columns 43 to 45 (and 40 to 42 and 37 to 39) for the B to A node direction.

Columns 43-45 (Field 3 - Speed or Time) - For a one-way link these fields are left blank. For a two-way link, the traveltime or speed is reported for the B to A node direction. As before, fields 1 and 2 may also be used for a simultaneous coding of alternate networks.

Columns 50-53 (Node B of link to be changed) - These columns are not used in the initial development of a highway network description. They are used when a link is to be removed from the system or to change or correct a link. The coding of this information will be discussed later in "Network Corrections" (chapter III, section B-3).

Columns 55-60 (Optional) - This field is used by the capacity restraint programs. If a 2-way link is coded on a single card, as evidenced by a punch in column 35, then the practical capacity for both directions may be coded in this field. If directional capacities are to be used, each link must be coded on a separate card, treating all links as one-direction links. A capacity is not required for all links in the system. However, the capacity restraint programs are more effective if as many links as possible have capacity and volume count coded. Either an hourly capacity or a "total daily capacity" may be coded.

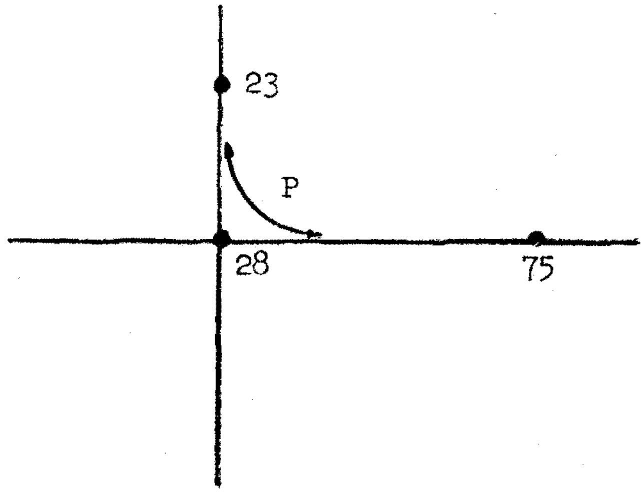
Columns 61-66 (Optional) Count - This field contains the traffic volume counts as measured during the inventory. If both directions of the street segment are coded on the card, the traffic count must also be for both directions. It is reported in whole numbers and must represent either a 24-hour count or a peak-hour count, depending on the type of trips that are to be loaded on the network.

Column 72 - A (4) must be punched in column 72 of all link data cards for card identification. This signals the computer that it is a link data card.

Columns 67-71 and 73-80 (Optional) - These fields are not used by the computer program and they may contain any information the coder desires. Street or highway names are generally coded in these fields for link identification.

f. Coding turn prohibitors.--A different type of coding form is used for coding the prohibited turning movements in a network. A sample coding form is shown as figure III-16.

One card is prepared for each prohibited movement. The example below shows a node at which turning movements are to be prohibited in both directions. This will require two cards.



Three node numbers are required to identify the turning movement. The "back" node (A) is coded first then the intersection node itself (B) and finally the "ahead" node (P). This illustration would be coded as follows:

Node A	Node B	Node P		
Cols. 3-6	Cols. 9-12	Cols. 15-18	Col. 24	Col. 72
0023	0028	0075	A	5
0075	0028	0023	A	5

The (5) in column 72 identifies this as a turn prohibitor card. Column 24 must contain an (A) to add a turn prohibitor. The program checks that the links are actually in the network before inserting the prohibitor. Prohibitors are deleted from the network in a similar manner; coding is the same except column 24 contains a (D).

All prohibitors may be deleted from the network before updating by setting a switch via the parameter card. In the past, some difficulty has been encountered when networks have been revised and the old turn prohibitors inadvertently left in the network. To prevent this from happening all prohibitors should be cleared from the network by use of the coded "delete" card described above, and the new "add" prohibitor card should be reinserted into the deck.

TRAFFIC ASSIGNMENT

AREA TRANSPORTATION STUDY TURN PROHIBITORS DATE ______ CODER ______

	A-NODE OF ENTRY LINK		B-NODE OF ENTRY LINK		P-NODE		TYPE OF PROHIBITOR			
1 2	3 4 5 6	7 8	9 10 11 12	13 14	15 16 17 18	19 20 21 22 23	24	25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71	72	73 74 75 76 77 78 79 80
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	
									5	

NOTE:
"A" INDICATES ADD PROHIBITED TURN, "D" INDICATES DELETE PROHIBITED TURN.

Figure III-16.--Turn prohibitor coding form.

Needless to say, the intersections of one-way streets do not need to have turn prohibitors coded for the prohibited turns.

g. Checking for errors.--The coding of the network continues until all of the links have been coded and checked. Then the link data cards are keypunched and an A node and B node card listing is prepared as indicated in step 4 of the flow diagram. The B node listing is prepared first by sorting the link data cards on the B node field and listing them with tabulating equipment. The cards are then re-sorted on the A field and again a listing is prepared.

These two listings provide a permanent record of the link data cards and permit a preliminary manual editing of the information. At this time it is advisable to determine that each centroid has at least one connection to the arterial street system, that there are no more than four outbound links from a node, and that there are no misplaced card punches or illegal codes. Usually a brief scanning of these listings will indicate some errors that should be corrected before any further processing. Samples of a partial A node and B node listing are included in figures III-17 and III-18.

If errors are found at this stage, those cards that are in error are removed from the original card deck and their corrected replacements are inserted. This is step 5 on the flow diagram.

Step 6, the link data editing routines, is included as an optional process. There have been several recent computer programs developed which examine the link data cards and perform the routine contingency checks. These programs will also perform the card-to-tape operation that is required before proceeding to the larger machines. A short IBM 1401/1410 program for this editing operation is UPN-M-11, available from the Bureau of Public Roads.

If the link data editing programs have diagnosed errors in the cards, the revised cards are keypunched and inserted in the card deck. The cards are then resubmitted to the editing programs and a new input tape is written.

The format for writing these cards on tape is prescribed by the build network description program (PR-6). If a network is to be built under the BELMN Monitor System, the parameter cards must be on tape with the link data cards. If the TEXAS Control Program is used, the cards are simply transferred to tape in BCD, one card per record, 80-80 column reproduction with a standard end of file.

At this point, the link data cards that describe the network have been examined for errors and transferred to tape. They are now ready for processing on the IBM 7090 or 7094.

1	1	194	10	000	S	000	S	000	4
1	1	195	00	000	S	000	S	000	4
1	1	71	10	000	S	000	S	000	4
1	2	171	00	000	S	000	S	000	4
1	2	196	10	000	S	000	S	000	4
1	2	197	00	000	S	000	S	000	4
1	2	198	10	000	S	000	S	000	4
1	3	199	10	005	S	100	S	100	4
1	3	191	00	013	S	100	S	100	4
1	3	200	10	013	S	100	S	100	4
1	4	192	00	012	S	100	S	100	4
1	4	202	10	012	S	100	S	100	4
1	5	176	10	017	S	100	S	100	4
1	5	177	10	019	S	100	S	100	4
1	5	203	10	013	S	100	S	100	4
1	6	98	10	023	S	200	S	200	4
1	6	180	00	038	S	200	S	200	4
1	7	92	00	000	S	000	S	000	4
1	7	204	00	000	S	000	S	000	4
1	7	205	10	000	S	000	S	000	4
1	8	183	10	005	S	100	S	100	4
1	8	168	00	020	S	100	S	100	4
1	8	207	00	010	S	100	S	100	4
1	9	208	10	000	S	000	S	000	4
1	9	179	00	000	S	000	S	000	4
1	10	186	00	010	S	150	S	150	4

Figure III-17.--Partial A-node listing, Your City, U.S.A.

1	312	34	10	000	S	000	S	000			4
1	73	35	00	000	S	000	S	000			4
1	111	36	00	000	S	000	S	000			4
1	78	39	00	000	S	000	S	000			4
1	188	40	10	000	S	000	S	000			4
1	151	45	00	000	S	000	S	000			4
1	187	49	10	000	S	000	S	000			4
1	44	70	00	000	S	000	S	000			4
1	1	71	10	000	S	000	S	000			4
2	107	71	00	005	S	150	S	150	7000	7290	4
2	75	72	10	055	S	300	S	300	2700	1300	4
2	218	72	00	018	S	360	S	360	3700	300	4
2	72	73	00	049	S	360	S	360	5300	1100	4
1	50	74	00	000	S	000	S	000			4
1	33	75	00	018	S	200	S	200			4
2	77	75	10	048	S	300	S	300	2700	1300	4
2	81	76	10	025	S	250	S	250	1000	500	4
2	310	76	00	062	S	350	S	350	4500	2300	4
2	82	77	10	025	S	300	S	300	4500	1200	4
2	219	77	00	019	S	300	S	300	9700	3000	4
2	77	78	00	050	S	400	S	400	4500	250	4
1	32	79	00	020	S	200	S	200			4
2	86	79	10	048	S	350	S	350	2700	1590	4
2	79	80	10	026	S	350	S	350	2700	1500	4
2	309	80	00	048	S	300	S	300	3000	500	4
1	32	81	00	012	S	200	S	200			4
2	80	81	00	013	S	300	S	300	3000	500	4

Figure III-18.--Partial B-node listing, Your City, U.S.A.

B. Processing the Traffic Assignment

The traffic assignment system described in this section is a family of computer programs for the IBM 709/7090/7094 electronic computers. It is a library of programs, stored on one or more magnetic tapes, in such a fashion that any of the programs can be easily called upon in any desired order through the use of the master control program. The basic traffic assignment programs in this system were developed as a joint project involving the Bureau of Public Roads, the Washington Regional Highway Planning Committee, and the General Electric Computer Department. In this section of the report, it is intended that the logical flow of information from one program to another be emphasized rather than the detailed descriptions and requirements of the various programs. For specific information regarding each of the programs, the reader is referred to chapter VI.

1. System parameters.--The computer will require specific items of information concerning the coded network and the trip tables that were built as described in section A of this chapter. These are called system parameters. The format of the parameter card is discussed in detail in chapter VI, but an example of the type of data required is listed below.

		Example
(a)	Last centroid number	0340
(b)	First external station number	0281
(c)	Last node number	3000
(d)	Longest link time	600
(e)	Turn penalty	030
(f)	Longest link distance	315
(g)	First freeway node	2100
(h)	First node of required turns	1000
(i)	Last node of required turns	2600

There may be additional information required for a specific computer program but these data are usually required for all programs. A permanent record is made of these parameters and marked on all maps, listings, and magnetic tape labels to avoid confusion after several different networks have been built.

2. Building the network description.--The data processing for a traffic assignment begins with the building of a binary network description. This is indicated as step 8 on the flow diagram, figure III-8. The IBM 7090/94 program that performs this function is called PR-6 (Build or Update Network Description). This program converts the network description deck (link data cards) to a single binary record and writes this record in binary on an output tape. In the process of building the network description the program also performs edit checks on the input data. All of the errors that are found and all one-way links are written on a

BCD tape to be printed off-line. One of the edit checks made by the computer is a speed limits check for each type of facility. These speed limits may be designated by the user. A link is entered into the network, however, even if it fails the speed limits check.

3. Correction of network errors.--There are two methods of correcting the errors that are found by the build network description program. One method is to remove those cards that are in error from the link data deck and replace them with revised cards. This new link data deck then returns to step 6 on the flow diagram and the process is repeated. This procedure has some advantage in that a "clean" deck of network description cards is always available. If the capacity restraint option is to be used later, this procedure is mandatory. There is no procedure available for correcting the network description after the capacity restraint process has been initiated.

An alternate procedure to the one described above is to correct the binary network description that has been written on tape. This is step 10. If this option is used, delete, change, and add cards (see below) are submitted to the update part of the build network description computer program in order to correct the network errors. By specifying this option of the program it will then read the old binary network description and the update cards, revise the network while it is in core storage, and write a new binary network description tape containing the network modifications. This portion of the program also edits the update cards for errors and compatibility with the old network. If errors are found they are written on tape for printing off-line. These errors should then be corrected by coding and punching more update cards and revising the new network.

As mentioned before, there are three types of update cards that are used to make corrections to the network description or to produce a modified network description for testing alternate networks. The changes are made by: (1) deleting links from the network description; (2) changing the data for existing links; and (3) adding entirely new links.

The Delete card is used to completely remove a link from a network description. Referring to figure III-15, the following information would be coded to delete a link:

Columns 3-6 - Code the A node of the link to be deleted.

Column 35 - Code either a T or an S. Leave this column blank if the link that is to be deleted is a one-way link.

Columns 50-53 - Code the B node of the link to be deleted.

Column 72 - Code a 4, card identification.

All other columns on the coding form are left blank in a delete card.

A Change card is also coded exactly the same as a link data card except that the B node is entered in columns 50-53 as well as in columns 8-11. This card simply changes the distance, time, or speed parameters in the old network to the new information that is coded on the change card.

An Add card is coded exactly the same as a link data card (see section A, part 2-e).

These update cards may be used in a number of ways. If many alternate freeway routes are to be tested, for example, each alternative may be added to the system by use of these cards. Conversely, if an alternative is to be eliminated, these cards are also used. A network that represents an existing street and highway system may be updated to represent the future system with these update cards.

The order in which these cards are submitted to the computer is important. If a system is to be updated using all three types of update cards, it is mandatory to submit the delete cards first, then the add cards, and then the change cards. More detailed information concerning the computer operations in updating a network are given in chapter VI.

4. Printing the link data.--After all of the errors have been corrected by either one of the two methods, the binary network may be formatted or printed by Program PR-12 (Print Link Data). This program converts the data on the binary network description tape to a decimal tape in a format that is suitable for off-line printing. It is indicated as step 11. A partial printed network description for the sample network is included as figure III-19. This listing shows the outbound connections for each node and centroid. For example, the first line of the listing shows that centroid (71) is connected to nodes 108, 107, and 1. With each of the connections, the corresponding distance, traveltime, and speed is indicated. The jurisdictions, signs, and flags are also recorded.

EXISTING NETWORK

NODE	J NODE SF	D	T	V	J NODE SF	D	T	V	J NODE SF	D	T	V	J NODE SF	D	T	V
(71)	2(108)	20	70	17	2(107)	0	20	0	1(1)-	0	0	--				
(72)	2(218)	20	30	40	2(75)-	50	110	27	2(73)	50	80	38				
(73)	2(72)	50	80	38	1(35)	0	0	--								
(74)	2(310)	10	20	30	1(50)	0	0	--								
(75)	2(77)-	50	100	30	2(72)-	50	110	27	1(33)	20	50	24				
(76)	2(310)	60	110	33	2(219)	20	30	40	2(81)-	20	60	20				
(77)	2(219)	20	40	30	2(82)-	20	50	24	2(78)	50	70	43	2(75)-	50	100	30
(78)	2(77)	50	70	43	1(39)	0	0	--								
(79)	2(86)-	50	80	38	2(80)-	30	40	45	1(32)	20	60	20				
(80)	2(309)	50	100	30	2(81)	10	30	20	2(79)-	30	40	45				
(81)	2(82)	40	70	34	2(80)	10	30	20	2(76)-	20	60	20	1(32)	10	40	15
(82)	2(223)-	50	100	30	2(81)	40	70	34	2(77)-	20	50	24	1(32)	30	100	18
(83)	2(84)	30	50	36	1(47)	0	0	--								
(84)	2(85)	20	40	30	2(83)	30	50	36	1(30)-	10	40	15				
(85)	2(309)-	70	100	42	2(308)-	0	0	--	2(216)	30	60	30	2(84)	20	40	30
(86)	2(223) 1	70	130	32	2(216)	20	30	40	2(190)-	10	20	30	2(79)-	50	80	38
(87)	2(223)-1	30	60	30	2(189)-	40	80	30								
(88)	2(190)-	70	180	23	2(98)	30	40	45	2(97)-	20	60	20	1(10)	30	130	14
(89)	2(189)-	40	70	34	2(99)-	20	40	30	2(98)	20	30	40				
(90)	2(91)	80	110	44	1(43)	0	0	--								
(91)	2(307)	40	50	48	2(187)-	10	30	20	2(103)-	90	230	23	2(90)	80	110	44
(92)	2(181)-	10	20	30	2(96)-	20	100	12	1(7)	0	0	--				
(93)	2(307)	10	20	30	2(94)	30	60	30	1(29)-	0	0	--				
(94)	2(184)-	30	130	14	2(95)	10	30	20	2(93)	30	60	30				
(95)	2(204)-	10	60	10	2(186)-	10	50	12	2(96)	20	50	24	2(94)	10	30	20
(96)	2(97)	20	50	24	2(95)	20	50	24	2(92)-	20	100	12	1(10)-	10	60	10
(97)	2(180)-	30	90	20	2(96)	20	50	24	2(88)-	20	60	20	1(10)	30	140	13
(98)	2(89)	20	30	40	2(88)	30	40	45	1(6)-	20	70	17				
(99)	2(185)-	10	20	30	2(100)	100	150	40	2(89)-	20	40	30				
(100)	2(217)-	40	60	40	2(188)-	10	20	30	2(99)	100	150	40				
(101)	2(102)	70	100	42	1(38)	0	0	--								
(102)	2(305)	10	30	20	2(103)-	20	50	24	2(101)	70	100	42				
(103)	2(102)-	20	50	24	2(91)-	90	230	23	1(28)	0	0	--				
(104)	2(305)	30	60	30	2(210)	10	40	15	2(162)-	20	50	24	2(112)-	20	50	24
(105)	2(210)	10	40	15	2(200)	10	60	10	2(165)-	20	60	20				
(106)	2(200)	10	60	10	2(192)-	10	30	20	2(191)-	10	60	10	2(107)	10	60	10
(107)	2(195)-	10	40	15	2(114)-	20	70	17	2(106)	10	60	10	2(71)	0	20	0
(108)	2(203)	40	130	18	2(172)-	20	80	15	2(115)-	20	60	20	2(71)	20	70	17
(109)	2(203)	20	50	24	2(177)-	20	50	24	2(122)-	30	80	23	2(110)	100	150	40
(110)	2(217)-	60	110	33	2(111)	50	70	43	2(109)	100	150	40				
(111)	2(110)	50	70	43	1(36)	0	0	--								
(112)	2(193)	10	20	30	2(116)-	20	50	24	2(104)-	20	50	24				
(113)	2(202)	10	40	15	2(192)-	10	40	15	2(119)-	20	50	24	2(114)	20	50	24
(114)	2(220)	10	20	30	2(159)-	10	20	30	2(113)	20	50	24	2(107)-	20	70	17
(115)	2(220)	20	50	24	2(121)-	20	50	24	2(108)-	20	60	20	1(17)	40	180	13
(116)	2(123)-	30	60	30	2(117)	10	40	15	2(112)-	20	50	24				
(117)	2(118)	40	110	22	2(116)	10	40	15	1(13)-	0	0	--				
(118)	2(201)-	10	30	20	2(119)	10	40	15	2(117)	40	110	22	1(13)-	0	0	--
(119)	2(120)	20	50	24	2(118)	10	40	15	2(113)-	20	50	24	1(14)-	10	70	9
(120)	2(221)	10	20	30	2(159)-	10	30	20	2(127)-	20	60	20	2(119)	20	50	24

Figure III-19.--Sample output of PR-12 (Printed network description).

Column headings are as follows:

Node	-	"A" node end of link
J	-	Jurisdiction
Node	-	"B" node end of link (first link)
S	-	Sign
F	-	Flag
D	-	Distance (x.xx miles)
T	-	Time (x.xx minutes)
V	-	Velocity (xx miles per hour)
J	-	Jurisdiction
Node	-	"B" node end of link (second link)
etc.		etc.

The printing of the link data is an optional procedure. It is usually desirable though, as it provides a permanent record of the network description that is now on magnetic tape and is a handy reference for later operations.

5. Building selected trees.--The process continues with another network checking operation by building several selected trees. By using a program control card, a tree or set of trees may be built by the Build Trees Program (PR-1). As a usual practice, about 6 to 10 selected trees are prescribed to be built by the computer. The selected trees that are chosen are, of course, at the option of the program user. It is advisable to build at least one tree from a centroid in a central part of the study area and several trees scattered around the peripheral area. For the sample problem, trees for centroids 1 (CBD), 22, 28, 32, and 36 were built. This provides good coverage of the entire study area for detecting illogical routings caused by network coding errors.

The purpose of building these selected trees is to determine if there are additional errors in the network that may have passed the edit routines in the build network description program. Typical of this type of error is the so-called "jumper," which is illustrated as one of the examples in figure III-20.

In building the selected trees by program PR-1, the computer is instructed to read and store the entire network description and develop the trees for each centroid that has been selected. After building the tree, the computer writes it in binary on a magnetic tape as one tape record.

6. Formatting selected trees.--These selected trees must now be converted to a readable format as indicated in step 13. Two computer

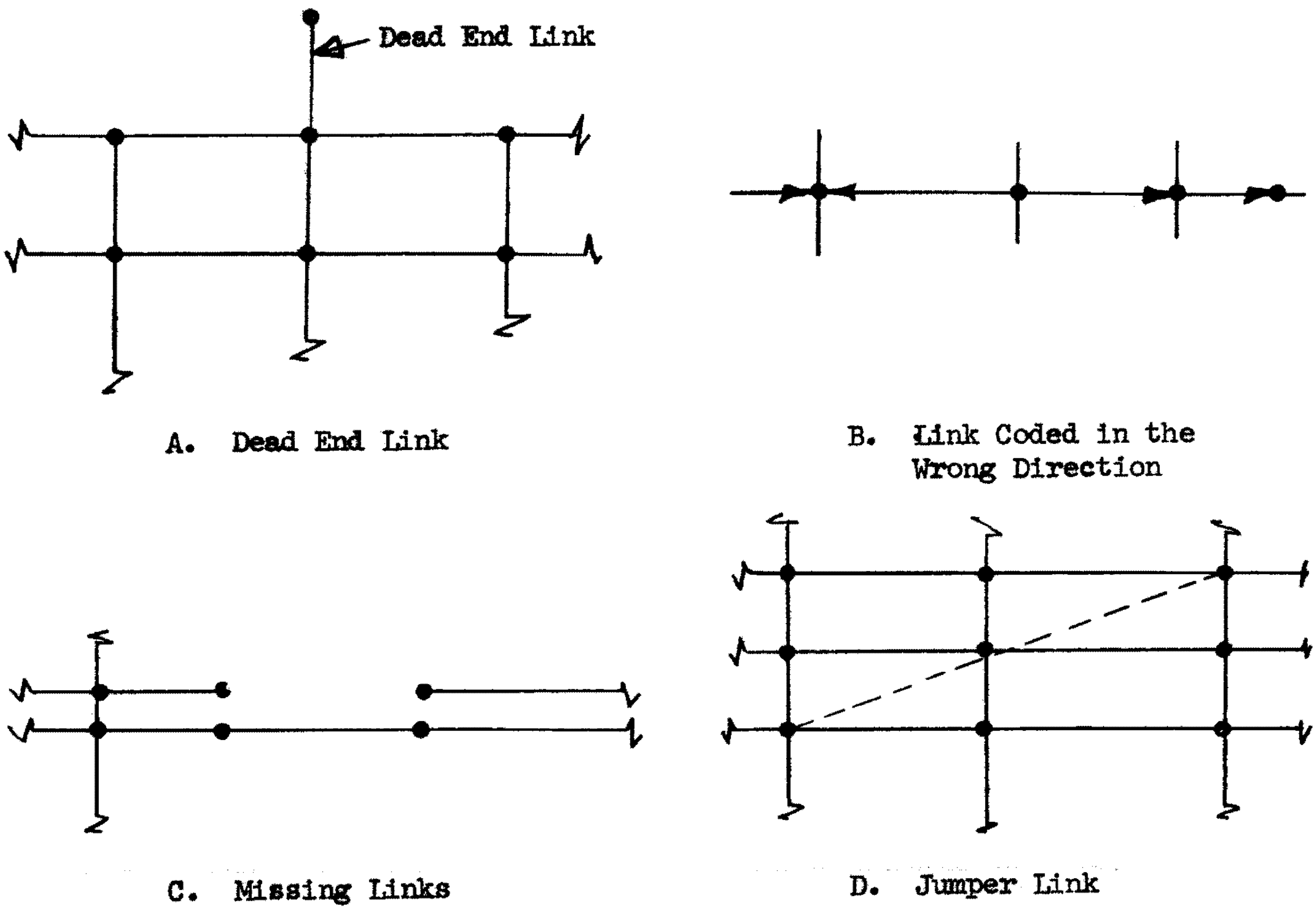


Figure III-20.--Common coding errors.

programs are provided for this purpose, PR-11 and PR-50. Sample outputs of both of these programs are illustrated as figures III-21 and III-22.

Program <u>PR-11 (Format Selected Trees)</u> converts all or selected trees from the binary tree tape produced by program PR-1 to a decimal tape in a format suitable for printing and analysis. Figure III-21, the sample output from program PR-11, is part of the formatted tree number (1) for the sample network. This listing records all the links involved in the tree trace in sequential order on the A node. It simply shows the A node and the B node and the elapsed traveltime in minutes and hundredths of a minute from the selected centroid to the B node.

TREE NO. 1

NODE	NODE HOME	TIME NODE												
1			2 -	198	150	3 -	200	280	4	192	270	5 -	203	340
6	180	490	7	204	350	8	168	300	9 -	208	400	10 -	96	480
11 -	163	400	12 -	210	300	13 -	118	360	14 -	119	330	15	159	200
16 -	121	320	17	115	400	18 -	129	400	19 -	124	460	20	212	520
21	215	620	22	157	660	23	190	730	24	185	600	25	122	570
26 -	149	800	27 -	158	960	28	103	510	29 -	93	530	30 -	84	790
31	189	730	32	79	870	33 -	219	1110	34 -	312	920	35	73	1180
36	111	500	37 -	300	840	38	101	500	39	78	1050	40 -	188	650
41 -	152	720	42	155	860	43	90	680	44	-	-	45	151	800
46	156	610	47	83	770	48 -	153	780	49 -	187	630	50	74	830
51	-	-	52	-	-	53	-	-	54	-	-	55	-	-
56	-	-	57	-	-	58	-	-	59	-	-	60	-	-
61	-	-	62	-	-	63	-	-	64	-	-	65	-	-
66	-	-	67	-	-	68	-	-	69	-	-	70	-	-
71 -	1	0	72	218	1100	73	72	1180	74	310	830	75 -	77	1050
76	310	920	77 -	82	950	78	77	1050	79 -	86	780	80 -	79	820
81	80	880	82 -	223	900	83	84	770	84	85	720	85 -	308	650
86 -	190	700	87 -	189	710	88 -	97	500	89 -	99	560	90	91	680
91	307	570	92 -	181	320	93	94	500	94	95	440	95 -	204	380
96 -	92	420	97 -	180	440	98	88	570	99 -	185	520	100 -	217	630
101	102	500	102	305	400	103 -	102	480	104	210	310	105	200	230
106	107	110	107	71	50	108	71	100	109	203	280	110	109	430
111	110	500	112 -	104	390	113 -	192	210	114 -	107	150	115 -	108	190
116 -	112	440	117	118	440	118	119	330	119 -	113	260	120 -	159	200
121 -	115	240	122 -	109	390	123	124	490	124	125	430	125	160	370
126 -	127	290	127 -	120	260	128 -	121	300	129	128	370	130	129	390
131 -	122	450	132	211	540	133	134	440	134 -	126	360	135 -	128	420
136	213	500	137	136	510	138 -	131	550	139 -	133	560	140	141	600
141 -	212	510	142 -	215	540	143	145	650	144 -	138	650	145	142	610
146 -	141	620	147 -	157	650	148	147	730	149	148	770	150 -	144	760
151	150	800	152 -	146	720	153 -	150	780	154	127	320	155	158	860
156	304	610	157 -	142	580	158	301	830	159 -	114	170	160	126	350
161	163	410	162 -	104	390	163	164	370	164	166	330	165 -	105	320
166	169	220	167 -	191	230	168 -	169	150	169 -	170	130	170 -	195	70
171 -	172	140	172	194	80	173 -	171	190	174 -	197	270	175	198	170
176	175	240	177	176	310	178 -	177	390	179 -	178	400	180 -	174	350
181 -	173	300	182 -	168	260	183	182	330	184	183	350	185 -	179	500
186 -	95	430	187 -	91	630	188 -	100	650	189 -	89	630	190 -	88	680
191 -	106	200	192 -	106	170	193	202	390	194 -	1	0	195	1	0
196	173	270	197 -	175	230	198	172	120	199	167	320	200	106	170
201 -	118	390	202	113	280	203	108	230	204 -	182	320	205	182	350
206 -	125	440	207 -	166	320	208	174	370	209	165	390	210	105	270
211	133	490	212 -	134	440	213	135	480	214 -	137	620	215 -	135	500
216	85	740	217 -	110	570	218	311	1070	219	76	950	220	114	200
221	120	250	222	167	290	223	87	770	224	-	-	225	-	-
226	-	-	227	-	-	228	-	-	229	-	-	230	-	-
231	-	-	232	-	-	233	-	-	234	-	-	235	-	-
236	-	-	237	-	-	238	-	-	239	-	-	240	-	-
241	-	-	242	-	-	243	-	-	244	-	-	245	-	-

Figure III-21.--Sample output of PR-11 (Formatted tree trace).

TREE NO. 1 DESTRUCTIVE TREE TRACE 1

NODE	TIME	NODE	TIME	NODE	TIME	NODE	TIME	NODE	TIME	NODE	TIME	NODE	TIME
1	.00												
2	1.50	198	1.20	172	.80	194	.00	1	.00				
3	2.80	200	1.70	106	1.10	107	.50	71	.00	1	.00		
4	2.70	192	1.70	106	1.10								
5	3.40	203	2.30	108	1.00	71	.00						
6	4.90	180	3.50	174	2.70	197	2.30	175	1.70	198	1.20		
7	3.50	204	3.20	182	2.60	168	1.50	169	1.30	170	.70	195	.00
1	.00												
8	3.00	168	1.50										
9	4.00	208	3.70	174	2.70								
10	4.80	96	4.20	92	3.20	181	3.00	173	1.90	171	1.40	172	.80
11	4.00	163	3.70	164	3.30	166	2.20	169	1.30				
12	3.00	210	2.70	105	2.30	200	1.70						
13	3.60	118	3.30	119	2.60	113	2.10	192	1.70				
14	3.30	119	2.60										
15	2.00	159	1.70	114	1.50	107	.50						
16	3.20	121	2.40	115	1.90	108	1.00						
17	4.00	115	1.90										
18	4.00	129	3.70	128	3.00	121	2.40						
19	4.60	124	4.30	125	3.70	160	3.50	126	2.90	127	2.60	120	2.00
159	1.70												
20	5.20	212	4.40	134	3.60	126	2.90						
21	6.20	215	5.00	135	4.20	128	3.00						
22	6.60	157	5.80	142	5.40	215	5.00						
23	7.30	190	6.80	88	5.00	97	4.40	180	3.50				
24	6.00	185	5.00	179	4.00	178	3.90	177	3.10	176	2.40	175	1.70

Figure III-22.--Sample output of PR-50 (formatted destructive tree trace).

It is a difficult task to plot the tree from this listing. It requires searching the entire listing for the nodes and their various connections. Program PR-50 (Destructive Tree Trace), however, formats a tree in a manner that is more convenient for plotting. Here the tree is rearranged so that the listing forms a logical sequence from one node to another. For example, line two of figure III-22 is the trace from the "home" centroid (1) to centroid (2). Centroid 2, reading from left to right, is connected to node 198, 172, 194, and back to 1. The total elapsed traveltime from centroid (1) to centroid (2) is 1.50 minutes. The word destructive means that the duplicate traces are not printed for each routing.

7. Plotting and analyzing the selected trees.--Step 14 involves the manual plotting of the selected trees that have just been formatted. Each tree is plotted on a separate transparent overlay that is placed over the base map. Each link that appears on the trace is drawn on the overlay and the elapsed traveltime to the B node is recorded.

One of the selected trees is shown as figure III-23 for the sample city. Isochronal lines can be drawn on the selected tree traces showing the equal time contours. These contours may be compared to the traveltime data collected during the inventory. It is also possible to show the "drainage area" for particular sectors of the study area. These indicate how the traffic drains from corridors to the selected centroid.

The principal reason for plotting these selected trees, however, is for the examination of network coding errors and illogical routing. Each tree should be examined for faulty traces, jumpers, and other inconsistencies (see figure III-20). This is the last edit check prior to loading the network with the trips. If errors are encountered in this step, the flow diagram indicates that the errors are to be corrected by returning to point "B" (page III-15) on the flow diagram. If the network is free of errors, the process continues through the loading of the network.

The plotting of selected trees may reveal that, in some instances, the true minimum time path has not been determined. This condition is usually caused by the addition of turn penalties (signs and flags) and turn prohibitors to the network. This does not mean that turn penalties and prohibitors always force the computer to build a tree this way. However, the computed minimum time paths should be examined for illogical routings, and the turn penalties and prohibitors adjusted (added or removed) when necessary.

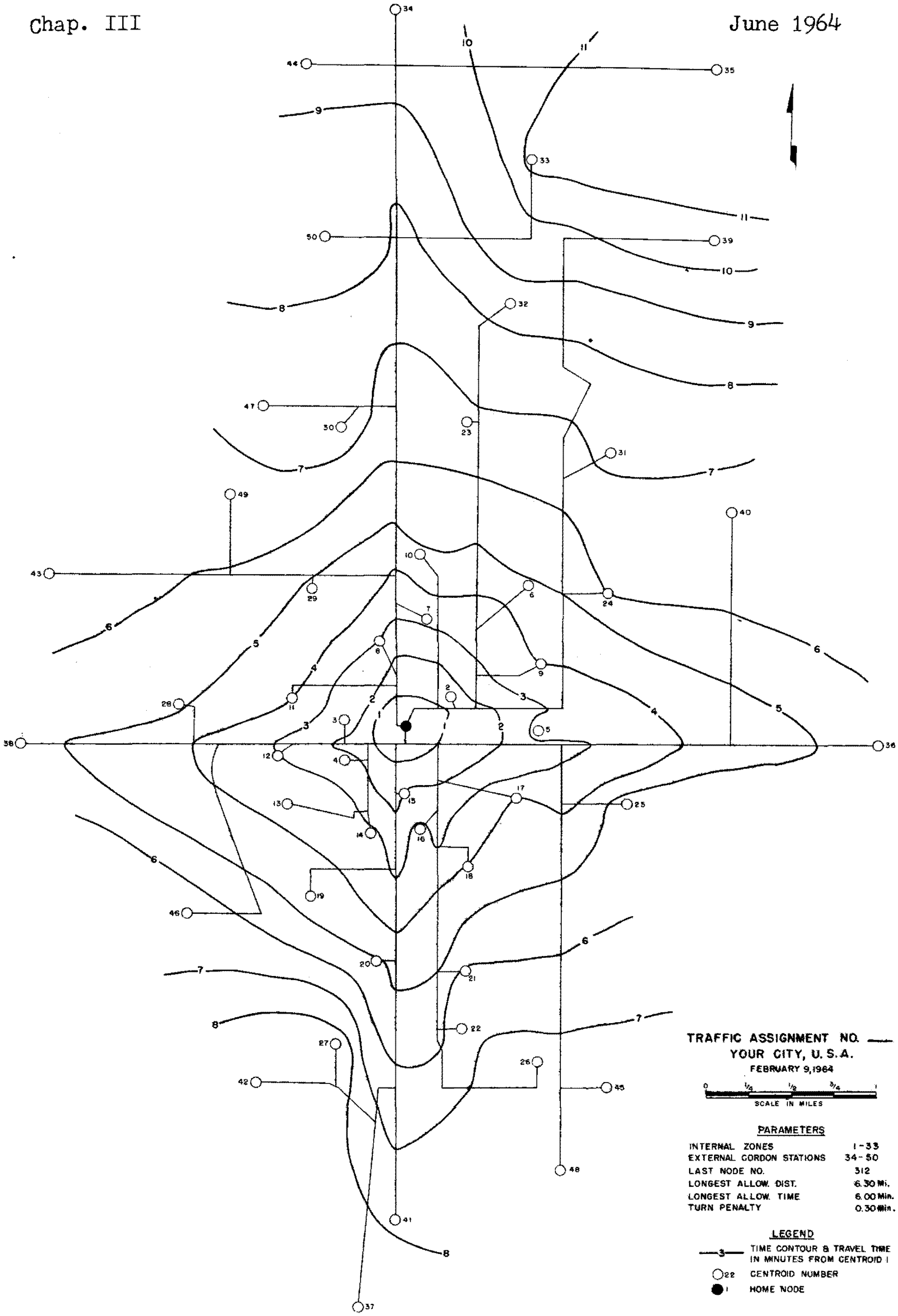


Figure III-23.--Sample plotted tree, Your City, U.S.A.

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

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

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

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

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

8. Building all trees.--Step 15 on the flow diagram is the building of all of the trees for the entire study area. There will be one tree for each centroid in the system. Program PR-1 (Build Trees) is used in this phase. This is the same computer program that was used to build the selected trees, but now all of the trees are selected. The input to this program is the binary network description on magnetic tape, and the output is the binary coded tree traces also on magnetic tape(s).

9. Loading the network (all-or-nothing).--At this point the program user has the option of loading the trips on the network by diversion or "all-or-nothing." If the all-or-nothing option is chosen, the trees are loaded with the trip volumes by program PR-2, Load Minimum Paths Directional. This program performs the operation of loading the trips on a minimum time routing between the point of origin and the point of destination for each individual trip transfer. The input to this program is the binary tree tape previously written by program

PR-1, the binary network description tape from program PR-6, and the binary trip volume tape that was discussed in section A of this chapter.

The output from this program is a binary loaded network tape (memory Z) and a trip length frequency distribution table written on magnetic tape in BCD form to be printed off-line. The trip distribution table gives the total volume of trips loaded on the network that are of equal length by one-minute intervals. The trip length frequency distribution for the sample city is shown as figure III-24.

As the computer reads the trip volumes when loading the network, the volumes are immediately divided by four to reduce the storage requirements for the link volumes in the computer. Immediately prior to writing the trip volumes, they are multiplied by four. Thus, all trip volumes will be in multiples of four on the printout. In this process, some rounding of the numbers will occur, accounting for some of the minor discrepancies in a loaded network.

By designating certain groups of numbers as centroids, arterial nodes, and freeway nodes, the computer is able to calculate a summary of vehicle-miles and vehicle-hours on the various types of facilities. The links are identified by the computer as belonging to each of these types of facilities as follows:

Local street	-	One arterial node and one centroid
Arterial	-	Two arterial nodes
Ramp	-	One arterial node and one freeway node
Freeway	-	Two freeway nodes

These summaries are further subdivided by jurisdictions. A sample of the summary of vehicle-miles and vehicle-hours of travel as produced by the load minimum paths program is shown as figure III-25.

The average trip length can readily be calculated by dividing the total vehicle-miles of travel by the number of trips assigned. Similarly, the average time of trip may be calculated by dividing the total vehicle-hours by the number of trips assigned. The total vehicle-miles and vehicle-hours are used for economic comparisons of alternate systems.

It is possible, as an option, to load the trips between one or more individual centroids to one or more of the other centroids in the system. The trip length feature of this program also allows the loading of the network with only the trips between specified upper and lower traveltime limits. For example, only those trips between five and ten minutes in length might be loaded.

TRIP LENGTH DISTRIBUTION ZONE-TO-ZONE LOAD MIN PATHS

ONE-MINUTE INCREMENTS

MINUTE INTERVALS	0	1	2	3	4	5	6	7	8	9	TEN-MINUTE T
--	--	896	6,816	10,680	8,652	9,480	6,536	5,596	3,700	3,560	55,916
10	3,584	1,452	996	416	140	--	--	--	--	--	6,588
20	--	--	--	--	--	--	--	--	--	--	--
30	--	--	--	--	--	--	--	--	--	--	--
40	--	--	--	--	--	--	--	--	--	--	--
170	--	--	--	--	--	--	--	--	--	--	--
180	--	--	--	--	--	--	--	--	--	--	--
190	--	--	--	--	--	--	--	--	--	--	--
200 OR MORE	--										--

Figure III-24.--Sample trip length frequency distribution.

SUM VOL + TURNS

SUMMARY OF VEHICLE-MILES AND VEHICLE-HOURS BY JURISDICTION

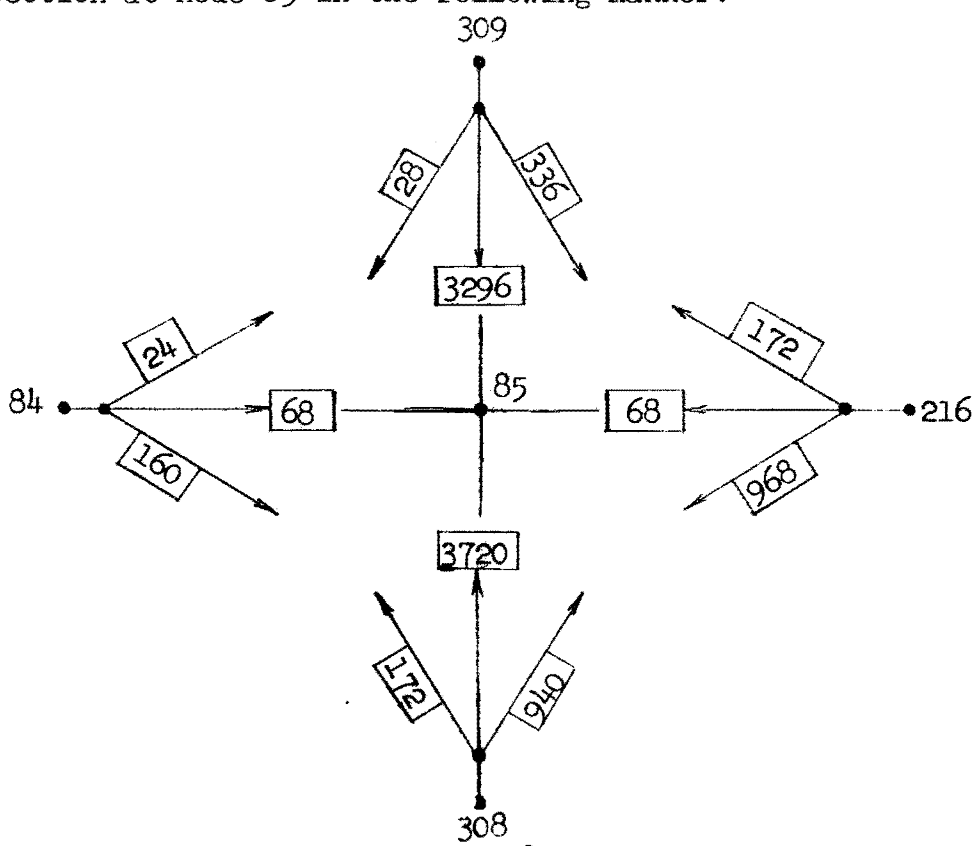
	LOCAL SYSTEM			ARTERIAL SYSTEM			RAMP SYSTEM			FREEWAY SYSTEM		
AREA	VEH-HR	VEH-MI	MPH	VEH-HR	VEH-MI	MPH	VEH-HR	VEH-MI	MPH	VEH-HR	VEH-MI	MPH
0	0	0	-	0	0	-	0	0	-	0	0	-
1	664	7651	11.52	0	0	-	0	0	-	0	0	-
2	0	0	-	4197	115604	27.54	10	653	65.30	0	0	-
3	0	0	-	0	0	-	0	0	-	0	0	-

Figure III-25.--Travel summary, Your City, U.S.A.

10. Sum volumes and turns.--After loading the network, the binary loaded network tape that has been produced must be converted for printing in a format that is suitable for analysis. The program that performs this function is PR-104, Sum Volumes and Turns. It is shown as step 21 on the flow diagram.

The output from this program is a listing of all the nodes in numerical order showing the traffic volumes assigned to every link emanating from each of the nodes. Also contained in this table is the number of trips assigned to each turn at each node, if they were requested. The BCD output of this program is illustrated as figure III-26 for the sample network. The A nodes are listed in the left-hand column and the outbound B nodes are listed in the four columns across the page. The corresponding assigned volume is listed along with the B node. When turns are involved, both the back node and the forward node are listed in the B node column, and the volumes that are indicated represent the movement from the back node through the A node to the forward node.

As an illustration, for A node number 85 the total assigned volume from node 85 to 309 is 3916 trips. From node 84 through node 85 to node 216, there are 68 trips. Similarily, from node 216 through 85 to node 308 there are 968 trips, and so on. Thus, all through movements and turning movements involved at the four-way intersection represented by node 85 can be read from the listing as produced by the sum volumes and turns program. The turning movements can be illustrated for the intersection at node 85 in the following manner:



ANODE	SUM VOL + TURNS BNODE	VOLUME	BNODE	VOLUME	BNODE	VOLUME	BNODE	VOLUME
79	(86)	992	(80)	140	(32)	532		
	(80- 86)	0	(80- 32)	0	(86- 32)	532		
	(86- 80)	140	(32- 80)	0	(32- 86)	992		
80	(309)	80	(81)	680	(79)	0		
	(81- 309)	80	(81- 79)	0	(309- 79)	0		
	(309- 81)	540	(79- 81)	140	(79- 309)	0		
81	(82)	44	(80)	80	(76)	504	(32)	948
	(32- 76)	408	(32- 80)	80	(32- 82)	0		
	(76- 80)	0	(76- 32)	408	(76- 82)	0		
	(80- 32)	540	(80- 76)	96	(80- 82)	44		
	(82- 76)	0	(82- 80)	0	(82- 32)	0		
82	(223)	324	(81)	0	(77)	432	(32)	144
	(32- 77)	60	(32- 81)	0	(32- 223)	80		
	(77- 81)	0	(77- 32)	60	(77- 223)	244		
	(81- 32)	0	(81- 77)	44	(81- 223)	0		
	(223- 77)	328	(223- 81)	0	(223- 32)	84		
83	(84)	228	(47)	236				
84	(85)	252	(83)	236	(30)	64		
	(83- 85)	212	(83- 30)	16	(85- 30)	48		
	(85- 83)	220	(30- 83)	16	(30- 85)	40		
85	(309)	3916	(308)	4424	(216)	1344	(84)	268
	(84- 216)	68	(84- 308)	160	(84- 309)	24		
	(216- 308)	968	(216- 84)	68	(216- 309)	172		
	(308- 84)	172	(308- 216)	940	(308- 309)	3720		
	(309- 216)	336	(309- 308)	3296	(309- 84)	28		
86	(223)	8	(216)	492	(190)	916	(79)	672
	(79- 190)	688	(79- 216)	304	(79- 223)	0		
	(190- 216)	92	(190- 79)	652	(190- 223)	4		
	(216- 79)	20	(216- 190)	228	(216- 223)	4		
	(223- 190)	0	(223- 216)	96	(223- 79)	0		
87	(223)	412	(189)	236				
88	(190)	1304	(98)	812	(97)	1092	(10)	584
	(10- 97)	0	(10- 98)	268	(10- 190)	320		
	(97- 98)	48	(97- 10)	0	(97- 190)	668		
	(98- 10)	264	(98- 97)	52	(98- 190)	316		
	(190- 97)	1040	(190- 98)	496	(190- 10)	320		
89	(189)	432	(99)	948	(98)	540		
	(99- 189)	408	(99- 98)	520	(189- 98)	20		
	(189- 99)	236	(98- 99)	712	(98- 189)	24		

Figure III-26.--Sample output of PR-104 (listing of assigned volumes).

11. Loading a network by diversion.--After step 15 on the flow diagram (figure III-8) where all of the trees were built for the network, the option was provided to assign the trips to the network by the all-or-nothing procedure or by diversion. An assignment by diversion requires that there be two routings for each interzonal movement. One route is via the arterial street system only, and one uses both the freeway facilities and the arterial street system. With two routings between centroids, a time ratio may be computed and a diversion curve consulted to determine the portion of the movement that is to be assigned to the links involved in the freeway facility routing and the portion to be assigned to the minimum path (quickest alternate) through the arterial street system. The theory for a diversion loading is discussed in detail in chapter V. The procedure for loading a network by diversion is discussed in this section.

The network and trees that were built in the preceding steps on the diagram should not have included the freeway system. For diversion loading, the freeways are now added to the network by coding and punching the freeway link cards and the necessary cards to alter the arterial street system as shown in step 16. Using the arterial network description as a base, it is now updated to include the freeway system. Again, the update portion of program PR-6 (Build and Update Network Description) is used. This is step 17 on the flow diagram.

All errors are eliminated from this new network description by repeating steps 9-15. As explained in the theory, freeway routings must be "forced" during the tree building process. The technique of forcing proposed facility usage may be accomplished by reducing the traveltime on the freeway links during the Build Network Description process. Reductions of 1/2 and 1/3 have been used. This time reduction on the freeway links has the effect of making the freeway facilities very attractive minimum path candidates. The freeway traveltime values are then restored to the original values after all trees have been calculated so that the proper traveltime will be used when the time ratios are computed.

At this point, two sets of trees have been produced; one by arterial routings and one with freeway routings. Program PR-3 (Load by Diversion) will read these two sets of trees, compute the time ratio between the traveltimes on the two sets of trees and, after consulting the diversion curve, load the required percentage of trips to each of the two routings. The output of this program is a binary tape containing the accumulated trip volumes on each link in a format identical to the output of program PR-2.

Step 19 is the translation of the binary loaded network to a readable form through the use of program PR-104 (Sum Volumes and Turns). This is done exactly the same as step 21 previously described.

Before deciding to load a network by diversion, one should investigate thoroughly the differences between the two methods; their advantages and disadvantages. Loading by diversion is considerably more costly than the all-or-nothing method because of the necessity of building two separate sets of trees. As the program is written now, the diversion of traffic is from the arterial to a freeway only, with no diversion possible between alternate arterials or freeways. However, the diversion method does result in an assignment which closely simulates the actual traffic pattern in the network. The diversion assignment technique can be operated under TEXAS control only, but the all-or-nothing method is available under either TEXAS or BELMN control. Presently, very few transportation studies are performing their traffic assignments by the diversion method.

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

The loading is analyzed by transferring the assigned volumes from the output of program PR-104 to a print of the network maps. This is a rather time-consuming procedure and, in practice, only the assigned volumes on the major facilities are investigated initially. If the assignment has been of existing traffic to the existing network, the assigned volumes may be compared with the ground counts. If not, the assigned volumes are compared to the capacities of the facilities.

Any errors found at this stage of the traffic assignment process should be corrected before continuing to the next step in the flow diagram (figure III-8, page III-15-18). The process should start again at point "B" in the flow diagram, and the indicated steps separated until all known errors have been corrected. If there are no errors, the user may now elect to restrain the assignment.

13. Restraining assignments.--In restraining a traffic assignment, adjustments are made to the link parameters (traveltime or speed) to account for factors other than traveltime in the choice of a route. Prior

to the adjustment of an assignment, the minimum time path was chosen strictly on the basis of an average speed on a link or a known traveltime. After adjustment, these traveltimes become a measure of travel impedance. If the assigned volume was low, the speed on the link is increased, making the route more attractive in the assignment process. If the link was overloaded, the speed is decreased (or traveltime increased) to make the link less attractive.

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

The manual restraint of a traffic assignment is simply a process of deciding what adjustments are necessary for the link parameters, coding and keypunching the necessary update cards, and revising the network description. Step 23 is the process of analyzing the previous traffic assignment and increasing or decreasing the appropriate link speeds and changing the parameters on the network map. The link parameters are revised on this map in accordance with the (assigned) volumes.

Step 24 is the coding and keypunching of the revised link data information corresponding to the adjustments made on the network maps. As before, the network adjustments may be made by either physically removing the link data cards from the card deck and substituting new ones, or by coding and keypunching the delete, change, and add cards. This was discussed in part 3 of this section. After the new cards are keypunched the procedure returns to step 9 on the flow diagram.

The process of revising the network is continued until the traffic assignment is satisfactory. It is evident that this manual restraining procedure may be very time-consuming and costly. If capacities are available for the links in the system, it is advisable to avoid these manual adjustments and allow the computer to make these adjustments automatically.

The capacity restraint procedure for adjusting a traffic assignment is a completely automated method of adjusting the network parameters. The theory of capacity restraint analysis is described in detail in chapter V.

To apply capacity restraint to a network, three IBM 7090/7094 computer programs are involved; PR-60, PR-61, and PR-63.

The capacity restraint process begins with the building of a historical record as indicated in step 25 on the flow diagram. Computer program <u>PR-60</u> (<u>Build Historical Record</u>) performs this function. The input to this program is a deck of link data cards which have the link capacities coded in columns 55-60, and volume counts in columns 61-66. Except for this, they are identical to the link data cards that were described previously. It is important to note that this deck of cards must be free of all errors before the capacity restraint analysis is begun. After initiating the analysis, there are no provisions for correcting network errors. The output of this program is a magnetic tape that is written in binary that will contain a historical record of the link parameters throughout the capacity restraint analysis.

As indicated in step 26, this historical record may be translated from binary to BCD for printing by program PR-63 (Format Historical Record). This program reads the binary tape containing the historical record into core storage, converts it to BCD information, and writes an output tape suitable for off-line printing. A sample of the output from this program is illustrated as figure III-27. This illustration is a historical record of four iterations of capacity restraint showing the changes that were made in the link parameters (speeds). The printing of a historical record at this point is, of course, optional.

Step 27 is the application of capacity restraint to the network description. In program PR-61 (Apply Capacity Restraint to a Network), the computer is instructed to read the previous binary loaded network tape, the historical record tape, and the corresponding network description tape and compare the previously assigned volume with the practical capacity for each link in the system having this information available. A ratio of the assigned volume to the capacity is computed, and the speed of the link is adjusted in accordance with a predetermined relationship (see chapter V - Theory).

Only those links in the system which have a recorded capacity will be adjusted. Those links for which no capacity is reported will not be adjusted in the capacity restraint process.

The program now writes a new binary network description on an output tape in binary. In addition, a new binary historical record tape is written which records the assigned volumes and speeds for those links that have been adjusted. These speeds will be used for the next trial loading. If the network is to be loaded by diversion, both the new freeway and arterial network descriptions are output from this program.

If the network is to be loaded by diversion, two sets of trees are built using the new network descriptions, and steps 15-18 are repeated. If an all-or-nothing assignment is to be used, steps 15, 20, and 27 are repeated. In effect, the complete loading process is repeated

HISTORICAL RECORD OF TRAFFIC ASSIGNMENTS   TEST CITY CALIBRATED NET 4 ITERATIONS CAP RES

		INPUT DATA					TRIAL 1			TRIAL 2			TRIAL 3			TRIAL 4			
NODE A	NODE B	COUNT	CAPACITY	DIST	TIME	SPEED	ASGND VOL	SPEED AT ASGND VOL	SPEED FOR NEXT TRIAL	ASGND VOL	SPEED AT ASGND VOL	SPEED FOR NEXT TRIAL	ASGND VOL	SPEED AT ASGND VOL	SPEED FOR NEXT TRIAL	ASGND VOL	SPEED AT ASGND VOL	SPEED FOR NEXT TRIAL	AVG ASGND VOL
175	197	980	3000	.08	.32	15.0	832	16.5	15.4	348	17.1	16.0	416	17.1	16.0	676	17.1	16.0	568
197	175	980	3000	.08	.32	15.0	936	16.5	15.4	392	17.1	16.0	588	17.1	16.0	1028	17.1	16.0	736
175	198	2000	1500	.13	.52	15.0	948	12.7	14.4	44	17.3	15.0	172	17.3	15.6	612	16.9	15.9	444
198	175	2000	1500	.13	.52	15.0	928	12.7	14.4	0	17.3	15.0	0	17.3	15.6	260	16.9	15.9	297
176	177	1100	1500	.25	.75	20.0	208	23.0	20.5	60	23.0	21.1	60	23.0	21.4	60	23.0	21.7	97
177	176	1100	1500	.25	.75	20.0	192	23.0	20.5	60	23.0	21.1	60	23.0	21.4	60	23.0	21.7	93
177	178	1220	2000	.20	.48	25.0	1248	20.3	23.5	1536	15.5	20.6	1132	23.0	21.0	1108	23.0	21.4	1256
178	177	1220	2000	.20	.48	25.0	1300	20.3	23.5	1532	15.5	20.6	1140	23.0	21.0	1140	23.0	21.4	1278
178	179	1550	2000	.06	.14	25.0	1312	20.0	24.0	1592	15.6	21.1	1188	22.5	21.1	1160	24.0	21.1	1313
179	178	1550	2000	.06	.14	25.0	1376	20.0	24.0	1576	15.6	21.1	1184	22.5	21.1	1184	24.0	21.1	1330
178	208	1290	2000	.25	.75	20.0	92	23.0	20.5	60	23.0	21.1	60	23.0	21.4	60	23.0	21.7	68
208	178	1290	2000	.25	.75	20.0	80	23.0	20.5	72	23.0	21.1	72	23.0	21.4	68	23.0	21.7	73
179	185	1390	2000	.42	1.01	25.0	1064	24.0	24.7	1144	22.9	24.2	940	25.4	24.4	884	25.9	24.7	1008
185	179	1390	2000	.42	1.01	25.0	1084	24.0	24.7	1124	22.9	24.2	956	25.4	24.4	928	25.9	24.7	1023
180	181	1200	1000	.23	.92	15.0	200	17.2	15.5	220	17.2	15.8	208	17.2	16.2	220	17.2	16.4	212
181	180	1200	1000	.23	.92	15.0	252	17.2	15.5	212	17.2	15.8	212	17.2	16.2	200	17.2	16.4	219
181	205	1200	1000	.08	.32	15.0	200	17.1	15.4	220	17.1	16.0	208	17.1	16.0	220	17.1	16.0	212
205	181	1200	1000	.08	.32	15.0	40	17.1	15.4	52	17.1	16.0	52	17.1	16.0	40	17.1	16.0	46
182	183	1200	1000	.10	.40	15.0	764	10.9	13.6	384	16.2	14.2	436	15.7	14.6	436	15.7	15.0	505
183	182	1200	1000	.10	.40	15.0	640	10.9	13.6	404	16.2	14.2	404	15.7	14.6	432	15.7	15.0	470
182	204	12980	12900	.15	.60	15.0	1480	17.3	15.5	2484	17.3	15.7	2336	17.3	16.0	2208	17.3	16.3	2127
204	182	12980	12900	.15	.60	15.0	1280	17.3	15.5	2860	17.3	15.7	1976	17.3	16.0	1372	17.3	16.3	1872
182	205	1200	1000	.15	.60	15.0	312	16.6	15.2	284	17.3	15.7	284	14.5	15.5	312	15.0	15.2	298
205	182	1200	1000	.15	.60	15.0	416	16.6	15.2	60	17.3	15.7	792	14.5	15.5	688	15.0	15.2	489
183	184	1200	1000	.05	.20	15.0	568	15.0	15.0	624	12.5	14.2	632	13.0	13.6	676	12.0	13.0	625
184	183	1200	1000	.05	.20	15.0	440	15.0	15.0	640	12.5	14.2	596	13.0	13.6	656	12.0	13.0	583
184	207	940	2000	.16	.64	15.0	108	17.1	15.4	80	17.1	15.7	88	17.1	16.0	224	17.1	16.2	125
207	184	940	2000	.16	.64	15.0	168	17.1	15.4	196	17.1	15.7	196	17.1	16.0	224	17.1	16.2	196
186	308	9580	12900	.90	2.16	25.0	1372	28.7	25.8	1592	28.7	26.4	1204	28.7	27.0	1444	28.7	27.4	1403
308	186	9580	12900	.90	2.16	25.0	1152	28.7	25.8	980	28.7	26.4	980	28.7	27.0	980	28.7	27.4	1023
193	202	700	1500	.36	1.08	20.0	652	18.4	19.6	744	20.1	19.8	664	20.7	20.0	484	22.5	20.5	636
202	193	700	1500	.36	1.08	20.0	1052	18.4	19.6	724	20.1	19.8	704	20.7	20.0	432	22.5	20.5	728
218	311	300	3700	.80	1.33	36.0	568	41.3	37.2	568	41.3	38.0	540	41.3	38.7	540	41.3	39.3	554
311	218	300	3700	.80	1.33	36.0	540	41.3	37.2	540	41.3	38.0	540	41.3	38.7	540	41.3	39.3	540

Figure III-27.--Sample output of PR-63 (historical record capacity restraint).

for each iteration of a capacity restraint, from building the trees through the loading of the network.

In practice, about four iterations of capacity restraint are necessary before the network can be considered satisfactory. There is a limit of nine iterations that may be performed for one network. During the process, summary information is written on an output tape showing the amount of adjustment that was made to the network. An examination of these summary statistics will indicate when the capacity restraint process should be terminated. Examples of the summary output are shown as figures III-28 and 29. Figure III-28 summarizes the speed adjustments by showing the number of links, by assigned volume-capacity ratio, that had positive or negative speed changes of a specified amount. In this illustration, 172 of the 428 links in the system were given a positive speed adjustment from one to two miles per hour.

Figure III-29 is divided into two sections. The top section of the page shows the statistics for a particular iteration of capacity restraint. The bottom of the page provides the same statistics as a summary of all previous iterations. The first entry is the comparison of the total assigned volumes on all of the links and the sum of the measured volume on the same links. Summary statistics are then reported for each volume group (in thousands of trips). In this example, the first line shows that there were 12 sections in the network that had an average ground count volume of 261 vehicles. For these 12 sections, the average difference between the traffic counts and the assigned volume was +425. In other words, the average assigned volume was 686. The standard deviation of the trips for these 12 sections was 558 which is 213.7 percent of the average count. The number of trips represented on these 12 sections is 0.6 percent of the total link-vehicles and, when weighted, 1.2 percent of the total weighted error.

In review, the capacity restraint process is an iterative type of procedure which may be terminated after any iteration. It is an automatic and reproducible method for making the network adjustments when balancing a traffic assignment.

After the determination has been made that the system is satisfactorily balanced, the historical record that contains the information for each iteration concerning the adjustments that were made to the link parameters should now be printed for a permanent record of the assignments via program PR-63. For a complete listing of all the assigned volumes and turning movements resulting from the last iteration of capacity restraint, the loaded network tape should be submitted to program PR-104 for a summary of the volumes and turns. This is step 31. It is an optional procedure in that the historical record gives the assigned volumes but without the

FOURTH ITERATION

DISTRIBUTION OF LINKS BY TRAFFIC VOLUME AND SPEED
NEW SPEED MINUS ASSIGNMENT SPEED, BY INTERVAL

VOL/CAP RATIO	NEGATIVE SPEED DIFFERENCE 10 UP	7-10	5-7	3-5	2-3	1-2	0.5-1.0	0.0-0.5	POSITIVE SPEED DIFFERENCE 0.0-0.5	0.5-1.0	1-2	2-3	3-5	5-7	7-10	10 UP	TOTALS NO SECT	AVG CAP	AVG LOAD
0.0-0.1	0	0	0	0	0	0	0	0	0	2	12	18	8	2	0	0	42	1721	84
0.1-0.2	0	0	0	0	0	0	0	0	0	0	14	20	8	2	0	0	44	2161	345
0.2-0.3	0	0	0	0	0	0	0	0	0	0	28	28	14	2	0	2	74	2820	735
0.3-0.4	0	0	0	0	0	0	0	0	0	3	31	18	2	2	0	0	56	2784	959
0.4-0.5	0	0	0	0	0	0	0	0	0	2	28	6	8	0	0	4	48	3383	1458
0.5-0.6	0	0	0	0	0	0	0	0	0	2	14	8	4	0	0	0	28	1493	814
0.6-0.7	0	0	0	0	0	0	0	0	2	2	16	4	2	0	0	0	26	1827	1188
0.7-0.8	0	0	0	0	0	0	0	0	0	4	12	4	0	0	0	0	20	2750	2027
0.8-0.9	0	0	0	0	0	0	0	0	2	7	11	0	2	0	0	2	24	1490	1260
0.9-1.0	0	0	0	0	0	0	0	0	6	8	2	2	0	0	0	0	18	1269	1194
1.0-1.1	0	0	0	0	2	2	2	2	2	0	0	0	0	0	0	0	10	1330	1387
1.1-1.2	0	0	0	0	4	0	0	2	0	0	4	6	0	0	0	0	16	900	1046
1.2-1.3	0	0	0	0	2	2	0	0	0	0	0	0	0	2	0	0	6	833	1057
1.3-1.4	0	0	0	2	0	4	0	0	0	0	0	0	0	0	0	0	6	750	1023
1.4-1.5	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	2250	3174
1.5-1.6	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	4	2125	3272
1.7-1.8	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	600	1068
1.8-1.9	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	750	1392
TOTAL	0	2	0	6	8	10	2	4	12	30	172	116	48	10	0	8	428	2220	958

Figure III-28.--Sample output of PR-61 (speed adjustments).

RESULTS OF FOURTH LOADING

TOTAL MEASURED VOLUME 564,385
TOTAL ASSIGNED VOLUME 410,164
AVERAGE PERCENT ERROR IN ASSIGNED VOLUME -27.3

VOL GROUP	NO. SECTS	AV COUNT	AVE DIFF	STAN DEV	PC STAN DEV	PC OF TOTAL	WEIGHTED
00-1/2	12	261	+ 425	558	213.7	.6	1.2
1/2-01	50	716	+ 161	694	96.9	6.3	6.1
01-02	69	1,364	- 219	805	59.0	16.7	9.8
02-03	28	2,423	- 147	1,793	73.9	12.0	8.8
03-05	27	3,480	- 780	2,433	69.9	16.7	11.6
05-10	16	7,182	- 2,566	4,043	56.2	20.4	11.4
10-15	13	11,885	- 6,616	7,824	65.8	27.4	18.0
TOTAL	215	2,625	- 717	2,396	91.2	100.1	66.9

TOTAL MEASURED VOLUME 564,385
TOTAL AVGD ASGND VOLUME 408,514
AVERAGE PERCENT ERROR IN ASSIGNED VOLUME -27.6

VOL GROUP	NO. SECTS	AV COUNT	AVE DIFF	STAN DEV	PC STAN DEV	PC OF TOTAL	WEIGHTED
00-1/2	12	261	+ 428	559	214.1	.6	1.2
1/2-01	50	716	+ 199	652	91.0	6.3	5.7
01-02	69	1,364	- 224	794	58.2	16.7	9.7
02-03	28	2,423	- 172	1,713	70.6	12.0	8.4
03-05	27	3,480	- 741	2,405	69.1	16.7	11.5
05-10	16	7,182	- 2,797	4,090	56.9	20.4	11.6
10-15	13	11,885	- 6,608	7,673	64.5	27.4	17.6
TOTAL	215	2,625	- 725	2,354	89.6	100.1	65.7

Figure III-29.--Sample output of PR-61 (volume comparison).

turns. Of course, the binary network description may be formatted at any time with program PR-12 (Print Link Data). This program, however, does not print the capacities or counted volumes on the links.

Step 32 may be considered as a final step in a complete traffic assignment. Here the result of the restrained traffic assignment is plotted on a copy of the base map and an illustration is prepared similar to figure III-30. If the assignment is unsatisfactory or requires additional adjustments, the process may be repeated by returning to steps 9, 24, or 27, depending upon the type of adjustments that are necessary.

After this point in a traffic assignment, many diagnostic options become available which facilitate the analysis of alternate networks or an evaluation of the system. These will be discussed in detail in the next section.

C. Analytical and Utility Computer Programs

Blocks 34-42 on the flow chart (figure III-8) represent some of the analytical and utility computer programs that are available at the completion of a traffic assignment. These programs are valuable for comparisons of traffic assignments on various systems and for the detailed diagnostics in system layout and design. As before, only the functions of the program will be discussed in this section. Before using any of these programs the program writeups should be carefully reviewed.

1. Load selected links.--Program PR-10 (Load Selected Links) is a very useful IBM 7090/7094 computer program. Extensive use of this program has been made in the past to analyze the assigned traffic movements on specific sections of a network.

As it is now written, the program has five options, but the purpose of each is about the same. In a selected link loading, an analysis is made of only those trips that would use a specific link or combination of links in a network. In addition, one option of the program provides for an analysis of only those trips whose minimum path trace passes through two or more selected nodes in a network. All of the trips that do not pass through the selected link or links (or the selected nodes) are disregarded in a selected link loading.

The five options provided in this program are listed below.

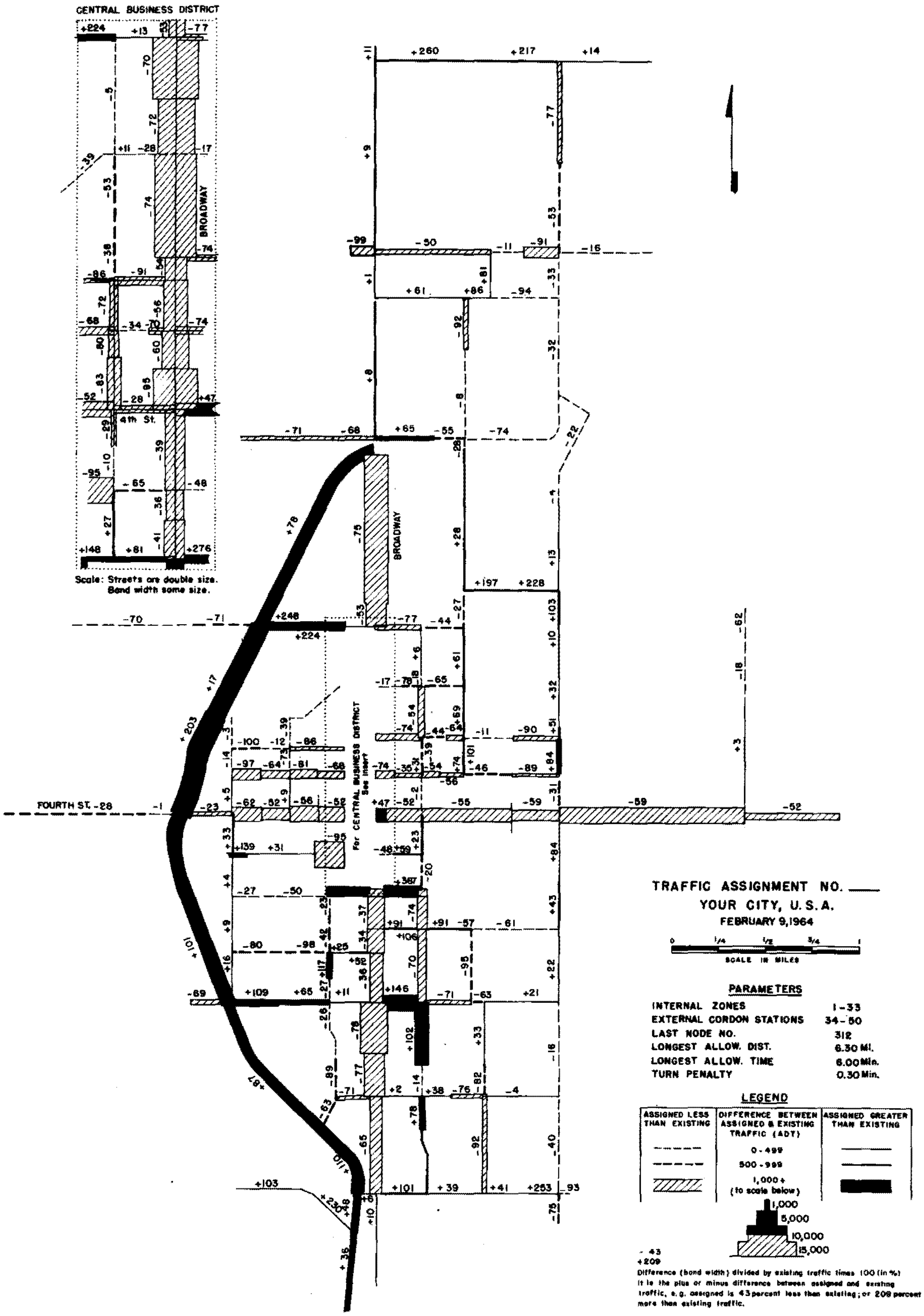


Figure III-30.--Comparison of assigned volumes to ground counts, Your City, U.S.A.

a. An output tape may be obtained, suitable for punching cards, that indicates the entrance to the selected link, the exit from the link, the origin and the destination of the trips passing through the link, and the volume of trips involved in that particular zone-to-zone movement. A sample of this output is shown as figure III-31.

b. Two or more selected <u>nodes</u> may be specified in the system and any trips whose trace passes through these nodes are loaded on the network.

c. Two different sets of trees may be submitted to the program and if a trip is found to pass through a selected link on one set of trees (or a pair of selected nodes) it is loaded on the alternate network.

d. A combination table may be built for each selected link showing the entry and exit link and the respective volumes.

e. A loaded network tape may be written using the original trees with only those trips using a designated selected <u>link.</u>

The use of program PR-10 is demonstrated for the sample city. A link on the bypass route (304-305) was chosen as the selected link and the results of the loading are presented in figure III-33. Only those trips whose minimum time path passed through the selected link were loaded on the network. The combination table showing the entry and exit link and the volume for the link is shown as figure III-32.

This program has recently been used in a bridge location study for a large metropolitan area. By using Option c (above) two sets of trees were built, one of which contained the proposed bridge in the network. The trips that would use the bridge (the selected link) were loaded on the network which did not contain the bridge. This analysis demonstrated very clearly the circuitous routings that would be necessary if the bridge were not provided.

This program will handle a maximum of 50 selected links in one pass of the computer. If more than one selected link is chosen, however, the output will not contain the individual loadings of each link that has been selected. It will be a combined loaded network which has all of the traffic volumes passing through all of the selected links. This may be of value, however, if those trips that pass through an entire route section are to be analyzed.

2. <u>Cost analysis</u>.--A travel cost computer program PR-17 (Compute Travel Cost) is available to compute any cost which can be expressed as a function of speed, typically, the operating cost, accident cost, and

Columns 1 and 2	Preceding link
Columns 2 and 3	Selected link
Columns 3 and 4	Succeeding link
Column 5	Origin zone
Column 6	Destination zone
Column 7	Trip volume

303	304	305	306	41	23	20
303	304	305	102	41	28	4
303	304	305	306	41	29	4
303	304	305	306	41	32	8
303	304	305	306	41	33	8
303	304	305	306	41	34	132
303	304	305	306	41	35	12
303	304	305	102	41	38	20
303	304	305	306	41	39	4
303	304	305	306	41	47	4
303	304	305	104	42	1	28
303	304	305	104	42	2	4
303	304	305	306	42	10	4
303	304	305	306	42	23	4
303	304	305	102	42	28	4
303	304	305	306	42	34	4
156	304	305	306	46	7	4
156	304	305	306	46	10	4
156	304	305	306	46	24	4
156	304	305	306	46	34	4
306	305	304	132	47	19	8
306	305	304	132	47	21	12
306	305	304	303	47	22	4
306	305	304	303	47	37	12
306	305	304	303	47	41	4
303	304	305	306	48	7	4

Figure III-31.--Sample output of PR-10 (selected link loading)

Column 1	Entrance node
Column 2	Exit node
Column 3	Total volume using this path

COMBINATION TABLE FOR LINK 304 TO 305

132	102	156
132	104	0
132	306	1008
156	102	0
156	104	0
156	306	16
303	102	92
303	104	384
303	306	1960
102	132	156
102	156	0
102	303	128
104	132	0
104	156	8
104	303	28
306	132	1000
306	156	16
306	303	1984

Figure III-32.--Combination table from PR-10.

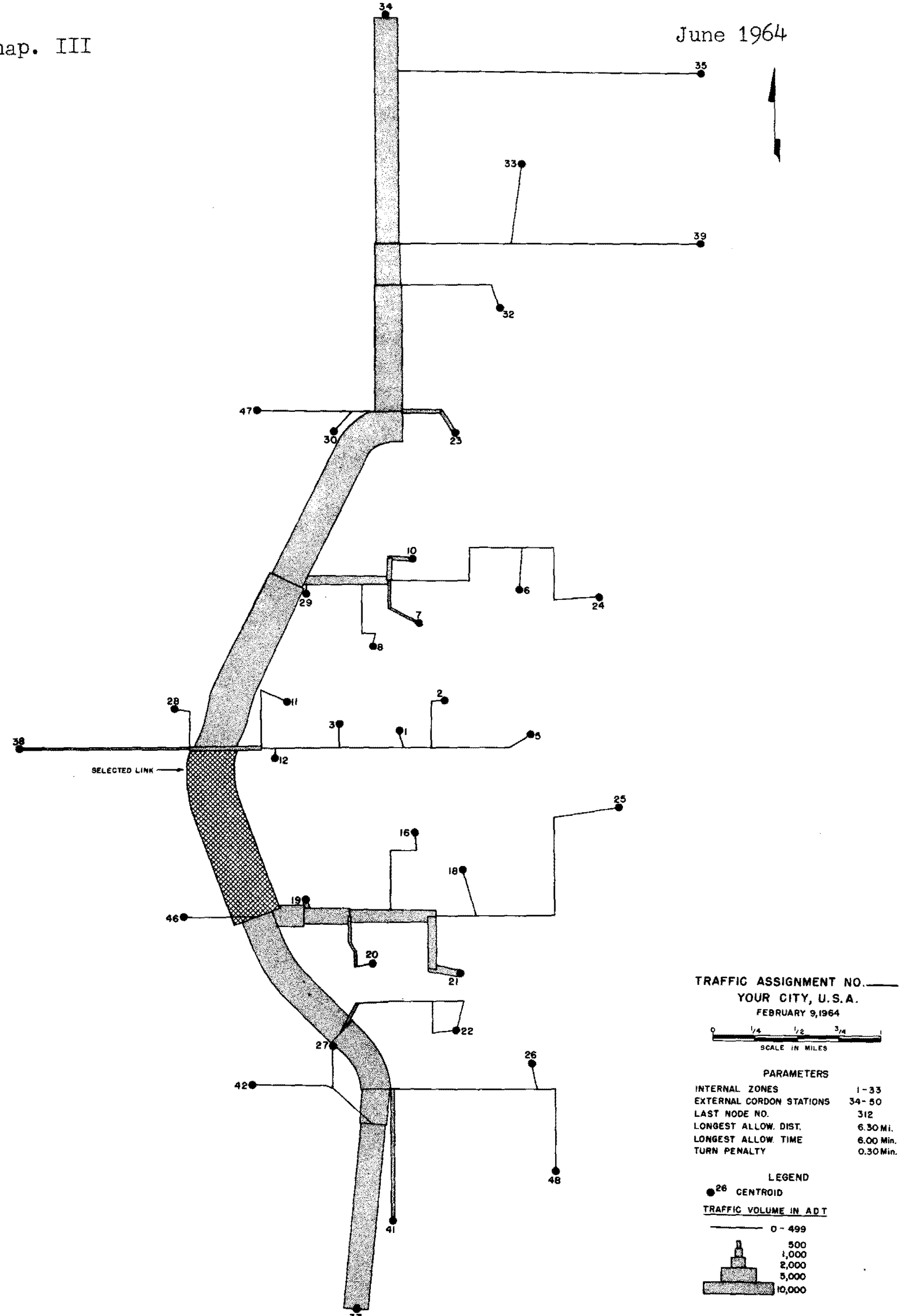


Figure III-33.--Selected link diagram, Your City, U.S.A.

time cost for each type of facility by jurisdiction in the study area. The method employed is similar to that reported by G. Haikalis in HRB Bulletin 306. Briefly, this program reads the network description and the loaded network tapes and calculates the speeds on each link while retaining the distance, traveltime, volume, jurisdiction, and system subdivision. The travel cost data is given to the computer in control cards for each speed interval. Ordinarily, the cost data are furnished for speeds ranging from 5 to 63 m.p.h. The cost may vary with speed or be constant depending upon the type of analysis being conducted.

After reading the cost values on the control cards, the computer makes a link by link determination of travel cost by multiplying the cost factor times the length of the link and times the number of vehicles using the link. When all of the links have been analyzed, the cost of travel totals are converted to BCD and printed. The computer then reads the next set of control cards and prepares the next table.

The output from this utility program will yield values which may be used in conjunction with other cost data to derive benefit-cost ratios.

3. Skim trees and format.--The IBM 7090/7094 computer program PR-130 (Skim and Update Trees) builds a binary tape which contains the elapsed traveltime from all centroids to all other centroids. It is similar in format to a binary memory J (trip table) except that trips are replaced by traveltimes rounded to whole minutes. The tape is produced by copying only the first part of the total tree record from a tree tape. The output of this program is one of the inputs to the gravity model trip distribution program that is discussed in a companion manual (58).

This program also provides for revising a set of skim trees by either replacing, adding, or subtracting given values from any of the cells in the record. Thus, the terminal times, and the intrazonal traveltimes may be inserted into the skim tree record by the update portion of this program.

A companion program to PR-130 is program PR-13 which has been discussed in section A of this chapter. Program PR-13 will read a skim tree tape and write a BCD output tape suitable for printing off-line. This provides a printed output which shows the skimmed traveltimes similar to a square trip table. Any or all of the centroids may be selected for printing.

4. Load selected zone-to-zone movements.--The option of loading only those trips from selected origins to selected destinations is provided by program PR-2 (Load Minimum Paths Directional). This option in the loading program is exercised by control cards submitted to the computer when the program is being performed.

This is a valuable diagnostic tool for the analysis of specific movements between portions of study area. For instance, only those trips to and from the central business district may be separately loaded to a network. Only origins can be selected for loading under the BELMN version of PR-2, but both origins and destinations can be selected under the TEXAS version.

5. Another useful option incorporated under both versions of PR-2 (Load Minimum Paths Directional) is the loading of only those trips of a selected time length. Again, this is an option that is exercised by the submission of a control card to the computer.

This option of the program is valuable in determining the location of very short trips loaded on the high-type facilities, or long trips assigned to arterial streets.

6. Another useful analytical program is program PR-124 (Trip Comparison Program). This program will:

a. Make a comparison of two binary trip tables.

b. Compare the link volumes of two loaded networks.

c. Prepare a table of differences for either of the two inputs mentioned above by 16 volume groups that are each divided by 32 difference groups. In addition, the mean difference, the standard deviation, the sum of the squares of the differences, and the total number of trips involved are printed for analysis.

Figure III-34 illustrates the output of a link by link comparison of two loaded networks that is typical of this program. Figure III-35 is a sample of the statistical information provided by this program for a particular volume group (200 to 299 trips).

Program PR-124 has been found very useful for comparing synthetic trip distributions to the measured trip interchanges. The volume groups and the difference groups may be designated by the program user.

7. Nondirectional converter.--It may not always be necessary to analyze a traffic assignment where the assigned volumes are reported by direction of travel. In a standard directional assignment, the total volume on a two-way segment of the network is determined by manually adding the volumes in both directions. Unfortunately, these two volumes are usually located in two different places on the listing. The person who is posting the assigned volumes is required to perform the extra steps of locating the directional volumes in the printout, adding the two, and then transferring the results to the traffic assignment map.

TABLE 1 - COMPARISON OF LINK VOLUME

NODE	NODE	O-D VOLUME	G-M VOLUME	DIFFERENCE
13	15	52	96	44
13	1017	60	28	-32
14	13	4	36	32
14	17	540	444	-96
14	134	580	684	104
14	1014	1,508	1,156	-352
15	13	464	488	24
15	16	11,876	14,924	3,048
15	38	3,744	3,940	.196
15	1015	12,888	14,304	1,416
16	15	12,684	15,028	2,344
16	1017	1,400	3,916	2,516
16	1019	2,592	3,088	496
17	14	532	356	-176
17	133	1,668	4,028	2,360
17	1017	5,952	8,364	2,412
17	2017	584	416	-168
18	20	2,560	2,436	-124
18	138	872	832	-40
18	140	1,528	2,320	792
19	20	1,928	1,932	4
19	25	1,028	1,364	336
19	140	1,200	1,472	272
19	1019	9,864	9,844	-20
20	18	3,196	3,872	676
20	19	4,084	3,820	-264
20	26	3,188	2,616	-572
21	22	1,728	1,308	-420
21	30	2,844	2,920	76
21	55	3,472	2,988	-484
21	2058	1,468	636	-832
22	21	1,036	464	-572
22	23	3,028	2,556	-472
22	1022	16,196	16,252	56
22	1030	3,856	3,456	-400
23	22	2,208	1,696	-512
23	36	10,740	11,584	844
23	39	7,148	5,804	-1,344
24	25	2,080	1,872	-208
24	39	11,884	10,844	-1,040
24	1028	2,648	1,712	-936
24	1030	2,872	1,700	-1,172
25	19	576	704	128
25	24	5,544	5,940	396
25	27	2,176	1,988	-188
25	38	2,556	1,880	-676

Figure III-34.--Sample output of PR-124 (link comparison output) Part 1.

TABLE 2 - FREQUENCY DISTRIBUTION AND ANALYSIS OF DIFFERENCES

VOLUME GROUP 200 TO 299

DIFFERENCE	FREQUENCY	SUM OF DIFFERENCES
-10000 AND UNDER	0	0
-7000 TO -9999	0	0
-5000 TO -6999	0	0
-4000 TO -4999	0	0
-3000 TO -3999	0	0
-2000 TO -2999	0	0
-1000 TO -1999	0	0
-800 TO -999	0	0
-600 TO -799	0	0
-500 TO -599	0	0
-400 TO -499	0	0
-300 TO -399	0	0
-200 TO -299	0	0
-100 TO -199	2	-242
-50 TO -99	17	-1,156
0 TO -49	56	-1,106
0 TO 49	42	718
50 TO 99	15	1,144
100 TO 199	5	630
200 TO 299	2	412
300 TO 399	0	0
400 TO 499	0	0
500 TO 599	0	0
600 TO 799	0	0
800 TO 999	0	0
1000 TO 1999	0	0
2000 TO 2999	0	0
3000 TO 3999	0	0
4000 TO 4999	0	0
5000 TO 6999	0	0
7000 TO 9999	0	0
10000 AND OVER	0	0
------	------	------
TOTALS	139	400

MEAN DIFFERENCE = 3

STANDARD DEVIATION = 54

SUM OF SQUARES = 420,262

TOTAL O.D. TRIPS = 34,063

TOTAL G.M. TRIPS = 34,463

Figure III-35.--Sample output of PR-124 (link comparison output) Part 2.

When directional volumes are not required, program PR-131 (Nondirectional Converter), may be used to produce a nondirectional listing of the assigned volumes. This IBM 7090/7094 computer program reads the binary loaded network tape from a directional assignment and adds the assigned volumes for both directions of the two-direction segments. It disregards all one-way street segments. The program writes a new binary loaded network tape which may be submitted to program PR-104 for the BCD listing.

This is not a nondirectional traffic assignment, but is a conversion of a directional assignment to a nondirectional loading. For a truly nondirectional loading, a triangular trip table is loaded to a nondirectional network. The computer programs that are necessary to perform a nondirectional traffic assignment have not been converted from the IBM 704 to the IBM 7090.

8. Extract zone-to-zone distances via trace.--The IBM 7090 computer program, PR-19 (Extract Zone-to-Zone Distances via Trace), produces, in effect, a binary square table of the distances between all zones over the minimum time path. The distances will be reported in tenths of a mile. The input to program PR-19 are the binary network description and the binary trees. The output is a binary tape that is in a format similar to a memory J or skim tree tape.

At the moment, the practical applications for this program are limited, but it definitely has value in research applications. For statewide networks, it would be valuable in determining the travel distances between urban areas for the State.

The reader should be aware of the distinction between this program and another operation that builds minimum distance trees. To build minimum distance trees, an option in program PR-1 (Build Trees) is invoked. The program is instructed to calculate a set of trees using the distance between the nodes as the parameter rather than the traveltime. Minimum distance trees also have applications for research.

9. Convert memory A to link data cards.--Program PR-83 (Convert Memory A to Link Data Cards) is used to produce a deck of link data cards from a binary network description. The program reads the binary network description from tape and produces a new BCD tape with the card images that may be transferred to punch cards on peripheral equipment.

It should be noted that the link data cards produced by this program will not contain the capacity or volume count information even though it may have been punched in the original link data cards. The binary network description does not retain this information in the record. To punch a deck of link data cards that does retain the capacity and volume data requires a program to convert the binary historical record to cards. There is a program available to do this at the present time, but the output does not give signs, flags, and jurisdiction.

This program has been found useful when a new link data card deck is required after several updates. It may also facilitate the process of performing a major network update.

Only those analytical and utility computer programs that have a direct application in the traffic assignment process have been discussed in the preceding paragraphs. There are many other programs available that are not directly associated with a traffic assignment, but may be useful for transportation system planning. These will be discussed in chapter IV, Additional Information and Applications.

D. Analysis and Presentation of the Results

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

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

(1) Are they existing or forecasted trips?

(2) For which year?

(3) Total daily or peak period movements

(4) The type of trips - total vehicles, work trips only, transit trips, etc.,

(5) For which land use plan?

(6) Other identifications.

Concerning the network, the following information should be included:

(1) Is it an existing or forecasted network?

(2) Representing which year?

(3) How was the loading performed - all-or-nothing, diversion, restrained, etc.,?

(4) A total daily or peak hour system

(5) Any specific links that were tested

(6) "System" numbers - It has been found useful to distinguish different transportation networks used in the assignment process by successive "system" numbers, even though the differences between networks may be small. The system number can then be used to identify link data cards, computer on-line and off-line output, network maps, and traffic volume maps. The differences between systems should be clearly identified.

(7) Other details.

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

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

Some conversion of the output from the traffic assignment process is usually necessary. Recognizing that the accuracy of the traffic assignment is limited, the final reporting of the assigned trip volumes should be rounded to the nearest hundred trips in a normal situation. This is, of course, at the discretion of the program user. If design-hour traffic volumes are required from the assignment, the conversion of the assigned volumes to either a 30th highest hour or a peak-hour should be done before rounding unless peak-hour trips were assigned directly (see chapter IV, section E).

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

Perhaps a more useful illustration would be to compare the assigned traffic volume to the capacity of the segment and record the percent usage of the capacity. To avoid a misrepresentation, however, either the capacity or the assigned volume must also be shown. Figures III-30, III-36, and III-37 are examples of traffic assignment illustrations.

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

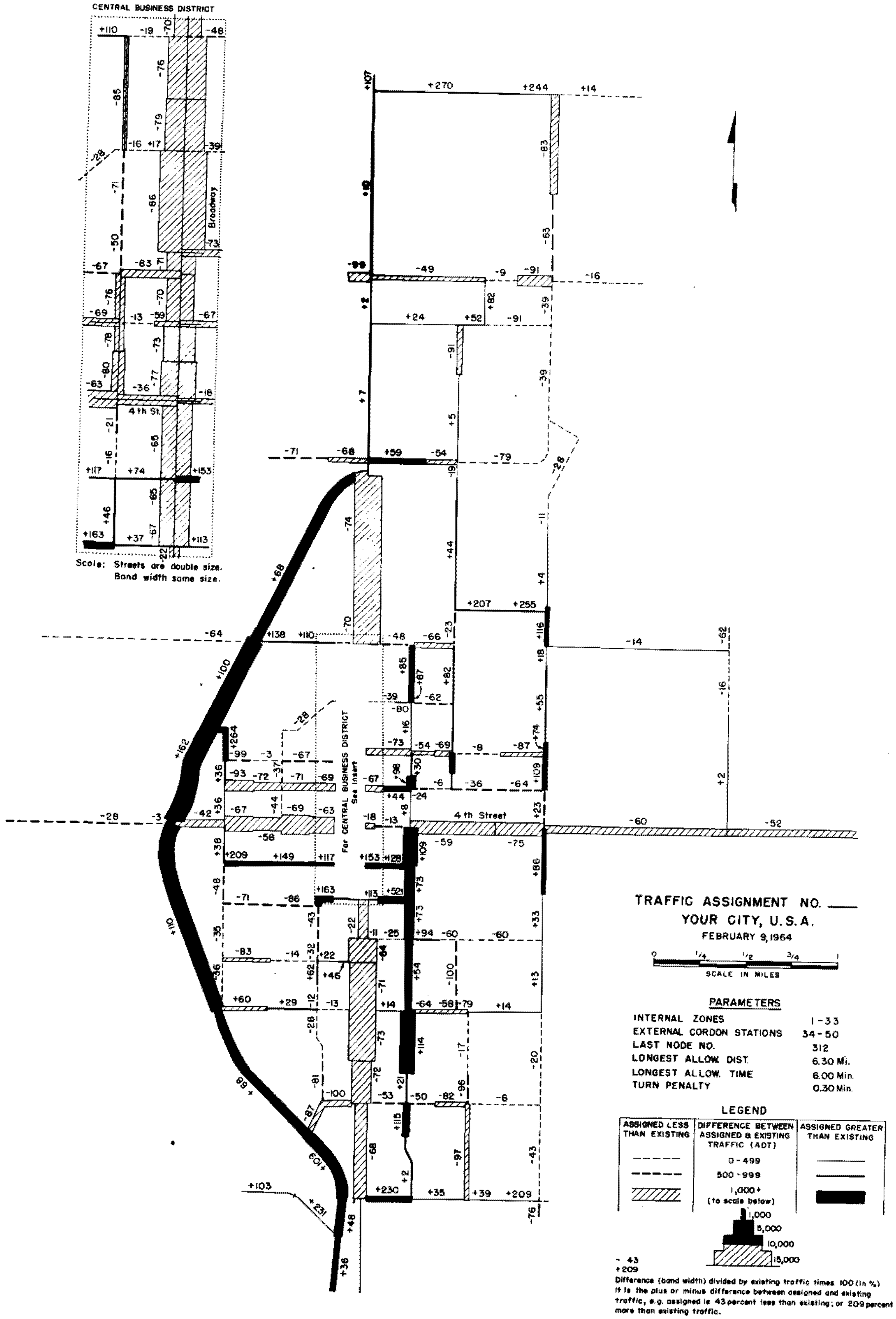


Figure III-36.--Plot of volume/capacity ratios on network, Your City, U.S.A.

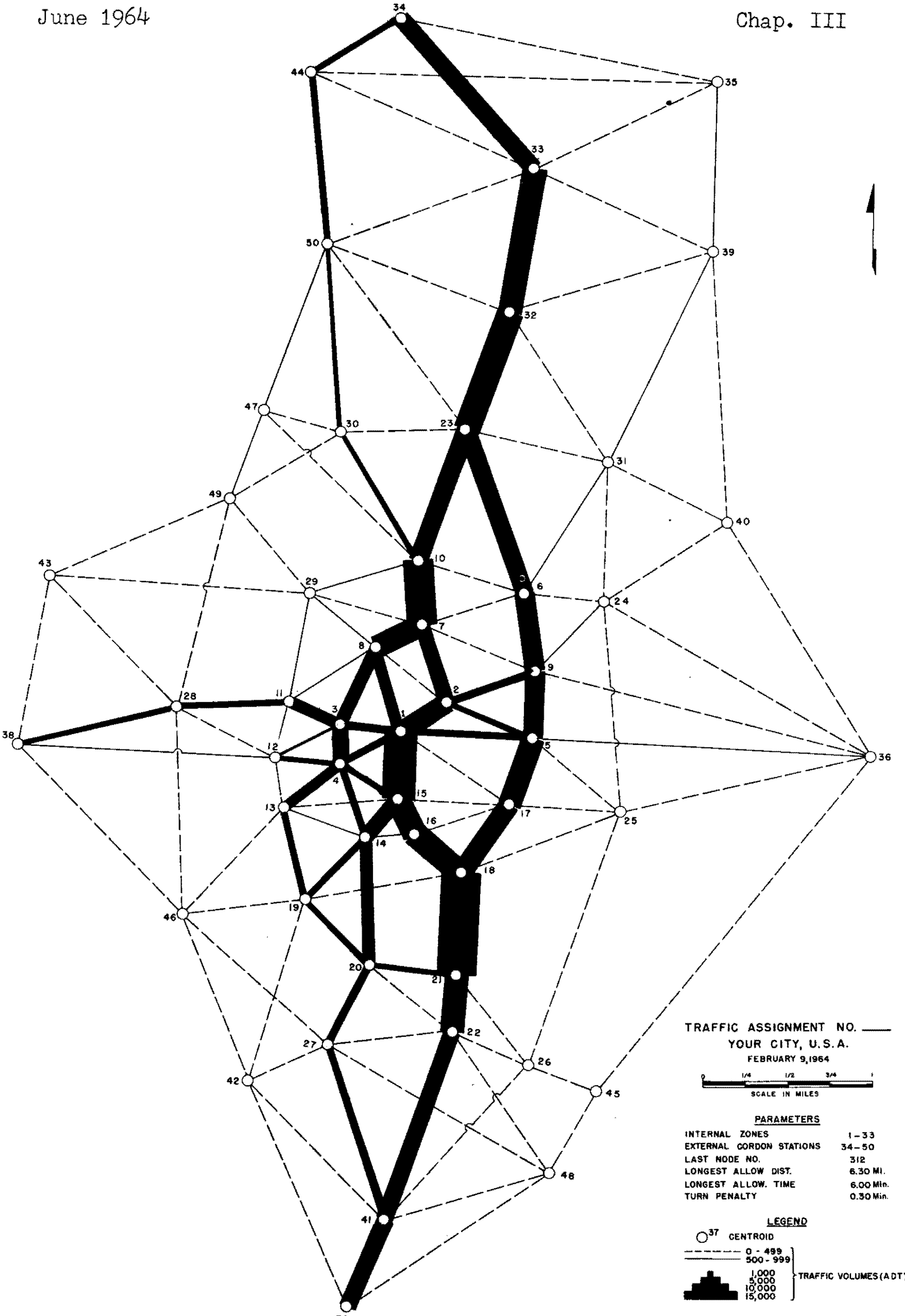


Figure III-37.--Loaded spider network map, Your City, U.S.A.

This chapter has been included in the manual to provide a location for the miscellaneous information regarding the assignment of traffic. Each section of the chapter contains a completely separate discussion about one peripheral element of traffic assignment.

After a discussion of some other techniques that are currently being used for traffic assignment, various types of networks are described in sections B, C, and D. The conversion of an assignment to design-hour volumes is discussed in section E, followed by a short review of systems analysis.

The remainder of the chapter is devoted to the additional considerations of traffic assignment such as cost, accuracy, staff requirements, technical assistance, etc.

A. Other Traffic Assignment Procedures

Several other traffic assignment procedures are currently in use, and like the concepts presented in this text, they incorporate the traffic assignment process as a portion of the complete planning operation, including trip estimation and distribution. This and the trip loading procedures could be considered the principal differences between the methods. Brief resumes of these concepts are given in the following paragraphs.

1. Chicago Area Transportation Study approach (63).--In addition to incorporating the traffic assignment process and the trip distribution procedure in one computer program, this approach has another unique feature, i.e., the application of the capacity restraint technique is not an iterative process.

Traveltime is again used as a measure of travel resistance. The highway or transit network is coded in a manner similar to that described in this manual. Turns are permitted at any node but are not computed and recorded. Additional nodes may be inserted at intersections where turning movement volumes are required.

The procedure for this type of assignment is as follows:

a. A minimum traveltime path (tree) is constructed from an origin zone to all other zones.

b. The interzonal trips from this zone are accumulated in the computer on the network links as indicated by the tree.

c. The accumulated volumes on each link are then compared with the capacity of that link. Adjustments are made to the traveltimes from the predetermined relationship between traffic volumes, capacity, and traveltime, and the network description is updated.

d. The next minimum traveltime path tree is then constructed and the process repeated.

Thus, by relating the assigned volume to the link capacity, the network adjustments are made <u>during</u> the calculation of the trees. To minimize the bias in network loading, the zones to be loaded are selected "at random."

2. <u>Metropolitan-Toronto Planning Board approach</u>.--There are five stages in this procedure:

a. Trip generation

b. Route generation

c. Trip distribution

d. Vehicle assignment

e. Traveltime calculation

The procedure may be summarized as follows: An initial generation produces the total number of trips originating in each zone. The initial trip distribution, route generation, and vehicle assignments are then computed on the basis of an ideal traveltime. After the first loading of a network, a new traveltime between all zones is calculated using a relationship between traveltime and volume. A new route generation, trip distribution, and vehicle assignment is then made on the basis of the new traveltimes. Once again, the capacity function is used for adjusting the traveltime and the complete process repeated for a series of iterations until the total number of vehicle-hours in the system becomes constant.

The network is also described by a series of nodes and links. Each link may be defined by three variables--the length, the number of lanes, and the parameter indicating the function to be used in determining the capacity.

Routes are generated using the minimum traveltime path principle by means of a modified form of the Moore Algorithm (see chapter V). The link traveltime depends upon the stage reached in the assignment. Initial traveltimes are "ideal," but for successive trials, the traveltimes are defined by the capacity restraint formulation. In this assignment program, the capacity restraint feature has three distinct effects.

a. The trip distributions by the gravity model are repeated using traveltimes adjusted by the volume actually using each link.

b. The minimum traveltime paths are changed to reflect the new traveltimes, adjusted by the volume actually using each link.

c. Trips may be assigned to only one or as many as four routes between the origin zone and all other zones.

3. Trip length approach.--Another procedure is based on the premise that the longest trips should be loaded to the network first. As the loadings increase, speeds are adjusted in the same manner that has previously been discussed. Thus, shorter trips are not loaded on the high-volume facilities if the longer trips load them to the point where speeds become unattractive.

B. Transit Networks

The traffic assignment procedure described in this text is readily adaptable, with minor adjustments, to transit network assignments. That is, the minimum path is calculated and the predetermined zone-to-zone movements are loaded and accumulated to obtain the total assigned volume for each link.

There are several problems in representing travel in a network which are unique with transit. For example, there is the problem of accounting for transfers from one transit line to another or from one vehicle to another. Another difficulty is accounting for persons who drive or ride in an automobile to a transit station and "change mode" to become transit riders. Finally, there is the problem of assessing walking and waiting times at the beginning and end of a trip.

One method of handling these problems is by inserting artificial links into the network. To account for waiting time due to transferring, an artificial link may be inserted between the two transit lines at points where transfers are allowed. The traveltime for this link is equal to the estimated waiting time, usually considered as one-half of the headway of the line transferred to. To transfer from one line to another, the trip is routed over the transfer link and absorbs the time penalty equivalent to the transfer time.

To account for walking and waiting at each end of the trip, an artificial link is sometimes inserted into the network connecting each centroid to the transit system. The traveltime for this link is equal to the estimated walking and waiting time at each end of the trip. To get into and out of the network the trips must use these links, thus absorbing a traveltime equal to the walking and waiting times at the trip terminals. The trips to rapid transit stations in passenger cars may be handled in a similar manner. Again, artificial links may be created, linking the zone centroids to the rapid transit stations in the appropriate areas. By this device, persons from certain zones where no transit service is provided are allowed to use the transit system. The accumulated person trips on these artificial links represent those persons who drive, ride as automobile passengers, or ride buses to rail transit stations.

Usually, the bus and rail systems are represented as one integrated network. The traveltime (or speed) on the links should reflect the acceleration and deceleration time requirements and a representative speed limit. To represent the more complex systems where express bus or rail facilities are utilized, separate network routings must be coded for this situation, limiting the access along the route.

These techniques should provide the person trip loads for a complete network of bus and rail transit facilities for any system configuration.

C. Analysis (Spider) Networks

An analysis or "spider" network for an urban area is illustrated as figure IV-1. A loaded spider network was illustrated previously as figure III-36. This simplified network is a series of direct connections between centroids. It is used for analytical purposes during the development of synthetic trip distribution models. It may also have other uses such as the comparison of trips crossing arbitrarily selected screenlines.

These networks are coded exactly the same as the more traditional networks described in this text, except that a constant speed is coded for all links, usually 30.0 m.p.h. All of the basic limitations and requirements still apply. Another difference is in the tree building process. During normal tree building, the minimum time paths are not permitted to be routed through centroids. For this type of network, however, the trees must be routed through the centroids. To permit a minimum time path to be routed through a centroid, an option is provided in program PR-1 (Build Trees).

The loading of the trip matrix to a spider network will produce a trip desire-line illustration as the trips between two centroids are

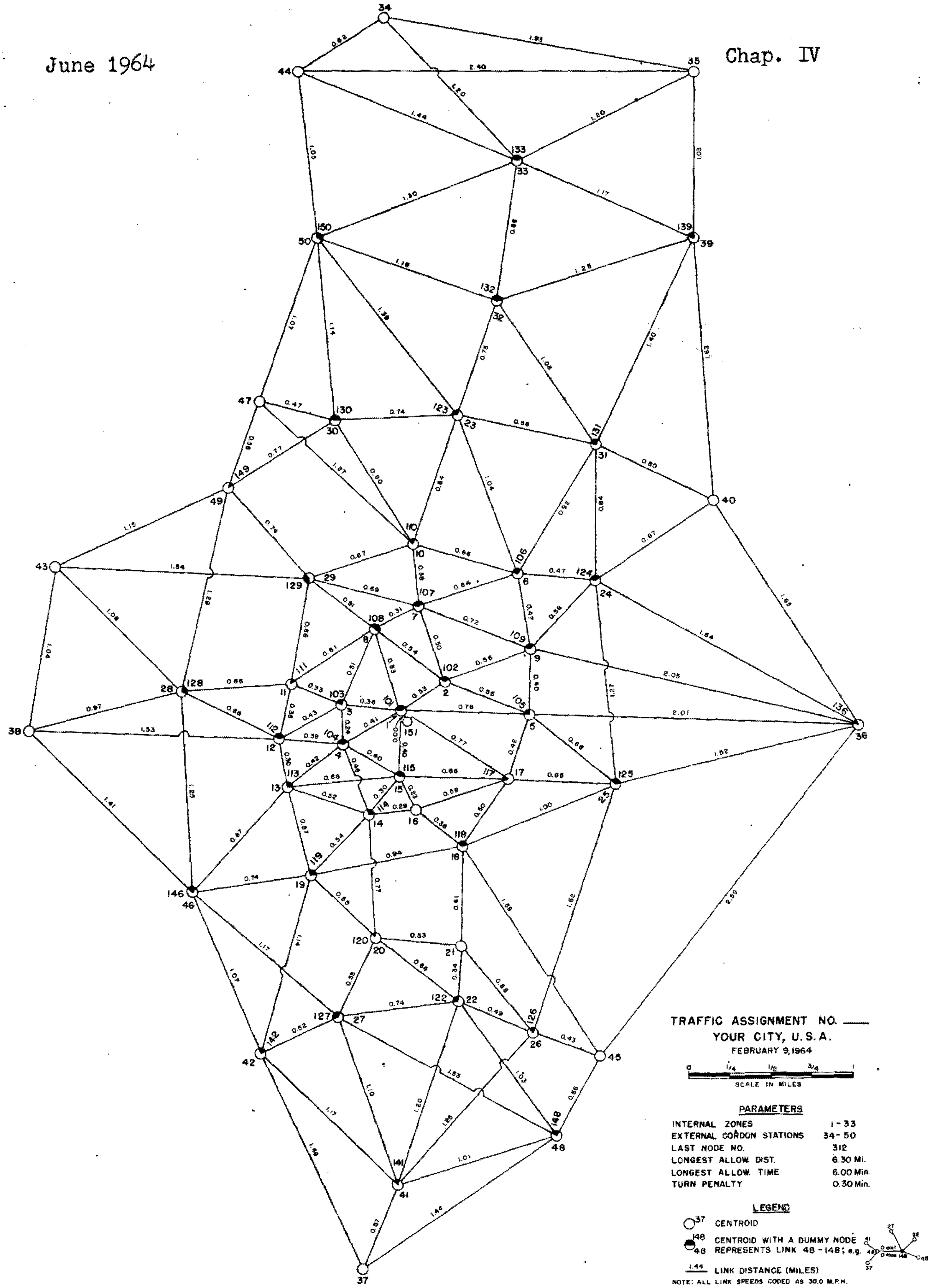


Figure IV-1.--Analysis (spider) network.

routed on a path that is essentially a straight line. Thus, the preparation of the desire-line charts are greatly facilitated by loading an analysis network. See figure III-37, page III-81.

D. Truck Networks

In several metropolitan areas, large numbers of automobiles are carried on parkways on which trucks are prohibited. Conversely, through truck routes are generally established and their use is encouraged for truck traffic. In this situation, it may be desirable to assign truck trips separately to a specially modified truck network. It would then be possible to obtain a truck network loaded with trucks only. This loading could also be added to the network loaded with auto trips.

E. Statewide Networks

Some States have recently shown an interest in applying these traffic assignment techniques for the analysis of statewide transportation systems. The coding of a statewide network should proceed exactly the same as a network for an urban area. All of the limitations and requirements of the procedure would remain in effect for a statewide network. The limit of 4,000 nodes and 999 centroids may not be adequate to describe the entire highway network. Usually, all of the Interstate System, all of the primary system, and some of the secondary system can be defined, provided the State lines form the boundary for the study area.

The maximum link distance of 9.99 miles may be troublesome when coding such a gross system. It would be possible, however, to set the maximum distance at, say, 3.15 miles and adjust the map scale so that this would actually represent 31.5 miles on the ground.

The problem of external station trips appears to be more critical for a statewide analysis than with the urban areas. A method should be devised when coding the network to afford an opportunity for the external trip to be diverted to any of the possible entrances to or exits from the State. One solution to this problem would be to code two separate networks. The first network would be a national or regionwide network with only the major facilities within the State under analysis coded in detail. All trips external to the State would be loaded to this system.

The second network would be the State network as previously described. Only the internal trips would be loaded to this network. The sum of the two loaded networks would be the total traffic assignment.

This concept of two networks, where one of them is of a regional scope, would afford an opportunity for the external trip to be diverted to, from, or through the State over the minimum path. In addition, those trips that currently bypass the State would perhaps be diverted to or through the State if a high type facility is provided in the future.

For those urban areas within the State, the network detail must necessarily be limited. Only the major movements would be adaptable to this procedure because of the limited accuracy in the assignment. It definitely should not replace a comprehensive analysis of an urban area transportation system.

The trip information for a statewide analysis may be derived from a multiple screenline study, a series of external cordon interviews, synthesized, or perhaps a combination of these. Regardless of the type or source of trip information, it must be converted to the format described in chapter III.

The use of these traffic assignment procedures for an analysis of statewide traffic movements is still under development. Without question, the procedure can be adapted and should provide a useful tool for State, regional, or even national highway system planning.

F. Design-Hour Traffic Volume From Assignments

One of the products of the transportation planning process must eventually be a recommended transportation system. The system must be described in detail adequate for design purposes. This includes not only the function of each mode of transportation and their system configurations, but must also include the design-hour traffic volumes. These design-hour volumes form the basic data from which the street and highway system may be detailed and constructed.

Naturally, the procedure for obtaining these design-hour traffic volumes would be different for an urban area than it would be for a State or national network where excess capacity is common. For this reason, the following discussion has been divided into two sections. The first concerns the urban analysis, and the second will discuss a procedure for statewide applications.

1. Urban assignments.--Within urban areas, the recommended policies for highway design state that the system should be capable of handling the 30th highest hour traffic (60). Commonly, this value has been assumed to be equivalent to the average weekday peak-hour that occurred during the period of the survey.

It is possible, of course, that the 30th highest hour traffic at some specific locations within an urban area would occur on a weekend.

However, in a very limited amount of research, this has not been substantiated. Assuming that the design requirements may be fulfilled by an investigation of the traffic movement during the peak hour, the following procedures that have been used in various transportation studies are described.

a. Factoring an ADT assignment.--The simplest procedure for obtaining design-hour volumes on a network would be to apply a uniform factor to all of the traffic loads resulting from a total average daily traffic assignment. A commonly used percentage for the amount of traffic flowing in the peak hour is 10 percent, with an estimated directional split of 60-40. These averages, however, appear to have a wide variation--from about 6 percent to 18 percent--with a similar variance in the directional split. Therefore, the simple factoring of a total daily traffic assignment may involve a considerable amount of error.

The factoring may be done manually after the traffic assignment results are posted, but two procedures are availabe for applying a single factor to a network by the computer. One is to factor the trip matrix prior to loading. Program PR-51 will apply a factor to a binary trip table. Secondly, the loaded network may be factored by a constant factor using a program called Factor Loaded Networks. Either procedure will obtain the same results.

A slightly more advanced technique would be to apply the conversion factors selectively. Instead of determining only one factor from the survey data, several factors are developed and correlated with the type of facility and its location within the study area. For example, a radial facility in the proximity of the CBD would have different peaking characteristics than a circumferential route in the suburban area. After the correlation, a table is produced which lists the conversion factors by the various categories. They are then applied to the forecast network assignments.

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

One of the first steps is to identify the peak periods of traffic movement. There are computer programs available to determine (from the O-D survey data) the number of vehicles or persons-in-motion in each 6-minute time interval during the day (PR-185 and PR-186). The curves may be plotted by the IBM 1401 program M-2 and M-3. From the printed output of these programs, it is possible to analyze the time distribution of vehicles or persons-in-motion and determine when the peak periods of traffic movement occur (see figure IV-2).

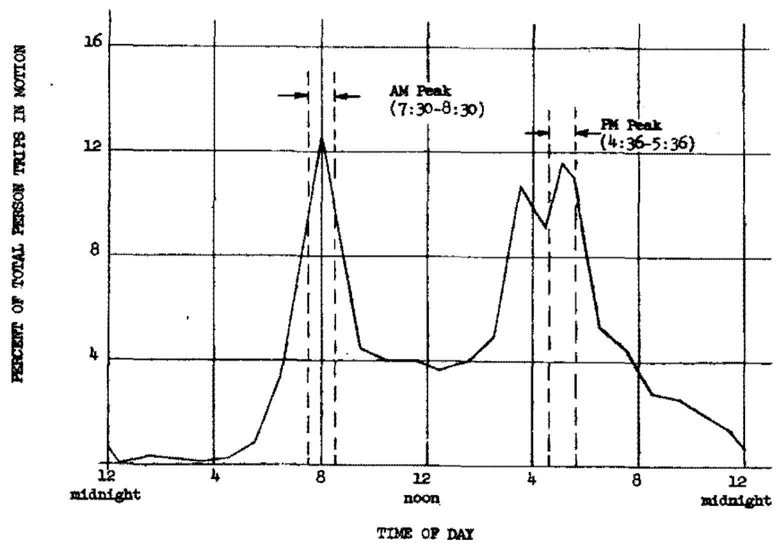


Figure IV-2.--Time distribution of total person trips in motion by time of day.

After the beginning and ending times of the peak periods have been established, it is possible to examine each trip card, determine the midpoint time of the trip, and place it in the proper peak or offpeak period trip file. This would result in three trip files: two, 1- or 2-hour volume tapes, and an offpeak volume tape. All of the trip information should be reduced to one of the three trip files, including the external trips, trucks, and taxis.

From each trip file a "memory J" trip tape is prepared and loaded separately on the corresponding highway network. Of course, the options of diversion assignment and capacity restraint are available.

To assign the forecasted peak-hour movement, the percentage of the total trips occurring during the peak periods by purpose of trip is analyzed from the survey data. These factors may then be applied for each trip purpose to the forecasted information and a trip file produced which represents the peak-period traffic movement (61).

For a Fratar analysis, separate growth factors may be applied for the three existing trip files and the forecasted peak-period trip movements obtained directly. Synthetic models specifically for peak-period movements have not been investigated as yet.

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

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

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

2. Statewide assignments.--To date, the experience concerning statewide traffic assignments is very limited. The conversion of these assignments to represent a 30th highest hour, or design-hour movement, may be made by applying factors as discussed in the urban assignments. The percentage of trips occurring during the 30th highest hour and the

directional split should probably be related, for statewide assignments, to the type of facility. The various links or route sections should be identified as to the type of traffic they serve. Procedures for this type of analysis have been discussed in "A Method of Estimating Traffic Behavior on All Routes in a Metropolitan County," by T. C. Muranyi of the Chicago Area Transportation Study (64).

Usually truck trips, or at least heavy trucks, are assigned separately on a statewide network. This would allow separate factors to be applied to the truck movements in determining the design-hour volumes. Of course, the same programs that were illustrated before to factor either the trip tape or the loaded network would be available for statewide systems.

G. Analysis of Systems

A well-designed transportation plan must:

Be economically attainable

Adequately provide for future travel with an acceptable level of service

Effectively serve the projected land uses

Utilize an integrated network of all modes of travel

Be compatible with the requirements of the ultimate development of the region.

The analysis of alternate transportation systems and the determination of the best plan is, even with the latest theories and techniques, a trial and comparison procedure. To date, there is no procedure which will directly analyze and test the future trip-making potential of the study area and automatically prescribe the best possible transportation system. Given a land use plan, a network, and a propensity for trip making, the transportation system planner's responsibility is to test the alternate schemes and systematically select the best according to some pre-established criteria.

This implies that there must be available a set of goals or standards prior to the development or analysis of a transportation network. These goals should include the nature of the transportation system, the quality of travel service that it should provide, compatability with desirable community development, and the size of the capital investment that can be made. The nature of the transportation system, with its mixture between highways and transit or other modes of travel, will be established in relation to the estimated market for person and vehicle travel. A desirable quality of travel service for both person and vehicle movements will set the standards for speed, safety, and accessibility. Economically, the plan must be one in which the benefits will surpass its cost within an acceptable level of annual investment.

Some attempts have been made to develop procedures which would permit the design of the optimum system directly from the forecasted future trip interchanges. These are still in the process of development and may not yet be considered applicable for the transportation planning process. The background of these theories usually relates to the summation of the differences between traveltimes or distance on the planned network and a hypothetical optimum network where travel is in straight lines and at constant speeds. Thus, measures of deficiencies (excess traveltimes or distances) are determined for each movement within the study area. These deficiencies are multiplied by the number of persons or vehicles desiring to make the particular movement, and a total deficiency for the area-to-area movements is described. The analysis and presentation of this information, however, is difficult and still does not lead directly to the design of the optimum transportation system.

The more traditional procedure for the development of an optimum transportation system may be broken into four phases. These four phases are discussed in some detail in the following paragraphs.

1. <u>Testing the plan</u>.--As mentioned before, the development of a future transportation system is done by a comparison of alternate preconceived plans. Each plan as it is tested is compared with previous plans and, in the process, the most desirable features are incorporated into the next trial plan. Initially, a sketch of the future transportation system is drawn and coded into a network. An estimate of the future traffic may be loaded on this network by the procedures that were previously discussed in this manual.

The transportation plan for the Washington, D.C., area was conceived from four basic alternate schemes--the auto dominant, the express bus system, the rail transit dominant, and the optimum "balanced" system. Planners for the Philadelphia area are evaluating five basic alternatives for their system analysis. The Chicago area plan was based upon the development of a theoretical formula for route spacing.

The CATS approach assumes that, given a particular network of arterial streets and a particular distribution of trips by length, an optimal spacing for a regular grid of expressways can be determined by the use of a mathematical formula. The formula is obtained through the following steps (62):

First, expressway construction costs are described as a direct function of expressway spacing. This is done readily, because the spacing determines the miles of expressway within any given area, and construction costs are directly related to route length.

The second step is to describe operating costs (in the same annual dollar terms as construction costs), also as a function of expressway spacing. This again can be done, because the trip length distribution is expected to be stable, and the behavior of traffic in seeking the quickest (or cheapest) route is expected to be constant. This means that the vehicle-miles of travel on the expressways will vary inversely with spacing, and that the total travel costs will vary directly as a function of spacing.

Construction costs rise in a measurable way as spacing falls. In contrast, the travel costs fall as spacing is closer, and also in a measurable way. It is possible to write all of these relationships in equation form, so that total costs are a function of spacing.

Doing this, and solving for the case where total costs are at a minimum (i.e., where the first derivative of costs with respect to expressway spacing is set equal to zero), the following formula is obtained:

$$Z = 2.24 \sqrt{\frac{C}{DKPs\ (Wa - We)}}$$

Where

Z = the optimum expressway spacing in miles

C = the average annual capital cost per mile of expressway

D = the trip density of the region in vehicle equivalent trip destinations per square mile

K = a constant for converting travel cost differentials to annual dollar values

Wa & We = average cost of a mile of travel on arterial and expressway facilities, respectively

Ps = the proportion of all trips which will use an expressway for part of their journey.

A simple graphic solution of the problem is portrayed in figure IV-3. In this example, costs were calculated for a region of uniform traffic density and with a constant and regular spacing of arterial streets. The two assumptions that densities and arterial street spacing are uniform throughout the region are not true in real situations; however, they do allow useful answers to the spacing problem at a scale that the planner can apply to problems of regional design.

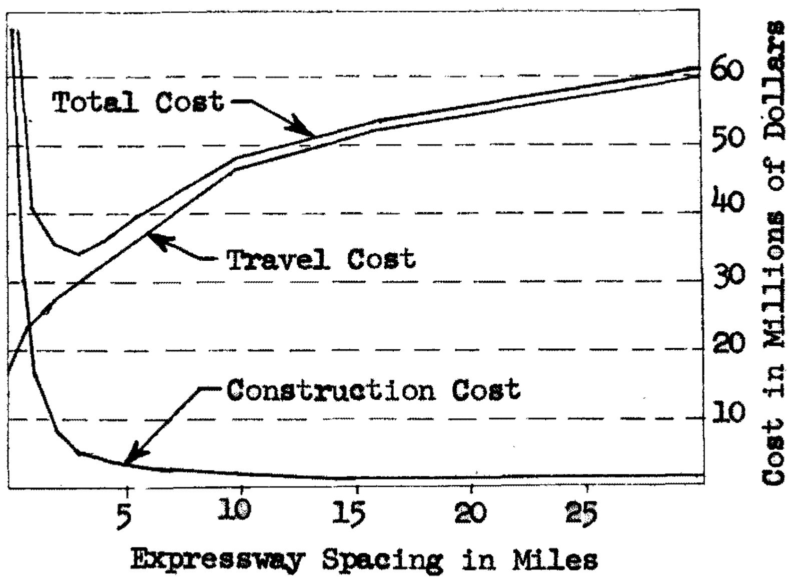


Figure IV-3.--Construction costs, travel costs, and total costs as a function of expressway spacing for an average square mile of area.

In figure IV-3 costs are shown as functions of spacing. As spacing increases, capital costs fall and operating costs rise. The sum of both costs is at a minimum at a particular spacing value. The best spacing value will change with density, so that it will be different in different parts of the region. New graphs would have to be prepared for different densities. The curves in figure IV-3 are calculated for an area of 20,000 daily trip destinations per square mile, with expressway construction costs of $8 million per square mile, and arterial streets one-half mile apart.

Although these methods do not provide a final answer to the problem of a best network design, they can point to the kind of design most likely to approach the desired result. They help to narrow the search for the best plan, and they allow a more direct approach to the desired solution.

Using the methods outlined above, a best spacing was calculated for typical conditions in rings 2-5 in the Chicago study area. Vehicle trip densities for each ring were based on the estimated 1980 trip making in each ring. The results of these estimates are shown in table IV-1. Other alternatives having substantially different amounts of new facilities were also tested.

Table IV-1.--Estimated least cost spacings of expressways for 1980

RING	1980 Vehicle trip destinations per. sq. mile	Current expressway construction cost per sq. mile (in millions)	Estimated least cost expressway spacing
2	28,700	$14	3 miles
3	25,300	12	3 "
4	19,600	8	3 "
5	13,400	6	4 "
6	10.000	4	6 "
7	7,700	2	6 "

Traffic assignment for system planning usually incorporates a "free" assignment to show if a network tends to satisfy the travel desires. This is followed by a series of restrained assignments to "balance" the traffic loads. In addition, selected trees are drawn for the comparisons of traveltime bands and the traffic drainage areas for the sectors of the study area. Later, assignments may include selected link analysis and the drafting of maps which show the volume to capacity ratios on the links. In each traffic assignment, however, there should be a conversion of the link data (volume, distance, traveltime, etc.) to an estimate of total travel cost.

In any case, the results of the traffic assignments are posted on the network maps to any detail that may be desired. The next step would be the confirmation of the validity of the traffic assignment. The overall travel summary should be evaluated for reasonableness, and spot checks should be made of the trip volumes entering and leaving the centroids. The amount of checking necessary to verify the validity of the traffic assignment is a matter of judgment. If the traffic assignment appears to be valid, the analysis of the assignment may proceed.

2. Analysis.--The analysis of traffic assignments in preparation for system design involves a summary of information with respect to, perhaps, the four following categories.

a. Economic data.--Listed below is the type of information that should be specified for each traffic assignment.

Annual travel cost to the motorists

The loss or gain of taxable revenue

System construction cost, including right-of-way cost

Percent change in travel costs from base year

Comparison of total costs per vehicle-mile

Cost of relocation

The total travel cost to the users of a transportation network was calculated in Chicago and Pittsburgh by a summary of three items of cost which are all related to the speed of travel and type of facility. The three items of cost are operating costs, accident costs, and time costs.

Computer programs are available to compute the summation of the link travel cost by type of facility for the complete transportation network. An excellent discussion of the Chicago and Pittsburgh procedures is detailed in a paper titled "Economic Evaluation of Traffic Networks," by G. Haikalis and H. Joseph. The paper was presented to the Highway Research Board in January of 1961 (HRB Bulletin 306).

The construction cost must be estimated for each alternate plan. Usually, the precision to which construction costs are estimated is compatible with the nature of the network being evaluated. If the network has not been described in detail and is to be considered only a sketch, the calculation of construction cost may be approximated by an equation which relates the cost per mile with net residential density as was done in Chicago and Pittsburgh. Major structural expenditures should be measured separately. Right-of-way and other costs should also be estimated for the cost-benefit analysis.

b. Performance.--The summaries regarding the performance of a trial network usually include the following items:

The average system speeds by type of facility

The total vehicle-miles and vehicle-hours of travel

The average traveltime and distances by type of facility and location within the study area

The total miles of coded network by facility type

c. Design.--A summary of these elements with regard to design features of a network should be included in the analysis of the traffic assignment.

The total system capacity by type of facility

A comparison of trip length frequency distributions

The total trips assigned to the network

The total mileage by volume group

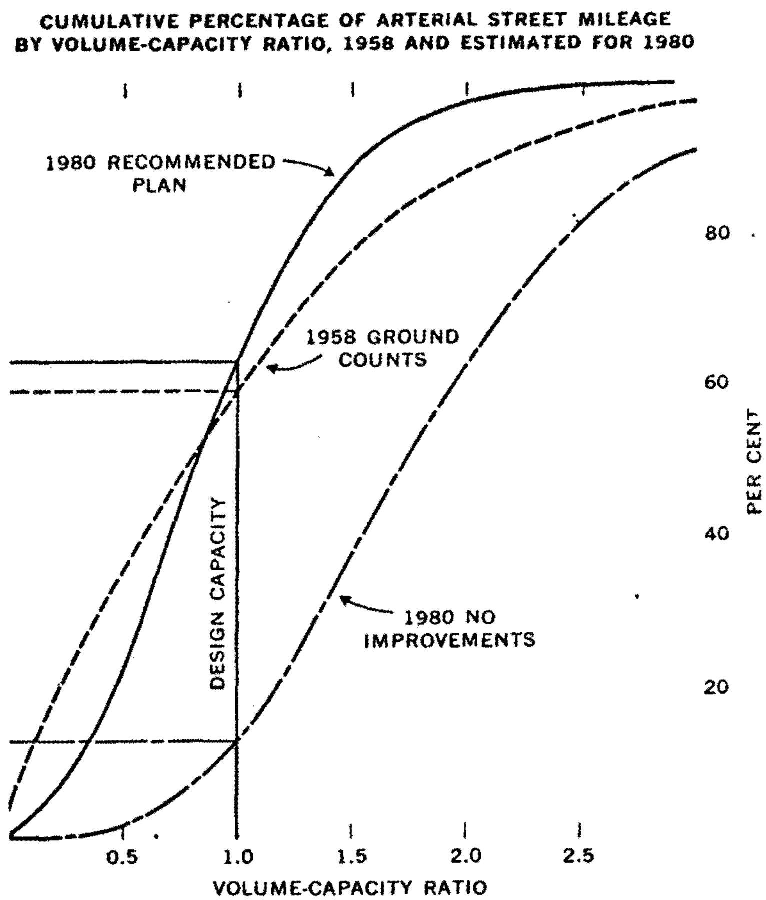
The average spacing of freeway interchanges

The person-miles per mile of roadway by facility type

The volume to capacity ratios for each capacity group and for each major link.

d. Other.--An analysis of either the sketch plans or design plans should also involve a calculation of several other items of information. The number of displaced persons or families should be estimated for each proposal. In addition, the network should be tested for its compatibility with other study area improvement programs such as urban renewal, redevelopment projects, utility systems, etc. The final plan should be tested with regard to the relationship of the transportation system within the study area to the regional and national network.

3. Evaluation.--The evaluation of the plan is usually in the form of a benefit-cost analysis, an empirical evaluation of the level of service and a measure of its impact on community development. The summation of the travel costs that were developed in the preceding paragraphs, i.e., vehicle operation costs, accident costs, and personal traveltime costs, are compared to the estimated construction cost. This process of traffic assignment and benefit-cost analysis is a means of selecting the best plan or the plan that minimizes the community's total transportation costs. The level of service, which is usually measured with reference to an average speed, is an important measure of the quality of travel service. The volume to capacity ratio is another important parameter in measuring the level of service of a highway system. Figure IV-4 shows a cumulative curve plot of arterial street mileage against volume-capacity ratios resulting from three different traffic assignments in the Pittsburgh transportation study. A ratio of 1.0 represents a balance between assigned



Source: PITTSBURGH AREA TRANSPORTATION STUDY VOLUME 2

Figure IV-4.--Cumulative plot of arterial street mileage by volume-capacity ratio for 1958 and estimated for 1980.

volume and link capacity. The three curves represent the conditions on the arterials in 1958, conditions in 1980 without any highway improvements, and conditions with the 1980 PATS recommended plan.

In summary, the evaluation of a transportation network is largely a comparison of alternate schemes. As the process of trial and adjustment continues, the best plan gradually evolves and is then submitted to more detailed analysis for design purposes. This would include the close examination of CBD oriented trips, selected link analyses for sections loaded above their capacity, peak-hour studies, and the preparation of illustrations to indicate the amount of freeway usage, comparison of traveltimes, volume to capacity ratios, etc.

4. Adjustments.--For each trial network, the new network is usually developed by simply a modification of the previous network. Adjustments may be of the following form:

Tightening of the freeway spacing

Adding additional freeway capacity on existing routes

Addition of a completely new freeway

Improving the access to arterial streets

Adding additional arterial capacity

Reexamination of the provisions for mass transit

Reanalysis of the land use forecasts

Others

H. Automatic Data Plotting

The printed data from a traffic assignment are usually so voluminous that transferring all of the information to maps may delay the analysis from several weeks to several months. Some output is of such a nature that extensive drafting work is required before the information is of maximum digestible value. In addition, there may be some errors in the transcribing process. For these and other reasons, the use of automatic data plotting systems warrants consideration and application.

Automatic plotters can be equipped to draw lines, plot points, and draw or print symbols at fixed or variable scales, depending on the type of plotter used. Input can be provided by magnetic tape, punch cards, punch paper tape, and from a keyboard. Plotting pens can be automatically or manually changed to allow plotting of varying widths and colors of lines. Plotting surfaces can be obtained from about 30 x 30 inches up to about 60 x 60 inches in certain types of plotters, and from 12 to 30 inches wide on a continuous roll on other types of plotters.

A typical data plotter consists of a plotting board or drum on which a sheet of paper is placed and held down by a vacuum, or by tension. The sheets used for plotting may be preprinted with a cordon line, zone boundaries, or a grid system. In some systems, there is an arm parallel to the plotting board which can move to traverse the width of the board. Connected to this arm is a plotting pen which moves along the arm. The arm and pen are connected by a servo-mechanism allowing the pen to be positioned for a point, line, or a symbol. Other machines are available which operate with a moving pen and a rotating drum.

Automatic data plotters may be used in conjunction with the traffic assignment process in the following operations:

1. The network description, after it has been coded, can be plotted automatically. This plot provides a visual check of the accuracy of system coding if adequate editing is not possible.

2. A sample plot of about 5 to 10 trees is usually required to check the adequacy of the coded network, and the reasonableness of the route selection before loading. This may be accomplished automatically, and time contours (isochronal lines) may be plotted on a tree from a given node.

3. A map of the assigned volumes, volume/capacity ratios, lane demands, or a map of the overloads and underloads, may be prepared automatically.

4. A density plot of speeds, vehicle-miles assigned versus capacity (v/c ratio) per given grid network may also be plotted automatically.

5. Land use patterns or other basic data files may be effectively displayed automatically by block, grid, or zone.

For each traffic assignment in a large urban area the work required for plotting the network, plotting the selected trees, and displaying the traffic volumes would be about 4 man-weeks if done manually. This could be done within several hours with an automatic data plotter, based on the limited amount of information that is available.

A data plotter that is adaptable for traffic assignment to a medium-size city would cost from $8,000 to $30,000 if purchased outright. It may be rented for approximately $900 to $1,500 per month. The cost varies, depending on the type and the input mode; e.g., whether it is tape or card input, and if it is on-line or off-line equipment. Some data processing centers provide plotter service on a rental basis at a rate of $35 to $50 per hour. The Puget Sound Regional Transportation Study has had extensive experience in the use of modern data plotters. They have established a rental rate of $15 per hour for other governmental agencies. This rate is based on a standard amortized schedule, assuming 60 percent usage.

At the present time, automatic data plotters are not in use as extensively as they could be. Certainly, the possibility of considerable savings in time and man-hours demonstrated at current transportation studies should increase the use of these machines in the future.

I. Accuracy of Traffic Assignments

The only method to evaluate the adequacy of a traffic assignment is to assign existing trips to a simulated existing network. The accuracy of the assignment may be determined by a link-by-link comparison of the assigned volumes with ground counts. A series of screenlines cutting through the study area may also indicate, to some degree, the accuracy of an assignment. The vehicle-miles of travel for various jurisdictions within a study area may be computed from ground count information and compared to the traffic assignment results.

These procedures, however, do not measure the error attributable to the traffic assignment procedure. These comparisons indicate the total error incurred from the following sources:

Trip survey or model errors

Errors in the ground counts

Errors in capacity calculations

Errors in the assignment procedure

The errors in the traffic assignment procedure may be attributed to many sources; these include an inappropriate number of links in the network, zone sizes too large, faulty link parameters, assumptions of the minimum path theory, failure to assign the intrazonal trips, etc.

There appears to be no way to evaluate the portion of the total error that is contributed by each of the above factors. Nevertheless, it may be valuable to report the findings of some typical transportation studies after an assignment of the existing trips to the existing system is compared to ground counts. The total ADT traffic for the Salt Lake City urban area has recently been assigned by the all-or-nothing method through seven iterations of capacity restraint. The following results from Salt Lake City are derived from the two-way daily volumes on 1,549 links. The total count on the 1,549 links was 10,989,600 vehicles. These links carried a wide range of traffic volume from less than 500 vehicles per day to more than 30,000 per day. The percentage of links included in each traffic volume group and the proportion of the total count accumulated for this volume group are shown in figure IV-5.

The accuracy of the traffic assignments for each iteration of capacity restraint is shown by figure IV-6. The results of the individual trials are plotted on the left side of the chart. Cumulative results of average link loads from all previous trials are plotted on the right side of the chart. The portion of the total error contributed by each traffic volume group is evident. The capacity restraint feature apparently reduces the error of the traffic assignment if the cumulative feature is used. The total "weighted" percent error (see figure III-29) after the sixth trial for Salt Lake City was 31.9 percent, well below normal.

If the results of the sixth trial alone were used, the total percent weighted error would be 52.4 percent. About 16 percent of the total error is for the volume groups of 5,000 to 10,000 vehicles.

Considering all links in the network with the full range of volumes, the weighted percent error for a typical "free" traffic assignment would be in the range of 60 percent. This may be reduced to approximately 30 to 40 percent by submitting the "free" assignment to automatic restraints according to link capacity.

J. Cost of Traffic Assignments

The precise cost of a traffic assignment is difficult to estimate because of the number of options available within the process. There are two costs involved--data processing cost and personnel cost. The following information may be useful in estimating the personnel cost for a traffic assignment. Depending, of course, on the size of the network, the time required to completely define a network to the computer would vary from about one man-week to a maximum of four man-weeks. Selected trees may be plotted at the rate of about one per man-day. Finally, the posting of traffic volumes usually requires from about three man-days to, perhaps, two man-weeks.

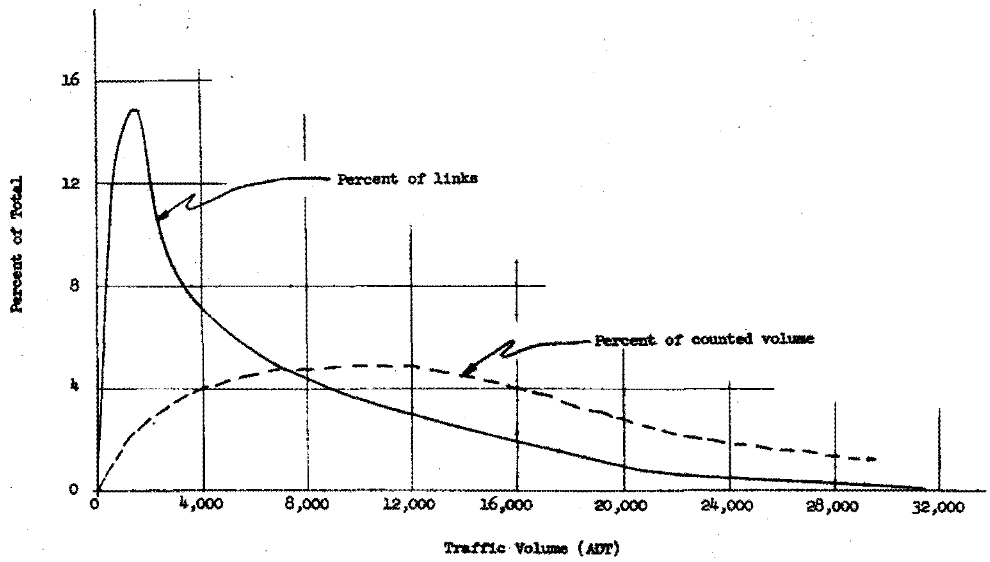


Figure IV-5.--Distribution of traffic counts on Salt Lake City Transportation Network.

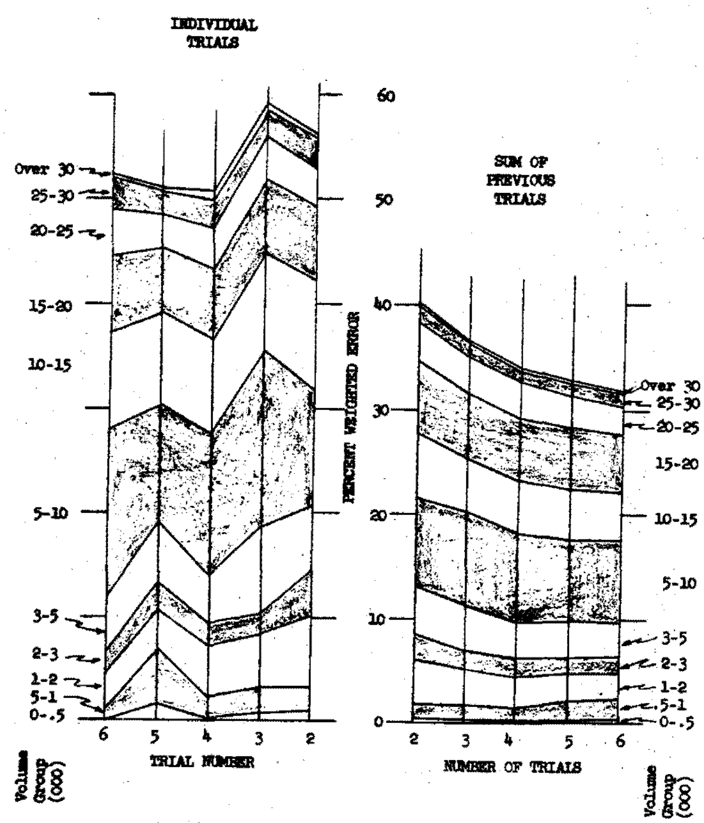


Figure IV-6.--Accuracy of traffic assignment in Salt Lake City, Utah.

An estimate of the data processing costs for a traffic assignment depends upon at least four items: (1) the number of centroids in the system, (2) the number of links in the system, (3) the options to be used in the process, and (4) the type and size of the computer.

The initial cost of building the trip table as described in section A of chapter III would usually be between $500 and $2,000, depending upon the number of memory J's to be built and the number of centroids involved. The programs which process input tapes in one-card records will take considerably more time on the IBM 7090/94 than those that will handle 10- or 20-card records. The data processing time for building memory J's is approximately equal to the time required to read an input tape (about 6 minutes per reel).

The computer time required to build a network description or update a network description should never exceed one or two minutes, and may be considered a negligible part of the total computer time.

Assuming that the trip tables have been built and that the network description needs only to be updated, a complete all-or-nothing traffic assignment for a system of approximately 600 centroids and 3,400 nodes would require about 40 minutes on the IBM 7094. For the same network, about 60 minutes would be required for the IBM 7090.

The following breakdown for IBM 7094 times may be useful:

2 minutes - Build or update memory A

15 minutes - Build all trees

17 minutes - Load minimum paths

6 minutes - Sum volumes and turns

For diversion loading, two sets of trees are required which adds approximately 50 percent more computer time to a traffic assignment. To estimate the cost of a capacity restrained assignment, it may be assumed that each iteration of the capacity restraint is one complete traffic assignment. Thus, an all-or-nothing traffic assignment to the system mentioned above through four iterations of capacity restraint would require about 160 minutes on an IBM 7094, at a cost of approximately $1,300.

Data processing on off-line equipment for printing the traffic assignment information may be approximated as 10 percent of the total traffic assignment cost. Smaller networks, of course, require less data processing time. A system of about 100 centroids and 500 links may be processed in approximately 10-12 minutes, at a cost of approximately $100.

Average rental rates for the IBM 7090 vary between $400 and $500 per hour. For the IBM 7094 the rental rates are from $500 to $600 per hour. These vary by the time of day the equipment is used and the rate of usage at the installation.

It is impossible to estimate the cost of traffic assignment for a city without knowing a great amount of detail concerning its goals and the anticipated quality of the work to be performed. In chapter II, section E, a discussion of the recommended number and types of assignments indicated that every city must determine the number and quality of assignments to be performed on the basis of goals, needs, and available financial resources.

Using the estimates of time needed for running the different computer programs, the reader should be able to approximate the total cost of traffic assignment in his city. However, in making this approximation it is important to consider the time lost due to errors incurred in running these programs. When using the mechanical procedures described herein, it should be expected that the inexperienced will run into many problems and make many mistakes until he becomes familiar with the procedures. These mistakes may increase the initial estimate by 10 to 100 percent.

K. Staff Requirements

Traffic assignment is usually only one phase of a transportation planning study, and the members of the organization who perform the assignment may not devote full time to this part of the operation. The size of the study staff depends upon the size of the area under study, the scope of the analysis, and available funds.

A minimum number of people who would be required to conduct and analyze a traffic assignment on a fairly systematic schedule would be as follows:

- 1 - Director (engineer)
- 2-4 - Technicians
- 1 - Computer operator and programer
- 1 - Draftsman

Preferably, the director would be a person who is a specialist in traffic assignment or transportation planning. The technicians would be semi-professional engineering technicians whose responsibility would be coding the networks, plotting the sample trees, and the preparation of the traffic volume maps. It is usually desirable to have on the staff one man who is a trained computer operator or programer. His responsibilities would include the computer operation and the necessary logistical support, such as maintaining tape logs, card files, and a library of output listings. The necessity of having a qualified draftsman as a member of the staff cannot be underestimated. His assistance in preparing the basic coding maps and the illustrations of the results of the traffic assignments will convert a highly technical procedure into an analysis that will be meaningful to the layman.

L. Availability of Computer Programs and Technical Assistance

Any or all of the computer programs that have been mentioned in this manual are available at no cost through the U.S. Bureau of Public Roads. Request for information or computer programs should be addressed to:

Mr. G. E. Marple
Chief, Urban Planning Division
U.S. Bureau of Public Roads
1717 H Street, NW.
Washington, D.C., 20235

State highway departments and urban planning studies should direct their requests to the appropriate division office of the U.S. Bureau of Public Roads.

When requesting computer programs, the exact description of the program or programs and the form of the program should be prescribed. Any or all of the following items should be requested specifically: (1) program source deck, (2) assembled program deck, (3) program listing, (4) program writeup, (5) program flow chart, if available.

If assembled program decks are requested, the basic tape writer program will normally be included. However, it should be specified in the request. If program library tapes are desired, sufficient blank tapes should be submitted with the request. This would normally be two tapes; one for the BELL Monitor and the second for the BELMN program library tape. If a program library tape under the TEXAS or IBSYS control system is required, only one tape is necessary. If several program source decks are requested, it may be desirable to request a tape to be written which contains an 80-80 column card reproduction of the source programs followed by a standard EOF (End of File).

Staff members of the Urban Planning Division of the U.S. Bureau of Public Roads are available for technical assistance in the use and operation of these programs. A request for technical assistance should be directed to the appropriate division office of the Bureau of Public Roads.

This chapter presents detailed discussions of the theory on which several phases of the traffic assignment process are based. Included is a description of the internal operation of the computer during the execution of the traffic assignment programs.

Section A describes the theory of the Moore Algorithm and the steps in determining the minimum time path from one node to all other nodes in a highway network. Both the computer and manual methods are discussed.

Section B describes the theory of assigning traffic to a network by the diversion method. Based on a theoretical diversion curve, part of the traffic is diverted to the freeway system, and the remainder is assigned to the arterial system.

The theory of capacity restraint is illustrated in section C, and section D describes the mechanical procedure used by the computer to scale link times and distances to 63rds to conform to the program restrictions incorporated in the Bureau of Public Roads traffic assignment battery. Section E explains why there may be no more than four outbound links coded at each node on the network.

A. Determining the Minimum Time Path Between Zones

In all of the traffic assignment techniques developed to date, it is assumed that the vehicle operator desires to use the "easiest" route between his origin and destination. The easiest route could be the one comprising the shortest distance, the shortest traveltime, requiring the least number of stops and turns, having the minimum amount of pedestrian interference, or any combination of these.

The determination of the minimum paths between centroids is a difficult task and very time-consuming if done manually. For example, to arrive at a point four blocks east and four blocks south of a point of origin on a regular grid pattern, there are 40 different routes or paths that appear to have approximately equal traveltimes. However, by precisely adding the time (or distance) on each segment involved for each route, the single route with the least overall traveltime may be selected.

The following sample problem illustrates the method of calculating a minimum path manually on the hypothetical highway network shown in figure V-1.

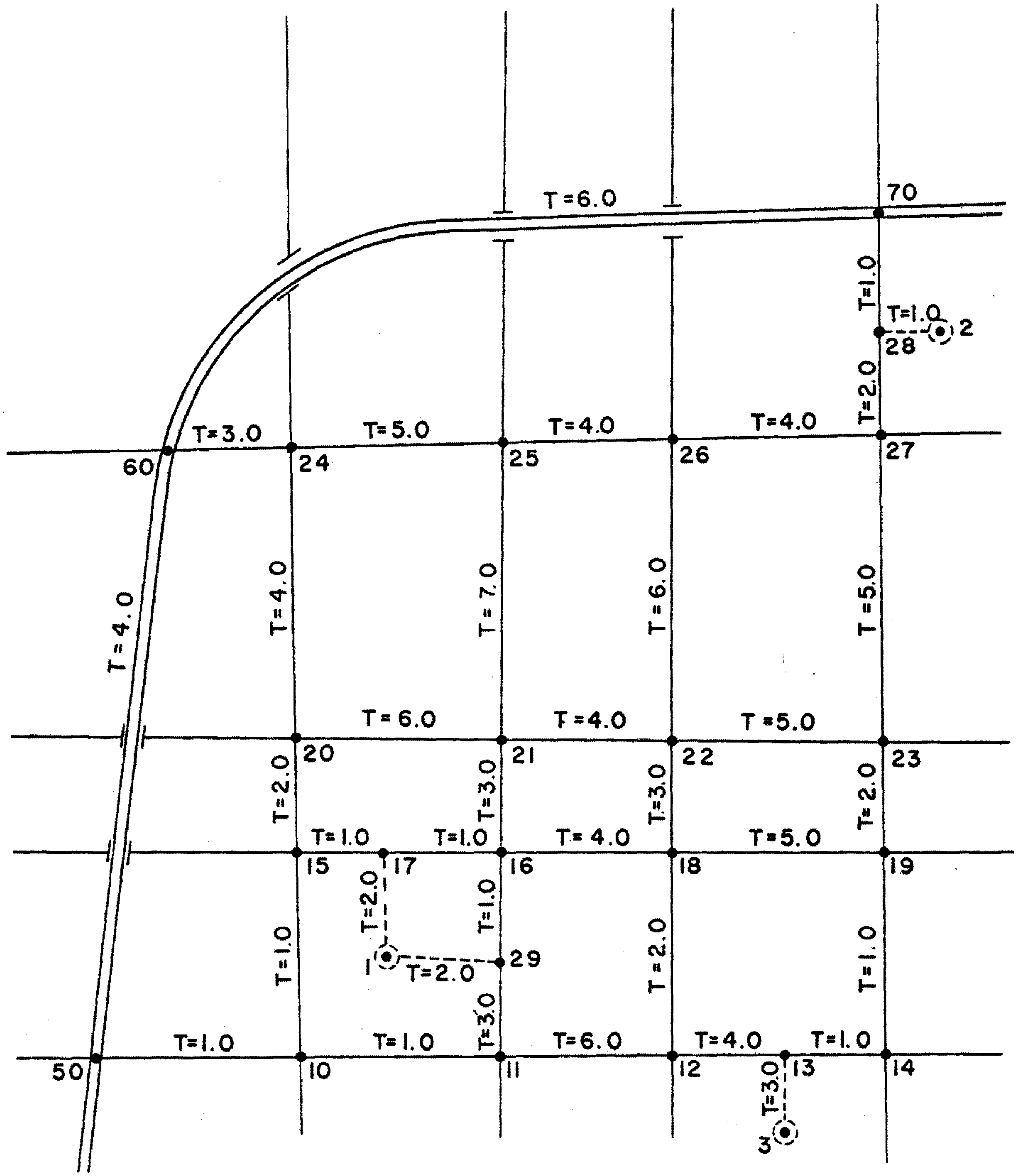


Figure V-1.--Sample network for manual tree calculation.

Each street intersection in the sample network is designated by a node number. The three zone centroids, indicated by ⊙ , are assigned centroid numbers, 1, 2, and 3. The measure of travel resistance between nodes is in terms of time (in minutes, shown as T = 2.0). However, this factor could be any consistent variable such as cost, distance, or speed. The object of this sample problem is to determine the minimum time path from centroid 1 to all other nodes in the network. This is done as follows:

Starting at node 1, proceed outward to all connecting nodes and record at each node the traveltime to it. Thus, record the time to get to node 17 as $T_{17} = 2.0$, and the time to get to node 29 as $T_{29} = 2.0$ minutes.

The node closest in time to node 1 (the home node) is considered next. In this case, either 17 or 29 could be next, since the time to each is 2.0 minutes. However, the lowest numbered node, 17, is taken in this situation. Record the cumulative time from node 1, through node 17 to nodes 15 and 16; thus:

$T_{15} = 3.0$

$T_{16} = 3.0$

Node 29, which is the next closest in time to node 1, is considered next; thus:

$T_{16} = 3.0$

$T_{11} = 5.0$

At this point, note that two routes have been calculated to node 16, each requiring 3.0 minutes. The one built to node 16 first (1-17-16) is used, and the second is erased.

From node 15:

$T_{20} = 5.0$

$T_{10} = 4.0$

From node 16:

$T_{21} = 6.0$

$T_{18} = 7.0$

From node 11:

$T_{10} = 6.0$

$T_{12} = 11.0$

At this point, note that two routes have been calculated to node 10; one route using the path 1-17-15-10 required 4.0 minutes and the second route using path 1-29-11-10 required 6.0 minutes. As the minimum path is desired, the first route (1-17-15-10) is chosen. Its traveltime (4.0 minutes) is recorded, and the higher value (6.0 minutes) is erased.

This process is continued until all nodes have been reached via the minimum time path from zone centroid 1. Figure V-2 on the following page shows the final minimum path tree trace for centroid 1.

The same procedure may be used to build trees for zones 2 and 3, or for all zones in the network.

After manually computing several minimum time paths between zone centroids in the sample problem, it is apparent that the determination of these paths is a time-consuming and tedious task. Fortunately, a mechanical procedure has been developed for use on a high speed computer which builds trees in an efficient and rapid manner. This mechanical procedure is based on a theory called the Moore Algorithm (56).

It is important that the Moore Algorithm be fully understood before proceeding to a more detailed discussion of its application. For purposes of illustration, a hypothetical street network is shown in figure V-3, and a sample mechanical calculation is presented for building the trees from one node to all other nodes in this network.

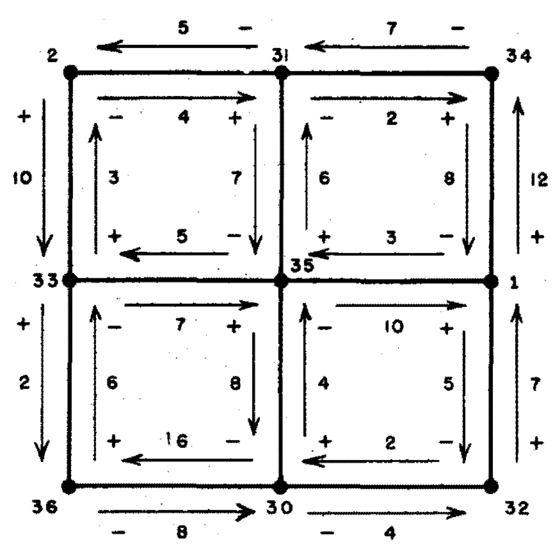


Figure V-3.--Sample network for tree calculation by computer.

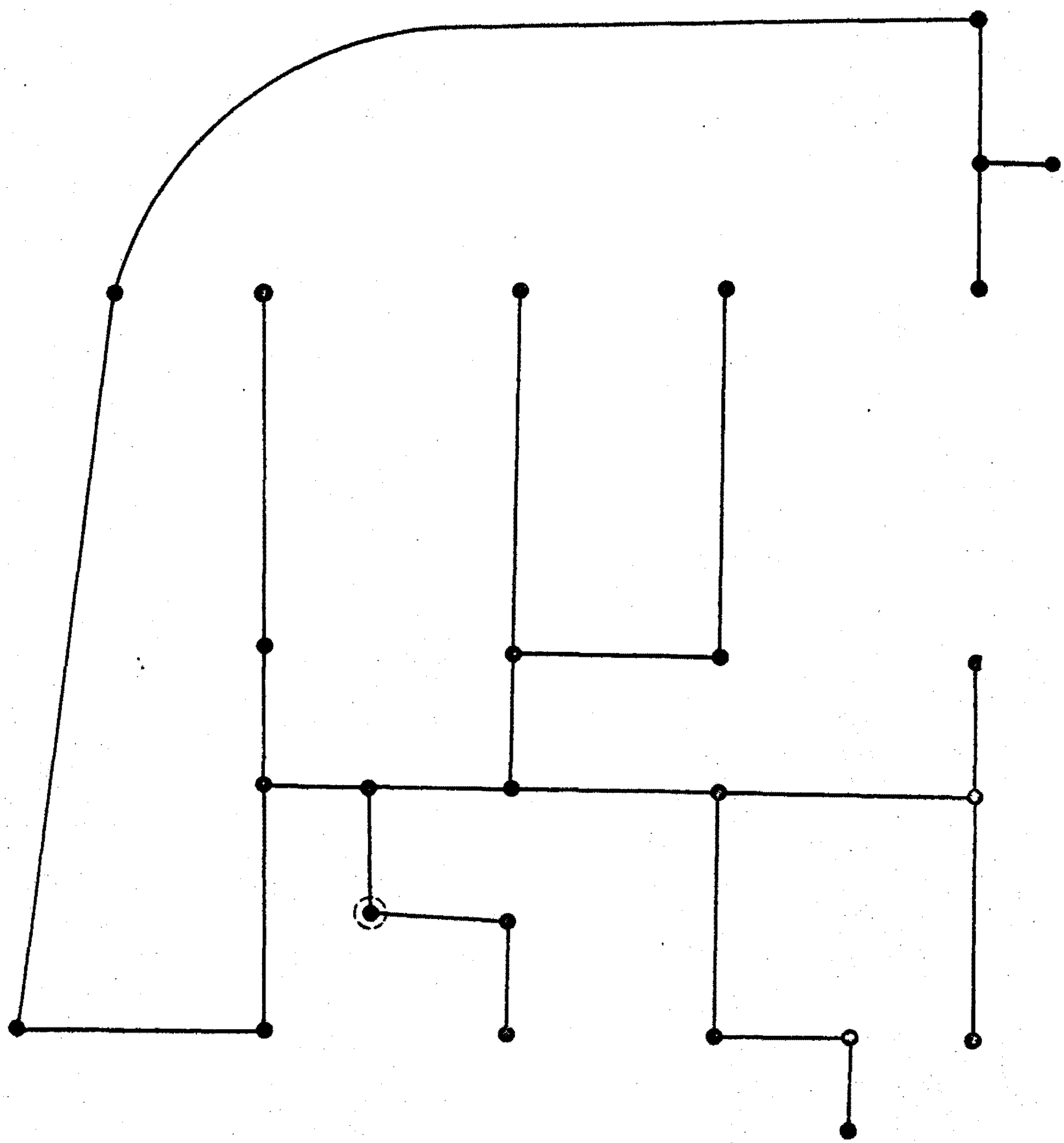


Figure V-2.--Tree for zone 1.

Note that the numbering of the nodes can be in any order. The values adjacent to the arrows indicate the impedance in the direction of the arrow. These may represent traveltime, distance, cost, or any other parameter for travel impedance. To develop a computer solution for the Moore Algorithm, the network must be described digitally in some fashion. A method of doing this is shown in table A, figure V-4. Note that there is one entry for each direction of travel on each link. If any of the links are to be considered as one-way streets, the entries for the reverse travel would be missing in the table. The table is constructed by treating each node in ascending numerical order and tabulating each exit from that node. In the example that follows, table A may be considered to be stored in the memory of a computer and will remain unchanged throughout the calculation of the minimum path routings.

Table B, figure V-4, represents the memory storage area set aside for tree calculations. This table will eventually contain the tree trace from the home node (the node from which the tree is built) to all other nodes. The column labeled A_B is constant throughout all calculations, and is simply a listing of all the nodes in ascending numerical sequence. Columns B_B and T_B will change throughout the calculations. The remaining tables are intermediate working areas.

Figure V-5 is a simplified flow diagram for the tree calculations. The values shown in the intermediate storage areas and in columns B_B and T_B in table B in figure V-7 are for their condition <u>at the conclusion of calculating the tree from node 1 to all other nodes</u>. Figure V-4 illustrates the numbers present in the storage areas before the first step of the flow diagram is initiated. Figure V-6 shows the numbers present in the intermediate storage areas after treating the first link in table A (1-32-5) only. These numbers are obtained as follows:

Step 1 - Set home node counter (N_H) to 1.

Step 2 - Set all T_B storage areas to the maximum value of 99 minutes.

Step 3 - Get the first link located in table A where $N_H = A_A$. Since $N_H = 1$, the link to choose in table A is 1-32-5. Store 1-32-5 in storage area D.

Step 4 - Get the link located in table B where $A_B = A_D$. Since $A_D = 1$ (from storage D), $A_B = 1$ also. Set B_B and T_B' to zero and store this link in table B and in storage area E.

LINK TABLE A

NODE A_A	NODE B_A	TIME T_A
1	32	5
1	34	12
1	35	3
2	31	4
2	33	10
30	32	4
30	35	4
30	36	6
31	2	5
31	34	2
31	35	7
32	1	7
32	30	2
33	2	3
33	35	7
33	36	2
34	1	8
34	31	7
35	1	10
35	30	8
35	31	6
35	33	5
36	30	8
36	33	6

TREE TABLE B

NODE A_B	NODE B_B	TIME T_B
1		
2		
30		
31		
32		
33		
34		
35		
36		

SEQUENCING TABLE C

TIME T_C	NODE N_C
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	

TEMPORARY LINK STORAGE D

NODE A_D	NODE B_D	TIME T_D

TEMPORARY LINK STORAGE E

NODE A_E	NODE B_E	TIME T_E

TEMPORARY LINK STORAGE F

NODE A_F	NODE B_F	TIME T_F

HOME NODE COUNTER H

N_H	

TEMPORARY NODE STORAGE I

N_I	

TEMPORARY SUMMATION OF TIME STORAGE G

T_G	

Figure V-4.--Contents of storage areas before starting flow diagram.

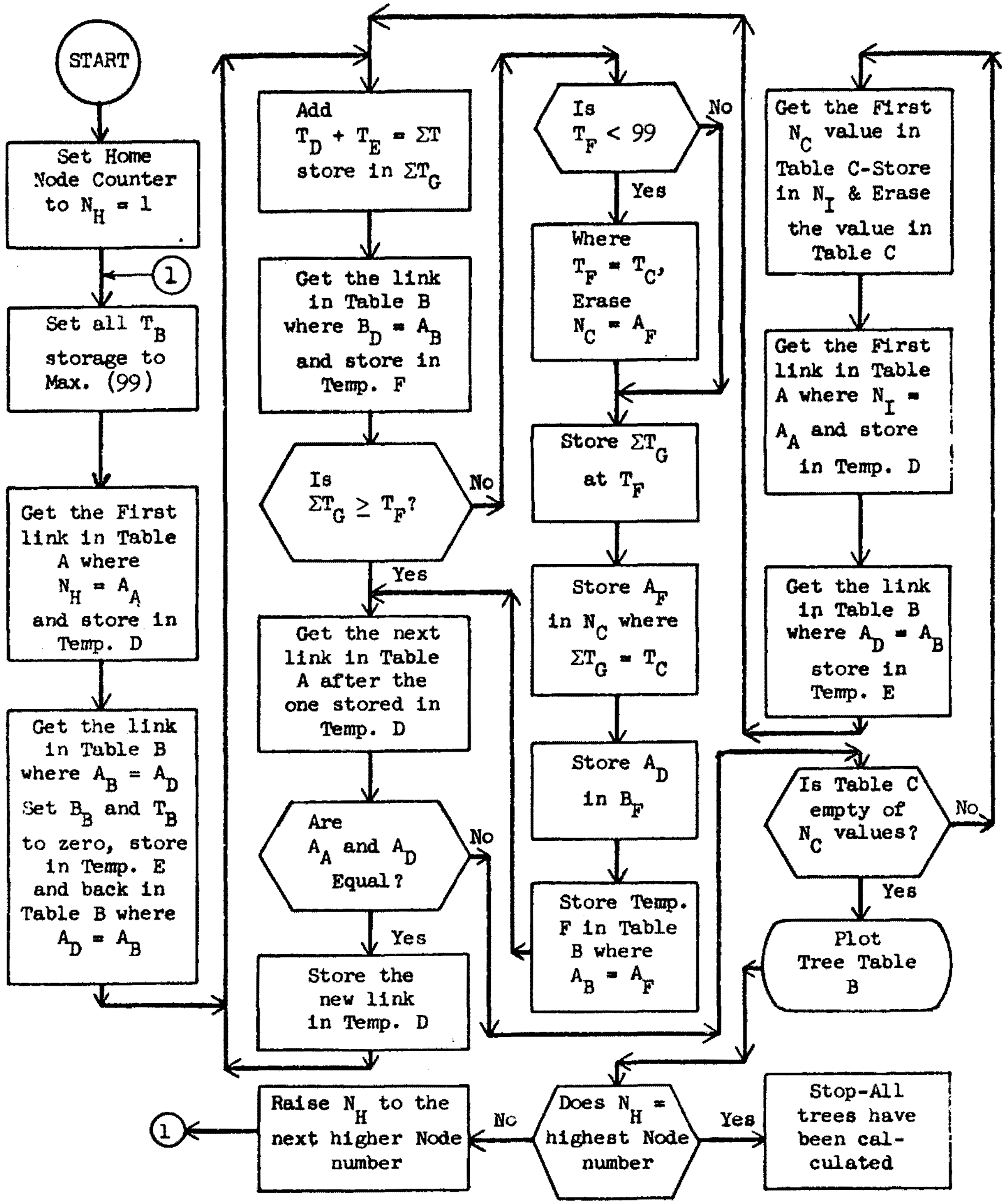


Figure V-5.--Build trees - flow chart.

LINK TABLE A

NODE A_A	NODE B_A	TIME T_A
1	32	5
1	34	12
1	35	3
2	31	4
2	33	10
30	32	4
30	35	4
30	36	6
31	2	5
31	34	2
31	35	7
32	1	7
32	30	2
33	2	3
33	35	7
33	36	2
34	1	8
34	31	7
35	1	10
35	30	8
35	31	6
35	33	5
36	30	8
36	33	6

TREE TABLE B

NODE A_B	NODE B_B	TIME T_B
1	0 (4)	0 (4) ~~99~~ (2)
2		99
30		99
31		99
32	1	5 ~~99~~ (12)
33		99
34		99
35		99
36		99

SEQUENCING TABLE C

TIME T_C	NODE N_C
1	
2	
3	
4	
5	32 (10)
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	

TEMPORARY LINK STORAGE D

NODE A_D	NODE B_D	TIME T_D
1	32	5 (3)

TEMPORARY LINK STORAGE E

NODE A_E	NODE B_E	TIME T_E
1	0	0 (4)

HOME NODE COUNTER H

N_H	1 (1)

TEMPORARY LINK STORAGE F

NODE A_F	NODE B_F	TIME T_F
32 (6)	(11) 1 ~~31~~ (6)	5 (9) ~~99~~ (6)

TEMPORARY NODE STORAGE I

N_I	

TEMPORARY SUMMATION OF TIME STORAGE G

T_G	5 (5)

(1) **Corresponds to step number in text**

Figure V-6.--Contents of storage areas after completing first run through flow diagram.

LINK TABLE A

NODE A_A	NODE B_A	TIME T_A
1	32	5
1	34	12
1	35	3
2	31	4
2	33	10
30	32	4
30	35	4
30	36	6
31	2	5
31	34	2
31	35	7
32	1	7
32	30	2
33	2	3
33	35	7
33	36	2
34	1	8
34	31	7
35	1	10
35	30	8
35	31	6
35	33	5
36	30	8
36	33	6

TREE TABLE B

NODE A_B	NODE B_B	ΣTIME T_B
1	0	0 ~~99~~
2	33	11 ~~99~~
30	32 ~~35~~	7 ~~11~~ ~~99~~
31	35	9 ~~99~~
32	1	5 ~~99~~
33	35	8 ~~99~~
34	31 ~~1~~	11 ~~12~~ ~~99~~
35	1	3 ~~99~~
36	33 ~~30~~	10 ~~13~~ ~~99~~

SEQUENCING TABLE C

ΣTIME T_C	NODE N_C
1	
2	
3	~~35~~
4	
5	~~32~~
6	
7	~~30~~
8	~~33~~
9	~~31~~
10	~~36~~
11	~~30~~ ~~2~~ 34
12	~~34~~
13	~~36~~
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	

TEMPORARY LINK STORAGE D

NODE A_D	NODE B_D	TIME T_D
34	31	7

TEMPORARY LINK STORAGE E

NODE A_E	NODE B_E	TIME T_E
34	31	11

HOME NODE COUNTER H

N_H	1

TEMPORARY LINK STORAGE F

NODE A_F	NODE B_F	TIME T_E
31	35	9

TEMPORARY NODE STORAGE I

N_I	34

TEMPORARY SUMMATION OF TIME STORAGE G

ΣT_G	18

Figure V-7.--Contents of storage areas at the conclusion of calculating the tree from node 1 to all other nodes.

Step 5 - Add $T_D + T_E = \sum T$, or $5 + 0 = 5$. Store "5" in storage area G.

Step 6 - Find the link in table B where $B_D = A_B$. Since $B_D = 32$ (storage D) $A_B = 32$. Store this link, 32-blank-99, in storage F.

Step 7 - Examine the values of T_G and T_F. In this case T_G is less than T_F so follow the "no" path.

Step 8 - Examine the value of T_F. In this case it is not less than 99, therefore follow the "no" path.

Step 9 - Store the value of T_G (equals 5) in storage F. (Erase 99 and replace it with 5.)

Step 10- Store the value of A_F (equals 32) in column labeled node N_c, in table C where $\sum T_g = T_c$. In this case $T_g = 5$, so place 32 in N_c at a value of $T_c = 5$.

Step 11- Store the value of A_D (equals one) in B_F (storage F).

Step 12- Store the contents of storage F (32-1-5) in table B, where $A_B = A_F$. Since $A_F = 32$, this link is placed in the fifth row from the top, where $A_B = 32$.

This ends the first phase of the tree building process. The procedure should now be continued, carefully following through the remaining steps in the flow diagram until the final results, as shown in figure V-7, have been obtained. Note that a tree is calculated by processing each entry in link table A only once.

The minimum path tree for node 1 to all other nodes is shown in figure V-8. This is a schematic representation of the information shown in table B, figure V-7. The information may be plotted in any order, as separate links. For example, the interest may be in only the routing from the home node 1 to node 36. Plotting must begin at node 36 and work back to the home node. In table B at node 36, the routing is to node 33 and the summation of time from the home node to node 36 is 10 minutes. At node 33 the routing is to 35; at 35 the routing is to 1, the home node. If all routings are desired, each link in table B may be plotted with the direction of the arrow being from B_B to A_B. If the flow chart is followed to its conclusion, trees will be computed from each node in the system to all others.

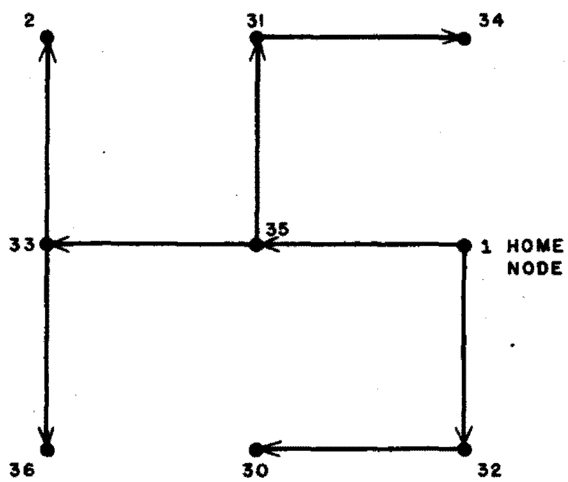


Figure V-8.--Minimum path tree calculated from node one in sample network.

In traffic assignment, the interest is usually in routings from zone centroids to other zone centroids via a street or highway system. In the example just given, if it is assumed that nodes 1 and 2 are zone centroids, only the trees from 1 and 2 would be calculated to obtain the minimum path routings from 1 to 2 and from 2 to 1. The reverse routing is not the same because the links may not have the same traveltime in both directions. If they were equal, however, the routing would be identical.

As an example of the speed of the computer in building trees, for a small network containing 84 zones and approximately 300 nodes, all 84 trees can be built in 15 seconds.

B. The Theory of Diversion Assignment

An alternate technique for assigning traffic to a network is the diversion assignment procedure. This method assumes that a proportion of trips, as determined by a diversion curve, are diverted from an arterial route to a freeway. Three types of diversion curves are in current use--the time ratio curve developed by the Bureau of Public Roads (figure V-9), the distance and speed ratio curve used in a Detroit study, and the time and distance differential curve being used in California.

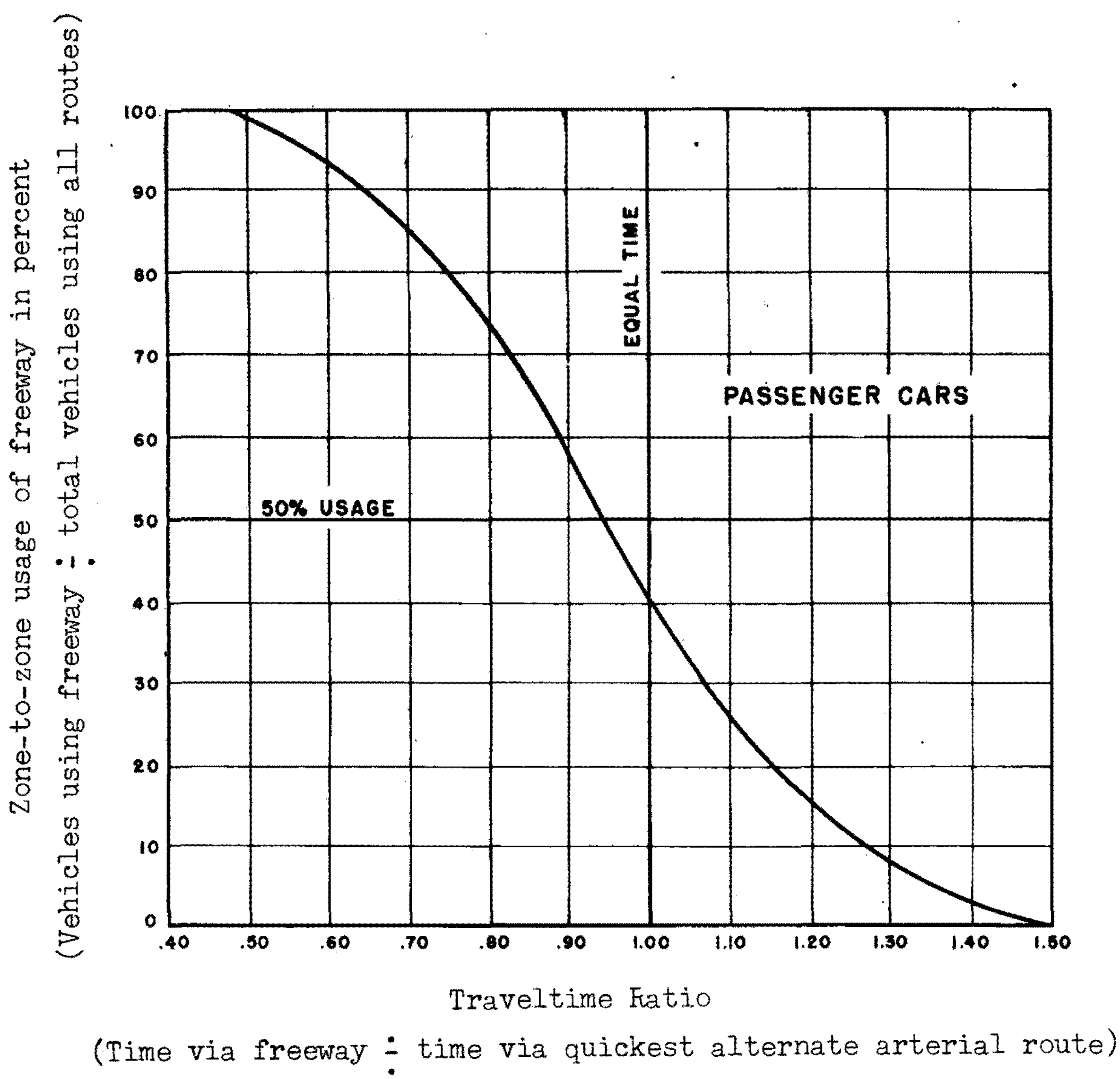


Figure V-9.--Bureau of Public Roads diversion curve.

The Bureau of Public Roads time ratio curve bases the percentage of trips to be assigned to a freeway facility on the ratio of the traveltime via the freeway to the traveltime via the quickest alternate route. The percentage of trips using the freeway varies as an S-shaped curve from 100 percent at a time ratio of 0.5 or less to zero percent at a time ratio of 1.5 or more. If the traveltime via the freeway is equal to the traveltime via the alternate route (time ratio equal 1.0), approximately 42 percent of the trips are assigned to the freeway because the freeway trips, with the faster speed, require a longer travel distance.

The speed ratio curves developed for the Detroit Area Transportation Study consist of a family of curves relating the percentage of freeway use to speed and distance ratios. These curves are also S-shaped for normal conditions. With a speed ratio of 1.0 and a distance ratio of 1.0, approximately 45 percent of the trips are assigned to the freeway. Since these curves represent a three dimensional surface with an undefined mathematical relationship, they are difficult to use in a computer application.

The California time and distance curves consist of a family of hyperbolas. With equal time and distance on the freeway and on the best alternate arterial route, 50 percent of the trips are assigned to the freeway. These curves are expressed in the equation:

$$P = 50 + 50(d + \tfrac{1}{2}\,t)\left[(d - \tfrac{1}{2}\,t)^2 + 4.5\right]^{-\frac{1}{2}}$$

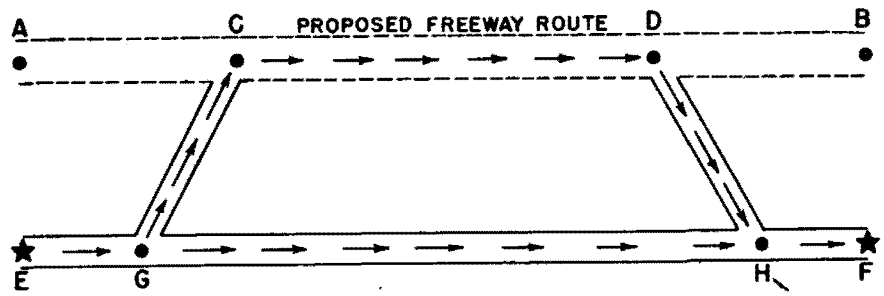
Where: P = percentage of freeway usage.

d = distance saved in miles via the freeway.

t = time saved in minutes via the freeway.

The Bureau of Public Roads diversion curve, which will be referred to in all subsequent discussion, was developed to be applied only at "points of choice."

A point of choice is defined as that point where the arterial and freeway routings diverge from a common path at the origin end of the route, and the last point where the freeway and arterial routes converge to a common path at the destination end of a route. In figure V-10, the points G and H are considered to be points of choice, since links EG and HF are common to both the freeway and the arterial route when traveling from point E to point F on the network.



AB = Proposed freeway route
E&F = Terminals of an interzonal traffic movement
EGHF = Routing from E to F via existing street system
EGCDHF= Routing from E to F via the freeway
GC&DH = The portions of the existing street system used to gain access to the freeway
G&H = Points of choice

Figure V-10.--Schematic example of diversion to a freeway.

The diversion curve has been developed for application at points of choice to allow reasonable diversion to freeways when only short sections of a freeway are used in long routings. If diversion was used between point of origin and point of destination in this situation, a time ratio close to 1.0 would nearly always be obtained.

Diversion assignment requires that there be two routings for each interzonal movement, one via the arterial street system and one via the freeway system, including the parts of the arterial street system that are necessary for access to the freeway. This allows either a time ratio, a speed ratio, or a time and distance ratio, depending on the type of diversion curve used, to be computed between the two routings for the interzonal movement. The diversion curve may then be consulted to determine that portion of the movement to be assigned to the links involved in the freeway routing, and the amount to be assigned to the minimum path (quickest alternate) through the arterial street system.

The Moore Algorithm is used to compute both routings. Two separate systems must be described in the form shown in table A, figure V-4, one comprising the arterial street system only, the other comprising the arterial street system plus the freeway facilities. The trees must be calculated separately. This can be done by first creating table A, figure V-4, for the arterial street system only and calculating all trees. Table A can then be modified to include the freeway system, and all trees involving the arterials plus the freeways can be calculated.

There is an additional restriction that must be imposed during the calculation of trees for the arterial or freeway system in diversion assignment. The traffic must be forced to use the freeway facilities for a part of each zone-to-zone movement if it is likely that any part of a movement might divert to the freeway facilities, even though the routing may be longer in total time than the routing over the arterial street system. If this were not the case, no time ratios greater than 1.00, as shown in figure V-9, would occur. This would render the right-hand portion of the diversion curve useless. If forcing a movement to use a freeway system results in a very high time ratio, it is disregarded because any ratio greater than the upper limit of the curve results in no assignment to the freeway facilities for the particular zone-to-zone movement in question. Adverse time routes, however, are basically incompatible with the minimum path concepts.

The technique of forcing the use of a proposed facility has been accomplished by reducing the traveltime on the freeway links during the calculation of the arterial, plus freeway system trees, as explained in chapter III.

To further clarify the time reduction feature, refer to figures V-9 and V-10. The sum of the traveltime for GC + CD + DH must be less than that for GH for a minimum path program to establish that EGCDHF is a minimum time path. Ideally, routings that involve portions of a freeway are desired in all cases where the time ratio is 1.50 or less. Time ratios greater than 1.50 result in zero traffic volume assigned to the freeway, so routings over the freeway are not required. In figure V-10 the time ratio is (GC + CD + DH) ÷ GH. Referring to figures V-10 and V-11, if GC and DH are zero, the time ratio is CD ÷ GH. In any case where CD is 1.50 times GH or greater, all time ratios will be greater than 1.50, or beyond the limits of the diversion curve. This would result in zero assignment to CD. If (GC + DH) is equal to GH, the time ratio will be 1.50 or greater in all cases where CD is one-half or more of GH. This establishes the line HH in figure V-11.

If GC and DH are zero, any case where CD is equal to or less than GH will result in EGCDHF being the minimum path. If the sum (GC + DH) is equal to or more than GH, EGCDHF is not the minimum path. This establishes the line JJ in figure V-11. All cases that fall between the two lines have time ratios between 1.00 and 1.50, indicating that there will be some diversion to the freeway routes but no minimum paths will be calculated involving freeways; thus, the volumes that should be

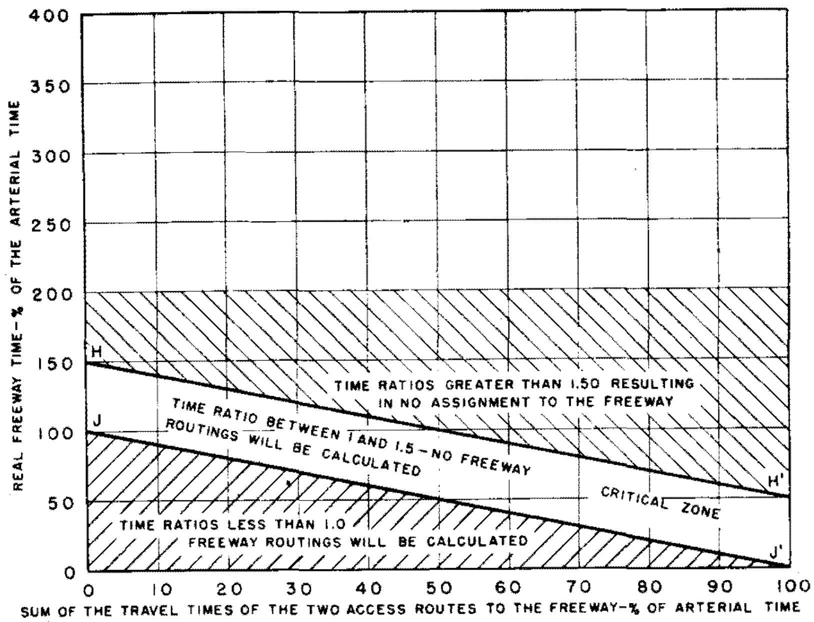


Figure V-11.--Freeway route calculation at full time.

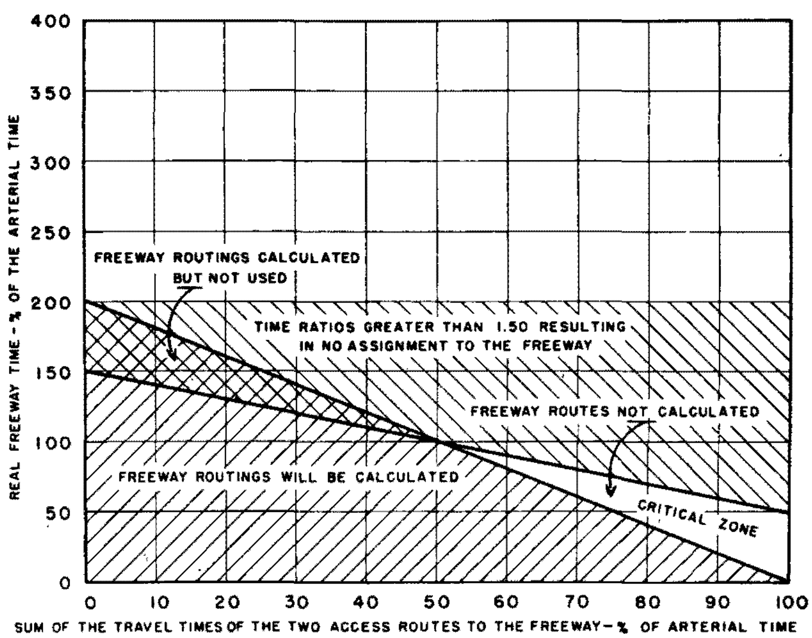


Figure V-12.--Freeway route calculation at one-half time.

diverted will not be assigned. In this case 100 percent of the volumes will be assigned to the arterial street system.

Figure V-12 shows the situation that would result if the freeway traveltimes were halved during the tree calculations, and then restored to their full values before time ratios are calculated. The unshaded triangle shows the critical area where time ratios would be between 1.00 and 1.50, but no routings involving a portion of a freeway route would be calculated. Note that the area has been reduced to one-quarter of the critical area shown on figure V-11.

Figure V-13 shows the results if the freeway traveltimes are cut to one-quarter of their original values. The critical area in this case is 8.5 percent of that shown in figure V-11. However, experience has shown that routings become somewhat unrealistic when freeway link traveltimes are reduced by more than one-half.

Figure V-14 is a plot of the critical area versus the fraction of the original time to which the time is reduced. Cutting the freeway traveltimes to zero would force all routings to use a portion of the freeway system, but the criteria for route selection would be lost. For example, if a trip entered the outer circumferential of a freeway and wanted to leave the freeway after a short distance, zero freeway time might route the trip completely around the city to the exit point.

To summarize, the problem of forcing traffic to use freeway or proposed routes when the traveltime is adverse to the arterial street system routes (time ratios between 1.00 and 1.50) is a difficult one when using some systematic method for route selection. However, reducing the traveltime on the freeway links allows the same tree calculation program to be used for both the arterial street network and the arterial plus freeway network.

C. Capacity Restraint Theory

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

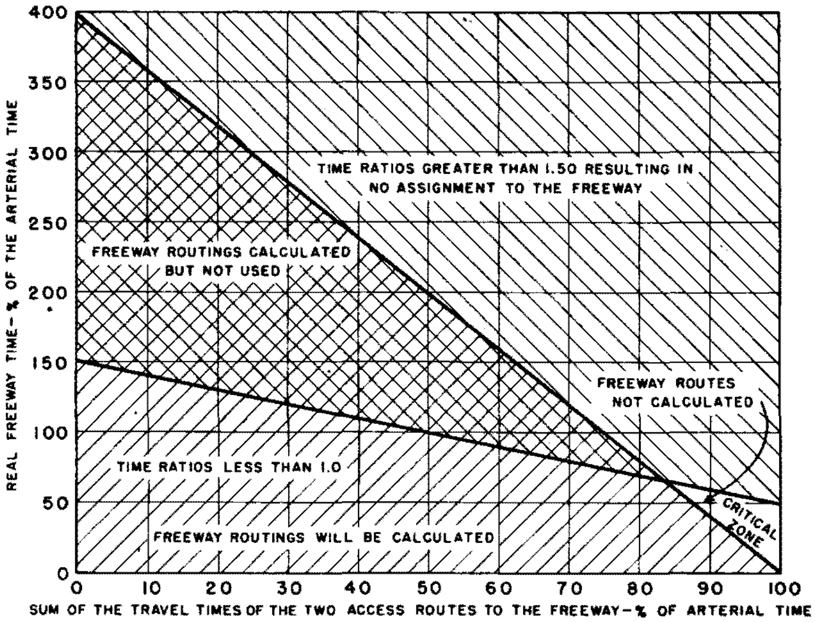


Figure V-13.--Freeway route calculation at one-fourth time.

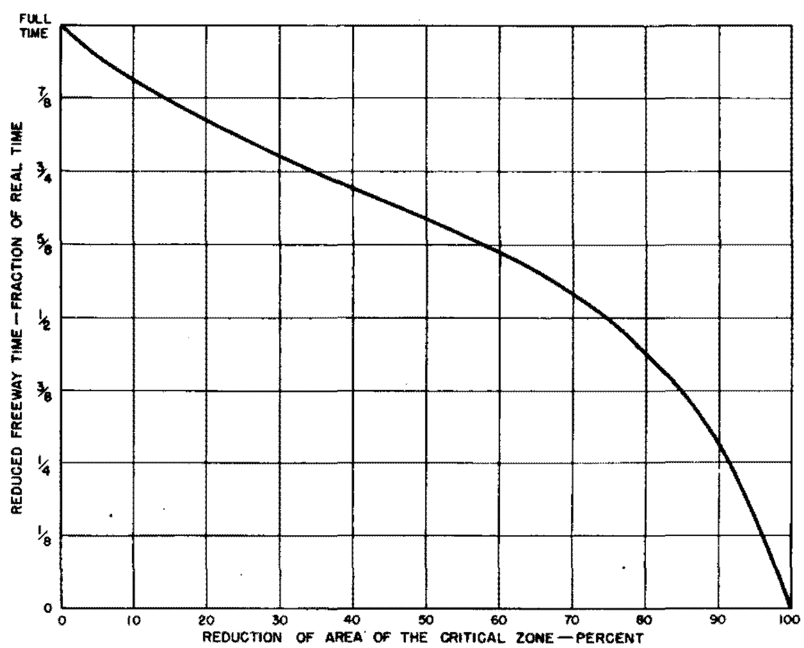


Figure V-14.--Relation of the critical zone area to the freeway time reduction.

The iterative technique, called capacity restraint, is one in which resultant loadings are analyzed by the computer to determine whether an initial estimate of the speed on a link should be changed, and to what degree this should be done. The capacity restraint program begins its operation by first reading into storage the practical capacity on each link, together with the speed at which traffic would flow on this particular link when loaded to practical capacity. Trees are then built based on these speeds, and the highway network is loaded with traffic. Now, a historical record of speeds and volumes for each link is prepared, and the volume assigned to each link on the loaded system is compared with the capacity of that link.

It is assumed that there is a relationship between traveltime (or speed) and the volume peculiar to each link in a highway network which can be expressed by the following equation:

$$T = T_0 \left[1 + 0.15 \left(\frac{\text{Assigned volume}}{\text{Practical capacity}}\right)^4\right]$$

where: T = Traveltime at which assigned volume can travel on the subject link.

T_0 = Base traveltime at zero volume = traveltime at practical capacity x 0.87.

This relationship is shown graphically in figure V-15.

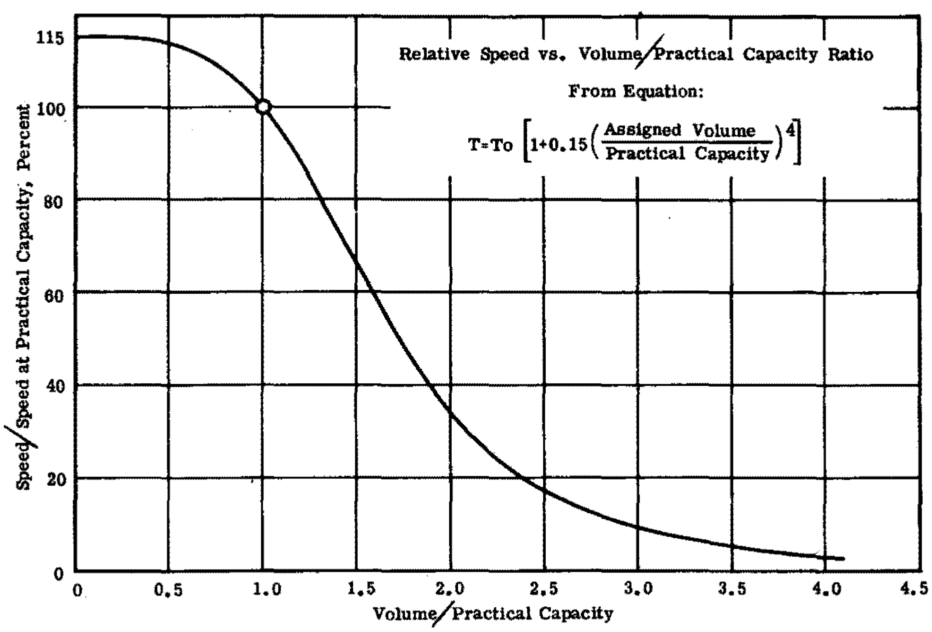


Figure V-15.--Capacity restraint relationship.

Using this equation it is possible to determine the speed at which the assigned volume could theoretically be carried. For example, assume that link 3403 - 3406 is one mile long, has a practical capacity of 32,000 vehicles per day, and a speed at that capacity of 40.0 m.p.h. The traveltime on the link, therefore, is 1.50 minutes at practical capacity. The traveltime at zero volume is 1.50 x 0.87 minute = 1.31 minutes or 45.8 m.p.h.

After the tree building process was completed and the network loaded, say that a volume of 50,000 vpd was assigned to the link. Using the volume to practical capacity ratio of 1.56 in the above equation,

$$T = 1.31 \left[1 + 0.15\ (1.56)^4\right] = 1.31 \left[1 + 0.89\right] = 2.48 \text{ minutes, or } 24.2 \text{ m.p.h.}$$

(speed at which 50,000 vpd can travel).

A new speed, based on an adjustment of the balance traveltime, is then calculated for the next iteration to minimize the imbalance of volume on the link. Recognizing that changing the traveltime on a link is likely to result in an inverse change in loading, the full effect of this change is moderated by using a speed for the next iteration which is obtained by going only one-fourth of the way from the last assignment speed toward the new balance speed. It has been found that this method of adjustment eliminates large oscillations of loads on the links from one iteration to the next.

In the example using link 3404 - 3406, a speed of 40 m.p.h. corresponds to a traveltime of 1.50 minutes. Similarly, the traveltime at 24.2 m.p.h., the speed at which the first assigned volume could travel, is 2.48 minutes. To find the speed to use for the next iteration, one-fourth of the difference between 2.48 and 1.50 minutes, or 0.245 minute, is added to the previous traveltime. This results in a value of 1.745 minutes, or a speed of 34.4 m.p.h.

The next step in the procedure is to build a new set of trees by using the adjusted speeds (34.4 m.p.h. for link 3404 - 3406) on each link, load the modified network, and examine the volume to capacity ratios again for each link.

An alternate method of moderating the speed in the capacity restraint analysis may be used at the discretion of the engineer. This is done by adding a "patch" to the capacity restraint program. This patch averages the balance traveltime with the traveltime used in the previous assignment. Thus, in the example using link 3404 - 3406, the average of the two traveltimes (1.50 and 2.48) is 1.99 minutes, corresponding to a speed of 30.1 m.p.h. to be used for the next assignment.

This process may be continued for as many iterations as desired. However, experience has shown that after four iterations the accuracy of the assignments does not improve appreciably.

D. Internal Scaling by the Computer

The traffic assignment programs that have been described in this manual restrict the link parameters to a maximum traveltime of 9.99 minutes and a maximum distance of 9.99 miles. The maximum traveltime includes the time of the turn penalty. Because of the limited amount of storage available within the computer, the link times and distances are scaled to 1/63 increments of the longest time and distance that are specified in the parameter card. Sixty-three is the largest number that may be described in six binary bits.

All of the computer programs that interrogate the speed or time data on the link data card must first compute the conversion factors. This conversion factor is calculated by multiplying 63 times 60 and dividing the result by either the maximum traveltime or distance that is indicated on the parameter card. When the speed or distance data are subsequently read by the computer, they are immediately converted to sixty-thirds. When the speed and time data are written in binary on the magnetic tape, they remain scaled to increments of sixty-thirds.

This internal scaling by the computer has the effect of rounding some of the quantities and may cause some inconsistencies in the assignment. To maintain a sufficient level of accuracy, it is suggested that the maximum link time and distance be specified as <u>low</u> a value as possible.

The rounding will be illustrated in the following two examples. Example 1 specifies the maximum distance and time of 9.99 miles and minutes respectively. The second example specifies 6.30 as the maximum distance and time. Both examples perform the conversion on a link of 0.70 mile at 25 miles per hour.

From the following examples, a higher degree of accuracy was obtained for time, distance, and speed by using a lower value when specifying the maximum distance and time parameters.

INPUT: A link of 0.70 mile at 25 m.p.h.
(Traveltime is 1.68 minutes)

Item	Example 1	Example 2
	Max. dist. = 9.99 miles Max. time = 9.99 minutes	Max. dist. = 6.30 miles Max. time = 6.30 minutes
Scale factor	$\frac{63 \times 60}{9.99} = 378$	$\frac{63 \times 60}{6.30} = 600$
Scaled time	$\frac{0.70 \times 378}{25} = 10.5 = 11$ (63rds.)	$\frac{0.70 \times 600}{25} = 16.8 = 17$ (63rds.)
Scaled distance	$\frac{0.70 \times 63}{9.99} = 4.4 = 4$ (63rds.)	$\frac{0.70 \times 63}{6.30} = 7.0 = 7$ (63rds.)
Converted time	$\frac{11 \times 9.99}{6.3} = 1.74$ minutes	$\frac{17 \times 6.30}{63} = 1.70$ minutes
Converted distance	$\frac{4 \times 9.99}{63} = 0.63$ mile	$\frac{7 \times 6.30}{63} = 0.70$ mile
Converted speed	$\frac{4 \times 60}{11} = 21.8 = 22$ m.p.h.	$\frac{7 \times 60}{17} = 24.7 = 25$ m.p.h.

It is suggested that a value of 6.30 be indicated as a maximum traveltime, including the turn penalty, and 6.30 as a maximum distance. For a greater degree of accuracy on very short links, such as 0.3 mile, a maximum time and distance should be specified as 3.15. In some networks, however, this could cause a shortage of nodes. It is possible, of course, to specify each parameter differently. For instance, the maximum traveltime including the turn penalty may be specified as 6.30 minutes, and the maximum distance as 3.15 miles.

E. The Maximum Number of Links Outbound From a Node

The computer program which builds the network description has been written to allow a maximum of four outbound links from each node. If an error has been made in coding the link data and five or more outbound connections are made from a node, the computer will not accept the additional links; instead, it will write the link data card as an error. Intersections with more than four legs may be handled in a manner that has been previously described (see page III-27).

The reason for this restriction is that when a network description is built within core storage, there are (4)(M) number of cells reserved for the description, where M is the highest node number. If the network description is to be constructed beginning at location N in core storage, then N + 4M would be the location of the information for the highest node number in the system.

Thus there are four cells reserved in storage for each node in the network description. The location of the information pertaining to node X would be at storage location N + 4X. In this manner, the cells reserved for the nodes in the system are not identified by number, but by their location within core storage.

Part of the information contained in the four cells for each node is the outbound connection or node number from that particular node. Obviously, if the computer receives information for a fifth outbound connection from the node, there would be no place to store the data and, as such, it must be considered as an error.

There are no restrictions concerning the number of inbound links to a node. If one leg of a five-leg intersection is one-way inbound, it may be coded in a normal manner. However, it is suggested that a maximum of four inbound links be used also. Experience has shown that, when more than four are used, inaccurate turning movements are assigned to the intersection.

TRAFFIC ASSIGNMENT MANUAL

CHAPTER VI - COMPUTER PROGRAMS AND OPERATIONS	June 1964

Chapter VI is devoted to the detailed description of the computer programs involved in a traffic assignment. It begins with a section that describes the procedures for computer programing within the BELL-BELMN System. This section has been included for those who desire to program additional routines that will be incorporated within the system. Only experienced computer programers should study this first section. It may be disregarded by those who only intend to utilize the available computer programs.

A section of "standard" card and tape formats is included. These formats have been referenced throughout the text to avoid lengthy repetition each time they are mentioned. These will also be beneficial to those who desire to make changes in the existing programs or write additional routines.

One of the most important sections in this chapter is devoted to the computer operations. In this section the techniques, requirements, and descriptions for operating the computer and the programs are explained. This is followed by the program writeups. There is an abbreviated program writeup for each major program that is discussed in the text.

Each of the computer programs that is used during a traffic assignment is "stacked" on one magnetic tape that is referred to as a "program library tape." To use a specific program from this library tape, all the user must do is request another computer program, called the control program, to find that particular program on the library tape and load it into core storage. The control program is instructed to load the specified program that has been designated on the program call card. The program call card simply says,"find Program PR-XX and load it into memory." Some additional cards are required to give the computer additional information about the run.

As described later in this chapter, the computer will be given its instructions concerning the traffic assignment run by what are known as system control cards. These cards instruct another program called a senior monitor, which is an integral part of the operating system of the computer installation. The senior monitor program performs many functions. Its primary function, however, is to control the processing of many different jobs on the computer without delay. In other words, the computer may be processing a traffic assignment program and upon completion, immediately begin processing a completely different job.

The traffic assignment programs are available for use with a monitor program called the BELL System. Actually, two monitors are required: the senior BELL MONITOR and a submonitor called BELMN. The operation of the traffic assignment programs as they are discussed in the following sections is with regard to these two monitors.

Presently there are only three programs that have not been revised to operate under these monitors. These are programs PR-10 (load selected links), PR-3 (load by diversion), and PR-83 (convert Memory A to link data cards). It is expected that these three programs will be converted in the near future.

It is possible to operate these programs without the monitors by utilizing the TEXAS Control Program. A different type of program library tape is required to operate with the TEXAS control, and the operation of these computer programs with TEXAS control usually requires an experienced operator throughout the run. An advantage of this system is that there are no system tapes required for the run other than the program library tape.

With TEXAS control, the control program (the first program on the library tape), is loaded into core after pressing "load tape" on the computer. The control program then reads the required parameter cards, locates the subject program on the library tape, and loads it into core. Control is then transferred to the subject program.

All of the traffic assignment programs are available with the TEXAS control program, including programs PR-10, PR-3, and PR-83, except the capacity restraint programs (PR-60, PR-61, and PR-63).

The decision to operate with either the BELL MONITOR or the TEXAS systems will depend upon the computer installation and the availability of operators who are familiar with the procedures. At the present time both systems are being used extensively.

A new control system called IBSYS has been written for application with the battery of traffic assignment programs described in this manual. At the time of this writing the IBSYS control system has not been thoroughly tested by the Bureau of Public Roads. However, this control system and the writeups for the traffic assignment programs operating under it are available. As explained in chapter IV, information regarding the IBSYS control system may be obtained by contacting the Urban Planning Division, U.S. Bureau of Public Roads.

Table VI-1 lists the computer programs available under each of the three control monitors.

Table VI-1.--List of available computer programs

Program No.	Control monitor			Program name
	TEXAS	BELMN	IBSYS	
PR-1	X	X	X	Build trees
PR-2	X	X	X	Load minimum paths
PR-3	X		X	Load via diversion
PR-6	X	X	X	Build-update network description
PR-7	X			Build trip tables from summary cards
PR-10	X			Load selected links
PR-11	X	X	X	Format trees
PR-12	X	X	X	Print link data
PR-13	X	X		Format trip table
PR-15	X	X	X	Sum ins and outs
PR-17		X		Travel costs
PR-19		X		Extract zone-to-zone distances via tree traces
PR-27		X	X	Trip conversion program
PR-47		X	X	Prepare trip table from standard format
PR-50	X	X		Format tree trace (Destructive)
PR-51		X		Binary trip table modifier
PR-60		X	X	Build capacity restraint binary historical record
PR-61		X	X	Apply capacity restraint to network description
PR-63		X	X	Format historical record of capacity restraint
PR-104	X	X	X	Sum volumes and turns
PR-124		X	X	Trip comparison
PR-126		X	X	Trip table compressor
PR-130	X	X	X	Skim trees and update
PR-131		X		Nondirection adjustment
PR-133	X	X	X	Build trip volumes
PR-152		X		Add or subtract trip tables
PR-183		X		Accumulate selected interzonal volumes

A. Concepts of a Computer Monitor System - IBM 7090/7094

The IBM 7090/7094 traffic assignment programs operate under control of the CONTROL PROGRAM. The TEXAS control program:

Loads and initiates the subject program.

Reads the remarks cards which are printed on-line as instructions to the operator.

Prints the program running time off-line.

Prints program options on-line.

The most efficient use of the TEXAS programs usually requires that a person who is familiar with the program requirements be present during the operation. Messages are written with the assumption that decisions are being made at the console by a person familiar with the problem and the programs.

In recent years, the larger computer centers have preferred that the programer and program-user use the computer remotely. Programs are written and runs are set up so that a computer operator of ordinary ability can perform the operation. This trend has led to the development of monitor systems such as the BELL System, IBSYS, and the FORTRAN MONITOR. These are production monitors, inasmuch as they load and initiate the subject programs. They also have features which make them of great value in testing and correcting a program. "Snapshots" may easily be planted within the program to record the contents of designated cells under specified conditions. Core and tape dumps may also be obtained during or after the running of a program. All of this is done with no special manipulation from the console.

The main disadvantages of a monitor system are that it requires some core storage and does not allow use of console sense switches in a subject program.

With the advent of the IBM 7090/94, the advantages of a monitor system became even more important. A control system was developed which takes advantage of a monitor system without losing the required ease and flexibility of operation. Although this control system was written specifically for the BELL System, only minor changes would be required for operation with other existing or future monitors. Some general principles of this control system are:

Keeps the input-output operations separate from internal operations within a program.

Refers to the input-output and conversion subroutines by means of a transfer vector table.

Allows a program to make use of the monitor when desired, such as debugging, but still makes it possible to use all of the storage when necessary.

Provides for flexible tape addressing.

By adhering to these principles, any change in the monitor system or in the control program will require a reassembly of only the control program. The subject programs should not require modification.

The control system developed for use with the BELL System consists of a revised control program and a tape loader called BELMN. For convenience, the name BELMN is also used when referring to the entire control system concept.

Specifically, BELMN is a one-card tape loader (non-self-loading) which calls the control program from tape. If it is desired to run completely outside of BELL, use a loader with an origin at 2150_8.

1. Program requirements of the BELMN System

a. Use the "Table of Equivalents" to define tape unit numbers and transfer table locations, including sense switch tests.

b. ORG programs at 1135_{10}; 2157_8.

c. The first word of program must contain only the program number in decrement. The second word is an IOCD or IORP containing the beginning location in the address and the number of words in the program in the decrement. The third word is used to show date of assembly (e.g., BCI 1,010164 for 1/01/64). The fourth word (usually 2162_8) must be the first instruction to be executed. For example:

```
        ØRG     1135
        PZE     ,,78
        IØCD    BEGIN,,TAIL+1-BEGIN
BEGIN   REWA    J
          |                     SUBJECT
          |                     PRØGRAM
TAIL    PZE     TAIL
CØN     BSS     12
BUFFR   BSS     1000
        END     BEGIN
```

A program using less than $25,489_{10}$ cells will run completely within the BELMN System. Programs within this limitation can use all the advantages of BELMN and BELL. To avoid becoming too dependent upon the BELL System, these rules should be followed:

Do not use library subroutines.

Initialize all storage areas by reference to the transfer table. (See the following example.)

Check for overrun. (See the following example.)

Never halt the program except for an empty card reader or a full output tape.

Check for end of tape on BCD output (A3).

When each program has finished, the control program should be recalled. However, if an error is encountered, control should be transferred by XEC ENDJ which transfers control to BELL and terminates the run. (This assumes that BELL is intact in core. If it is overwritten, use the TRA ERROR procedure illustrated later.)

If you are running with BELL in storage and wish to go to the BELL System, XEC SYS will send you to BELL. The BELL commands, PAUSE and REMARK, may be used to communicate with the computer operator while under control of BELL. (See BELL manual.) Remarks cards (* in col. 1) may also be used while under control of the BELMN control program.

If the program overwrites BELL and BELMN, return to the control program at completion and then use a TJ card to bring BELL back.

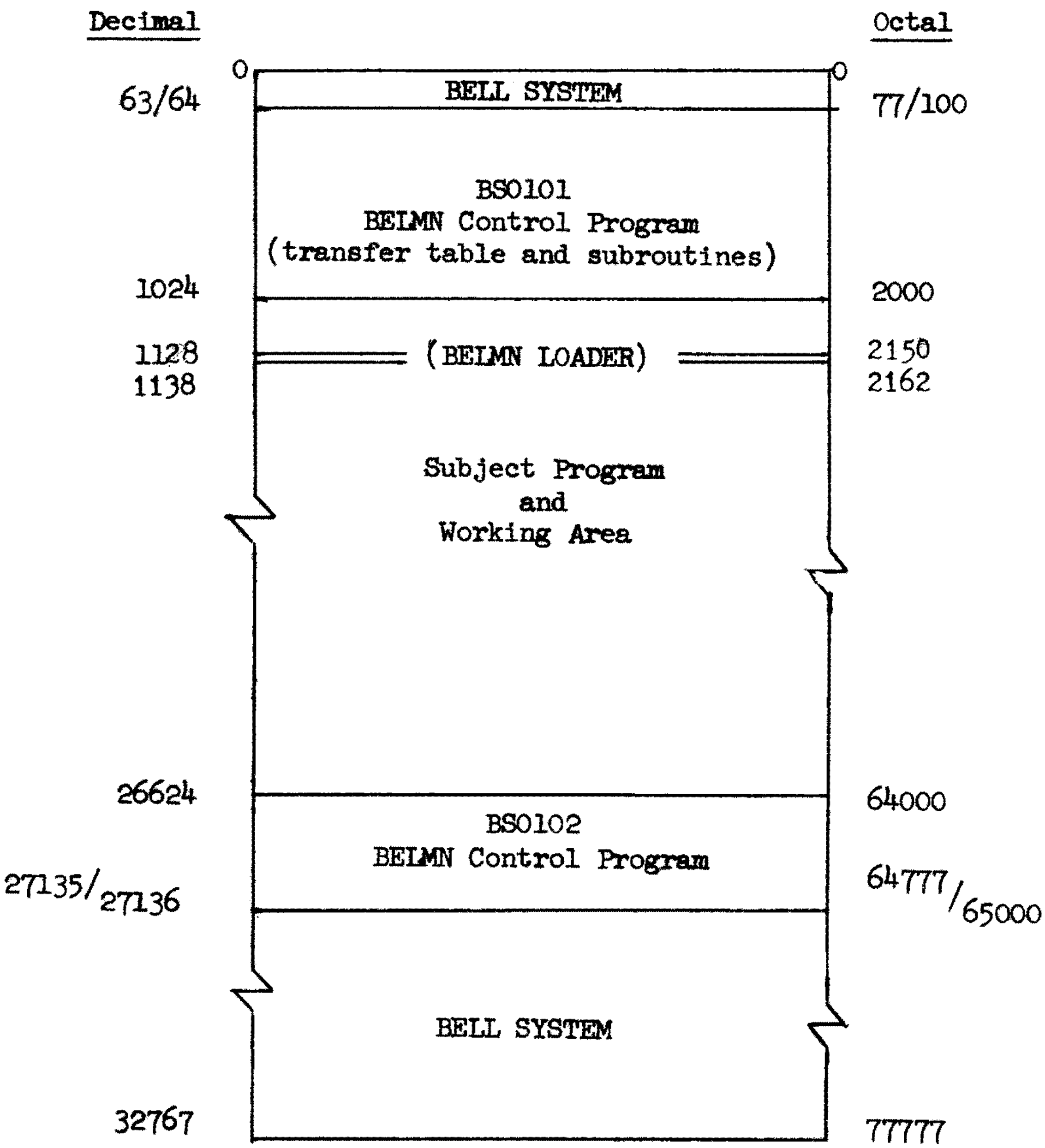
2. <u>The transfer table</u>

A table of references called the "transfer table" is maintained in storage. Each cell in the table contains the address of the variable portions of the system. For instance, references to input-output routines are made via the transfer table. If changes are made to the input-output routine which change their initial locations, only the entries in the transfer table are changed. No changes are necessary within the subject programs. It is expected that the transfer table will always remain in the same location. (See memory map of BELMN production run in figure VI-1.)

The transfer table contains the addresses for:

Input-output subroutines.

Binary and BCD conversion subroutines.



Note: 64000_8 - 77777_8 may be overwritten if SYSTEM routines are not used

Figure VI-1.--Memory map of BELMN production run.

Tapes.

BELL System addresses for error, end of job, and clockout situations.

Return to the control program.

It also contains the switching instructions which are executed remotely by a subject program. Finally, storage allocations for working areas are defined.

3. Sense switches

The BELL System reserves all console sense switches for its use as follows:

Sense switch		
1	ON	Read console keys for further instruction.
2	ON	Stop at the next JOB.
3	ON	Go to error dump instead of reading next control card.
4	OFF	Punch off-line.
	ON	Punch on- and off-line.
5	OFF	BCD input from tape A2.
	ON	Input from card reader.
6	OFF	BCD output on tape A3.
	ON	BCD output on-line, as well as tape A3.

4. Program options

Up to 32 options may be designated by punching a "1" in columns 1-32 of the parameter card. Option "n" is designated by a 1 punch in column "n."

5. Return to the control program

XEC RETURN

6. Symbol table

```
     I  EQU      8            IØSAT  BØØL     105
     J  EQU      2              BIN  BØØL     106
     K  EQU      3              BCD  BØØL     107
     L  EQU      4              SYS  BØØL     110
     M  EQU      5             ENDJ  BØØL     111
     N  EQU      6              SW1  BØØL     112
     P  EQU      7              SW2  BØØL     113
     Q  EQU      8              SW3  BØØL     114
    QQ  EQU      9              SW4  BØØL     115
     R  EQU     10              SW5  BØØL     116
     S  EQU      1              SW6  BØØL     117
     T  EQU      2             STØT  BØØL     120
     U  EQU      3            MEMAS  BØØL     121
     V  EQU      4            MEMAL  BØØL     122
     W  EQU      5               IØ  BØØL     123
     X  EQU      6             STØP  BØØL     124
    XX  EQU      7            REDAT  BØØL     125
    XY  EQU      8            RITAT  BØØL     126
     Y  EQU      9             CLKT  BØØL     127
     Z  EQU     10            TRTIØ  BØØL     130
 CDIMT  BØØL   100            CPRIØ  BØØL     131
 BNCDT  BØØL   101             ØPEN  BØØL     132
 IMAGT  BØØL   102           RETURN  BØØL     133
 STSWT  BØØL   103            PUTBE  BØØL     134
 IØSBT  BØØL   104
```

7. Programing examples

The proper method for handling data cards is to read them and immediately write them offline so the person using the program can always check his parameters and controls along with his output.

Following is one recommended procedure:

```
*               READ AND WRITE IDENTIFICATION  CARD
BEGIN   REDE    CARD,ERR1,ERR2
        RITE    CARD-1,13,1,ERR1,ERR2,0
        CLA     CARD+11
        ANA     MASKT           OCT 77
        SUB     ONE
        TNZ     BAD72           BAD CARD
        AXT     12,1
        CAL     CARD+12,1       MOVE CARD TO ID AREA
        SLW     ID+12,1
        TIX     *-2,1,1
*               READ AND WRITE PARAMETER CARD
        REDE    CARD,ERR1,ERR2
1       RITE    CARD-1,13,1,ERR1,ERR2,0
        CLA     CARD+11
        ANA     MASKT
        SUB     TWO
        TNZ     BAD72
*               NOW UNPACK  THE OPTIONS  %COLS 1-36¤
*               PUT THEM IN ONE WORD IN SENSE INDICATORS
        AXT     1,1
```

```
UNPAK   CAL     CARD+6,1
        ANA     TEST              010101010101
        AXT     6,2
        LGR     1
        ARS     5
        TIX     *-2,2,1
        TXI     *+1,1,1
        TXL     UNPAK,1,6
        STQ     OPTION
        LDI     OPTION
*               NOW UNPACK THE  REST OF THE PARAMETER CARD
*                                 AS IT SUITS THE PROGRAM
*
*               NOW READ CONTROL CARD
        REDE    CARD,ERR1,ERR2
        RITE    CARD-1,13,1,ERR1,ERR2,0
        CAL     CARD+11
        ANA     MASKT
        SUB     THREE
        TNZ     BAD72
        AXT     11,1              MOVE CARD TO CON AREA
        CAL     CARD+11,1
        SLW     CON+11,1
        TIX     *-2,1,1
```

```
*              NOW READ TAPE  ASSIGNMENT CARD
        REDE   CARD,ERR1,ERR2
        RITE   CARD-1,13,1,ERR1,ERR2,0
        CAL    CARD+11
        ANA    MASKT
        TZE    ALLIN
BAD72   RITE   INVAL,4,1,ERR1,ERR2,0
        XEC    ENDJ
INVAL   BCI    4, IMPROPER CARD TYPE
ERR1    SXA    *,4             END OF FILE OR TAPE
        RITE   FILER,4,1,ERR1,ERR2,3
        XEC    ENDJ
FILER   BCI    4, END OF FILE OR TAPE
ERR2    SXA    *,4
        RITE   REDUN,3,1,ERR1,ERR2,3
        XEC    ENDJ
REDUN   BCI    3, REDUNDANCY ERROR
ALLIN   AXT    5,1
        CAL    CARD+5,1
        SLW    ASCD+5,1
        TIX    *-2,1,1
        TRA    PROCES          ALL CARDS IN GO TO IT
```

```
ONE     DEC    1
TWO     DEC    2
THREE   DEC    3
        BCI    1,
CARD    BSS    14
HEAD    BCI    1,
ID      BSS    12
CON     BSS    12
ASCD    BSS    14
OPTION  PZE
TEST    OCT    010101010101
*       NOTE   THE FOLLOWING  MACRO COULD REPLACE
*              MOST OF THE READ IN CODING
NEXCRD  MACRO  COL72,
        REDE   CARD,ERR1,ERR2
        RITE   CARD-1,13,1,ERR1,ERR2,0
        CAL    CARD+11
        ANA    MASKT
        SUB    COL72,
        TNZ    BAD72
NEXCRD  END
```

* SET UP OPTIONS IN SENSE INDICATORS

The Sense Indicator Register is used to carry the designated options. Use the "on test for indicators" to test for an option:

```
        ONT   S15   MASK- 020000000000
         -     -    OFF
         -     -    ON
```

* INVERT AND WRITE NETWØRK DESCRIPTIØN

```
WRITE  CLA     LNN
       ALS     2
 GØTD  STØ     **
       CLA     *-1
       STA     ZWRZ+1
       AXT     0,5
 SPØP  LDQ*    MAMØ1             INVERT NETWØRK
       CLA*    MEMØ4
       STQ*    MEMØ4
       STØ*    MAMØ1
       TXI     *+1, 1, -1
       TXI     *+1, 4, 1
 XWRX  TXL     SPØP, 4, **
 ZWRZ  WATBB   XX, **, **, ERR1, ERR2
       WTMB    XX, ERR1, ERR2
       REWB    XX
```

* MASKS FØR TESTING SENSE INDICATØRS

```
  SI1  ØCT     400000000000    ØPTION FROM CØL. 1
  SI2  ØCT     200000000000    ØPTION FROM CØL. 2
  SI3  ØCT     100000000000    ØPTION FROM CØL. 3
  SI4  ØCT     040000000000    ØPTION FROM CØL. 4
  SI5  ØCT     020000000000    ØPTION FROM CØL. 5
       *
       *
       *
 SI35  ØCT     000000000002    35
 SI36  ØCT     000000000001    36
```

Error return

```
  ERRØR CLA     ERFLAG
        STØ     BELMN+
        XEC     RETURN
 ERFLAG XEC     PUTBE
```

```
*           NORMAL PARAMETER UNPACK
      CLA   CARD+6         COLS  37-39
      ARS   18
      TSX   BIN,4
      STO   LZNO           LAST ZONE CENTROID
      CLA   CARD+6         COLS 41-44
      ANA   MASKZ          7777
      LDQ   CARD+7
      LGL   12
      TSX   BIN,4
      STO   LNN            LAST NODE NUMBER
      CLA   CARD+7         COLS 46-48
      ANA   MASKW          777
      TSX   BIN,4
      STO   LTIM           LONGEST TIME
      CLA   CON+8          COLS 50-52
      ARS   12
      ANA   MASKW
      TSX   BIN,4
      STO   TPENT          TURN PENALTY
      ADD   LTIM
```

```
STO     LTTP          LONGEST TIME + TURN PENALTY
LDQ     CARD+9        COLS  55-60
CLA     CARD +8             49-54
LGL     12
ANA     MASKW         SAVE  54-56
TSX     BIN,4
STO     LD15          LONGEST  DISTANCE
LDQ     CARD+10       COLS  61-66
CLA     CARD+9              54-60
LGL     6
ANA     MASKZ         SAVE  58-61
TSX     BIN,4
STO     FFNN          FIRST FREEWAY NODE NUMBER
CLA     CARD+10       COLS  63-66
ANA     MASKZ
TSX     BIN,4
STO     FTN           FIRST TURN NODE
CLA     CARD+11       COLS  67-70
ARS     12
TSX     BIN,4
STO     LTN           LAST  TURN NODE
```

```
*     CALCULATE AVAILABLE STØRAGE AND INITIALIZE TABLE ADDRESSES

STØRG CLA     LNN               NETWØRK
      ALS     2
      ADD     LZNØA             DISTANCE TABLE
      ADD     LNN               TREE
      ADD     TAIL+5038         PRØGRAM + BUFFERS
      STØ     CELLS
      SUB     ØPEN              AVAILABLE STORAGE WITHIN SYSTEM
      TPL     SQASH             NETWØRK TØØ BIG TØ WØRK WITHIN SYSTEM
      CAL     MEMAS             NETWØRK FITS WITHIN SYSTEM
      STA     MEMA
      TRA     READ
SQASH CLA     MEMAL             CHECK IF NETWØRK
      SUB     CELLS             IS TØØ BIG
      SUB     BEGIN             FØR THIS
      TMI     SIZE              MACHINE
      CAL     MEMAL
      STA     MEMA
      TRA     READ
 SIZE RITE    SIZEM, 6, 1, ERR1, ERR2, 2
      XEC     ENDJ
SIZEM BCI     6, PRØBLEM TØØ LARGE FØR THIS MACHINE
CELLS PZE
 MEMA PZE
 SETM CLA     MEMA              SET UP FØR
      STA     MEMØØMEMA         INDIRECT
      STA     MEMØ2MEMA,2       NETWØRK
      STA     MEMØ4MEMA,4       REFERENCES
      ADD     ØNE
      STA     MEM11MEMA+1,1
      ADD     THREE
      STA     MEM43MEMA+4,3
      STA     MEM46MEMA+4,6
      ADD     ØNE
      STA     MEM55MEMA+5,5
MEMØØ PZE
MEMØ2 PZE     0,2,0
MEMØ4 PZE     0,4,0
MEM11 PZE     0,1,0
MEM43 PZE     0,3,0
MEM46 PZE     0,6,0
MEM55 PZE     0,5,0
  MAM PZE
MAMØØ PZE
MAMØ1 PZE     0,1,0
```

```
*     READ AND INVERT NETWØRK DESCRIPTION

 READ CLA    LNN                SET
      ALS    2                  UP.
      STØ    TEMP               INITIALIZATIØN
      ALS    17                 FØR
      STD    XREX               INVERTING
      STD    XWRX               NETWØRK
      ALS    1
      ADD    ØNED
      STD    ZWRZ+1
      CLA    MEMA
      SUB    TEMP
      STA    MAMØ1
      SUB    ØNE
      STA    READN+1
      STA    GØTD
      STA    NETØ+1
      ADD    TWØ
      STA    MAMØØ
READN RDTBB  T, **, ERR1, ERR2
      READYB
      CLA*   READN+1            CHECK
      ANA    AMASK              000000077777 WØRD CØUNT
      CAS    TEMP               AGAINST PARAMETERS
      TRA    NØCHK              N. G.
      TRA    XREFR-1            Ø. K.
      TRA    NØCHK              N. G.
NØCHK RITE   NCKM, 9, 1, ERR1, ERR2, 2
      XEC    ENDJ
 NCKM BCI    9, NETWØRK WØRD CØUNT DØES NØT CHECK WITH PARAMETERS
      AXT    0, 5               INVERT NETWØRK
XREFR LDQ*   MAMØ1
      CLA*   MEMØ4
      STØ*   MAMØ1
      STQ*   MEMØ4
      TXI    *+1, 1, -1
      TXI    *+1, 4, 1
 XREX TXL    XREFR, 4, **
      TRA    NEXT
```

B. Operation of BELMN with BELL Monitor System (BESYS 3)

BELMN is a submonitor designed to operate the IBM 7090/94 traffic assignment programs under a senior monitor system (e.g., BELL or FORTRAN). The BELMN System was designed to make the computer system a remote operation, and to make available all the control which is a part of the BELL System.

Running a computer program under BELMN can be a completely remote operation for the engineer. A BELMN job is set up by the engineer desiring to run a program, and the prepared card deck is delivered to the computer site by messenger. The run is made as a normal BELL System job, and the results are collected by messenger and returned to the engineer. An efficient messenger system can make BELMN nearly as efficient as actual machine operation by the engineer. For large jobs which must be completed quickly, the engineer can move to the site of the computer and still, without operating the computer, submit runs more quickly after the results of previous runs have been investigated.

1. Details of BELMN

Any job begins as a normal BELL run, which means that the BELL System tape (mounted on unit A1) is read into core storage into cells 0-77[1] and 65000-77777. Cells 100-64777 are set to STR (5000 0000 0000) and control is sent to BELL System which reads a control card. Any BELL control card may be inserted at this point, but the normal procedure for production runs is to request the BELMN control program using a special loader.

A BELL "LOAD" card is used to load the series of instructions (PR-99, called BELMN Loaders)[2]; these instructions begin loading at location 2150. A binary transfer card follows the BELMN Loader to instruct BELL that the load is completed. If octal cards are used for the BELMN Loader the load and binary transfer cards are not required. A BELL transfer card (TRA 2150) is read and causes control to pass to the BELMN Loader located at 2150.

---

[1] All storage locations referred to in this writeup are in octal.

[2] See page VI-29 and VI-32 for details of BELMN Loader.

The BELMN Loader then reads the first two records (BELMN control program) from tape unit A8. It loads the first record (PR-101) into locations 100-2000, and the second record (PR-102) into 64000-64777. PR-101 contains the transfer table, the input-output and other subroutines used by the subject programs. PR-102 is the control program proper written to accept and operate from four types of cards: Remark Cards, Pause Cards, Subject Program Call Cards, and Time Cards. (See CARD Formats on page VI-31.)

Remark and Pause Cards are used to communicate with the operator. The message on a Remark Card is written on-line and on A3. A Pause Card, in addition to being written on-line and on A3, halts the machine, so that upon pressing "START" the program execution continues.

When a subject program call card is encountered, the BELMN control program searches the BELMN program library tape on unit A8 until it finds the designated program. It then begins loading the subject program into storage (usually at 2162 upward). After the loading has been completed, the BELMN control program transfers control to the starting location of the subject program.

Time cards are used to clock the running time of a job, or any portion thereof. A "TS" (time of start) card is used to record the beginning time of a job. A "TP" (time of phase) card will cause the calculation and recording of time elapsed since the last time card. A "TJ" (time of job) card causes the calculation and recording of the time elapsed since the last TS card. Also, when a TJ card is encountered by the BELMN control program, the contents of the BELL System tape on A1 are read back into core and control is transferred to BELL. If the installation does not have a clock compatible with BELL, the time cards should not be used.

Each subject program is expected to read its own identification, parameter, and control (if any) cards for execution of the run. At the end of the subject program run, control is transferred to either the BELMN Loader or the BELMN control program, depending upon the instructions of the subject program. If the subject program uses enough storage to squash the BELMN control program, it may return to the BELMN Loader, which will, in turn, call in the BELMN control program. Or, the subject program may have squashed everything else, in which case, the program itself calls on A8 and reads the BELMN control program back into storage,[3] and transfers control to it.

---

[3] These returns are explained in detail on page VI-26.

Any number of subject programs may be run as a single BELL job through judicious use of remark and pause cards to allow for tape changing. Some examples of simple job set-ups are illustrated as figures VI-2, VI-3, VI-4, VI-5, VI-6, and VI-7.

```
          JOB      10461,PR,HERRINGTON
          REMARK    MOUNT BPR X15 ON A8
          REMARK    MOUNT UTB  31 ON B7 BIN NET DESC
          REMARK    MOUNT UTB  37 ON B5 BIN TREES
          REMARK     MOUNT UTB 38  ON A7 BIN LOADED NET
          REMARK    MOUNT UTB 30  ON B6 PKAN MEM J
          PAUSE
          SPACE
    2150  OCT 77200001210,76200001230,54000002156,6000002153,76100000000    BELMN1
    2155  OCT 7400464000,-3200000,277777000100,-3200000,377777064000      PDBELMN2
          TRA      2150

  PR   1
  PKAN BUILD ALL TREES    HUMPHREY  12/4/63                              1
                                       050 0312 600 030 630 0312         2
       1    50

  PR   2
  PKAN LOAD MIN PATHS     HUMPHREY  12/4/63                              1
                                       050 0312 600 030 630 0312 0051 03122
     001   050                                                           3
       1   200          8                                                4

  PR 104
  PKAN SUM VOL & TURNS    HUMPHREY  12/4/63                              1
                                       050 0312 600 030 630 0312 0051 03122
  TJ
```

Figure VI-2.--Typical job set-up for programs 1, 2, and 104.

```
          JOB      10463,PR,MUELLER
          REMARK    MOUNT BPR X 15 ON A8
          REMARK    MOUNT UTB 31    ON B7   BIN NET DES
          REMARK    POOL B5
          SPACE
          PAUSE
    2150  OCT 77200001210,76200001230,54000002156,6000002153,76100000000    BELMN1
    2155  OCT 7400464000,-3200000,277777000100,-3200000,377777064000      PDBELMN2
          TRA      2150

  PR   6
  PKAN BUILD NETWORK & EDIT          HUMPHREY 10/10/63                   1
        111                            050 0312 600 030 630 0312         2
              00 25        00 50       00 35        00 60                3
                                                                         9

  PR  12
  PKAN EXISTING NETWORK              HUMPHREY 10/10/63                   1
        11                             050 0312 600 030 630 0312         2
              00 25        00 50       00 35        00 60                3

  PR   1
  PKAN BUILD SELECTED TREES          HUMPHREY 10/10/63                   1
                                       050 0312 600 030 630 0312         2
       1,   22,   28,   32,   36

  PR  11
  PKAN FORMAT SELECTED TREES         HUMPHREY 10/10/63                   1
                                       050 0312 600 030 630 0312         2
       1,   22,   28,   32,   36

  PR  50
                                                                         0
  PKAN DESTRUCTIVE TREE TRACE        HUMPHREY 10/10/63                   1
  1                                    050 0312 600 030 630 0312         2
       1,   22,   28,   32,   36
  TJ
```

Figure VI-3.--Typical job set-up for programs 6, 12, 1, 11, and 50.

```
        JOB       10461,PR,HERRINGTON
        REMARK    MOUNT  BPR X15 ON A8
        PAUSE
        SPACE
   2150 OCT 7720001210,7620001230,54000002156,6000002153,76100000000     BELMN1
   2155 OCT 7400464000,-3200000,277777000100,-3200000,377777064000      PDBELMN2
        TRA       2150

PR  60
PKAN TEST CITY CAPACITY RESTRAINT   HUMPHREY 12/6/63          001000001000
                                                                     FF FF

PR  61
 630 600 030 050            0312 0312
PKAN TEST CITY FIRST ITERATION CAP RES HUMPHREY 12/6/63            FFFFFN
**        PR 1 NEXT

PR   1
PKAN TEST CITY TREES FOR CAP RES 1  HUMPHREY 12/6/63                    1
                                    050 0312 600 030 630 0312           2
     1    50

PR   2
PKAN TEST CITY LOAD NET FOR CAP RES 1  HUMPHREY 12/6/63                 1
                                    050 0312 600 030 630 0312 0051 03122
   001   050                                                            3
     1   200       8                                                    4
**   * PR 61 NEXT

PR  61
 630 600 030 050            0312 0312
PKAN TEST CITY FIRST ITERATION CAP RES HUMPHREY 12/6/63            FFFFFN
**        PR 1 NEXT

PR   1
PKAN TEST CITY TREES FOR CAP RES 1  HUMPHREY 12/6/63                    1
                                    050 0312 600 030 630 0312           2
     1    50

PR   2
PKAN TEST CITY LOAD NET FOR CAP RES 1  HUMPHREY 12/6/63                 1
                                    050 0312 600 030 630 0312 0051 03122
   001   050                                                            3
     1   200       8                                                    4
**     PR 61 NEXT

PR  61
 630 600 030 050            0312 0312
PKAN TEST CITY FIRST ITERATION CAP RES HUMPHREY 12/6/63            FFFFFN
**        PR 1 NEXT

PR   1
PKAN TEST CITY TREES FOR CAP RES 1  HUMPHREY 12/6/63                    1
                                    050 0312 600 030 630 0312           2
     1    50

PR   2
PKAN TEST CITY LOAD NET FOR CAP RES 1  HUMPHREY 12/6/63                 1
                                    050 0312 600 030 630 0312 0051 03122
   001   050                                                            3
     1   200       8                                                    4
**     PR 61 NEXT

PR  61
 630 600 030 050            0312 0312
PKAN TEST CITY FIRST ITERATION CAP RES HUMPHREY 12/6/63            FFFFFN
**        PR 1 NEXT

PR  63
PKAN TEST CITY CALIBRATED NET 4 ITERATIONS CAP RES                 FF N N

PR   1
PKAN TEST CITY TREES FOR CAP RES 1  HUMPHREY 12/6/63                    1
                                    050 0312 600 030 630 0312           2
     1    50

PR   2
PKAN TEST CITY LOAD NET FOR CAP RES 1  HUMPHREY 12/6/63                 1
                                    050 0312 600 030 630 0312 0051 03122
   001   050                                                            3
     1   200       8                                                    4

PR 104
PKAN TEST CITY SUM VOL & TURNS CAP RES 1  HUMPHREY 12/6/63              1
                                    050 0312 600 030 630 0312 0051 03122
TJ
```

Figure VI-4.--Typical job setup for four iterations of capacity restraint.

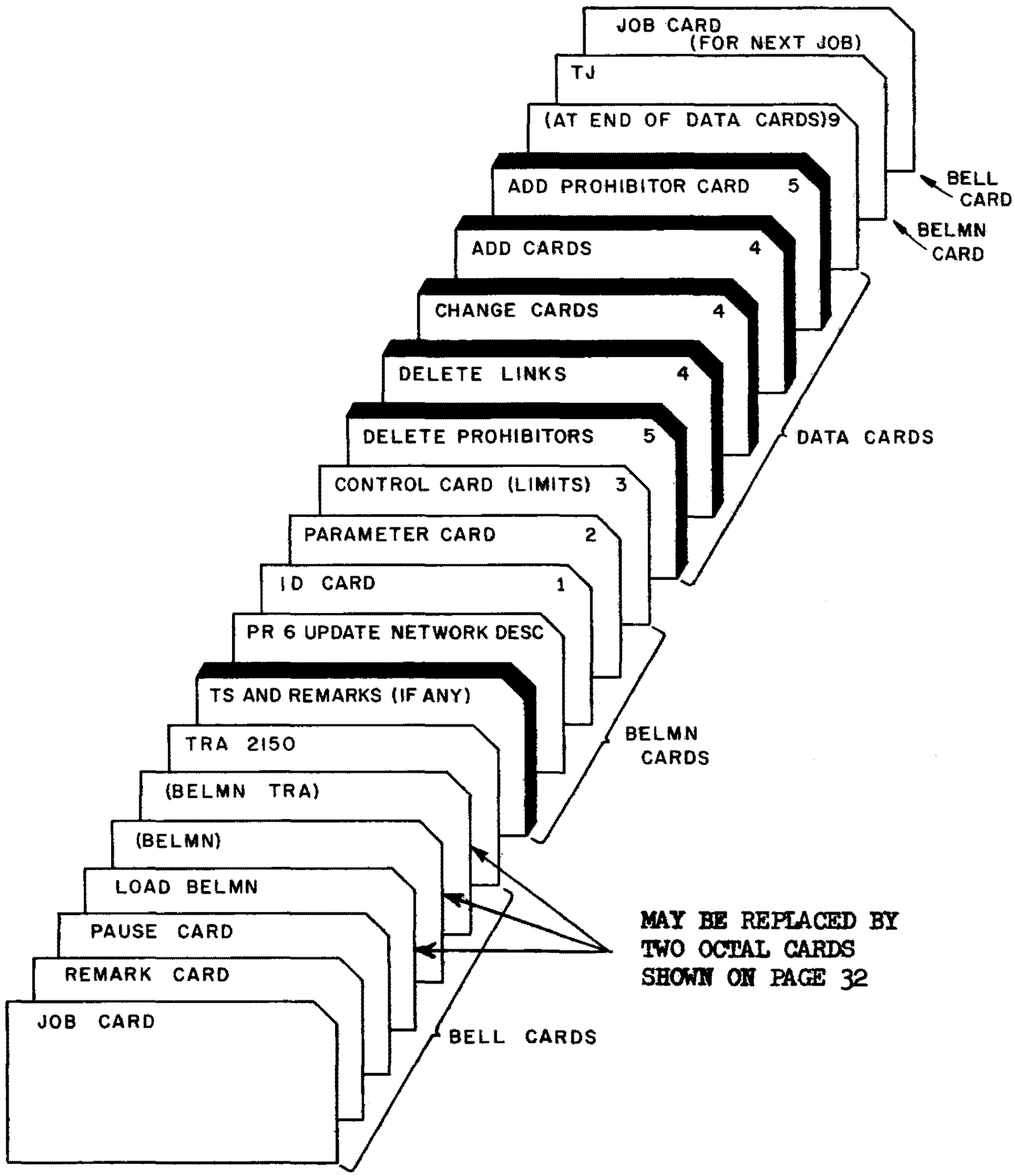


Figure VI-5.--Typical job set-up, PR-6 - Build and update network description.

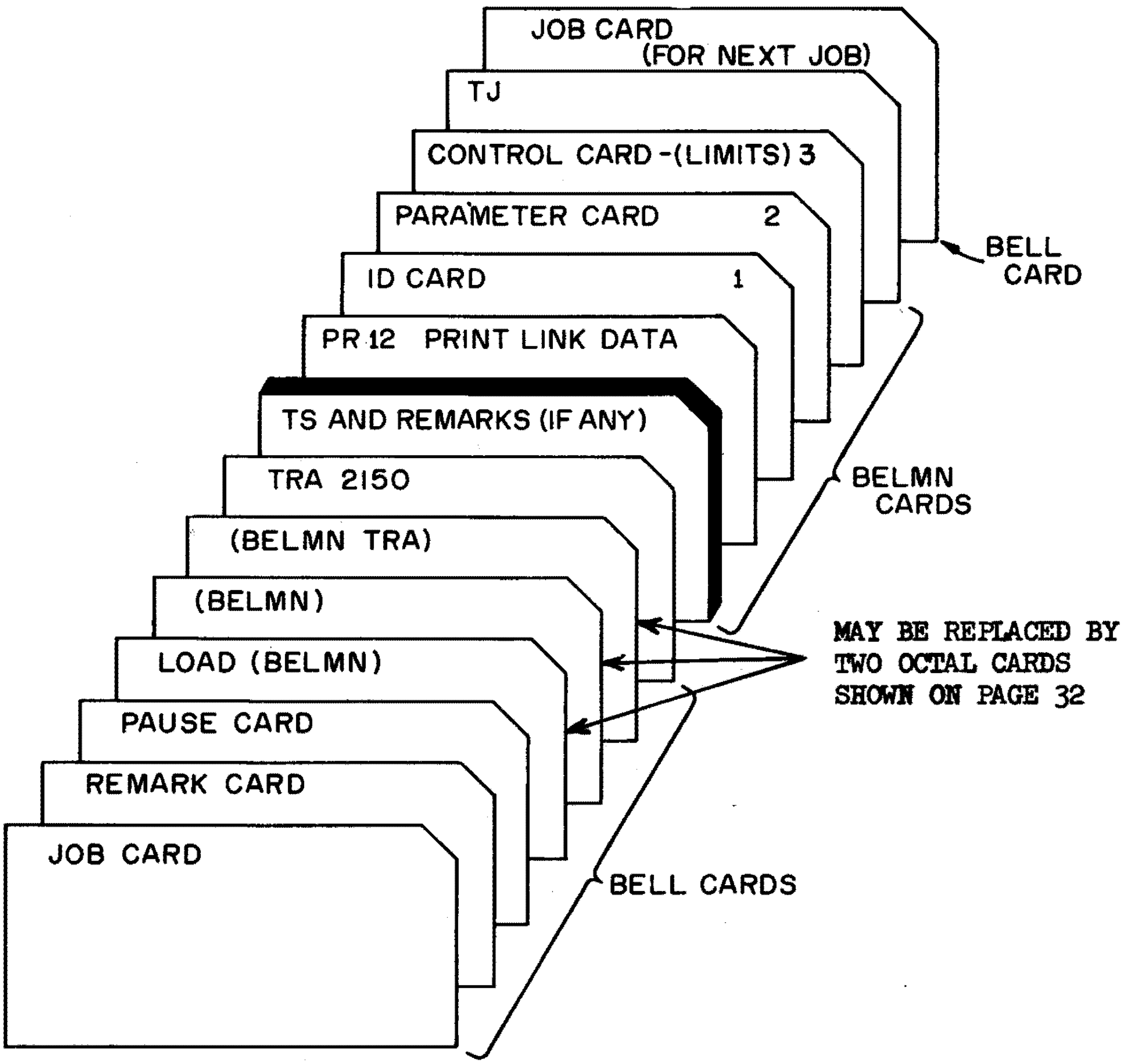


Figure VI-6.--Typical job set-up, PR-12 - Format network description.

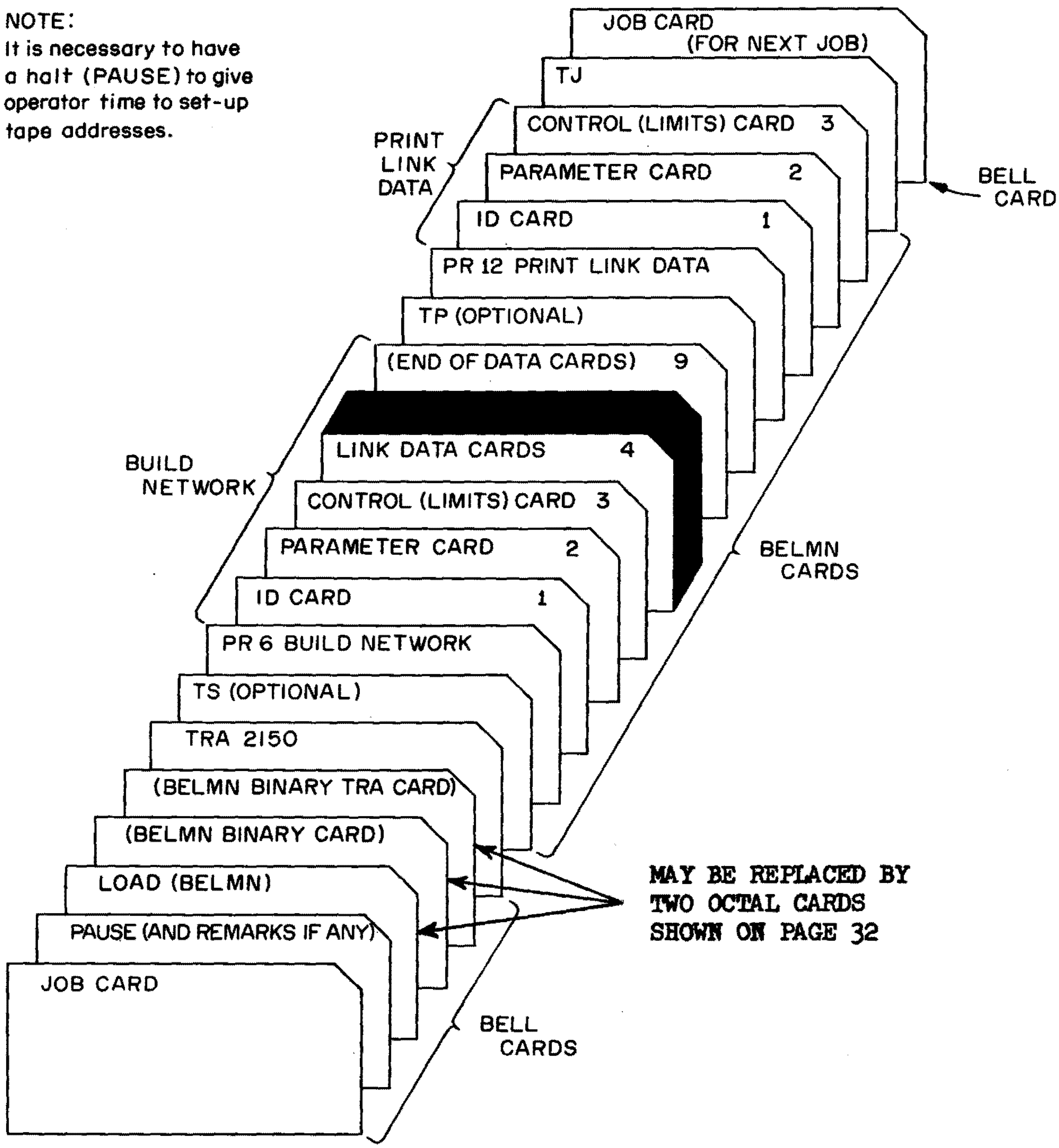


Figure VI-7.--Typical job set-up for programs 6 and 12 (combined) using a minimum number of cards.

2. Transfer from subject program to BELMN control program

The BELMN control program is brought in new after each subject program execution. The reason, obviously, is to insure against the destruction of the BELMN control program by a wayward subject program, thereby creating an unexplained machine stoppage.

The first and most desirable of the two approved methods of returning control from a subject program to the BELMN control program is by transfer through the transfer vectors in the BELMN control program to the BELMN Loader.

The subject program in the following example (Example A) arrives at cell 03962 and executes the instruction XEC. The BOOL instruction, which was assembled with the program, prepares an address of 00131 for the XEC instruction. This XEC instruction operates on the BELMN control program transfer vector at 00131, which is TSX BELMN, 4, and thus transfers control to the BELMN Loader. This transfer to the BELMN Loader puts the loader into operation, pulling the BELMN control program in fresh, and then transfers control to the BELMN control program.

Example A

```
          (Control Program Transfer Vectors)
00131 0074 0040 2150          RETURN TSX BELMN, 4

          (BELMN Loader)
02150 0772 0000 1210          BELMN REWA 8
02151 0762 0000 1230                RTBA 8

          (Subject Program)
                              RETURN BOOL 131
03962 0522 0000 0131                 XEC RETURN
```

If the subject program is of such a size that it destroys the BELMN Loader in core, the recommended procedure is that the subject program have the ability to restore the loader in core, so that subsequent programs may operate properly. This is done in the following manner.

Example B

```
BINARY CARD NO. BELMN001
    00000  0774 00 1 00012         AXT     10,1
    00001 -0500 00 1 00017         CAL     LOADER&10,1
    00002  0602 00 1 02162         SLW     BELMN&10,1
    00003  2 00001 1 00001         TIX     *-2,1,1
    00004  0020 00 0 02150         TRA     BELMN
    00005  0772 00 0 01210  LOADER REWA    8
    00006  0762 00 0 01230         RTBA    8
    00007  0540 00 0 02156         RCHA    BELMN&6
    00010  0060 00 0 02153         TCOA    BELMN&3
    00011  0761 00 0 00000         NOP
    00012  0074 00 4 64000         TSX     PR102,4
    00013 -0 00003 2 00000         IOCPN   ,,3
    00014  2 77777 0 00100         IORP    64,,-1
    00015 -0 00003 2 00000         IOCPN   ,,3
    00016  3 77777 0 64000         IORT    PR102,,-1
                     002150 BELMN  BOOL    2150
                     064000 PR102  BOOL    64000
                                   END
```

3. Procedure for making more tape drives available

The standard tape set-ups for BELL and BELMN production runs are shown in figure VI-8. If a particular subject program requires more tape drives than are available, including the BELL tapes, the following procedure is recommended for increasing the number of units.

First, mount as many tapes as possible. Second, have the cards set up so that a BELMN pause card (** in columns 1-2) follows the TRA 2150 card. This will then allow the operator to remove tapes B-0 and B-1 and mount the remaining required tapes. When this has been done the operator should press "START," and the subject program will be loaded into memory and executed.

Before BELMN is allowed to return to the BELL Monitor, the system tapes should be remounted. This can be accomplished by having another BELMN pause card before the TJ card. After the tapes have been remounted, the operator should press "START." The TJ card will then be read, causing a return to the BELL Monitor.

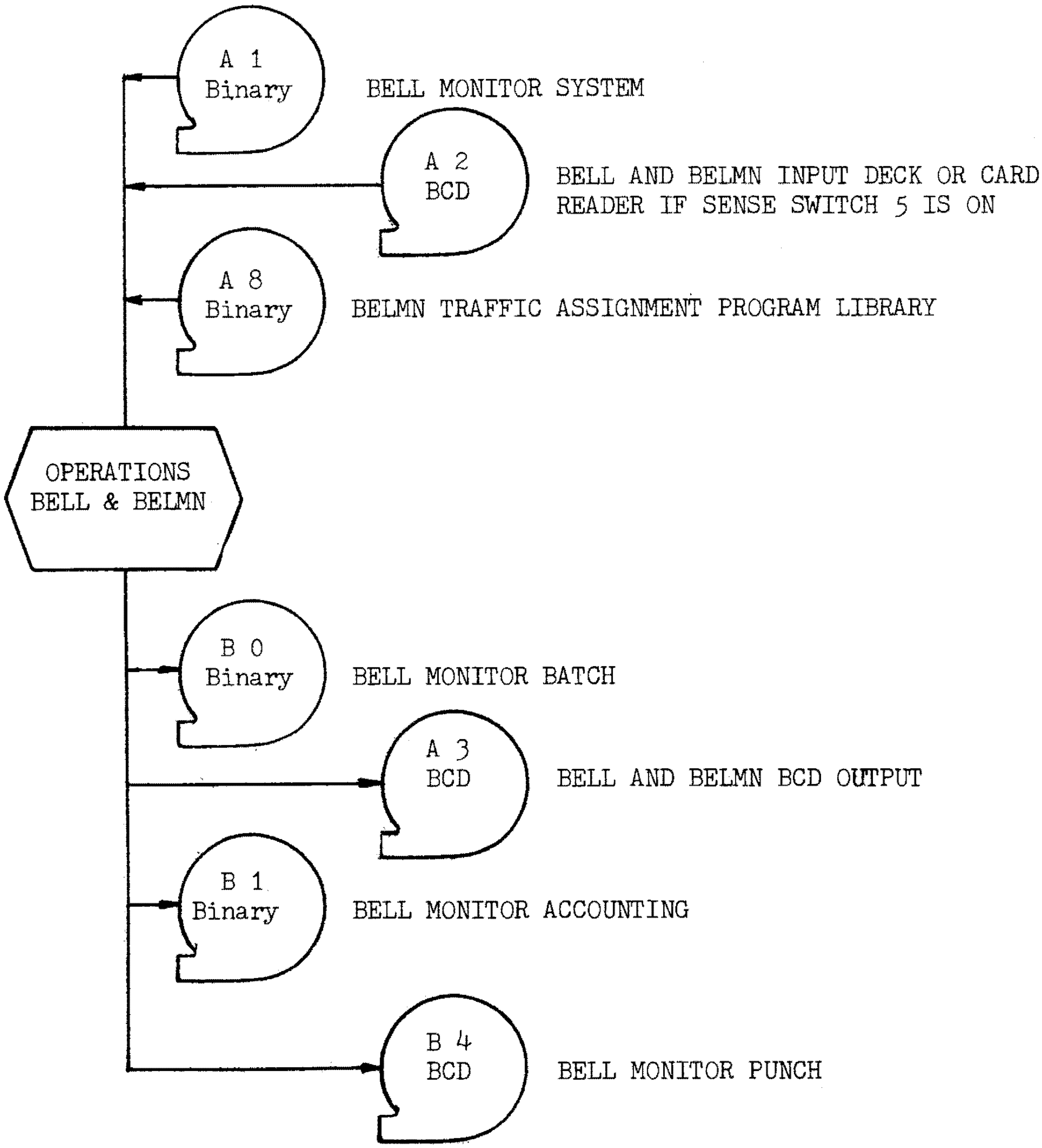


Figure VI-8.--Standard tape set-ups for BELL and BELMN production runs.

4. Procedure for patching subject programs

Should it become necessary to alter a particular instruction or group of instructions in a subject program, the following procedure has been developed.

The word PATCH is punched in the program call card in columns 8-12. This informs the BELMN control program that BELL Monitor cards are to follow, and BELMN returns control to the BELL Monitor after loading in the subject program. If no program number is designated on the call card, the control will be returned to BELL without first loading the subject program. It is then possible to have any BELL card follow the program call card. After all the desired BELL cards have been read and processed, control must be returned to the subject program at location 2162 with a TRA card. A typical set-up would be as follows:

```
         JOB
         REMARK
         PAUSE
         OCT        BELMN
         OCT        LOADER
         TRA        2150         to BELMN LOADER
PR  1    PATCH
2250     OCT        076100000000
         TRA        2162
         ID         CARD
         PARAMETER  CARD
         CONTROL    CARD
TJ                  CARD
         JOB        IDLE
```

5. BELMN Loader

The BELMN Loader, as assembled, is shown below. This set of instructions is the key to getting the control program from tape A8 into core and control transferred to it. It is an exact duplicate of the return used in the subject programs as described above.

```
                          ABS
                          ORG    1127
2147  6010  0010  0602    BCI    1,080862
2150  0772  0000  1210    REWA   8
2151  0762  0000  1230    RTBA   8
2152  0540  0000  2156    RCHA   * +4
2153  0060  0000  2153    TCOA   *
2154  0761  0000  0000    NOP
2155  0074  0046  4000    TSX    26624,4
2146  4000  0320  0000    IOCPN  ,,3
2157  2777  7700  0100    IORP   64,,-1
2160  4000  0320  0000    IOCPN  ,,3
2161  3777  7706  4000    IORT   26624,,-1
                          END
```

6. The procedure for BELL and BELMN production runs[4]

a. BELL System read from tape unit A1 upon pushing "Load Tape."

b. BELL System receives control automatically.

c. BELL System handles BELL System cards, "Job," "Remarks," and "Pause," and then loads the BELMN Loader from A2, upon receiving "Load" card, or the two octal cards.

d. BELMN Loader receives control from BELL System upon receiving "TRA 2150."

e. BELMN Loader loads BELMN control program from A8.

f. BELMN control program receives control from BELMN Loader automatically.

g. BELMN control program loads subject program from A8 upon receiving call card, e.g., "PR 6."

h. Subject program receives control from BELMN control program.

i. Subject program executes, reading in identification, parameter, and control cards.

j. Subject program either transfers to BELMN Loader or recalls BELMN control program and transfers to it. If transfer is to BELMN Loader repeat steps e and f. Steps g-j repeated for subsequent subject programs. If last subject program:

k. BELMN control program loads BELL System from A1 upon receiving "TJ" card.

l. BELL System receives control automatically.

m. Next BELL job can then be executed, or computer will halt upon receiving the BELL System card, "Job Idle."

---

[4] See page VI-23 for deck these steps refer to.

C. Standard Card Formats

1. BELL monitor cards

Title of card	Columns	Contents
Job	8-10	"JOB"
	16-20	Any 5 numbers (usually a job number, e.g., 10461)
	21	Comma (,)
	22-23	"PR"
	24	Comma (,)
	25-30	Any 6 alphabetic characters (usually a name, e.g., HAReed)
	31-72	Anything desired
Remarks	8-13	"REMARK," the contents of the card is written on-line and on tape A3.
	16-72	Anything desired
Pause	8-12	"PAUSE," causes the machine to halt
	16-72	Anything desired
Load	8-11	"LOAD," informs the BELL monitor that a column binary card will follow and should be loaded into memory.
	17-72	Anything desired
Transfer	8-10	"TRA"
	17-71	Octal location of where transfer is to be made, or blank if transfer is to program just loaded by BELL
Job idle	8-10	"JOB"
	16-19	"IDLE" - this informs the BELL Monitor that it has processed the last job, and the machine will halt.
Octal correction	2- 6	OCTAL location of new instruction
	8-10	"OCT"
	16-27	New Instruction in OCTAL.

The contents of every BELL Control Card are written on-line as well as on tape A3.

2. BELMN Control Program Cards

Title of card	Columns	Contents
Remarks	1	"*" (denotes remark card)
	2-72	Any message desired. This data is written on-line and on A3.
Pause	1- 2	"**" (denotes pause card)
	3-72	Any message desired. This data is written on-line and on A3.
Subject Program Call Card	1- 2	"PR"
	4- 6	Subject program number, right-justified.
	7-72	Blank, or anything desired
Time Card	1- 2	"TS" - for time of start card
	1- 2	"TP" - for time of phase card
	1- 2	"TJ" - for time of job card
	3-72	Blank, or anything desired
Subject Program Call Card with option to patch desired subject prog.	1- 2	"PR"
	4- 6	Subject program number, right-justified
	8-12	"PATCH"
BELMN Loader (OCTAL Form, 2 cards)- Card 1	3- 6	"2150"
	8-10	"OCT"
	12-69	77200001210,76200001230, 54000002156,6000002153, 76100000000
Card 2	3- 6	"2155"
	8-10	"OCT"
	12-65	7400464000,-3200000,277777000100, -3200000,377777064000

3. Subject Program Cards

Five types of cards are read initially by most subject programs. After these cards are read and checked they are usually printed out again for record purposes. Each data card should be positively identified. For example, in **Program 6, update cards are recognized by a 4 in column 72.**

a. Tape Assignment Card

Field No.	Columns	Contents
1	1- 2	Channel & unit (Tape 1)
2	4- 5	" " " (" 2)
3	7- 8	" " " (" 3)
4	10-11	" " " (" 4)
		(" N)
	72	"0"

Fields must be separated by commas. When this card is required by a particular subject program the writeup will specify the tape in relationship to field number.

The first blank or zero field terminates tape reassignment.

b. Identification Card

Columns	Contents
1-71	Identification card: The contents of these columns will be put on all output for off-line printing.
72	1 (A decimal "1" is the conventional identification card).

c. Parameter Card

Columns	Contents
1-32	Field to specify program option. Up to 32 options may be designated by punching a 1 in columns 1-32 of the Options-Parameter card. Option "n" is designated by a 1 punch in column "n."
33-35	First external station
37-39	Last zone centroid
41-44	Last node number
46-48	Longest link time
50-52	Turn penalty
54-56	Longest link distance
58-61	First freeway node number
63-66	First turn node
68-71	Last turn node
72	"2" punch (necessary for identification of parameter card).

d. Control Card

This card is used to designate the zone trip tables or series of zones to be selected.

A general statement for the requirement for the control card is that for any series of zones (considering a single zone as a one-item series) the last zone of the series must be followed by a comma if more series of zones are to follow.

Punch the first desired zone number, right-justified in column 6. If it is to be a single zone, follow it with a comma (,) in column 7; if it is to be the first zone of a consecutive series, punch the last zone of the series, right-justified, in column 12. Additional series or single zones may be selected by using successive 6-column fields through, but not past, column 67.

For example, suppose zone 6, 9-15, 18-20, 27, and 133 are to be selected. The control card would be punched as follows:

Columns	Contents
6	"6"
7	"," (comma)
12	"9"
17-18	"15"
19	"," (comma)
23-24	"18"
29-30	"20"
31	"," (comma)
35-36	"27"
37	"," (comma).
40-42	"133"
72	"3" (necessary for identification of control card).

e. Speed Limits Card

Columns*	Contents
13-14	Lower local speed limit (m.p.h.)
16-17	Upper " " " "
25-26	Lower Arterial Speed Limit (m.p.h.)
28-29	Upper " " " "
37-38	Lower Ramp Speed Limit (m.p.h.)
40-41	Upper " " " "
49-50	Lower Freeway Speed Limit (m.p.h.)
52-53	Upper " " " "
72	3 (A decimal three normally identifies a control card).

*Columns not specifically indicated may contain anything.

f. End of Data Card

Columns	Contents
1-71	Anything desired
72	"9"

D. Standard Tape Formats

1. Binary network description

The first word contains four times the highest node number (the number of words remaining in the record). Taken in groups of four, the remaining words of the record describe the links from a common node (A node). Thus, the A node is determined by location in the record, and the B nodes are designated by bits 6-17. Unused words are filled with zeros.

The complete word format is:

Word bit	Contents
Sign	Direction of link
1- 4	Turn prohibitors for links 1-4 at B node.
5	Not used
6-17	B node or "to" node
18-19	Municipality or jurisdiction code
20	Flag
21-26	Distance (in 63rds) from A to B
27-29	Not used
30-35	Time (in 63rds) from A to B

2. Binary loaded network

The first record is the network description, except that the tag is blank and the address contains link volume rather than time and distance. To eliminate overflow possibilities, the volume in the record is one-fourth the actual volume assigned to the link.

The second record is a turn table, containing a "2" in the decrement of the first word and the remaining word count in the address. The turn table consists of two words for each four-way arterial and for each freeway node. The relative position in the record determines the A node of the word pair beginning with the first designated turn node and continuing to the last designated turn node. The decrement contains the B node, and the address contains one-fourth of the turn volume between the B node indicated and the highest node connected to node A.

3. Binary tree

The length of a tree record is the last node number in the network plus one. The first word of the record contains the word count of the rest of the record (exclusive of itself) in its address, and the origin zone number in its decrement. The rest of the record contains the following information for each node in the transportation network (the node number being the relative word location in the record).

Word part	Contents
Prefix	Plus or minus to indicate direction of entry to node from back node.
Decrement	Last prior node (back node) in minimum path from origin.
Address	Elapsed time from origin to this node scaled to 1/63 increments of the longest specified time plus the turn penalty.

If the decrement is zero and the address contains 77777_8, the node is either inaccessible or not used in the system.

4. Binary trip table or skimmed tree

The length of each tape record in words is the number of zones in the network plus one. There are as many records as there are zones. The first word of the record is the identification, with the number of the record (origin zone) in the decrement and the remaining number of words (total number of zones) shown in the address. The second word contains a number in the address which represents the number of trips (or time) from the record zone to zone one. The third word contains the trips (or time) from the record zone to zone two, and so on.

E. BPR Standard Trip Record Formats

1. Dwelling unit summary

Word 6 char.	Decrement first half	Address second half	Whole word
1	Card number = 1	Structure type	-
2	Total cars	Total persons	-
3	Total persons over 5 yrs. old	Total persons over 5 yrs. making trips	-
4	-	Census tract	-
5	-	-	Trip factor
6	-	-	Residence zone (xxxxx.x)
7	Day of travel	Month of travel	-
8	Total trips	Total auto drive trips	-

2. Internal survey cards

Word 6 char.	Decrement first half	Address second half	Whole word
1	Card number = 2	Mode	-
2	From purpose	To purpose	-
3	-	-	Origin zone
4	-	-	Destination zone
5	-	-	Trip factor(xxxxx.x)
6	-	-	Residence zone
7	Start time	Arrive time	-
8	From land use	To land use	-

3. External survey cards

Word 6 char.	Decrement first half	Address second half	Whole word
1	Card number = 3	Vehicle type	-
2	From purpose	To purpose	Or, only purpose
3	-	-	Origin zone
4	-	-	Destination zone
5	-	-	Trip factor(xxxxx.x)
6	Direction	Occupants	-
7	Garage location	Time of interview	-
8	From land use	To land use	-

4. Truck survey cards

Word 6 char.	Decrement first half	Address second half	Whole word
1	Card number = 4	Vehicle type	-
2	-	-	Zeros
3	-	-	Origin zone
4	-	-	Destination zone
5	-	-	Trip factor(xxxxx.x)
6	-	-	Zeros
7	Start time	Arrive time	Or...Midpoint time
8	From land use	To land use	-

5. Taxi survey cards

Word 6 char.	Decrement first half	Address second half	Whole word
1	Card number = 5	Vehicle type-1	-
2	-	-	Zeros
3	-	-	Origin zone
4	-	-	Destination zone
5	-	-	Trip factor(xxxxx.x)
6	-	-	Zeros
7	Start time	Arrive time	Or...Midpoint time
8	From land use	To land use	-

All values right-justified in word or half word.

TRAFFIC ASSIGNMENT MANUAL

CHAPTER VII GLOSSARY OF TRAFFIC ASSIGNMENT TERMS	June 1964

ACCESS TIME

1. The time between the instant at which information is called for from storage and the instant at which it is delivered.

2. The time between the instant at which information is ready for storage and the instant at which it is stored.

ACCESSIBILITY - ACCESSIBILITY INDEX

Potential of opportunities for interaction. The denominator of the gravity model formula.

ADD CARD

A link data card used to update a network description by the addition of a street section. This card has the same format as a standard link card.

ADDRESS

A label, name, or number which designates a register, a location, or a device where information is.

ALL-OR-NOTHING ASSIGNMENT

The process of allocating the total number of trips between two zones to the path or route with the minimum traveltime.

ALPHANUMERIC

Characters which may be either letters of the alphabet, numerals, or special symbols. See Binary Coded Decimal.

ANALOG COMPUTER

A computer in which numbers are represented by physical magnitudes such as the amount of rotation of a shaft or a quantity of electrical voltage or current.

ANALYSIS AREA

Any group of zones that are combined for the purpose of making an analysis.

ARITHMETIC UNIT

That part of the computer which performs the arithmetic operation.

ARTERIAL

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

ASSEMBLY

Process whereby instructions written in a symbolic form by the programer are changed by the machine to a machine language.

ASSIGNMENT

See Traffic Assignment.

AUTOMATIC PROGRAMING

Technique whereby the computer, itself, will translate a program written in a pseudo language easier for the programer to use into a machine-sensible language which the computer may use efficiently.

Example: Autocoder, COGO, FORTRAN.

BINARY

A number system using the base of two. There are only two symbols: one or zero ("on" or "off"). Digit values reading from <u>right</u> to left are: 1, 2, 4, 8, 16, 32, etc.

BINARY CODED DECIMAL (BCD)

A system of representing decimal numbers, letters, and characters in six binary bits; also a mode of tape input and output in which the lateral bits are even in parity as opposed to the binary mode with an odd parity check.

BIT

1. An abbreviation of "binary digit."

2. A single character of a language employing exactly two distinct kinds of characters.

3. A unit of storage capacity. The capacity, in bits, of a storage device is the logarithm to the base two of the number of possible states of the device.

BLOCK DIAGRAM

A schematic representation of a sequence of steps designed to solve a problem using symbols to represent an operation such as read, write, compare, switch, etc.

CAPACITY

The maximum number of vehicles that can pass over a given section of a lane or roadway in one direction (or in both directions for a two-lane or three-lane highway) during a given time period under prevailing roadway and traffic conditions. It is the maximum rate of flow that has a reasonable expectation of occurring. The terms "capacity" and "possible" capacity are synonymous. In the absence of a time modifier, capacity is an hourly volume. The capacity would not normally be exceeded without changing one or more of the conditions that prevail. In expressing capacity, it is essential to state the prevailing roadway and traffic conditions under which the capacity is applicable. Refer to the revised edition of the "Highway Capacity Manual" for more detail.

CAPACITY RESTRAINT

The process by which the assigned volume on a link is compared with the practical capacity of that link and the speed of the link adjusted to reflect the relationship between speed, volume, and capacity. The procedure is iterative until a realistic balance is achieved.

CENTROID

An assumed point in a zone that represents the origin or destination of all trips to or from the zone. Generally, it is the center of trip ends rather than a geometrical center of zonal area.

CENTRAL PROCESSING UNIT (C.P.U.)

That portion of the hardware of a computer which directs a sequence of automatic operations, interprets the coded instructions, and initiates the proper signals to the computer circuits to execute the instructions.

CHANGE CARD

A link data card which deletes a specified link from a network and replaces it with another link.

CHARACTER

A decimal digit, alphabetic letter, or special symbol such as $, %, etc. See Binary Coded Decimal (BCD).

CHECK

AUTOMATIC CHECK Provision, constructed in the computer, for verifying information transmitted, manipulated, or stored by an unit or device of the computer.

PARITY CHECK One type of redundancy check.

REDUNDANCY CHECK Use of summation of bits and redundant bits (check digits) to insure accuracy.

CHOICE, POINT OF

The points at which two routes diverge or converge. Between these points a traveltime ratio can be computed.

COLLECTOR - DISTRIBUTOR STREET

An auxiliary roadway, separated laterally from but generally parallel to the expressway or thru roadway, which serves to collect and distribute traffic from several access connections between selected points of ingress to and egress from the through traffic lanes.

COMPATIBILITY (SIMULATOR)

A set of computer instructions which permit the operation of a program designed for a particular machine or other type.

COMPUTER

Any device capable of accepting information, processing the information, and providing the results of these processes in acceptable form.

CONSOLE

A piece of computer hardware which an operator may use to control the machine manually; correct errors; determine the status of machine circuits, registers, and counters; determine the contents of memory; and revise the contents of memory.

CONTROL CARD

A data card which usually controls which zones in the traffic assignment network are to be processed in a particular run.

CORDON LINE

An imaginary line enclosing a study area.

COUNT

The traffic volume counted on a street or highway.

DEBUGGING

A procedure to establish program accuracy by running the program with selective data to find logical or clerical "bugs" or errors.

DELETE CARD

A link data card that is used to remove a link from the network description.

DESIRE LINE

A straight line connecting the origin and destination of a trip. A desire-line map is made up of many such desire lines, the width or density of which represents the volume of trips moving between the origins and destinations.

DESTINATION

The zone in which a trip terminates.

DIGITAL COMPUTER

The data processed by a digital computer consists of clearly defined numbers as opposed to physical quantities which are processed in an analog computer.

DISTRIBUTION

The process by which the movement of trips between zones is estimated. The distribution may be measured or be estimated by a growth factor process, or by a synthetic model.

DISTRICT

A grouping of contiguous zones that are aggregated to larger areas.

DIVERSION ASSIGNMENT

The process of allocating trips between two possible routes on the basis of measurable parameters.

DRIVING TIME

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

EDIT

To rearrange information: for instance, editing may involve the deletion of unwanted data, the selection of pertinent data, etc.; also tests for validity and reasonableness of information.

EXPRESSWAY

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

FIELD

1. Punchcard machines: A set of one or more columns in each of a number of punchcards which is regularly used to report a standard item of information. For example: if columns 16 through 19 are regularly used to report weekly rate of pay, then these columns would constitute a field.

2. Computers: A set of one or more characters which is treated as a whole.

FILE

A group of records on a magnetic tape, separated by a special gap on the tape.

FIXED WORD LENGTH

Refers to computers in which data is treated in units containing a set number of characters.

FORMAT

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

FORTRAN

(FORmula TRANslation) a method of program coding (for IBM computers) which is written in terms very similar to algebraic equations. Its use does not require a detailed knowledge of computers, and it is especially useful in solving mathematical problems.

FRATAR DISTRIBUTION

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

FREEWAY

An expressway with full control of access.

In traffic assignment, a link connecting two freeway nodes.

GRAVITY MODEL

A mathematical model of trip distribution based on the premise that trips produced in any given area will distribute themselves in accordance with the accessibility of other areas and the opportunities they offer.

GROWTH FACTOR

A ratio of future trip ends divided by present trip ends.

HARDWARE

The mechanical, magnetic, electrical, and electronic devices from which a computer is constructed.

HARMONIC ANALYSIS

As used in planning, the determination and use of a mathematical equation which passes through 24 hourly traffic volumes.

HISTORICAL RECORD

A binary tape record used in capacity restraint programs to provide link distance, traveltime, speed, capacity and/or count. It also carries information about previous loadings. The output of program PR-60.

INPUT

This is information (instructions or data) to be transferred from external storage (usually tape or cards) to the internal storage of the machine.

INSTRUCTION

An order to the machine to perform a particular operation.

INTERACTANCE MODEL

A variation of the gravity model utilizing a series of curves to represent trip interaction between land uses of varying intensity.

INTER-RECORD GAP

A 0.75-inch space which occurs between records on tape. These are produced by the acceleration and deceleration of the tape in a write status.

INTERZONAL TRAVELTIME

The total traveltime between zones consisting of the terminal times at each end of the trip plus the driving time.

INTERZONAL TRIP

A trip traveling between two different zones.

INTRAZONAL TRAVELTIME

The average traveltime for trips beginning and ending in the same zone, including the terminal time at each end of the trip.

INTRAZONAL TRIP

A trip with both its origin and destination in the same zone.

JURISDICTION

This item, coded in the link card, can define the political subdivision of study area in which the link is found. Alternately, it can identify a portion of the network such as the Interstate system.

LEVEL OF SERVICE

The term used to indicate the quality of service provided by a facility under a given set of operating conditions. Refer to the revised edition of the "Highway Capacity Manual" for more detail.

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.

LOADING

The process of determining the link loads by selecting routes of travel and accumulating the trip volumes on each link that is traversed.

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.

MACHINE LANGUAGE CODING

Coding in the form in which instructions are executed by the computer; contrasted to relative, symbolic, and other nonmachine language coding.

MAGNETIC CORE

A small doughnut-shaped ferrite designed and constructed to obtain "on" or "off" magnetization. Arrays of these cores are used to store information in the computer.

MAGNETIC TAPE

A flat ribbon of plastic which is coated on one side with a material which can be magnetized. Information is stored on the tape by a combination of magnetized spots in certain patterns.

MAJOR STREET OR HIGHWAY

An arterial highway with intersections at grade and direct access to abutting property, and on which geometric design and traffic control measures are used to expedite the safe movement of through traffic.

MEMORY A

The binary network description record prepared by the build or update network program (PR-6) from the link data cards. Also, the area of storage into which this record is read by subsequent programs.

MEMORY J

The binary zone-to-zone trip volume records.

MEMORY Z

The binary loaded network record containing all links and link loads. Output of load minimum paths program (PR-2).

MINIMUM PATH

That route of travel between two points which has the least accumulation of time, distance, or other parameter to traverse. This path is found by the build trees program (PR-1).

MODAL SPLIT

The term applied to the division of person trips between public and private transportation. The process of separating person trips by the mode of travel.

MODE OF TRAVEL

Means of travel such as auto driver, vehicle passenger, mass transit passenger, or walking.

MODEL

A mathematical formula that expresses the actions and interactions of the elements of a system in such a manner that the system may be evaluated under any given set of conditions. See Various Models listed herein.

MULTIPLE CORRELATION

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

NETWORK DESCRIPTION

The binary record which describes the highway system within the computer in terms of distance and time and includes turn indications and turn prohibitors. See Memory A.

NODE

A numbered point representing an intersection or zone centroid. Up to four links may be connected to each node. There are three types of nodes - centroid, arterial, and freeway. They are identified by the magnitude of their numbers, the lowest numbers being centroids, and the highest range being freeways.

OBJECT DECK

Card output from an assembly program in which are punched several instructions in machine language per card. Input to the assembly program consists of one instruction per card, thus, the name condensed deck is used for output of the assembly programs. This is the acutal program execution deck; it is the input to the computer for direct processing.

OFF-LINE

Operation of input/output and other devices not under direct computer control; most commonly used to designate the transfer of information between magnetic tapes and other input/output media.

ON-LINE

Operation of an input/output device as a component of the computer under programed control.

ORIGIN

The zone in which a trip begins.

OUTPUT

Information transferred from the internal storage of a computer to output devices or external storage.

OUTPUT DEVICE

Part of a machine which translates the intangible electrical impulses processed by the machine into tangible permanent results.

1. Printed forms
2. Punched cards
3. Magnetic "writing" on magnetic tape

PARAMETER

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

PATCH

A section of coding inserted into a routine (usually by transferring control from the main routine to the patch and back again) to correct a mistake or alter the routine.

PEAK HOUR

That one-hour period during which the maximum amount of travel occurs. Generally, there is a morning peak and an afternoon peak and traffic assignments may be made for each period, if desired.

PENN-JERSEY MODEL

An interarea travel distribution formula developed by Mr. Tomazinis of Penn-Jersey Transportation Study. (Competing Opportunities Model).

PERIPHERAL

See Off-line.

PRINTER, ON-LINE PRINTER

Unit of the machine which prints the results obtained from processing some data. Numbers, letters, or symbols may be printed, depending on the device.

PROGRAM

A precise sequence of machine coded instructions for a digital computer to use to solve a problem.

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 copy, usually from one form of storage to another, particularly from external or secondary storage to internal storage.

RECORD

A group of related facts placed either on a card or tape and then read into memory. See Inter-record Gap.

REGIONAL GROWTH MODEL

A land use model used to estimate and distribute growth in population, employment, etc.

ROOT-MEAN-SQUARE ERROR - RMS

A statistical measure of error between two series.

$$RMS = \sqrt{\frac{\Sigma(x-y)^2}{N-1}}$$

ROUTE

That combination of street and freeway sections connecting an origin and destination. In traffic assignment, a continuous group of links connecting two centroids that normally requires the minimum time to traverse.

ROUTINE

A set of computer instructions which carries out some well defined function. See subroutine.

RUN

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

SCHNEIDER MODEL

A mathematical model for distributing trips based on the assumption that the trips originating in any zone will distribute themselves to other zones in proportion to the probability that the trips have not found a prior destination and that they will be as short as possible. (Intervening Opportunities Model).

SCREENLINE

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

SEQUENCED ZONE

To distribute trips or to assign traffic to a network, it is necessary that all zones be numbered in an unbroken sequence beginning with zone 1. This sequenced zone number designates the zone to the computer programs.

SKIMMED TREES

A series of binary records containing the traveltimes only between each pair of zones. The data is obtained from a portion of the binary tree records.

SOFTWARE

A computer program.

SORT

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

SPIDERWEB (SIMPLIFIED) NETWORK

A simulated highway system for a given area composed only of connections between zone centroids without respect to the physical street layout. This network is usually used for corridor type analysis.

SQUARE TRIP TABLE

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

STANDARD ERROR OF ESTIMATE

The difference between the actual and estimated values of the dependent variable, as found by the least squares analysis, within which one would expect to find 67% of the cases.

STATION

A location at the external cordon line where driver interviews are conducted.

STORAGE

A general term for the equipment that retains information.

SUBROUTINE

A routine which is arranged so that control may be transferred to it from a Master Routine and so that, at the conclusion of the subroutine, control reverts to the Master Routine. This avoids repeating the same sequence of instructions in different places in the Master Routine.

SYMBOLIC PROGRAMING

Coding a program in a language other than that which is accepted directly by the machine itself. This type of program, which lessens the chance of clerical errors, must be converted to machine language before it can be executed by the machine.

TAPE

Se Magnetic Tape.

TERMINAL TIME

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

TRACE (TREE)

That sequence of nodes which defines the links comprising the minimum path between two centroids. See Minimum Path.

TRAFFIC ASSIGNMENT

The process of determining route or routes of travel and allocating the zone-to-zone trips to these routes.

TRAVELTIME

The time required to travel between two points, including the terminal time at both ends of the trip.

TRAVELTIME RATIO (DIVERSION ASSIGNMENT)

Traveltime between points of choice by a freeway route divided by the traveltime between the same points by a nonfreeway route.

TREE

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

TRIANGULAR TRIP TABLE

A table of zone-to-zone trips between each pair of zones nondirectionally, normally in the low-to-high direction only. See Square Trip Table.

TRIP

A one-direction movement which begins at the origin at the start time, ends at the destination at the arrival time, and is conducted for a specific purpose.

TRIP CARDS

Data cards containing survey-derived trip information and related information. The data for each surveyed trip is punched in one trip card. See Trip.

Comprehensive surveys will produce the following types of trip cards:

No. 1 card - Dwelling Unit Summary
A summary of trips and related information regarding the occupants of one dwelling unit.

No. 2 card - Internal Trip Report
Contains information describing one trip by a resident of the survey area, and also contains certain information regarding the person making the trip.

No. 3 card - External Trip Report
Contains the information describing one trip by a vehicle which has crossed the external cordon line.

No. 4 card - Truck Report
Contains the information describing one trip by a truck registered or garaged in the survey area.

No. 5 card - Taxi Report
Describes one trip by a taxi registered or garaged in the survey area. In some studies taxi trips are included in the No. 4 cards.

TRIP END

Either a trip origin or a trip destination.

TRIP FACTOR

The number of trips represented by the trip card in which the trip factor appears. Basically it is the ratio of dwelling units to the interviewed dwelling units or a similar ratio of vehicles. It may be modified to offset a poor screenline check.

TRIP LENGTH FREQUENCY DISTRIBUTION

The array which relates the trips or the percentage of trips made at various trip time or distance intervals.

TURN

In the traffic assignment loading process, a movement from a link to another link, which is identified by the node numbers comprising the two links. 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.

UPDATE (verb)

To modify a master file according to current information, which is often contained in a transaction field, according to a procedure specified as part of a data processing activity.

UPDATE NETWORK

A phase of the build or update computer program during which changes in a network description are introduced by means of update cards. These may be add cards, delete cards, or change cards.

VARIABLE WORD LENGTH

A term applied to computers in which the number of characters to be operated on by an instruction is almost completely under control by the programer; contrasted to fixed word length.

WORD

An ordered set of characters which is the normal unit in which information may be stored, transmitted, or operated upon within the machine.

WRITE

To copy information usually from internal to external storage--to transfer information to an output medium.

ZONE

A portion of the study area, delineated as such for particular land use and traffic analysis purposes. There may be two types of zones used in the traffic assignment process:

1. Survey Zone - A subdivision of the study area which is used during the data collection phase of the study.

2. Traffic Assignment Zone - A subdivision of the study area represented by a centroid.

TRAFFIC ASSIGNMENT MANUAL

CHAPTER VIII. SELECTED BIBLIOGRAPHY ON TRAFFIC ASSIGNMENT	JUNE 1964

(1) ANALYSIS OF 24-HOUR TRAFFIC COUNTS BY DIGITAL COMPUTER, by S. M. Breuning and F. A. Wagner, Traffic Engineering, April 1961, pp. 15-18.

(2) APPLICATION OF THE IBM 650 DATA PROCESSING MACHINE TO TRAFFIC ASSIGNMENT ON A PROPOSED FREEWAY, by Marvin Brubaker, IBM, New York, 1957, 13 p.

(3) APPLICATION OF MECHANICAL ANALYSIS TO TRAFFIC RECORDER DATA, by J. A. Head and R. C. Blensly, Highway Research Bulletin 203, 1961, pp. 25-47.

(4) ASSIGNMENT OF TRAFFIC TO EXPRESSWAYS (as determined by diversion studies), by Moses Earl Campbell, Southeastern Association of State Highway Officials, Proceedings, 1951, pp. 64-65.

(5) CALIFORNIA METHOD OF ASSIGNING DIVERTED TRAFFIC TO PROPOSED FREEWAYS, by Karl Moskowitz, Highway Research Bulletin 130, 1956, pp. 1-26.

(6) CAPACITY RESTRAINT IN MULTI-TRAVEL MODE ASSIGNMENT PROGRAMS, Highway Research Board Bulletin 347, 1962, pp. 258-289.

(7) A COMPUTER METHOD FOR TRAFFIC ASSIGNMENT DEVELOPED AND USED IN STOCKHOLM, by A. Broberg, International Road Safety and Traffic Review (Great Britain), vol. 11, no. 3, summer 1963, pp. 27-31.

(8) COMPUTER PROGRAMS FOR ALLOCATING TRAFFIC BY THE QUICKEST ROUTE METHOD, by P. D. Whiting, Research Note No. RN/3829 PDW, Department of Scientific and Industrial Research, Road Research Laboratory.

(9) CURRENT INTERSECTION CAPACITIES, Committee on Highway Capacity - Highway Research Board, Highway Research Correlation Service - Highway Research Board Circular 376, Washington, D.C., 1958.

(10) DENVER METROPOLITAN AREA TRANSPORTATION STUDY CAPACITY REPORT, Planning and Research Division, Colorado Department of Highways, 1962.

(11) DESIGN CAPACITY CHARTS FOR SIGNALIZED STREET AND HIGHWAY INTERSECTIONS, by J. E. Leisch, Public Roads, vol. 26, no. 6, February 1951, pp. 105-139.

(12) A DIRECT APPROACH TO TRAFFIC ASSIGNMENT, by Morton Schneider, Highway Research Board Research Record, No. 6, 1963, pp. 71-75.

(13) THE DISTRIBUTION OF TRAFFIC ON A ROAD SYSTEM, by J. G. Wardrop, Symposium on the Theory of Traffic Flow, Warren, Michigan, 1959, Proceedings, 1961, pp. 57-58.

(14) EFFECTS OF TRAVEL IMPEDANCE COSTS, by Nathan Cherinack, Highway Research Board Special Report No. 56, 1959, pp. 99-107.

(15) ELECTRONIC TRAFFIC PROJECTION AND ASSIGNMENT, by Lloyd A. Rivard, American Highways, vol. XIXXX, no. 3, July 1960, pp. 5, 14-16.

(16) ESTIMATING THE DAILY VEHICLE-MILES OF TRAVEL IN THE CHICAGO AND PITTSBURGH METROPOLITAN AREAS, by Louis E. Keefer, Highway Research Board Bulletin 281, 1961, pp. 1-15.

(17) ESTIMATING TRAVEL TIME ON ALL ROUTES IN A METROPOLITAN COUNTY, by Thomas G. Muranyi, Chicago Area Transportation Study Research News, vol. 5, no. 2, April 1963, pp. 2-12.

(18) EVALUATION OF FRICTION MEASURES, by E. L. Gardner, Chicago Area Transportation Study Research News, vol. 2, no. 5, March 14, 1958, pp. 10-13.

(19) EVALUATION OF TECHNIQUES FOR DETERMINING OVER-ALL TRAVELTIME, by Donald S. Berry, Proceedings, Highway Research Board, vol. 31, 1952, pp. 429-440.

(20) EXPERIENCE IN APPLICATION OF STATISTICAL METHOD TO TRAFFIC COUNTING, by Boris B. Petroff, Public Roads, vol. 29, no. 5, December 1956, pp. 110-117.

(21) FIVE MINUTE CLUSTER SAMPLING FOR DETERMINING URBAN TRAFFIC VOLUMES, by Warren T. Adams, Proceedings, Highway Research Board, 1955, pp. 502-507.

(22) HIGHWAY CAPACITY MANUAL, Committee on Highway Capacity, Department of Traffic and Operations, Highway Research Board. U.S. Department of Commerce, Bureau of Public Roads, United States Government Printing Office, Washington, D. C., 1950.

(23) AN ITERATIVE ASSIGNMENT APPROACH TO CAPACITY RESTRAINT ON ARTERIAL NETWORKS, by Robert Smock, Highway Research Board Bulletin 347, 1962, pp. 60-66.

(24) A MATHEMATICAL MODEL FOR TRAFFIC ASSIGNMENT, by James Simmons Masters Thesis, Wayne State University, 1961, 22 p.

(25) MEASUREMENT OF URBAN TRAFFIC CONGESTION, by C. A. Rothrock and L. E. Keefer, Highway Research Board Bulletin 156, 1957, pp. 1-13.

(26) A MECHANICAL METHOD FOR ASSIGNING TRAFFIC TO EXPRESSWAYS, by E. Wilson Campbell, Traffic Engineering, vol. 28, no. 5, February 1958, pp. 9-14, 35.

(27) A MECHANICAL PROCEDURE FOR ASSIGNMENT OF TRAFFIC TO A NEW ROUTE, by J. K. Mladinov and R. J. Hansen, Highway Research Board Bulletin 130, 1956, pp. 59-68.

(28) A METHOD OF TRAFFIC ASSIGNMENT TO AN URBAN NETWORK, by J. Douglas Carroll, Highway Research Board Bulletin 224, 1959, pp. 64-71.

(29) NATIONAL COMMITTEE ON URBAN TRANSPORTATION, Procedure Manuals: 1A, 3A, 3B, 4A, 5A, 7A, 8A, and 10A, Public Administration Service, 1958.

(30) OBJECTIVE AND SUBJECTIVE CORRELATES OF EXPRESSWAY USE, by E. Wilson Campbell and Robert S. McCargar, Highway Research Board Bulletin 119, 1956, pp. 17-38.

(31) OBSERVATIONS CONCERNING URBAN TRAFFIC VOLUME PATTERNS IN TENNESSEE, by Boris B. Petroff, Public Roads, vol. 30, no. 5, December 1958, pp.123-131.

(32) A POLICY ON ARTERIAL HIGHWAYS IN URBAN AREAS, American Association of State Highway Officials, 1957.

(33) PREDICTING THE EFFECT OF EXPRESSWAYS ON ADJACENT ARTERIAL ROUTES, by George W. Wickstrom and Walter Kudlick, Traffic Engineering, vol. 29, no. 7, April 1959, pp. 25-28.

(34) PRESSURIZED INTERSECTIONS, by Robert C. Blumenthal and John W. Horn, Highway Research Board Bulletin 167, 1957, pp. 42-61.

(35) PRINCIPLES AND TECHNIQUES OF PREDICTING FUTURE DEMAND FOR URBAN AREA TRANSPORTATION, by B. V. Martin, F. W. Memmott,III, and A. J. Bone, Massachusetts Institute of Technology, Report No. 38, June 1961, p. 215.

(36) PROGRAM FOR ASSIGNING TRAFFIC TO A HIGHWAY NETWORK, by Glenn E. Brokke, Highway Research Board Bulletin 224, 1959, pp. 89-97.

(37) TRAFFIC ASSIGNMENT, by K. G. McWane, Southeastern Association of State Highway Officials Proceedings, 1952, pp. 85-88.

(38) TRAFFIC ASSIGNMENT, Highway Research Board Bulletin 61, 1952, 70p.

(39) TRAFFIC ASSIGNMENT, Highway Research Board, Highway Research Record, No. 6, 1963, 75 p.

(40) TRAFFIC ASSIGNMENT ANALYSIS, by E. Richard Kolesar, Pittsburgh Area Transportation Study Research Letter, vol. 4, no. 1, Jan.-Feb. 1962, pp. 16-36.

(41) TRAFFIC ASSIGNMENT ANALYSIS AND EVALUATION, by David K. Witheford, Highway Research Board, Highway Research Record, No. 6, 1963, pp. 1-11.

(42) TRAFFIC ASSIGNMENT BY IBM, by Gerald Wood, Traffic Quarterly, vol. 15, no. 2, April 1961, pp. 331-340.

(43) TRAFFIC ASSIGNMENT BY MECHANICAL METHODS, Highway Research Board Bulletin 130, 1956, 77 p.

(44) TRAFFIC ASSIGNMENT BY MONTE CARLO METHODS, by Karl H. Dieter and Henry H. McNeilly. Presented to Origin-Destination Survey Committee, Highway Research Board, January 1962.

(45) TRAFFIC ASSIGNMENT TO NEW HIGHWAY FACILITIES, by Wolfgang S. Homburger, International Road Safety and Traffic Review (Great Britain), vol. 5, no. 2, spring 1957, pp. 5-6, 8.

(46) TRAFFIC ASSIGNMENT AND ROAD USER ECONOMIC STUDIES, by Robert E. Schmidt and M. Earl Campbell, Highway Traffic Estimation, 1961, pp. 140-151.

(47) TRAFFIC ASSIGNMENT TO STREET AND FREEWAY SYSTEMS, by William L. Mertz, Traffic Engineering, vol. 30, no. 10, July 1960, pp. 27, 33, 53.

(48) TRAFFIC ASSIGNMENT TRAVELTIMES, Pittsburgh Area Transportation Study Research Letter, vol. 1, no. 6, July 1959, pp. 1-5.

(49) TRAFFIC ASSIGNMENT USING IBM COMPUTATIONS, by R. M. Brown and H. H. Weaver, Highway Research Board Bulletin 130, 1956, pp. 47-58.

(50) TRAVEL MODE SPLIT IN ASSIGNMENT PROGRAMS, by D. M. Hill and Norman Dodd, Highway Research Board Bulletin 347, 1962, pp. 290-301.

(51) TRAVELTIME - AN EFFECTIVE MEASURE OF CONGESTION AND LEVEL OF SERVICE, by Edward M. Hall and Stephen George, Jr., Proceedings, Highway Research Board, vol. 38, 1959, pp. 511-529

(52) TECHNIQUES FOR MEASURING OVERALL SPEEDS IN URBAN AREAS, by Donald S. Berry and Forest H. Green, Proceedings, Highway Research Board, vol. 29, 1949, pp. 311-318.

(53) TRIP CHARACTERISTICS AND TRAFFIC ASSIGNMENT, Highway Research Board Bulletin 224, 1959, 135 p.

(54) TRIP CHARACTERISTICS AND TRAFFIC ASSIGNMENT, Highway Research Board Bulletin 347, 1962, 318 p.

(55) SELECTED LINK ASSIGNMENT SUBROUTINE, by Robert Kochanowski, Pittsburgh Area Transportation Study Research Letter, vol. 5, no. 1, April 1963, pp. 1-9.

(56) THE SHORTEST PATH THROUGH A MAZE, by E. F. Moore, International Symposium on the Theory of Switching, Proceedings, Harvard University, April 2-5, 1957, pp. 285-292.

(57) MANUAL OF PROCEDURES FOR HOME INTERVIEW TRAFFIC STUDY, by U.S. Department of Commerce, BPR, October 1954.

(58) CALIBRATING AND TESTING A GRAVITY MODEL FOR ANY SIZE URBAN AREA, by U.S. Department of Commerce, Bureau of Public Roads, July 1963.

(59) DISCUSSION OF FRATAR PROCEDURE FOR FORECASTING INTERZONAL VOLUMES, by Arthur B. Sosslau, U. S. Bureau of Public Roads.

(60) A POLICY ON ARTERIAL HIGHWAYS IN URBAN AREAS, American Association of State Highway Officials, 1957.

(61) PEAK PERIOD TRIP FACTORS BY DIRECTIONAL PURPOSE OF TRIP FOR WASHINGTON, D.C., by C. G. Herrington, U.S. Bureau of Public Roads, August 27, 1962.

(62) CHICAGO AREA TRANSPORTATION STUDY, VOLUME III, 1962

(63) MANUAL FOR OPERATING CATS TRAFFIC ASSIGNMENT PROGRAMS, CATS, March 10, 1964.

(64) A METHOD OF ESTIMATING TRAFFIC BEHAVIOR ON ALL ROUTES IN A METROPOLITAN COUNTY, by T. C. Muranyi, Chicago Area Transportation Study.

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

TRAFFIC ASSIGNMENT MANUAL

APPENDIX TABLE OF CONTENTS	June 1964

TRAFFIC ASSIGNMENT MANUAL

APPENDIX - (PR-1, BELMN) BUILD SELECTED TREES	June 1964

A. IDENTIFICATION

Deck No.: BS0001 (PR-1 BELMN) - BUILD SELECTED TREES

Written by: Jennings, G.E. Computer Division, February 1960 for IBM 704; revised for IBM 7090 by Mitchell, Texas A&M, June 1961; converted to BELMN by Hansen, Vogt-Ivers and Associates, January 1963.

Assembly date: 9-13-63

B. PURPOSE

PR-1 develops the minimum time or distance paths (trees) from a designated node to all other nodes using the described transportation network via the Moore Minimum Path Algorithm. Any number of nodes may be designated.

C. INPUT - OUTPUT [1]

Input	Output
1. Tape	
B7 - Binary Network Description	A3 - BCD
	B5 - First Reel of Binary Trees
	B6 - Second Reel (if required) of Binary Trees

2. Cards

Program Call Card
Identification Card
Parameter Card
Control Card
Tape Assignment Card

[1] See Chapter VI, Part C.

D. OPTIONS

Program options are inserted by punching a 1 in columns 1-32 of the parameter card.

Program Option	Condition	Result
1	On	Trees are built through centroids resulting in trees suitable for spider network loadings.
2	On	Trees are built via the minimum distance paths. Note: Turn penalty should be zero.

E. PROGRAM OPERATION

Following the program call card, which is read by the BELMN Control Program, there must be an identification card, then a parameter card, then a control card. After PR-1 is located on the library tape (A8) and loaded into core storage by BELMN Control Program, control is transferred to PR-1. The network, as built by PR-6, is read into core storage and the housekeeping and initialization operations are performed. Then the identification, parameter, and control cards are read and stored in memory. Trees are built one at a time and written on tape(s) (one binary record per tree) until all selected trees have been built.

The summation of times to all zones (in whole minutes) is written throughout the operation in BCD format on A3. At the conclusion of building all trees an EOF is written on B5. It is then rewound and control is returned to the BELMN Control Program.

F. TIMING

It takes approximately 15 minutes to build 552 trees for a 4000 Node Network.

G. ERROR MESSAGES

STATISTICS OF TREE OVERFLOW NOT FOUND - Tree time accumulation overflows indicating a mistake in tree building which causes the tree to put too many links in a trace. The program continues to build trees.

CARD IN ERROR -- (card which has error) -- FIRST CARD MUST BE IDENTIFICATION CARD - The program checks the first card for a 1 punch in column 72. If it isn't found, this message and the card are printed on BCD output tape and control is returned to BELL.

CARD IN ERROR -- (card which has error) -- SECOND CARD MUST BE OPTIONS--PARAMETER CARD - The program checks the second card for a 2 punch in column 72. If it isn't found, this message and the card are printed on the BCD output tape and control is returned to BELL.

TREE SELECT CARD IN ERROR - The first zone of group is greater than the last zone in the group. Program cannot operate and control is returned to BELL.

TREE ERROR COUNT____________ - This is the number of trees in which errors were encountered.

FILE ERROR - This message indicates there is an End of File on the BCD input tape or an End of Tape encountered in writing on the BCD tape.

REDUNDANCY ERROR - Redundancy error encountered in reading tape or invalid card punch.

BEGAN REEL 2 WITH TREE_________ - If there is more than one reel of trees, the first tree on the second reel is given in this message.

APPENDIX - (PR-2, BELMN) LOAD MINIMUM PATHS, DIRECTIONAL	June 1964

A. IDENTIFICATION

Deck No.: BS0002 (PR-2 BELMN) - LOAD MINIMUM PATHS, DIRECTIONAL

Written by: Jennings, G.E. Computer Division, February 1960, for IBM 704; revised for IBM 7090 by Mitchell, Texas A&M, June 1961; revised for destination selection by Mertz, WMATS, February 1962; converted to BELMN by Vogt-Ivers and Associates, 1963.

Assembly date: 8-21-63

B. PURPOSE

1. To produce a binary loaded network using the minimum time path criteria and the appropriate zone-to-zone volumes.

2. To produce a trip length frequency distribution of the loaded trip volumes.

C. INPUT - OUTPUT [1]

Input	Output
1. Tape	
B5 - Binary trees	A3 - BCD
B6 - Binary trip volumes	A7 - Binary loaded network
B7 - Binary network description	

2. Cards

Program Call Card
Identification Card
Parameter Card

3. Origin Control Card

This card specifies which zones are to be used as origin zones. These zones must be in a consecutively numbered range. If all trips are

[1] See Chapter VI, Part C.

to be used, the first and last centroids are designated on the origin control card.

Columns	Contents
4-6	First zone of range of origin zones
10-12	Last zone of range of origin zones
72	"3"

4. Time Limits Card (special for this program)

This card sets the limits of the time intervals of the BCD output of the trip length distribution. The maximum time interval should be greater than the maximum tree time. This card also sets the effective trip length that will be loaded, e.g., to load only those trips whose lengths are between 10 and 15 minutes. The lower limit would be coded 10 and the maximum would be coded 15.

Columns	Contents
4-6	First time interval in minutes - (usually - "0")
10-12	Maximum time interval in minutes - (usually - "200")
22	"8"
72	"4"

D. OPTIONS

There are no options in this program.

E. PROGRAM OPERATION

Following the Program Call Card, which is read by the BELMN Control Program, these cards are required:

1. Identification Card
2. Parameter Card
3. Origin Control Card
4. Time Limits Card

After PR-2 is located on the library tape (A8) and loaded into core storage by BELMN Control Program, control is transferred to PR-2. The parameter card, the origin control card, and the time limits card are read in and processed. Then the program begins loading trips. The trip tape and tree tape are alternately read until all traces have been loaded. Then they are rewound and the loaded network is written. The trip length distribution is written, the network description tape is rewound, and control is transferred to the BELMN Control Program.

F. TIMING

It takes approximately 25 minutes to load a 550 zone, 4,000 node network.

G. ERROR MESSAGES

RECORD LENGTH DOES NOT MATCH WORD COUNT - The program has compared the network description tape to the last freeway node number from parameter card and has encountered a difference. Control is returned to BELL.

NETWORK NOT COMPATIBLE WITH PARAMETERS - The network description appears to be shorter than that dictated by parameters. Control is returned to BELL.

READ ERROR ON TAPE B7 - Network description on B7 has a read error which could not be corrected after 10 tries.

READ ERROR ON FREWAY TREE TAPE - Tree tape on B5 has unreadable record, attempted 10 times.

READ ERROR ON ZONE TRIP TAPE B6 - Trip tape has unreadable record, attempted 10 times.

(FWY)/(ART) TREE (Zone No.) BAD, NOT LOADED - Loading continues.

(Origin Zone) TO (Destination Zone), LINK (A node) TO (B node), TRIPS LOST (Trips) - Trips not loaded for this zonal interchange because of difficulties encountered.

TRAFFIC ASSIGNMENT MANUAL

APPENDIX - (PR-6, BELMN) BUILD OR UPDATE NETWORK DESCRIPTION	June 1964

A. IDENTIFICATION

Deck No.: BS0006 (PR-6, BELMN) - BUILD OR UPDATE NETWORK DESCRIPTION

Written by: Jennings, G.E. Computer Division, February 1960 for IBM 704; converted to 7090 by Hood, WMATS, May 1962

Assembly date: 8-8-62

B. PURPOSE

1. To convert the network description deck (link cards) to a single binary record for use by other programs of the traffic assignment library, or

2. Make additions, deletions, or changes to an existing binary network description. The data are checked for various types of errors.

C. INPUT - OUTPUT[1]

1. BUILD OPTION

Input	Output
a. Tape	A3 - BCD
	B2 - Intermediate tape (if edit is performed during build). **Maximum** time and distance blank.
	B7 - binary network description

[1] See Chapter VI, Part C.

b. Card

Program Call Card
Identification Card
Parameter Card
Speed Limit Card
Link Data Cards
Turn Prohibitor Cards (Optional)
End of Data Card

2. UPDATE OPTION

a. Tape

B8 - Old binary network description

A3 - BCD

B7 - New binary network description

b. Card

Call Card
Identification Card
Parameter Card
Speed Limit Card
Link Data Cards
1. Delete
2. Change
3. Add
Turn Prohibitor Cards (optional)
End of Data Card

The three types of data cards may be used in several different combinations. In UPDATE network description it is most important that Delete cards normally precede Add or Change cards. Following are two typical combination of data cards:

a. BUILD network

Link data Add cards
Turn Prohibitor data Add cards
End of Data card

b. UPDATE network

Turn Prohibitor Delete cards
Link data Delete cards
Link data Add cards
Turn Prohibitor Add cards
End of Data card

D. OPTIONS

Program options are inserted by punching a 1 in column 1-32 of the parameter card.

Program Option	Condition	Result
1	ON	Speed/time taken from field 1
2	ON	Speed/time taken from field 2
1 and 2	OFF	Speed/time taken from field 3
4	ON	One-way links written on error tape
5	ON	Freeway links entered at half time
6	ON	All old turn prohibitors removed from network
7	ON	BUILD network
7	OFF	UPDATE network
8	ON	Suppress infinite speed check
9	ON	Suppress normal link speed check

E. PROGRAM OPERATION

Following the program call card, which is read by the BELMN Control Program, there must be an identification card, then a parameter card, then a control card; all three of which are read by PR-6. After PR-6 is located on the library tape (A8) and loaded into core storage by BELMN Control Program, control is transferred to PR-6. The identification, parameter, and control cards are read, stored in memory for later reference, and also written on A3. Beyond this point behavior of the program is determined by whether program option 7 was specified in the parameter card.

1. BUILD

If BUILD option is specified by punching 1 in column 7 of the parameter card and, in addition, columns 46-48 (longest time) of the parameter card are blank or zero, then the link data cards are edited for longest time and longest distance. After all cards have been edited, the results of this editing are printed. The field for speed/time is designated by program option. A new network is built based on the results of the editing; i.e., the maximum time and maximum distance found in the link data cards are used as parameters. Any turn prohibitor data cards present during the editing are disregarded.

If BUILD option is specified by the parameter card and longest time and longest distance are given, then the new network is built without editing for longest distance and time. Data cards are read from tape or the online card reader and errors are written on tape A3. The new network is written on tape as a single binary record and rewound.

2. UPDATE

If the UPDATE option has been specified in the parameter card, then the old network is changed as indicated by the data cards. The old network tape is read and rewound. Data cards are read from tape or the online card reader, and errors are written on tape A3. The new network is written on tape as a single binary record.

F. TIMING

It takes about one minute or less to build or update even the largest networks.

G. ERROR MESSAGES

DUPLICATE LINK FROM (A node) TO (B node) NOT ENTERED - This message caused by an Add card whose A and B nodes are already present in the network. During an UPDATE this message can be encountered as "DUPLICATE LINK FROM (A node) TO (B node)." This means that during the sorting of B nodes for a given A node, duplicate links have been found.

LINK (A node) TO (B node to be changed) MISSING, NOT CHANGED TO (New B node) - This message caused by a change card during UPDATE. The old network does not contain the link to be changed; therefore, no new information is entered.

(A node) HAS TOO MANY LINKS OUT, (B node) NOT ENTERED - Network contains 4 B node entries for this A node. This Add card cannot be entered.

UNABLE TO FIND (A node) (A) TO (B node) (B), PROHIBITOR

NOT (ENTERED) (DELETED) - If the new network does not contain link A to B, then the new turn prohibitor cannot be entered, or if the old network does not contain link A to B, then the old turn prohibitor cannot be removed.

PROHIBITED CONNECTION (B node) (B) TO (P node) (P) NOT FOUND. PROHIBITOR NOT (ENTERED) (DELETED) - Entry link A to B of prohibited turn was found, but exit link B to P was not found; therefore, the addition of deletion of turn information could not take place.

NO EXIT FROM ZONE (A node) - During the final editing of the new network it is discovered that there is no outbound link from centroid A.

SPEED_____________MPH TOO (HIGH) (LOW) (LOCAL, ARTERIAL,) (RAMP, FREEWAY) LINK (A node) TO (B node) DISTANCE_____________MILES - Speed of time ($V = f(T)$) Given is not within the specified limits. The type of link (local, arterial, ramp, or freeway) is determined from the parameters given for last centroid number and for first freeway. This error alone does not prevent the given data being entered into the network. If the speed is infinite ($t = 0$) then the portion of the message "DISTANCE_____ MILES" is omitted.

IMPROPER DATA CARD. DATA NOT ENTERED - (Columns 1-72 of card in error) - Indicates that Col. 72 does not contain a 4. Also used when Col. 24 of a Turn Prohibitor data card is improper.

(A node) TO (B node), 5TH LINK AT (B node) - Indicates that the A node, designated as B node in message, has an inbound link connection which will not appear in the formatted link data. It should be noted that a given A node may have any number of inbound links but only four outbound links.

(Columns 1-54 of card in error) (TIME) (DIST) EXCESSIVE - The time or distance given in data card violates the parameters given. Data is not entered.

(Columns 1-54 of card in error) NODE CODE ERROR - A or B node given in card is too high (or zero) for the parameter last node number specified. Data is not entered.

ONE-WAY LINK (A node) TO (B node) - This message occurs only if program option 4 is envoked. It indicates that the reverse link B to A is not in the new network.

ILLEGAL PUNCH IN CARD - Improper Hollerith character in data card. Data is not entered.

MAX DIST_________, MAX TIME IN F1, F2, F3___________ - This is output from the edit portion of the program.

A. IDENTIFICATION

Deck No.: BS0007 (PR-7, TEXAS) BUILD TRIP VOLUMES

Written by: Jennings, G.E. Computer Division, February 1960 for IBM 704; revised for IBM 7090 by J. Mitchell, Texas A&M

Assembly date: 8-23-63

B. PURPOSE

To convert the zone-to-zone trip data from summary cards to a binary tape format suitable for efficient usage by the other programs of the assignment system.

C. INPUT - OUTPUT

Input	Output
1. Tapes	
A1 - Texas Control, BS0300	B1 - Binary trip tables
A2 - Trip cards	
A8 - Trip cards (second reel)	

2. Cards

Parameter Card

Cols.	Contents
2-4	Longest link distance (miles and hundredths)
6-8	Longest link time (minutes and hundredths)
10-12	Turn penalty (minutes and hundredths)
14-16	Last centroid number
19-21	First turn group node
23-26	Last turn group node
28-31	First freeway node number
33-36	Last freeway node number
38-72	Identification (will be printed online)

Program Call Card

Cols.	Contents
1-2	"PR"
6	"7"
7-72	Anything desired

Trip Summary Card

Cols.	Contents
1-3	Origin zone (or low zone)
4-6	Destination zone (or high zone)
7-12	Trip volume (Alternate 1)
13-18	Trip volume (Alternate 2)
19-24	Trip volume (Alternate 3)
28-80	Not used

D. OPTIONS

Sense Switch

1 ON	Trip data taken from card columns 7-12
2 ON	Trip data taken from card columns 13-18
3 ON	Trip data taken from card columns 19-24
6 ON	2nd reel of input on A8

E. PROGRAM OPERATION

PR-7 is one of a library of programs using Texas Control Program. After the Texas Control Program reads the parameter card, PR-7 is called from the library tape A1 by means of the program call card which is also read from the online card reader.

The order of cards in the card reader at the start of a run is:

1. Parameter card
2. Program call card

After PR-7 is placed in memory, control is transferred to it and the program title and run identification are printed online. Then a program stop occurs. When START is pushed, the trip data is read from A2, one card at a time. After a card is read, the origin zone is checked to see if it is still the first zone being handled.

When the origin zone changes, a record is written on B1 for the first origin zone and then the program begins operating on the next origin zone. As each card is read the sense switch settings are checked by the program to see which card field (alternate 1, 2, or 3) the trip information is to be taken from.

The trip information is taken from the card field indicated by the switch settings and placed in the array for the origin zone being processed. If there are no cards for the origin zone in line to be processed, the program writes on B1 a binary record containing all zero trips for that origin zone, and then goes on to the next zone. This processing continues until an End of File is encountered on the A2, the input tape. If, at this time, sense switch 6 is on, the program will begin reading the trip cards from A8. If sense switch 6 is off, the last origin zone record will be written on B1 and on End of File written after it, then B1 and A2 will be rewound, and control returned to the Texas Control Program.

F. MESSAGES

INPUT TAPE ERROR. PRESS START TO IGNORE RECORD ____ ______
Redundancy error which couldn't be overcome in three attempts.

ORIGIN ZONE OUT OF SORT. PRESS START TO IGNORE (Origin zone of record) (Number of zones) The program continues with the next card, ignoring the wrong one, if START is pressed.

TRAFFIC ASSIGNMENT MANUAL

APPENDIX - (PR-10, TEXAS) LOAD SELECTED LINKS	June 1964

A. IDENTIFICATION

Deck No.: BS10DC (PR-10, TEXAS) - LOAD SELECTED LINKS

Written by: Blumke (GE) and Sullivan (D.C. Highways) for IBM 704; converted to IBM 7090 by Nussbaum, November 1963

Assembly date: 10-14-63

B. PURPOSE

To obtain one or more of the following options:

1. To obtain tape output suitable for punching cards, indicating the entrance to the link, the exit from the link, the origin and destination involved, and the volume of trips in the movement.

2. To load between selected nodes (SELNO). Any trip which passes through two or more of the selected nodes is loaded on the network.

3. To load alternate trees. If trip is found to pass through a selected link or a pair of selected nodes on one set of trees, it is loaded on the network using the alternate trees. (Must be used in combination with option 2 (SELNO).

4. To build a combination table for each selected link reporting the entry and exit link and their respective volumes; available only when using option "A."

5. To load the network using original trees with trips using a flagged selected link.

This option can be used in combination with option 2 (SELNO). If only 1 link is flagged, the output of this option is the same as option 2.

C. RESTRICTIONS

This program is used with Texas Control Program which supplies subroutines used; therefore, PR-10 must be written as a subject program on the Texas library tape.

PR-10 is written for a 32K 7090 with online card reader, online printer, and a minimum of 7 tape units.

The control program should be supplied with a Program Call Card (see writeup for Texas control program) containing a decimal 10 in columns 5 and 6 to load this program from the library tape.

The program can handle a maximum of 50 selected links.

Selected link card must be followed by trip length limits card or else by an empty card reader.

D. INPUT - OUTPUT

Input	Output
1. Tape	
B1 - Trip volumes	A3 - Trip length distribution table
B2 - Network description	
B5 & B6 - Trees (original)	B4 - Selected link cards
B7 & B8 - Trees (alternate)	A7 - Loaded network

2. Card

Parameter Card (Read by Texas Control Program)

Cols.	Contents
1	Blank
2-4	Largest link distance (miles and hundredths)
6-8	Largest link time (minutes and hundredths)
10-12	Turn penalty (minutes and hundredths)
14-16	Last centroid number
19-21	First turn group node
23-26	Last turn group node
28-31	First freeway node number
33-36	Last freeway node number
38-72	Identification: will be put on BCD output.

Program Call Card (Read by Texas Control Program)

Cols.	Contents
1-2	"PR"
5-6	"10"
7-72	Anything desired

Selected Link Card

Cols.	Contents
6	Flag (0, blank - no flag: 1, flag) If the link is flagged, the network will be loaded with the selected link trips.
9-12	A node (1-4,000)
15-18	B node (1-4,000)
20-24	SELEC

Trip Length Limits Card

Cols.	Contents
3-6	Low-time limit
10-12	High-time limit (Maximum range 1-200)

Column 22 must have an 8.

E. OPTIONS

SW 2: For selected node loading (no combination table or card output)

SW 3: For loading alternate trees

SW 4: Loaded network written on (B3) not (A7).

SW 5: On for nondirectional system

F. PROGRAM OPERATION

1. Following the parameter card, which is read by the control program, there must be a program call card, desired selected link cards, and trip length limit card.

2. After PR-10 is located and loaded into storage by Texas control program, control is transferred to PR-10.

3. Online sense switch instructions are printed.

4. Press START to continue.

TRAFFIC ASSIGNMENT MANUAL

APPENDIX - (PR-11, BELMN) FORMAT SELECTED TREES	June 1964

A. IDENTIFICATION

Deck No.: BS0011 (PR-11, BELMN) - FORMAT SELECTED TREES

Written by: Paul Jennings, G.E. Computer Division, February 1960 for IBM 704; revised for IBM 7090 by Joseph Mitchell, Texas A&M, June 1961; put in BELMN by Dick Hansen, Vogt-Ivers and Associates, January 1963

Assembly date: 9-13-63

B. PURPOSE

PR-11 converts selected binary tree records to a BCD tape format suitable for printing.

C. INPUT - OUTPUT[1]

Input	Output
1. Tape	
B5 - Binary tree	A3 - BCD

2. Cards

Program Call Card
Identification Card
Parameter Card
Control Card

D. OPTIONS

There are no options in this program.

E. PROGRAM USAGE

1. Following the program call card, which is read by the BELMN control program, there must be an identification card, then a parameter card, then a control card.

1/ See Chapter VI, Part C.

2. After PR-11 is located on the library tape (A8) and placed in core storage by the BELMN Control Program, control is transferred to this program which then reads the control card and begins searching tape B5 (binary trees input) for the designated record. When the binary record is found, BCD records are written on tape A3 for offline printing. The procedure is repeated until all designated records have been processed. Tape B5 is then rewound and control is transferred back to the control program.

F. TIMING

Processing requires 2-10 seconds per record depending upon the number of nodes in the highway system. Additional time is required for searching for specified trees. For large systems, it may prove more economical to build the selected trees as input to this program rather than consume time by having the program search the complete tree record for the designated tree(s).

G. ERROR MESSAGES

FILE ERROR - This message indicates a faulty end of file on the BCD input tape or an end of tape encountered in writing on the BCD output tape.

REDUNDANCY ERROR - This message indicated a redundancy encountered in reading or writing which cannot be overcome.

CARD IN ERROR -- (card which has error) - SECOND CARD MUST BE IDENTIFICATION CARD. This program checks the first card for a 1 punch in column 72. If it is not found, this message and the data card are printed on the BCD output tape.

CARD IN ERROR -- (Card which has error) - SECOND CARD MUST BE OPTIONS - PARAMETER CARD. The program checks the second card for a 2 punch in column 72. If it is not found, this message and the data card are printed on the BCD output tape.

LZNO NOT COMPATIBLE WITH RECORD LENGTH - The zone number in the last record handled was not equal to the last zone number from the parameter card.

TREE SELECT CARD IN ERROR - The first zone in the group was greater than the last zone in the previous group.

A. IDENTIFICATION

Deck No.: BS0012 (PR-12 BELMN) - PRINT LINK DATA

Written by: Jennings, G.E. Computer Division, February 1960, for IBM 704; revised by Hood, WMATS, May 1962 for IBM 7090 (BELMN)

Assembly date: 8-8-62

B. PURPOSE

PR-12 converts the binary network description record produced by PR-6 into a BCD tape format suitable for offline printing.

C. INPUT - OUTPUT [1]

Input	Output
1. Tape	
B7 - Binary network description	A3 - BCD
2. Cards	
Program Call Card	
Identification Card	
Parameter Card	
Speed Limit Card	

D. OPTIONS

Program options are inserted by punching a "1" in column 1-32 of the parameter card as desired.

Option(Column)	Contents	Result
8	"1"	Suppress infinite speed check
9	"1"	Suppress normal link speed check

---

[1] See Chapter VI, Part C.

If program option(s) 8 and/or 9 are not used, and it is not desired to obtain an exact speed check on every link, it is suggested that speed limits of "00" and "99" be used for the lower and upper speed limits, respectively, for the four types of facilities. Then, only extremely high (or infinite) link speeds will be printed.

E. PROGRAM OPERATION

Following the program call card, which is read by the BELMN Control Program, there must be an identification card followed by a parameter card, and a speed limits card. After PR-12 is located on the library tape A8 and loaded into storage by BELMN Control Program, control is transferred to PR-12. The identification, parameter, and speed limits card are read, stored for later reference, and written on the system BCD output tapes.

The binary network description is read into storage from tape and each individual A-node of the network and its outbound links with their data are converted to BCD and written on tape A3. This process continues until all of the A-nodes in the network have been processed. If a prohibited turn is encountered at a B node, then a separate image line is formed and written on the print tape immediately after the data line. If program option(s) 8 and/or 9 are not used, speed error images are formed and stored until a full page is accumulated. At the end of the next page in the link data printout, this accumulated page of speed errors is written. After the entire network has been formatted, the control program is loaded into storage and control is relinquished to it.

F. TIMING

It takes about one minute to process a 4,000 node network on the IBM 7090.

G. ERROR MESSAGES

NO ONE PUNCH IN COLUMN 72 - (card which is in error) - This program expects the first card to be an identification card with a 1 in column 72.

NO TWO PUNCH IN COLUMN 72 - (card which is in error) - This program expects the second card to be a parameter card with a 2 punch in column 72.

NO THREE PUNCH IN COLUMN 72 - (card which is in error) - This program expects the third card to be a speed limits card, with a 3 in column 72.

WORD STORAGE OVER-RUN - Storage available is not enough for the input network size as described by the parameter card.

______________IS LAST NODE NUMBER ACCORDING TO TAPE - The tape identification does not agree with given parameters.

SPEED_________MPH TOO (HIGH) (LOW) (LOCAL, ARTERIAL) (RAMP, FREEWAY) LINK (A node) TO (B node) DISTANCE_______________MILES - Speed or time (V = f(T)) given is not within the specified limits. The type of link (local, arterial, ramp, or freeway) is determined from the paramters given for last centroid number and for first freeway. This error alone does not prevent the given data being entered into the network. If the speed is infinite (t = o) then the portion of the message (DISTANCE_____ MILES) is omitted.

A. IDENTIFICATION

Deck No.: BS0013 (PR-13, BELMN) - PRINT TRIP TABLES

Written by: Jennings, G.E. Computer Division, February 1960 for IBM 704; revised for IBM 7090 (BELMN) by Hansen, Vogt-Ivers and Associates, June 1962

Assembly date: 9-3-63

B. PURPOSE

PR-13 converts binary trip records to a BCD format suitable for offline printing.

C. INPUT - OUTPUT[1]

Input	Output
1. Tape	
B5 - Binary Trip Table or Binary Skim Trees	A3 - BCD

2. Cards

Call Card
Identification Card
Parameter Card
Control Card (3 in column 72 required)
Tape Assignment Card

D. OPTIONS

There are no options in this program

E. PROGRAM OPERATION

Following the program call card, which is read by the BELMN Control Program, there must be an identification card, a parameter card,

[1] See Chapter VI, Part C.

and a control card. After the control program has read the call card and has located the subject program on A8 and loaded it into memory, control is transferred to the subject program. The identification, parameter, and control cards are then read, stored in memory and printed on A3.

The program then selects and reads in the first record specified on the control card, processes it and writes it in BCD on A3. It then proceeds to the next designated record and repeats the operation. This continues until all designated records have been processed. At the end of the job, the input tape rewinds and control is given to the BELMN Control Program.

This program has been designed to print the trip tables on 72 column paper with from one to four tables to a page depending upon the maximum size of the table:

Number of Zones	Tables Per Page
210 or more	1
140 - 209	2
70 - 139	3
69 or less	4

At the end of each table, the total trips for that table is printed.

F. TIMING

Processing requires 2-10 seconds per record depending upon the number of zones in the trip table.

G. ERROR MESSAGES

NO ONE PUNCH IN COLUMN 72 - (card which has error) - Bad identification card.

NO TWO PUNCH IN COLUMN 72 - (card which has error) - Bad parameter card.

LAST ZONE NO. OMITTED - (Card which has error) Bad parameter card.

NO THREE PUNCH IN COLUMN 72 - (card which has error) - Bad control card.

Any of the above errors will prevent the program from operating and control will be returned to BELL.

A. IDENTIFICATION

Deck No.: BS0015 (PR-15 BELMN) - SUM INS, OUTS, AND INTRAS

Written by: Brown, WMATS, March 1961 for IBM 704; revised for IBM 7090 BELMN by Hood, WMATS, and Manning, BPR, August 1962

Assembly date: 9-7-62

B. PURPOSE

This program reads a binary trip table and produces a BCD summary of trip ends; giving Trips In, Trips Out, Intrazonal Trips, Total Trips, Total Trip Ends, and Total Ins and Outs for each zone.

C. INPUT - OUTPUT[1]

Input	Output
1. Tape	
B5 - Binary Trip Table	A3 - BCD
A5 - Binary Trip Table, if option 1 is selected	

2. Cards

Program Call Card
Identification Card
Parameter Card
Tape Assignment Card

D. OPTIONS (see parameter card)

Program Option (Column)	(Punch)	Option Description
1	"1"	Binary trip tape (input) on A5
	Blank	Binary trip tape (input) on B5
2	"1"	Input is in stacked files

[1] See Chapter VI, Part C.

E. PROGRAM OPERATION

Following the program call card, which is read by the BELMN Control Program, there must be an identification card followed by a parameter card. After the control program has read the call card and has located the subject program on A8, it loads the program into memory and transfers control to this program. The identification and parameter cards are then read, stored in memory for later reference, and printed on A3.

The program then reads the first record from the binary trip file and accumulates the trips from that zone to each of the other zones at the proper locations ("trips out" for the origin zone and "trips in" for the destination zone). The next record is read and the process repeated. When all records are processed the BCD summaries are written on A3, the trip tape is rewound, and control is relinquished to the BELMN Control Program.

This program is limited to 1,000 zones.

F. TIMING

It takes about 2 minutes to sum ins and outs for 552 zones.

G. ERROR MESSAGES

NO 1 PUNCH IN COLUMN 72 - (card which has error) - Identification card in error.

NO ZONE NUMBER - Last centroid not given in parameter card.

NO 2 PUNCH IN COLUMN 72 - (card which has error) - Parameter card in error.

Any of the above errors will prevent the program from operation and control will be returned to BELMN

TRIP TABLE TOO BIG FOR MEMORY - Calculated from parameter card information - 1,000 zone limit.

RECORD ________ IN ERROR--WRONG NUMBER OF WORDS - SHOULD BE ________ WORDS - The number of words per record on binary trip table does not compare with the last zone number from the parameter card.

A. IDENTIFICATION

Deck No.: BS0019 (PR-19, BELMN) EXTRACT ZONE-TO-ZONE DISTANCES VIA TRACE

Written by: Sullivan, WMATS, August 1962

Assembly date: 8-16-62

B. PURPOSE

To determine the distance along the minimum time path.

C. INPUT - OUTPUT[1]

Input	Output
1. Tapes	
B7 - Binary network description	A3 - BCD
B5 - Binary trees	A7 - Binary zone-to-zone distances via minimum time paths (xxxx.x)
B6 - Second reel binary trees	

2. Cards

Program Call Card
Identification Card
Parameter Card
Control Card

D. OPTIONS

There are no options to this program.

1/ See Chapter VI, Part C.

TRAFFIC ASSIGNMENT MANUAL

APPENDIX (PR-27, BELMN) - TRIP CONVERSION PROGRAM	June 1964

A. IDENTIFICATION

Deck No.: BS0027 (PR-27 - BELMN) - TRIP CONVERSION PROGRAM

Written by: Brown, WMATS, June 1961 for IBM 704; revised for IBM 7090 BELMN by Hood, WMATS, and Manning, May 1962

Assembly date: 7-12-62

B. PURPOSE

PR-27 takes a file of trip volumes in which values represent trips produced at the origin zone, and converts it into a file of "true" origin-destination movements. At the same time, these volumes may be factored so that the output values represent a specific percentage of input values.

For example, assume the following matrix is representative of trips on the input file:

Origin zone	Destination Zone			
	1	2	3	4
1	A	B	C	D
2	E	F	G	H
3	I	J	K	L
4	M	N	O	P

In this table, the letters represent the number of trips produced at the origin zone and attracted to the destination zones. Say a file having a 60%-40% split of daily zone-to-zone movements is desired. The resulting file would be formed by first factoring the trips originating from zone 1 and adding these values to the proper location in the row for origins from zone 1. Then the second step of this phase would apply the other factor to the same trips and add these values to the proper location in the column for destinations in zone 1.

At the end of the first phase (zone 1) the resulting table would appear as:

Origin Zone	Destination Zone			
	1	2	3	4
1	.6A + .4A	.6B	.6C	.6D
2	.4B			
3	.4C			
4	.4D			

Repeating this process for all records the final table would appear as:

Origin Zone	Destination Zone			
	1	2	3	4
1	.6A + .4A	.6B + .4E	.6C + .4I	.6D + .4M
2	.4B + .6E	.6F + .4F	.6G + .4J	.6H + .4N
3	.4C + .6I	.6J + .4G	.6K + .4K	.6L + .4O
4	.4D + .6M	.6N + .4H	.6O + .4L	.6P + .4P

The percentages (factors) may be varied in order to build tables for a.m., peak, p.m., peak travel, etc.

PR-27 is most efficient when the entire input file can be carried in storage (i.e., when the number of zones is less than 175).

No provision is made for more than <u>one</u> reel of input. PR-27 is most accurate when the percentages used are 50-50. It is doubtful that useful results can be obtained when either of these figures is below five percent. This is especially true where the average trip volume is less than 10.

C. INPUT - OUTPUT[1]

Input	Output
1. Tape	
B9 - Binary Trip Table	A3 - BCD
	A5 - New Binary Trip Table
	B2 - Intermediate storage

2. Cards

Program Call Card
Identification Card
Parameter Card (special for this program)
Tape Assignment Card

Parameter Card Format:

Cols.	Contents
1-36	Blank, or anything desired
37-39	Number of zones
47-48	Percent origins (percent of trips produced by a zone to be converted into "trips originated by" that zone) e.g., "09" for 9% origin factor.
65-66	Percent destinations (percent of trips produced by a zone to be converted into "trips destined to" that zone) e.g., "91" for 91% destination factor.
72	"2" punch

D. OPTIONS

There are no special options in this program.

E. PROGRAM OPERATION

The trip volume tape is read one record at a time. As each of these records is placed in memory, its duplicate is written out on the intermediate tape. On completion of this phase, both tapes are rewound and the first group of converted trip records is written on the output tape. The intermediate tape is then read completely, rewound, and the second group of trip records written on tape A5. The original input

[1] See Chapter VI, Part C.

tape is then read completely, rewound, and the third group of trip records is written. This process continues until the output tape is completed. An end of file is written on the output and the tapes are then rewound.

F. ERROR MESSAGES

NO ONE PUNCH IN COLUMN 72 - (card which has error) - Identification card error.

NUMBER OF ZONES NOT GIVEN - Parameter card doe not have last zone number.

NO PERCENTAGE GIVEN - Neither origin nor destination factor has been punched in the parameter card.

NO TWO PUNCH IN COLUMN 72 - (card which has error) - Parameter card error.

Any of the above errors will prevent the program from operating and control will be returned to BELL.

A. IDENTIFICATION

Deck No.: BS0047 (PR-47, BELMN) - PREPARE TRIP TABLE FROM STANDARD FORMAT

Written by: Sosslau and Skilton, BPR, January 1963

Assembly date: 4-9-63

B. PURPOSE

PR-47 reads BCD tape records, converts the data, and writes a binary trip table.

C. INPUT - OUTPUT[1]

Input	Output
1. Tape	
B5 - BCD Trip Cards in 80 or 160 word records (unless reassigned), on Origin Zone sort.	A3 - BCD
	A7 - Binary trip table (unless reassigned)

2. Cards

Call Card
Tape Assignment Card
  Field 1 Input tape
  Field 2 Output tape
Parameter Card (special for this program)

Cols.	Contents
1-54	Remarks (anything desired)
55-60	Input record length, number of words
61-66	Last zone number
67-72	Simulated switch settings, see OPTIONS

All numbers are punched right-justified in columns shown.
Note: No scaling is performed on the factors.

---

[1] See Chapter VI, Part C.

D. OPTIONS

Various options are specified by punching "N" or "F" (ON or OFF) in columns 67-72 (simulated switches 1-6) in the parameter card. No sense switches are used by the program.

Simulated Switch	Program Option
1-5	One switch on for each additional input tape (all off if only one input)
6	On to include mode 1, only, if processing #2 cards

E. PROGRAM OPERATION

The control program reads the program call card, finds the program, loads it into memory, and transfers control to it. PR-47 reads the tape assignment card and modifies input and output operations as required, reads the parameter card, and performs required initialization.

It then reads from the input tape and summarizes data for trips from zone 1. When the origin zone changes, a binary trip table record is written out and processing of trips from zone 2 is begun. Dummy trip records are written for zones without originating trips. On encountering an end of file on the input tape, it is rewound. If additional inputs are indicated, a message to this effect is printed and a program halt occurs. The next input tape is manually dialed on, the last one dialed off, and the program restarted. On finishing the last input reel, the last record is written out, (if necessary, dummy records are written until the last zone number is reached) and control is returned to the BELMN Control Program.

F. TIMING

Exclusive of setup time, the total running time is approximately equal to read-in time plus writeout time and varies with the number of zone and trip cards.

G. ERROR MESSAGES (printed online only)

NO ZERO IN COL. 72 - Tape assignment card does not have a "0" (zero) in column 72.

THE FOLLOWING CARD LOOKS OUT OF SORT - I SHOULD BE HANDLING ORIGIN ZONE__________ - BUT THIS CARD IS FOR ZONE _______.

______________ZONE NO. TOO BIG.

COULD NOT WRITE ON A7 - End of tape encountered on A7.

OPERATOR, OUT OF CARDS OR EOF ON A2 - Ready cards or new A2, Press Start and the program will begin.

READ ERROR, TAPE A2 OR CARDS

COULD NOT READ INPUT TAPE, B5

SWITCH ON ADDITIONAL OUTPUT TAPE, A7 - End of tape encountered on A7 output, ready next output and restart.

DIAL NEXT INPUT TO B5, RESTART - End of file encountered on B5 input,ready next input and restart.

A. IDENTIFICATION

Deck No.: BS0050 (PR-50, BELMN) FORMAT TRIP TRACE

Written by: Nussbaum, converted to BELMN by Skilton, June 1962

Assembly date: 6-17-63

B. PURPOSE

To format selected binary tree records into a BCD from which consists of the nodes involved in each zone-to-zone trace in a continuous line.

C. INPUT - OUTPUT[1]

Input	Output
1. Tapes	
B5 - Binary Trees (unless reassigned)	A3 - BCD
B6 - Second reel of binary trees (unless reassigned)	

2. Cards

Program Call Card
Tape Assignment Card
  Field 1 First reel of trees
  Field 2 Second reel of trees
Identification Card
Parameter Card
Control Card (3 in Column 72 required)

More than one control card may be used by placing the following information in column 67 of the control card:

1/ See Chapter VI, Part C.

Cols.	Contents
67	Blank: This is the last control card
67	, (comma): New range of zones begins with the next control card ("3" in cc 72)
67	* : New range of zones begins in cc 64-67 and ends in cc 4-6 of next control card.

D. OPTIONS

Program options are specified by punching a "1" in the specified columns of the parameter card as follows (option and column are synonomous):

Option	Punch	Result
1	Blank	Print out entire trace for every node for each specified tree.
	"1"	Use destructive trace method. See method for details.

E. PROGRAM OPERATION

The BELMN Control Program, upon reading the program call card, loads in PR-50 and transfers control to it. PR-50 then reads, prints, and stores the input cards and makes the necessary tape reassignments.

A tree is read and its identification word is checked for origin zone. If it is not the first tree specified on the control card, succeeding trees are read and checked until the specified one is read. The word for the first destination zone is read and the back node and elapsed time are stored. The program then reads the corresponding word for the back node and stores its back node and elapsed time. The program continues reading and processing in the current tree record until the origin node has been read. When the origin zone has been read, the trace from the origin zone to zone one is printed on A3.

A printed line contains the ending node and its elapsed time (time from origin zone). To its right, or on the next line, as the case may be, is the back node and its elapsed time from the origin zone. The back nodes are shown until the origin zone is encountered.

The program then, using the same tree, repeats the above process, this time with the trace beginning with the second (or next) node. If OPTION 1 (destructive trace) has been specified in the parameter (2) card, the program, upon reaching a node it has previously encountered for this tree, discontinues the process for the current trace, and goes on to the next one. For analysis, simply look above that node in one of the previous traces to find the remainder of the trace. The destructive trace option is used only to eliminate excessive output, and its use is highly recommended.

When all traces (equal to number of zones specified) for the current tree are completed the program reads the control card to determine next tree. If the tree specified is in a range begun by the previous tree, the above tracing process is completed until all trees in the range are processed. If the tree specified on the control card begins a new range, the program merely skips down the tree tape until it encounters the specified tree and then goes through the tracing process.

When the program has processed the last specified tree, it rewinds the input tape(s), prints "PR 50 COMPLETED" online and offline, A3, and returns to the BELMN Control Program.

F. TIMING

With use of OPTION 1 (Destructive Trace Method), PR-50 will process about 7 trees per minute. (Based on about 350 zones). Without OPTION 1 specified, running time may be slightly increased due to additional output.

G. MESSAGES

INVALID CARD, COL. 72 IN ERROR - Self-explanatory; written after the offending card. Run terminated and control returned to BELMN.

LAST 3 CARD HAS BEEN READ, ABOVE CARD NOT USED - Another 3 card has been read after one with a blank col. 67 has been read.

COL. 67 MISCODED, ACCEPTED AS COMMA - A 3 card with something other than an asterisk or comma in column 67 was read. It is accepted as a comma, and the run continues.

10 READ, BUT A 0, 1, 2, OR LAST 3 CARD NOT READ, GO ON - Ten cards have been read, and although they have all had a valid punch (0, 1, 2, or 3) in column 72, one of the types has been missing. Run continues by program beginning to process trees.

BAD CHANNEL ASSIGNMENT - Either column 1 or 4 of the tape assignment card is neither an "A" or "B." Run terminated and control returned to BELMN.

BAD TAPE NUMBER - Either column 2 or 5 of the tape assignment card is not a valid number. Run terminated and control returned to BELMN.

TREE (No.) BAD, WILL SKIP. . . Error while trying to read the tree, this tree omitted; run continues.

PR 50 FORMAT TRIP TRACES INPUTS ON B5 + B6 BCD OUTPUT ON A3 - Written online at beginning of run.

OUTPUT TAPE FULL--REPLACE, PRESS START. Self-explanatory.

PR 50 COMPLETED - Printed online if program operated properly and control returned to BELMN.

A. IDENTIFICATION

Deck No.: BS0051 (PR-51, BELMN) BINARY TRIP TABLE MODIFIER

Written by: Vogt-Ivers and Associates, 1963

Assembly date: 10-25-62

B. PURPOSE

To modify a binary trip table by replacing, subtracting, adding, or substituting constants in selected cells in the table.

C. INPUT - OUTPUT[1]

Input	Output
1. Tape	
A9 - Old binary trip table	B5 - New binary trip table
	A3 - BCD
2. Cards	

Program Call Card
Identification Card
Parameter Card

Control Card (special for this program more than one card may be used).

---

[1] See Chapter VI, Part C.

Cols.	Contents
4-6	From - origin zone
10-12	Through - origin zone
16-18	To - destination zone
22-24	Through - destination zone
25	Character to determine type of modification
26-30	Modifying constant of the form XXX.XX the decimal is assumed so on the card it is XXX.XX for multiplication only - others are XXXXX.
34-36	From - origin zone
40-42	Through - origin zone
46-48	To - destination zone
52-54	Through destination zone
55	Character to determine type of modification
56-60	Modifying constant
72	"3"

Column 25-55 code:

X Multiply by a constant

S Substitute a constant

A Add a constant

M Subtract a constant

Last data card

72 "9"

D. OPTIONS

There are no options in this program.

A. IDENTIFICATION

Deck. No.: BS0060 (PR-60, BELMN) - BUILD CAPACITY RESTRAINT BINARY HISTORICAL RECORD

Written by: Sosslau and Skilton, BPR, June 1962

Assembly date: 9-12-62

B. PURPOSE

PR-60 builds a special network description called a "Historical Record" for use in the capacity restraint process.

C. INPUT - OUTPUT[1]

1. Tape

Input	Output
A5 - Link Data Cards	A3 - BCD
A6 - Link Data Updates	B5 - Binary Historical Record

2. Cards

Program Call Card
Parameter Card (special for this program)

Cols.	Contents
1-60	Identification of run
61-66	Capacity factor (percent of assigned travel occurring in period covered by listed capacity) Ex. 100% = 001000
67-72	Count factor (percent of assigned travel occurring in period covered by listed count)

1/ See Chapter VI, Part C.

Program Options Card

Cols.	Contents
1-66	As desired
67-72	Program switches N or F - See OPTIONS for instructions.

Special Tape Format

The first record in the binary historical record file has 13 words, of which the first 10 are the project description from the parameter card, the next word is the count divisor from the parameter card, the next word is the capacity divisor from the parameter card and the last word is the iteration number for this tape (zero when written by PR-60).

Subsequent records have a variable number of words depending on the number of the iteration. These records, when written by PR-60, have the following format in each 16 word record:

Word	1	Node A
"	2	Node B
"	3	Distance
"	4	Count
"	5	Capacity
"	6	T_o = Time (7) x 0.87
"	7	Time (original)
"	8	Speed (original)
"	9	Node B
"	10	Node A
"	11	Distance
"	12	Count
"	13	Capacity
"	14	T_o = Time (word 7) x 0.87
"	15	Time (original)
"	16	Speed (original)

The first eight words are for link A-B and the second eight are for link B-A.

Note: The number of words per record is increased when processed by PR-61.

D. OPTIONS

Several options can be used by appropriate punching in the second parameter card.

"N" in Column	Option
67	Take time/speed from field 1
68	Take time/speed from field 2
67, 68, both "F"	Take time/speed from field 3
70	Updates on unit A6
71	Second reel of updates

If a second update tape is required a message to this effect is printed online and it must be switched manually on the appropriate halt.

E. PROGRAM OPERATION

The program reads link card records and prepares, from each directional link, two packed words, INA and INB which are stored in MEMA1 and MEMA2 storage areas. When all link cards and update cards have been processed, the two words are unpacked in order of A node number and from them 16-word records are prepared and written. The two words have the following form:

INA		INB	
Count	: Pos. S-17	Speed (+) or time (-) indicator:	Pos. S
Capacity	: Pos. 18-35	Time or speed:	Pos. 4-13
		Distance:	Pos. 14-23
		Node B:	Pos. 24-35

The count and capacity of each link are divided by the count factor and capacity factor, respectively, and divided by 1,000 to put them on the same base as the trips which will be assigned.

The control program reads the Program Call Card, finds the program, loads it into memory, and transfers control to it.

Program PR-60 reads the parameter cards, prints them, clears the work areas and transfers to the main routines.

These routines accomplish the reading and processing of link cards and (if specified by an "N" in column 71) of update cards. Cards without a "4" in column 72 are rejected and these and other errors are printed online with self-explanatory remarks. Ends-of-file are required at the end of input tapes. The 16-word output records are written in one file, preceded by a 13-word record containing the first parameter card plus the iteration number (zero).

The only stops are end of input or output and read-write errors; appropriate messages are printed for the operator at these stops.

On completion, control is returned to the BELMN system.

F. TIMING

Exclusive of setup time, the total running time is approximately equal to read-in time plus write-out time and varies with the number of link cards and links.

G. MESSAGES

5 BAD READS - The BCD input tape is unreadable after five attempts and an end of file is written on B5. It is rewound and control is returned to the BELMN Control Program.

(Card that is duplicate) THIS CARD A DUPLICATE

____________________ 4 LINKS AT NODE__________

____________________ CAN'T DELETE LINK AT______

____________________ THIS IS NOT LINK DATA - No "4" punch in column 72 or incorrectly prepared card.

CARD READ ERROR - Illegal punch in card, control is transferred to BELMN.

WRITE ERROR ON FIRST WRITE, GET OFF - Tried to write but failed - program returned control to BELMN.

KEEP THAT CARD READER FILLED - When an end of file is received on card reader this message is printed.

SWITCH SECOND UPDATE TAPE TO A6 - Push start to read A6 after setting up tape.

FINIS - This message is printed out after program is completed even if there is an error.

TRAFFIC ASSIGNMENT MANUAL

APPENDIX - (PR-61, BELMN) APPLY CAPACITY RESTRAINT TO NETWORK DESCRIPTION	June 1964

A. IDENTIFICATION

Deck No.: BS0061 (PR-61, BELMN) - APPLY CAPACITY RESTRAINT TO NETWORK DESCRIPTION

Written by: Urban Planning Division, Bureau of Public Roads, June 1962

Assembly date: 4-4-64

B. PURPOSE

PR-61 modifies tne speeds in the network description according to the capacity - volume ratio.

C. INPUT - OUTPUT[1]

Input	Output
1. Tape	
B5 - Old binary historical records (output of PR-61 or PR-60)	A3 - BCD
A7 - Binary loaded network	A5 - New binary historical record, updated
A6 - Binary network description (freeway if diversion loading)	B6 - Binary network description updated (freeway network if diversion loading)
	B7 - Arterial binary network description if diversion loading.

1/ See Chapter VI, Part C.

Special Tape Format

The first record in the binary historical record file has 13 words of which the first 10 are the project descriptions from the parameter card, the next word is the count divisor, the next is the capacity divisor (both from the parameter card) and the last word is the iteration number. This number corresponds to the number of loading cycles completed. The first iteration output will be in 26 word records with five words added to each record (see PR-60 output format) for each directional link or 10 words. These records will look like this:

Word	1	Node A
"	2	Node B
"	3	Distance
"	4	Count
"	5	Capacity
"	6	T_o = Time (word 7) x 0.87
"	7	Time (original)
"	8	Speed (original)
"	9	Volume from assignment 1
"	10	Time at volume (9)
"	11	Speed from (10)
"	12	New Time for Link
"	13	Speed from (12)
"	14	Node B
"	15	Node A
"	16	Distance
"	17	Count
"	18	Capacity
"	19	T_o = Time (word 7) x 0.87
"	20	Time (original)
"	21	Speed (original)
"	22	Volume from assignment 1
"	23	Time at volume (22)
"	24	Speed from (23)
"	25	New time for link
"	26	Speed from (25)

The next iteration would add 10 more words to each record and each iteration after that would add 10 more. The maximum number of iterations is nine for this process.

The 10 words added in this next iteration would be added to the directional links just as the last 10 were added. The first five pertaining to link A-B would be added as words 14 through 18 and the second five pertaining to link B-A would be added as words 32 through 36. The eight original words pertaining to link B-A would be moved to 19 through 26.

2. Cards

Program Call Card
Parameter Card (Special for this program)

Cols.	Contents
2-4	Maximum link distance
6-8	Maximum link time
10-12	Turn penalty
14-16	Last zone number
19-22	Lowest node number to be deleted from freeway network to convert to arterial network description (Note: Removes all links with this node value or higher on either end of a link).
24-26	Blank for all-or-nothing assignment; for diversion, N/D, where N/D equals time ratio, freeway/arterial.
28-31	First freeway node
33-36	Last freeway node. This will be highest node permitted (Note: Factored traveltimes used on all links between first and last freeway nodes).
37-72	Description

Option Card

Cols.	Contents
1-65	Any remarks
66-72	Seven simulated switch settings N for ON, F for OFF.

D. OPTIONS

Various options are specified by punching "N" or "F" (ON or OFF) in columns 66-72 (simulated switches 0-6) in the second parameter card. No sense switches are used by the program.

Simulated Switch		Program Option
0	ON	if link volumes from loaded network need not be multiplied by 4.
1	ON	if diversion loading desired
2	ON	if directional capacities given
3	ON	if directional counts given
4	ON	to zero unequal capacities/counts if switch 2 and/or 3 is/are off
	OFF	to average unequal capacities/counts
5	ON	if time in parameter card is to be used as base for network description calculations
	OFF	if maximum traveltime found in historical record is to be used as base
6	ON	if counts are present and if an evaluation is to be made against assigned volumes

E. PROGRAM OPERATION

After transfer is made to the system (see BELMN system description) the BELMN loader cards are read and they read the BELMN control program from tape A8. The control program reads the Program Call Card, finds the program, and transfers control to it. The program reads the parameter cards and performs some initialization, then reads the binary loaded network.

The program then proceeds to read a link historical record, find, and insert the latest loading. If either the capacity or the count is nondirectional, this value is investigated in each direction and appropriate adjustment is made (see OPTIONS) and described in an online printout.

If a link appears in the historical record but cannot be located in the loaded network, the link is deleted from the historical record and the link number involved is printed; no halt is made. If the link is found, the loaded network entry is zeroed after being used.

If a link has a coded capacity, a new speed is computed, and the traveltime is inserted in the historical record and in the network description. If the traveltime computed for the next assignment is found to be greater than the maximum specified by the parameter card, it is replaced by this maximum and an online message to this effect is printed. Again, no halt is made.

When the historical record file is completely read and rewritten, the tapes are rewound and the loaded network record is tested to insure that all links have been handled and any discrepancies are printed. A distribution of links by volume/capacity ratio and recommended change in speed is printed online. This is followed by a statistical summary of volume vs. count comparison, if specified (see OPTIONS).

The maximum link traveltime is printed and, depending upon the option selected, either it or the parameter value is used as a base in converting traveltimes to sixty-thirds for insertion in the old network description. If a new traveltime is zero, no change is made in the old link. The revised network description is written out, and if non-diversion loading is specified, control is transferred to the BELMN system.

If diversion is indicated (see OPTIONS) the freeway network description is altered by deleting freeway links and then is cross-referenced to show inbound links, etc. Discrepancies are printed online. Statistical summaries are written on tape A3 for offline printing. The new arterial network description is then written and control is returned to the BELMN system.

F. TIMING

The total running time is approximately equal to writeout time and varies with the number of links in the network.

G. ERROR MESSAGES

____________TO_______, FIFTH LINK AT NODE - May be all right. There can be more than 4 links outbound from any node.

COULD NOT WRITE ON A5, WILL TRY AGAIN

NO SOAP - The program quits after trying to write and returns to the BELL system.

COULD NOT READ MEMORY A ON A6 - Redundancy encountered in reading A6, and it could not be corrected. Control is transferred to BELL System.

END OF FILE ON MEMORY A INPUT - An end of tape or end of file encountered while in reading the network description from tape A6. Control is transferred to the BELL System.

COULD NOT WRITE MEMORY A ON B6, MOUNT NEW TAPE - A redundancy was encountered while writing on tape B6. Mount another B6 and press "START" to continue the program.

EOT B6 MEMA OUTPUT - End of tape encountered on B6 while writing the new network description. As the network description is very short, the error exit END OF JOB is used to go to the BELL System.

COULD NOT WRITE MEMA ON B7, MOUNT NEW TAPE - Mount a new B7 and push "START." The program will attempt to write a new arterial network description.

EOT B7 MEMA OUTPUT - An end of tape encountered on A7 while writing the new network description. As the network description is very short, the error exit END OF JOB is used to go to the BELL System.

_______________BAD READS, B5. WILL TRY AGAIN - A redundancy was encountered while reading B5.

COULD NOT READ MEMORY Z - Either an end of tape, an end of file, or a redundancy was encountered while reading. Control is transferred to BELL System.

NODE NUMBER TOO HIGH ON LINK______TO_______ - Program continues.

MEMORY Z HAS NO LINK BETWEEN_______AND______ - Although there is a link in the network description, there is none in the loaded network with these node numbers. Program continues.

THE FOLLOWING LINKS ARE NOT INCLUDED IN HISTORICAL RECORD - (A NODE B NODE VOLUME) - There was no link with these nodes in the Historical Record although the link was in the loaded network. Program continues.

NEW TIME ON LINK_____TO_____IS_______, MADE MAX - The time for the link was greater than the maximum allowed. Program continues.

A. IDENTIFICATION

Deck No.: BS0063 (PR-63, BELMN) - FORMAT HISTORICAL RECORD OF CAPACITY RESTRAINT

Written by: Sosslau and Skilton, Urban Planning Division, BPR, June 1962

Assembly date: 9-12-63

B. PURPOSE

PR-63 formats the "Historical Record" from the capacity restraint process. It will process the output of PR-60 or PR-61.

C. INPUT - OUTPUT[1]

Input	Output
1. Tape	
A5 - Binary Historical Record	A3 - BCD
	B5 - BCD - Formatted Historical Record

2. Cards

Program Call Card
Parameter Card (special for this program)

Cols.	Contents
1-66	Identification for page headings on BCD printout
67-72	"N" or "F" see OPTIONS

C. OPTIONS

Options are specified by punching "N" or "F" (on or off) in columns 67-72 (simulated switches 1-6) in the parameter card.

[1] See Chapter VI, Part C.

Simulated Switch		Program Option
1	ON	if capacity scale multiplier is desired
1 OFF	2 ON	if count scale multiplier is desired
Both	OFF	no multiplier used
4	ON	input on A5, output on B5
4	OFF	input on B5, output on A5
6	ON	print averages of all link loadings

D. PROGRAM OPERATION

After transferring to the system (see BELMN system description) the BELMN loader cards are read and used to read the BELMN control program from tape unit A8. The control program, in turn, reads the program call card, finds the program, and transfers control to it.

Program PR-63 reads the parameter card, performs certain initialization including changing of input/output instructions, if specified, to interchange the input and output channels. It then reads the binary link historical records and prepares two lines of information for printing. If indicated by simulated switches (see OPTIONS) counts, capacities and assigned volumes are multiplied by one of the factors contained in the first record on the input tape (see PR-60, Special tape format). Also, if (see OPTIONS) there are data for two or more iterations on the input tape, an average of all loadings for each link is printed.

There are no program stops except at the end of the input, the end of the output or if there are read-write errors. Appropriate messages are printed for the computer operator. On completion (or failure due to tape errors) control is returned to the BELMN System.

E. TIMING

The total running time is approximately equal to twice the read-in time and varies with the number of links in the network.

F. ERROR MESSAGES

CAN"T MAKE 1ST READ - A read error which cannot be overcome on tape B5 or A5 (whichever is the Historical Record tape) has been encountered. Control goes to the BELL System.

COULDN'T WRITE ON A5, PRESS START TO TRY AGAIN - This message indicates a redundancy has been encountered in writing. Push "START" to try again. Change tape A5 and start again.

_____________BAD READS, B5. PRESS START TO TRY AGAIN - This message indicates a redundancy has been encountered in reading. Push "START" to try again. Rebuild B5 and try again.

END OF FILE ON FIRST READ - An end of tape or an end of file encountered on first read of tape B5 or A5, the Historical Record. Control goes to the BELL System.

END OF FILE ON INPUT TAPE, B5 - This indicates that the job has been completed and end of file has been written on output and control transferred to the BELMN Control Program.

COULD NOT READ FIRST RECORD - This message indicates that a redundancy error has been encountered in reading the Historical Record that could not be corrected. Control is transferred to the BELL System.

OPERATOR, OUT OF CARDS OR END OF FILE ON A2 - Put cards in reader or check A2 for wrong tape. Correct and restart.

CHANGE OUTPUT TAPE A5 - Put on a new tape on A5 as the present one is full. Push "START" when ready.

FINIS - This message is printed online just before control is transferred back to the BELMN Control Program.

TRAFFIC ASSIGNMENT MANUAL

APPENDIX - (PR-104, BELMN) - SUM VOLUMES AND TURNS	June 1964

A. IDENTIFICATION

Deck No.: BS 0104 (PR-104, BELMN) - SUM VOLUMES AND TURNS

Written by: Jennings, G.E. Computer Division, February 1960 for IBM 704; revised for IBM 7090 by Mitchell, Texas A&M, June 1961; converted to BELMN by Vogt-Ivers and Associates, 1963

Assembly date: 8-21-63

B. PURPOSE

PR-104 provides a loaded network output suitable for analyses. This output includes turns for selected nodes and a summary of vehicle miles and hours by jurisdiction and by type of facility.

C. INPUT - OUTPUT[1]

Input	Output
1. Tape	
A7 - Binary loaded network	A3 - BCD
B7 - Binary Network description	
2. Cards	
Program Call Card	
Identification Card	
Parameter Card	

D. OPTIONS

There are no options in this program.

E. PROGRAM OPERATION

The binary loaded network is read in from A7 converted to BCD and written on tape A3. The network description is read from B7, and a summary of vehicle-miles and vehicle-hours are calculated for each type of facility and jurisdiction.

1/ See Chapter VI, Part C.

A. IDENTIFICATION

Deck No.: BS0126 (PR-126, BELMN) - ZONE TO DISTRICT COMPRESSOR

Written by: Bunyan, Alan Mr. Voorhees and Associates, September 1963

Assembly date: 12-19-63

B. PURPOSE

1. To prepare a binary tape of district-to-district trip volumes from a binary tape of zone-to-zone trip volumes, according to certain district-zone equivalents.

2. To expand a trip volume tape by filling with zeros.

C. RESTRICTIONS

PR-126 is limited to 999 zones and 999 districts.

D. INPUT - OUTPUT [1]

Input	Output
1. Tapes	
B2 - Zonal binary trip volumes unless reassigned	A3 - BCD B6 - District binary trip volume unless reassigned

2. Cards

Program Call Card
Identification Card
Parameter Card
Control Card (district equivalents cards, special this program)
Tape Assignment Card

Field 1	Input tape
Field 2	Output tape

[1] See Chapter VI, Part C.

There must be only one card per district and all districts must be present in sequential order. All zones of input must be accounted for. A zone may be placed in more than one district. If the user wishes to change the zone numbering, each district may be set equal to a single zone, with district required in sequential order where zone can be in any order.

The zones in a district are specified in columns 1 to 66 in a format exactly like the control card described in Chapter VI, Part C. The district number to correspond to the selected zones is punched in column 68-70. A "3" punch in column 72 is required.

E. OPTIONS

There are no options in this program.

F. PROGRAM OPERATION

The "3" cards are read into the equivalents table and checked. When the tape assignment card is read the program performs the necessary tape reassignments and begins processing.

It then searches the input zonal volume tape for the zones specified for the first district and accumulates them. This results in a table of district to zone interchanges.

The destination zones to this accumulated district are then combined to give district-to-district trip interchanges. This table is then written as a single binary record on the output tape and the procedure continues with the next sequential district. Processing continues until all the districts are completed in this manner.

The user should note that PR-126 can also be used to expand or square the table of a binary trip volume tape.

A. To expand or square a trip table. The program will write a record of n (number of districts) zeros (with the exception of the ID word) for a district with no specified zonal equivalency.

G. PROGRAM USAGE

A production run is obtained through the normal BELMN setup, with the cards in the same order as described under Input-Output. After all records are processed and written out, the input and output tapes are rewound, and control is returned to the BELMN Control Program.

H. TIMING

Timing will vary greatly depending on the grouping of zones into districts and the sequence of zones within the district sequence. Because of tape search time, run time will be greatly reduced if the equivalents tables are in sort of sequential order instead of using random selections. For example, to compress 40 zones to five districts:

Zones	District Number
1-11	1
12-26	2
26-32	3
32-39	4
40	5

would be more efficient than:

Zones	District Number
1, 7-11, 5, 14	1
6, 2-4, 28-30, 22	2
12, 13, 15-21	3
31-37, 23-27, 39	4
38, 40	5

However, either will work.

I. MESSAGES

ERROR IN PARAMETER CARD, JOB TERMINATED. The parameter card does not have a "2" punch in column 72, or columns 37-39 do not contain the number of zones on the input tape. Control is returned to the Monitor.

ERROR IN CONTROL CARD, JOB TERMINATED. The district equivalents cards are not in an ascending order by district number, or a zone selection series is improperly specified. Control is returned to the Monitor.

NO EQUIVALENT FOR ZONE_______RUN TERMINATED. The zone number indicated has not been placed within a district. Control is returned to the Monitor.

ZONE_______NOT ON INPUT, OR PARAMETER ERROR. The zone number indicated is not on the input tape. Check the input tape or the number of zones specified on the Parameter Card. Control is returned to the Monitor.

END OF FILE, BCD INPUT. JOB TERMINATED. Necessary input cards are not all present. Control is returned to the Monitor.

READ ERROR ON INPUT. RUN TERMINATED.

OUTPUT WRITER ERROR, RUN TERMINATED. Both of these messages are self-explanatory I/D errors. These tapes should be checked. Control is returned to the Monitor.

BAD CHANNEL ASSIGNMENT. Tape Assignment Card has an improper channel designation. The job is terminated and control is returned to the Monitor.

BAD TAPE NUMBER. Tape Assignment Card has an improper tape number. The job is terminated and control is returned to the Monitor.

TOO MANY TAPES ______________________. More tapes are assigned than are specified on the Parameter Card. The job is terminated and control is returned to the Monitor.

________________DISTRICTS. Number of districts on output tape.

JOB COMPLETED. Execution has been completed and control is returned to the BELMN Control Program.

A. IDENTIFICATION

Deck No.: BS0130 (PR-130, BELMN) - SKIM AND UPDATE BINARY TREES

Written by: Original IBM 704 Program by Sosslau, BPR, in 1961; revised for IBM 7090, including updating options by Brown, Alan M. Voorhees and Associates, Inc., 1962; converted to BELMN by Bunyan, Voorhees, in 1963

Assembly date: 11-14-63

B. PURPOSE

1. To prepare an interzonal traveltime binary file from a file of binary trees produced by the BUILD TREES (PR-1) Program.

2. To update a file of interzonal traveltimes or trip volumes.

C. INPUT-OUTPUT[1]

Input	Output
1. Tape	
B5 - Binary trees, B2 if option 4 envoked	A3 - BCD
	A4 - Binary Skimmed Trees, B6 if option 4 exercised (time in whole minutes)

2. Cards

Program Call Card
Identfication Card
Parameter Card (special format for this program)

---

[1] See Chapter VI, Part C.

Cols.	Contents
1-6	See OPTIONS
37-39	(N) Last zone number
46-48	(SF) Longest link time, plus turn penalty, if OPTION 3 not specified. Same units (X.XX minutes) as used when the trees were built.
72	"2" (Necessary)

Term Card (Used only if terminal times are to be added)

Cols.	Contents
1-4	"TERM"

Terminal Time ("T") Cards

Terminal times for consecutive zones punched, right-justified, in successive three column fields, with the beginning zone number in cols. 4-6.

Cols.	Contents
4-6	(ZI) First zone of the group on this card
7-9	Terminal time for ZI
10-12	" " " ZI + 1
13-15	" " " ZI + 2
Etc.	--------ETC.---------
64-66	" " " ZI + 19

A "T" card need not have times for 20 zones. There may be any number of "T" cards.

UPDT Card (<u>Must</u> be used if OPTION 5 not specified)

Cols.	Contents
1-4	"UPDT"

Update ("U") Cards

Cols.	Contents
4-6	(OZ) Origin zone
10-12	(D1) First destination zone of range

Update ("U") Cards (continued)

Cols.	Contents
16-18	(D2) Last destination zone of range begun by D1. May be blank if D2=D1.
19	Blank, if UT (cols. 20-24) is to replace the amount in the input record, "+," if UT is to be added to the record, or "-," if UT is to be subtracted from the record.
20-24	(UT) Amount of update in whole minutes or trips
72	"U" (Optional)

A "U" card is required for each range of zones.

Last Card (Must be used if OPTION 5 not specified)

Cols.	Contents
1-4	"LAST"

D. OPTIONS

Program options are specified on the parameter card by punching a "1" in the proper column. (Option and column number are synonomous).

Option	Punch	Results
1	blank	All BCD input cards will be written on A3.
	"1"	Only the "1" and "2" cards written on A3.
3	blank	Tree times scaled according to the longest link time. (Normal).
	"1"	No scaling will be done.
4	blank	Input on B5, output on A4.
	"1"	" " B2, " " B6.
5	blank	Updating will be done.
	"1"	No update cards will be read.

E. PROGRAM OPERATION

PR-130 is called from the library tape A8 by means of the program call card, and control is transferred to it. It first reads and prints offline the "1" and "2" cards, and then unpacks the parameter ("2") card and determines the OPTIONS and parameters.

If OPTION 5 (no updates) has not been specified, a card from the BCD input is read. If it is a TERM card, the following cards are read (and stored for later usage) until a UPDT card is encountered. If OPTION 5 has been specified this operation is not performed.

The program then reads the first N + 1 words of the first record on the binary input. (N = number of zones as per cols. 37-39 of the "2" card). The first word (identification word) of the record is processed so that it will contain the origin zone number in its decrement and the number of destination (N) zones in its address. The next N words are read and converted to whole minutes in accordance with the scale factor (Cols. 46-48 of the "2" card). At the same time the sign and back node of the word are set to zero. If OPTION 3 has been specified, this conversion is not performed.

At this time, if OPTION 5 has been specified, the skimmed tree is written on the binary output tape. If OPTION 5 has not been specified, the program returns to the second word (first destination zone) of the converted tree and begins processing it. The next card from the BCD input is read and checked to see if it applies to this O-D pair. If it does, the updating (adding, subtracting, or replacing) takes place, and the next word is read. If the current update card applies to this zone the updating takes place and the next word is read. This process continues until the last destination zone (D2) on the update card does not apply to the current word. At this time the next card is read and first checked to see if it applies to the current tree. If so, the processing continues in the above manner until a card is read that does not apply to this tree. The program then returns to the beginning of the same tree and goes through it, adding the terminal times. The skimmed and updated tree is then written on the binary output.

It then steps to the next tree, and the entire operation is repeated. Anytime a LAST card is read, a flag is setup so that no more cards will be read.

After the last zone is processed, an end of file is written on the output tape and it is rewound, and the input tape is unloaded.

The cards are used in the order as shown in Card Format. Cards 4 through 8 are optional. If card 4 is used, cards 5, 6, and 8 must be used also. If "U" cards (7) are used, cards 6 and 8 must also be used. A complete run (skim, add terminal times and apply updates) would involve all the cards 1-8. The cards may be read from the MONITOR input tape or from the card reader if Sense Switch 5 is ON.

The tapes are mounted as shown under TAPES. At the end of the run, the output tape is file-ended and rewound. The input tape is unloaded so it cannot be written on by a subsequent program. Control returns to the BELMN Control Program.

F. TIMING

A 300 zone tree can be skimmed and updated in about 1-2 minutes.

G. MESSAGES

READ ERROR, BCD INPUT - Ten unsuccessful attempts have been made to read the BCD input. Control returned to BELL.

ERROR IN ID CARD - The first card read did not have a "1" in column 72. It was accepted as the "1" card anyway. Run continues.

ERROR IN PARAMETER CARD. JOB TERMINATED - The second card read does not have a "2" in col. 72, the number of zones (cols. 37-39) is missing, or the longest time factor (cols. 46-48) is missing. Control returned to BELL.

END OF FILE, BCD INPUT. JOB TERMINATED - An end of file has been encountered on A2 (or the card reader) before all the input cards have been read. Control returned to BELL.

WRONG IDENT. ON UPDATE FILE - The card following the "2" card was neither a TERM nor a UPDT card. (OPTION 5 not specified). Run continues as though OPTION 5 were specified.

NO ZONE IN TERMINAL TIME CARD - A card(s) between the TERM card and UPDT card had nothing in cols. 1-6. The faulty card is printed following the message, and is not used. The next card is read. When 5 such cards are found, the run is terminated, and control returned to BELL.

2ND DEST. ZONE IS LESS THAN FIRST

NO ORIGIN ZONE IN UPDATE CARD

NO DEST. ZONE IN UPDATE CARD

UPDATE CARD OUT OF SORT - The above 4 messages are self-explanatory and all refer to the cards read between the UPDT and the LAST cards. The offending card is printed after the message and is not used. Five bad update cards are allowed before the run is terminated, and control returned to BELL.

READ ERROR, BINARY INPUT. JOB TERMINATED - Ten unsuccessful attempts have been made to read the binary input tape. Control returned to BELL.

PREMATURE END OF FILE ON BINARY INPUT, RUN TERMINATED - An end of file has been encountered before the specified number of zones has been read. Control returned to BELL.

UNABLE TO WRITE BINARY OUTPUT. JOB TERMINATED - Several unsuccessful attempts have been made to write the output tape. Control returned to BELL.

END OF BCD OUTPUT TAPE

END OF BINARY OUTPUT TAPE

Above messages written online and the program halts to allow the operator to mount new tapes. Pressing start continues run.

END OF JOB - Written when program has completed successfully. Control returns to BELMN Control Program.

TRAFFIC ASSIGNMENT MANUAL

APPENDIX - (PR-131, BELMN) - NONDIRECTIONAL ADJUSTMENT PROGRAM	June 1964

A. IDENTIFICATION

Deck No.: BS0131 (PR-131, BELM) - NONDIRECTIONAL ADJUSTMENT PROGRAM

Written by: Bunyan, Alan M. Voorhees and Associates, September 1963

Assembly date: 11-12-63

B. PURPOSE

To accept a binary loaded network produced by Program 2 (Load Minimum Paths) and convert it into a nondirectional assignment. Turns, if present, are not affected. Link volume is two-directional and is repeated for convenience on both directions of a link. One-way volumes are not affected.

C. INPUT - OUTPUT[1]

Input

1. Tape

A7 - Binary Loaded Network (Directional)

2. Cards

Program Call Card
Identification Card
Parameter Card

Output

A3 - BCD

A7 - Binary Loaded Network (nondirectional)

B0 - Intermediate Storage Tape

D. OPTIONS

There are no options in this program.

[1] See Chapter VI, Part C.

A. IDENTIFICATION

Deck No.: BS133PR - Program 133, BUILD TRIP VOLUMES FROM SURVEY CARDS

Written by: Brown, Alan M. Voorhees and Associates, May 1962, revised for BELMN by Bunyan, A. M. Voorhees and Associates

Assembly date: 9-18-63

B. PURPOSE

PR-133 prepares binary files of trip volumes from O-D survey cards. For home-based trips, the zone of residence (production zone) is regarded as the "origin" zone and the zone of attraction as the "destination" zone. For the purpose of directional assignment, these tables must be converted into true origin-destination tables by means of a conversion program (PR-27 Trip Conversion Program). Nonhome based trips, which must be processed separately, are built in true origin-destination form. Up to six files of trips may be built during a single run of the program. Files may be built for specified purposes of travel, modes of travel, land uses, occupations, etc., or for any combination of these.

C. DESCRIPTION

During the first phase of the program a table of survey zone-assignment zone equivalents is read in and stored in memory. During the second phase, the survey cards are read in, decoded, and checked for errors. Cards in error are written on an error tape for offline printing.

Each card is matched against a set of criteria (provided by the user) to determine which, if any, of the trip tables it is to be entered in. The number of cards failing to meet any of the given criteria is printed online at the end of the program.

As the trip tables are being accumulated, a summary of trip ends for each of the outputs is also accumulated. During the final phase of the program, the trip end tables are written on tape for offline printing.

D. RESTRICTIONS

The amount of core storage needed for a particular run of PR-133 may be calculated from the formula below.

$$W = 2326 + 4\ ZN + E$$

where

Z = No. of zones
N = No. of tables required (1 to 6)
E = No. of cards in the table of zone equivalents (not to exceed 15,000)

E. DATA PREPARATION

Program Call Card

Cols.	Contents
1-2	"PR"
4-6	"133"

Identification Card

Cols.	Contents
1-71	Identification. The contents of these columns will be printed on all output for offline printing.
72	"1"

Parameter Card

Cols.	Contents
6	Numbered purposes (From 1 to 6)
9-12	Blank if trip purpose is reported by means of purpose "from" and purpose "to." FLAG (Cols. 9-12) if trip purpose is reported by means of general purpose and a "FLAG" denoting place trip started. "FLAG" is 1 if trip started at home, 2 if trip ended at home, and blank or zero if trip is nonhome based.

Parameter Card (continued)

Cols.	Contents
13-18	Maximum number of error cards allowed.
19-24	Trip scale factor. This number is usually either 1 or 10 depending on whether trips are reported in whole numbers or in tenths respectively. Immediately prior to writing, accumulated trip volumes are divided by the number punched in this field.
25-30	Options (Indicated by a (1) punch.) Col. 27.— No Trailer card, end of file denotes end of tape.
28	Second reel of trip cards on A5 following EOF.
29	Trip cards are on A4 rather then A2.
30	No equivalent cards.
34-35	Contains the blocking factor for the trip cards, maximum of 50 cards per physical record.
37-39	Last centroid number.
47-48	Contains the number of words per card. Example: When 80 column cards are put on tape they must be expanded to 84 columns, commonly referred to as card to tape 80/84. In this example the word count would be 14, i.e., 84 divided by 6 (number of characters per word) equals 14.
72	"2"

Format specification card

This card specifies the fields in the survey card from which certain items of data are to be extracted. For each item of data the last column of the field and the number of columns in the field must be provided.

Data Item	Last Col.	No. of Cols.
1. Zone of residence	Cols. 2-3	6
2. Origin zone	8-9	12
3. Destination zone	14-15	18

Format specification card (continued)

	Data Item	Last Col.		No. of Cols.
4.	Purpose (from) [1]	Cols. 20-21		24
5.	Purpose (to) [1]	26-27		30
6.	General purpose [1]	32-33		36
7.	Purpose flag [1]	38-39		42
8.	Trip factor	44-45		48
9.	Land use (origin)	50-51		54
10.	Land use (destination)	56-57		60
11.	Mode of travel	62-63		66
		72	Punch a "3"	

If, for example, the survey card had the zone of residence punched in cols. 14-17, then the specification card would have 17 punched in cols. 2-3 and 4 punched in col. 6.

If mode or land use are not present in the survey cards, or if they are not required as criteria for building trip tables, the appropriate field in the specification card may be left blank. This does not apply to the purpose or zone fields. Data items not listed above (e.g., day of the week, occupation, etc.) may be specified in place of mode or land use.

PR-133 is written to accept a "basic" trip survey card in which at least items 1, 2, and 3 and either 4 and 5, or 6 and 7 are present. Hence these items must be accounted for in the specification card. If zone of residence is not reported in the survey card or if, as in the case of nonhome based trips, it is not to be used, then item 1 should have the same specification as the zone of origin. If trip purpose is not reported, or not used, cols. 13-18 of the Program Control Card should be left blank. 81 and 1 should be punched as the last column and number of columns for both items 4 and 5 in the specification card.

Trip criteria cards

These cards provide the program with sets of criteria according to which trips are accumulated in specified tables. By means of this device, the user has complete freedom of selection over the input data (survey cards). For example, the following binary tables are typical of those which might be obtained during a single run of the program.

---

[1] Depending on which method of reporting trip purpose is used. If general purpose, then fields 4 and 5 may be blank or vice versa.

a. Home-to-work auto driver trips with residential land use at the origin and industrial land use at the destination, combined with work-to-home auto driver trips having industrial land use at the origin and residential land use at the destination.

b. Home-to-shop transit, auto-driver, and auto passenger trips having residential land use at the origin and commercial land use at the destination, combined with the reverse of this.

In general, purpose, mode, and land use are specified. Provision is made for 18 purpose codes, 10 mode codes, and 10 land use codes. Zero is recognized as a legitimate code.

Criteria cards are prepared by punching a (1) in the appropriate column. The format for these cards is as follows:

Cols.	Designation	Codes
1-18	From Purpose	0-17
19-36	To Purpose	0-17
37-46	Mode	0-9
47-56	Land Use (Origin)	0-9
57-66	Land Use (Destination)	0-9
67-72	Table (Tape) No.	1-6

For purposes of illustration, the following survey card codes will be assumed.

Trip Purpose Code	Mode Code	Land Use Code
00 - Home	1 - Auto driver	1 - Residential
01 - Work	2 - Auto passenger	2 - Industrial
02 - Shop	3 - Transit	3 - Commercial

In order to build the trip tables described in (a) and (b) above, the following criteria cards would be required.

a. 1 punch in cols. 1, 20, 38, 48, 59, and 67.
b. 1 punch in cols. 2, 19, 38, 49, 58, and 67.
c. 1 punch in cols. 1, 21, 38-40, 48, 60, and 68.
d. 1 punch in cols. 3, 19, 38-40, 50, 58, and 68.

Trip criteria cards are used by the program in the following way: First, a table is compiled containing two words for each criteria card. Then, as each survey card is read in, the appropriate data items are encoded into two words. The pair of words thus formed is then tested against each pair of criteria words. When a pair of criteria words is found which includes (in the logical sense) the survey card pair, the trips from this card are entered in the appropriate table.

It is important to note that the program does not seek an exact match between the word pairs. Hence it is not necessary for each criteria card to contain a unique set of criteria. As seen in the example above, criteria cards c. and d. each contain mode codes 1 through 3.

When trip purpose is reported in the survey cards by means of a general purpose code and a flag it is unnecessary to punch a home purpose code in the criteria cards. In this case, when the program encodes the survey card data, either the "From" or "To" purpose fields of the code word will be ignored, depending on the direction indicated by the flag.

End of data card

A card with a 9 punch in column 72 will signal the program that the last criteria card has been read.

Survey cards

Since there is complete variability of card format (and data content) between one survey and another, PR-133 has been written to accept cards in any format. Format specifications are provided by the user for a particular run of the program. (See below).

Survey cards are written on tape, offline, in full 14 word (84 column) format. Cards may be blocked any number up to 50 cards per physical record.

The first card on a reel is a label card having TRIPS punched in columns 1-5 and the reel number (1, 2,...) punched in column 6. The last card on a reel is a trailer card having ENDS punched in columns 1-4. The last card on the final reel has LAST punched in columns 1-4.

Home-based trip cards are sorted by zone of residence prior to writing them on tape; nonhome based trips, which must be processed separately, are sorted by origin zone.

Zone equivalent cards

These are punched one to each survey zone (or subzone) as follows:

Cols. 1 - 6 Survey zone number
7 -12 Assignment zone equivalent (centroid)

These cards are written on tape in 14-word format. The first card in the file is a label card having EQUIV punched in columns 1-5. The last card in the file is a trailer card having ENDEQ punched in columns 1-5.

Note: Assignment zone numbers must be allocated to survey zones in such a way that when the survey zone numbers are ordered in an increasing sequence the associated assignment zone numbers form a (monotonically) increasing sequence.

The order of cards in the card reader or on tape A2 at the start of a run is:

a. Program call card
b. Identification card
c. Program parameter card (see DATA PREPARATION)
d. Format specification card (see DATA PREPARATION)
e. Trip criteria cards (see DATA PREPARATION)
f. End of data card
g. Zone equivalent cards

G. TAPE ALLOCATION

A2 - Program control cards
A3 - BCD output survey cards in error and trip end summaries
A4 - Survey cards
B2 - through B7 - Binary trip tables

TRAFFIC ASSIGNMENT MANUAL

APPENDIX - (PR-152, BELMN) - ADD TRIP TABLES	June 1964

A. IDENTIFICATION

Deck No.: BS152 (PR-152, BELMN) - ADD TRIP TABLES

Written by: Vogt-Ivers and Associates, revised by Alan Voorhees and Associates, December 1963

Assembly date: 12-19-63

B. PURPOSE

PR-152 accumulates up to nine (9) binary trip tables. The program will also subtract two binary trip tapes if patched.

C. INPUT-OUTPUT [1]

Input	Output
1. Tape	
B2-B10 - Binary trip tables	A3 - BCD A5 - Total binary trip tables

2. Cards

Program call cards
Identification card
Parameter card
(special - this program)

Column 6	Number of input tapes
Columns 7-12	Averaging Constant. The output tape values will be divided by this constant. If field is blank or zero, this operation is not performed.
Columns 37-39	Last zone number

Note: If three (3) or more input tapes are used, a double asterisk card (**) in column 1 and 2 must follow the parameter card. This card will

[1] See Chapter VI, Part C.

be printed out online and the machine will halt. The System Tape B-4 should then be dismounted and the desired binary trip tape mounted. By pressing start, the program will continue.

D. OPTIONS[2]

To subtract two tapes, the following procedure must be used: The octal location 2323, symbolic location AE must be patched. The new instruction should be OCT 040200200000 (SUB **,2).

---

[2] See Chapter VI, Part B4.

A. IDENTIFICATION

Deck No.: BS0183 (PR-183, BELMN) - ACCUMULATE SELECTED INTERZONAL VOLUMES

Written by: Manning, BPR, December 1962; revised April 1964 by Seiders, BPR

Assembly date: 12-6-63

B. PURPOSE

To accumulate and print selected interzonal interchanges from a binary trip table.

C. INPUT - OUTPUT[1]

Input	Output
1. Tape	
* Binary Trip Table	A3 - BCD

2. Cards

Program Call Card
Identification Card(s) (Up to 10)
Parameter Card (special for this program)

Cols.	Contents
37-39	Last zone number
41-44	Number of sets of origin and destination selection, right-justified
72	"2"

* Must be assembled

---

[1] See Chapter VI, Part C.

ID Card for set (1 per set)
Control Card (origin zone selection. A 3 punch is required in column 72). (Up to 5 per set).
Control Card (destination zone selection)
Same as standard control card except a 5 is punched in column 72. (Up to 5 per set).
Tape Assignment Card

Cols.	Contents
12	Channel - A or B
13	Unit 0 thru 9
72	A (0) - Zero punch

D. OPTION

There are no options to this program.

E. PROGRAM OPERATION

The program reads in the sets of selected origins and destinations first, then it reads in a trip record and checks the table of origins to see if it is selected. If the record is selected in the origin selections the volumes for selected destinations are accumulated. When all the records have been read in and the accumulations completed, the set totals are written out together with their identification.

Following the program call card, which is read by the control program, are the program cards in the following order:

1. Identification cards for page headings, up to 10 cards -
2. Parameter card, 1 card -
3. First set identification card, 1 card -
4. First set origin selection cards, up to 5 cards -
5. First set destination selection card, up to 5 cards -
6. Second set identification card, etc....
7. At end of last set, tape assignment card, 1 card - (Maximum of 65 sets)

After PR-183 is located on the library tape A8 by BELMN Control Program and loaded into core storage, control is transferred to PR-183. The identification cards (up to 10) are read in and then the parameter card is read in and the parameters stored for program use. Next the sets of origin (up to 5 cards per set) and destination selections (up to 5 cards per set) lead by their set identification cards (up to 65 sets) are read in until the tape assignment card is encountered. After the tape assignment card is read in, the program reads in the first trip record, checks it for errors and looks into the origin selection table for each set. When it finds a set in which the record is selected it accumulates the volume according to the set's destination selections. When it has read in the last record and processed it, writing out begins. At the top of each page the page identification cards are written out, then the set identification card and, on the same line, the sum accumulated for the set.

★ U.S. GOVERNMENT PRINTING OFFICE : 1964 O—734-746