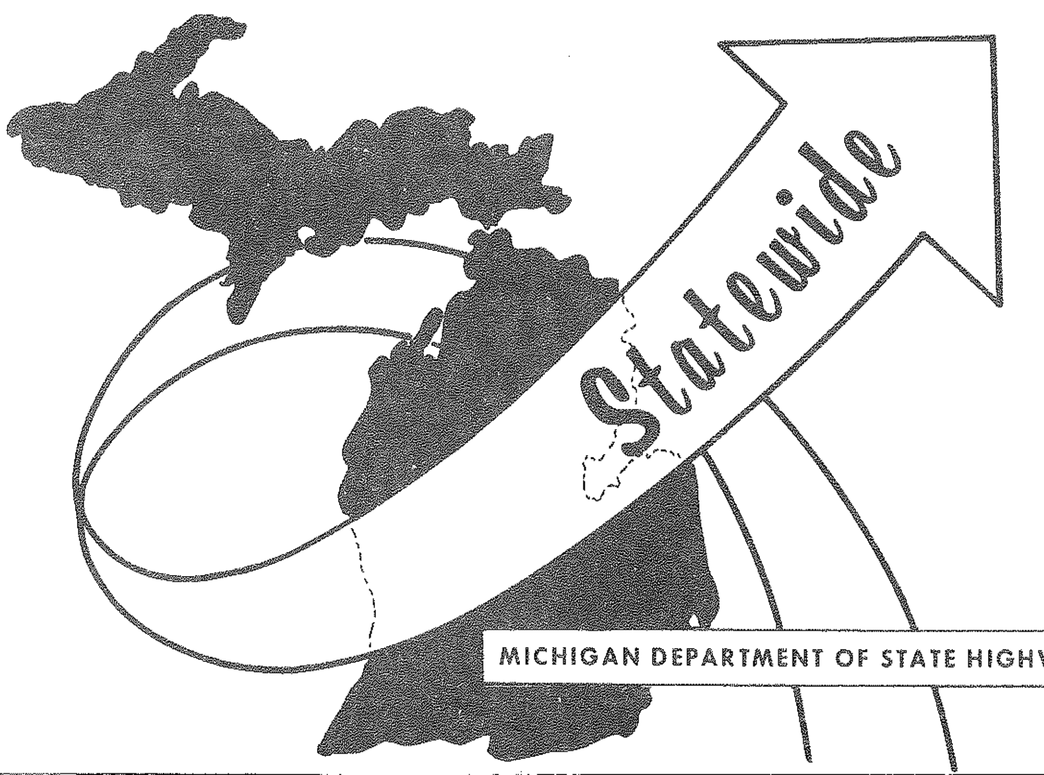
Statewide Transportation Analysis & Research

Michigan's
Statewide Transportation
Modeling System

Volume X-A
STATEWIDE TRAVEL IMPACT
ANALYSIS PROCEDURES

Statewide Interagency Procedures
Research and Development Section

September 9, 1974



MICHIGAN DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

MICHIGAN DEPARTMENT

OF

STATE HIGHWAYS AND TRANSPORTATION

BUREAU OF TRANSPORTATION PLANNING

Michigan's
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September 9, 1974

STATE OF MICHIGAN

WILLIAM G. MILLIKEN, GOVERNOR

DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

STATE HIGHWAYS BUILDING - POST OFFICE DRAWER K - LANSING, MICHIGAN 48904

JOHN P. WOODFORD, DIRECTOR

September 9, 1974

Mr. Sam F. Cryderman, Deputy Director
Bureau of Transportation Planning
Department of State Highways and Transportation
P.O. Drawer K
Lansing, Michigan 48904

Dear Mr. Cryderman:

The Highway Planning Division of the Bureau of Transportation Planning is pleased to present Volume X-A, first in a series of four reports which document those procedures utilized in the monitoring of projected impacts generated by the simulated construction of alternate highway proposals. While the other reports within the series emphasize the social, economic, and environmental ramifications of highway construction, this report details the concepts behind and the operational "steps" employed in the development and application of sixteen travel impact indicators. When each of these indicators are applied separately, they measure only a single aspect of the total travel picture - taken together, they form a valuable process of highway system analysis and evaluation.

The computerized Statewide Travel Forecasting Model has provided the basis upon which these procedures for analysis/evaluation have been built and the framework in which they are being constantly expanded. The process as described in this report has been applied to three exemplary highway configurations. The presentation of the results obtained through this application is not meant to actually choose a best alternate route within the test area, but rather to demonstrate that the techniques/procedures developed to date do, in fact, supply answers to many real world problems currently facing the highway planner. Given that fiscal resources cannot be stretched to meet present and future user demand, how are highway funds optimally spent in the maintenance of the present network and in the removal of projected system deficiencies? A substantial portion of the answer to this tremendously complex question can be produced through the systematic employment of the methodologies documented within this report.

This report was prepared by Mr. Mark D. DuBay of the Statewide Interagency Procedures Research and Development Section under the supervision of Mr. Richard E. Esch.

Sincerely,

R. J. Lilly

R. J. Lilly, Administrator
Highway Planning Division

MICHIGAN
THE GREAT LAKE STATE

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STATEWIDE TRAVEL IMPACT

ANALYSIS PROCEDURES

BY

Mark D. DuBay

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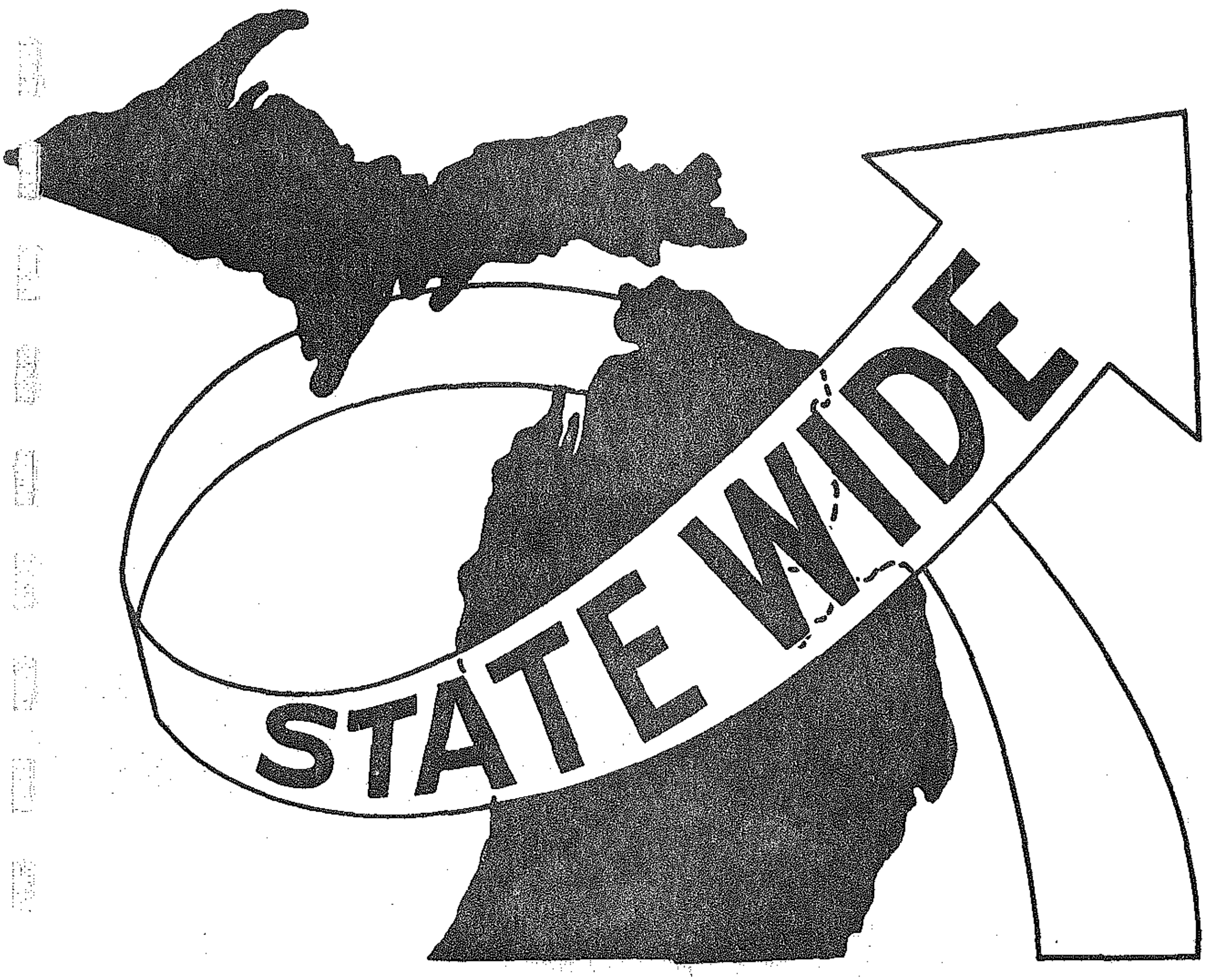

P R E F A C E

In the years since the initial development of its computerized Statewide Traffic Forecasting Model (June 1970), the Michigan Department of State Highways and Transportation has periodically published reports detailing the further development of varying phases of its operation. These reports document assorted modeling techniques which have substantially added to the system's power of predicting the social, economic, environmental, and travel impacts of proposed highway plans. A vast majority of the publications have, to date, dealt with the explication of certain component-models which, when utilized within the system framework, are vital pieces of the total modeling effort. These reports have typically placed a tremendous emphasis on the technical aspects of the model's development and methodology. While this documentation frequently presents specific analytical "tools", which may be employed by the user to determine the above mentioned impacts, its treatment of this extremely relevant information has, often times, been cursory.

This particular report, which is the first in a series of four, attempts to review, reevaluate and expand, whenever necessary, the discussion of those "tools" for monitoring travel impacts which have received superficial treatment in previously published works. It, moreover, demonstrates the applicability of those analytical techniques which have since been developed but, as of yet, have not been submitted for public scrutiny. This publication diverges from the path taken by those currently in print in that it stresses system application rather than system development. The work presented here should prove to be of special interest and value to those wishing to develop a system of travel impact analysis measurements of their own. Three subsequent reports have similarly examined those analytical "tools" which have been devised to study specific social, economic, and environmental impacts of alternate highway proposals.

A current listing of reports dealing with the Statewide Model's development and application is presented here for your convenience.

STATEWIDE TRAVEL MODELING SERIES

Volume	I --	Objectives and Work Program
Volume	I-A--	Region 4 Workshop Topic Summaries
Volume	I-B--	Single and Multiple Corridor Analysis
Volume	I-C--	Model Applications: Turnbacks
Volume	I-D--	Proximity Analysis: Social Impacts of Alternate Highway Plans on Public Facilities
Volume	I-E--	Model Applications: Cost-Benefit Analysis
Volume	I-F--	Air and Noise Pollution System Analysis Model
Volume	I-G--	Transportation Planning Psychological Impact Model
Volume	I-H--	Level of Service Systems Analysis Model: A Public Interaction Application
Volume	I-J--	Service-Area Model
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Volume	II --	Development of Network Models
Volume	III --	Multi-Level Highway Network Generator ("Segmental Model")
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Volume	VI --	Corridor Location Dynamics
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Volume	VII --	Design Hour Volume Model Development
Volume	VII-A--	Capacity Adequacy Forecasting Model
Volume	VIII --	Statewide Public and Private Facility File
Volume	IX --	Statewide Socio-Economic Data File
Volume	X-A--	Statewide Travel Impact Analysis Procedures
Volume	X-B--	Statewide Social Impact Analysis Procedures
Volume	X-C--	Statewide Economic Impact Analysis Procedures
Volume	XI --	Computer Run Times - An Aid in Selecting Statewide Travel Model System Size

INTRODUCTION

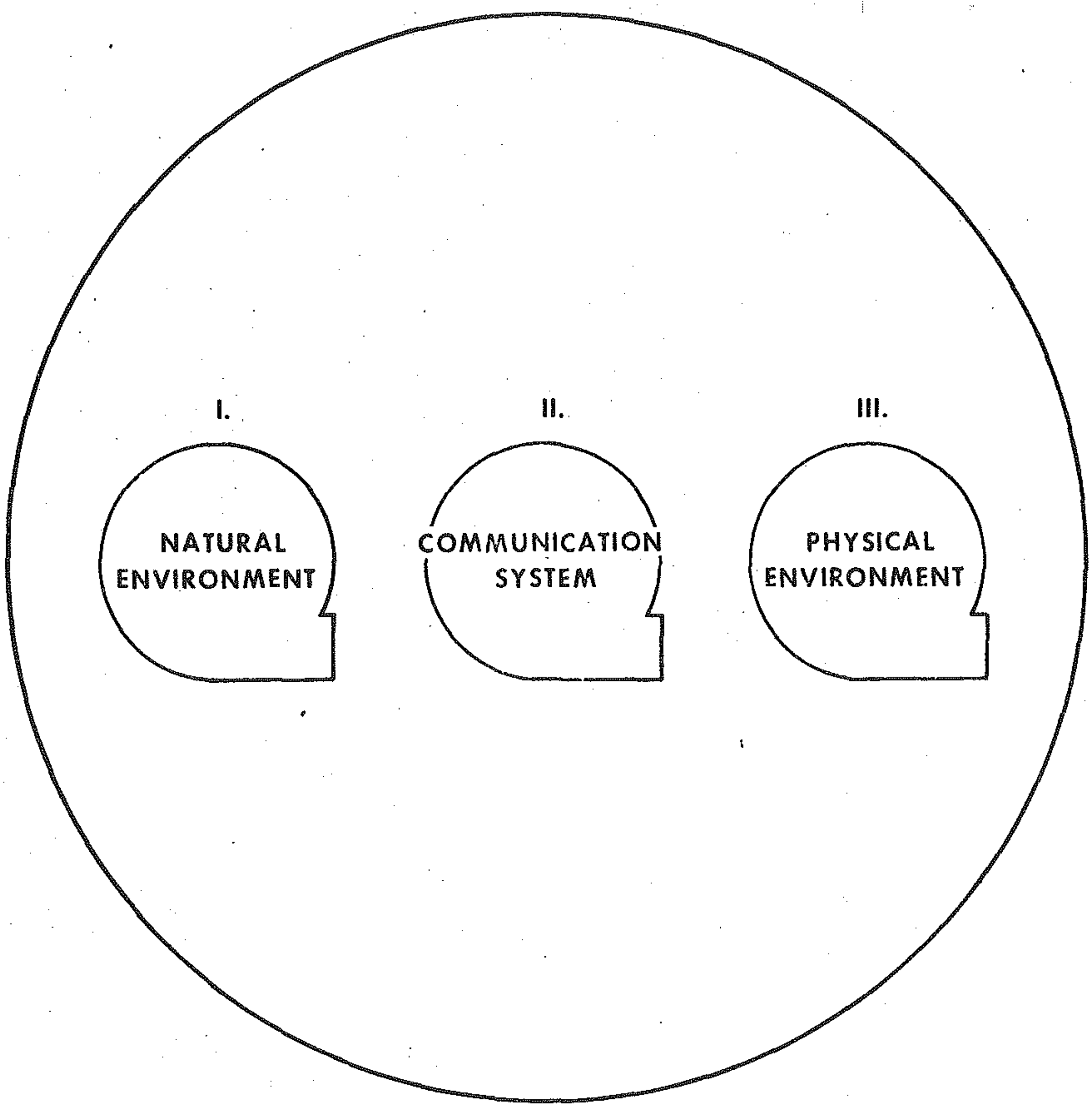
INTRODUCTION

The construction and utilization of a transportation corridor has long been recognized by social scientists as having a tremendous pervasive effect upon a region's political, economic, and social structure. The psychological and environmental impacts of such a construction, at first glance not obvious, have, in recent years, added to the growing list of social variables with which state highway departments must become concerned. This concern, previously an obligation in, perhaps, only a moral sense, has been translated into a legal responsibility by recent federal legislation. Each state to be in compliance with section 109 (h) of title 23, U.S. Code, must formulate an "action plan" which details the exact methodology to be utilized in the determination of a transportation plan's social, economic, and environmental impacts. Identification, measurement and evaluation of these effects are mandatory and underlie the "challenge" presently confronting state highway departments throughout the nation (see "A Statewide Transportation Modeling System Effectively Meets the Transportation Challenge of the 70's").

By laying the groundwork for its statewide traffic forecasting model in the mid-60's, the Michigan State Department of State Highways and Transportation anticipated the need for its transportation planning process to become more dynamic and comprehensive in its approach to formulating alternative highway proposals. Research and analysis convinced the Statewide Interagency Procedures Research and Development Section of the Bureau of Transportation Planning that the development of a statewide transportation modeling system was the most effective, efficient means of fulfilling the Department's expanding realm of responsibility. A complete in-depth description of the statewide modeling system has been documented in the various reports cited above and, therefore, duplication of those efforts is avoided here. Briefly, the statewide model is a systematic approach to the evaluation and analysis of travel and its social, economic, and environmental impacts as they might occur if alternative transportation plans were actually implemented. The modeling system, as a computerized simulation of the "real world", allows its user to specify possible transportation corridors, to identify those social, economic, environmental and travel aspects of a region which are most heavily impacted, and to choose, on the basis of this information, the optimal alternate plan.

The statewide modeling system is greatly dependent upon the utilization of three information files which were, in the early developmental phases of the statewide system, defined as representing society (see Figure 1). The first of these files contains data descriptive of man's natural environment--i.e., those elements of the real world which are not physically created by man himself. A sample of the items which appear in this file are shown in Figure 2. The third file known as the "Statewide Public and Private Faculty File" contains information pertinent to the man-made, physical aspects of the human environment. A complete listing of the categories currently being utilized within the modeling process are presented in Figure 3. Man's communication system provides, in both the real and simulated worlds, a logical connection between these two environments. The second file, which is critical from a transportation planning perspective, currently employs only that data relevant to a description of the highway network. Figure 4 shows a base year (1970) computer plot of Michigan trunklines and county roads. Considerable progress has been made in the last year toward converting the "communication" file to an approach in which all modes of statewide transportation are represented (i.e., airways, railroads, waterways, pipelines). The multiple applications of such a comprehensive

SOCIETY



I. STATEWIDE SOCIO-ECONOMIC DATA FILE

II. STATEWIDE TRANSPORTATION NETWORK

III. STATEWIDE PUBLIC & PRIVATE FACILITY FILE

FIGURE 2

STATEWIDE SOCIO-ECONOMIC DATA FILE *

GENERAL CHARACTERISTICS OF POPULATION

SCHOOL ENROLLMENT BY TYPE OF SCHOOL
YEARS OF SCHOOL COMPLETED
CITIZENSHIP BY AGE

INCOME CHARACTERISTICS OF POPULATION

FAMILY INCOME
INCOME BY OCCUPATION AND SEX
RATIO OF FAMILY INCOME TO POVERTY LEVEL

LABOR FORCE CHARACTERISTICS OF POPULATION

EMPLOYMENT BY AGE
EMPLOYMENT BY OCCUPATION AND SEX
EMPLOYMENT BY INDUSTRY AND SEX

SOCIAL CHARACTERISTICS OF POPULATION

AGE BY SEX
TYPE OF FAMILY
MARITAL STATUS

AREA CHARACTERISTICS

LAKE FRONTAGE
ASSESSED VALUATION
WATER AREA

*THOSE ITEMS LISTED HERE ARE SAMPLES TAKEN FROM THE COMPLETE FILE WHICH CONTAINS OVER 700 ITEMS.

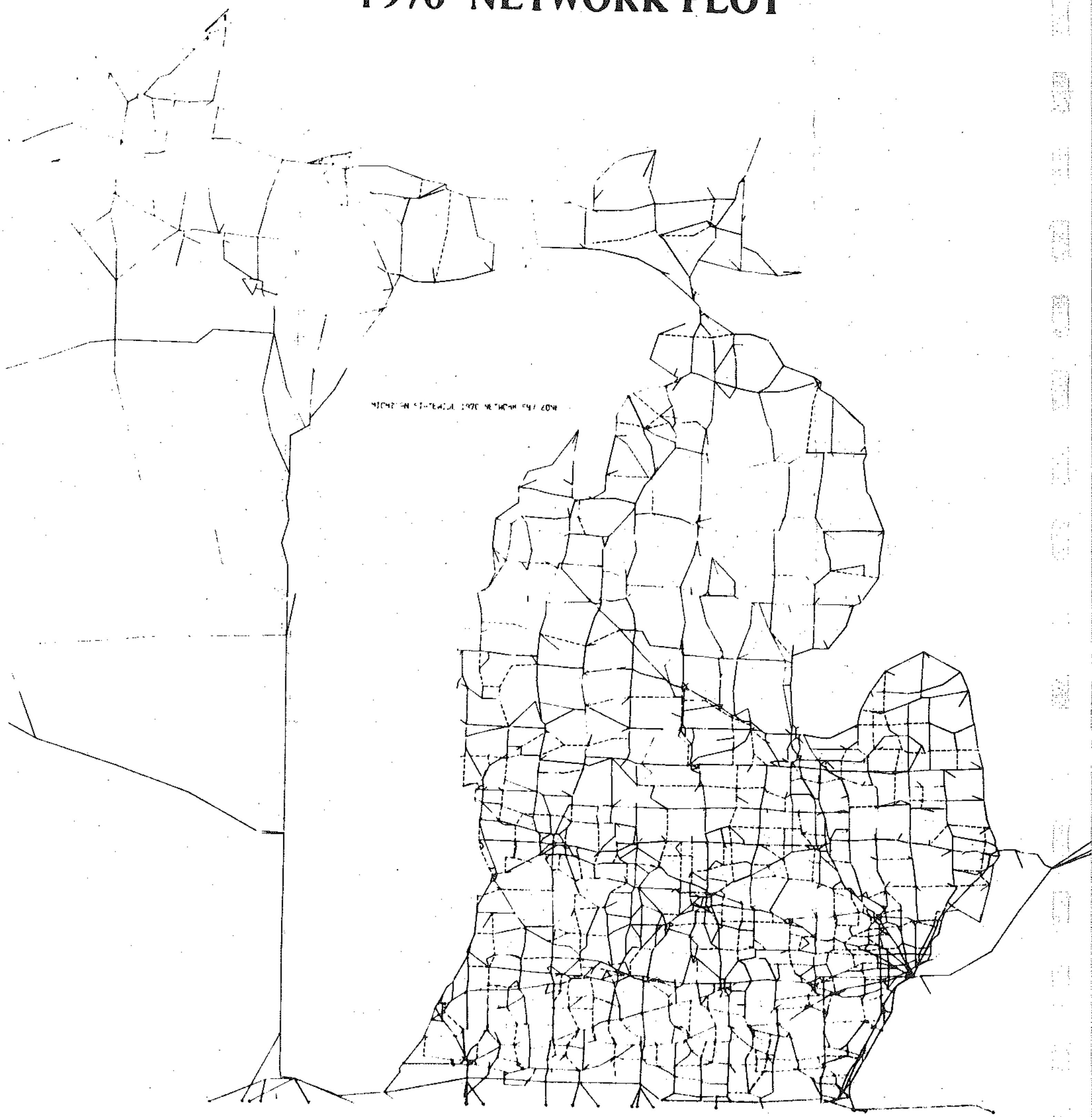
FIGURE 3

STATEWIDE FACILITY FILE

AIRPORTS
AMBULANCE SERVICE
BUS TERMINALS
CAMP GROUNDS, PUBLIC AND PRIVATE
CERTIFIED INDUSTRIAL PARKS
CITIES OVER 30,000 POPULATION
CITIES OVER 5,000 POPULATION
CIVIL DEFENSE TERMINALS
COLLEGES, NON-PUBLIC
COLLEGES, PUBLIC COMMUNITY
COLLEGES AND UNIVERSITIES, PUBLIC 4 YEAR
CONVENTION CENTERS
GAME AREAS
GOLF COURSES
HIGH SCHOOLS
HISTORIC SITES
HOMES FOR THE AGED
HOSPITALS
MAJOR COMMERCIAL CENTERS
MANUFACTURERS
MENTAL HEALTH CENTERS
NEWSPAPERS, DAILY
NEWSPAPERS, WEEKLY AND BIWEEKLY
NURSING HOMES
PORTS
RAIL TERMINALS
SECRETARY OF THE STATE OFFICES
SEWAGE TREATMENT FACILITIES
SKI RESORTS
SNOWMOBILE TRAILS
STATE PARKS
STATE POLICE POSTS
TOURIST ATTRACTIONS
TREASURY OFFICES
TRUCK TERMINALS
UNEMPLOYMENT OFFICES
WEATHER SERVICE STATIONS-NATIONAL
WHOLESALE TRADE CENTERS

FIGURE 4

1970 NETWORK PLOT



system seem, at present, to be extraordinary. The highway network file shown in Figure 5 has been created through the summarization of data stored in the following files:

A. TRUNKLINE VEHICLE-MILES MASTER FILE

B. MICHIGAN HIGHWAYS YEARLY SUFFICIENCY RATING FILE

C. ACCIDENT MASTER FILE

D. STATE TRUNKLINE CONTROL SECTION LOG RECORD FILE

E. STATE TRUNKLINE NEEDS FILE

The true power of the three basic information files, of course, lies not in the amount or type of data which they store but rather in the user's ability to rapidly add and delete information as the need arises. This feature allows the modeling process to employ only that information which is most currently available. Collection, storage and retrieval of all data employed within the process is tied to a 547 zone system. Of this total, 508 are actually "in-state" zones (see Figures 6 and 7). The zonal concept is of extreme importance in that it provides a dynamic link between information retrieval and actual modeling procedures. The flow of "raw" data from the storage within the information files to its conversion into accurate travel, social, economic, and environmental indicators has been effectively accomplished as a result of "gearing" the entire system to a zonal format. The zone system also plays a considerable role in translating typical numeric output into graphic form. Various statewide model plotting techniques, such as the network node plot shown in Figure 4, shall be discussed and presented at timely intervals throughout this report.

The information files discussed here have provided a solid foundation upon which the entire statewide modeling system has been built. But "raw" data, regardless of its format, is innately of little consequence. The conversion

FIGURE 5

STATEWIDE HIGHWAY NETWORK

LINK FILE

CONTENTS OF EACH HIGHWAY SEGMENT OR LINK

- AVERAGE SPEED
- DISTANCE
- URBAN-RURAL DESIGNATION
- TYPE OF ROUTE
- TRAFFIC VOLUME CAPACITY
- AVERAGE ANNUAL DAILY TRAFFIC VOLUME
- COMMERCIAL TRAFFIC VOLUME
- DESIGN HOUR VOLUME
- ACCIDENT FATAL RATE
- ACCIDENT INJURY RATE
- ACCIDENT RATE
- NUMBER OF LANES
- LANE WIDTH
- SURFACE CONDITION
- RIGHT OF WAY
- SIGHT RESTRICTION

FIGURE 6

MICHIGAN'S TRANSPORTATION MODELING SYSTEM

547 ZONE
OUTSTATE ANALYSIS ZONES

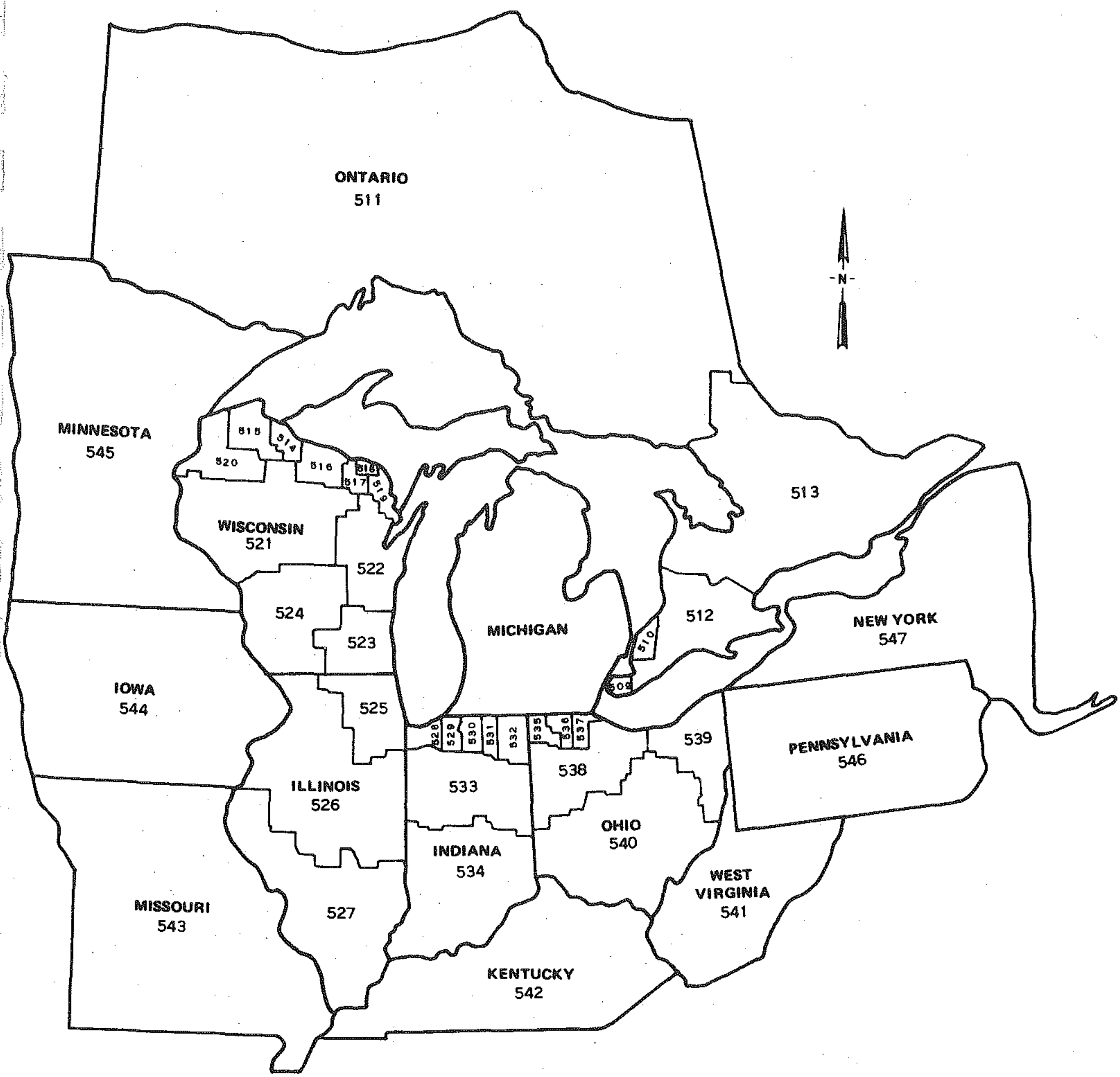
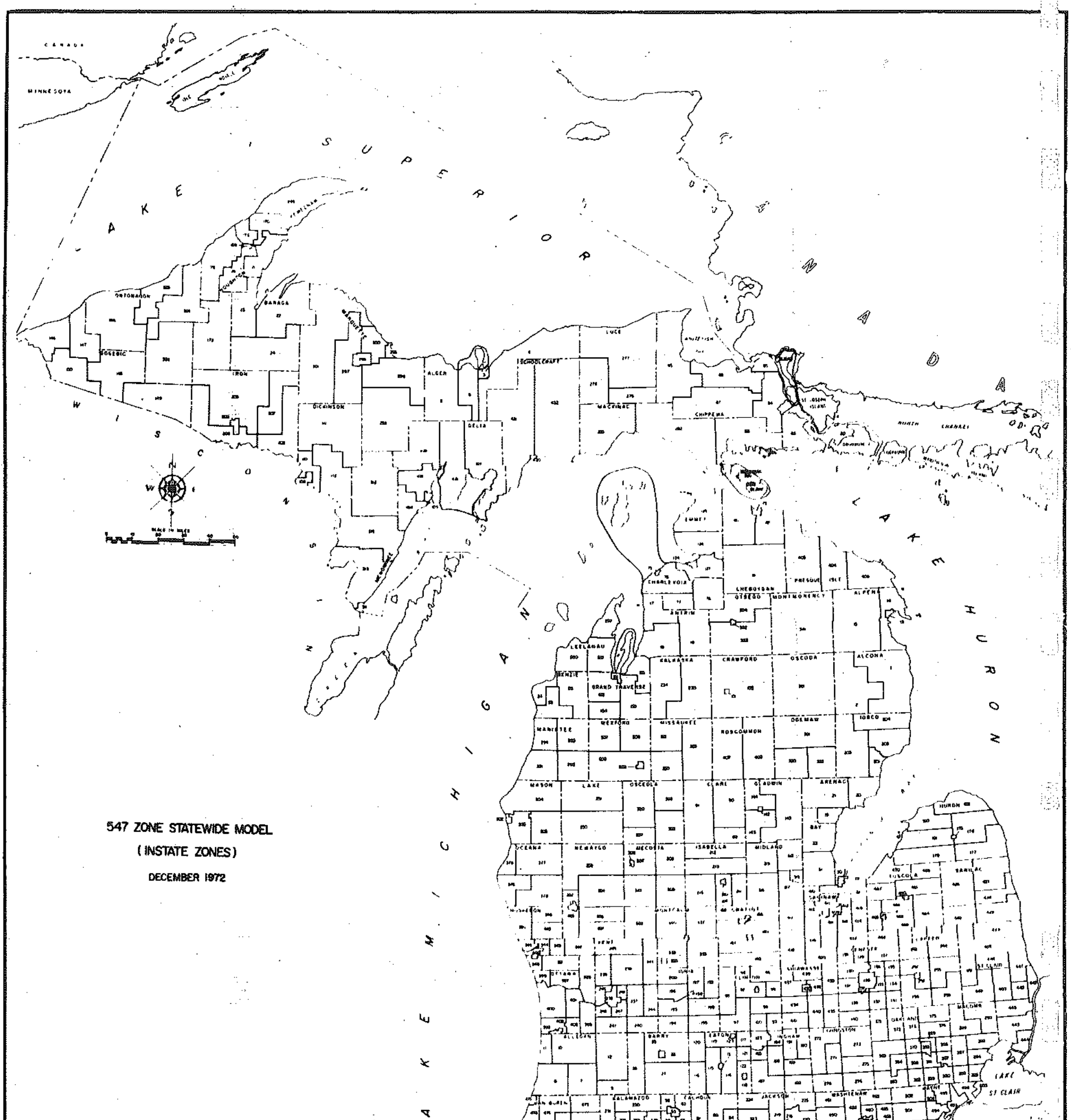


FIGURE 7


547 ZONE STATEWIDE MODEL
(INSTATE ZONES)
DECEMBER 1972
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
CANADA
WISCONSIN
INDIANA
OHIO
LAKE ERIE
LAKE ST CLAIR

of data from its simple state into that of an accurate indicator results directly from its systematic manipulation by various sub-system, component-models. A schemata showing the entire statewide system is presented in Figure 8. Many system programs, files and models were developed exclusively for the purpose of simulating real world phenomena--specifically, human travel behavior. A majority of the procedures utilized within the statewide system, however, are analytical in nature. The effective use of numerous system "tools" allows one to monitor the actual simulation process and to output information relevant to a particular study area. This information typically in the form of impact measurements, determines the system-level importance of various changes in the highway network. Optimization of limited highway resources, as a result of the modeling process, becomes a simple matter of comparing state and regional impact measures to determine which of the simulated plans prove to be most beneficial from a system perspective.

This report documents those analytical tools and their corresponding indicators which have been molded into a process of evaluating various highway proposals with respect to travel patterns and characteristics. The following portion of this document defines and describes those component models which are essential to the operation of this travel impact evaluation process. A "real world" situation to which all of the analytical impact measurements (see Figure 9) have been applied is presented in a subsequent section. This list should not be considered all-inclusive, for the Statewide Interagency Procedures Research and Development Section is constantly devising and refining various measurements of highway impact which impinge upon all areas of human existence. Nevertheless, it is believed that any agency that possesses or develops tools and indicators of the sophistication presented here should be more than amply prepared to meet "The Challenge of the 70's".

STATEWIDE MODELING SYSTEM COMPONENTS

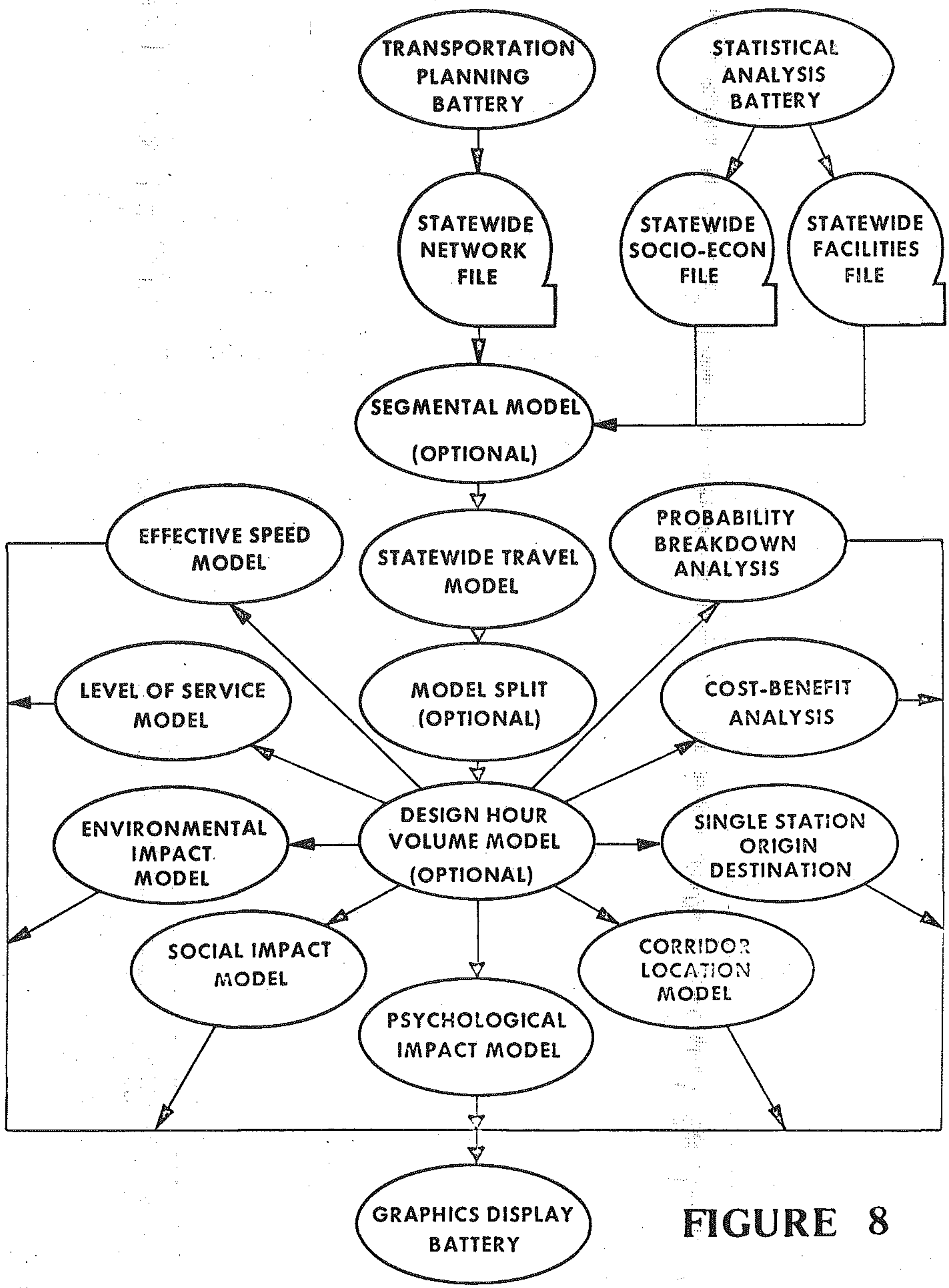


FIGURE 8

FIGURE 9

TRAVEL IMPACT INDICATORS

HIGHWAY VOLUME DEFICIENCY

LEVEL OF SERVICE

EFFECTIVE SPEED

CAPACITY ADEQUACY

TRIP LENGTH DISTRIBUTION

AVERAGE TRIP LENGTH

VEHICLE MILES

VEHICLE HOURS

TRAVEL VOLUME

ZONE OF ORIGIN

SELECTED ROUTE

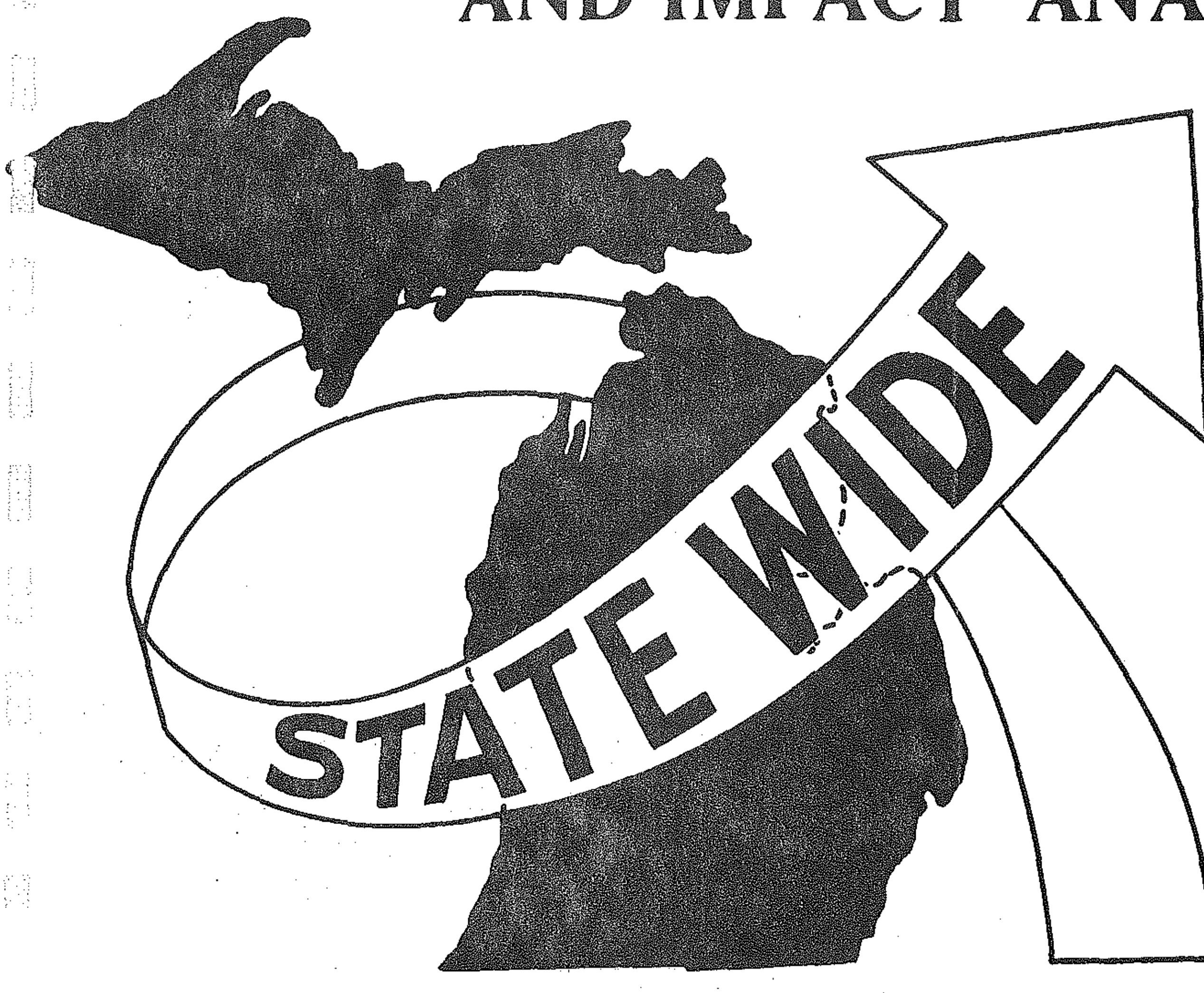
SELECTED TREE

TRAVEL MODE ACCESSIBILITY

SYMAP/TIME BAND

POPULATION SHED

PROCEDURES FOR TRAVEL FORECASTING AND IMPACT ANALYSIS



PROCEDURES FOR TRAVEL FORECASTING AND IMPACT ANALYSIS

The Introduction to this report provides a brief descriptive discussion of the Statewide Modeling System. No attempt was made to give a detailed account of the "software" (programs, sub-models, and models) utilized in making the system operational. Such an effort is essential here, for without it, those unfamiliar with the process would find the discussion of the specific impact procedures difficult, if not impossible, to comprehend. By quickly reviewing the software involved in making route and alternate route assignments, the reader may familiarize himself not only with the essential concepts which underlie the system but also with the unavoidable "jargon" in which they are embodied.

A. Travel Forecasting Procedures

The Statewide Travel Forecasting Model (shown in Figure 10) provides a core around which the entire modeling system has been built. Its sole purpose is the provision of travel projection figures for all road segments (links) within the state highway network. In performing this function, the model utilizes the output from four sub-models: 1) the Highway Network Model; 2) the Trip Generation Model; 3) the Trip Distribution Model; and 4) the Traffic Assignment Model.

Through the Highway Network Model, one is able to describe to the computer, in its own "language", the highway system under study. Presently, simulation of the basic network includes all state trunklines, approximately 1,500 miles of county roads, and several major outstate routes. Figures 11 and 12 show this network as used within the zone system discussed earlier in this report (see Figures 6 and 7). The 1970 highway network was defined in the computer

STATEWIDE MODELING SYSTEM COMPONENTS

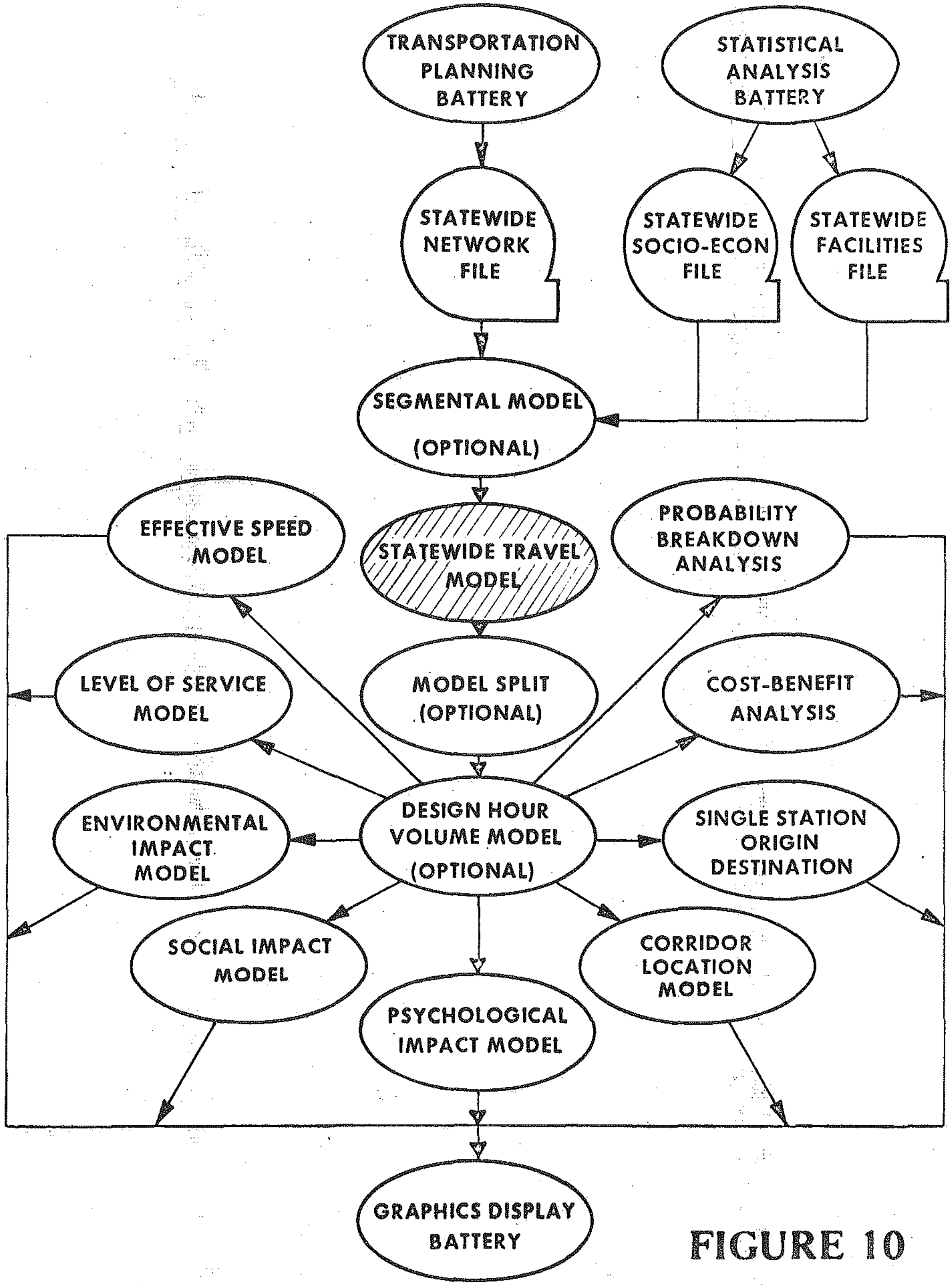


FIGURE 10

FIGURE 11

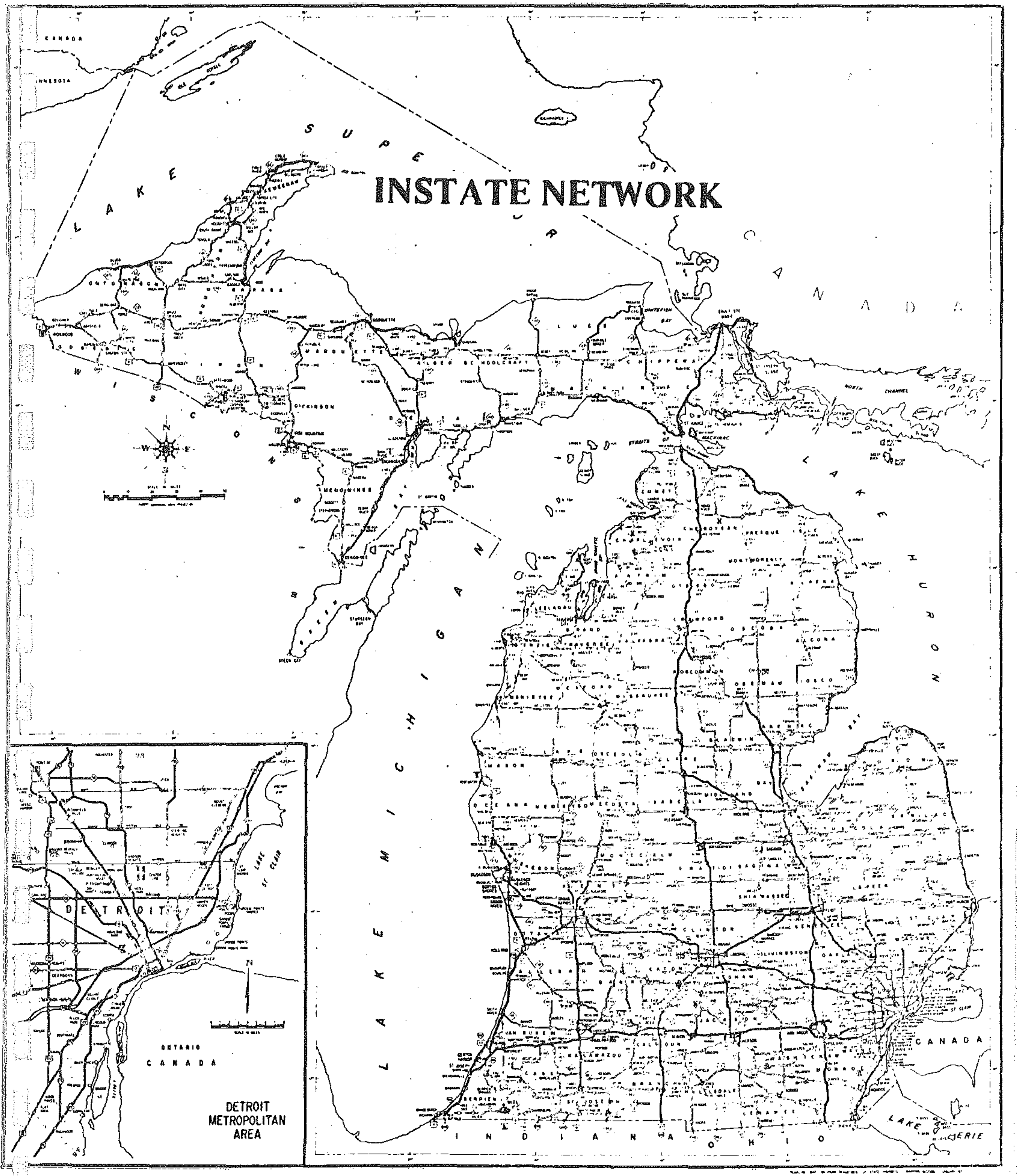
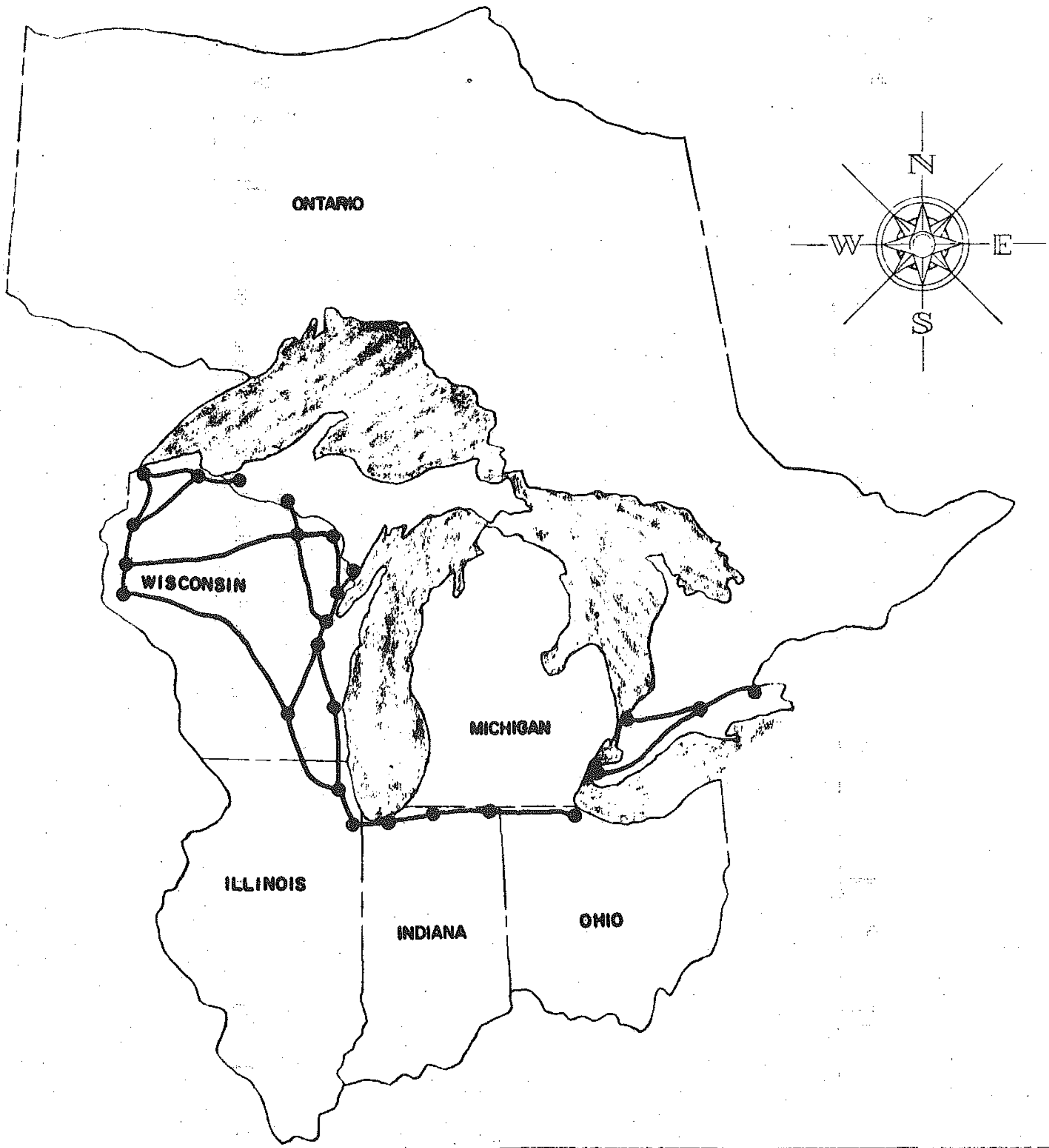

INSTATE NETWORK
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
CANADA
WISCONSIN
INDIANA
OHIO
LAKE ERIE
DETROIT
ONTARIO
CANADA
DETROIT
METROPOLITAN
AREA

FIGURE 12



540 ZONE TRAFFIC FORECASTING SYSTEM

OUTSTATE HIGHWAY NETWORK

MICHIGAN DEPARTMENT OF STATE HIGHWAYS
TRANSPORTATION PLANNING DIVISION
STATEWIDE STUDIES UNIT

model as a set of links and nodes. The numbered nodes represent link intersections. The location of a link is described by a paired set of nodes - i.e., a link is defined by its connection of two specific network nodes. Figure 13a shows a conceptual drawing of a portion of the highway network as used within several zones of the 540 zone system. The illustration indicates that there are two basic types of system links - regular highway links and pseudo-links known as zone centroids or "loading nodes". A regular highway link is used to describe a section of highway while a centroid, in connecting itself to a node of the base network, allows the feeding of traffic to and from a zone, off of and onto the highway system. The pseudo-link concept of separating intersection and loading nodes is necessary in making the model operational. Why this is so will become more clear as the other travel forecasting sub-models are described.

The user of the Highway Network Model must also differentiate between types of highway links according to certain physical and travel characteristics. Though the figures may vary with each link, the type of data coded during the initial link-node (network) definition includes all that which is listed in Figure 5 (the Highway Network File). Each discrete "piece" of link-specific descriptive data is stored on magnetic tape in what is known as "volume fields". Twenty-five such fields are now associated with each link on the standard (base) network tape. Their primary function is to organize the storage of the link data by appropriately numbering the area of tape in which particular information is contained - thus facilitating user access.

Appreciation of the "volume field" concept is critical to one's comprehension of the modeling system for it is consistently employed throughout the process. Figure 13b illustrates how a link's descriptive data might

NETWORK DESCRIPTION

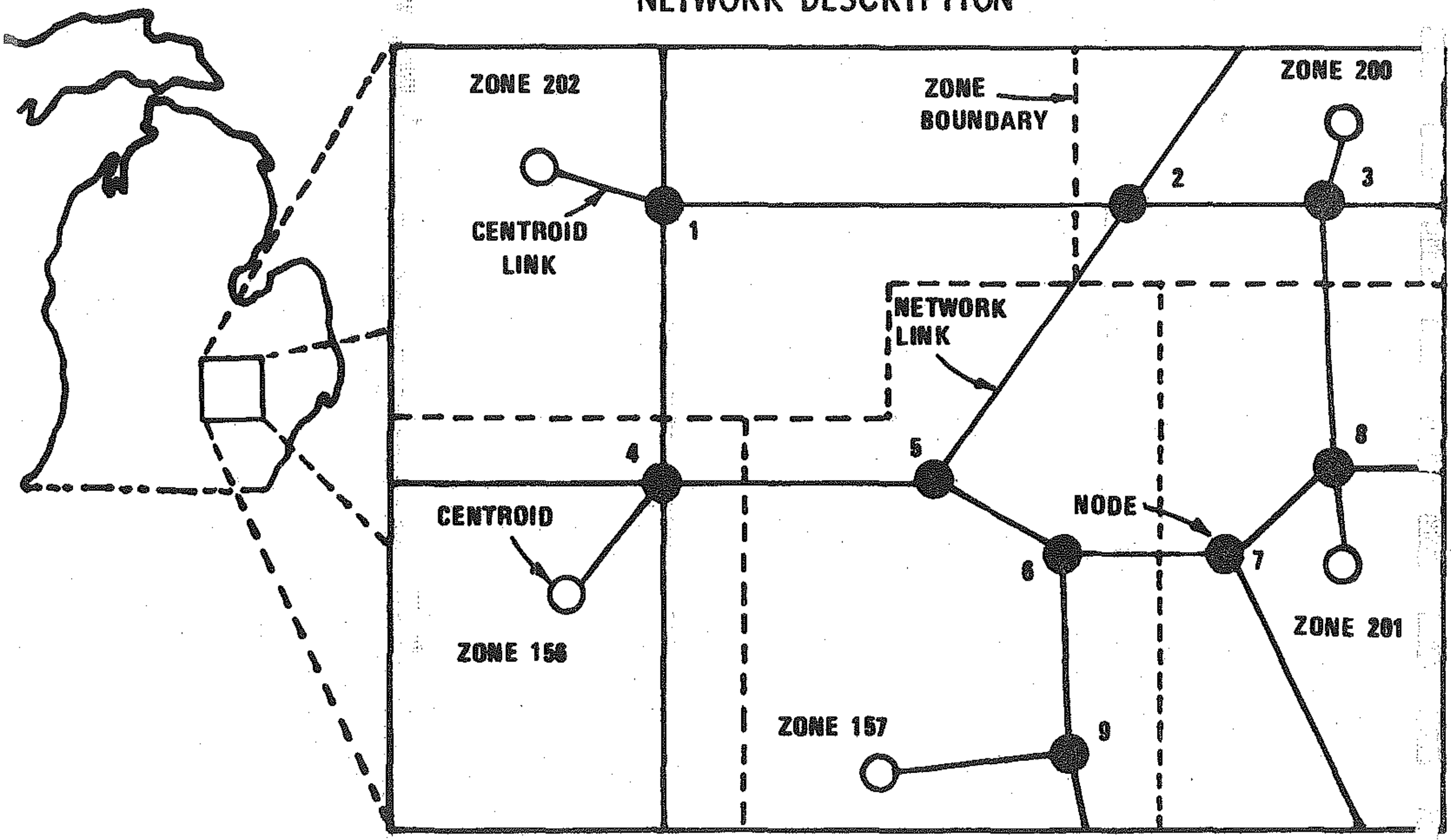


FIGURE 13 A

LINK DESCRIPTION

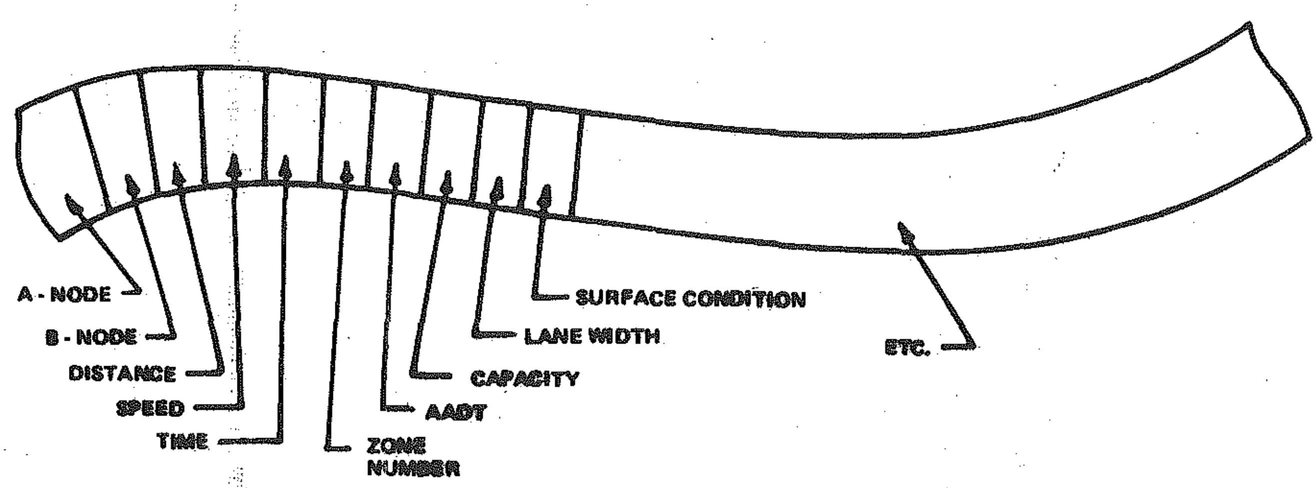


FIGURE 13 B

appear on a segment of magnetic tape if it were visible to the human eye. Over 7,000 such data records are taken from punched cards (input) and recorded sequentially on the output (network) tape. First, a link's A and B nodes are recorded to distinguish it from others within the network. The distance from node A to node B is measured in tenths of a mile and speed at the legal rate. Each link is assumed to be symetrical - that is, as a two way link, all data applicable to one direction is applicable to the other. Therefore, direction is always coded as a "2". This initial portion of a link's data file contains other information pertinent to its description - e.g., type (existing or newly created?), jurisdiction (who funded the construction and maintains the road?), etc. Of the twenty-five, eight character volume fields which currently exist on the base network tape, the last seven are used by various system models to store output for either further, future manipulation or for direct output through the graphic display battery. The travel impact procedures to be discussed below utilize these fields extensively for storage while using the information of the previous eighteen fields as their input.

Once the 1970 network tape is created through standard coding procedures and specialized computer programs, it may be modified, in any number of ways, to stimulate alternate highway proposals. Many such changes are performed when comparisons of travel impacts are desired. The output from this sub-model, regardless of the network described, provides a primary input for not only the travel forecasting model, but for all models developed within the system.

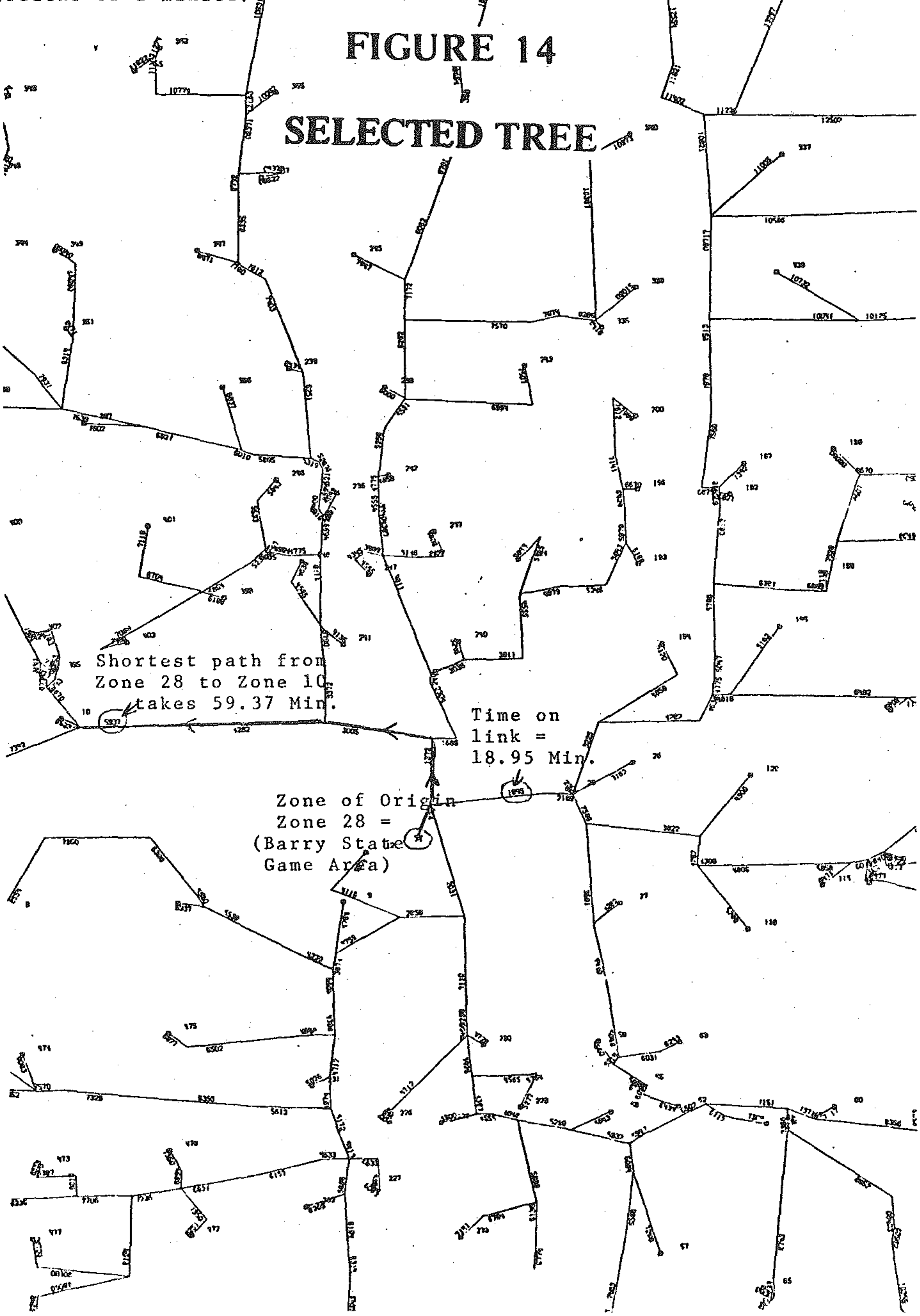
The second sub-model essential to statewide traffic forecasting, known as the trip generation model, simulates the number of trips produced within each of the 547 analysis zones. To accomplish this, the model utilizes a mathematical formula which is derived from calculating the statistical relationship between a zone's population and its actual generated trips as recorded in selected origin and destination studies. By calculating a zone's trip producing power in a base year, future traffic figures may be determined by projecting a zone's population to a specified target year. Knowing the number of generated trips for each study area is not enough; their interaction on a statewide basis must be calculated. This function is performed through the Trip Distribution Model - the third of the traffic forecasting sub-models.

The Trip Distribution Model uses a gravity principle in determining the trip interchange between zones. It incorporates into its computer programs a mathematical expression which states that the number of trips distributed between zones is proportional to their population size and is inversely related to the distance between them. The distance between each zone and every other zone within the system is calculated according to the minimum highway path between them in terms of either time, distance, or cost. Since these minimum paths, when graphically displayed, are similar to branches of a tree, one's "running" of the computer program that performs this function has come to be known as "building trees". A single, selected tree is shown in Figure 14. Five hundred and forty-seven such trees are built for each network - one for each zone centroid. When the minimum paths and the generated traffic figures are combined according to the requirements of the gravity principle, they create a trip table (matrix) which accounts for all simulated trips between zones. Figure 15 shows the trip matrix for zone 1 using the base (1970) network as input. The trip table does not indicate which links within the highway network are utilized in determining the traffic interchange between zones nor does it record the exact number of statewide traffic which employ a particular highway link. These tasks are left to the fourth sub-model of the traffic

Skimmed tree from Zone 28 (*) to all other zones. Note: 1) Values of links are cumulative times from *. 2) Numbers represent hundredths of a minute.

FIGURE 14

SELECTED TREE



INTERCHANGE VALUES FROM ZONE 1 TO ALL OTHER ZONES TABLES NUMBER 101

	0	1	2	3	4	5	6	7	8	9
0		0	395254	153	193	113	31	281	317	309
1	263	98	330	369445	159238	55855	620	1035	1297	5422
2	17074	6224	65	65	41	253	443	285	468	5311
3	2314	3671	1977	7339	346	465	395	277	301	241
4	262	116	166	305	263	189	193	92	178	80
5	161	118	195	177	127	517	125	173	368	287
6	183	154	187	211	105	39	245	129	101	180
7	136	125	77	84	173	748	513	1115	1270	4799
8	2002	2905	3363	1117	230	379	362	798	205	784
9	1603	1131	398	219	184	268	374	262	331	235
10	535	1968	2499	190	50	57	189	49	79	121
11	43	66	74	189	170	171	179	426	109	166
12	165	122	141	178	2524	3319	1441	1262	5622	788
13	1975	1181	1177	1408	751	281	1203	585	592	679
14	1381	302	1141	3166	1267	1383	110	61	26	16
15	71	2011	1138	1000	174	664	1018	677	826	499
16	230	178	153	165	129	135	138	130	167	77
17	139	65	62	20	29	68	548	1139	670	1014
18	875	1254	1153	3036	721	383	403	343	200	218
19	182	303	238	74	206	100	214	178	279	207
20	254	83702	232456	20316	1153249	66	65	66	24	54
21	1212	510	477	658	359	644	767	488	360	412
22	480	270	133	103	170	242	1098	421	174	84
23	344	90	46	344	971	769	1888	221	587	297
24	219	327	119	223	285	439	194	418	800	418
25	466	171	211	562	349	501	373	268	311	1166
26	761	1056	527	208	288	122	494	267	257	228
27	186	464	341	393	532	387	281	341	152	239
28	534	385	272	205	1270	2112	2202	1501	441	482
29	484	1062	236	471	561	276	154	84	212	144
30	53	98	488	328	355	275	590	321	493	473
31	234	235	107	204	101	3480	1905	1294	1150	956
32	1105	498	830	495	235	132	123	193	308	432
33	187	61	117	248	73	303	732	691	282	322
34	470	19602	627	349	173	333	122	159	183	158
35	331	249	162	355	347	163	293	325	1778	1261
36	3195	1166	1211	760	795	775	734	543	717	351
37	1641	402	261	710	765	373	295	473	324	151
38	7504	6264	10330	119	59	150	222	521	678	542
39	346	24511	1074	1370	1354	228	234	99	259	293
40	195	166	223	140	25433	4566	29379	4502	6287	5632
41	512	3026	1205	965	661	949	647	1145	552	304
42	676	805	612	619	750	637	838	629	748	665
43	207	60	280	771	190	414	396	345	177	150
44	128	191	1610	613	691	215	149	456	365	295
45	164	308	235	128	183	115	141	144	85	117
46	491	614	747	625	420	961	1115	784	786	553
47	536	128	228	208	197	118	122	89	244	1903
48	138	280	299	692	577	180	297	280	165	126
49	231	188	275	5401	2324	6194	4999	2162	853	857
50	850	2064	2065	949	1152	1303	472	239	645	2000
51	1553	1908	3746	5965	206	378	662	209	137	426
52	1686	3877	1828	3085	1287	6862	3440	2855	1807	780
53	1906	603	1487	1729	3451	608	1085	2302	2514	7425
54	7388	170	337	246	176	327	821	672		

TOTAL = 3016009 MEAN = 5513.728

FIGURE 15

A PRINTOUT OF A SINGLE TRIP MATRIX

forecasting process known as the Traffic Assignment Model.

The primary function of this model is to coordinate the output of the other sub-models. By using as its input the base network (built through the Highway Network Model), the minimum highway paths (determined by the TPTRE and TPSKIM computer programs) and the trip table (calculated by the trip Generation/Distribution Models), the Assignment Model places ("loads") simulated traffic figures upon all network links. An example of how this loading process works is shown in Figures 16a and 16b. The model determines that the trip table contains one hundred trips which have their origin in zone 156 and their destinations in zone 201. The tree building programs designate links 4-5, 5-6, 6-7, 7-8 as being the shortest highway path between the two zones. Each link within this path has recorded as passing through it, the one hundred interzonal trips. The trip table, likewise, indicates that fifty trips have their origin in zone 202 and their destination in zone 157. The minimum highway path calculated as 1-4, 4-5, 5-6, 6-9 has associated with each path related link, the fifty trips generated in zone 202 and attracted to zone 157. This process is repeated not only until all those trips leaving zone 202 destined for each other zone within the system have been recorded, but also until the procedure is repeated from the "perspective" of all system zones. The model, run to its completion, outputs a network tape with the "load" information for each link stored in volume field #20. It is worth noting here that the centroid link of any network indicates the number of trips entering and leaving a specific study zone. This is contrasted to a highway link which shows its total use within the system regardless of its location within the zone system.

THE "LOADING PROCESS"

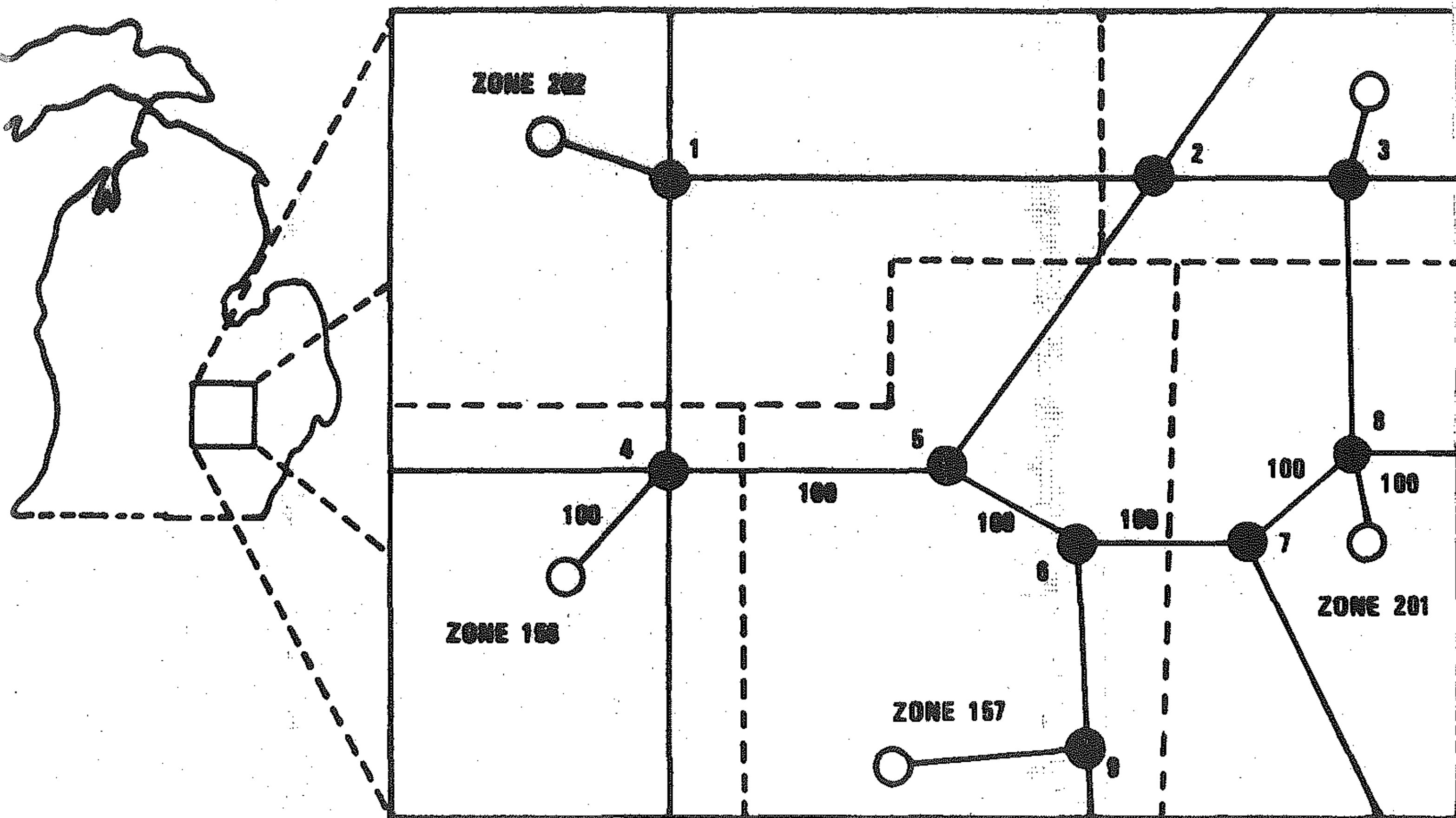


FIGURE 16 A

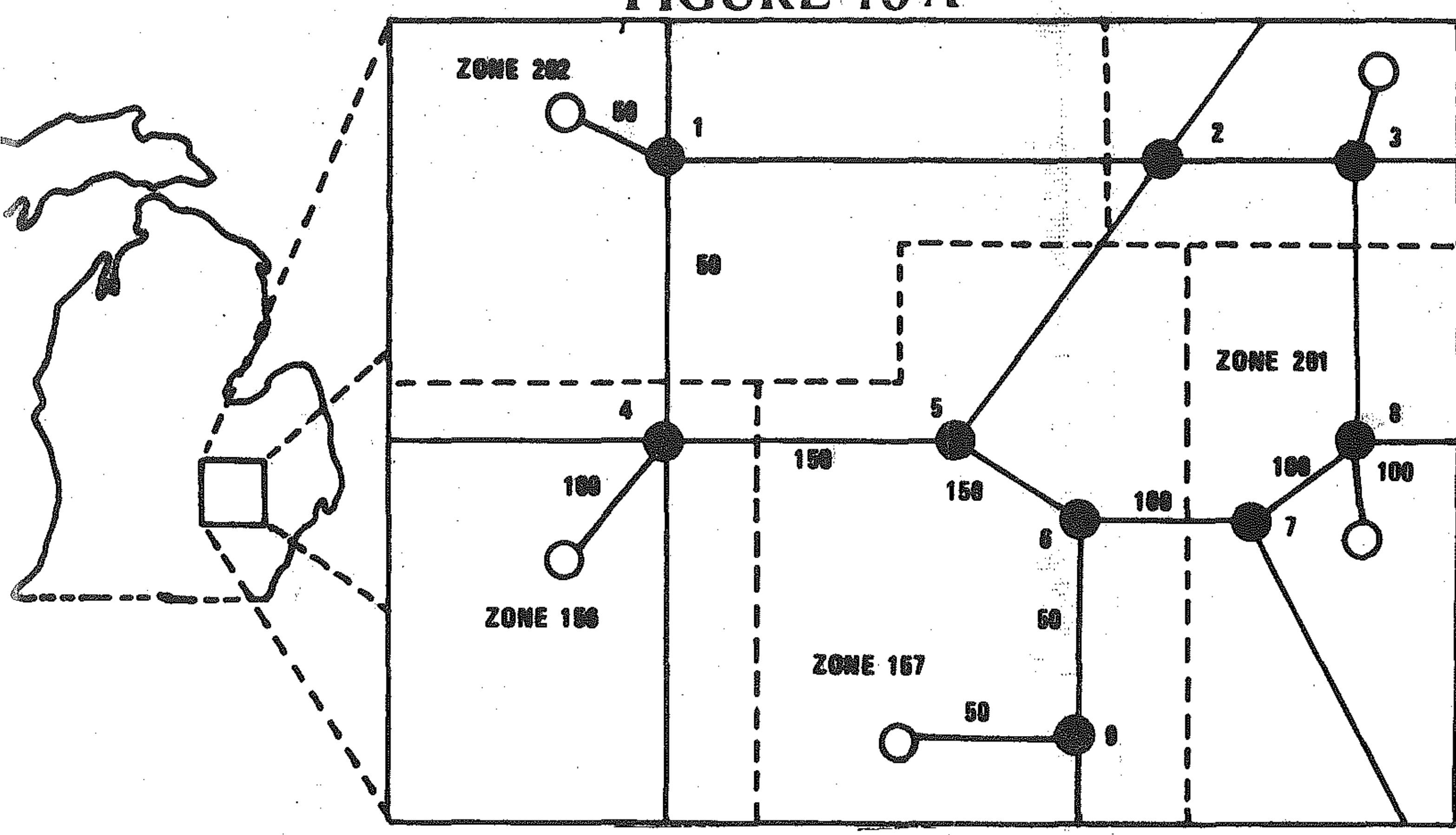


FIGURE 16 B

The Trip Generation/Distribution Models are not totally reliable in the production and distribution of trips, for obviously, the mathematical expressions they employ do not (possibly cannot) include all significant variables that bear upon statewide travel behavior. Therefore, although the model successfully simulates the state's generalized traffic patterns, many major and minor routes and/or links may be inappropriately assigned without varying degrees of modification. To resolve this situation, a process of model "calibration" is undertaken to logically explain the variance of simulated traffic figures from those of the actual travel study. Calibration is the final step necessarily performed in obtaining an accurate descriptive model.

As suggested above, the model becomes predictive in nature when projections of future zonal population are employed in the Trip Generation/Distribution sub-models. These projection estimates, taken in 5-year increments, give the Planning Engineer an indication of when portions of the highway system, as they presently exist, will become "overloaded" - i.e., when future traffic volumes will exceed the simulated physical capacity of the road. The Travel Forecasting Model is an efficient planning tool in that it provides an answer to the complex question: "How are the present and projected deficiencies of the state highway network best resolved?" The first step in deriving an optimal solution to the problem is by simply modifying the present network configuration to meet the specified travel demand. Since certain portions of the base network, as currently described, are unable to handle traffic volumes at an acceptable level, one must determine which of a series of highway networks would be capable of doing so at the least social cost. The alternate route assignment process gives the transportation analyst a solid basis for comparing proposed network changes. The sole difference in developing an alternate network, of course, lies in the descriptive procedures of the highway network model. Certain links and/or nodes are added to or deleted from those areas of the base network which are currently or are projected to become deficient. The "tree" programs are then run using this network to determine the shortest highway path between zones; the trip Generation/Distribution Model builds the necessary alternate trip tables and the Network Assignment Model "loads" the trip table to the alternate network. Figure 17 shows the sequence of programs which are used during every alternate run of the Traffic Forecasting Model. The ultimate output from this process is a magnetic tape known as a "final working network". Ten, Twenty, or even thirty such tapes may be obtained to describe a single portion of the base network. These tapes contain an enormous amount of information relevant to the potential cost/benefits of these highway proposals. But how is this information accessed, identified, and compared? How is an optimal highway network actually chosen from a series of network configurations which were all proposed to provide an equally satisfying answer to the particular planning problem at hand? The answer to these questions are to be found in the discussion of the travel impact analysis process described below.

B. Travel Impact Analysis Procedures

The impact indicators listed in Figure 9 were developed with the idea of giving one the ability to efficiently identify and compare the possible present and future effects of implementing a proposed highway plan. Each of these sixteen indicators are aimed at quantifying a single aspect of a proposed network's impact upon travel behavior. It is essential, therefore, to consider these procedures as an interrelated whole. Their application, upon this basis, it is believed, forms a

STATEWIDE MODEL
ALTERNATE ROUTE
ASSIGNMENT PROCESS

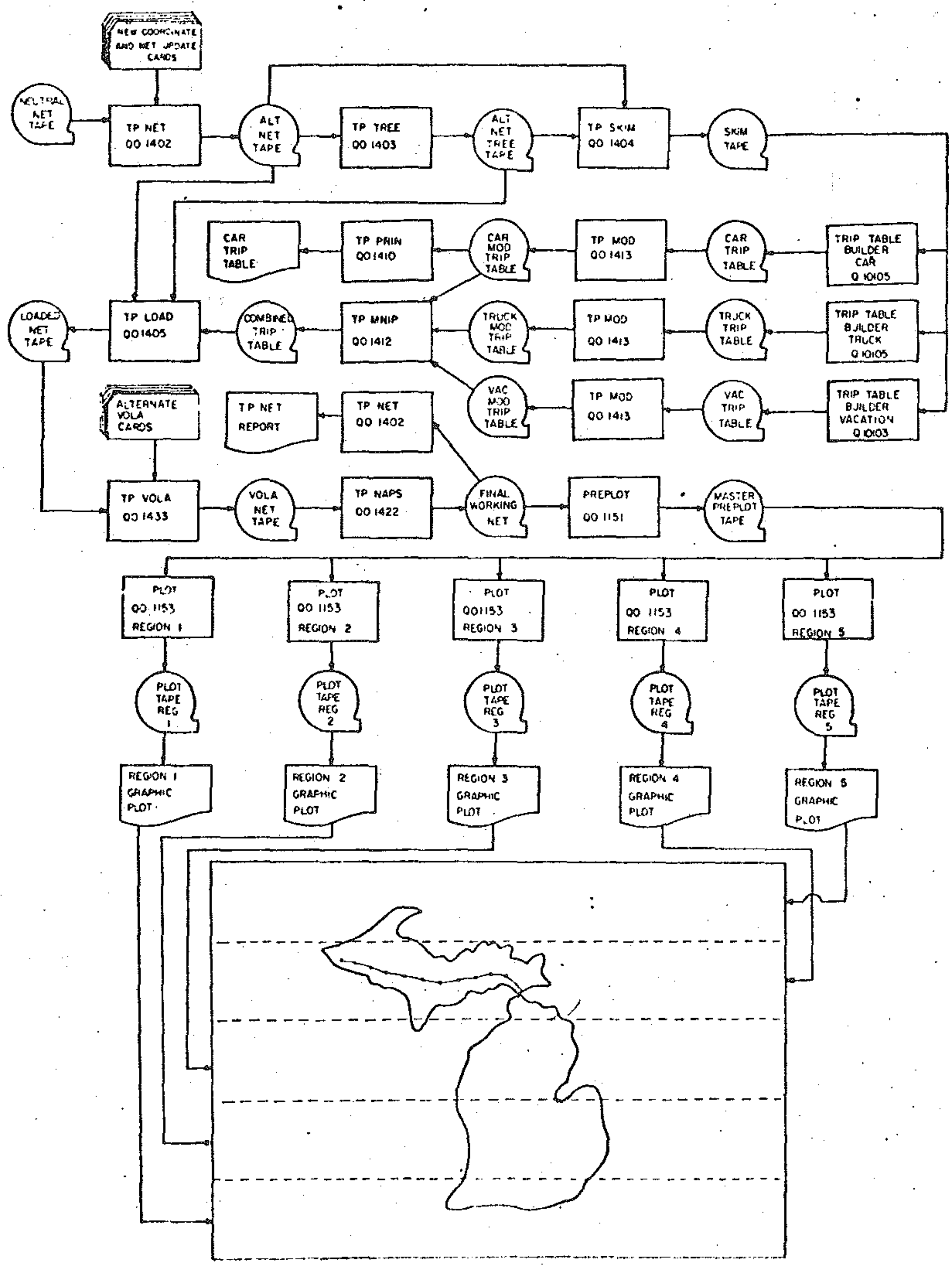


FIGURE 17

comprehensive process of travel analysis/evaluation which enables one to more than adequately describe travel impacts on the system level. As these sixteen individual analytical steps are utilized upon a series of alternate highway networks, one is incrementally given insight into why one particular network is considered optimal from a travel (impact) perspective. The system procedures performed in obtaining output from the impact indicators are reviewed below. Emphasis is placed on the concept behind each indicator and the mechanics of its operation. Many of the analytical techniques to be described here are similar in that they utilize a majority of the same system programs, files, and component models. Indeed, a few indicators differ only in perspective - i.e., they may enjoy an identical approach but selectively manipulate a particular travel element. Other indicators, though sharing the model as a common framework, utilize more varied system techniques. The purpose of the following discussion, then, is to note procedural similarities, to familiarize the reader with operational steps, and to show how an indicator actually describes a potential travel impact. When this has been accomplished, the reader should be sufficiently prepared to embark on a demonstration of the Travel Impact Analysis Process as it is presently applied.

1) Highway Volume Deficiency

The Michigan Department of State Highways and Transportation, as do all such departments, have a responsibility to make the state's transportation system operate as efficiently as economically possible. Underlying this responsibility is a need to know exactly where the system is not performing as expected - i.e., where the system is deficient. One of the best measures of highway inefficiency can be obtained by comparing the actual physical capacity of a road segment (link) to the volume of traffic it is forced to carry. A link, by definition, is said to be deficient when the volume to capacity (V/C) ratio is greater than one. Obviously, to make the highway network (at the system level) effective, all links currently deficient or those projected to become so, must be identified. It is not a coincidence that the two pieces of information needed to perform this analysis are stored in link associated volume fields. The capacity for a link is described in the original network description through the Highway Network Model and is stored in volume field #1. Base year (1970) trip volumes for all network links are taken from either actual O&D studies or historical trend data and are recorded in volume field #2. Projected traffic figures, as simulated through the Traffic Forecasting Model, are typically placed in volume field #20. A program known as TPNAPS (taken from the TP Battery of computer programs - see Figure 18) has been designed to allow its user to "key" on various volume fields for the performance of particular arithmetic operations. In this case, TPNAPS is "set-up" to divide either a link's present or future traffic volume by its capacity. Another of the TP programs (TPVOlA - i.e., Volume Field Adder) takes the output from TPNAPS and stores it in a volume field of the "Final Network Tape". The user has several options concerning methods of data output but computer graphic techniques have become preferred since federal legislation now demands each highway department to be as effective as possible in their communication with the general public. The Graphic Display Battery (see Figure 19), specifically TP1153, through its versatility, allows one to pictorially present those links which are found deficient. This method has proved to be a powerful communicative device. The link-node plot of the highway network system (shown in Figure 4) is an example of a computer

STATEWIDE MODELING SYSTEM COMPONENTS

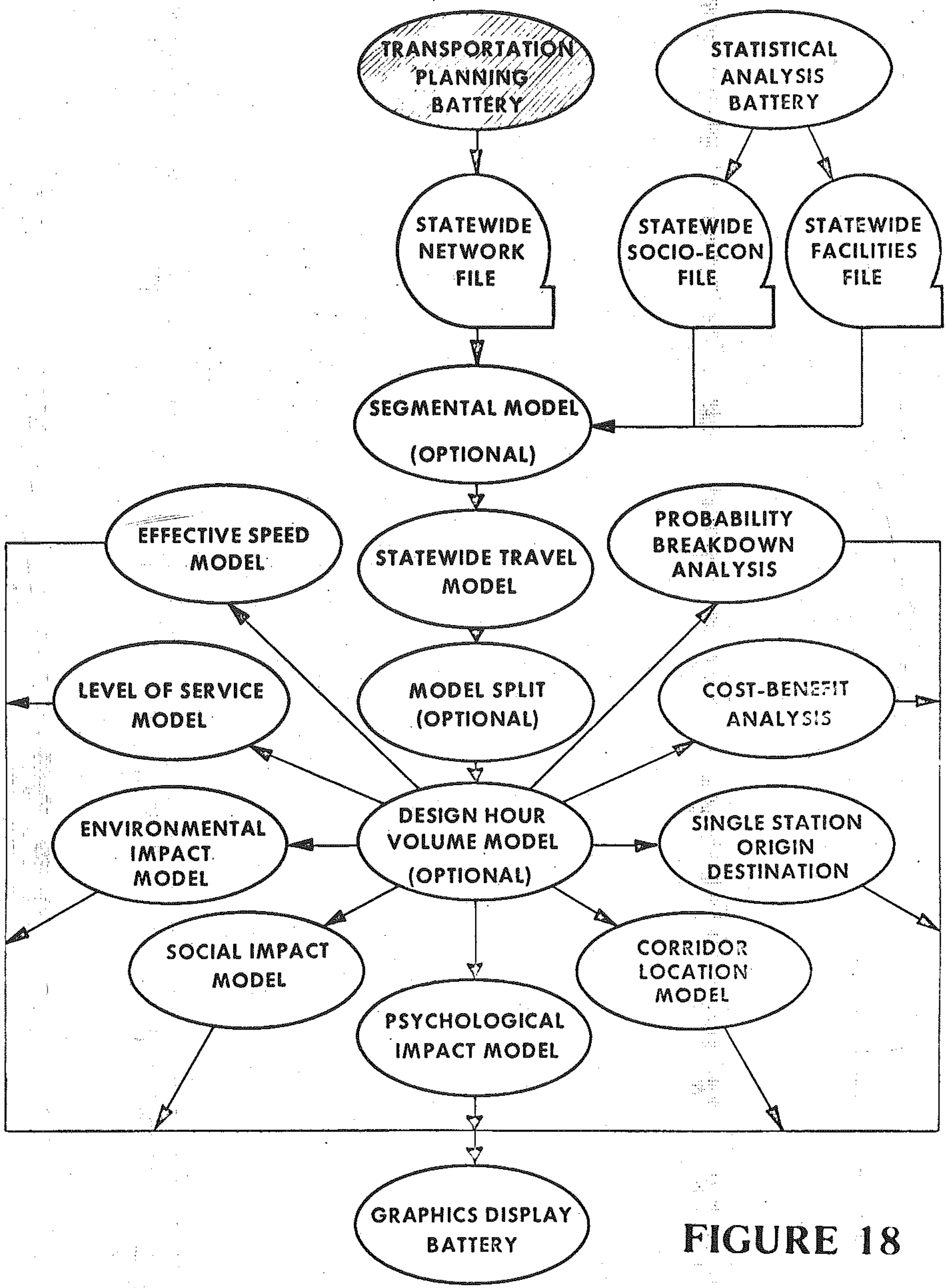


FIGURE 18

STATEWIDE MODELING SYSTEM COMPONENTS

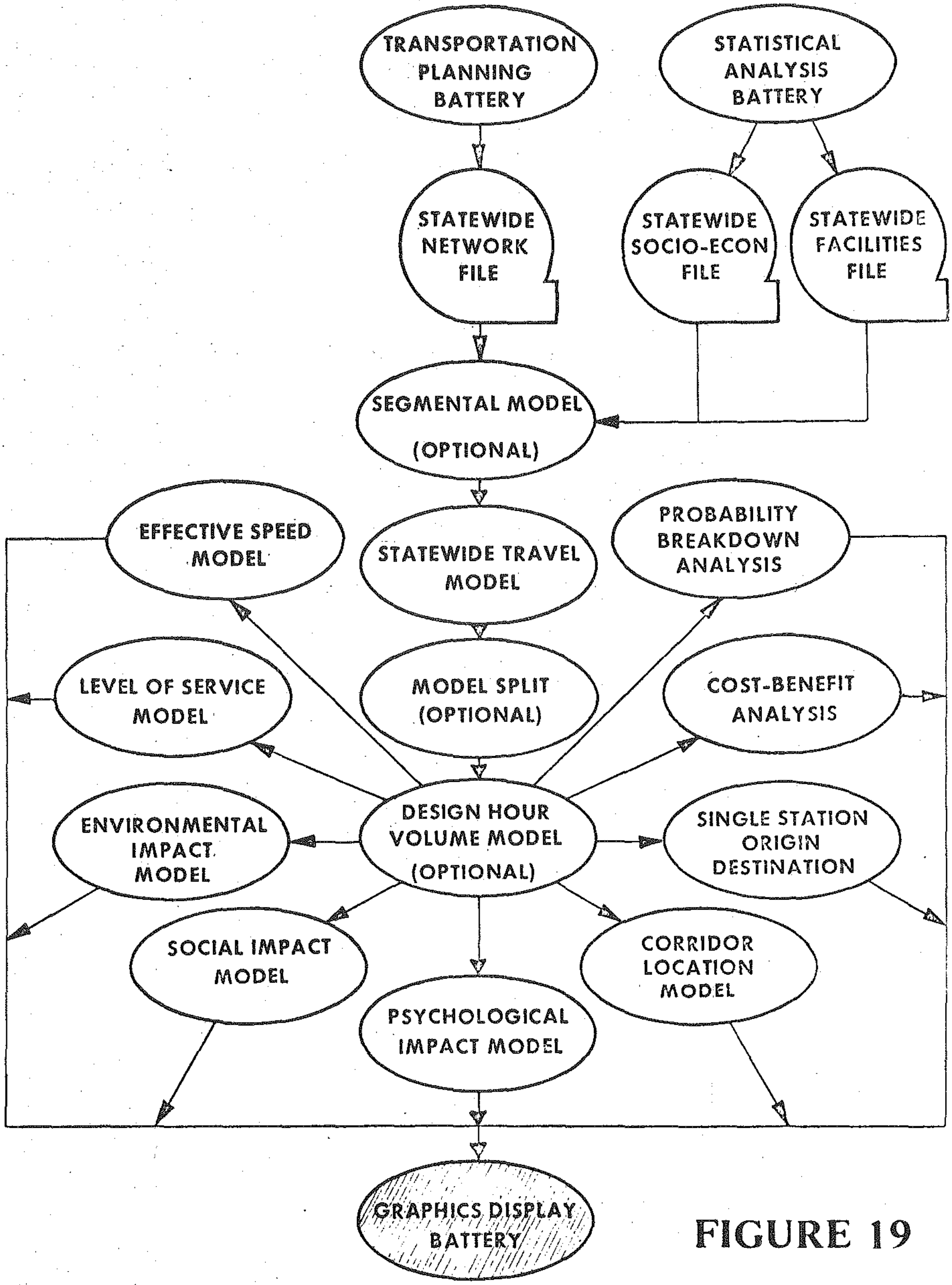


FIGURE 19

graphic technique - others will be presented for many of the impact procedures in the subsequent section on process application.

2) Level of Service

Development and application of the Level of Service Model has been thoroughly documented in Volume I, Part H, of the Statewide Model report series. The term "level of service" has been defined as "any of an infinite number of differing combinations of operating conditions that may occur on a given lane or roadway when it accommodates various traffic volumes". In theory, level of service is a qualitative measure of the effects of a number of factors - e.g., traffic interruptions, freedom to maneuver, driving comfort and convenience, etc. But because of insufficient data relating to these factors, the V/C ratio (mentioned above) has been accepted as a crude indicator of service level. The Highway Research Board in their 87th <u>Special Report</u> stratified all V/C ratios for rural roadways into a five-range classification (see Figure 20). Level A, numerically Level 1, indicates the best service that could be expected on a network link under a given set of conditions. Conversely, Level F(6) indicates the worst service - (anything greater than Level E(5) as shown in Figure 20 is automatically considered Level of Service F). This type of analysis differs from Highway Volume Deficiency in that one is not only able to distinguish between links which are deficient and/or sufficient, but also to what extent they are so. The operational "steps" taken to perform this analysis are similar to those of Deficiency Analysis in that it utilizes the V/C ratio as an essential factor. The major difference between the two approaches is simply this. Once the ratio of volume to capacity is calculated, it is compared to the values of the information found in Figure 20 which has been

FIGURE 20
V/C RATIOS FOR RURAL ROADWAYS

UNDIVIDED AND/OR UNCONTROLLED ACCESS MULTI-LANE HIGHWAY

LEVEL OF SERVICE	2 LANES	3 LANES	4 LANES	6 LANES
A	0.286	0.360	0.400	0.400
B	0.643	0.659	0.667	0.667
C	1.000	1.000	1.000	1.000
D	1.214	1.205	1.200	1.200
E	1.428	1.366	1.333	1.333

DIVIDED WITH CONTROLLED ACCESS MULTI-LANE FREEWAY

LEVEL OF SERVICE	4 LANES	6 LANES	8 LANES	10 LANES	12 LANES
A	0.509	0.552	0.567	0.575	0.581
B	0.727	0.805	0.833	0.850	0.860
C	1.000	1.000	1.000	1.000	1.000
D	1.200	1.126	1.100	1.078	1.065
E	1.455	1.379	1.333	1.307	1.290

read from tape and stored internally in two arrays, one for highway links and one for freeway links. Before its storage in one of the numbered volume fields, the model assigns the appropriate level of service classification to each link. By properly preparing TP1153, the computer "plotting" program, one may indicate into which service level each network link falls. Highway Volume Deficiency Analysis pin-points only those links which have a V/C ratio greater than one.

3) Effective Speed

Anyone who has ever operated an automobile knows intuitively that as the congestion on a particular route increases, the actual (effective) driving speed on that route drops. In other words, there is a definite, positive relationship between running speed and congestion (the volume-to-capacity ratio). The Effective Speed Model automates the process of calculating an adjusted speed for each link in the highway network based on simulated road conditions. The methodology for determining the V/C ratio as described above and as utilized in the previous two analytical procedures, is again applicable here. While the link-specific V/C ratios in the Level of Service Model were classified according to the tables shown in Figure 20, the Effective Speed Model relates the ratio to three separate sets of curves which are slightly-modified, piecewise-linear approximations of those developed by Curvy and Anderson (see Volume I, Part K, of the Statewide Traffic Forecasting Model). Representing the curves internally as a sequence of (x,y) points, the model determines which of the three functions is to be utilized by "keying" on two variables - the first of which is the type of road under consideration (freeway, two-lane, or multi-lane non-freeway) and the second, the number of lanes (for freeways) or the percent of length having at least 1,500 feet sight distance (for all other roadways). Reference to these curves according to the variable route conditions allows the model to define the effective running speed on a study link. For example, Figure 21 shows the three curves utilized in the determination of average running speed on four, six and eight lane freeways given a certain V/C ratio. If a link of a four-lane freeway has a V/C ratio of 0.4, it should be clear that the effective speed is the y-coordinate of that curve which corresponds to the V/C value - in this case, 55 miles per hour. This information, like the output from all Statewide system models, is stored on magnetic tape in a numbered volume field for later graphic output or further manipulation.

4) Capacity Adequacy

Use of the V/C ratio as an indicator of road adequacy, or inadequacy, provides the basis for some extremely useful analytical techniques but it should be kept in mind that volumes expressed in terms of annual average daily traffic (AADT) or design hourly volume (DHV) simply reflect a link's traffic conditions on the average day or the 30th highest volume hour. Its use poses a problem of route comparability in that two links, though having similar capacities and V/C ratios, may be quite different with respect to the number of days (in a year) the road actually experiences a "capacity breakdown" - i.e., when volume exceeds capacity.

This situation can be explained through the seasonal traffic variation among network links. Figure 22 shows the distribution of daily traffic on one link of the Michigan highway network over a period of one year. Notice the peak travel volumes on this road for the traditional vacation months of July and August. Other brief periods of peak travel may reflect either annual holidays or, say, the opening of a popular hunting season. A profile

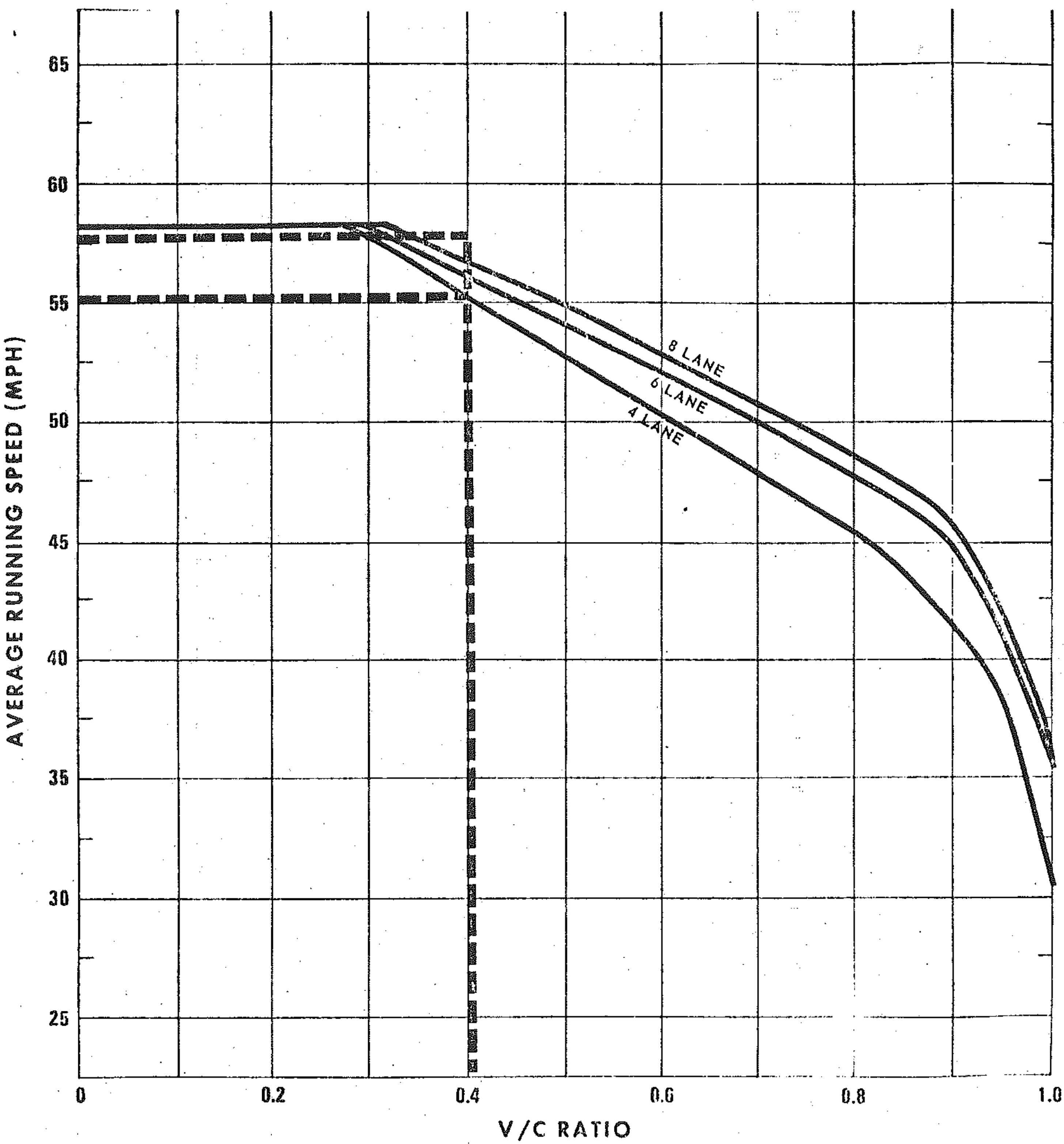

65
60
55
50
45
40
35
30
25
AVERAGE RUNNING SPEED (MPH)
8 LANE
6 LANE
4 LANE
0
0.2
0.4
0.6
0.8
1.0
V/C RATIO

FIGURE 21

DAILY TRIP DISTRIBUTION

FOR A SELECTED NETWORK LINK

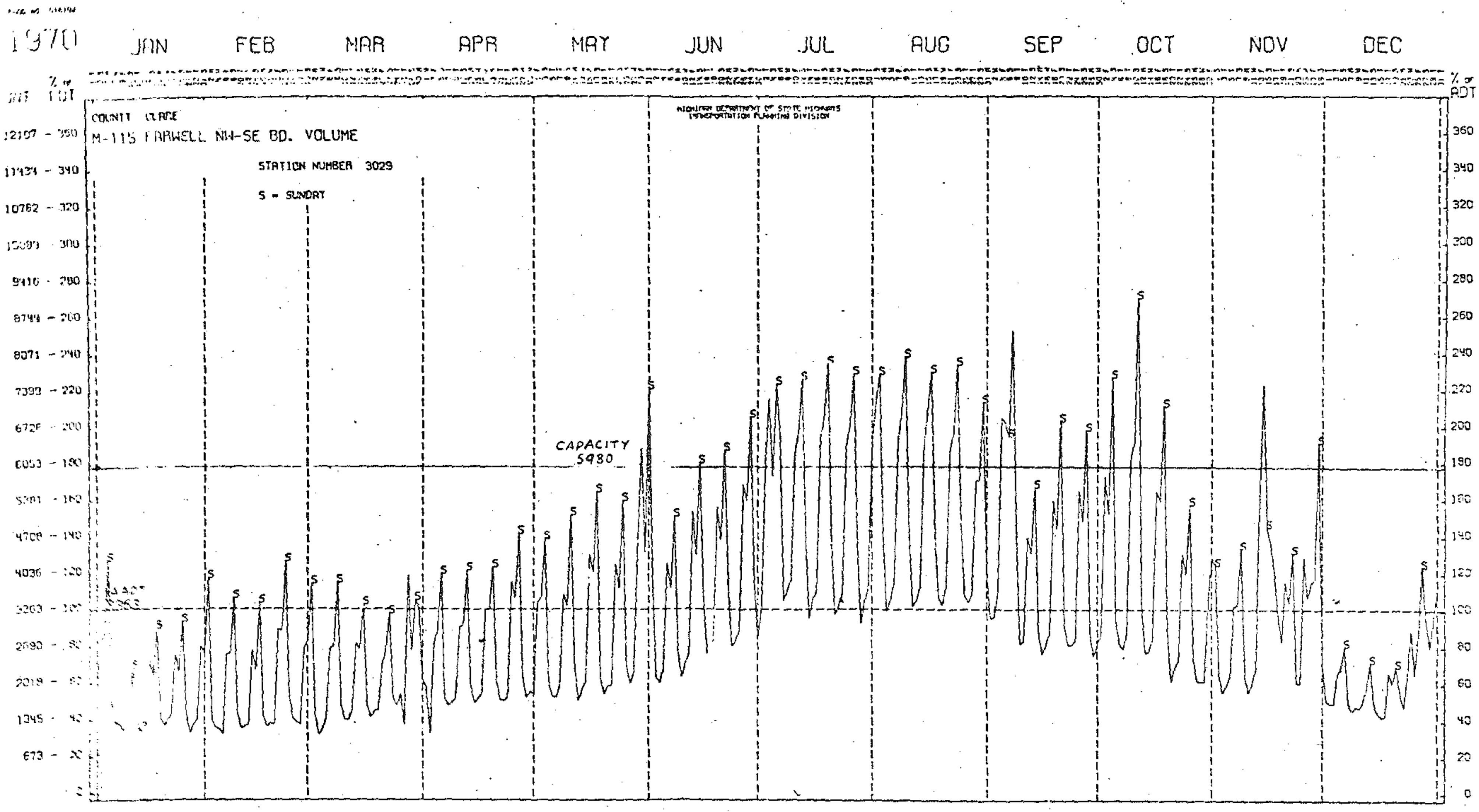


FIGURE 22

of a link's travel patterns are as unique as the road segment itself. Nevertheless, some routes are characterized as being predominantly recreational while others, located near urban areas, carry mainly work and shopping trips - thus having little seasonal fluctuation. A suburban link, which has an acceptable service level (V/C ratio less than one) and is of little or no importance to recreational travel, will experience a capacity breakdown at very infrequent intervals. However, a rural route characterized by heavy seasonal travel which also possesses a "border-line" V/C ratio (V/C ratio approximately equal to one) will become congested beyond acceptable service levels in direct relation to its peak travel periods. It has been observed that the higher a link's V/C ratio and the greater its seasonal variation, the more likely it will experience a capacity breakdown at frequent intervals.

To incorporate the effect of variation in daily traffic into a computerized model for predicting future adequacy of a highway link, seasonal fluctuation must be measured and expressed in variable terms. The design hourly volume (DHV) is widely regarded as being significantly related to peaks in daily traffic. A high DHV indicates frequent peaks in daily traffic volume. A DHV <u>factor</u> may be calculated by comparing AADT with the raw DHV to determine a percentage figure - the higher the DHV factor (DHV/AADT = DHV%) the greater the daily variation. When two roads have equal V/C ratios (volumes expressed in terms of AADT), their actual dissimilarity may not be obvious. The DHV factor reflects the pattern of daily traffic distribution and when used in conjunction with the V/C ratio is a better indicator of likeness between two links.

The capacity adequacy model (see Volume VII, Part A) has utilized several statistical methods to determine the interaction of V/C ratios with DHV factors and their combined relationship to a dependent variable (the number of days of capacity breakdown). Stratification of all observed DHV factors into three groups, namely, below 13.0%, 13.0% to 20.0% and over 20%, has resulted in the three curves shown in Figure 23. Present and projected DHV factors and V/C ratios are calculated for each of the links in the statewide network. Their storage in numbered volume fields allows the model to easily access this data and to determine which of the three curves should be employed in the link-by-link analysis. If, for example, a link has a DHV factor of over 20% and a V/C ratio of 0.7, the number of days the link will "breakdown" is 86 days. Using the same V/C ratio but changing the DHV factor to the curve representing factors between 13-20%, breakdowns for the link would drop to 49 days. Likewise, a V/C ratio 0.7 and DHV factor below 13% would result in breakdowns amounting to only three days a year.

5) Trip Length Distribution

A traffic volume expressed in terms of AADT or DHV gives one little indication as to the "character" of a particular highway link. An AADT figure produced by the Traffic Forecasting Model states simply that "a certain road segment is used for, on the average, x number of trips a day". Without further analysis, nothing is known about the type of trips which use the link and, therefore, to what purpose it is being put within the statewide network. A link which carries predominantly short distance, local traffic does not play a vital role in the movement of inter- and intrastate traffic and will not be given the amount of attention typical of those links which have a higher "functional classification" - i.e., those links which connect major population centers, carry trips that have a higher average trip length, etc. One of the tools used in functionally

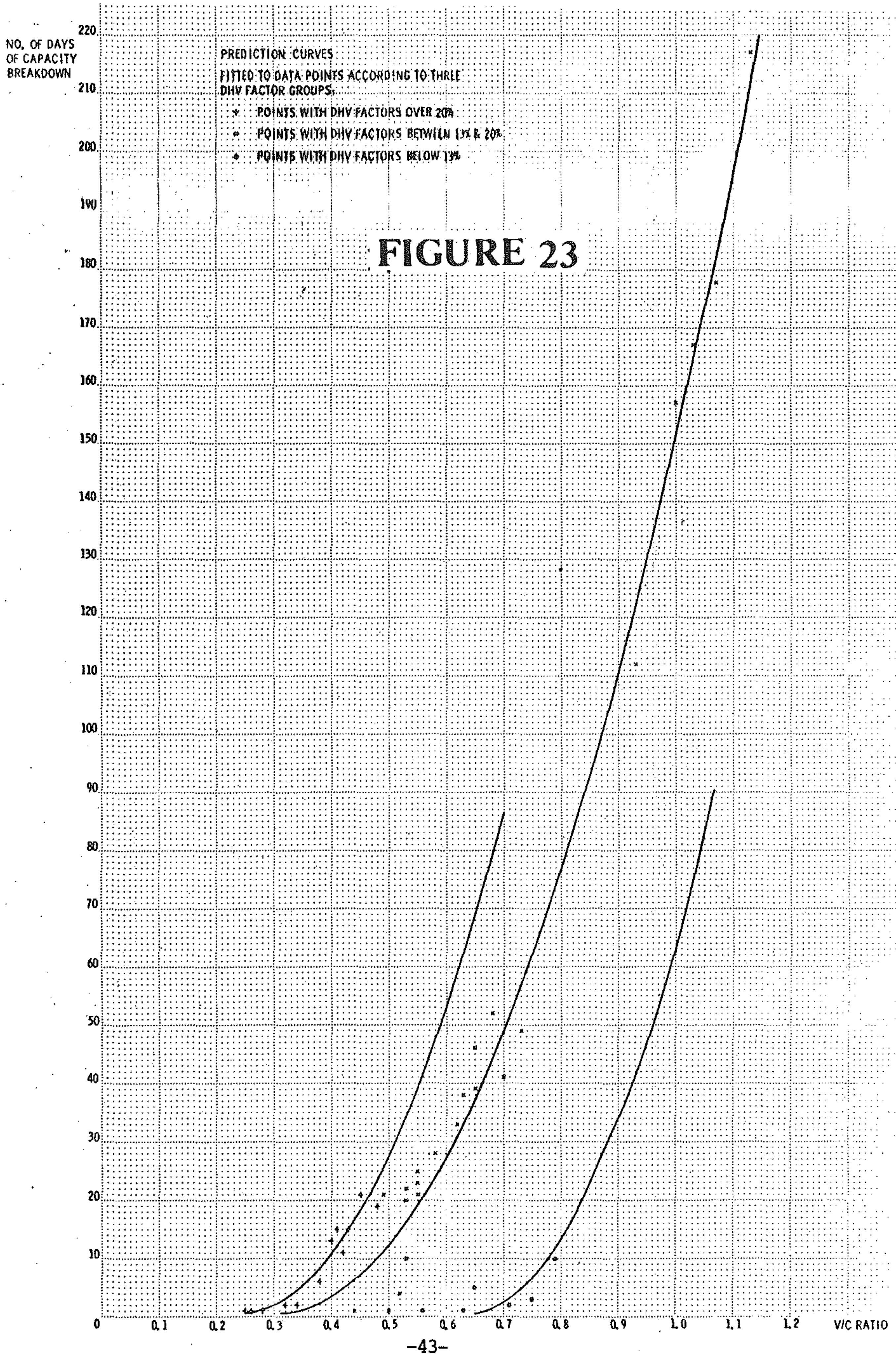

NO. OF DAYS OF CAPACITY BREAKDOWN
PREDICTION CURVES
FITTED TO DATA POINTS ACCORDING TO THREE DHV FACTOR GROUPS:
POINTS WITH DHV FACTORS OVER 20%
POINTS WITH DHV FACTORS BETWEEN 13% & 20%
POINTS WITH DHV FACTORS BELOW 13%
V/C RATIO

FIGURE 23

classifying road segments is a computer program known as TLD (TP1408) - Trip Length Distribution. The program, another within the transportation planning battery, allows its user to produce a printer map showing all trips which pass through a study link in relation to one another in terms of travel time. These trips are stratified into as many second/minute/hour intervals as necessary to accommodate the number of trips recorded as having passed through the link. If the link carries mostly local traffic, then only three or four intervals are necessary to classify the majority of recorded trips while a link which carries a predominant number of "through" trips will need a larger range of intervals since these trips will have a much greater distribution of origins and destinations. The TLD program makes this determination automatically by referring to the skim-tree and trip table input tapes. The output printer map usually presents not only the frequency but also the distribution of trips using a particular highway link. When the analysis is performed on the same road segment of differing alternate network configurations, the impact a specific proposal might have upon the type of travel using the study link becomes readily apparent. For example, a link which presently serves as a part of a major travel corridor (thus having a great distribution of network trips) may become almost totally of local importance if a freeway were to be constructed parallel to it - travelers opting to take the now "shorter path".

6) Average Trip Length

The TLD allows one to investigate the distribution of trip lengths which pass through a single network link. To run the program on a network of over 7,000 links would not only be time consuming, but expensive as well. A less costly means of measuring trip length for the entire statewide network may be calculated through the sequential utilization of several of the transportation planning computer programs - TP MINID and TP NAPS. TP1412 (MINIP) permits one to perform any of the four basic arithmetic operations on two matrices while these same operations may be performed on any combination of network volume fields through use of TP 1422 (NAPS).

Once the network is skimmed on distance in the creation of a matrix, the table is multiplied by the standard trip matrix to output a link-specific index (total vehicle miles traveled on each link) which is added to the network tape through use of TP V01A (mentioned previously). TP NAPS permits one to then divide the volume field containing this index by the contents of volume field #20 (the projected AADT) to produce an average trip length for each road segment. By inputting this tape into TP 1153 (of the Graphics Display Battery), a plot may be produced which indicates those network links which are presently used or are projected to become used for long and/or short distance travel.

7 & 8) Vehicle Miles and Vehicle Hours

How will an alternate highway network affect the total vehicle miles and hours traveled by the residents of a state? Fluctuation in either has obvious implications for the amount of gasoline consumed, the number of accidents experienced, the quantity of pollutants released and many other relevant factors which must be analyzed in the hopes of holding each at a minimum level. A program written within the Statewide Interagency Procedures Research and Development Section enables one to summarize vehicle miles and/or hours by any of three geographical areas - i.e., the county, region, or state. Total vehicle miles may be calculated through use of TP NAPS (1422) which multiplies, on a link by link basis, the length of a road segment (as calculated by TP SKIM). Summarization of a particular area may be stipulated through a program option. Figure 24 shows a state vehicle summary for the base year network.

9) Traffic Volume Analysis

Traffic Volume Analysis differs from others discussed in this report in that no additional computer manipulation is needed after obtaining what is known as the "Final Network Tape". This tape describes the physical characteristics of a network configuration and contains current and projected traffic figures expressed in both AADT and DHV forms. By properly preparing the computer graphics program (TP1153), one is able to plot alternate highway networks with traffic volumes annotated next to each link. After these traffic volume plots are obtained, the only step performed in this analysis is the manual drawing of "cordon" lines around the desired study area - making sure one crosses the network at points which are thought to be critical (see Figure 25). Comparison of the traffic volumes which enter and leave the study area via the specified points gives one an indication of which plan might generate/attract the greatest number of people. The production of additional incoming and/or outgoing trips is a function of accessibility which varies with network configurations. The desirability of this phenomenon is constantly debated but use of this analytical technique indicates a probable travel pattern prior to actual implementation.

10) Zone of Origin

Until recently when one wished a total of expected vehicle accidents occurring in a particular summary area (see Figure 24), the number calculated would indicate the number of projected accients but

FIGURE 24

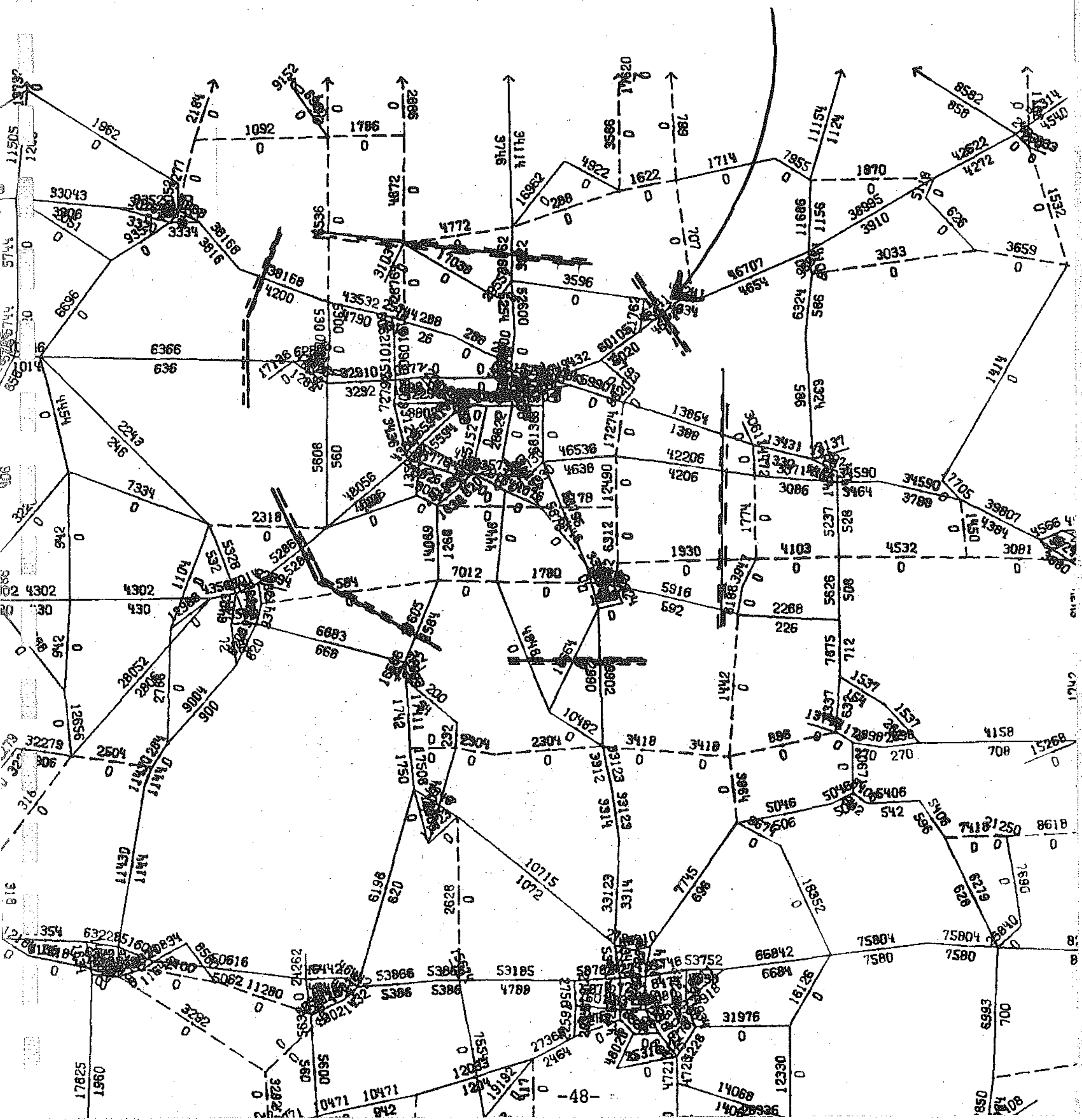
STATEWIDE VEHICLE SUMMARY, ALTERNATE 23
5/13/74 MICHIGAN STATEWIDE TRANSPORTATION MODELING SYSTEM

	INTER STATE	FAP FWY	FAP NON-FWY	FAS	TOTAL
TOTAL MILES	787	356	4685	2243	8073
ANNUAL VEHICLE-MILES (THOUSANDS)	7985668	3448062	16985695	3535285	31954711
ANNUAL VEHICLE-HOURS (THOUSANDS)	8193450	3487881	21332537	4753759	37767629
ANNUAL ACCIDENTS	19447	6485	67987	13748	107667
A.ACCS./A.V.M. (TIMES 100 MILLION)	243	188	400	388	336
A.ACCS./A.V.H. (TIMES 100 MILLION)	237	185	318	289	285
ANNUAL GASOLINE CONSUMPTION (THOUSAND GALS.)	441568	190677	805041	164674	1601962
MILES LS=1	59	44	77	242	423
MILES LS=2	121	79	886	906	1993
MILES LS=3	159	110	895	517	1683
MILES LS=4	90	16	609	158	874
MILES LS=5	94	38	313	96	542
MILES LS=6	263	67	1902	321	2555

NOTE--COLUMNS OF MILEAGE AND ROWS MAY NOT ADD DUE TO ROUNDING

FIGURE 25

LANSING AADT/DHV CUTLINE



could not reflect the origin or destination of the vehicles involved. If a zone had had an extraordinary projected accident rate, it might, for example, have been difficult to prove to an influential "decision-maker" that the improvement of a road in an area outside his political jurisdiction would actually be beneficial to travelers of his constituency. The development of the "zone of origin" technique permits one to predict the total number of accidents which the residents of a particular zone are expected to experience in a certain year given a particular highway network - i.e., the total reflects the accidents projected to occur to the residents of a specific zone regardless of their location within the system at the time of occurrence. The politician may now think twice before vetoing funds for the improvement of a road which has statistically been proven to provide a safer travel environment for people of his community.

Execution of this procedure required the rewriting of the TP SKIM (1404) computer program to allow the user to "skim" a network on the contents of any "volume field" rather than on just distance, time, or cost. Once an "accident per vehicle" factor is calculated through the multiplication of the link-specific accident rate by the link's distance* and is stored in a volume field, the network is skimmed on this factor and an "accidents per vehicle" rate table is created for each zone. Further multiplication of this rate table by the standard trip table yields a matrix in which projected

*The formula for calculating a link's accident rate is:

$$\text{Rate} = \frac{\text{Accidents} \times 100{,}000{,}000 \text{ vehicle miles}}{\text{Distance} \times 365 \text{ days} \times \text{AADT}}$$

for the link by changing the AADT to 1, an accident rate for single vehicle may be determined.

accidents for all 547 zones are recorded. A routine known as symap (to be discussed in greater detail below) allows one to display socio-economic data in any of three forms by stratifying system information into as many as ten discrete categories. The variance in total zonal accidents is indicated by symbolically shading an entire zone in accordance with th e predetermined range - a zone which contains one of the highest projected totals will, for example, be darkest in appearance.

11 & 12) Selected Route and Selected Zone Analysis

To those familiar with the statewide modeling system, the word "select" connotes the choosing of several routes, zones or trees for the purpose of performing a more detailed trip analysis. TP SELC (1424), the computer program utilized in selected route analysis, allows its user to specify those links which are thought to be most heavily impacted by additions to or deletions from the base network. Inputting the network tree and trip table tapes, the program "picks" from them those trips which, according to the predetermined minimum highway paths, pass through the designated link. If the link is solely of local importance, a plot will indicate a network distribution of trips which is consistent with the nature of the road. That is, trips, regardless of their number, will have their origin or destination in zones which have a close proximity to the study link. Likewise, a road segment which serves as a link in a regional or statewide travel corridor will produce a plot which displays a distribution of trips throughout a much greater percentage of the network. The TLD (discussed above) permits one to stratify a link's recorded trips into as many time intervals as needed to visually describe their frequency and distribution. The exact origin/destination (O&D) of these trips, however, is not known. The advantages of the selected route analysis is, then, that the O&D of each trip passing through the selected route, the trip volume contributed by each zone, and the minimum path taken by these trips is clearly indicated in a network plot.

The operational steps performed in selected zone analysis differs from those of selected route analysis in a single major respect - i.e., the type of link selected for the detailed study. The latter approach may use any of over 7,000 network links while the former is restricted to use of one or more of the 547 zone centroid links. This seemingly minor change gives the technique a new perspective. Since the study link is actually a centroid, all information associated with it is characteristic of the entire zone rather than merely the link as is the case in selected route analysis. Therefore, the O&D of every trip entering or leaving the link (zone) coincides with the total recorded in the output tapes of the Generation/Distribution Models. The minimum paths taken by these trips are identical to the paths used in the zonal exchange of trips as determined through the TP TREE computer program. One of the principle values of this technique lies in the fact that one may annotate trip volumes along each link of the minimum path. This is not possible when the selected tree program (discussed below) is utilized.

13) Selected Tree

The concept of "building trees" was presented earlier in the discussion of the Trip Distribution Model. From that discussion, it is known that the minimum highway path between each of the 547 zones must be calculated in order to determine the interzonal exchange of trips produced through the Trip Generation Model. It was also shown that a single selected tree could be plotted via the graphics display battery (see Figure 14). No mention, however, was made that the technique might also prove to be an effective means of indicating a specific travel impact. By using the computer program designed to build a selected tree (TP 1403) on the same zone centroid for different highway networks, one may determine the occurrence of "shifts" in minimum travel paths to and from a study zone. Obviously, not all "branches" of a selected tree are of critical importance - many connect the study zone with other zones which are sparsely populated and thus carry an insignificant percentage of statewide traffic. A few of the branches connect the study zone with others which generate a great travel demand. When this latter point proves true, any shift in the path taken between these zones will heavily impact not only the given region but perhaps the entire state as well. The selected tree program enables one to identify any change in the major traffic corridors leading to/from a study zone. The purpose of constructing an alternate highway network, of course, is to better accommodate traffic between two or more points (zones). Running a selected tree indicates whether the new facility will sufficiently reduce the minimum travel path between these zones to cause the desired shift.

14) Travel Mode Accessibility

Volume I, Part D, of the Statewide Traffic Forecasting Model (report series) documents an impact procedure known as Proximity Analysis. This "tool" automates a methodology in which social impacts of a highway network are measured by calculating to what extent the network makes selected services accessible to people. Accessibility varies with alternate network configurations. Using the computerized logic of this analysis, for example, one may determine which of a series of highway networks bring mass transit facilities "closest" to the greatest number of people in terms of travel time. By implementing a plan which does this, those who have a propensity to use such facilities will, theoretically, use them more often. Certainly this will affect future demand for particular transit modes and will impact overall state travel patterns.

The TP TREE and TP SKIM computer programs of the Transportation Planning Battery mentioned earlier provide the nucleus around which the proximity model has been built. The TP TREE program determines, using any network configuration, "the path of least resistance" from each zone to every other zone according to some user specified variable - (minimum travel time was utilized throughout this report except where stated otherwise). Since the model stresses the accessibility of a single (analysis) zone to, in our case, transit facilities, it is possible to build a selected tree from the analysis zone to all other system (destination) zones (as Figure 14 demonstrated). TP SKIM calculates the actual minimum separation variable from each zone to zone pair - in effect "skimming" the selected tree. The numbers associated with each link indicates the average time, in hundredths of a minute, necessary to go from the zone centroid to the end of a link. These times, therefore, are cumulative for each zone-to-zone (centroid) path. The proximity model allows its user to determine the number of transit facilities which surround an analysis zone according to specified intervals (bands). The model, which uses the skim-tree file as input, searches through the tape for each zone centroid and determines into which time band, if any, they fall. Each time interval has "accumulator" fields in which the zone number, time away from the analysis zone, and the desired transit facility information is stored for each zone within the band. Output may be obtained in several summary forms but only two program options were employed for this report. The first gives the analysis zone's relationship to the zones around it. Population proximity summarizes for each analysis zone and for each time band:

1) The percent of total population occurring in the band
2) A list of zones in the band
3) The number of servers (transit facilities) within the band
4) The number of people per server in the band (total population of the band divided by the number of servers in the band) - See Figure 26.

The second option treats each zone in the system in turn and summarizes the impact of the analysis zones on it. Server proximity indicates for each zone in the system and for each time band:

1) The number of analysis zones in the band
2) Number of service units (facilities) in the band
3) Total service capacity in the band (e.g., number of beds per hospital) - Total capacity is recorded as zero in travel mode accessibility. (See Figure 27).

15) Symap/Driving Band

Symap is a computer program used for producing two dimensional printer maps of socio-economic data. Raw data, when given to the computer in the appropriate format, may be related, manipulated, weighted and aggregated

PROXIMITY OF POPULATION

DATA FOR ZONE 151
POPULATION = 20690
NUMBER OF RAIL TERMS = 10
TOTAL CAPACITY = 0

	0- 15	0- 15
POPULATION	20690	20690
PERCENT OF TOTAL POPULATION	0.233	0.233
RAIL TERMS	10	10
POPULATION /RAIL TERMS	2069.00	2069.00

ZONE	TIME AWAY
151	0

	15- 30	0- 30
POPULATION	22912	43602
PERCENT OF TOTAL POPULATION	0.258	0.491
RAIL TERMS	120	130
POPULATION /RAIL TERMS	190.00	335.40

ZONE	TIME AWAY
152	19
153	26
154	30
155	17
261	18

	30- 45	0- 45
POPULATION	23806	67408
PERCENT OF TOTAL POPULATION	0.268	0.760
RAIL TERMS	180	310
POPULATION /RAIL TERMS	132.00	217.45

ZONE	TIME AWAY
18	36
35	45
36	38
234	40
259	44
260	33
507	44

OPTION 1

FIGURE 26

SERVER PROXIMITY

ZONE	SERVICE ZONES	RAIL TERMS	CAPACITY	POPULATION /RAIL TERMS	POPULATION /CAPACITY
1 0- 15MIN.	1	40	0	148.20	0.00
1 0- 30MIN.	1	40	0	148.20	0.00
1 0- 45MIN.	4	90	0	65.87	0.00
1 0- 60MIN.	5	110	0	53.89	0.00
2 0- 15MIN.	0	0	0	0.00	0.00
2 0- 30MIN.	0	0	0	0.00	0.00
2 0- 45MIN.	1	40	0	29.63	0.00
2 0- 60MIN.	3	100	0	11.85	0.00
3 0- 15MIN.	2	80	0	45.96	0.00
3 0- 30MIN.	2	80	0	45.96	0.00
3 0- 45MIN.	3	180	0	20.43	0.00
3 0- 60MIN.	3	180	0	20.43	0.00
4 0- 15MIN.	1	40	0	50.95	0.00
4 0- 30MIN.	1	40	0	50.95	0.00
4 0- 45MIN.	1	40	0	50.95	0.00
4 0- 60MIN.	1	40	0	50.95	0.00
5 0- 15MIN.	1	100	0	22.76	0.00
5 0- 30MIN.	2	170	0	13.39	0.00
5 0- 45MIN.	3	180	0	12.64	0.00
5 0- 60MIN.	5	310	0	7.34	0.00
6 0- 15MIN.	2	80	0	7.21	0.00
6 0- 30MIN.	3	180	0	3.21	0.00
6 0- 45MIN.	3	180	0	3.21	0.00
6 0- 60MIN.	5	310	0	1.86	0.00
7 0- 15MIN.	1	20	0	548.05	0.00
7 0- 30MIN.	7	270	0	40.60	0.00
7 0- 45MIN.	19	520	0	21.08	0.00
7 0- 60MIN.	37	930	0	11.79	0.00
8 0- 15MIN.	1	40	0	207.00	0.00
8 0- 30MIN.	1	40	0	207.00	0.00

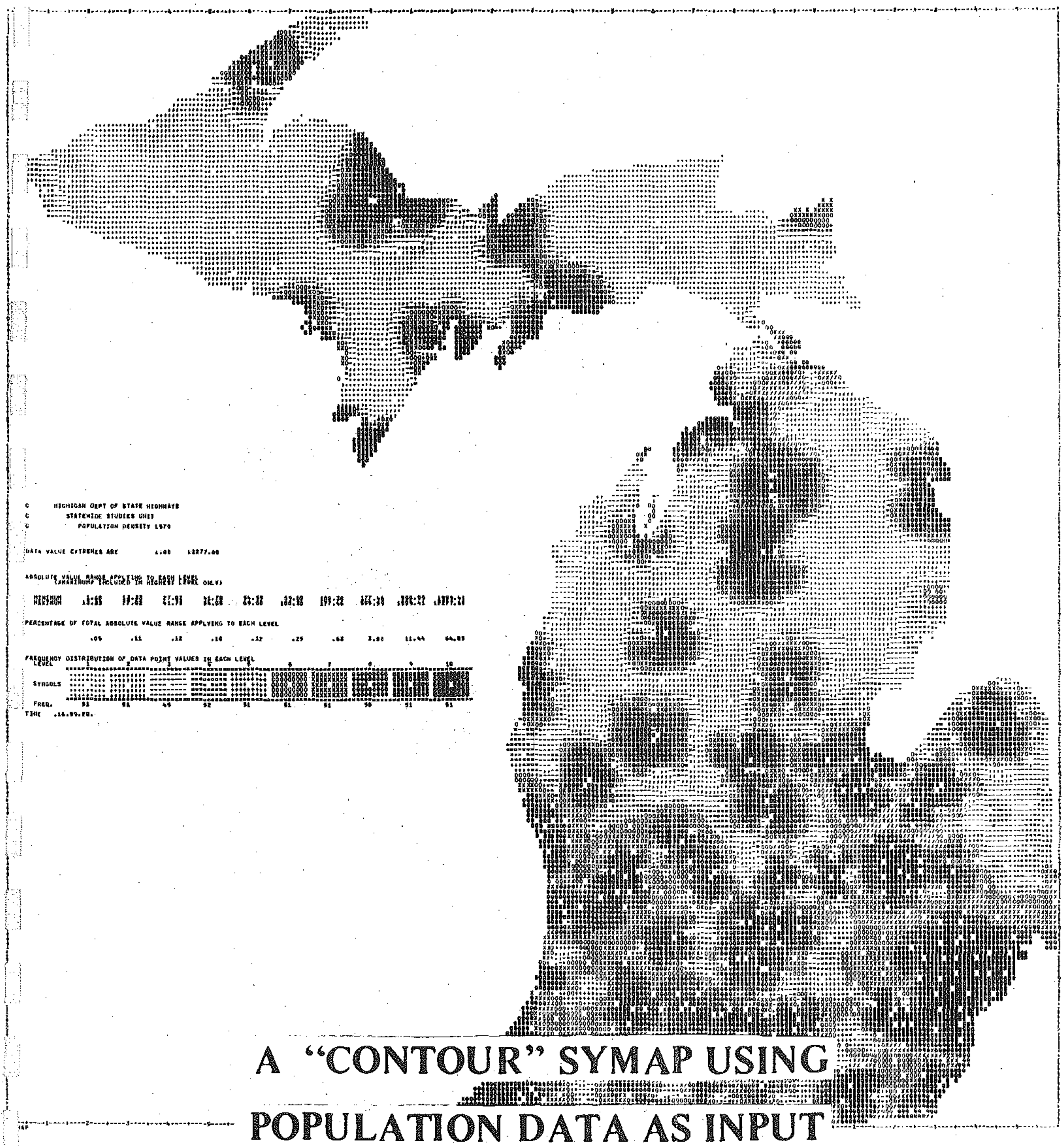
OPTION 2

FIGURE 27

in any manner desired. A range of ten symbols which correspond to data values, shade the output map. The program (available at Michigan State University) is currently able to produce one of three types of maps by specifying coordinate values for data points or zones. Since the Statewide Traffic Forecasting Model has 547 zones already defined, Symap is easily integrated into the analysis process. Each of the three map types differ only by the way in which data points (in our case, zone centroids) are related. The first map, known as the "contour" approach, associates the 508 instate zone centroids internally with a closed curved line. A continuous graduation is assumed between any two contour lines. Certain maps are best used for particular types of data - a contour map is best suited for continuous data such as population (see Figure 28). A "conformat" map allows its user to specify a boundary surrounding a data point. The area within the zone is shaded to match the value of the data for that zone. Boundaries and zone centroids are left blank (see Figure 29). A "proximal" symap shades the defined study area by comparing each symbol placed on the output map to the value of the nearest data point - therefore, no distinctions are made between zones and such boundaries are ignored (see Figure 30).

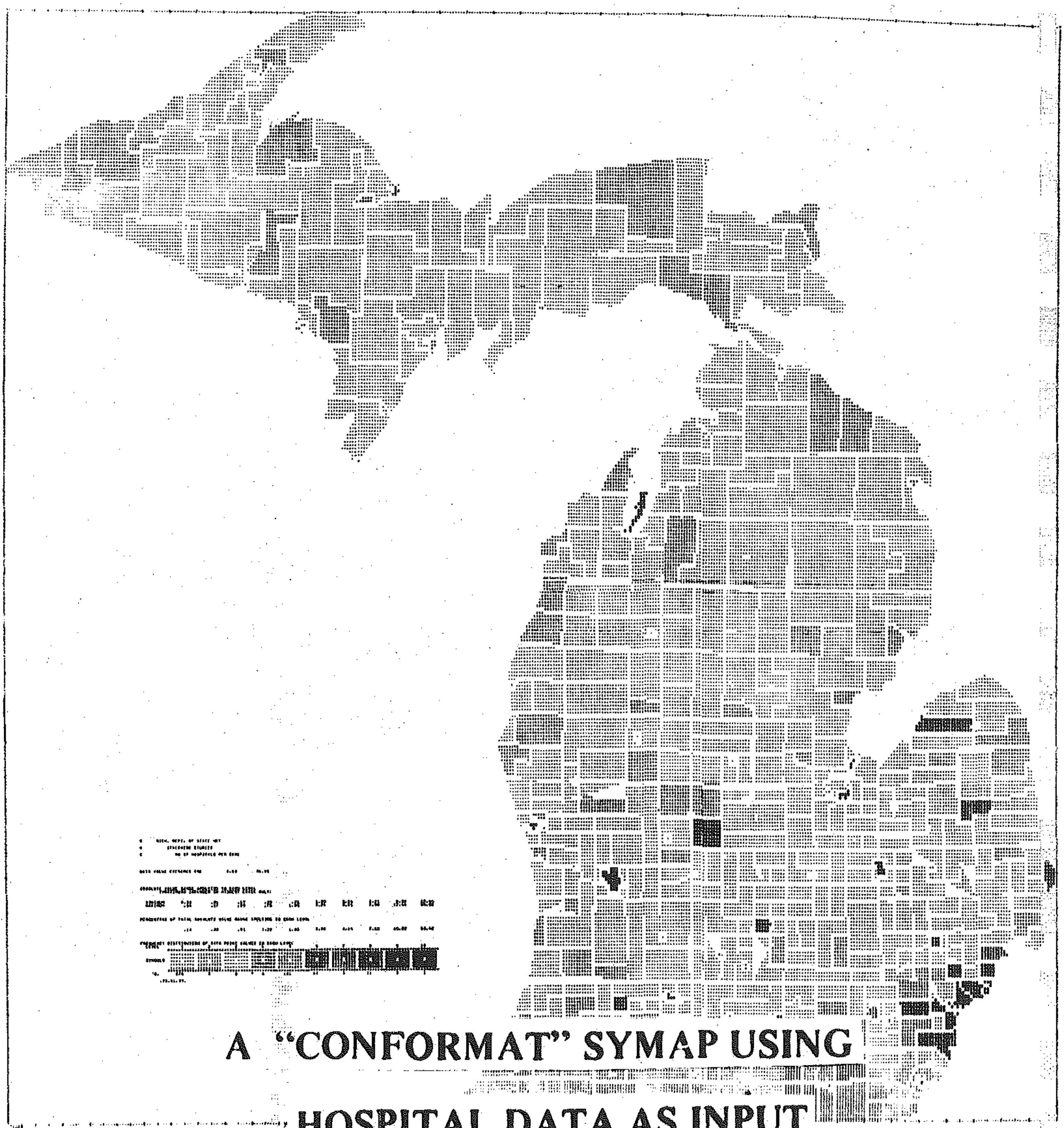
Time band analysis is a means of graphically comparing the accessibility of a selected zone through use of a proximal symap. The input information needed for this analysis is identical to that used in the analysis of travel mode accessibility. The TP TREE and TP SKIM computer programs calculate the minimum travel times between the analysis zone and every other instate zone. The time values associated with each of the zone centroids are stratified into a range of up to ten time intervals (bands). The area surrounding a centroid is shaded on the output map according to the predetermined time

FIGURE 28



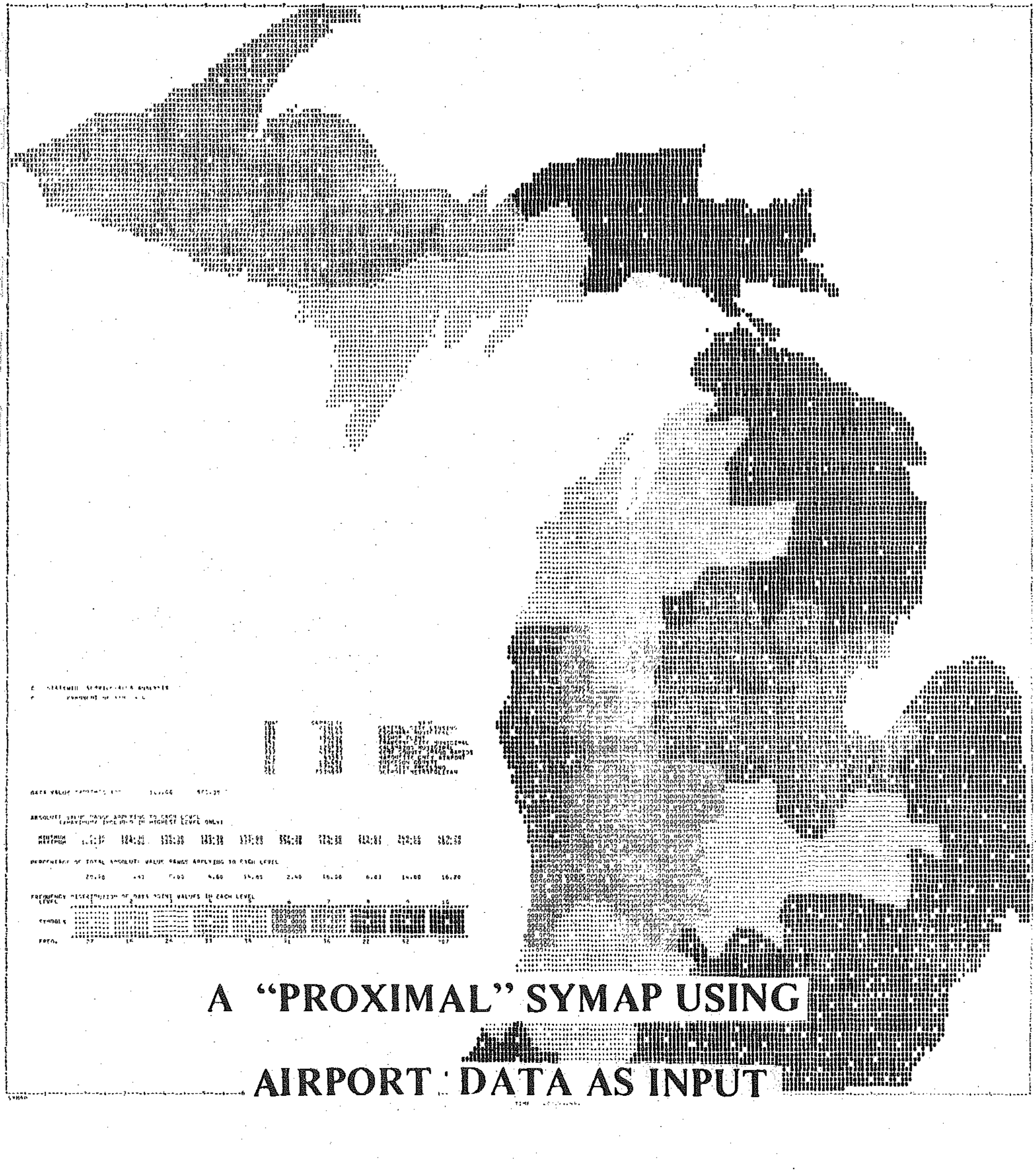
A "CONTOUR" SYMAP USING POPULATION DATA AS INPUT

FIGURE 29



A "CONFORMAT" SYMAP USING HOSPITAL DATA AS INPUT

FIGURE 30



A "PROXIMAL" SYMAP USING AIRPORT DATA AS INPUT stratification and the proximal technique of centroid association. Using this method, a zone's accessibility to the state driver becomes visually obvious. The expansion (from one alternate highway proposal to the next) of those time bands nearest the analysis zone indicates a greater degree of driver accessibility to the analysis zone. Likewise, an expansion of those bands farthest from the analysis zone (at the expense of other time bands) indicates that accessibility to the selected zone has been impaired.

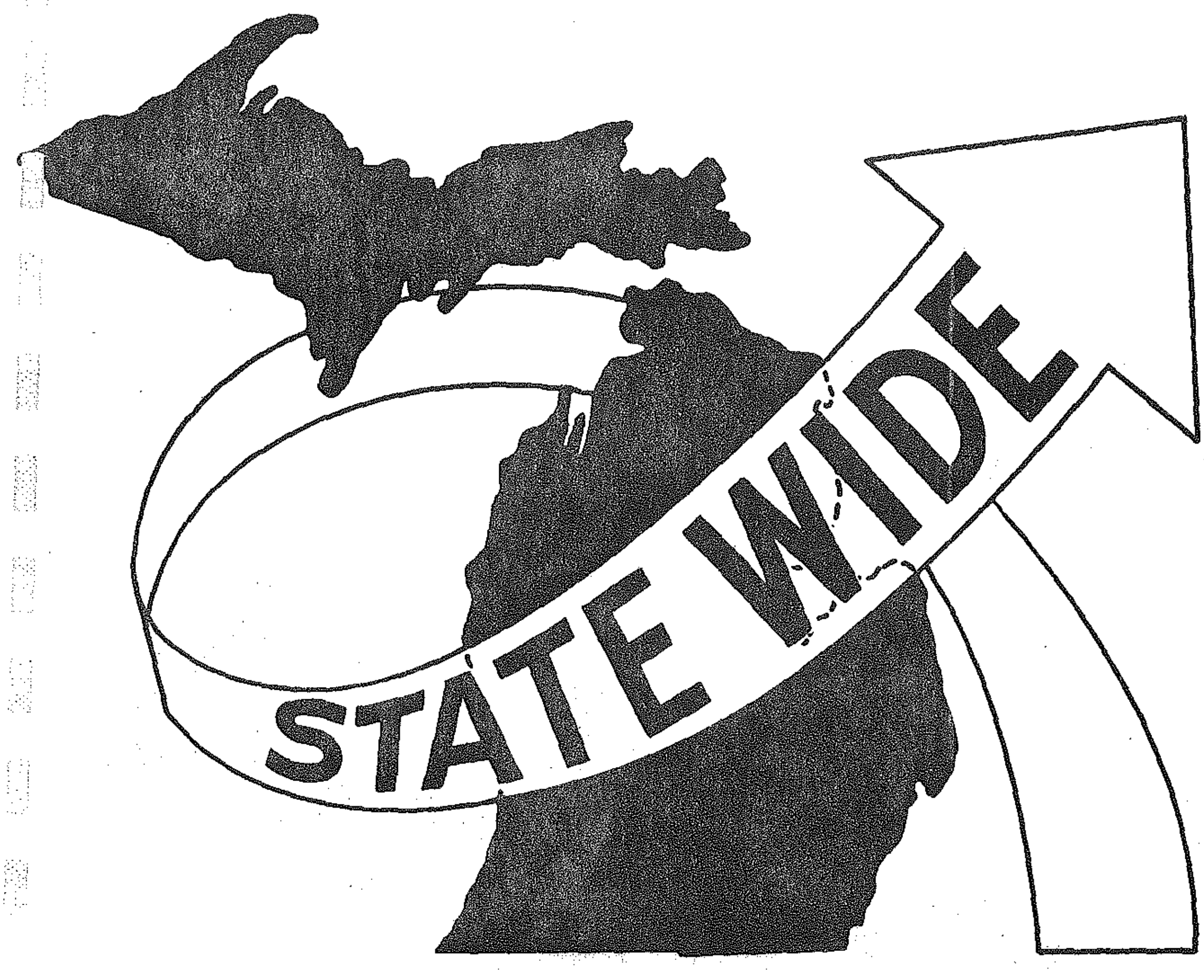
16) Population Shed

As previously suggested, the list of statewide impact indicators is constantly being updated to include newly developed and revised measures. Most other indicators included in this report have received attention in preceding documents, but the concept of a "population shed" is totally new. Its full potential is not realized here - this is not a definitive statement regarding its use. It is submitted to obtain whatever feedback it may deserve from those parties who believe it to have a fuller application in their particular area of concern.

The transportation planning computer program #1405, typically used to "load" trips to the network, was manipulated so as to (instead) allow the loading of total zonal population. A zone is selected to represent the destination of the population leaving the other 507 instate zones. The path taken by these "surrogate trips" is delineated (through use of TP TREE) as the minimum highway path. Since the population of distant zones seems to accumulate in paths which, as they came closer to the selected zone, carry greater and greater amounts of population, the plotted network comes to resemble a river system (watershed) in which its headwaters are transformed into zone centroids, its flow into people and its "mouth" into the selected zone (centroid link). The term "population shed", then, was counted as a result of this seemingly direct analogy.

A network assigned in this manner indicates the maximum number of persons who, if and when given sufficient reason, could travel to the selected zone via the minimum path corridors. From the perspective of the businessmen operating in the selected zone, the more populated branches of the population shed indicates those directions in which their marketing efforts should be oriented. To the highway planner, disruption of these paths might indicate a greater possible impact on present and future statewide travel.

PROCESS APPLICATION



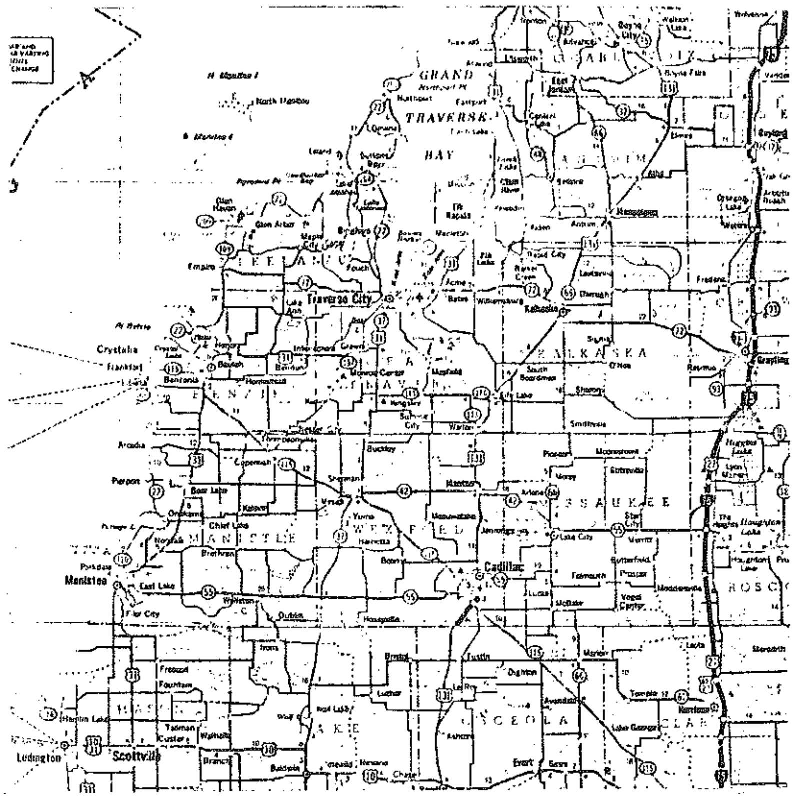
P R O C E S S   A P P L I C A T I O N

With the procedures behind the Travel Impact Analysis Process fully described, the individual techniques may now be applied to a "real world" situation. Figure 31 depicts the northwest region of Michigan's state highway network with two of three alternate proposals marked in a bold dotted line. Alternate "A" has no such line for it represents the "do-nothing", "no-build" option - i.e., the base (1970) network with no changes made in its physical description. Alternate proposals "B" and "C" incorporate into the base network not only the highway systems of the configuration shown in Figure 31 but also those highway links presently committed for near future construction. Inclusion of Alternate "A" is important in that it provides a means for comparing the "build" proposals with the present network system in determining whether the impacts created by them do, in fact, justify either of their implementations. Since the traffic volumes for each plan have been projected to the year 2000, each of the sixteen impact indicators attempt to describe the traffic situation as it might occur in that year. Zone 151, the Traverse City area, was chosen as the focus of this report's analysis - all indicators have been geared to measure the influence of the alternate highway configurations on traffic patterns to/from/in and around this study area.

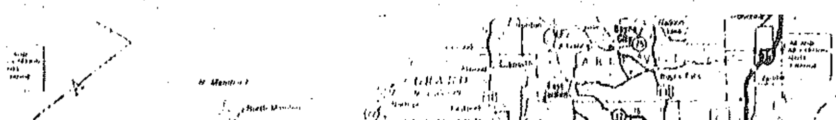
When monitoring projected travel impacts, an analyst normally can request regional and/or state plots at any scale he desires. But since larger network plots, when reduced to report size, lose their legibility, this exemplary analysis has restricted its numeric plotter output to a single, rather than small, portion of the M-37 travel corridor (see Figure 32). Other graphic techniques depicting link, regional, or state impacts will utilize the study area whenever possible, but will focus on other major

FIGURE 31

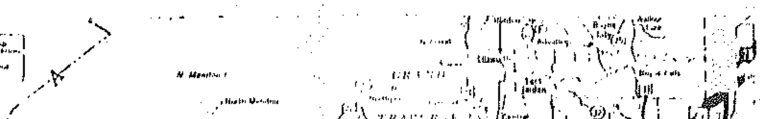
HIGHWAY CONFIGURATIONS



ALTERNATE "A"



ALTERNATE "B"



ALTERNATE "C"

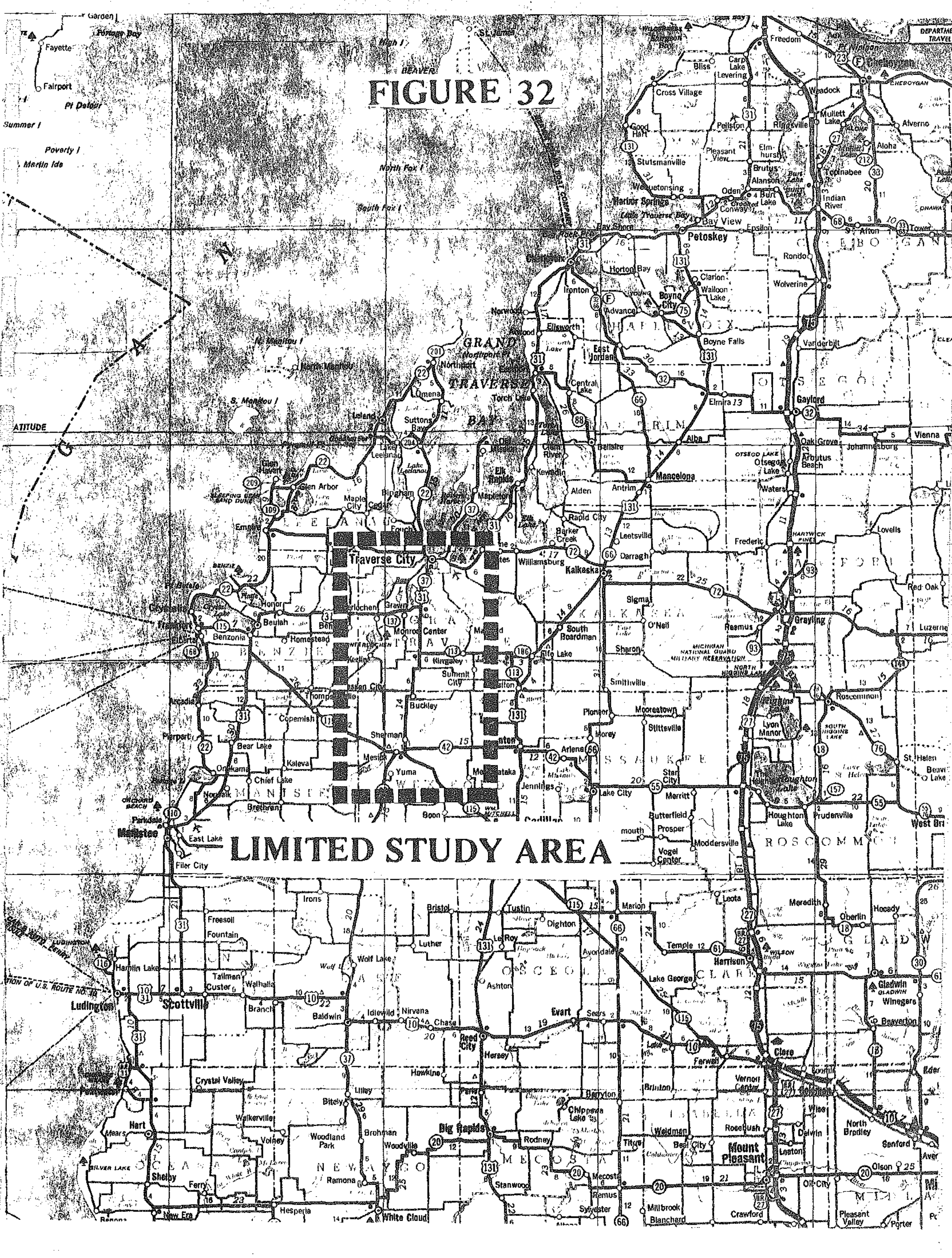


FIGURE 32

corridors if and when, for the sake of discussion, they prove more useful.

A word of caution. The purpose of the following analysis is not to actually choose a "best" highway proposal - - there are many socio-economic factors not discussed here which must be carefully considered in the making of that final determination. This analytical exercise was performed as a means of demonstrating the present abilities of the travel impact modeling process and to show how these techniques may systematically provide the highway planner with insight into the many traffic problems currently facing his department.

1) Highway Volume Deficiency

Certain options within the computer program TP1153 of the Graphics Display Battery permits its user to plot the contents of any network volume field along specified network links. By keying the program to volume field #23, which contains the V/C ratio discussed above, a computer map may be created which depicts all those network links which have a V/C ration greater than one. Figures 33, 34 and 35 show statewide deficiency maps for the three alternates under study. Alternate A, having fewer highway miles was expected to produce a plot which would indicate a network with a greater number of link deficiencies. Indeed, this proved to be the case. Although a statewide travel impact may be observed with a close examination of the three networks, the greatest deficiency difference between Alternate A and the two other proposals appears in the northwest region. Notice the number of alternate network links which, by the turn of the century, are expected to become deficient within the major north-south regional corridors (see Figure 36). Now compare how many of these deficiencies have been removed with the simulated construction of the high capacity freeways. The number is significant.

FIGURE 33

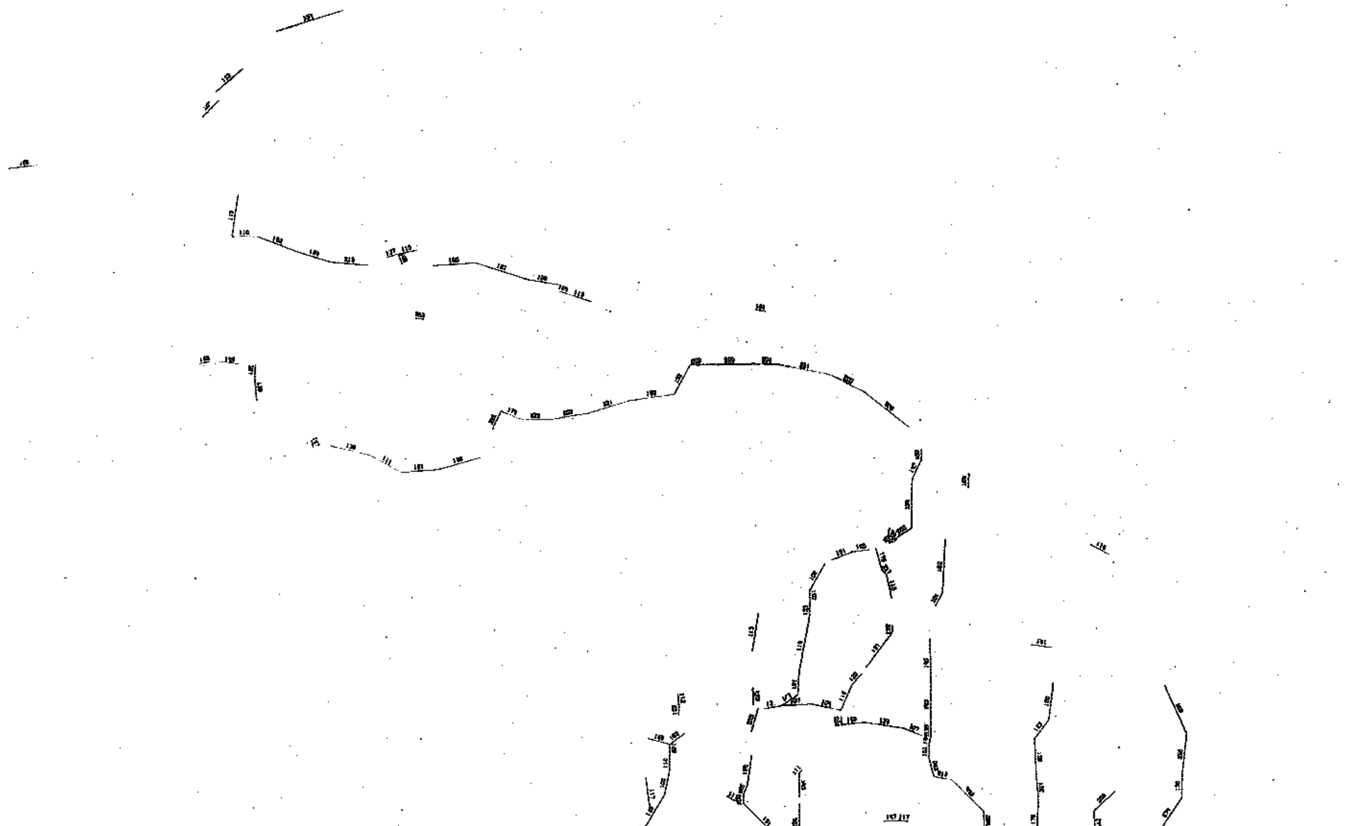


FIGURE 34

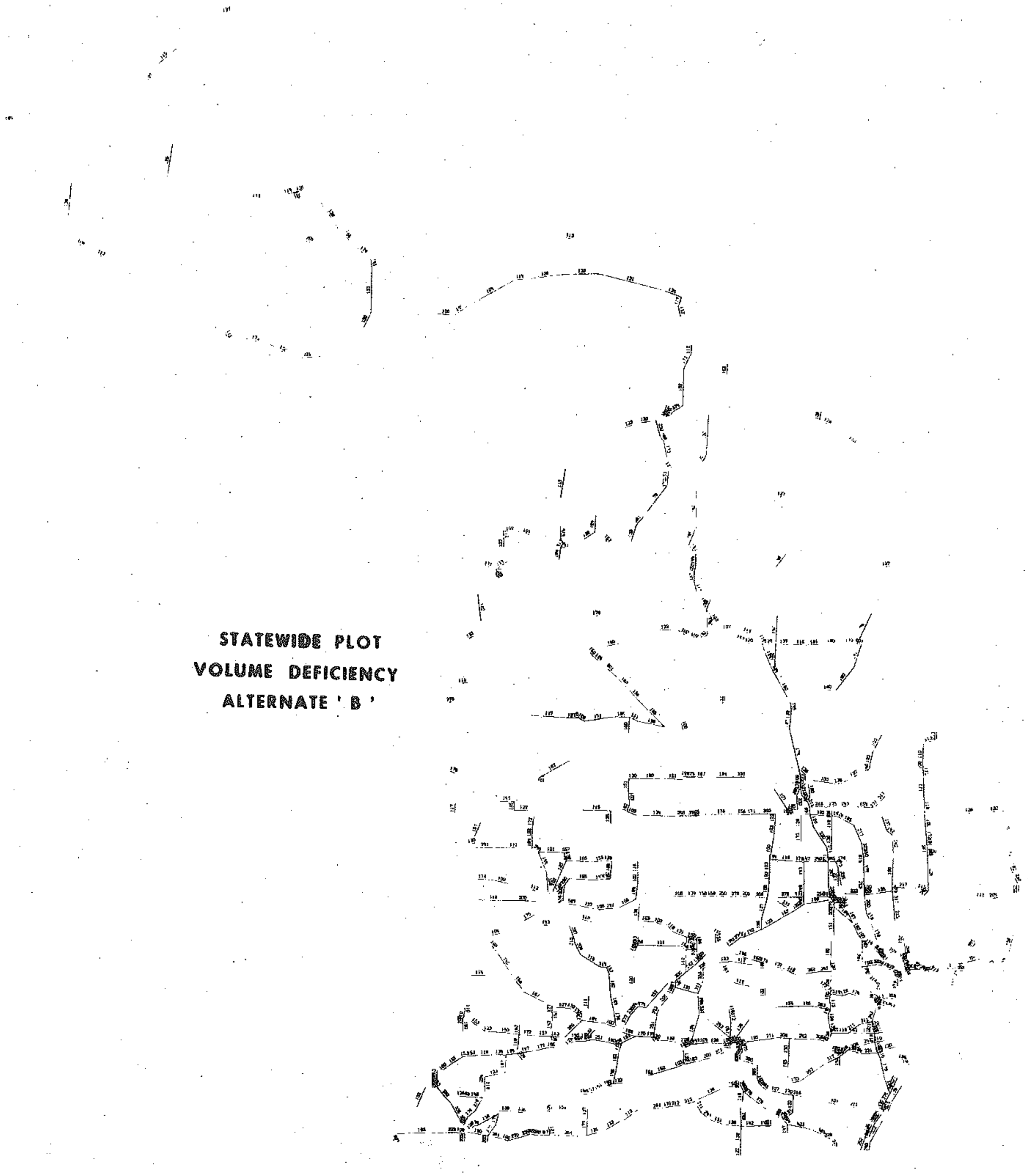
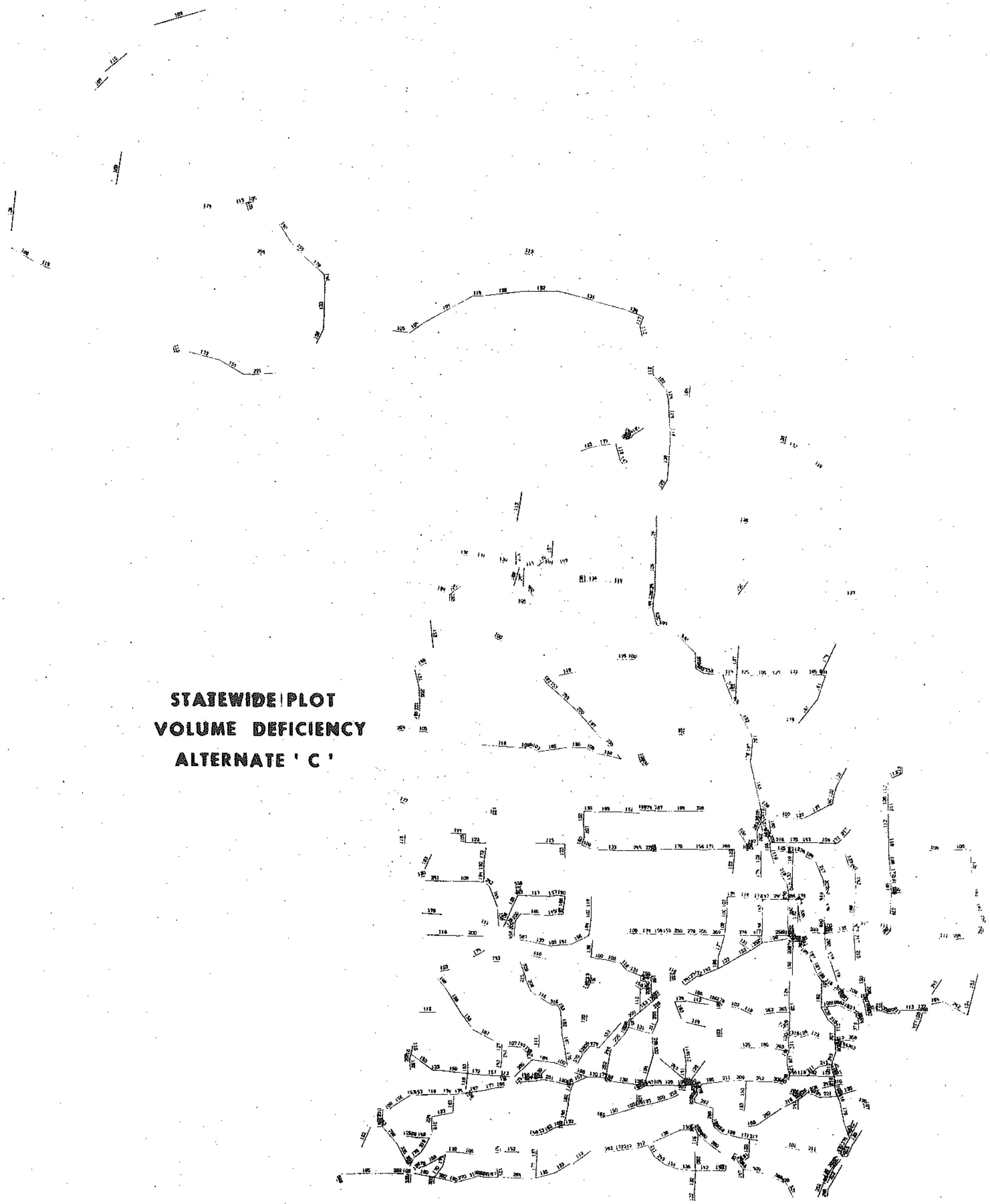


FIGURE 35



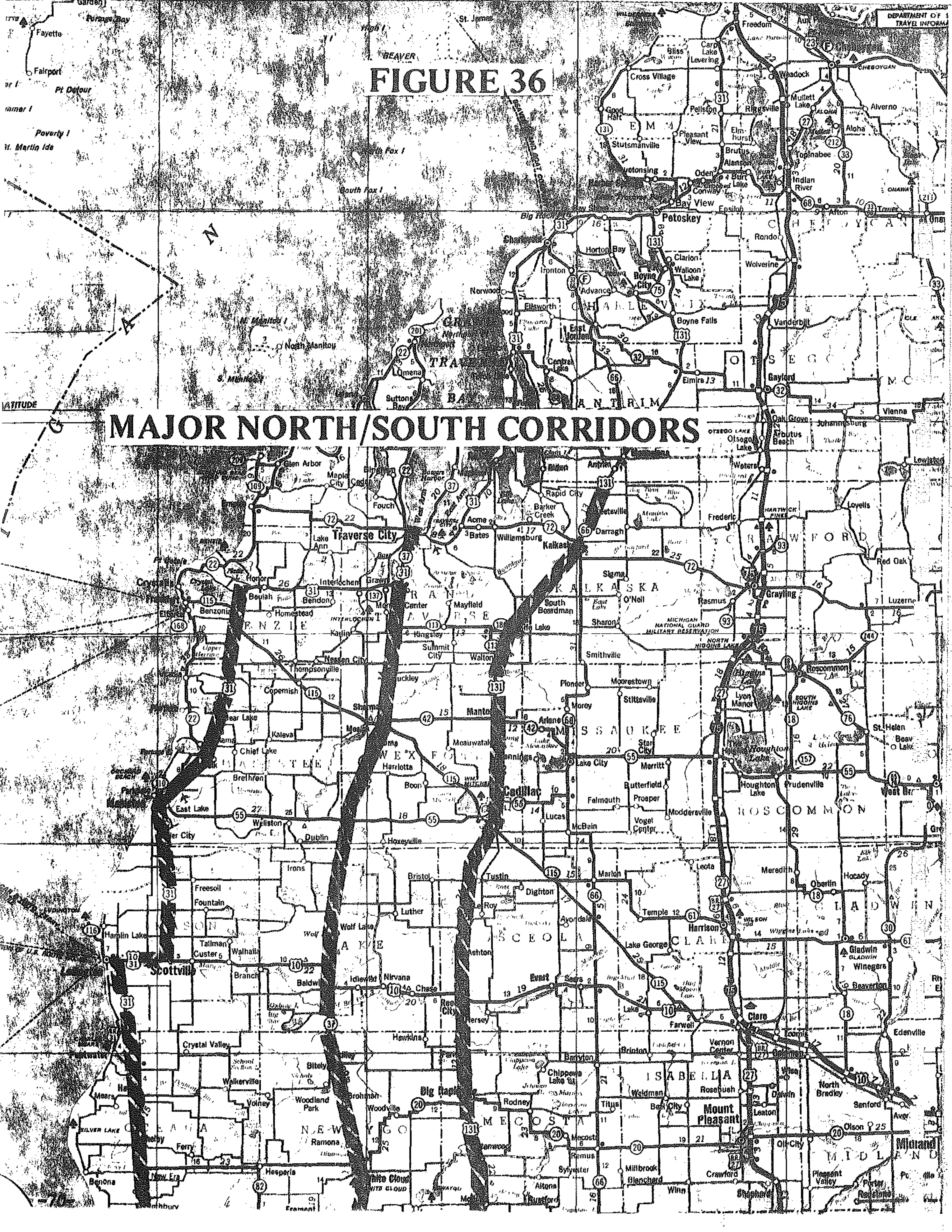


FIGURE 36
MAJOR NORTH/SOUTH CORRIDORS
Fayette
Fairport
St. James
Freedom
Cross Village
Pellston
Stutsmanville
Pleasant View
Brutus
Alanson
Oden
Conway
Bay View
Petoskey
Mullett Lake
Alverno
Aloha
Topinabee
Indian River
Afton
Tower
Charlevoix
Horton Bay
Ironton
Clarion
Walloon Lake
Boyne City
Advance
Norwood
Ellsworth
Wolverine
Rondo
Vanderbilt
Boyne Falls
East Jordan
Central Lake
Elmira
North Manitou
Gaylord
Suttons Bay
ANTRIM
OTSEGO
Vienna
Johannesburg
Oak Grove
Otsego Lake
Arbutus Beach
Waters
Glen Arbor
Maple City
Cedar
Elmwood
Antrim
Bellaire
Rapid City
Barker Creek
Acme
Bates
Williamsburg
Kalkaska
Darragh
Fouch
Traverse City
Lake Ann
Frederic
Lovells
CRAWFORD
Honor
Beulah
Benzonia
Frankfort
Elberta
Homestead
Bendon
Interlochen
Grawn
Mayfield
Kingsley
Summit City
Sigma
KALKASKA
O'Neil
South Boardman
Sharon
Rasmus
Grayling
Luzerne
Red Oak
Thompsonville
Copemish
Nessen City
Walton
Smithville
Buckley
Bear Lake
Kaleva
Chief Lake
Manistee
Mesick
Harrietta
Manton
Pioneer
Moorestown
Stittsville
Morey
Arlene
MISSAUKEE
Lake City
Merritt
Butterfield
Prosper
Roscommon
St. Helen
Cadillac
Brethren
East Lake
Wellston
Dublin
Boon
Falmouth
Lucas
McBain
Moddersville
Vogel Center
Houghton Lake
Prudenville
West Branch
ROSCOMMON
Hoxeyville
Irons
Freesoil
Fountain
Bristol
Tustin
Dighton
LeRoy
Marion
Leota
Meredith
Oberlin
Hocady
Luther
Wolf Lake
Avondale
Temple
Harrison
Hamlin Lake
Ludington
Tallman
Custer
Walhalla
Scottville
Branch
Idlewild
Nirvana
Baldwin
Chase
Reed City
Ashton
OSCEOLA
Evart
Sears
Lake George
CLARE
Gladwin
Winegars
Beaverton
Hersey
Hawkins
Lake
Farwell
Clare
Crystal Valley
Pentwater
Bitely
Walkerville
Barryton
Brinton
Chippewa Lake
ISABELLA
Vernon Center
Edenville
Hart
Mears
Volney
Woodland Park
Brohman
Woodville
Big Rapids
Rodney
Weidman
Rosebush
North Bradley
Sanford
Mount Pleasant
Leaton
Shelby
Ferry
Ramona
NEWAYGO
MECOSTA
Mecosta
Remus
Oil City
Midland
Olson
Benona
New Era
Hesperia
White Cloud
Sylvester
Millbrook
Blanchard
Crawford
Pleasant Valley
Austin
Rustford
Winn
Shepherd

The figure annotated along each link is the V/C ratio calculated through the network specific travel input. A link may be deficient for all three networks but the degree to which it is so, may vary from network to network. It should be noted that the addition of a freeway configuration is not only likely to reduce the total number of deficient links within the system, but also has a tendency to redistribute them. This phenomenon is commonly observed within the output of all the modeling techniques discussed in this report. Alternate configurations impact the building of the minimum paths between zones and determine the patterns in which traffic is assigned to the network. Therefore, although the plots of Alternate B and C indicate that volume deficiencies on the whole have been reduced, they also show that several links which were not considered deficient within the base network have become so within either of the alternate proposals as a result of this traffic reassignment/redistribution.

If something other than a quick visual analysis is desired, reference could be made to a printed listing (optionally produced) which gives details of the network in question. From this, one could determine the exact number of deficient links, their total mileage, their type, and any other bits of descriptive data associated with each network link. Typically, volume deficiency analysis is recognized for what it is -- a general indicator. It is meant simply to point out those areas expected to provide the planner with the most difficulty. It suggests areas where further analysis is necessary.

2) Level of Service

A special revision of the computer program TP1153 may be "set up" to create what is known as a "bandwidth" plot. A plot of this nature requires its user to know the range of the data to be mapped so as to permit its stratification into as many as ten discrete categories. A Level of Service Bandwidth Plot is produced by keying the plotter program on the volume field which contains the output from the Level of Service Model (discussed in the previous section). From that discussion, it is known that the best service level any road is capable of giving is represented numerically by a "one" and, conversely, the worst service level by a "six". The three regional bandwidth plots shown in Figures 37, 38, and 39 use bands (lines) to represent the Level of Service experienced by each of the network links - - a single line denotes a service level of 1(A), two lines - service level 2(B), etc. This approach to plotting data on the network provides a strong visual impact and simplifies the task of monitoring change from one network to another. Other examples of its use are demonstrated below.

Alternate A indicates that by the year 2000, if no additions/deletions are made to the present network, the service level experienced by motorists in the test region, while not completely intolerable, will, on many of the major routes, be considerably less than satisfactory. With the simulated construction of the alternate freeway configurations, this situation is significantly changed. Notice the impact that has occurred on those regional travel corridors which are parallel to the new facilities. Many of the links which were expected to experience a congested service level of D or above have dropped to a pleasant level of C or below. The reason for this, of course, is tied to the phenomenon of traffic redistribution/reassignment. By connecting the same regions as did the old routes, these alternates have reduced travel time between the areas to a point in which much of the traffic apts for the now faster roadway. Their higher capacity permits the passage of traffic at much greater volumes without the concomitant increase in service level.

FIGURE 37

LEVEL OF SERVICE
BANDWIDTH PLOT
ALTERNATE "A"

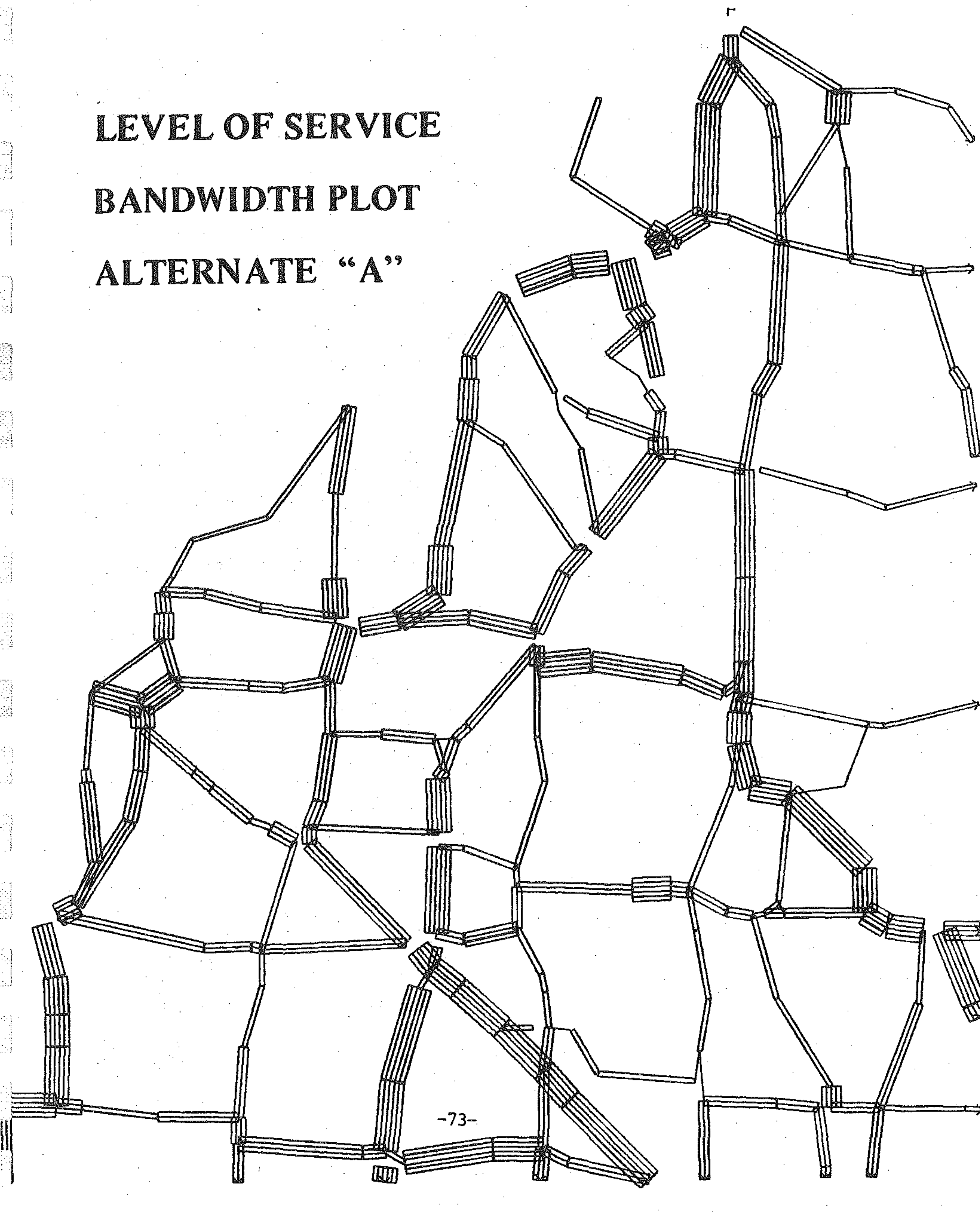


FIGURE 38

LEVEL OF SERVICE
BANDWIDTH PLOT
ALTERNATE "B"

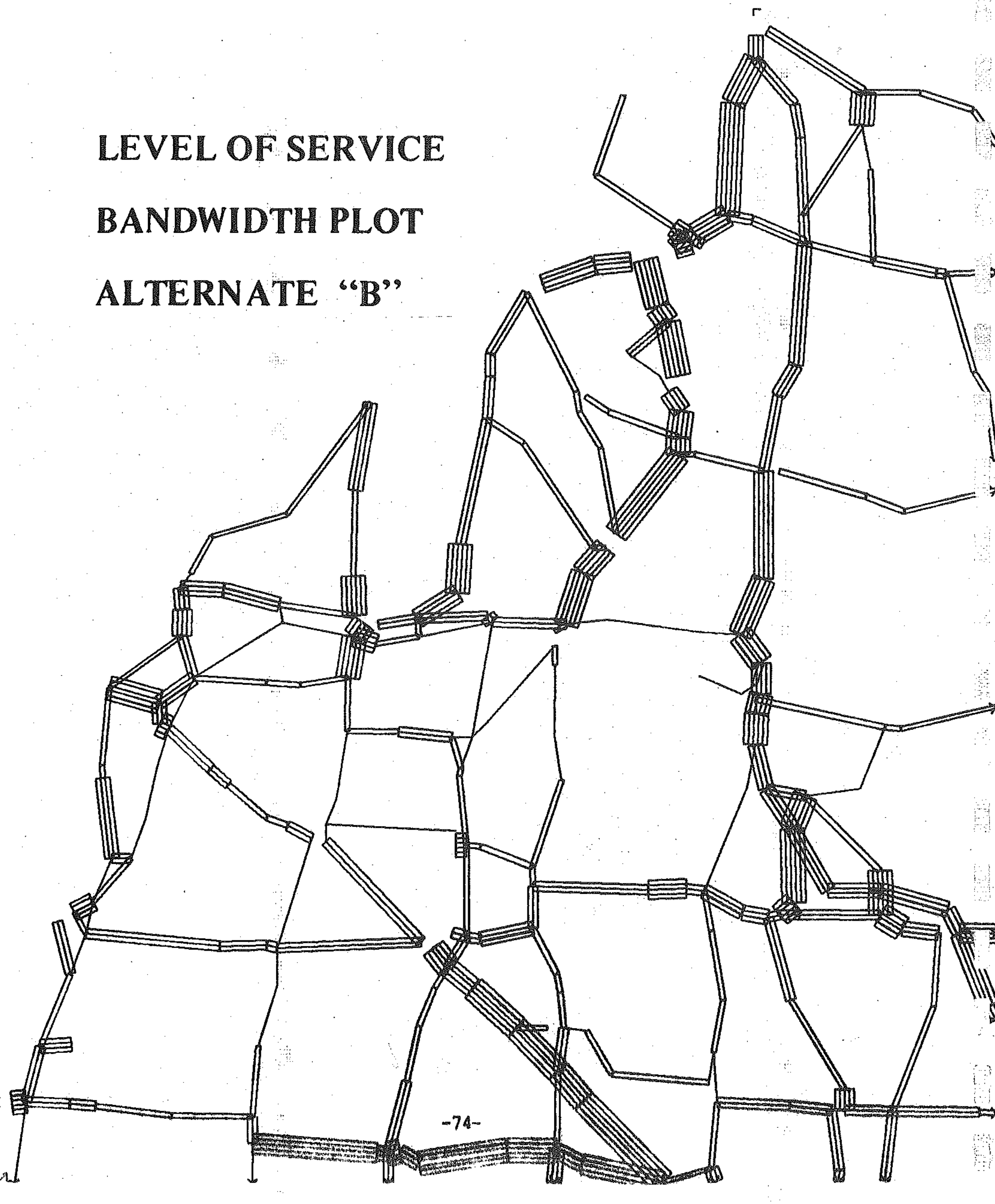
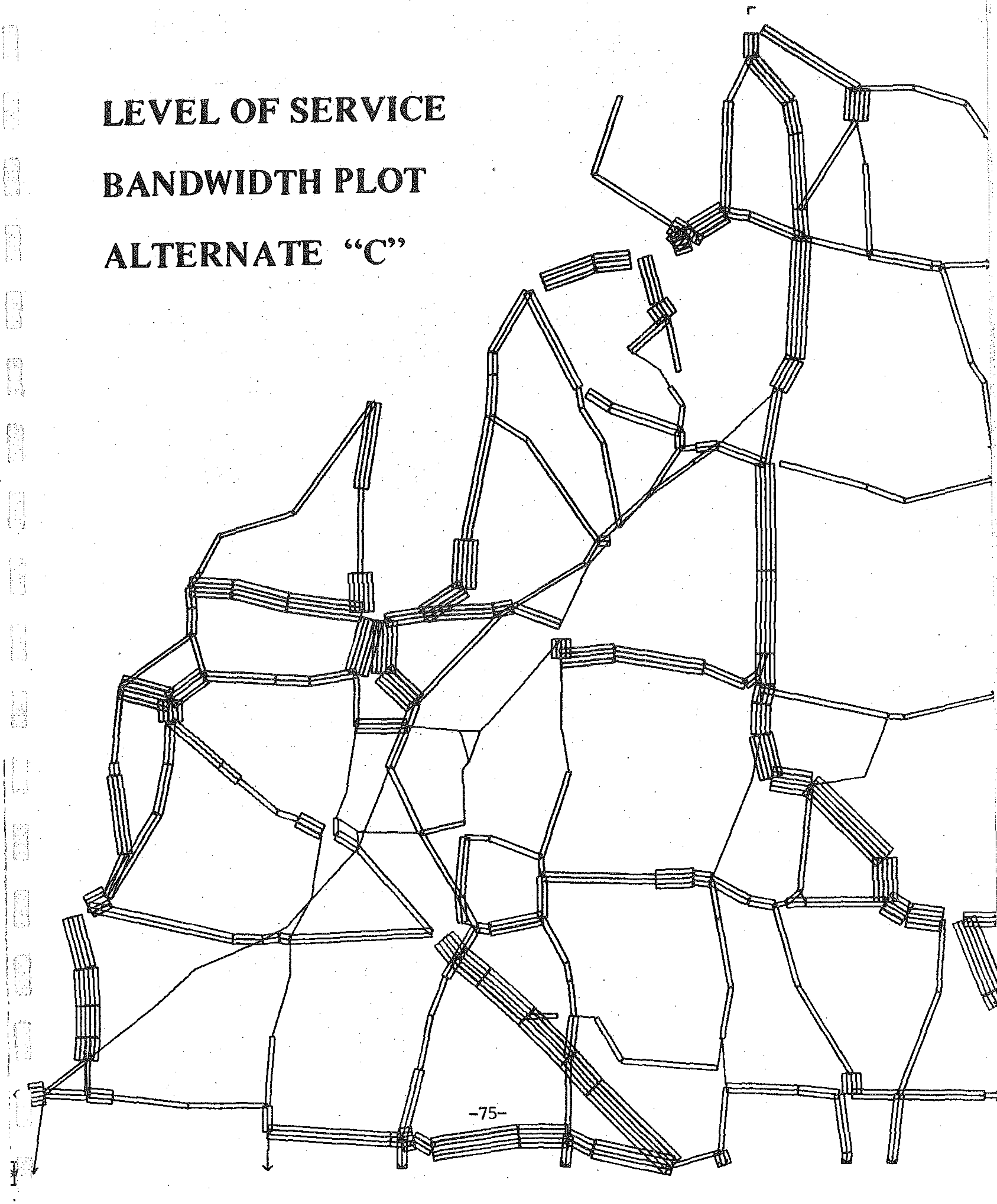


FIGURE 39

LEVEL OF SERVICE
BANDWIDTH PLOT
ALTERNATE "C"



3) Effective Speed

The Effective Speed Plots for the three alternates shown in Figures 40, 41, and 42 were again produced by the standard computer program TP1153. The Highway Network Model, one of the four basic sub-models within the traffic forecasting system, has coded in one of its twenty-five link descriptive volume fields an average speed experienced by motorists under "normal" driving conditions. This figure is annotated below each of the study area links. The output from the Effective Speed Model appears above each network link. The difference between the two figures gives one an indication of the speed expected to be experienced by motorists in an area as a result of a simulated road construction and projected traffic volumes. In Alternate A, the lack of additional roadways has caused many of the major travel routes to become congested to a point in which the model predicts traffic will be slowed to a maximum of 30 mph. (Actually, many links may become congested beyond this point, but the model has been designed to "bottom out" at this level.) The additional freeway links in both alternates B and C relieve pressure on the M-37 travel corridor such that speed levels are projected to once again approach or equal the average coded rate.

The output from the Highway Volume Deficiency analysis and the Level of Service Model seems to indicate that Alternates B and C, if constructed, would provide enough new roadway to, in many cases, more than adequately handle the projected traffic. Since these techniques share with the Effective Speed Model a common basis (i.e., the V/C ratio), it should come as no surprise that these three types of network plots have similarities which are readily apparent. For example, a link that is deficient according to the criteria established for conducting the Highway Volume Deficiency

FIGURE 40

EFFECTIVE SPEED

NUMERIC PLOT

ALTERNATE "A"

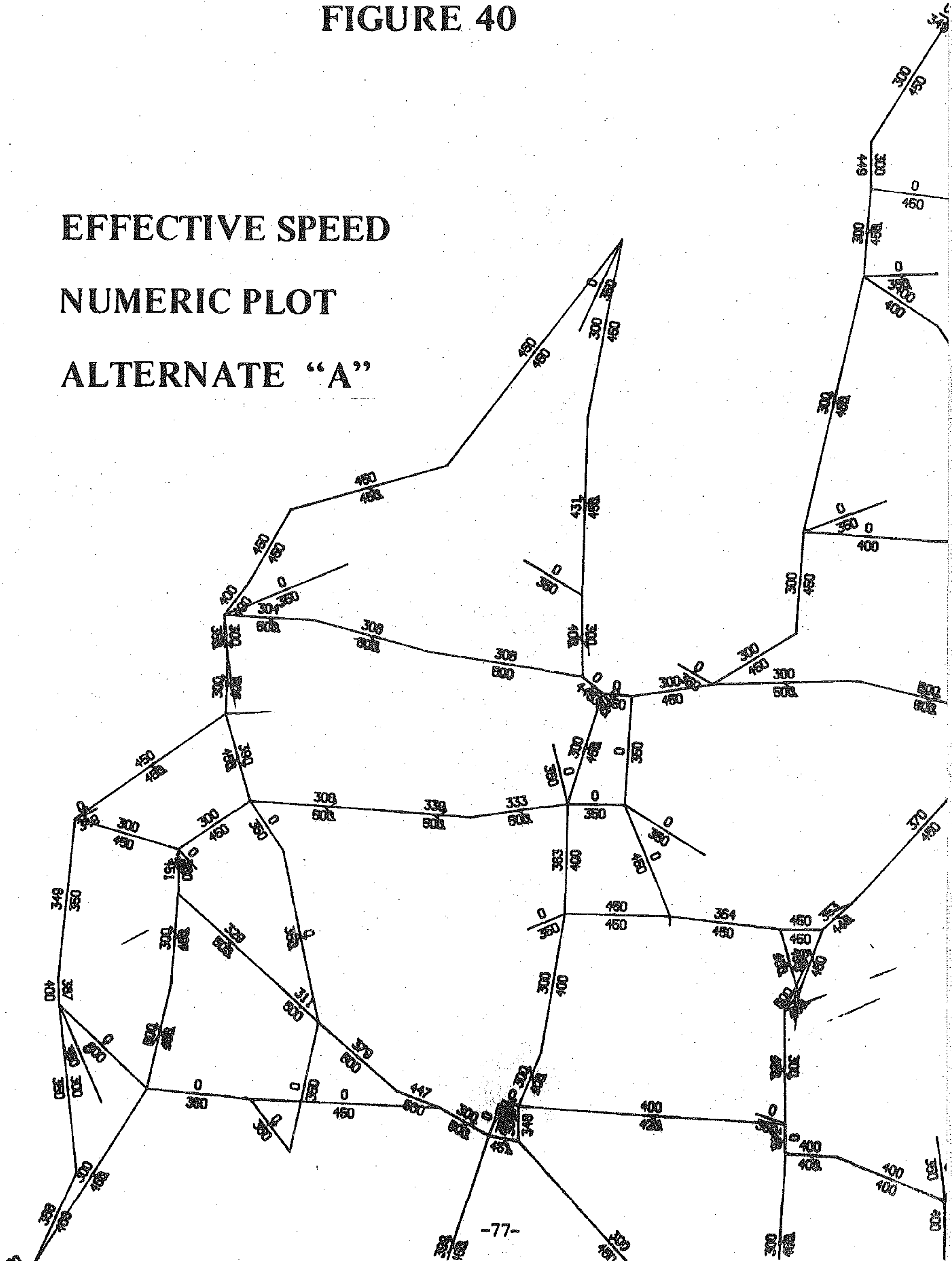


FIGURE 41

EFFECTIVE SPEED NUMERIC PLOT

ALTERNATE "B"

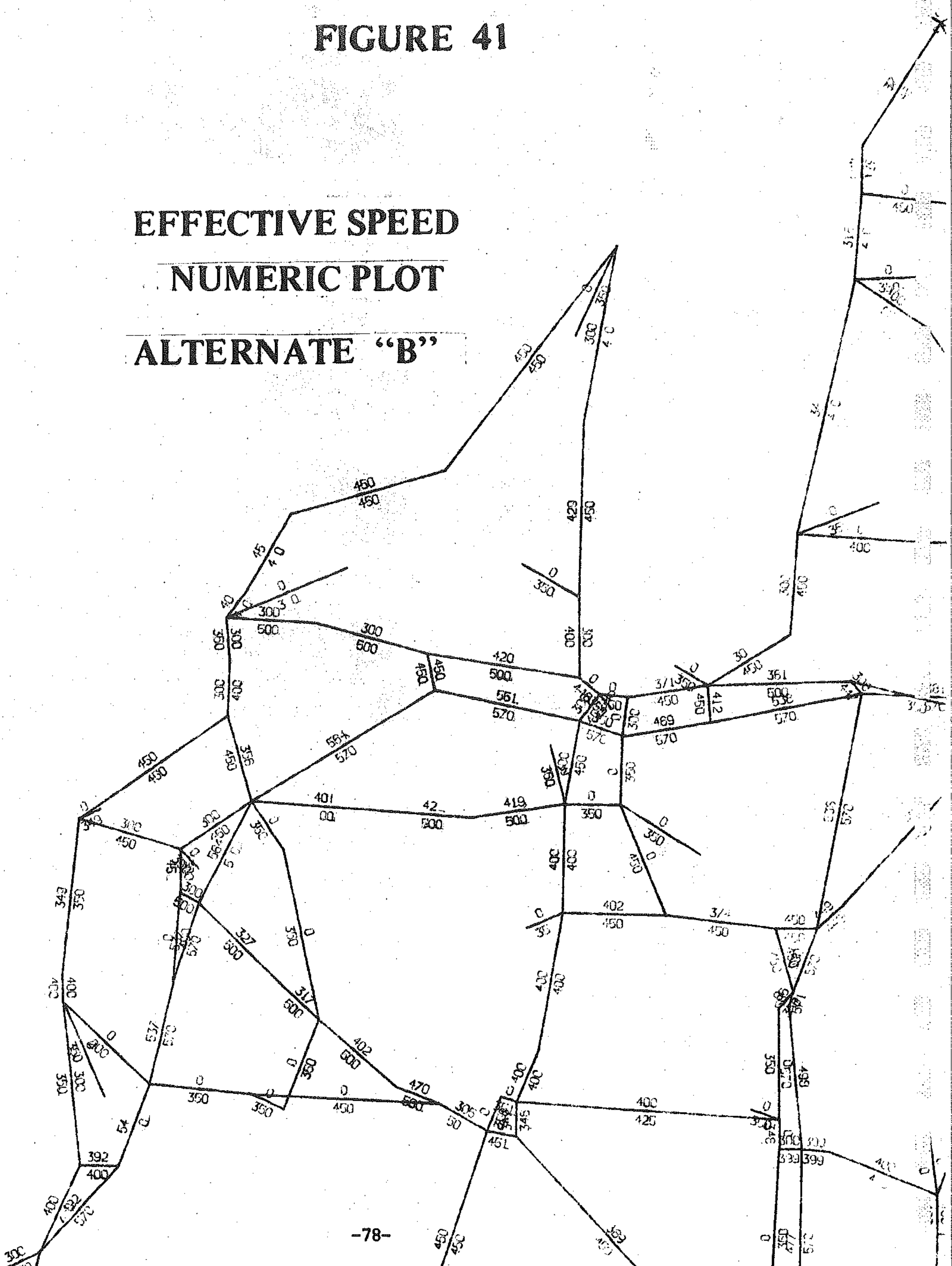
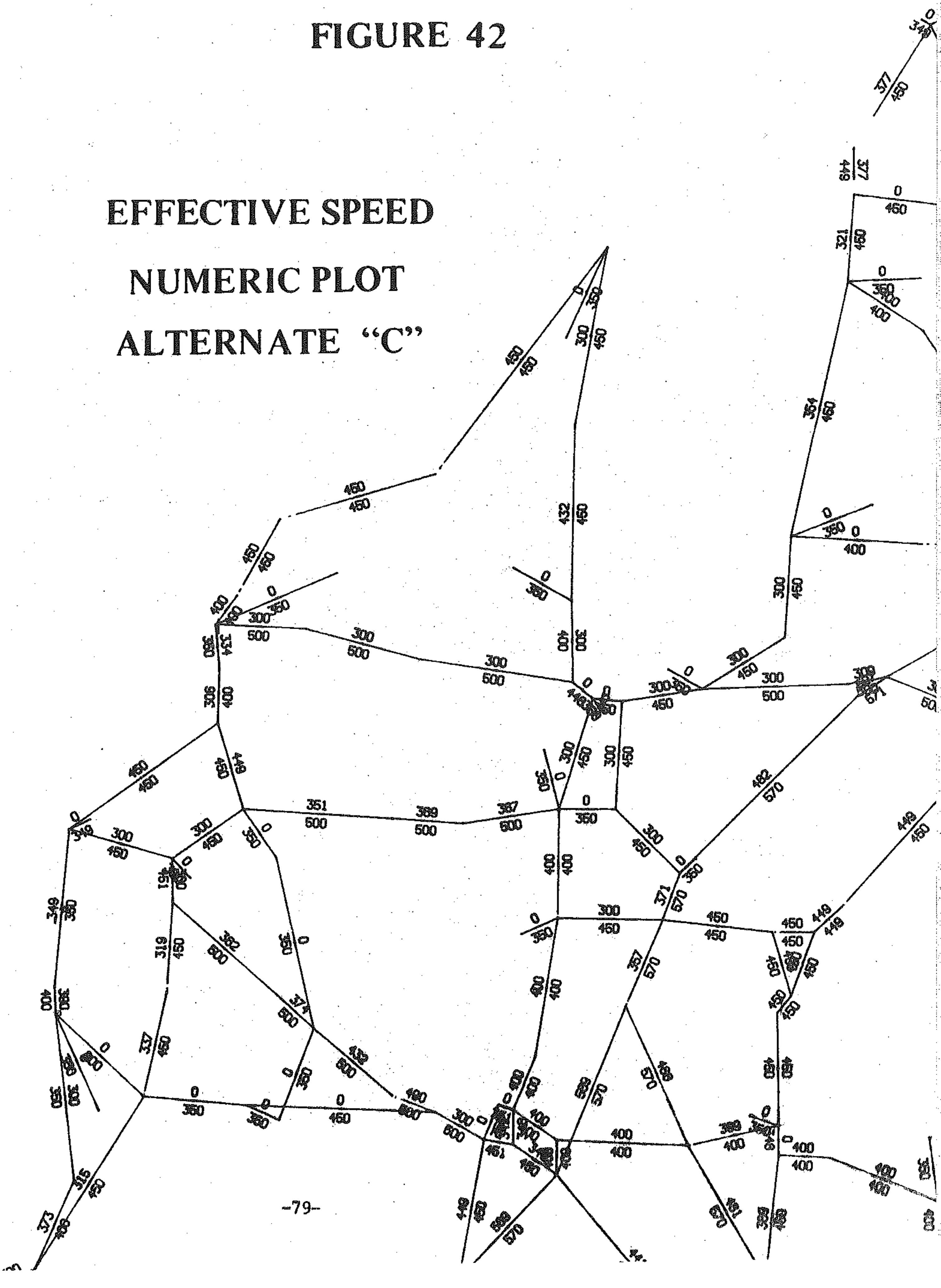


FIGURE 42

EFFECTIVE SPEED NUMERIC PLOT ALTERNATE "C"



Analysis will likewise be deficient (that is, have a service level of D(4) or below when the Level of Service Model is run). Those links shown to be deficient through either the Highway Volume Deficiency Analysis or the Level of Service Model will also experience a reduction in "normal" driving speeds proportional to the amount of traffic congestion experienced - the greater the indicated deficiency, the lower the probable running speed on those links will be. By comparing the Level of Service Plots to those of the Effective Speed Model, this relationship is verified - each link which was expected to have an improved service level, also experienced an increase in driving speed. Alternates B and C markedly improve the projected V/C ratios and therefore traffic congestion/speeds on many portions of the major travel corridors.

4) Capacity Adequacy Model

The Level of Service Model and Highway Volume Deficiency Analysis are techniques which give one a very general idea of total network deficiency. With both, the analyst is told that when certain links experience a V/C ratio, greater than one, they (the links) should, for all practical purposes, be considered inadequate. Since volumes are expressed in terms of the DHV, persons familiar with these techniques know that a link specified as being deficient will actually only be so when the 30th higher volume hour (DHV) is met or exceeded. As was stated previously, the number of days in a year in which the DHV is equaled or surpassed is tied to the amount of link-specific variation in daily traffic. (See the explanation presented in the previous section.) Without this knowledge, the inexperienced may mistakenly believe that the predicted network levels of deficiency occur <u>every</u> day. Under a given set of conditions, this, of course, is possible but not necessarily is it always the case.

The capacity adequacy model is designed to give yearly link deficiency information - to give the analyst an indication of the actual magnitude of network deficiency. It delineates a subset of the total set of deficient links by indicating which are most inadequate in terms of the number of days in a year volume exceeds capacity. (Inadequacy as used here refers to the number of deficient days in a year - not to the amount by which volume exceeds capacity!). The level of service plot may, for example, shows that each of three seemingly similar network links experience congestion equal to level of service D. How is the highway planner to determine which of these deficiencies is best removed first? By plotting data from the capacity adequacy model, the question becomes academic. Due to fluctuation in daily traffic (or lack thereof), each of the three roads may have a V/C ratio such that the model predicts deficiencies of ten, one hundred, or three hundred days a year respectively. Obviously, when the magnitude of the deficiency reaches nearly a year, it demands the soonest possible attention. Construction project priorities are then easily distinguishable with the running of this model.

The standard network plotting program (TP1153) was employed to create the capacity adequacy plots shown in Figures 43, 44, and 45. The number annotated directly above each network link indicates its V/C ratio; the other (above the V/C ratio) is the DHV "percent" used by the model in calculating capacity deficiency; the figure beneath each link is its projected yearly deficiency. Notice link 1288-2066 - it has, for all three alternates, a DHV percent of 11 (decimal places are not indicated). The V/C ratios for each link are variable - - Alternate A equals 89, B equals 57 and C equals 77. Using this DHV percent and these V/C ratios in the capacity adequacy model to predict total yearly deficiencies, the link is shown to be inadequate

FIGURE 43

CAPACITY ADEQUACY NUMERIC PLOT ALTERNATE "A"

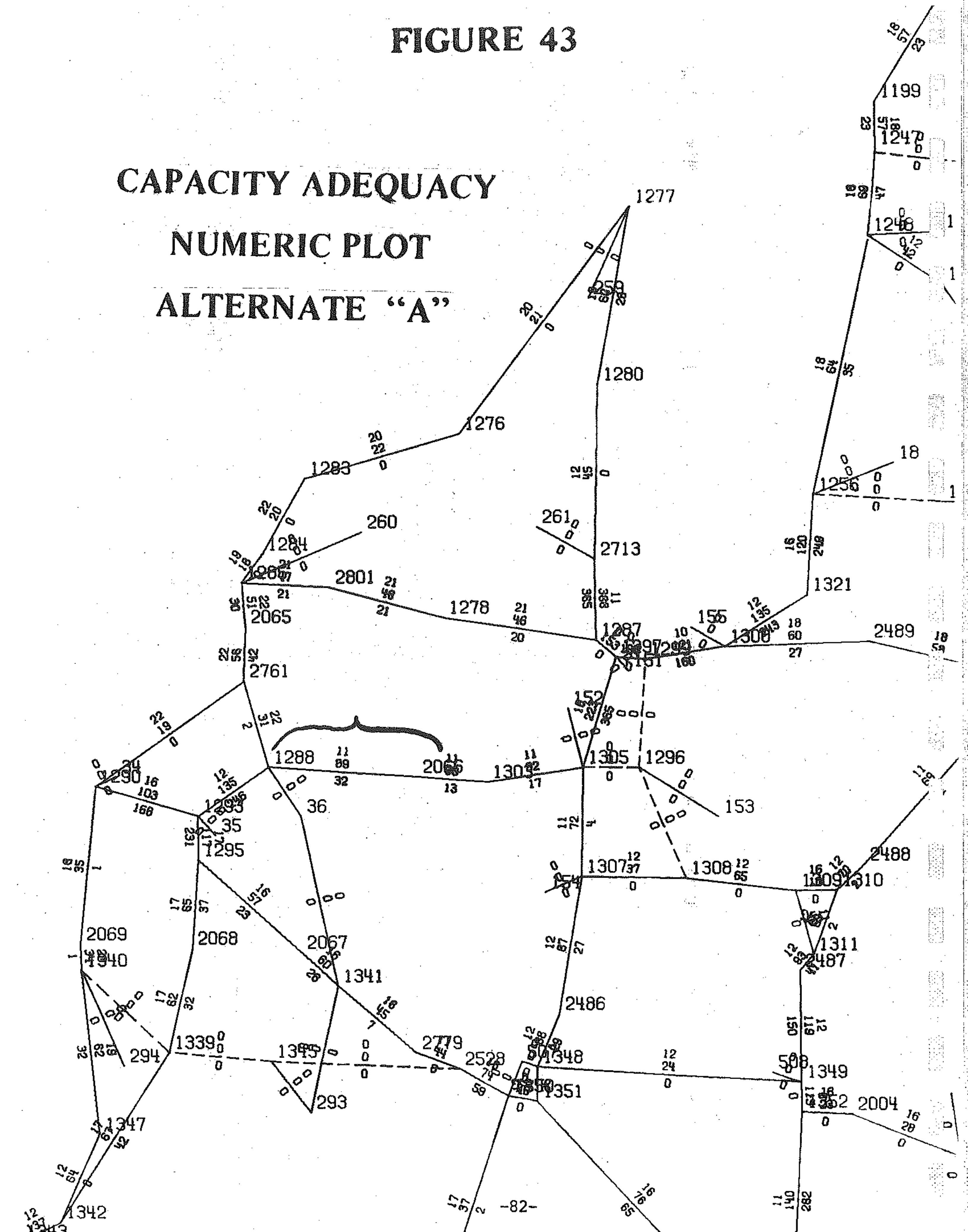


FIGURE 44

CAPACITY ADEQUACY NUMERIC PLOT ALTERNATE "B"

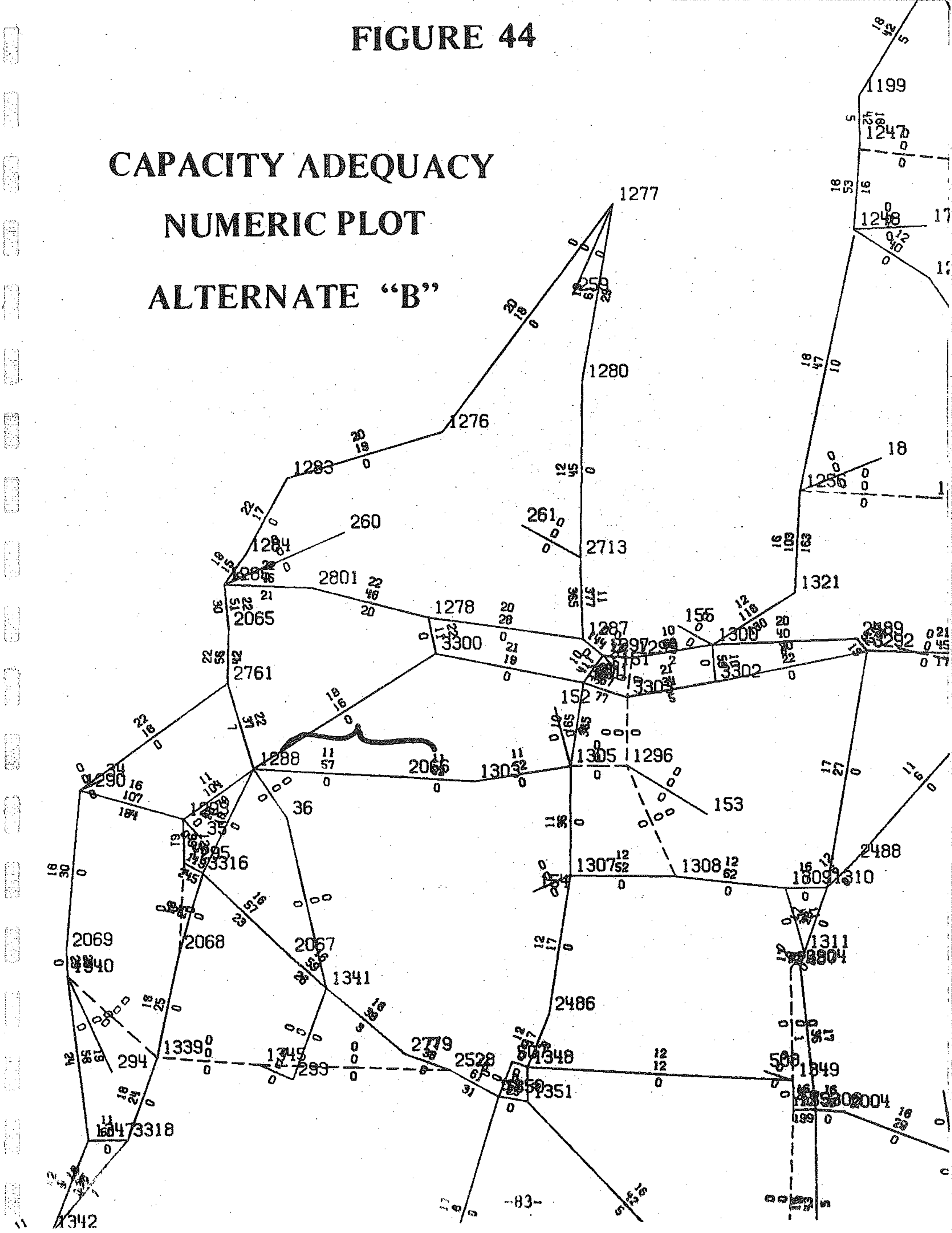
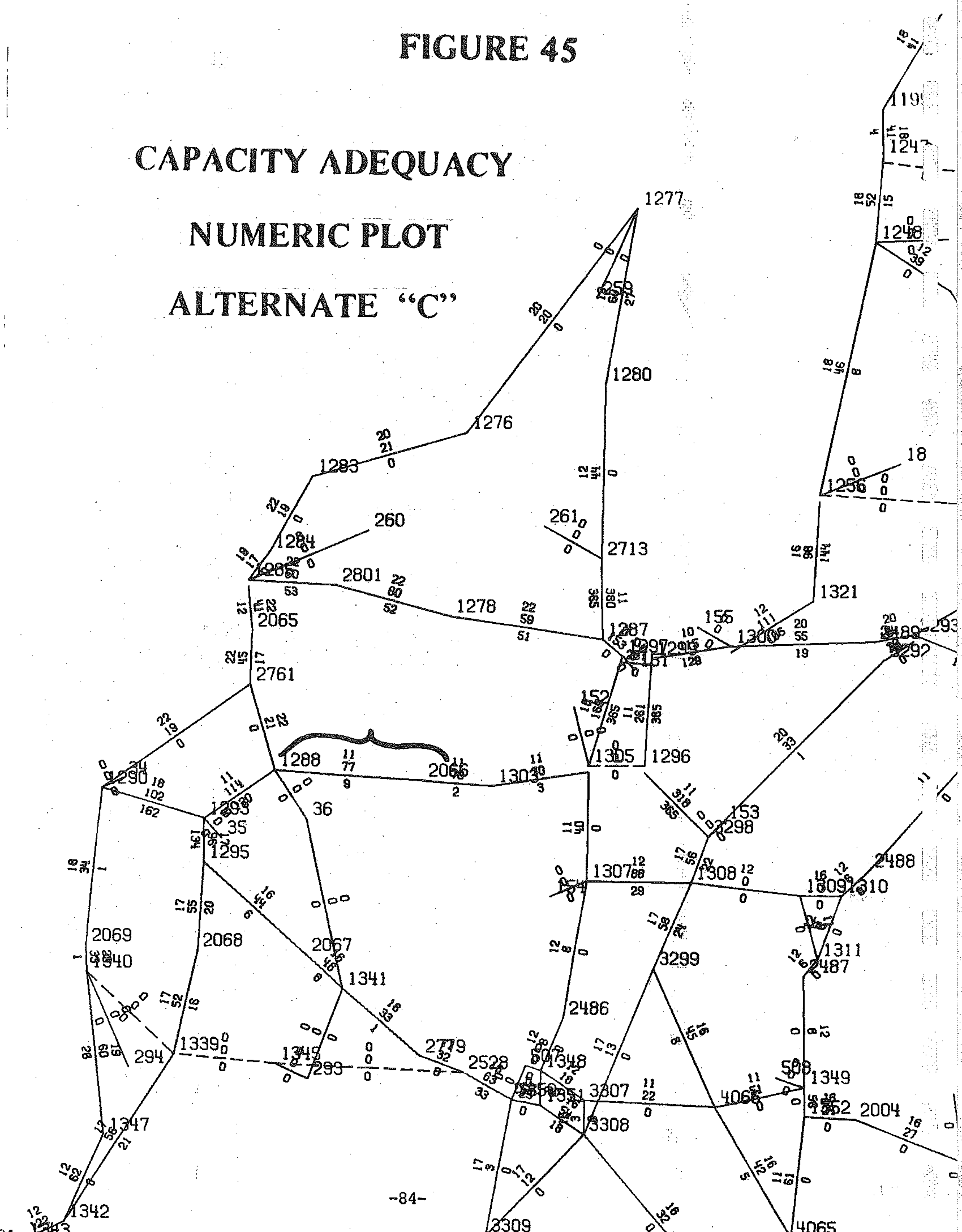


FIGURE 45

CAPACITY ADEQUACY
NUMERIC PLOT
ALTERNATE "C"



(in terms of properly handling traffic volumes) for thirty-two and nine days a year when Alternates A and C, respectively, are used as input. The link, if Alternate B were implemented, is projected to become totally adequate - that is to say, it is projected to experience the same service level year-round which, in this case, is level C. Since this level of service (experienced on each of the three study links) is acceptable, no near-future construction would be recommended. If, however, a more congested situation were observed, the Alternate A link would, obviously, have construction priority.

5) Trip Length Distribution

The level of service plots indicated that if either of the proposed alternate freeways were actually built, routes entering/leaving the Traverse City area would experience a drastic reduction in traffic. When this reduction reaches a level in which the function of the road is significantly affected, state highway officials must determine whether its continued maintenance as part of the state trunkline is truly necessary. That is, should the road be turned back to county jurisdiction? By running a TLD on a single link of the route in question, one may gather valuable information pertinent to the making of this decision. Figure 46 shows the printer maps produced by the TLD program for each of the three alternates. If no new highway construction were ever again undertaken, the distribution of trip lengths on a link of M-37 (just south of Traverse City) would be identical to that displayed as "Alternate A". The figures on the left-hand side of the graph represent ten-minute intervals and the figures to the top indicate the percent of traffic within the selected trip table which are of that trip length. A cumulative percentage for each interval is also noted to the right of the graph. The number of recorded trips range from 40 up to 850 minutes. The mean trip length has been calculated at the 240-minute

TRIP LENGTH FREQUENCY DISTRIBUTION

	P.C.	CUM.	ACTUAL
1.	0.000	0.000	0
2.	0.000	0.000	0
3.	0.000	0.000	0
4.	5.696	5.696	193101
5.	5.877	11.574	199223
6.	1.455	13.028	49316
7.	0.882	13.910	29893
8.	2.731	16.641	92580
9.	1.753	18.395	59435
10.	1.993	20.387	67549
11.	1.533	21.920	51952
12.	1.418	23.338	48062
13.	1.866	25.204	63251
14.	1.923	27.127	65202
15.	1.762	28.889	59733
16.	1.710	30.599	57970
17.	2.247	32.846	76166
18.	1.912	34.758	64802
19.	3.232	37.980	109490
20.	3.206	41.186	108693
21.	2.778	43.964	94168
22.	2.343	46.315	79416
23.	2.607	48.921	88357
24.	3.574	52.495	121143
25.	2.583	55.078	87557
26.	2.256	57.334	76481
27.	2.247	59.581	76165
28.	2.712	62.293	91941
29.	2.777	65.070	94126
30.	2.977	68.047	100915
31.	2.105	70.152	71353
32.	2.250	72.402	76262
33.	1.893	74.295	64183
34.	2.100	76.395	71197
35.	1.016	77.412	34445
36.	1.518	78.929	51447
37.	2.276	81.206	77165
38.	2.877	84.082	97521
39.	1.028	85.111	34854
40.	1.122	86.233	38046
41.	0.849	87.082	28790
42.	2.552	89.634	86494
43.	1.396	91.030	47336
44.	1.842	92.872	62444
45.	1.518	94.391	51470
46.	0.578	94.969	19602
47.	0.712	95.681	24142
48.	0.842	96.523	28531
49.	0.193	96.716	6545
50.	0.000	96.716	0
51.	0.000	96.716	0
52.	0.000	96.716	0
53.	0.025	96.741	843
54.	0.651	97.392	22079
55.	0.334	97.726	11325
56.	0.032	97.758	1083
57.	0.306	98.064	10375
58.	0.286	98.350	9682
59.	0.316	98.666	10706
60.	0.178	98.843	6031
61.	0.125	98.968	4234
62.	0.015	98.983	495
63.	0.037	99.020	1258
64.	0.103	99.124	3506
65.	0.226	99.349	7655
66.	0.119	99.468	4032
67.	0.011	99.479	369
68.	0.088	99.567	2980
69.	0.097	99.664	3293
70.	0.000	99.664	0
71.	0.023	99.687	787
72.	0.037	99.724	1245
73.	0.025	99.748	834
74.	0.000	99.748	0
75.	0.020	99.768	663
76.	0.016	99.784	536
77.	0.013	99.797	453
78.	0.000	99.797	0
79.	0.035	99.832	1203
80.	0.058	99.891	1975
81.	0.037	99.928	1254
82.	0.000	99.928	0
83.	0.029	99.957	988
84.	0.023	99.980	789
85.	0.020	100.000	673

REMAINING VALUES ARE ALL ZERO
NUMBER OF OBSERVATIONS= [illegible] SUM= 82024532. MEAN= 24.677 VAR= 196.116 SD= 14.004

FIGURE 46

ALTERNATE "A"

	P.C.	CUM.	ACTUAL
1.	0.000	0.000	0
2.	0.000	0.000	0
3.	0.000	0.000	0
4.	28.650	28.650	183681
5.	28.827	57.477	184815
6.	7.911	65.388	50717
7.	4.381	69.769	28090
8.	10.506	80.275	67355
9.	5.489	85.764	35190
10.	5.965	91.729	38245
11.	2.610	94.340	16736
12.	0.886	95.226	5681
13.	1.131	96.357	7252
14.	1.343	97.700	8611
15.	1.349	99.049	8647
16.	0.671	99.720	4304
17.	0.000	99.720	0
18.	0.280	100.000	1793

REMAINING VALUES ARE ALL ZERO
NUMBER OF OBSERVATIONS= 641117 SUM= 4095672. MEAN= 6.388 VAR= 7.748 SD= 2.764

ALTERNATE "B"

	P.C.	CUM.	ACTUAL
1.	0.000	0.000	0
2.	0.000	0.000	0
3.	0.000	0.000	0
4.	58.674	58.674	174921
5.	30.202	88.876	100624
6.	8.716	97.591	27884
7.	0.000	97.591	0
8.	0.000	97.591	0
9.	2.409	100.000	7207

REMAINING VALUES ARE ALL ZERO
NUMBER OF OBSERVATIONS= 119215 SUM= 1403362. MEAN= [illegible] VAR= 0.887 SD= 0.942

ALTERNATE "C"

level. Other statistical measures are noted at the bottom of each graph - e.g., the standard deviation, variance, etc. Displaying a distribution of this magnitude indicates to the transportation analyst that the road is used by a great many more people than merely area residents. Though the percentage is slight, a few persons by the turn of the century are expected to travel over 14 hours before using the link in the completion of their trip.

The study link's total usage within the state network has been radically affected with the simulated highway construction. The range of trip lengths for Alternate B may be stratified by employing a mere eighteen of the ten-minute intervals - as opposed to the 85 utilized for Alternate A. The mean has been lowered to slightly over an hour while other statistical measures have similarly been reduced. By applying this comparative process to Alternate C, an even greater reduction of long distance travel on the selected link becomes apparent. The mean trip length has dropped to a little more than three quarters of an hour and approximately 90% of all trips are included within the first five ten-minute intervals.

6) Average Trip Length

The TLD program provides perhaps the best trip "profile" of any indicator within the travel impact modeling process. Several statistical measures give one an excellent description of the distribution of trips passing through each selected network link. Cost and time constraints, as suggested, prohibit its running on an extensive basis. Complete trip length information for a single link is extremely useful; for the entire network, it would be invaluable. The TP Battery discussed in the above procedures section permits one to efficiently calculate a statewide (link-specific) average trip length (ATL). Although from a pure statistical point of view, it is unacceptable to describe a trip distribution solely in terms of its mean; use of the average trip length as an impact indicator provides a valid (though admittedly incomplete) description of an entire network's trip distribution.

Calculating a network average trip length through the standard TP programs, in addition to speeding the indicators process time and reducing the cost, has another advantage over the TLD method in that it allows its input to be displayed in a network plot. A portion of the Traverse City network (Alternate A) which includes the link studied in the TLD analysis, appears in Figure 47. The numbers associated with each link is the average trip length calculated according to the procedures outlined above. Through the TLD program, the mean for the selected study link (see bottom of Figure 46) was found to equal 240.4 minutes. The same link using the shortcut method equals 240.9 minutes - a single decimal place for each figure is not indicated. The minor discrepancy, approximately 30 seconds, is due to the fact that different rounding factors were used.

The ATL and TLD methods, then, do produce very similar results. The numeric plotting program is useful when one wishes to know specific impact data characteristics of each network link. But when a quick visual analysis is all that is desired, the bandwidth approach is most beneficial. Note the three ATL bandwidth plots in Figures 48, 49, and 50. The ATL information has been stratified into ten categories - the first band represents all those links which have an ATL of 50 minutes or less; the second band includes trip lengths of 51 to 100 minutes. The third, 101-150, and so on to the tenth which depicts anything greater than 451 minutes. Although the exact number of bands composing each link has become blurred with reduction,

FIGURE 47

AVERAGE TRIP LENGTH NUMERIC PLOT ALTERNATE "A"

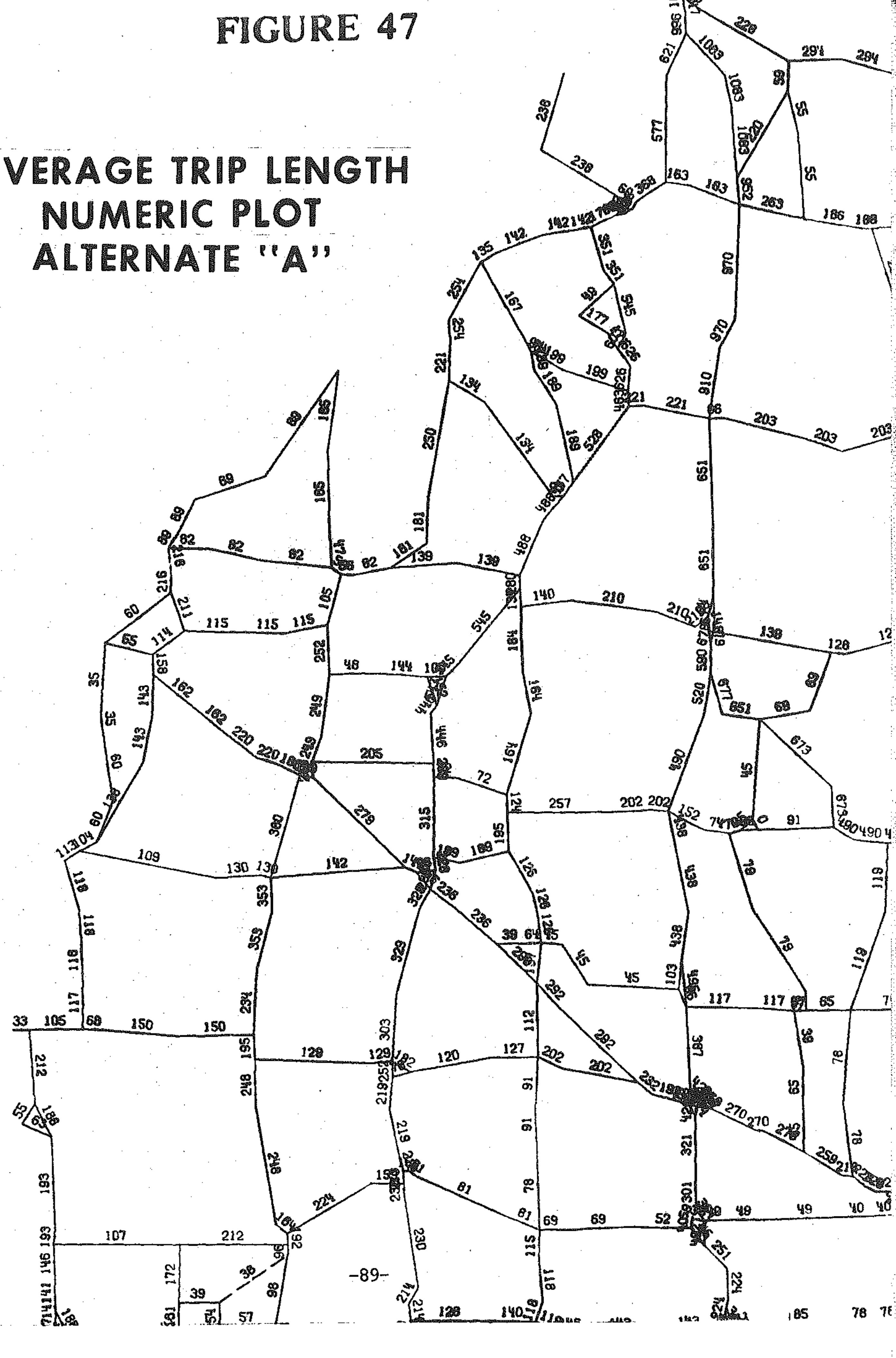
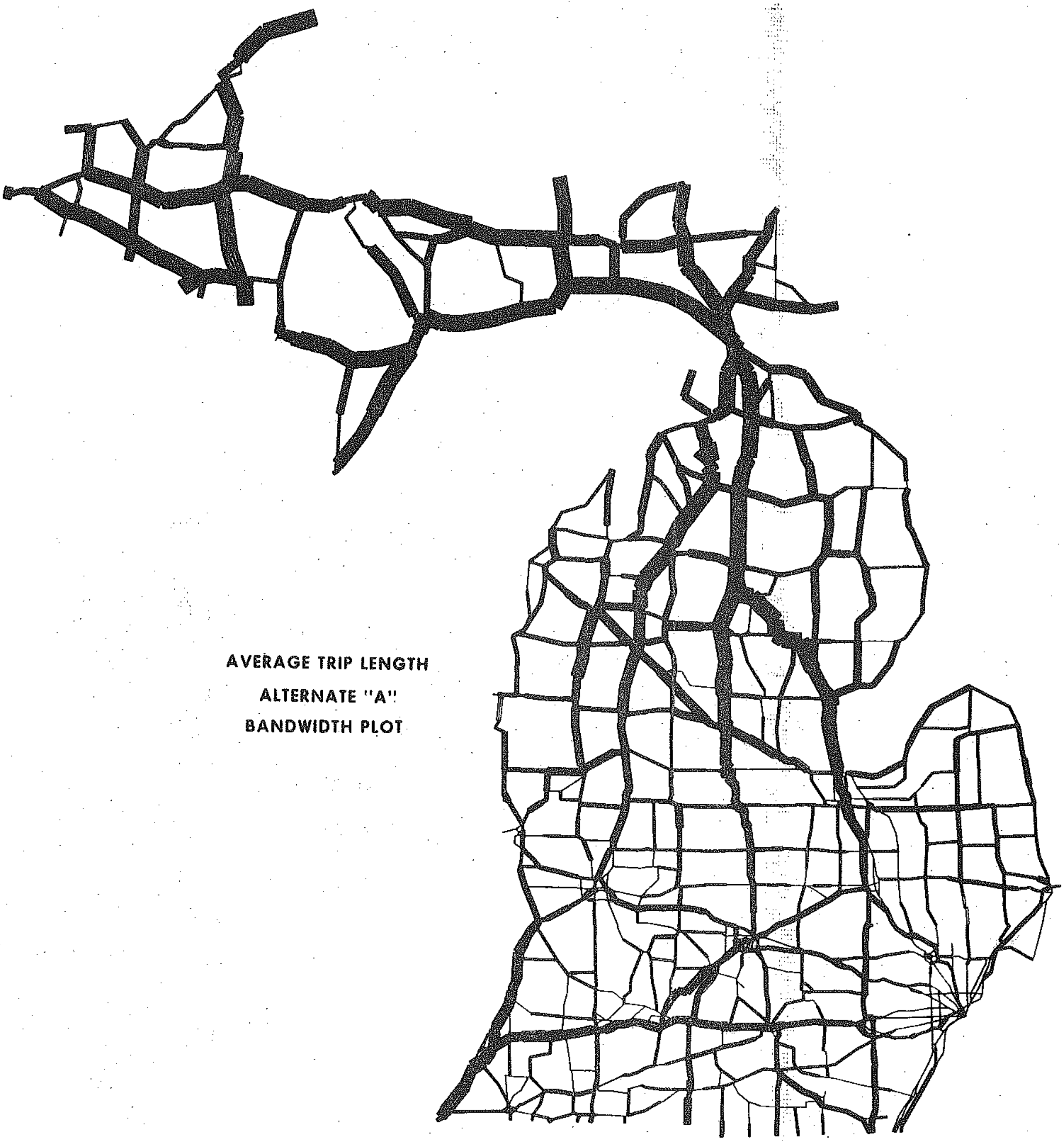


FIGURE 48



AVERAGE TRIP LENGTH
ALTERNATE "A"
BANDWIDTH PLOT

FIGURE 49

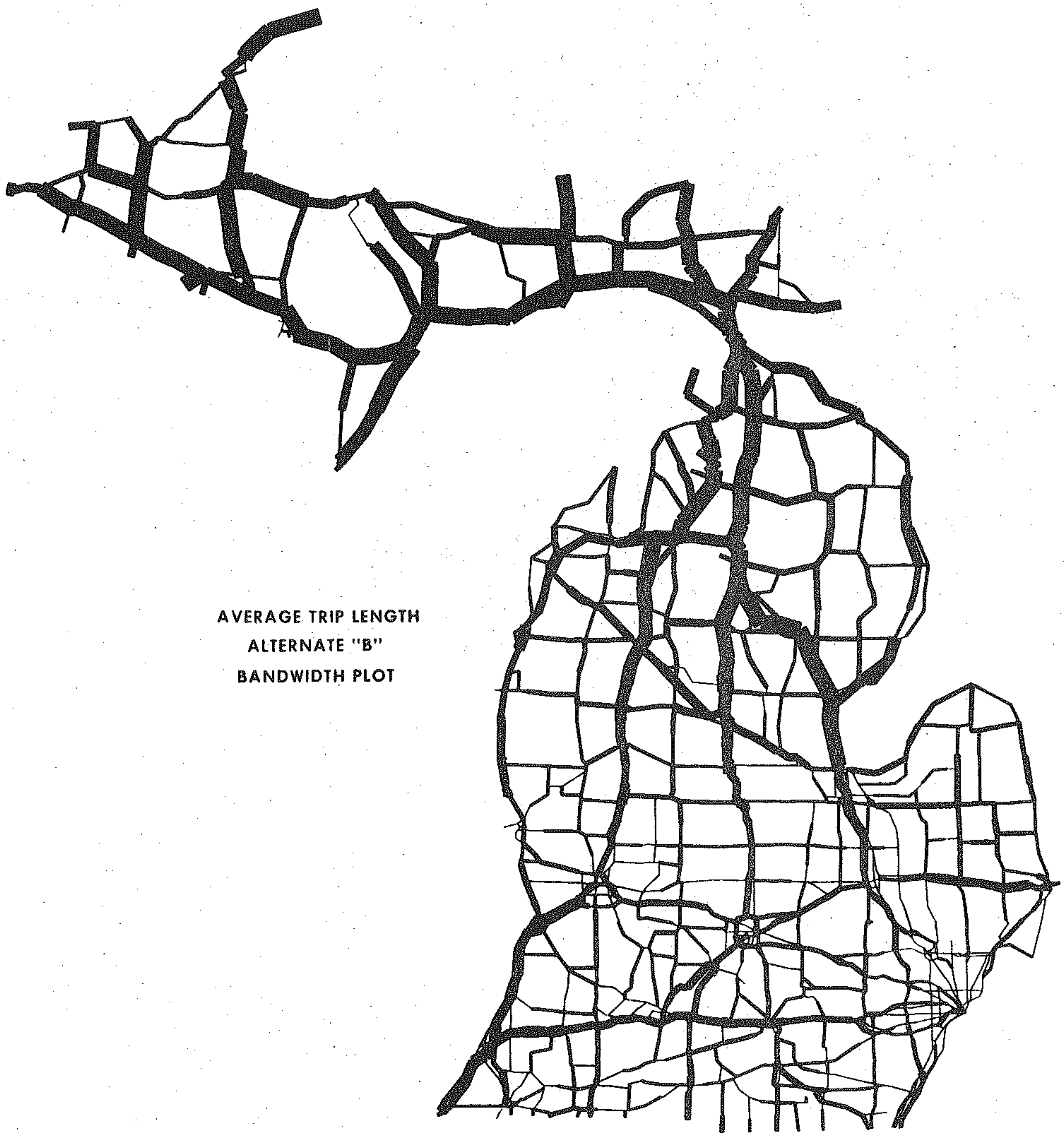
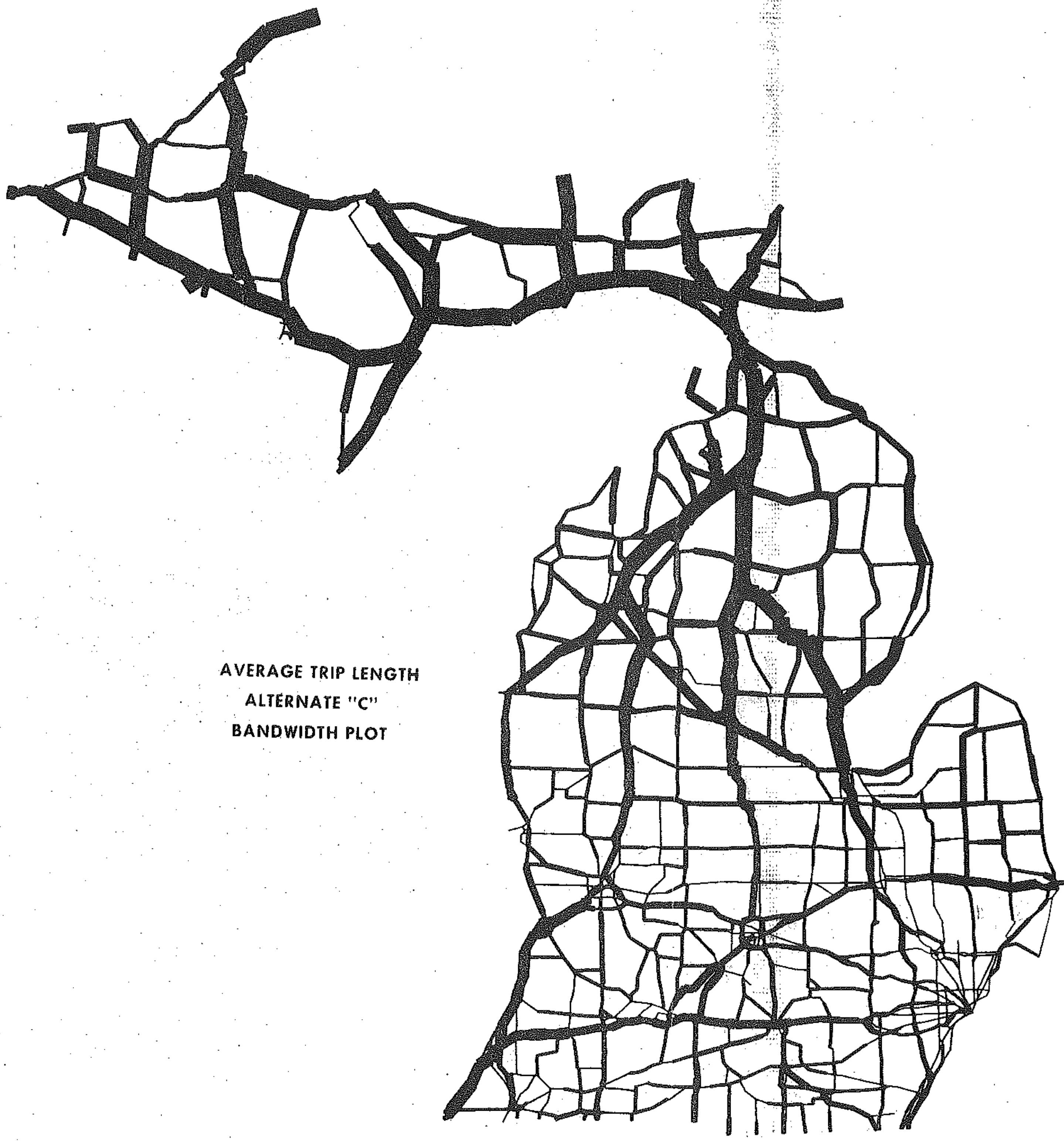


FIGURE 50



corridors traveled for greater distances are, nevertheless, distinguishable.

In the "no-build" proposal, M-37 and US-131 are projected to become of great importance for travelers entering and leaving the region - ATL's for these corridors vary between 3 and 6 hours. If Alternate B were constructed, however, travelers would tend to abandon M-37 in favor of US-31 and US-131 which would be expanded to freeway specifications. At no point, would M-37 (north of Grand Rapids) have an ATL larger than 150 minutes. Alternate C would, likeiwse, diminish the use of M-37. On several links south of M-37's intersection with the western leg of the proposed freeway (Alternate C), the ATL's approach the levels recorded in Alternate A.

This, in all probability, is a reflection of the fact that since the proposed freeway crosses the state much farther south than does Alternate B, M-37 will act as a freeway connector for many zones south of this intersection. Both of the freeway proposals effectively intercept and channel long distance north-south travel through the region.

7 & 8) Vehicle Miles/Vehicle Hours

The network plotting program facilitates a link by link analysis of the output produced through the various modeling techniques. It permits one to quickly note those links/corridors where the greatest travel impacts have been recorded without wasting valuable time thumbing through reams of printed listings. Despite this advantage, one wishing to know county, regional or state totals of specific impact data has, in the past, been required to summarize this information by hand. Although the summary program mentioned in the preceding section does not include output from the standard travel impact modeling process, with the exception of the level of service model, it nevertheless demonstrates the programmer's ability to incorporate these techniques at a later date. Keying the summary program in vehicle data alone has lead to the development of a new indicator which permits the monitoring of not only additional travel impacts, but also several of importance from a social, economic, and environmental perspective. Figures 51, 52, and 53 depict all that data currently produced through program options. Since our concern here is limited exclusively to the effects of alternate configurations on projected travel patterns, the following discussion focuses on the first three categories listed - - total miles, annual vehicle miles and annual vehicle hours.

Alternate A, the no-build proposal, has a regional total of 785 miles of which a mere three are of the high capacity interstate or FAP (Federal Aid Primary) variety. The Alternate B proposal consists of a total of 857 miles. While a spread of 62 miles between network totals does not seem significant, the crucial point is that proportionally Alternate B contains a greater overall percentage of the higher capacity freeways. The same holds true when Alternate B is compared to the third proposal (Alternate C). Despite the fact that the latter has a greater total mileage (909), the difference is composed predominantly of roadways capable of carrying (relatively) lower traffic volumes. This is of importance because the equation which determines network trip generation has incorporated into it a variable known as "induced traffic". This variable attempts to account for the fact that a freeway, since it tends to reduce travel time, encourages additional travel between zones. The more freeway links a network has, the greater number of trips it will produce. This phenomenon is then responsible for the larger VM/VH totals appearing at the bottom of Figure 52. Alternate B trips have

FIGURE 51

REGIONAL VEHICLE SUMMARY, ALTERNATE 23
INCLUDES COUNTIES NOS 51, 83, 57, 10, 45, 28, 40, 5, 15, 24
5/13/74 MICHIGAN STATEWIDE TRANSPORTATION MODELING SYSTEM

	INTER STATE	FAP FWY	FAP NON-FWY	FAS	TOTAL
TOTAL MILES	0	3	463	319	785
ANNUAL VEHICLE-MILES (THOUSANDS)	0	14921	973506	239623	1228051
ANNUAL VEHICLE-HOURS (THOUSANDS)	0	15689	1266958	338565	1621214
ANNUAL ACCIDENTS	0	16	3903	965	4884
A.ACCS./A.V.M. (TIMES 100 MILLION)	0	107	400	402	397
A.ACCS./A.V.H. (TIMES 100 MILLION)	0	101	308	285	301
ANNUAL GASOLINE CONSUMPTION (THOUSAND GALS.)	0	825	46468	11039	58332
MILES LS=1	0	0	0	16	16
MILES LS=2	0	3	30	208	242
MILES LS=3	0	0	135	66	202
MILES LS=4	0	0	137	14	152
MILES LS=5	0	0	41	6	47
MILES LS=6	0	0	118	6	125

NOTE--COLUMNS OF MILEAGE AND ROWS MAY NOT ADD DUE TO ROUNDING

FIGURE 52

REGIONAL VEHICLE SUMMARY, ALTERNATE 24
INCLUDES COUNTIES NOS 51, 83, 57, 10, 45, 28, 40, 5, 15, 24
5/13/74 MICHIGAN STATEWIDE TRANSPORTATION MODELING SYSTEM

	INTER STATE	FAP FWY	FAP NON-FWY	FAS	TOTAL
TOTAL MILES	0	142	395	319	857
ANNUAL VEHICLE-MILES (THOUSANDS)	0	535563	721730	216501	1473795
ANNUAL VEHICLE-HOURS (THOUSANDS)	0	563728	925670	305494	1794894
ANNUAL ACCIDENTS	0	963	2742	847	4552
A.ACCS./A.V.M. (TIMES 100 MILLION)	0	179	379	391	308
A.ACCS./A.V.H. (TIMES 100 MILLION)	0	170	296	277	253
ANNUAL GASOLINE CONSUMPTION (THOUSAND GALS.)	0	29616	34781	9977	74376
MILES LS=1	0	93	49	37	180
MILES LS=2	0	34	52	217	304
MILES LS=3	0	12	147	22	182
MILES LS=4	0	0	20	27	47
MILES LS=5	0	2	31	10	44
MILES LS=6	0	0	94	3	98

NOTE--COLUMNS OF MILEAGE AND ROWS MAY NOT ADD DUE TO ROUNDING

FIGURE 53

REGIONAL VEHICLE SUMMARY, ALTERNATE 26
INCLUDES COUNTIES NOS 51, 83, 57, 10, 45, 28, 40, 5, 15, 24
5/13/74 MICHIGAN STATEWIDE TRANSPORTATION MODELING SYSTEM

	INTER STATE	FAP FWY	FAP NON-FWY	FAS	TOTAL
TOTAL MILES	0	116	474	318	909
ANNUAL VEHICLE-MILES (THOUSANDS)	0	479145	728736	238399	1446281
ANNUAL VEHICLE-HOURS (THOUSANDS)	0	504317	953171	335608	1793098
ANNUAL ACCIDENTS	0	863	2913	941	4717
A.ACCS./A.V.M. (TIMES 100 MILLION)	0	180	399	394	326
A.ACCS./A.V.H. (TIMES 100 MILLION)	0	171	305	280	263
ANNUAL GASOLINE CONSUMPTION (THOUSAND GALS.)	0	26496	34621	11004	72122
MILES LS=1	0	35	79	36	150
MILES LS=2	0	65	75	170	311
MILES LS=3	0	16	179	62	257
MILES LS=4	0	0	47	18	65
MILES LS=5	0	0	43	25	69
MILES LS=6	0	0	48	6	55

NOTE--COLUMNS OF MILEAGE AND ROWS MAY NOT ADD DUE TO ROUNDING

been increased to such a level that, as a result of the additional 26 miles of freeways (over Alternate C), the disadvantage caused by fewer total network miles is overcome. Of the three networks, Alternate B enjoys the highest ratio of VM/VH to total network miles.

9) Travel Volume Analysis

Figure 54 indicates the approximate location of each of three regional cordon lines. To simplify this analysis, the AADT/DHV counts recorded in association with each network link intersecting the cordon have been duplicated in the chart appearing in Figure 55. Roadway numbers reflect the present highway numbering system - those routes which cross the cordon line more than once have an N (north), S (south), E (east), or W (west) designation. The first count (before the slash) is the link's projected AADT - the one after, its DHV. Alternates B and C have three network links which permit additional entry into the region - they have no route numbers and are designated simply as "new freeway".

Demonstrating the ability to efficiently forecast travel volumes on a network basis is what the statewide modeling system is all about. Insertion of a cordon line helps to ensure that the model is, in fact, producing accurate trip information; that the volumes and patterns generated are consistent with those expected and/or desired. Analytically, this technique should be one of the first employed since it is upon this statewide trip data that all social, economic, environmental and travel impact indicators are based. Once the analyst is convinced of the reasonableness of the projected network traffic, he may use the cordon (cultine) approach itself as an impact indicator - first, to determine whether any link deficiencies have been resolved with simulated road construction and secondly, to calculate

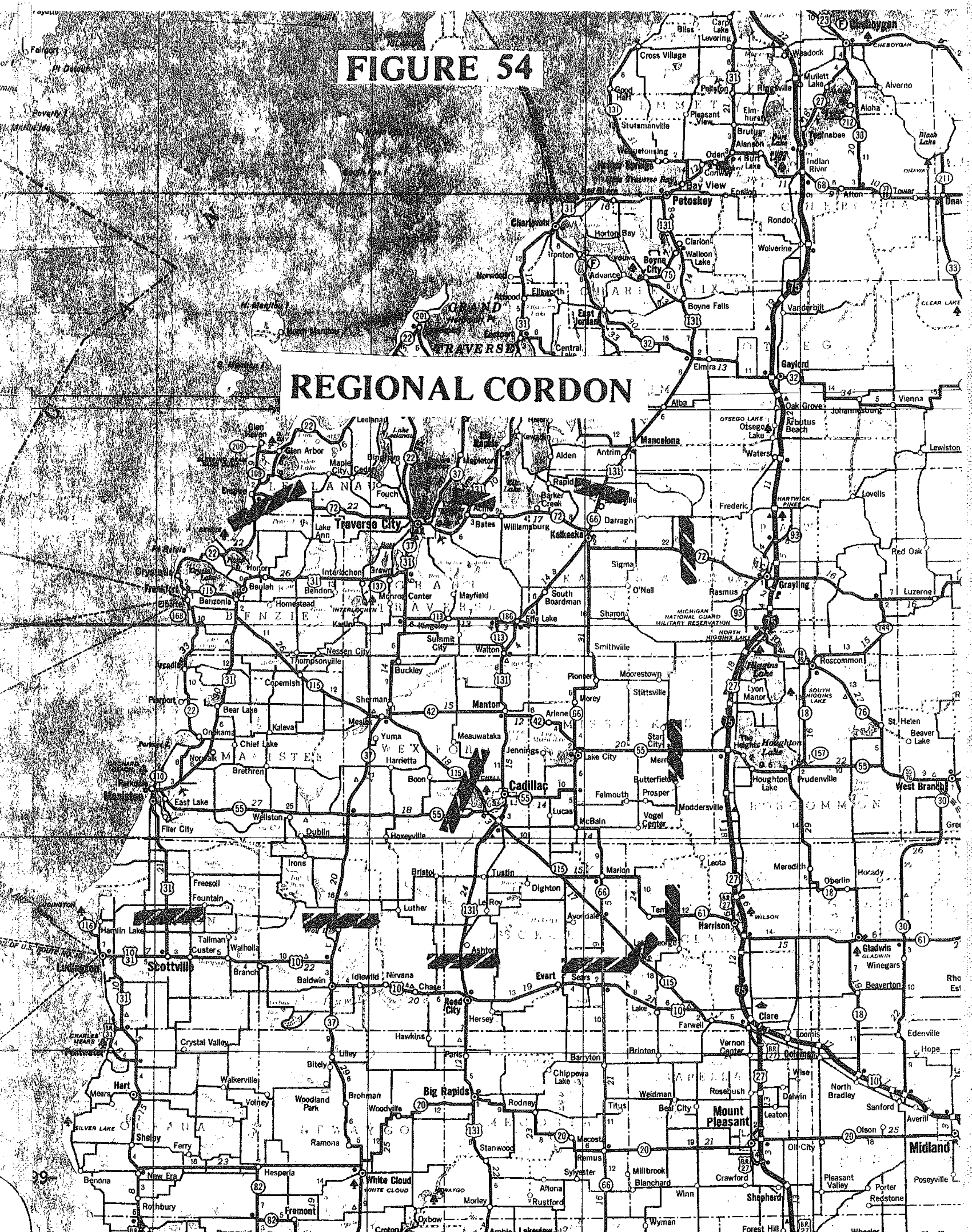


FIGURE 54

REGIONAL CORDON

FIGURE 55

AADT / DHV
CORDON LINE

ROAD NO.	ALT A	ALT B	ALT C
U.S. 31 (S)	* 10010 / 1702 *	642 / 0	806 / 216
New Freeway		15590 / 2806	13092 / 2296
M - 37	4223 / 688	1702 / 272	1920 / 306
U.S. 131 (S)	* 13779 / 1664 *	0 / 0	0 / 0
New Freeway		17,797 / 2848	18403 / 2944
M - 66	2842 / 512	1923 / 346	1977 / 956 *
M - 115 (E)	* 6904 / 1174 *	* 6542 / 1112 *	* 8260 / 1408 *
M - 61	1697 / 204	1508 / 180	1576 / 190
M - 55 (E)	4801 / 766	3833 / 612	3956 / 632
M - 72 (E)	3373 / 708	650 / 0	2652 / 584
New Freeway		6876 / 1446	
U.S. 131 (N)	* 6696 / 736	* 8995 / 990 *	1226 / 134
U.S. 31 (N)	* 7330 / 1172 *	* 6286 / 1006 *	* 6016 / 962 *
New Freeway			12159 / 2188
M - 22	2255 / 496	2254 / 496	1792 / 994 *
M - 72 (W)	2181 / 460	2162 / 476	2796 / 616
M - 55 (W)	2889 / 346	2802 / 336	3178 / 382
M - 115 (W)	4939 / 796	2752 / 444	2088 / 334
TOTAL { AADT/ DHV	73,919 / 11,424	82,314 / 13,370	81,897 / 15,142

the redistribution in traffic entering/leaving a study area.

A person attempting to calculate road sufficiency must consult some very specific engineering guidelines. The point at which a network link is considered in need of expansion varies with certain conditions specific to it. For example, a two-lane roadway, having the same width of paved surface as another, may be able to carry higher volumes of traffic simply because it has fewer hills and/or curves, is more limited in access, etc. Generally, however, when a two-lane road registers an AADT of 5,000 trips and a DHV of 900 trips, a highway agency begins to consider the link for a near-future improvement given the accompanying conditions warrant such action.

In Figure 55, all those links which have an AADT or a DHV over these accepted levels of adequacy have a * placed next to them. Alternate A has five links which show either or both AADT/DHV deficiencies. Notice that route 131 (N), as it passes through the cordon line, has an AADT of 6,696 but a DHV of only 736. Alternate C indicates a similar case in which the DHV is beyond the accepted DHV level but the AADT is not. Deficiency in one does not, then, automatically imply deficiency in the other. With the simulated construction of Alternates B and C, a significant traffic redistribution has taken place. The "new freeway" links have attracted regional trips to such an extent that the southern portions of US-31 and US-131 barely registers trip data at at all. Alternate B has little effect on the northern deficiencies of US-31 and US-131 while Alternate C, by passing almost parallel to the latter route, efficiently removes congestion in that area of the network. Although ocillation in traffic volume is apparent on all other links which cross the line, none are truly signficant.

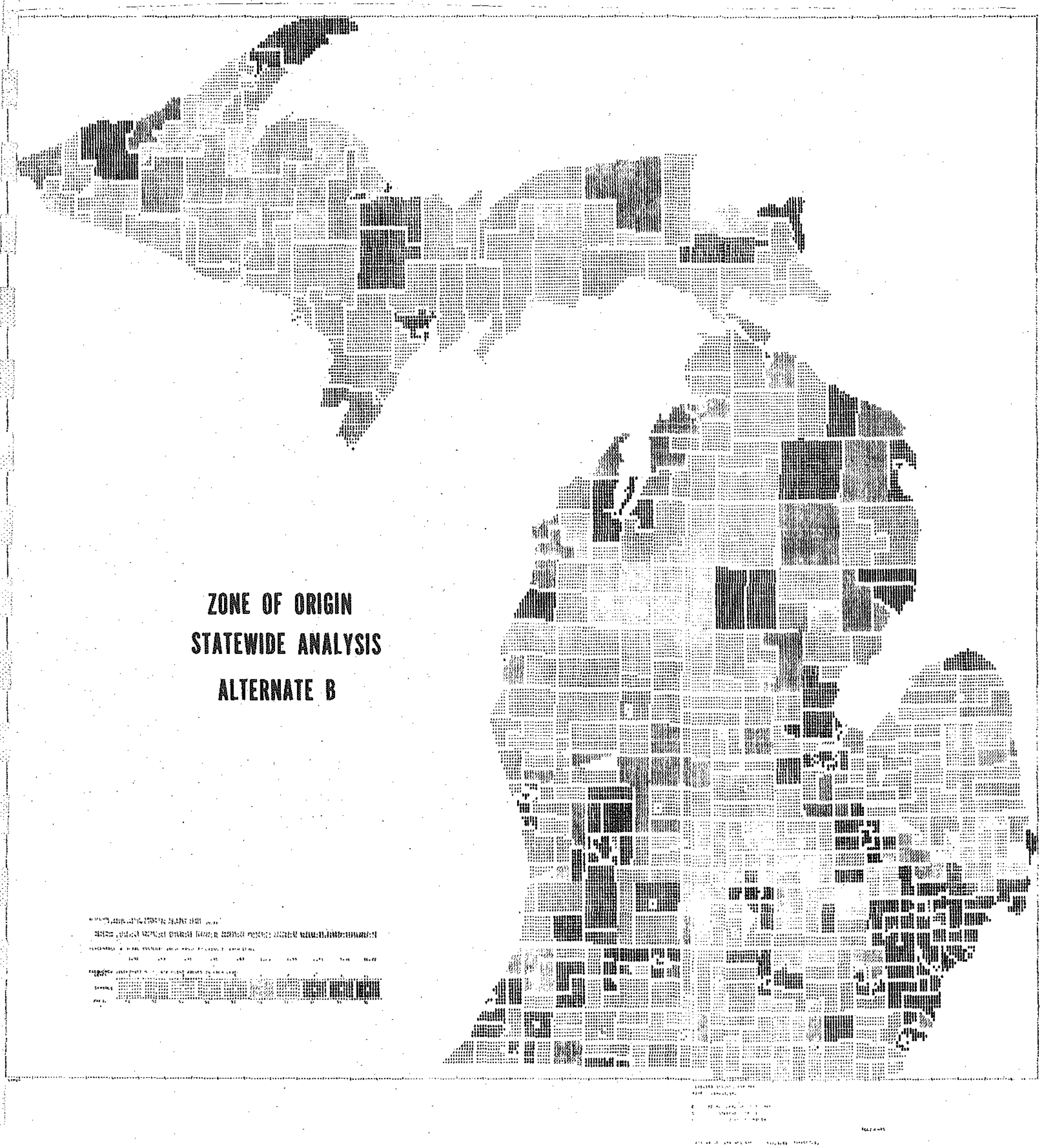
Using the cordon approach to monitor the removal of highway deficiencies/ traffic redistribution requires the analyst to employ the technique more than once to insure such removal/redistribution is, in fact, occurring at points other than merely those at which the cordon intersects the network. A single application of the technique may cloud the true picture of an area's generated travel patterns and, therefore, the analyst must rely on other indicators in developing a more accurate picture.

The cordon line, as a method of analysis, perhaps provides its greatest insight into the impacts generated by alternate highway proposals by indicating the projected exchange of trips between a selected study area and the rest of the state. Figure 55 has AADT/DHV regional totals listed for the three alternates. Alternate B shows a 11.4% increase in AADT and a 17.0% DHV increase over Alternate A. Likewise, Alternate C registers a 10.8% AADT/32.5% DHV regional increase. Whether this increment in trip generation is seen as being beneficial (harmful to the region from an overall social, economic, and environmental and travel perspective) depends largely on the type of results received for the other impact indicators and, to an even greater extent, on the values of the person interpreting and acting upon these results.

10) Zone of Origin

The conformat technique of centroid association (disucssed above) was employed to produce the Symap shown in Figure 56. The information displayed is the projected number of accidents experienced by residents of the 508 instate zones as they travel the state highway network. The amount of zonal shading appearing on the map represents aggregate accidents for each zone - the darker the shading, the higher the total number of projected accidents for that zone. Notice the zones in the Detroit metropolitan region - compare them with the zones of the Upper Peninsula. Statistically, persons in the

FIGURE 56



state's northern most zones are less likely to have accidents than are their counterparts in the more urbanized southern regions of the state. This bit of information should come as a surprise to no one - the more populated an area is, the more automobiles it will have and thus the greater number of accidents it will experience.

How will the construction of a new highway corridor affect the statewide accident data displayed here. Since information used as input to Symap was calculated by the procedures previously outlined, alternate highway configurations will significantly impact the number of accidents experienced by residents of all those zones which are projected to frequently use the new route during the interzonal exchange of trips. That is, certain highway proposals, by reducing travel time between zones will attract trips from the more accident-prone road segments to the higher capacity roadways - thus reducing total accidents within zones that are inclined to use the new facility. Alternate highway proposals may be evaluated on the basis of the amount of zonal shading produced by Symap when the various network configurations are used as input.

11 & 12) Selected Route and Selected Zone Analysis

Figures 57, 58, and 59 show perhaps the most striking visual examples of travel impact of any displayed in this report. The link chosen for the analysis is the same M-37 link utilized in the TLD technique. While the latter indicator described the distribution of trips in terms of time, the former focuses on raw traffic volume. By "picking" or "selecting" from the network trip table all those trips which pass through the study link, one is able to produce a series of bandwidth trip plots. Stratification

FIGURE 57

SELECTED ROUTE BANDWIDTH PLOT ALTERNATE "A"

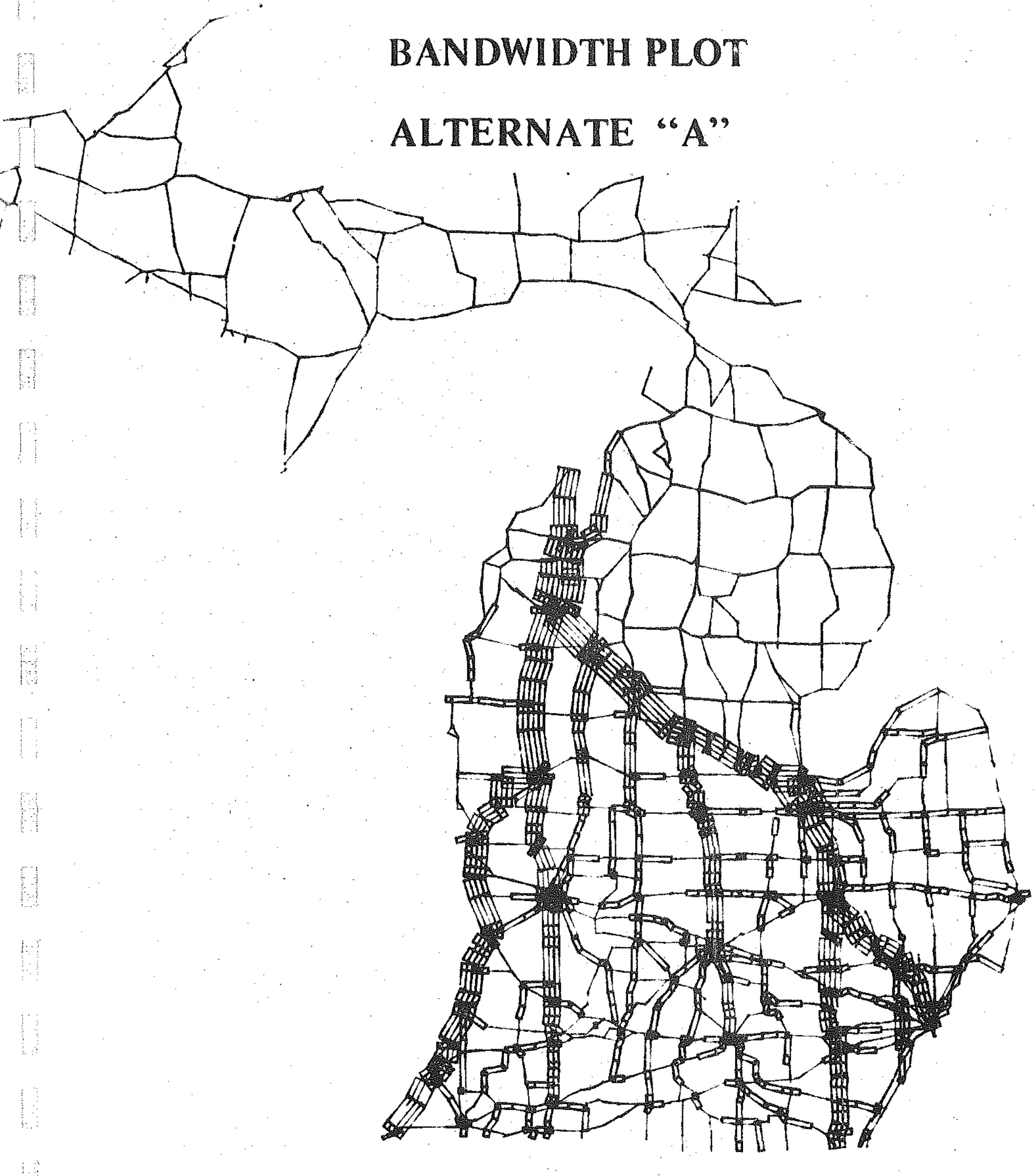


FIGURE 58

SELECTED ROUTE BANDWIDTH PLOT ALTERNATE "B"

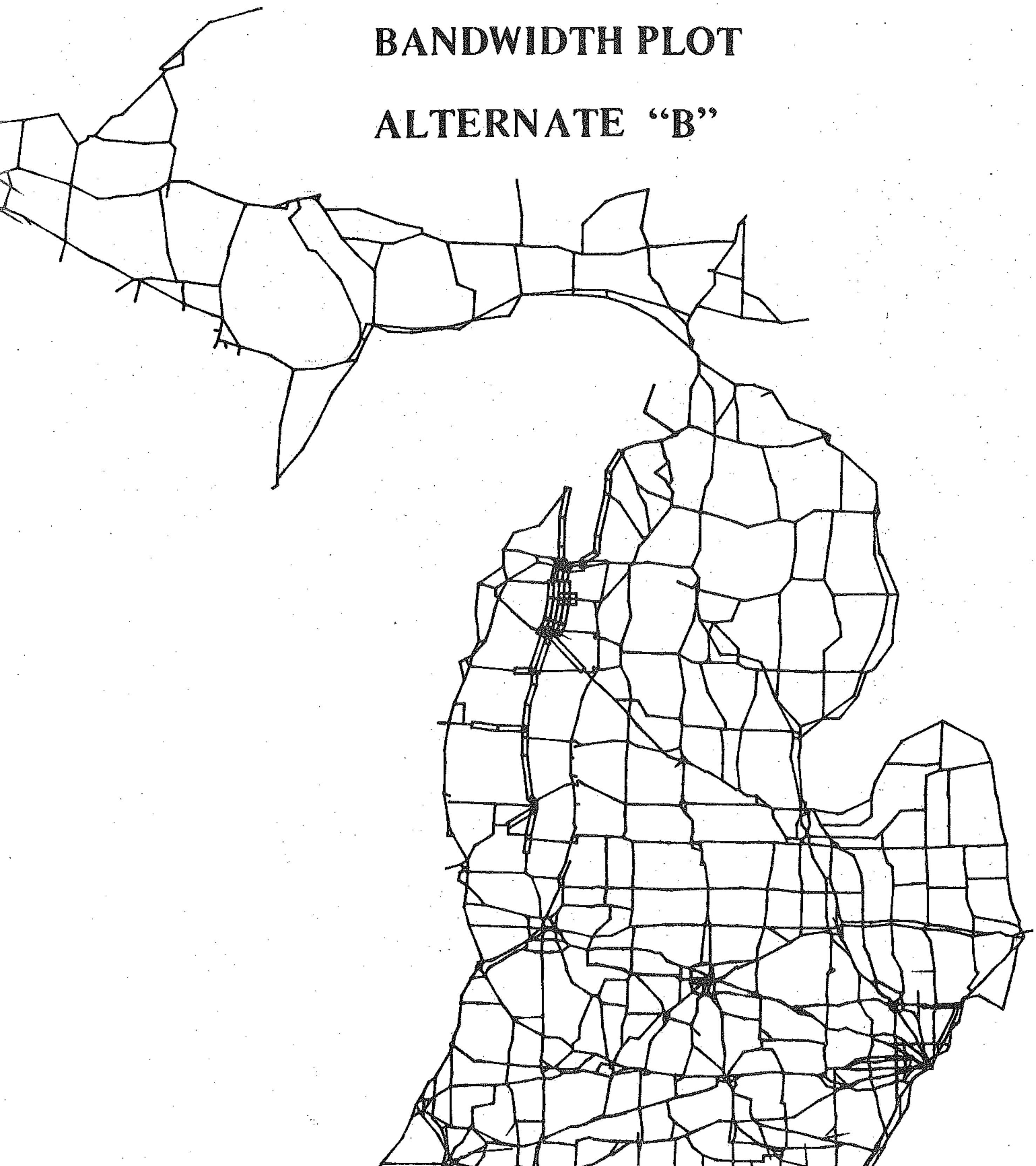
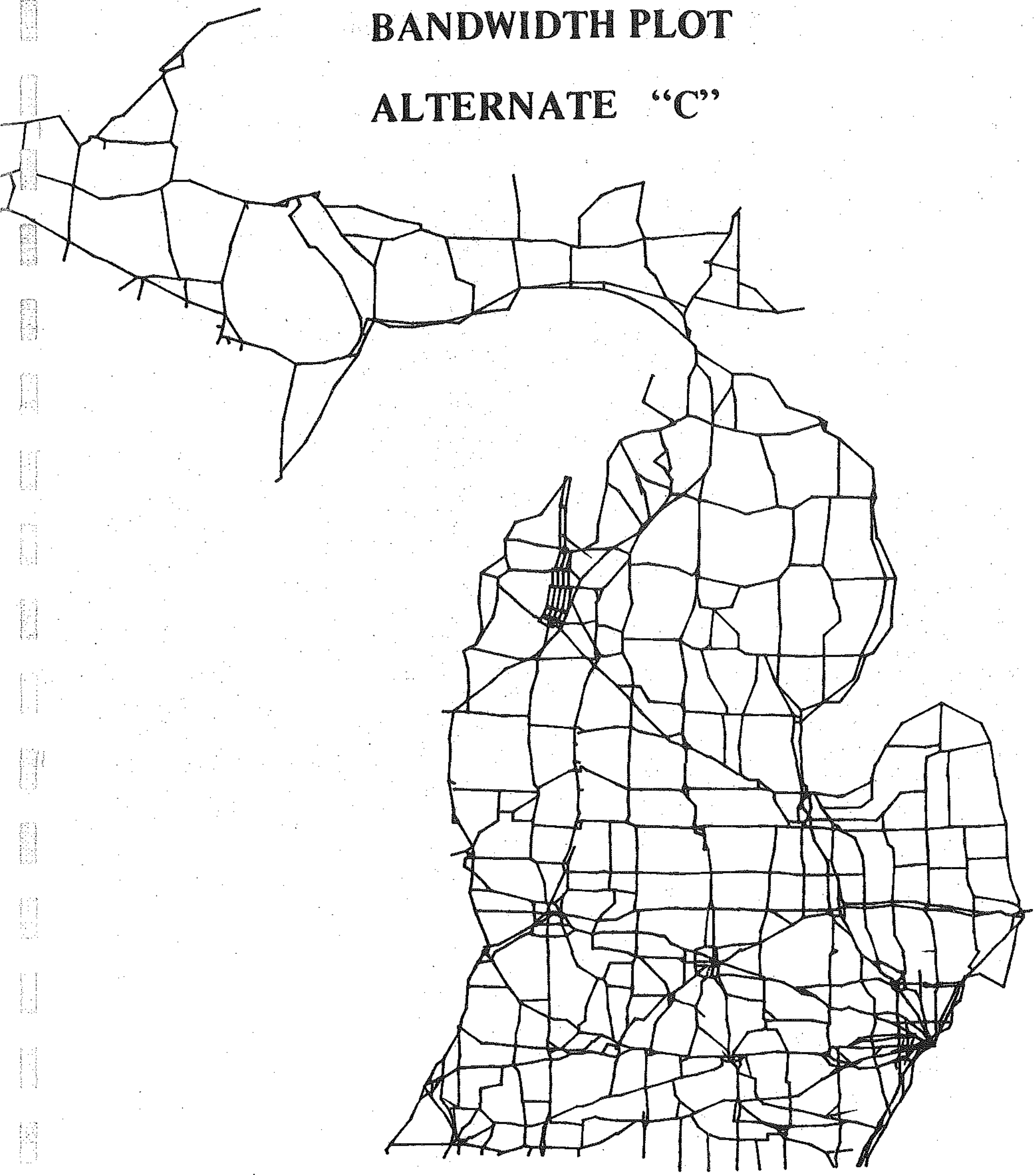


FIGURE 59

SELECTED ROUTE
BANDWIDTH PLOT
ALTERNATE "C"



of the trip data into ten discrete categories has not been done so that each group contains an equal number of trips. This manipulation was necessary to gain the desired visual effect. It is not necessary to know the exact designation but to give an idea of the data range being discussed - a single band equals no (zero) trips while ten bands equals anything over 2,200 trips. Alternate A indicates that the only link with enough recorded traffic to require ten bands is the study link itself. As greater and greater distances separate the study link from those links which permit access to it, the number of trips recorded in association with each gradually diminish.

Usage, however, is not only a function of proximity, but also of time reduction - the selected link is used by many distant travelers for the simple reason that it is a portion of the minimum path which connects them with their desired destinations. When one discovers a shorter path, they almost always opt for this route. This seems to have happened when either of the proposed freeway system were built. Prior to their construction, the base network relied on the M-37 corridor (or at least on this single link) to carry a substantial number of trips to and from the more populated zones of the test region (as the TLD has indicated). Every major travel corridor in the southern portion of the network is used by travelers either before or after they pass through the selected link. The importance of this road segment to the interzonal exchange of trips is, indeed, significant. With the simulated freeway construction comes a change of the role formerly played by M-37 - inter, and to a lesser extent, intra - regional traffic now loads to the higher capacity roadways. If one were to travel north along M-37 using either Alternates B or C, the traffic volumes encountered would be extremely low until one was within approximately 20-30 miles of Traverse City at which point the influence of local travel would be felt - volumes approach preconstruction levels. If other impact indicators substantiate this picture of projected travel patterns for the majority of M-37 links, then, the highway department must seriously consider officially deleting the route from the system of state trunklines.

Operationally, selected-link/zone analyses are identical. Their only difference is that the latter approach employs a centroid rather than a standard network link. The advantage gained with this modification is simply this: when the selected tree program is utilized, the analyst knows which paths the simulated traffic has taken from the study zone to every other system zone and how many trips have been actually exchanged between them but he cannot describe the distribution of trips along each path. He cannot attribute, let's say, x number of trips as having passed through y link. The selected zone analysis does not accumulate trips at the zone centroid, but rather gives this "selected" network distribution.

The importance of this technique does not lie in the fact that it provides some startling new travel impact - because, frankly, this is not the case. All data obtained through this approach can be obtained through some other indicator already existing within the system. Selected zone analysis is simply a convenience - it groups together in a single technique output which might have previously taken several indicators to assemble. It reduces process time and facilitates analysis.

It should be mentioned that all minimum paths utilized in the interzonal exchange of trips are not displayed in this type of plot - i.e., Figure 60 is still basically a network plot. Although the bands allow one to trace the flow of traffic from the selected zone to the other system zones, it does so only when they actually exchange trips. If no persons from a distant zone travels to the selected zone (or vice versa), the eventual path taken by them is not stipulated. To determine a minimum highway path most easily, one should consult a selected tree plot - links not used in gaining access to the selected zone are automatically deleted.

13) Selected Tree

The purpose of building a new series of highway links is, of course, to more adequately handle traffic wishing to travel between various points within the state network. By providing a highway path which requires less travel time, it is hoped that trips overloading a certain portion of the network will opt for the higher capacity roadways thus providing a more balanced distribution of network travel and gaining those advantages with which it is typically associated (e.g., fewer accidents). If an alternate network is built which does not lower travel times between zones, trips will continue taking their former routes despite the actual or simulated construction. To ensure the new facility "intercepts" those trips for which the construction was undertaken, one must monitor the loading process - must determine whether the minimum paths created through the new alternate are actually those desired.

Figure 61 displays the selected tree for zone 151/alternate network B. The numbers appearing next to each zone centroid reflect the present zonal numbering system. (Total trips exchanged between the selected zone and all other system zones may be annotated, as mentioned above, if one wishes to display this information.) The calculation of the minimum paths for a

FIGURE 60

SELECTED ZONE BANDWIDTH PLOT ALTERNATE "B"

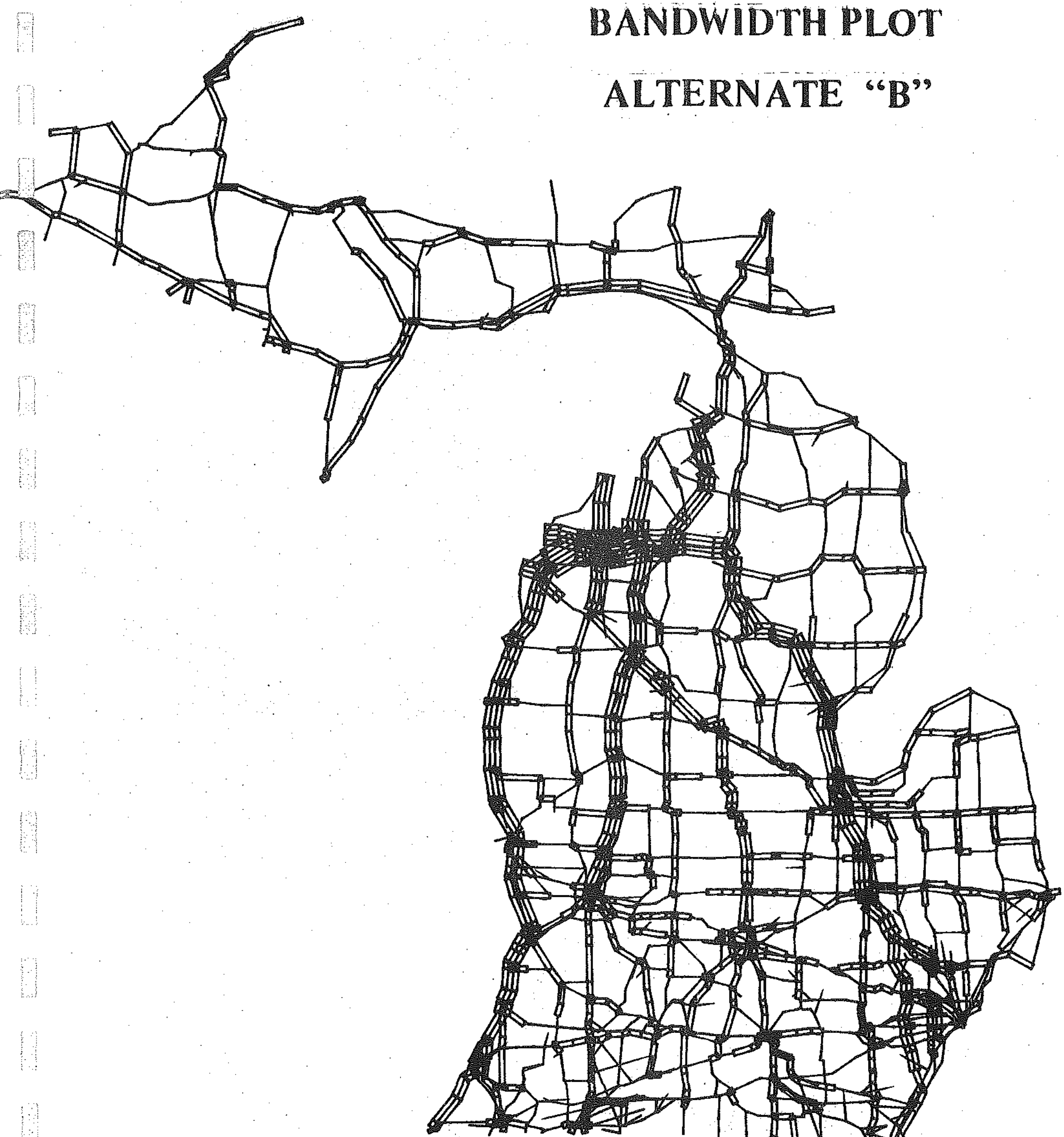


FIGURE 61

selected tree does not necessarily imply that trips are exchanged between the various system zones - it merely indicates those paths which would (most logically) be taken if traffic were actually assigned to travel between them. At this point, it should perhaps go without saying that the highway proposal (Alternate B) does, in fact, shorten travel time between the selected zone and every other system zone - the previous indicators have verified this fact.

14) Travel Mode Accessibility

User convenience has, to a great extent, given the automobile the popularity it enjoys today. Until other modes of transportation at least approach the present ease of automobile usage, no competitive atmosphere between modes will ever be developed. In the days of growing population, energy and pollution problems, this situation cannot long be tolerated. As suggested in the procedures section of this report, alternate highway configurations are able to bring a certain percentage of an area's population closer (in terms of travel time) to existing travel facilities. Those who have a tendency to use mass transit facilities will, most probably, be encouraged to use them more frequently if and when their accessibility is improved. Proximity (i.e., accessibility) analysis is a technique which permits one to measure the accessibility of (in our case) railroad stations to zonal population along minimum highway paths. It was pointed out previously that this type of analysis can be undertaken from several points of view. The first stresses the importance of making travel facilities more accessible to the population of a single zone while the other seeks to optimize accessibility on a county, regional or state level. Figure 26 displayed a portion of the actual output received using option one but due to the massive amounts of printed material involved, the output from the three alternates has been transferred to the chart appearing in Figure 62.

The headings for each of the categories are, for the most part, self-evident but as a quick example - Alternate A shows that within the first fifteen minutes of the city, a population of 20,690 has been recorded (which is .2% of the total state population). These people have access to a single railway station within this time span which provides a population to a railway station ratio of 20,690. Upon inspection of the various totals, it immediately becomes apparent that absolutely no differences exist between the alternates for the first three fifteen-minute intervals surrounding the centroid for zone 151 (Traverse City). Slight variations are registered when the computer scans the area three-quarters to a full hour from the city. Does obtaining these seemingly insignificant results mean that the concept behind the analysis has little or no value? Definitely not! The reason shall be discussed following review of the technique's second option.

The second summary form available to those performing accessibility analysis lists all those zones which have railway stations accessible to them within specified time intervals regardless of the facilities inclusion in that zone. In other words, the key factor is accessibility to a zone; if a single facility is, for example, within the first fifteen minute time band for ten different zones, it is counted ten different times regardless of in which zone it is actually located. This duplication or "overlapping" effect, it should be kept in mind, is reflected in all regional totals. Figure 63 depicts the ten county, thirty-five zone region utilized in this analysis while Figure 64 shows the regional summaries obtained by

ZONE 151

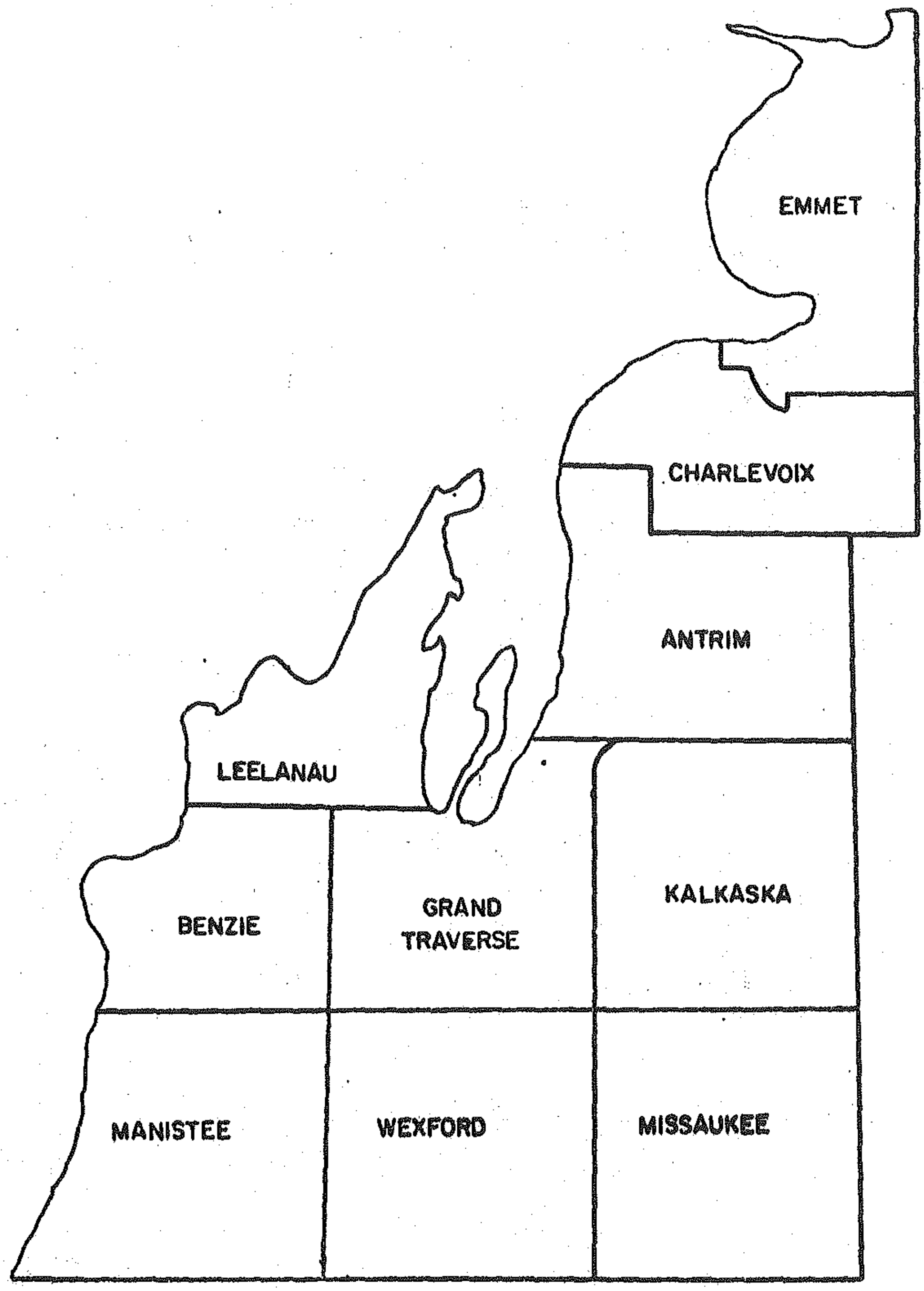
RAIL PROXIMITY — OPTION 1

	TRAVEL TIME IN MINUTES	POPULATION	% OF TOTAL STATE POPULATION	CUMULATIVE POPULATION	CUMULATIVE %	NUMBER OF RAILROAD STATIONS	CUMULATIVE # OF RAILROAD STATIONS	RATIO OF POPULATION TO # OF RAILROAD STATIONS	RATIO OF CUMULATIVE POPULATION TO CUMULATIVE RAILROAD STATIONS
A.	0 - 15	20690	.00233	20690	.23%	1	1	2069	2069
	15 - 30	22912	.00258	43602	.49%	12	13	190	335
	30 - 45	23806	.00268	67408	.75%	18	31	132	217
	45 - 60	13715	.00155	81123	.91%	9	40	152	202
B.	0 - 15	20690	.00233	20690	.23%	1	1	2069	2069
	15 - 30	22912	.00258	43602	.49%	12	13	190	335
	30 - 45	23806	.00268	67408	.75%	18	31	132	217
	45 - 60	15432	.00174	82840	.92%	12	43	128	192
C.	0 - 15	20690	.00233	20690	.23%	1	1	2069	2069
	15 - 30	22912	.00258	43602	.49%	12	13	190	335
	30 - 45	23806	.00268	67408	.75%	18	31	132	217
	45 - 60	23705	.00267	91113	1.00%	10	41	237	222

FIGURE 62

FIGURE 63

ANALYSIS AREA



ZONE 151

RAIL PROXIMITY — OPTION 2

	TRAVEL TIME IN MINUTES	TOTAL NUMBER OF RAILROAD STATIONS WITHIN BANDS FOR ALL ZONES	% OF RAILROAD STATIONS WITHIN BAND	AVERAGE OF RAILROAD STATIONS WITHIN BAND	CUMULATIVE AVERAGE WITHIN BAND	CUMULATIVE % WITHIN BAND
A.	0 - 15	111	9.91	3.17	3.17	9.91
	15 - 30	174	15.53	4.97	8.14	25.44
	30 - 45	343	30.62	9.80	17.94	56.06
	45 - 60	492	43.92	14.05	31.99	100.00
B.	0 - 15	111	8.86	3.17	3.17	8.86
	15 - 30	193	15.40	5.51	8.68	24.26
	30 - 45	382	30.49	10.91	19.59	54.75
	45 - 60	567	45.25	16.20	35.79	100.00
C.	0 - 15	111	8.87	3.17	3.17	8.87
	15 - 30	205	16.38	5.85	9.02	25.25
	30 - 45	356	28.45	10.17	19.19	53.70
	45 - 60	579	46.28	16.54	35.74	100.00

FIGURE 64

using the exemplary alternates as input. The category with the heading "% of Rail Stations Within Band" was calculated by determining the total number of stations accessible to regional zones for all bands and dividing it by the number specific to each of the four bands - e.g., Alternate A (first band) equals 9.91% by dividing 1,120 by 111. The second measure used within this option for comparing impacts is the average number of regional railway stations accessible per zone/per band. For example, since in the first band (Alternate A), 111 stations are accessible regionally, 3.17 are accessible per zone within fifteen minutes driving time - 111 observations divided by 35 regional zones. Unlike the previous option, results vary prior to the last fifteen minute interval, but again, the true significance of the differences involved is questionable.

If accessibility analysis is of such importance that it is mentioned in this report, why does not the output reveal more startling evidence of its worth? The reason for this is quite simple. The three alternate highway proposals do not shift travel times between zones to a point in which improved highway access to the regional railroad stations can be monitored below a sixty-minute level. That is, there are (no doubt) freeway configurations of such a size and shape that, if implemented, would significantly improve user access below a sixty-minute level but none of the three described here do, in fact, have this effect. Some may call into question the size of the zone system employed in this technique - reasoning that the larger the zone system utilized, the less sensitive the model in toto would be. This is a valid point but it should be kept in mind that this methodology has been successfully employed in monitoring impacts within fifteen minute time intervals of other study facilities. Use of larger time intervals would have (in a certain respect) resolved the problem of model sensitivity, but how many people would travel more than an hour to take advantage of some mass transit mode? A highway system attempting to encourage the use of mass transit must, logically, improve accessibility for persons living within very small time intervals of the facility itself - thus the emphasis on the fifteen minute intervals. A 2,300 zone system is in the process of being made operational. Once this system is adopted for daily use, the technique discussed here, it is hoped, will better show particular systems as being (at least from this one perspective) clearly superior.

15) Symap/Driving Band

It seems to be an accepted principle that the amount of physical distance separating persons determines to a great extent the degree of social interaction they experience. This principle, by extension, is applicable to geographical areas - the farther apart two zones/counties/regions lie in relation to one another, the less likely they are to have direct social ties - the converse, of course, is also true. Since the various modes of ground transportation are presently the most often used for intra-state travel, any reduction in highway travel time will significantly affect the number of trips exchanged between areas. All indicators included in this report have striven to quantify one particular aspect of intra-state travel which has been impacted with the addition of freeway links to the base network. Several have dealt exclusively with travel time - either on a network basis (as in ATL) or from the perspective of a single link (as in TLD). Both of these techniques were graphically displayed. Travel Mode Accessibility Analysis skimmed a selected tree on <u>time</u> to determine, among other things, the ratio of population to railroad stations within specified time intervals.

The Driving Band and accessibility methods of analysis are related in that the former takes the input utilized by the latter (skimmed trees) and displays it graphically by placing it in a symap format. Figures 65 and 66

FIGURE 65

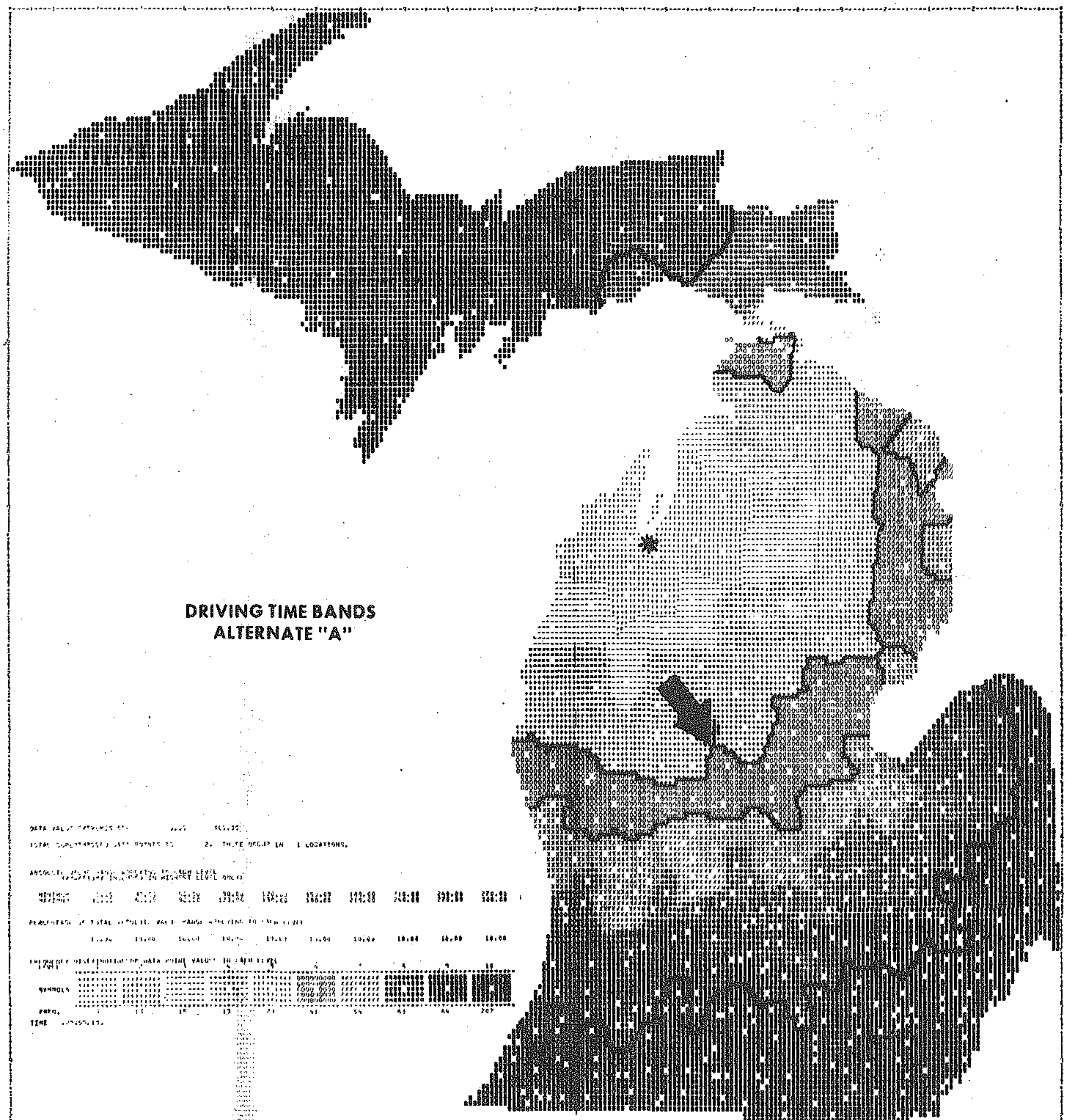
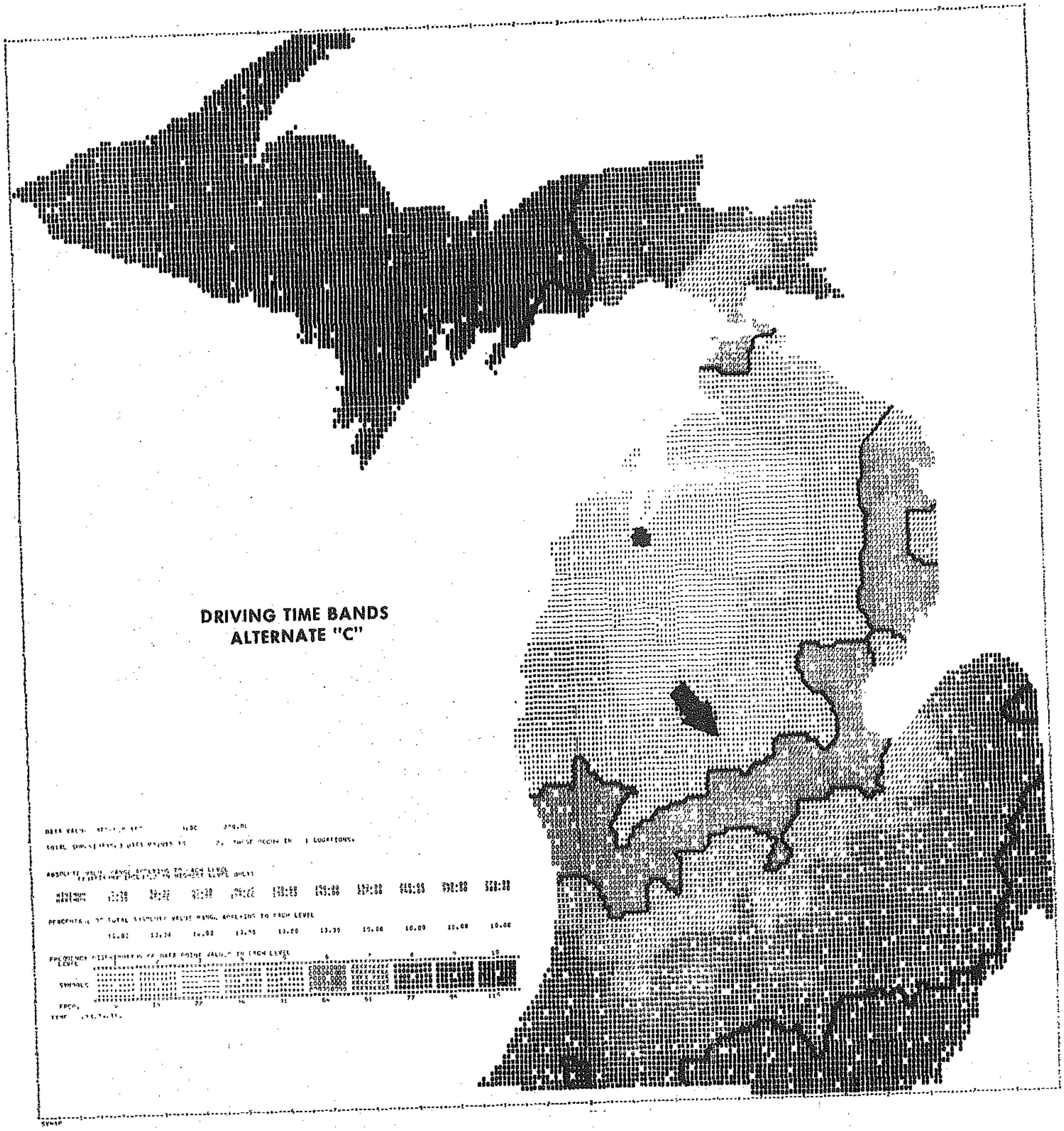


FIGURE 66



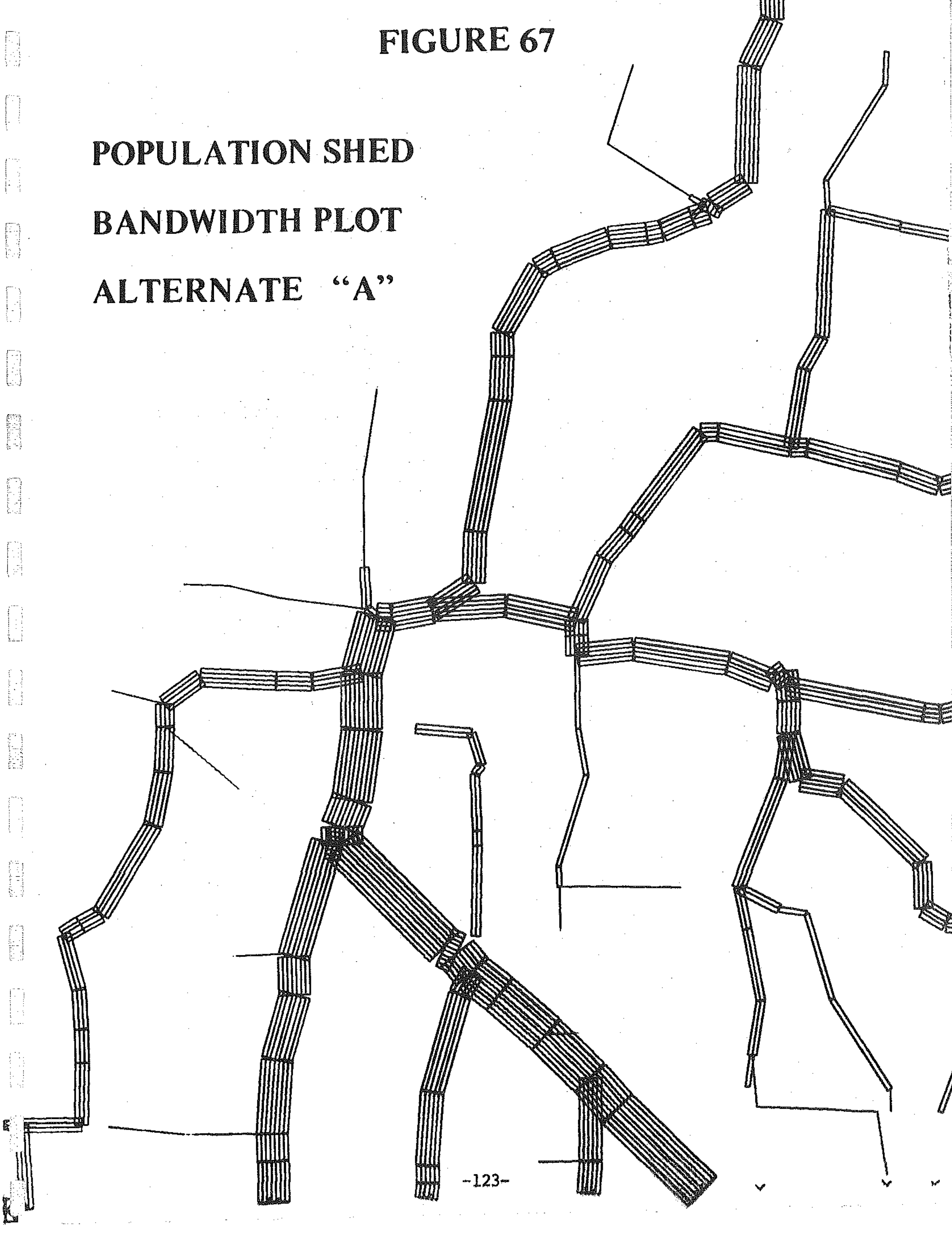
show the variations in driving times from zone 151 to every other system zones using alternate networks A and C. A line separating these bands has been manually drawn - the arrow designates the two and one-half hour (150 minute) band which approximately encircles the northwest region. Notice the position of this and other bands when people use Alternate A in driving to the selected zone. The addition of the proposed freeway links speeds north-south travel into/out of the test region by altering the minimum highway paths. Zones which were once, on a travel time basis, much farther south have been pushed northward.

16) Population Shed

Figure 67 depicts the "population shed" created through use of the minimum highway paths leading from zone 151 to every other system zone and the projected state population for the year 2000. Each band of this bandwidth plot does not represent an equal number of persons. The range included in each expands somewhat geometrically with the first encompassing 5,000 persons and the tenth, 5 million - i.e., any link composed of ten bands has anywhere between ten and fifteen million persons passing through it. Since the majority of the state's population resides in the system's southern most zones and the minimum highway paths were determined using Alternate network A as input, the major corridors designated in Figure 36 are those routes upon which a predominant number of the "surrogate trips" have been loaded. Notice the relative unimportance of the northern most branches of the selected tree - zones of this region are, by comparison, underpopulated. They, therefore, have far less potential for bringing persons into the Traverse City area. It should be kept in mind that each

FIGURE 67

POPULATION SHED
BANDWIDTH PLOT
ALTERNATE "A"



link of the selected tree merely indicates the accumulated number of persons who may use the link in gaining access to the selected zone.

One of the applications of this technique seems to be the determination of "corridor potential" in performing multi-modal analysis. Obviously, when planning mass transit facilities, one must calculate those alternate routes which supply the "best" access to the majority of the state's population. Since the automobile will continue to play a major role in transporting persons to mass transit "collector" stations, use of the minimum highway path as a fundamental planning concept is valid. Figure 67 shows that (using the base network) the M-37 corridor provides access to/from a substantial portion of the population residing in the test region. Whether better access could be accomplished through shifting the highway paths to the east or west, of course, entails the running of several alternate highway proposals. Analysis may indeed show another highway to be superior in terms of "collecting" potential users at the various mass transit terminal points.

CONCLUSION

C O N C L U S I O N

This report has documented sixteen travel impact indicators. It was mentioned in the opening pages of text that these indicators are a process - their results must be interrelated in order to clarify a clouded picture of the impacts generated by the actual or simulated construction of an alternate highway system. To view the output from a single technique in isolation gives one an indication as to the type of effect produced on the aspect of travel being studied but leaves one in confusion as to what it means on a comprehensive, system level. The output from each of the individual techniques must, by necessity, be correlated, integrated and reevaluated on a system basis. This is not to say that the present process is all-inclusive, that every contingency has been sufficiently examined, or that by developing a similar process, one will somehow be enabled to supply his superiors with a definitive impact statement. That is, of course, the dream but unfortunately not the present reality.

The travel impact modeling process as it now exists identifies and "measures" some of the more obvious areas of planning concern. To fine-tune the travel impact picture, to give the analyst-planner additional insight into the effects caused by highway construction, the search for more and better indications is never ending. The transportation planning package of computer programs is the primary "tool" employed in this pursuit. It, to some extent, resembles an "erector set" in that many of the analytical pieces are supplied - it is left for one to decide how they might best be utilized. In at least this one respect, then, the analyst-planner must be creative. Knowing the power, as well as the limitations, of the current system is essential. Resolution of daily problems is dependent on a proper mixture of ability.

The above analysis was exemplary - as such the method of analysis was modified for presentation purposes. In reality, when planning the construction of a system as expensive (in terms of social/environmental/ economic costs) as those discussed here, many more than the three alternate highway configurations would be studied - (again) the process of evaluation must be much more integrated, and impacts on a statewide basis would be given much more attention. Most of the analysis performed above was done visually - impacts with the help of the graphic display battery were made apparent. A numeric format, of course, lends itself to statistical analysis and, perhaps, permits one to study (a little more in-depthly) a particular travel phenomenon. This was not done since effective communication with the general public is now a Federal requirement (which is enhanced through a pictorial discussion) and because the visual approach (i.e., all plotting techniques) typically simplify the comparisons between alternate proposals.

The primary purpose of developing a sophisticated travel model is to permit the monitoring of impacts on a system level; that is, to enable one to efficiently develop numerous computerized procedures for identifying, measuring, and evaluating the various statewide effects generated by alternate highway proposals and to, on the basis of this information, make possible the selection of a most logical/optimal plan. Prior to the utilization of the system approach, a plan was evaluated on a project basis - what seemed to be the best solution to a traffic problem in one area of the state may have actually caused, in another portion of the network, a far worse situation. In terms of cost-benefit, the project may have been predominantly cost. No one could project this impact. The effect of a new roadway on the rest of the network was undeterminable. The Statewide Traffic Forecasting

Model and the sixteen travel impact indicators make possible the monitoring of the more important network changes in travel patterns - they inform one of the more probable travel conditions generated by a plan prior to its actual implementation. Systematic application of the methods outlined ensures the maximization of user benefits and reduction of user costs.