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Statewide Transportation Analysis & Research

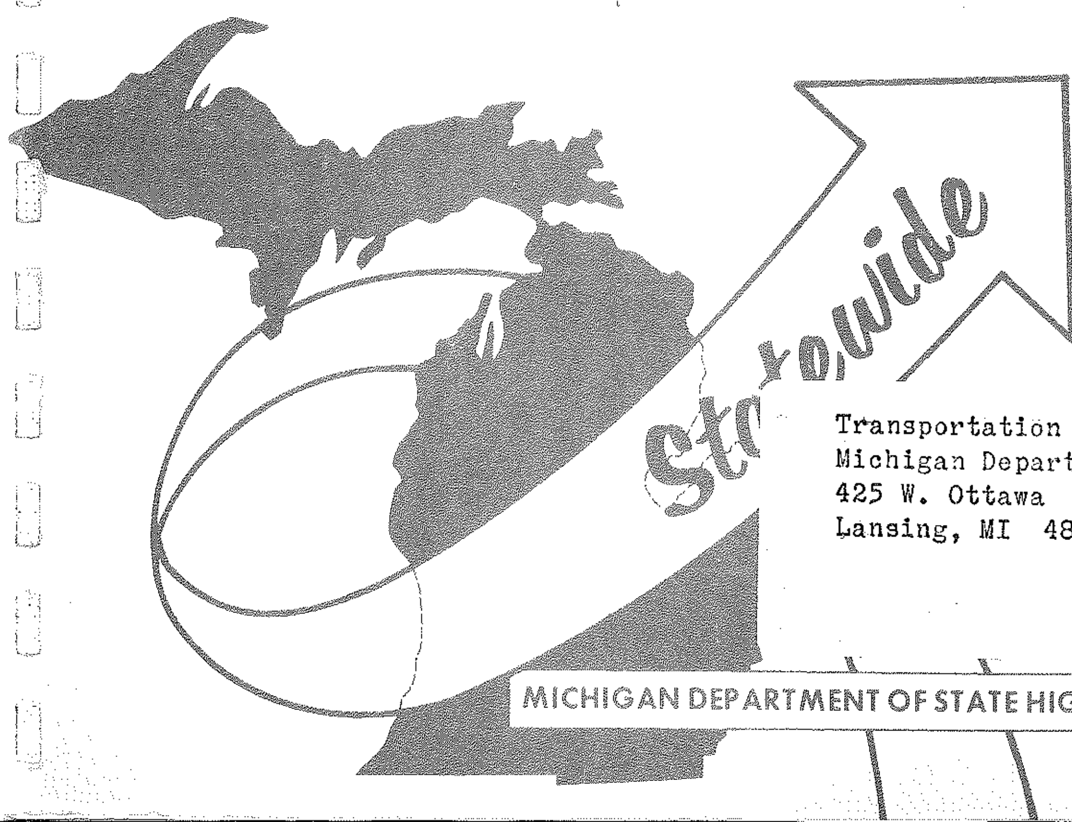
MICHIGAN'S STATEWIDE
TRANSPORTATION MODELING SYSTEM

VOLUME II-C

INTERACTIVE GRAPHIC APPLICATIONS IN MICHIGAN'S STATEWIDE TRANSPORTATION MODELING SYSTEM

STATEWIDE PROCEDURES SECTION

APRIL, 1980



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MICHIGAN'S STATEWIDE
TRANSPORTATION MODELING SYSTEM
VOLUME II-C

INTERACTIVE GRAPHIC APPLICATIONS IN MICHIGAN'S STATEWIDE TRANSPORTATION MODELING SYSTEM

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APRIL, 1980

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INTERACTIVE GRAPHICS IN MICHIGAN'S STATEWIDE TRANSPORTATION MODELING SYSTEM

VOLUME II-C

By Terry Gotts and Richard Esch

STATE OF MICHIGAN

WILLIAM G. MILLIKEN, GOVERNOR

DEPARTMENT OF TRANSPORTATION

TRANSPORTATION BUILDING, 425 WEST OTTAWA PHONE 517-373-2090
POST OFFICE BOX 30050, LANSING, MICHIGAN 48909

JOHN P. WOODFORD, DIRECTOR

May 1, 1980

Mr. Sam F. Cryderman, Deputy Director
Bureau of Transportation Planning
Michigan Department of Transportation
P.O. Box 30050
Lansing, Michigan 48909

Dear Mr. Cryderman:

As planners, we are being faced with a real dilemma. On one hand, the requests for information and analysis are increasing dramatically as we continue to increase public participation in the planning process. On the other, real revenues are declining. Moreover, it appears that both trends are likely to continue for some time to come. Our only viable alternative is to develop methods of increasing the productivity and efficiency of our planning procedures.

This report documents a process called NETEDIT, developed by our Transportation Planning Procedures Section. NETEDIT has proven to shorten the start-up time in the production of test networks for regional systems plans and transportation alternative analyses from two weeks to approximately four hours. It has markedly improved the throughput of travel impact analysis over the past three years.

NETEDIT was presented at the 1980 Annual Meeting of the Transportation Research Board. This report will be published late this year by TRB.

Sincerely,

G. Robert Adams, Administrator
Transportation Planning Services Division

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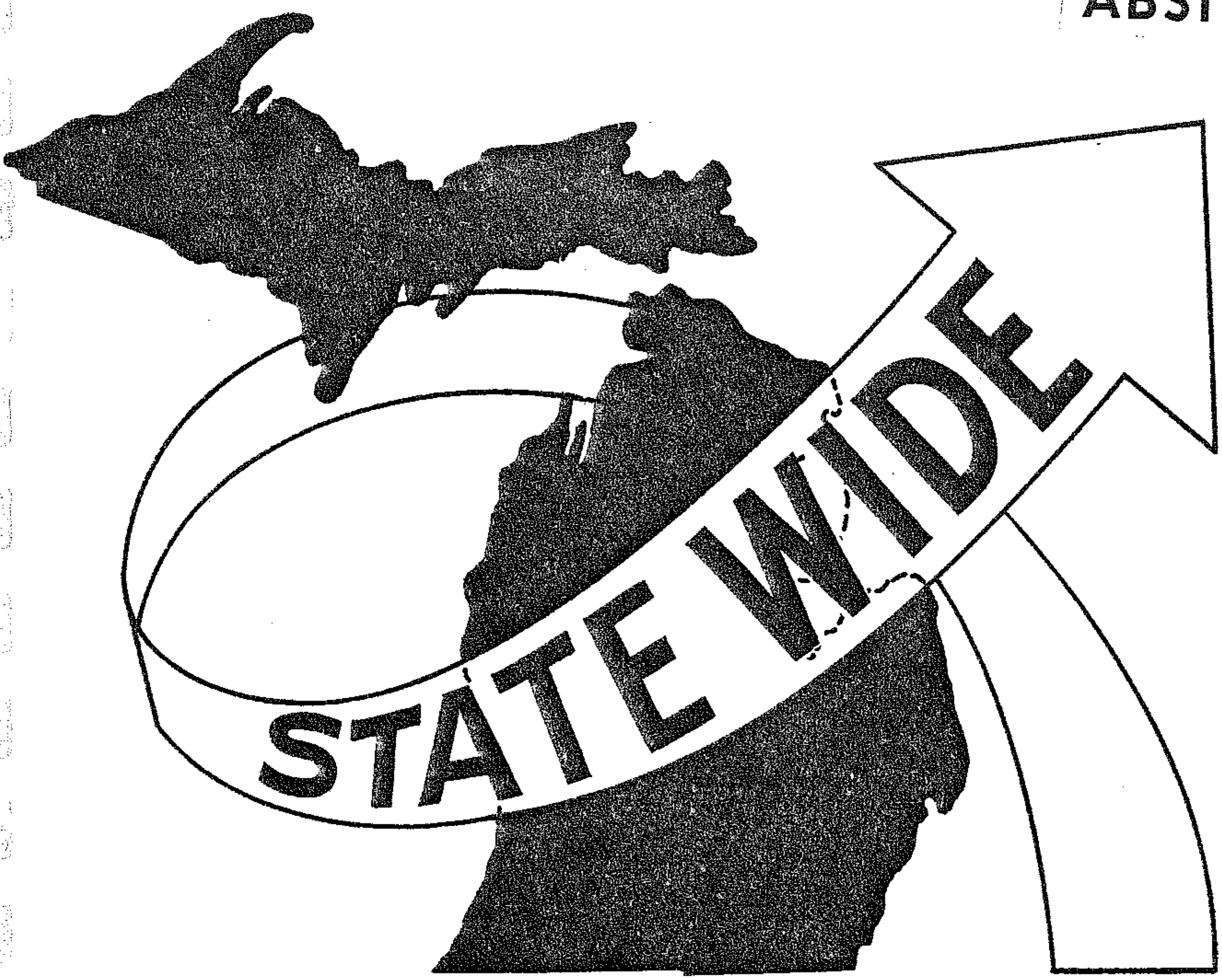
ABSTRACT



ABSTRACT

Modern transportation agencies face increasing responsibilities and decreasing revenues. The only viable solution is increased productivity and efficiency. NETEDIT, an operational interactive method of updating, displaying, and interrogating networks, has allowed Michigan's Department of Transportation to increase its analysis capabilities without sacrificing production time.

The utility of such a process is easily seen by contrasting manual coding and batch updating with the interactive update process. NETEDIT gives the user instant pictorial feedback, enabling errors to be corrected on the spot. This allows the average elapsed time for alternate generation to drop from two weeks to four hours. Additionally, the ability to vary the way a link is drawn based on its attributes--solid, dotted, dashed, cross-hatched, even bandwidth--lends versatility. The addition of a digitizer tablet has allowed creation of 2,000-node networks in two weeks. A tree plotting subroutine eliminates much of the elapsed time in network calibration.

Most importantly, NETEDIT, together with Michigan's Statewide Transportation Modeling System, has been used in over 350 actual planning applications over the past two and a half years. As a result, NETEDIT has become a valuable transportation planning technique in Michigan.

INTRODUCTION

INTRODUCTION

Governments face a challenge in meeting modern political realities. On one hand, legislation and public expectations demand thorough planning and implementation of an expanding range of governmental responsibilities. At the same time, the economic realities of the foreseeable future dictate a governmental "belt-tightening", with personnel and budgets being maintained or cut back rather than increasing.

Michigan's Department of Transportation is meeting just such a challenge in its Bureau of Transportation Planning. Although budget and personnel are not rapidly expanding, the demands on the planning process from federal legislation, the Department's Action Plan, and concerned citizens have grown tremendously. The Department must now consider many alternatives and modes and must examine an ever-widening range of impacts--travel, social, economic, environmental--for every major transportation project it undertakes. Moreover, the people who live in the region of the proposed project, and who will therefore be most affected by the final solution, must be involved in each step. Based upon the evaluation of the first set of alternates, new alternates may be proposed, and the whole cycle repeated until a consensus is reached.

With conventional methods of network updating, interrogation, and display, the emphasis on public involvement becomes self-defeating. As more and more enthusiastic citizens start asking questions, the planning machinery begins to bog down. Elapsed time between questions and answers keeps growing, and public enthusiasm declines. The end result is interested but frustrated private citizens who feel they cannot get answers, and well-meaning but frustrated transportation planners who would love to answer the questions but cannot get to them for two months.

The logical solution to the dilemma of increasing responsibility and decreasing resources is increased productivity. Michigan has a unique opportunity in this respect. Michigan's Statewide Transportation Modeling System is an operational multi-modal impact analysis system which has been used in over 350 applications over the past two and a half years. This system has allowed the Department to take full advantage of interactive graphics through the development of the NETEDIT computer program. NETEDIT is an interactive method of creating, displaying and analyzing alternate transportation networks and of relating associated socio-economic data to them. Through interactive graphics, NETEDIT: 1) has decreased workload, 2) has decreased elapsed time, and 3) has increased accuracy, thereby allowing the Michigan Department of Transportation to plan, design, and construct a transportation system more efficiently.

Hardware Requirements

There are only two basic hardware requirements for implementing an interactive system of network display and updating. First,the user needs a cathode-ray-tube (CRT) computer terminal--like the one in Figure 1, similar in appearance to a television screen--which is capable of drawing pictures as well as printing alphanumeric characters. Second, there must be access to a computer which supports a high-level programming language and allows a computer program to be linked with routines which actually do the drawing on the screen. These routines can usually be purchased from the manufacturer of the CRT at nominal cost.

It is important that the screen of the CRT be large enough to display a natural unit of data--say, a county--without appearing over-cluttered. If it is difficult for the operator to figure out what he is looking at, the objectives of increased efficiency and accuracy will not be realized. The most popular screen sizes range from about a ten inch diagonal rectangle to about 25 inches on the diagonal. The examples in this report were made on a Tektronix 4014-1, which has a 19 inch screen.

Resolution is important if the program is to calculate the actual length of a link from the screen coordinates of its end points. For example, the 4014 has 4096 X 4096 addressable points. By comparison, the small screen 4014 has only 1024 X 1024 addressable points, somewhat increasing the chance of approximation error. The user may decide approximately how many square miles should be displayed on the screen, then compute possible errors for each model of CRT being considered.

A third consideration is computer speed. Most high-level machines are quite fast; but, if a time-sharing system is overloaded, one should think very carefully about investing the time and money required to put up an interactive graphics system. Moreover, even a fast line will not help in such a situation: What good does it do to draw at 9600 baud if there is a 30 second pause between bursts of drawing?

Finally, the reliability of the time-sharing system to be used must be looked at objectively. If the system is prone to frequent periods of down time, this will produce many false starts and restarts in a network update.

In that case, it would be probably less frustrating and more productive to stay with manual coding techniques.

NETEDIT is presently running, with excellent results, on a large-scale Burroughs B-7700 computer with three processors and a 4.7 megabyte memory. An earlier version was run on a Control Data 6400-series machine. It is written in FORTRAN-IV and uses Tektronix Plot-10 graphics subroutines. The program is currently limited to networks of no more than 13,000 links and 16,000 nodes.

Statewide Transportation Modeling System Network Concepts

Collection, storage, and retrieval of all data employed within the Statewide Transportation Modeling System is tied to a 547 zone system. Of this total, 508 are "in-state" zones illustrated in Figure 2. The zonal concept is of extreme importance in that it provides a dynamic link between information retrieval and actual model procedures. The conversion of raw data from storage within the information files into accurate travel, social, economic, and environmental indicators has been effectively accomplished as a result of gearing the entire system to the zonal format.

The transportation network model is the means by which the transportation planner describes to the computer in its own "language" the transportation system under study. The network is defined in the network model as a set of links and nodes. Nodes are numbered points thich are located by (X,Y) coordinates referencing a statewide coordinate grid. A link is defined by its connection of two networks' nodes. Figure 3 shows a conceptual drawing of a portion of the highway network within several zones of a zone system. The illustration indicates that there are two basic types of system links--regular links and pseudo - links--known as centroid links. A regular link is

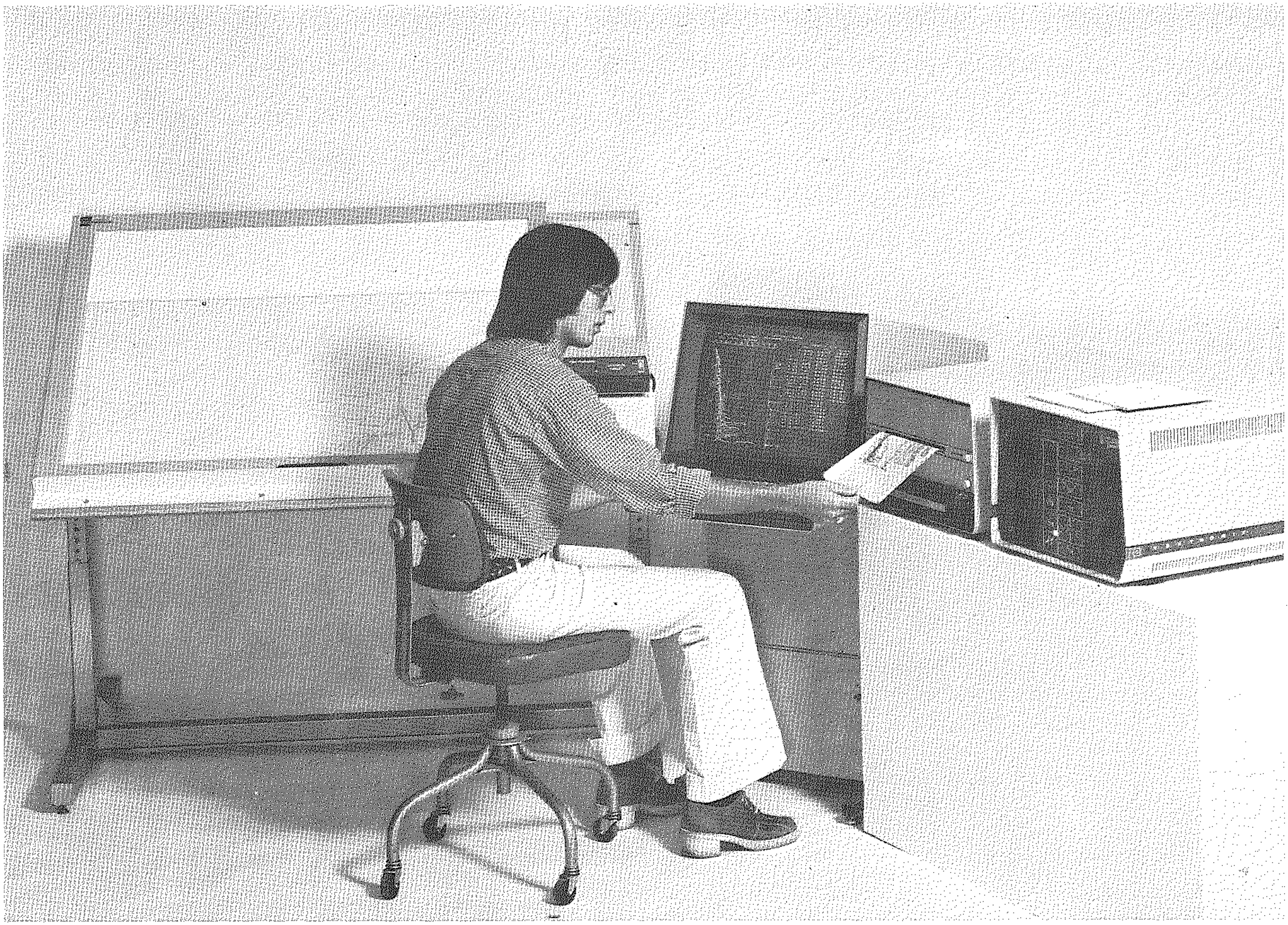


FIGURE 1

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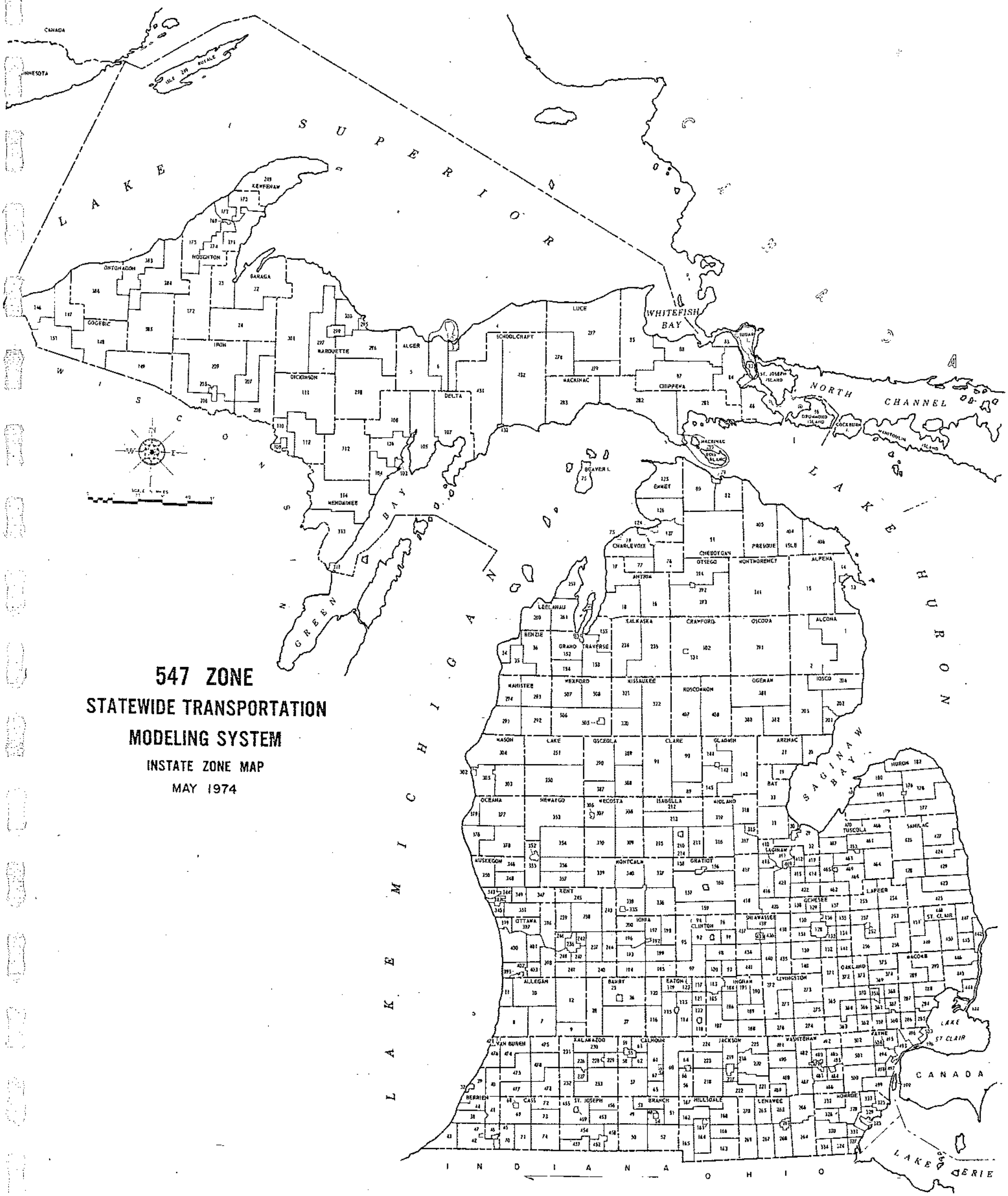
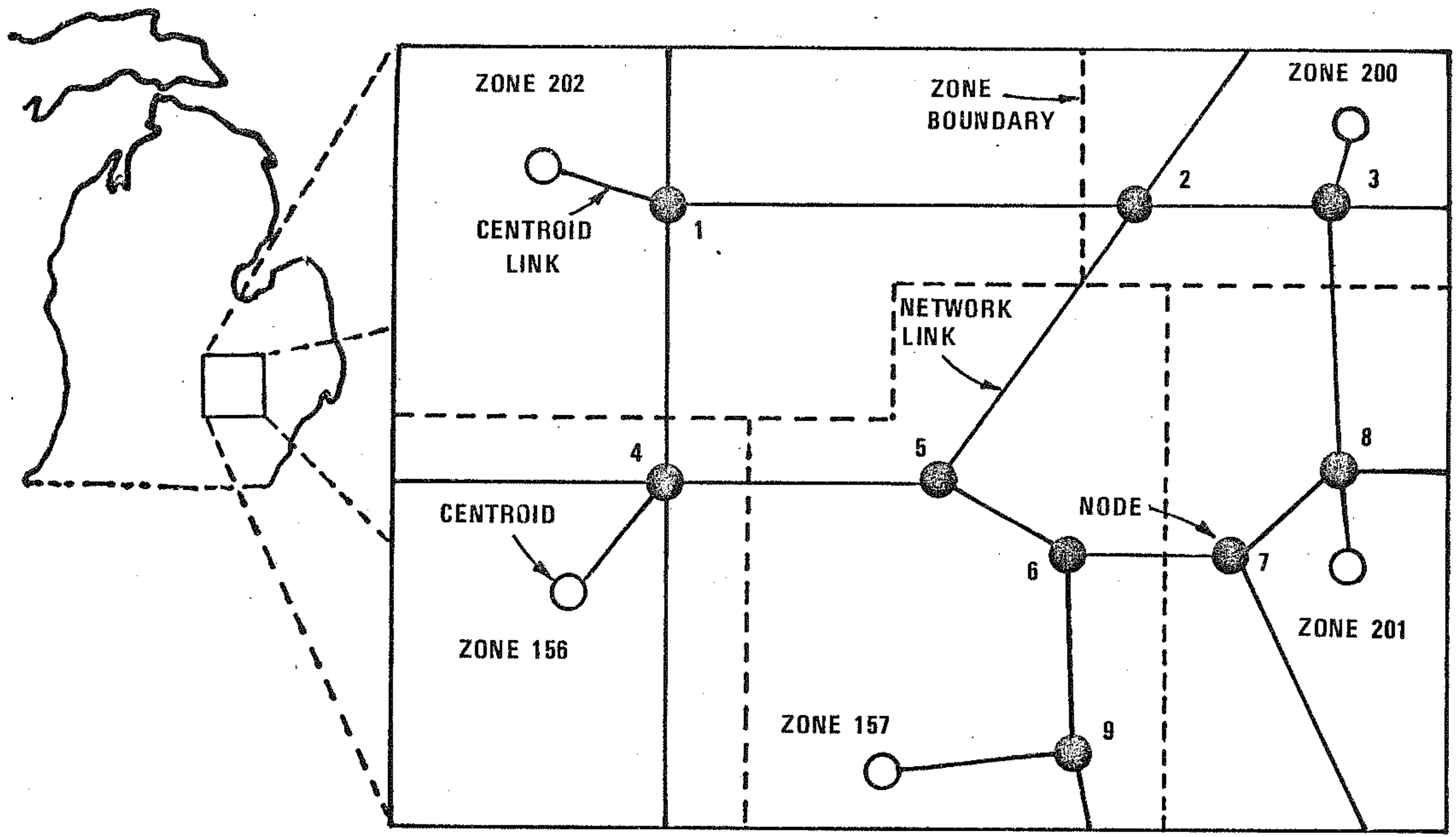
RICHARD ESCH

FIGURE 2:



NETWORK DESCRIPTION



used to describe a section of the transportation facility (e.g., highway or rail segment) while a centroid, in connecting itself to a node of the base network, allows the feeding of traffic to and from a zone, off and onto the system.

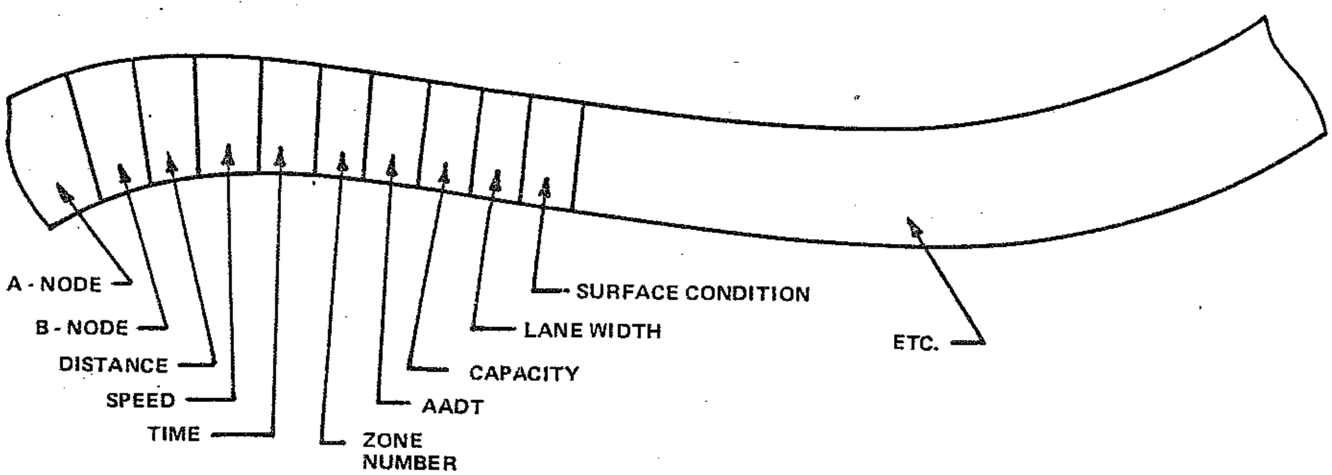
The transportation planner must differentiate between types of links according to certain physical and travel characteristics. Each discrete piece of link-specific descriptive data, or link attribute, is stored on a computer file in what is known as a "volume field". An understanding of the volume field concept is critical to one's comprehension of the modeling system, for it is consistently employed throughout the process. Figure 4 illustrates how a highway link's attributes might appear on a segment of magnetic tape if it were visible to the human eye. In creating the network model data records are taken from punched cards and recorded sequentially on the network data file. First, a link's A- and B-nodes are recorded to distinguish it from other links within the network. This initial portion of a link's data file contains, in volume fields, other information pertinent to its description, e.g., type (existing or newly created), jurisdiction (who funded the construction and maintains the facility), etc.

Network Updating: Manual vs. Interactive

Once the network file is created through standard coding procedures and specialized computer programs, it may be modified to stimulate alternate transportation proposals. Many such changes are performed when comparisons of travel impacts are desired. The transportation network model provides a primary input not only for the travel forecasting model, but for all models

FIGURE 4:

LINK DESCRIPTION



developed within the statewide system. The steps involved in creating and modifying networks are exacting and time consuming. These are the steps which the interactive network updating system was developed to replace:

Step 1: Cards must be punched to update a base network into the alternate network. For the analyst, this means coding, i.e., writing on forms from which cards will be punched, all the links and nodes which are to be added, deleted, or changed in the updated alternate network and the link attributes for the new or modified links.

Step 2: After the cards are keypunched, they are input into a series of computer programs which: 1) alter the base network to produce an updated alternate network, 2) change or add volume field (link attribute) information, and 3) create a computer-readable version of the network which can be plotted on paper.

Step 3: After the network has been plotted, producing a plot such as Figure 5, the analyst pores over it to ascertain that no errors have been made. Typically, the analyst must check: 1) the location of modified nodes, 2) that all the correct links have been added or deleted, and 3) that the volume fields have been correctly updated. If errors are discovered, further updating is begun, going back to Step 1. Often the entire process is repeated two or three times. Even if gone through only once, it usually takes up to two weeks for coding, computer runs, plotting, and plot checking.

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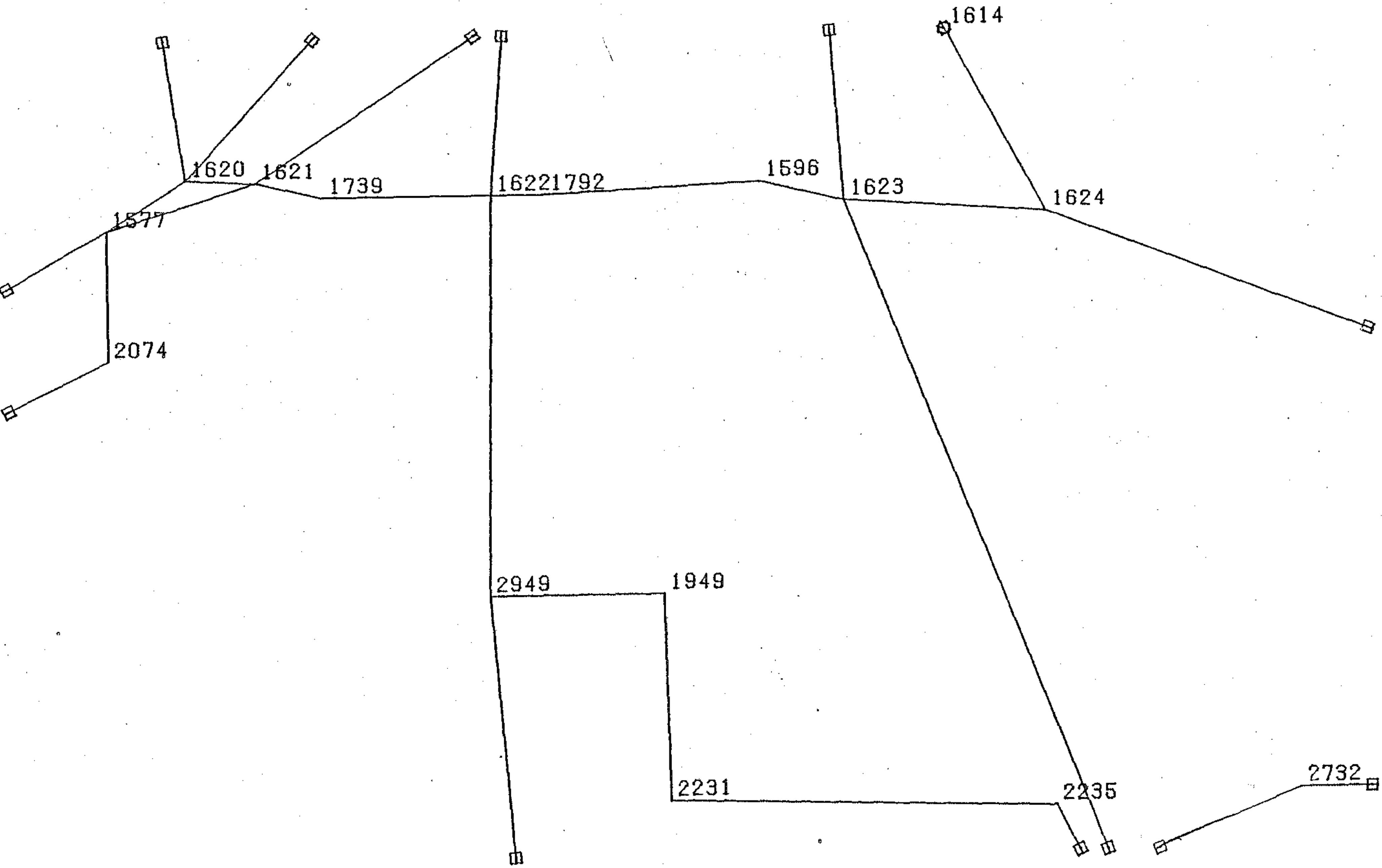
FIGURE 5

CALCOMP NETWORK PLOT



In comparison, the statewide interactive network updating system is simpler, less laborious, and provides for immediate verification. From the user's perspective, the system can be a simple one-input, one-output system as shown in Figure 6. The user merely specifies the necessary information to access the base network at the beginning of the program; all other file manipulation occurs internally. The user need only pay attention to the location of roads when building the desired network alternate.

NETEDIT presently manipulates networks stored in Burroughs' "TP-System" packed form. However, the program is modular enough, and its concepts general enough, that modifying the packing/unpacking subroutines should be all that is necessary to allow it to read and write networks in other forms, such as DCO/TRANPLAN or UTPS. After the updated network has been written to a disk or tape file, it is used like any network created by batch processes. Thus, NETEDIT uses no special interfacing mechanisms other than its own packing/unpacking routines. Internally, the program creates and manipulates several background files, as shown in Figure 7:

1. Link attributes--capacity, base-year counts, and up to 45 other pieces of link-specific data--are stored on a randomly accessed disk-file to save core space.

2. At any point between unpacking and packing, the current intermediate state of the network may be written to a disk-file by giving a SAVE command. That stored state may be restored at any time with a RCVR (recover) command, thus providing a check-point/restart capability.

3. As the user executes network modification commands, they are encoded and written to a "tank" on disk. After any system failure short of a disk crash, the user need only unpack the network he was working on when the system

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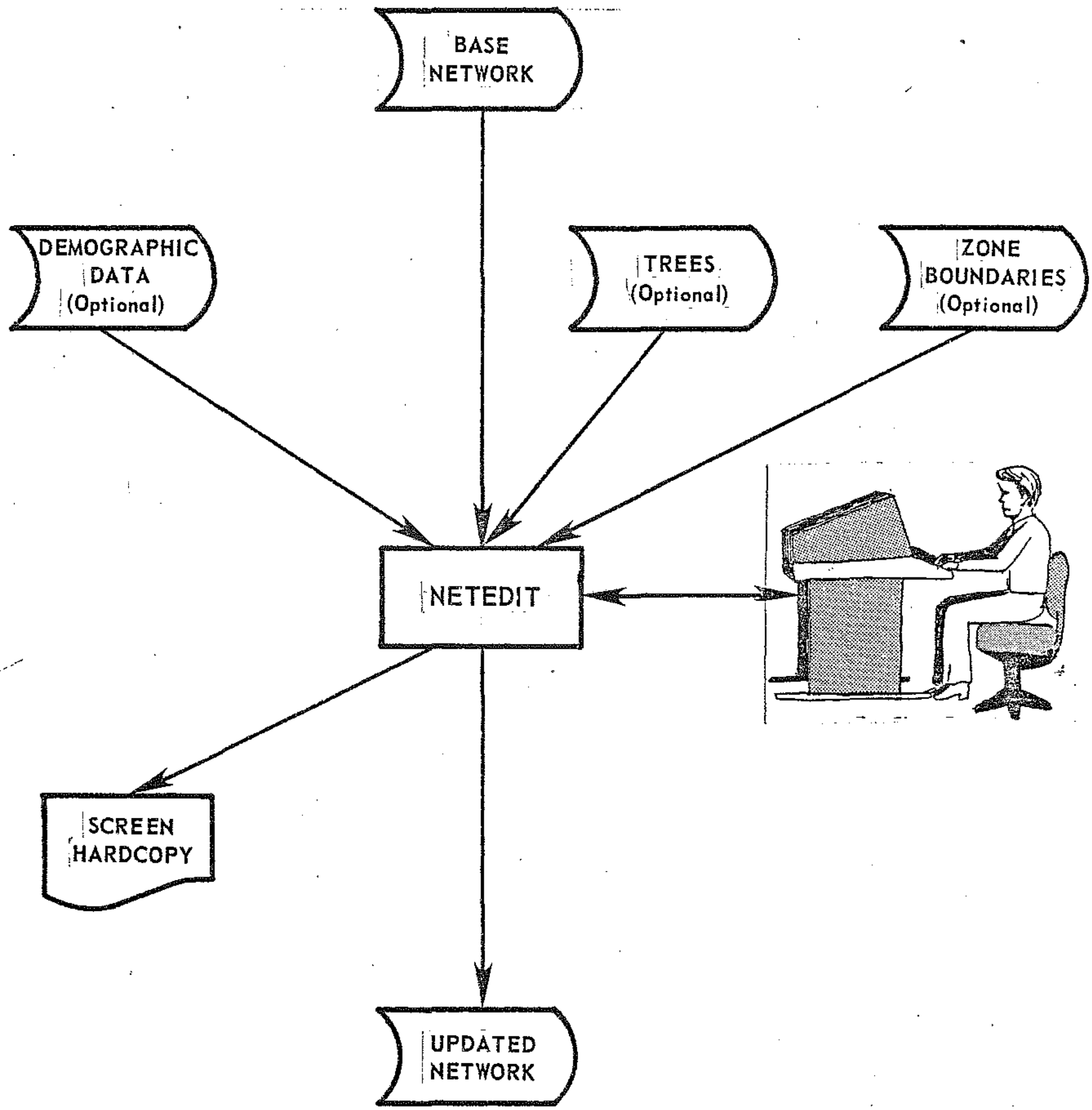
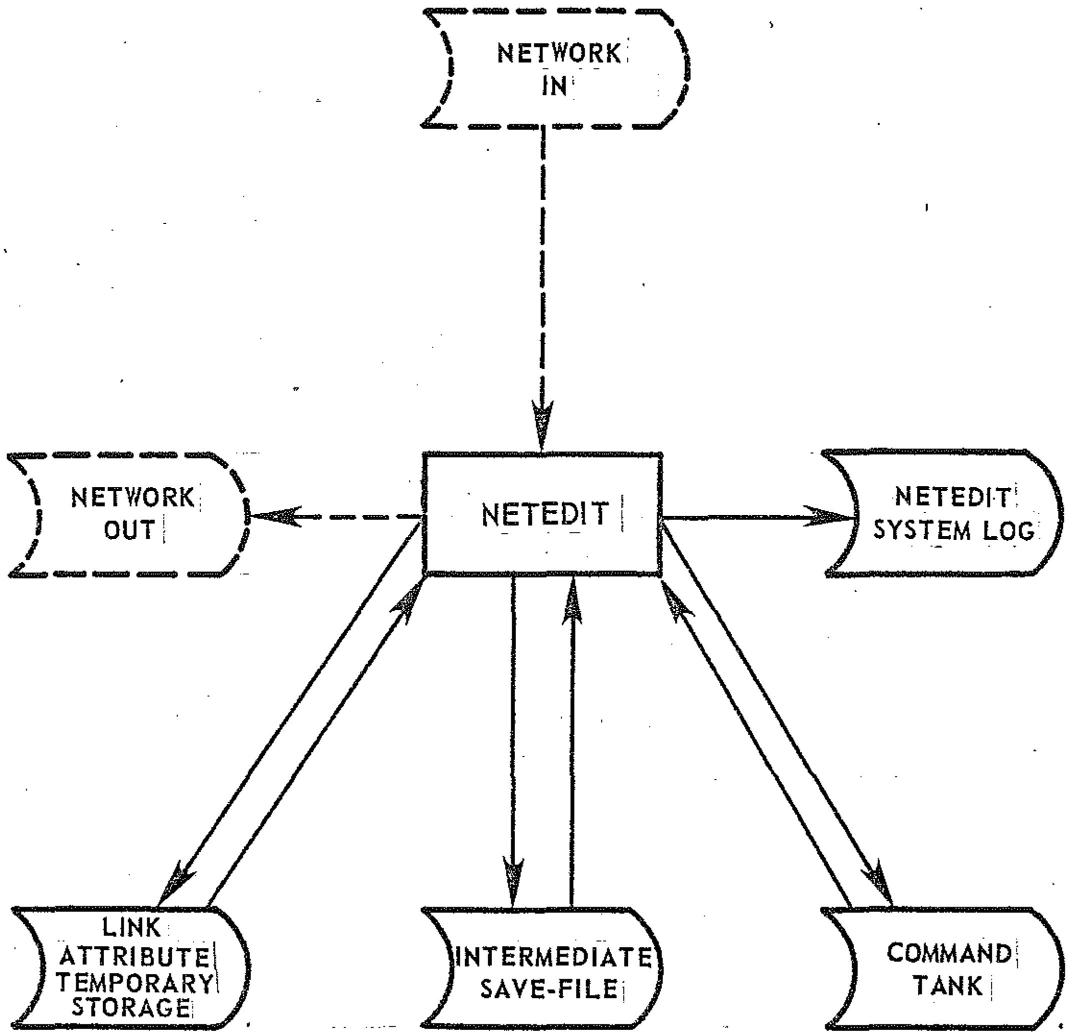
FIGURE 6

NETWORK UPDATING FROM THE USER'S PERSPECTIVE



BACKGROUND FILES



went down and execute a TANK command. The network will be changed as if every command had been re-entered.

4. A record of changes made by every user to every network is kept in a log file on diskpack. The file is periodically written to printer and rewound. Besides providing informational backup, the log is also handy for answering "why-doesn't-this-program-work-right" questions.

System Demonstration

There are five primary application categoreis for which NETEDIT is typically used on a daily basis: 1) Network updating, 2) Network display and presentation, 3) Network generation, 4) Tree (path) plotting, 5) Socio-economic data display. By considering each category in turn, the reader may see the extent and versatility of the NETEDIT command set. Commands may usually be given in any order, so that the user may base the next action of the results of the last. This characteristic also makes NETEDIT a useful tool in dealing with private citizens' inquiries, where the answer to one question often prompts another. Figures 9-20 were created by a hard-copy unit similar to the one shown in Figure 1. Over 9,000 such copies have been used in day-to-day planning over the past two and a half years in Michigan.

1. Updating

Consider now the portion of the highway net around Grand Rapids shown in Figure 5. Suppose the Department is asked to evaluate the impacts of putting in a bypass around Grand Rapids, as shown in Figure 8. The planner would begin by adding a link (ADDL) from I-196 to US-131 (nodes 2074 to 2949), as shown in Figure 9. In Figure 10, the change-parameter (CHGP) command is used to "reconstruct" county road 2949-1949 to a four-lane freeway. "CJ,3" changes

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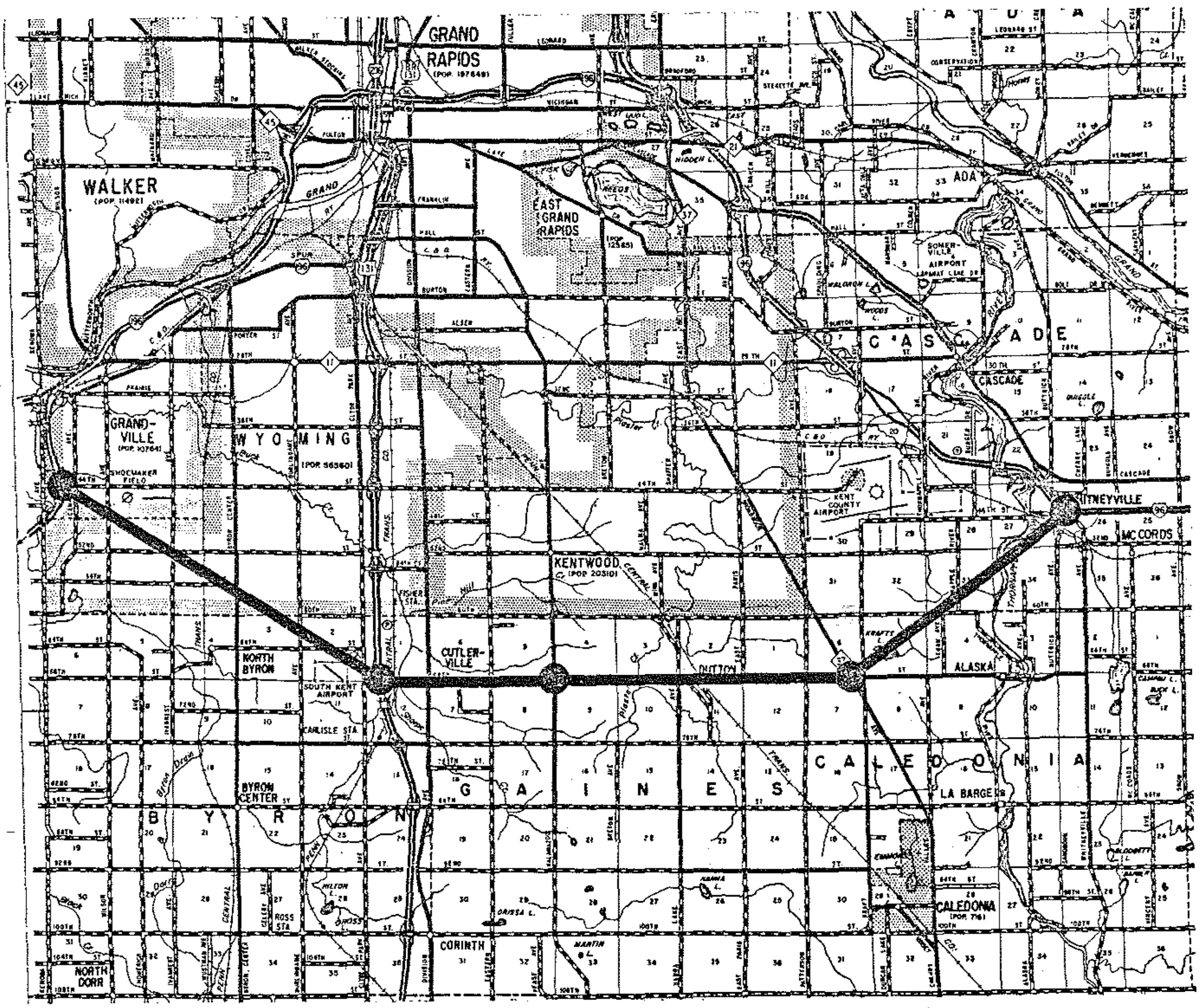
RICHARD ESCH

FIGURE 8

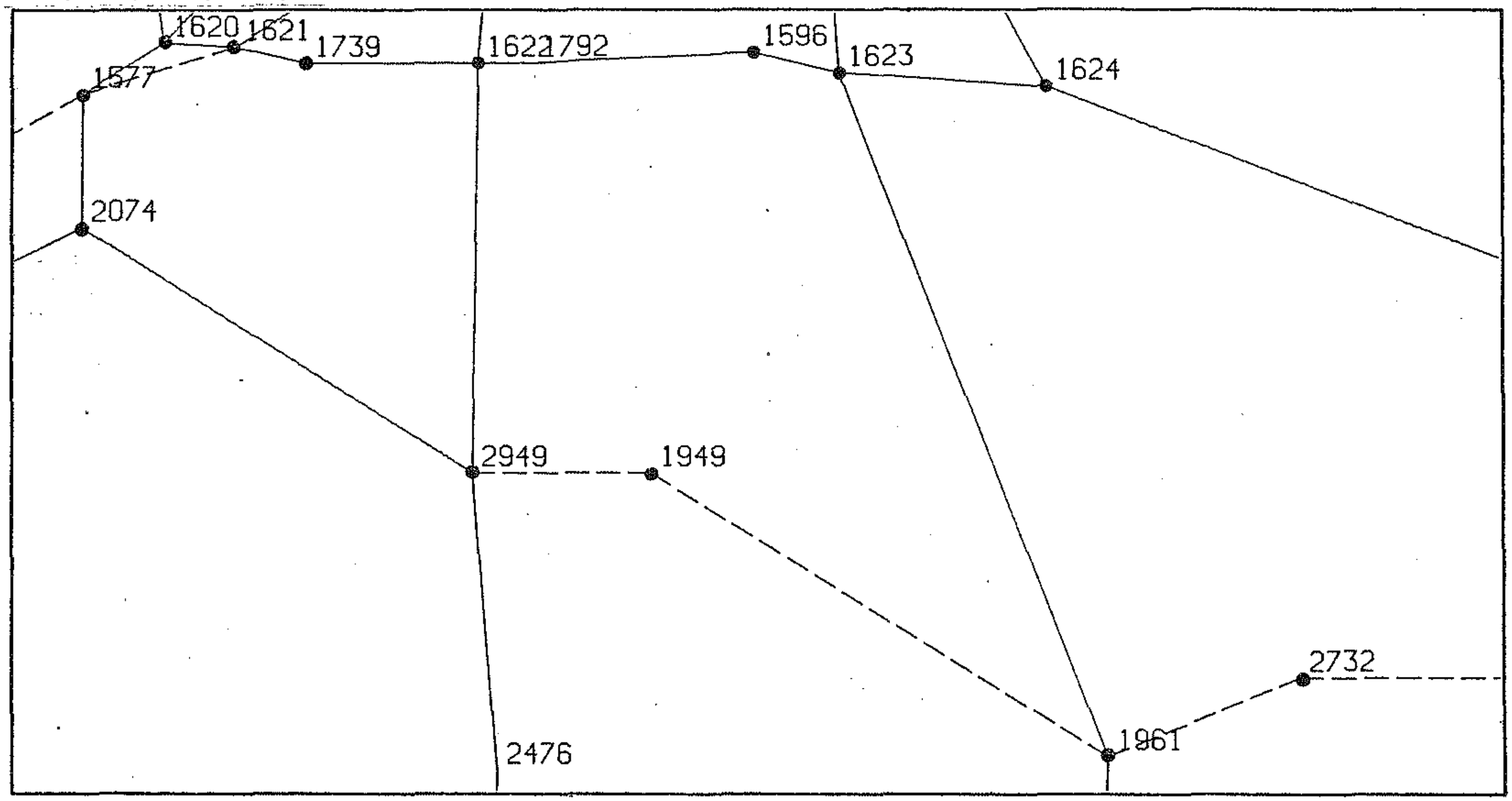
ROUTE OF PROPOSED BYPASS



ADDING A LINK

TLB/NET/1978/HWY/1.

COMMAND:
ADDL, 2074, 2949

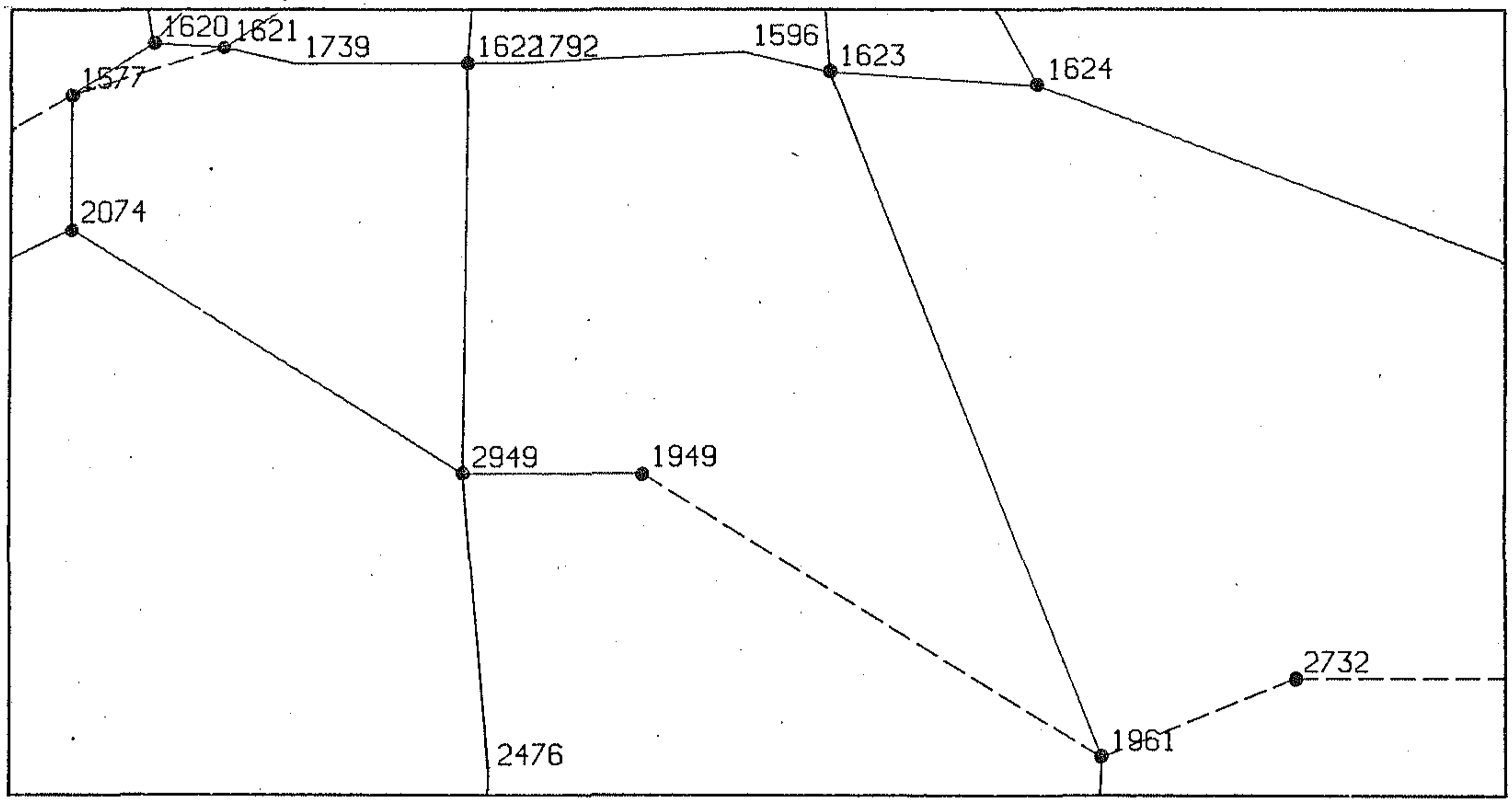


XMIN= 183.7,XMAX= 191.1,YMIN= 129.1,YMAX= 133.Ø

"RECONSTRUCTING"
A COUNTY ROAD TO FREEWAY STANDARDS

TLG/NET/1978/HWY/1.

COMMAND:
CHGP, 2949, 1949
CJ, 3
3, 12
5, 1



XMIN= 183.7,XMAX= 191.1,YMIN= 133.0

the road to jurisdiction 3 and puts in all volume-field defaults for that jurisdiction: then "3, 12" changes parameter 3 (link type) to 12, and "5, 1" changes parameter 5 (freeway code) to 1. "DISP" redraws the picture.

In Figure 11, an interchange is inserted on 1623-1961 at node 2231 with the split (SPLT) command. This is equivalent to adding node 2231, deleting link 1623-1961, and adding links 1623-2231 and 2231-1961; note that 1623-1961 is X-ed out, showing the delete. The two new links are given all the characteristics of the parent, and the sum of their distances is made to equivalent to that of 1623-1961. Finally, links 1949-2231 and 2231-1624 are added to complete the bypass.

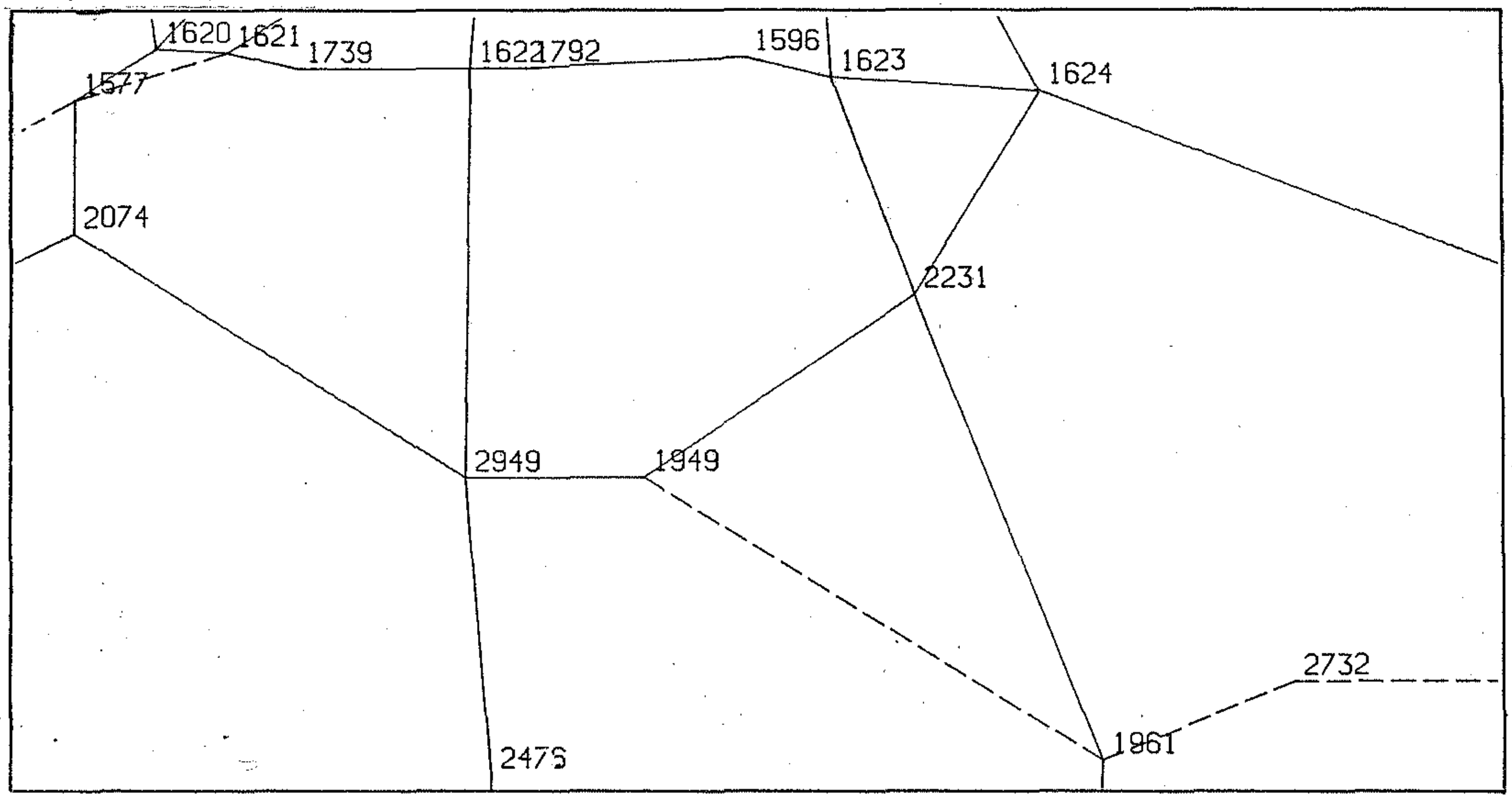
This small example points out an additional advantage to interactive updating: instant feedback. The user knows immediately whether the correct link has been deleted, or whether a link to be added was placed correctly.

2. Display

Whether the planner is investigating a portion of a network in detail, finalizing dimensions and parameters in preparation for an ink plot, or merely producing quick 8 1/2 X 11" plots for a meeting, NETEDIT cuts elapsed plot time from hours or days to seconds. For example, it is possible for the program to vary the manner in which a link is drawn based on link attributes. In Figure 12, solid lines are state trunkline, dashed lines are county roads, cross-hatches are rail links, and links marked with triangles are rail-to-highway connectors. One may also choose, or "filter", links in or out of the display based on attributes. Figure 13 is the result of filtering out all but rail links from Figure 12. A portion of the current display may be enlarged for further study: Figure 14 is the result of selectively windowing

ADDING AN INTERCHANGE

TLG/NET/1978/HWY/1.



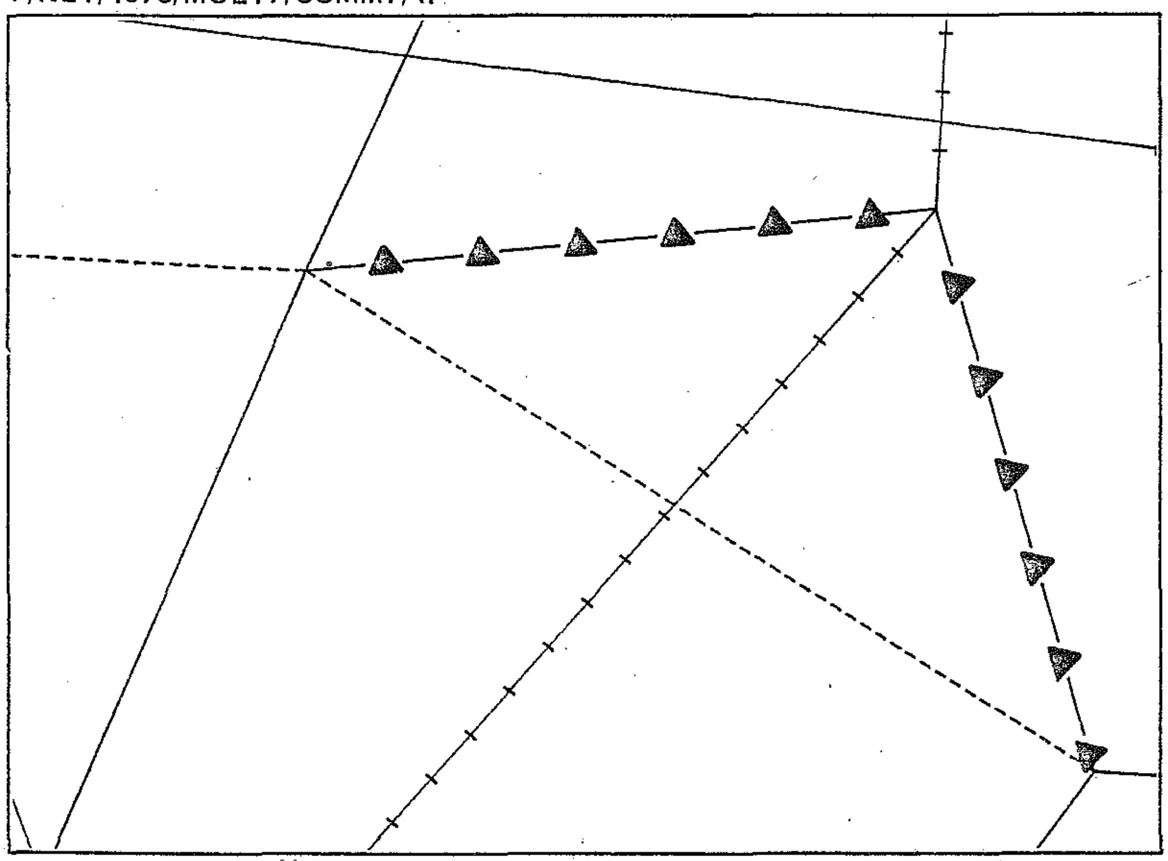
XMIN= 183.7,XMAX= 191.1,YMIN= 129.1,YMAX= 133.0

COMMAND:
SPLT, 1623, 1961
ADDL, 1949, 2231
ADDL, 2231, 1624

FIGURE 12:

DIFFERENTIATION BETWEEN LINK TYPES

P/NET/1978/MULT7/COMM7/1.

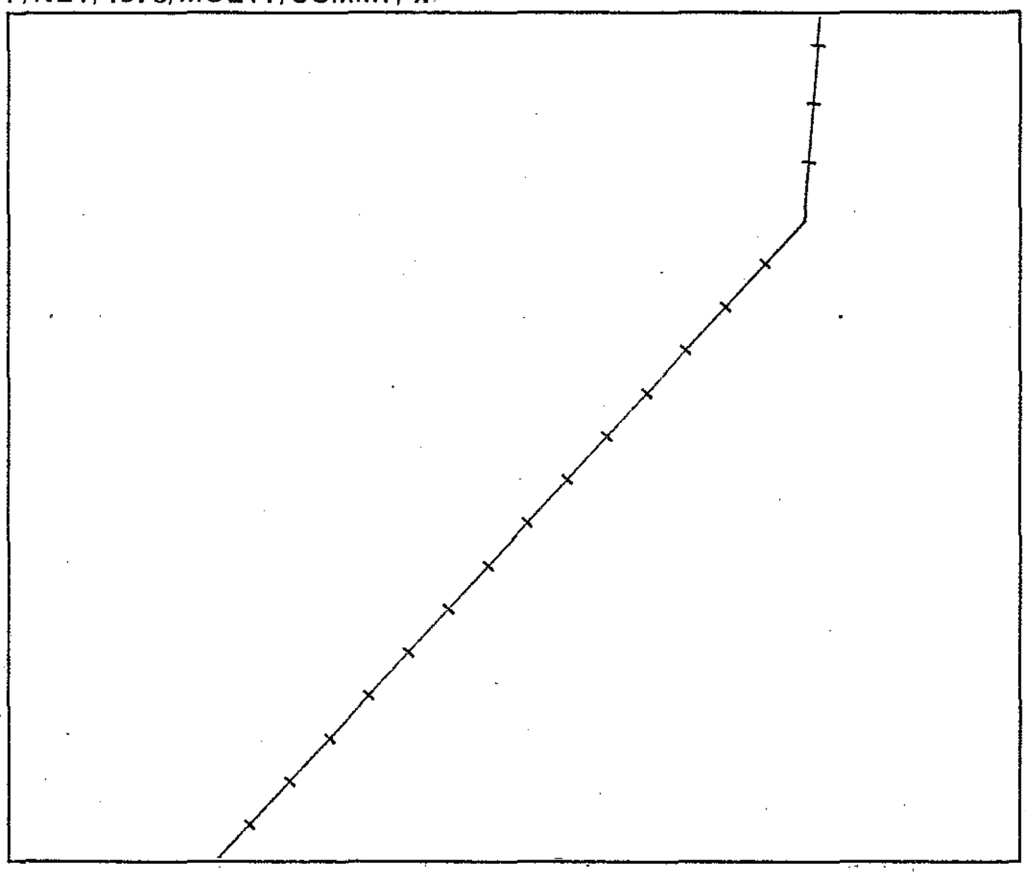


XMIN= 187.0,XMAX= 188.6,YMIN= 136.9,YMAX= 138.1

FIGURE 13:

FILTERING OUT ALL BUT RAIL

P/NET/1978/MULT7/COMM7/1.



XMIN= 187.0,XMAX= 188.6,YMIN= 136.9,YMAX= 138.1

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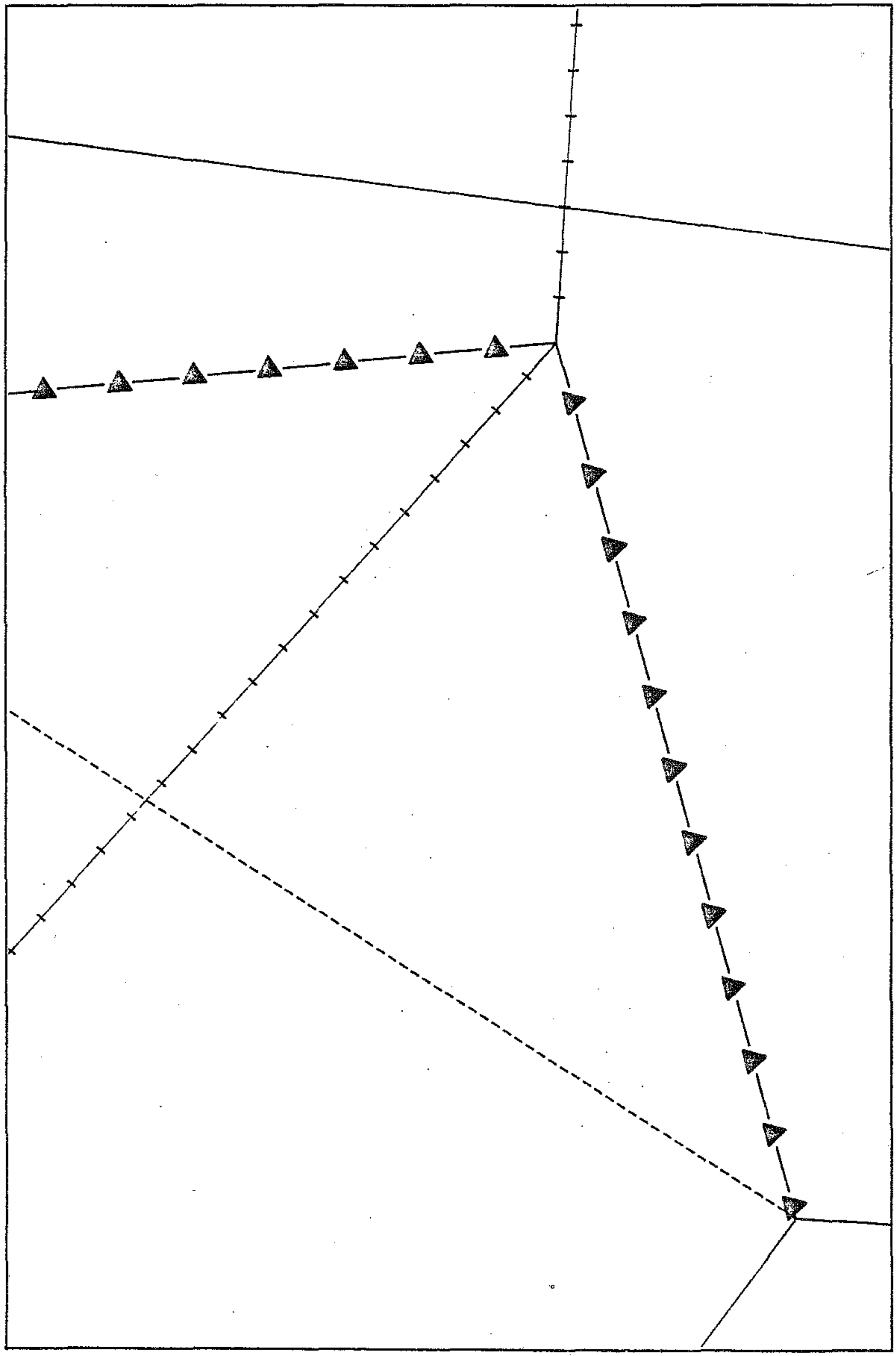
WINDOWING

P/NET/1978/MULT7/COMM7/1.



XMIN= 187.8,XMAX= 188.6,YMIN= 136.9,YMAX= 138.1

in on the right half of Figure 12. Zone boundaries can be superimposed in dot-dash lines (Figure 15). Link attributes can be displayed either numerically (Figure 16) or in bandwidth (Figure 17); attribute 7 is 1975 average daily traffic.

3. Network Generation

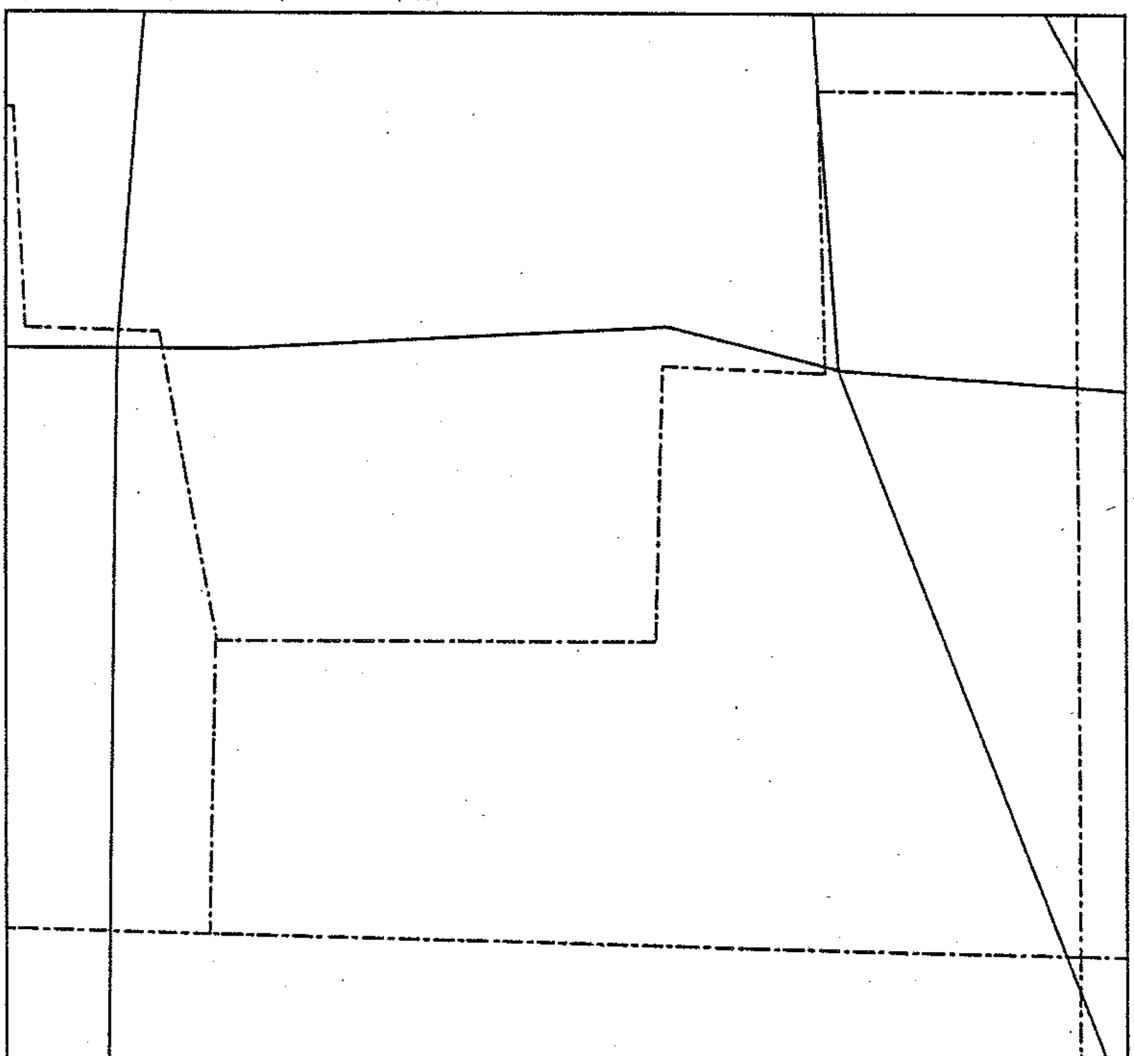
A digitizer tablet attached to a graphics terminal, such as the one shown in Figure 1, can be used to great advantage both in the initial creation of a network and in adding to an existing network. The user simply tapes a map to the tablet, enters two fixed points with the bullseye cursor or stylus, and informs the program where these points lie in the master coordinate system. From then on, one-letter "cursor commands" control the flow of the subroutines as the user moves with the cursor from node to node, automatically creating links between nodes. In this manner, it has been possible for people with only moderate familiarity with computers in general, and NETEDIT in particular, to digitize detailed networks of approximately 2,000 nodes and 2000-3000 links in two weeks. Because the tablet routines run as a subset of NETEDIT, one need not jump back and forth between programs to edit links entered from the tablet; and because the final product is a packed net, no further batch processing is necessary. This capability is presently allowing Michigan to digitize an A-node, B-node network for all roads in the state. This network will be the basis for future impact analyses and needs studies.

4. Tree Plotting

In network calibration as well as in alternative analysis, a large part of the job involves verifying that driving paths on the model reflect reality.

DISPLAYING ZONE BOUNDARIES

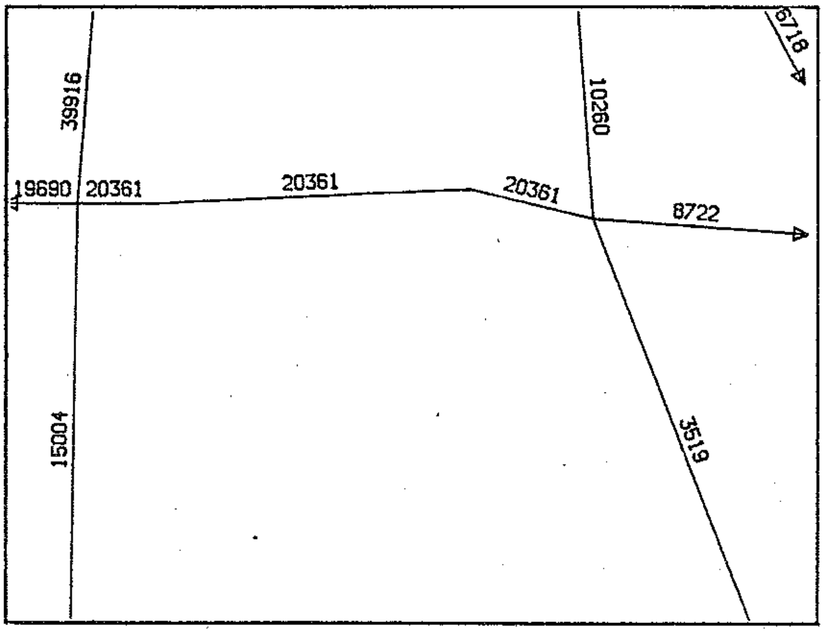
P/NET/1978/MULT7/COMM7/1.



XMIN= 185.8,XMAX= 188.5,YMIN= 131.0,YMAX= 133.5

NUMERICAL DISPLAY OF LINK DATA

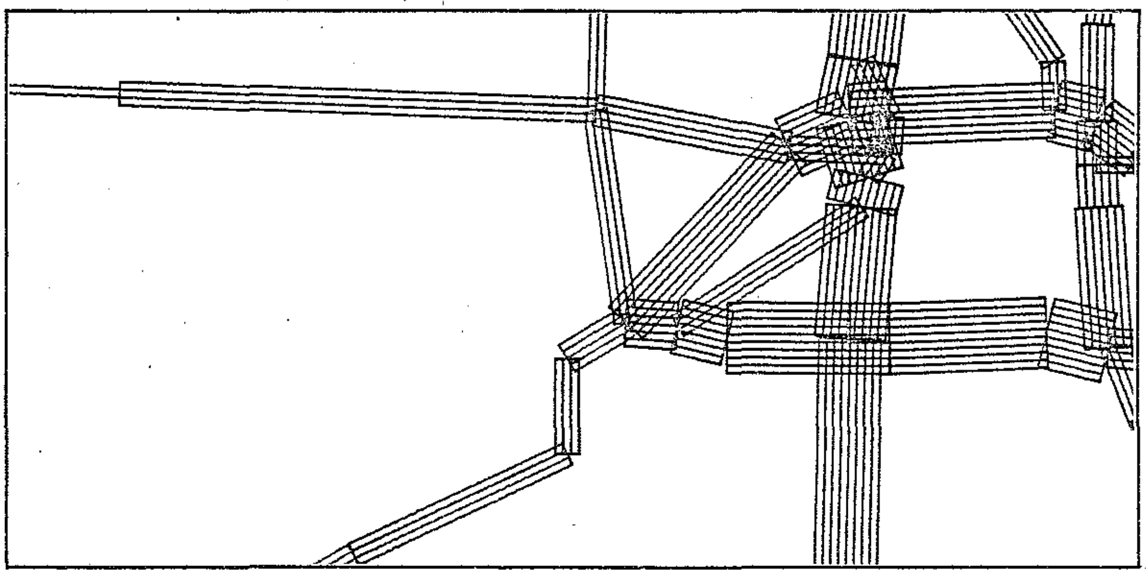
P/NET/1978/MULT7/COMM7/1.



XMIN = 185.8,XMAX= 188.5,YMIN= 131.1,YMAX= 133.4

BANDWIDTH PLOTTING

P/NET/1978/MULT7/COMM7/1.



XMIN= 189.0, XMAX= 188.0, YMIN= 131.0, YMAX= 135.0

KEY ATTRIBUTE= 7

BAND	MIN	MAX
1.	0	1000
2.	1000	2000
3.	2000	4000
4.	4000	6000
5.	6000	8000
6.	8000	10000
7.	10000	12000
8.	12000	15000
9.	15000	18000
10.	18000	99999

Usually, this is done by a batch-driven off-line plotter package. However, because most agencies have only one or two plotters to serve all users, a bottleneck often results.

The use of interactive graphics to plot trees offers several advantages, not the least of which is the reduction of turn-around time from days to minutes. In fact, interactive tree plotting has proven to eliminate as much as 90% of the elapsed time involved in highway network calibration.

Also, because the tree plotter is a subroutine of NETEDIT, all the options available in editing or displaying networks are accessible: windowing; changing line type based on link characteristics; and link attribute annotation. One could even plot trees in bandwidth, the width of the line being determined by, say, accident rate.

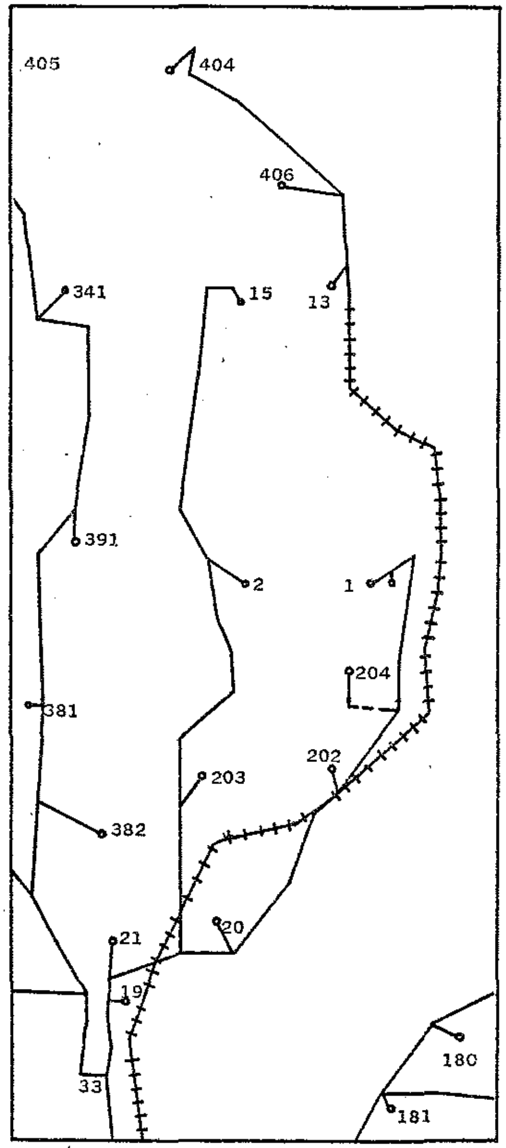
Figure 18 shows a portion of a multi-modal tree from Michigan's Statewide Transportation Modeling System. Note that in the interchange from zone 22 to zone 404, the tree proceeds on state trunkline to the rail-to-highway connector, gets onto the rail line, then gets off rail and finishes its path on trunkline.

5. Socio-Economic Data Display

Any data which can be associated with a node on a network can be superimposed on a network plot. Figures 19 and 20 show the same data, projected 1980 zone population, plotted as vertical bars and concentric circles; the height of the bar or number of circles indicate the magnitude of the zone's population relative to the other zones in the state. In these examples, zone boundaries have been drawn as dot-dash lines by NETEDIT. This subroutine becomes useful in attempting to relate a particular travel impact to the socio-economic classes it affects.

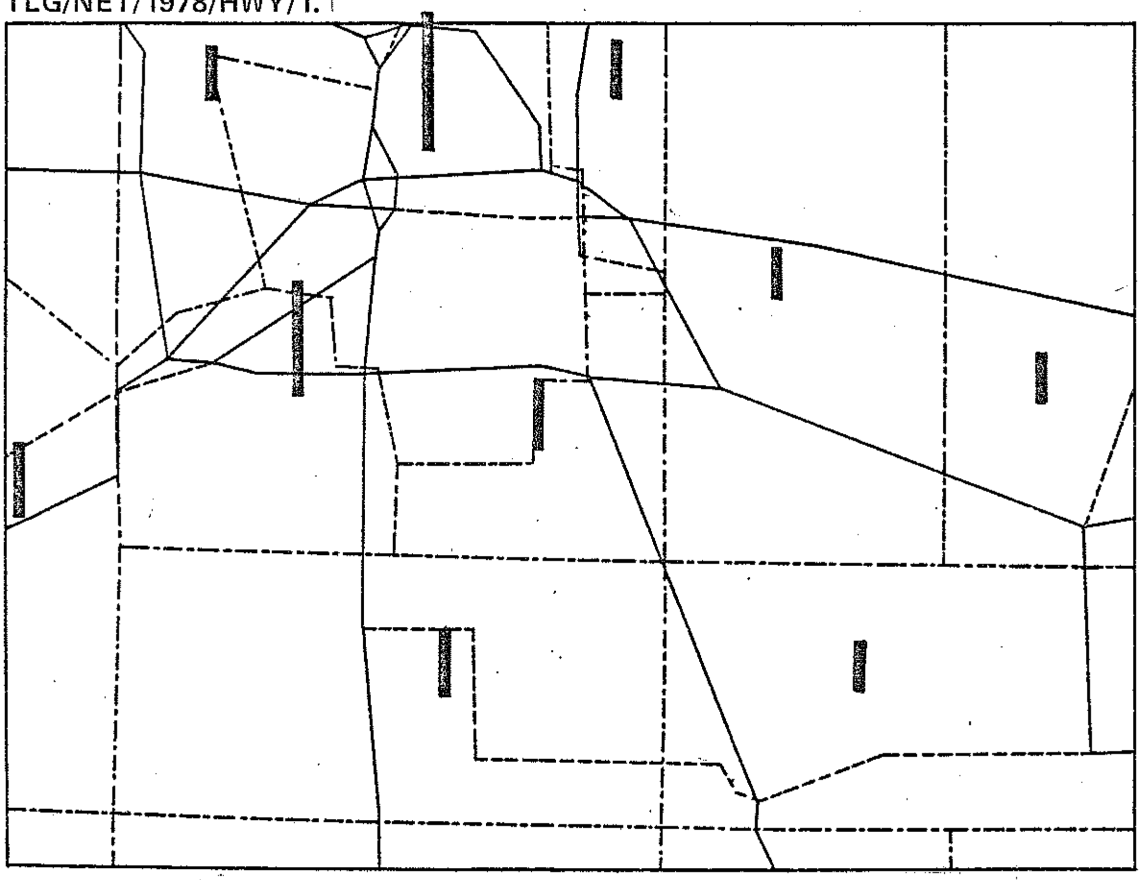
A MULTI-MODAL TREE PLOT

P/NET/1978/MULT7/COMM7/1.
TREE FROM ZONE 33



DISPLAYING DEMOGRAPHIC DATA (VERTICAL BARS)

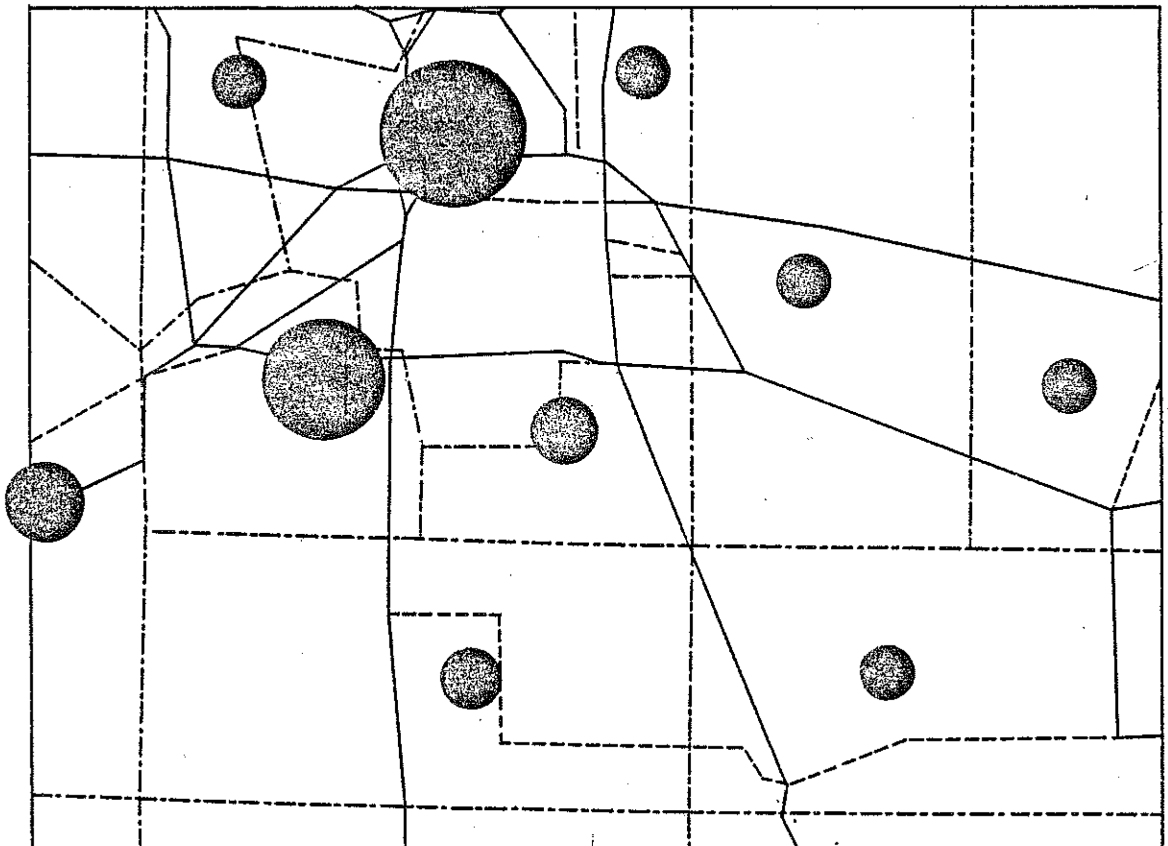
TLG/NET/1978/HWY/1.



XMIN= 183.2,XMAX= 192.0,YMIN= 128.8,YMAX= 135.4

DISPLAYING DEMOGRAPHIC DATA (CONCENTRIC CIRCLES)

TLG/NET/1978/HWY/1.



XMIN= 183.2, XMAX= 192.Ø, YMIN= 128.8, YMAX= 135.4

These examples have demonstrated only a few of the NETEDIT commands. A more comprehensive list follows:

Summary of NETEDIT Commands

1. Network Updating:

   ADDL - add new link

   ADDN - add new node

   CHGP - change link parameters

   DELL - delete link

   DELN - delete node and any link using it

   MOVN - move node

   SPLT - split link in two, adding new node

2. Network Display:

   DISP - display network in current coordinate window

   ENLG - enlarge a portion of the network

   GOTO - center window

   OLVW - return to previous virtual window

   ZONE - superimpose zone boundaries

   NOZN - turn off zone boundary overlay

   CENT - display centroid numbers only

   BLNK - turn off node annotation

   PAGE - move window one screen page in one of eight directions

   PARA - display link attributes

   FLTR - set filter criteria for inclusion of a link in the display

   CHGF - change existing filter criteria

LINE - change the line type for a link type-jurisdiction group

BSET - set key attribute and band limits for bandwidth plotting

LGND - display legend for bandwidth plot

3. <u>Network Creation</u> - In addition to all regular commands, the following cursor commands may be entered while the graphics tablet is receiving points:

A - automatically number new nodes

D - delete links or nodes

E - enlarge

F - window a full county or region

M - move node

N - return node sequence to an existing node

O(oh) - same as OLVW

P - plot; re-draw picture

R - return to main program

S - split link

- same as NODE

B - same as BLNK

4. <u>Tree Plotting</u>:

TREE - read tree file and plot portion of tree in current window

NEWT - close old tree file, open new one, and plot tree

TIME - annotate cumulative times on links of tree

5. <u>Socio-economic demographic data plotting</u>:

DEMR - read node data from disk

DSET - establish level cutoffs for node data

DEMB - plot demographic data as vertical bars

DEMC - plot demographic data as concentric circles

6. Miscellaneous Commands:

FIND - print out (x-y) coordinates for up to 4 nodes

SAVE - save current network configuration in temporary form on disk

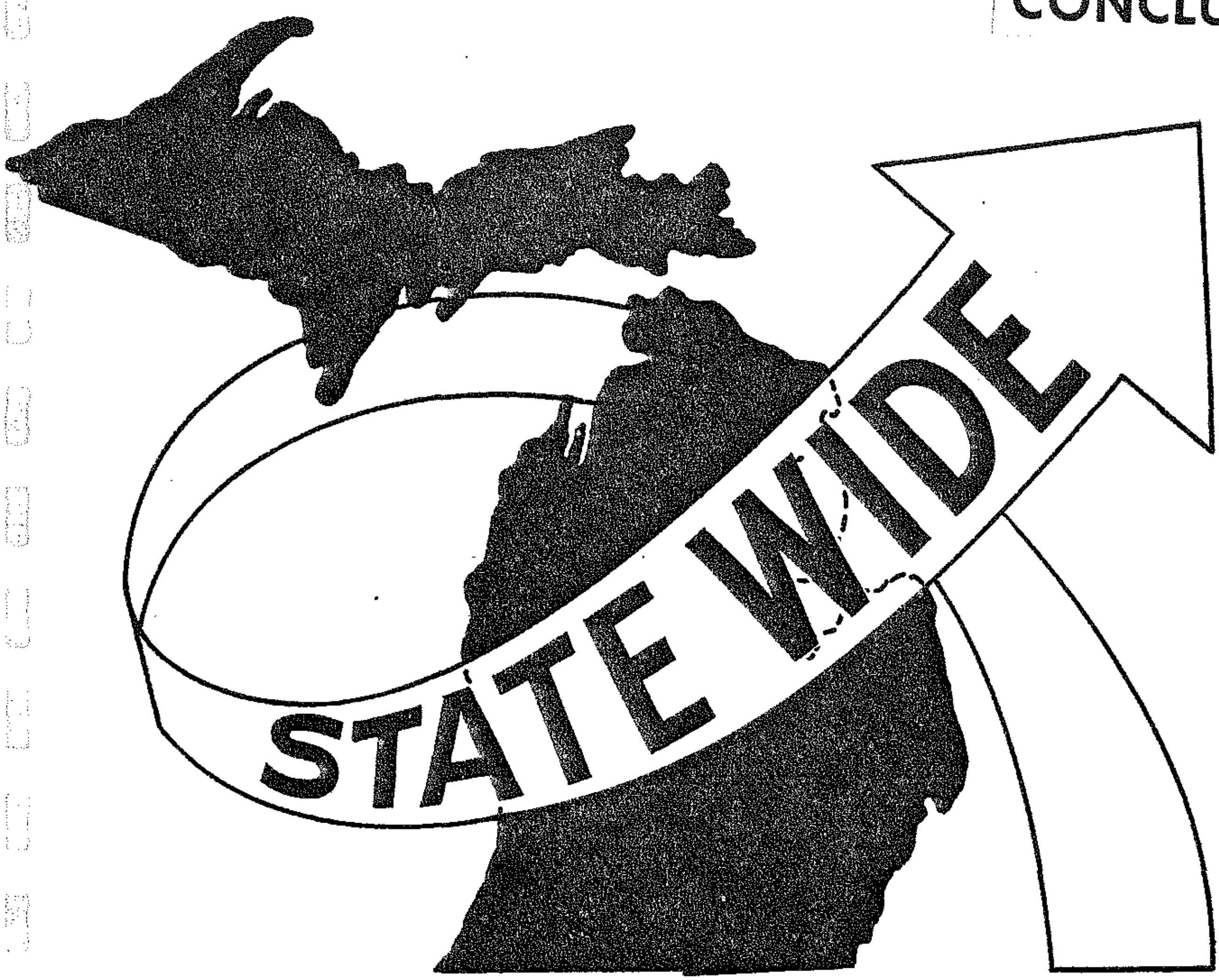
RCVR - return to last save

TANK - recover command tank and execute encoded commands

CHGH - change information in network header file

PACK - create output network in bit-packed form

CONCLUSION



CONCLUSION

In a time of increased emphasis on public involvement in the transportation planning process, it is important to ensure that the alternate generation process remains responsive to public feedback. Although the number of alternative plans to be considered increases dramatically, the planning system cannot allow itself to get bogged down. Elapsed time between citizen question and system answer must not become unreasonably long; this would have the ultimate result of killing the public's newly-found enthusiasm.

The interactive network graphics program described in this paper has helped relieve a potentially crippling burden on Michigan's planning procedure. It has eliminated a major part of the cost and elapsed time involved in alternate generation and evaluation. Because NETEDIT is much more interesting to use then manual methods, it also tends to eliminate a majority of the "mental-lapse" errors which can occur after hours of network coding.

Finally, it must be stressed that NETEDIT is a production technique, used in hundreds of Statewide Model applications. It is the proven productivity which makes NETEDIT such a valuable aid in transportation planning.

REFERENCES

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FIGURES