Statewide ★
Transportation
Analysis &
Research

MICHIGAN STATEWIDE TRAFFIC
FORECASTING MODEL

VOLUME III-A

SEMI-AUTOMATIC NETWORK

GENERATOR USING A "DIGITIZER"
November 1971

MICHIGAN DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

in cooperation with

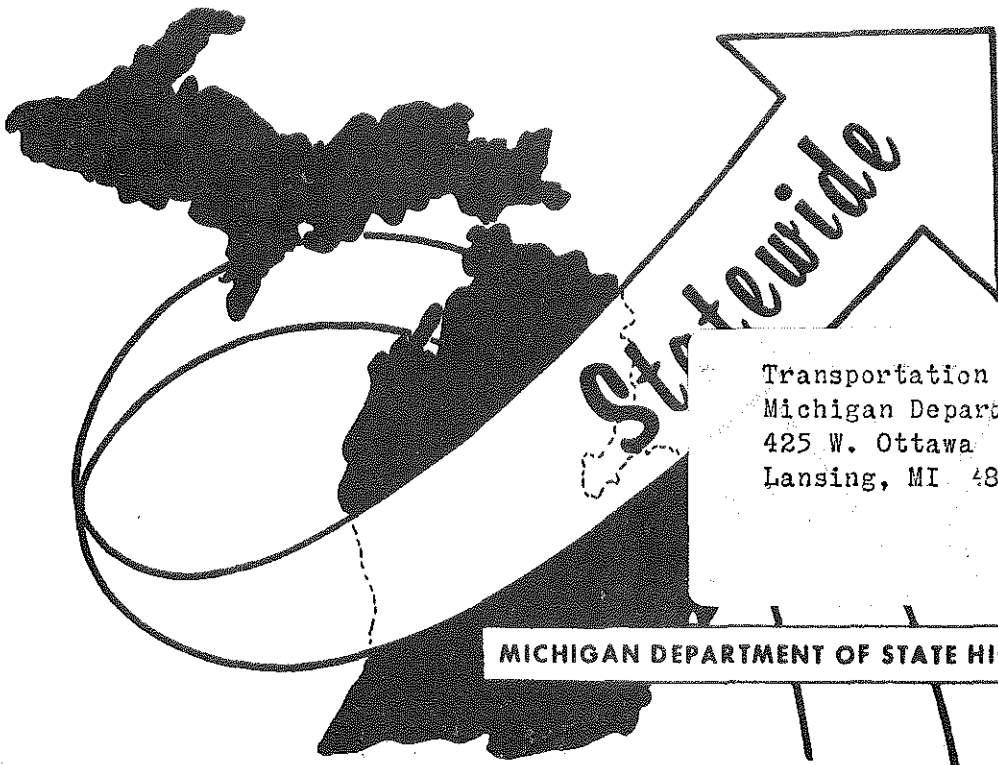The U.S. Department of Transportation

Federal Highway Administration

MICHIGAN STATEWIDE TRAFFIC
FORECASTING MODEL

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GENERATOR USING A "DIGITIZER"
November 1971

TRANSPORTATION PLANNING DIVISION
STATEWIDE STUDIES UNIT

Supervisor, _____
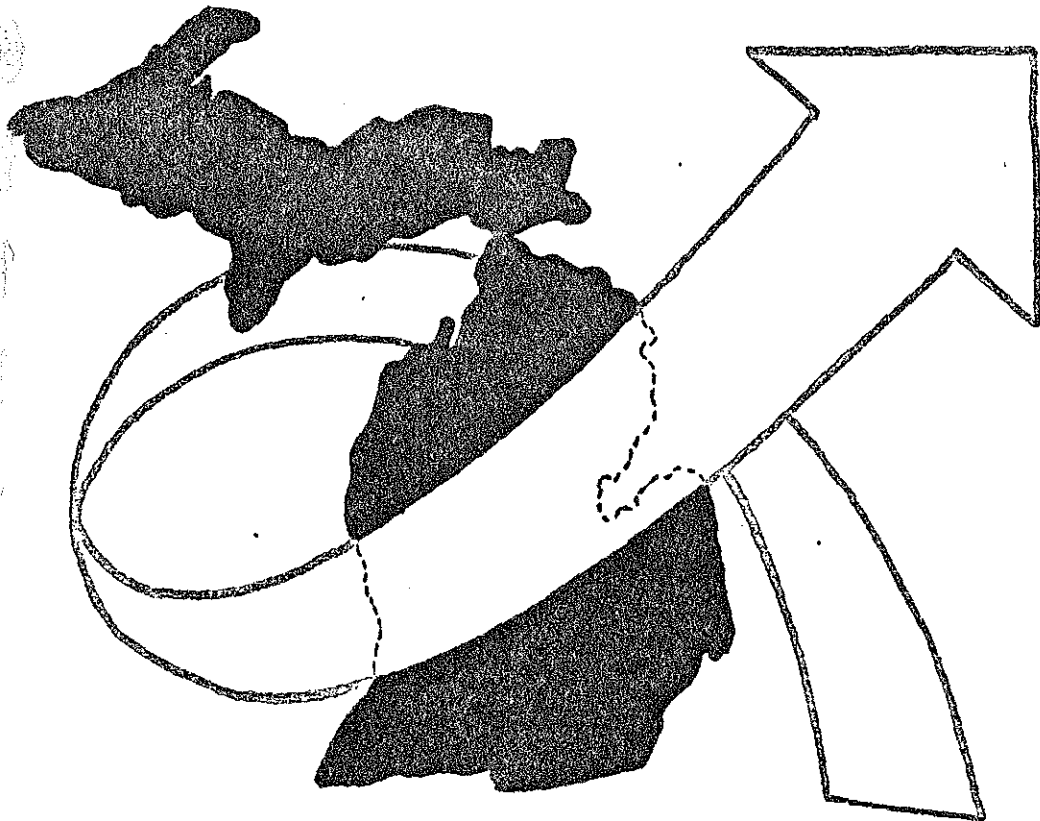   Richard E. Esch

ACKNOWLEDGMENTS

TABLE OF CONTENTS

PREFACE

PREFACE

This is a supplement to the third report in a series of reports dealing with the development of a statewide traffic forecasting model. The previous reports are as follows:

Vol. 1   Objectives and Work Program
Vol. 2   Development of Network Models
Vol. 3   Multi-Level Network Generator

Volume III-A was generated as a result of the development work completed for the "multi-level network generator project (Vol. 3)."

INTRODUCTION
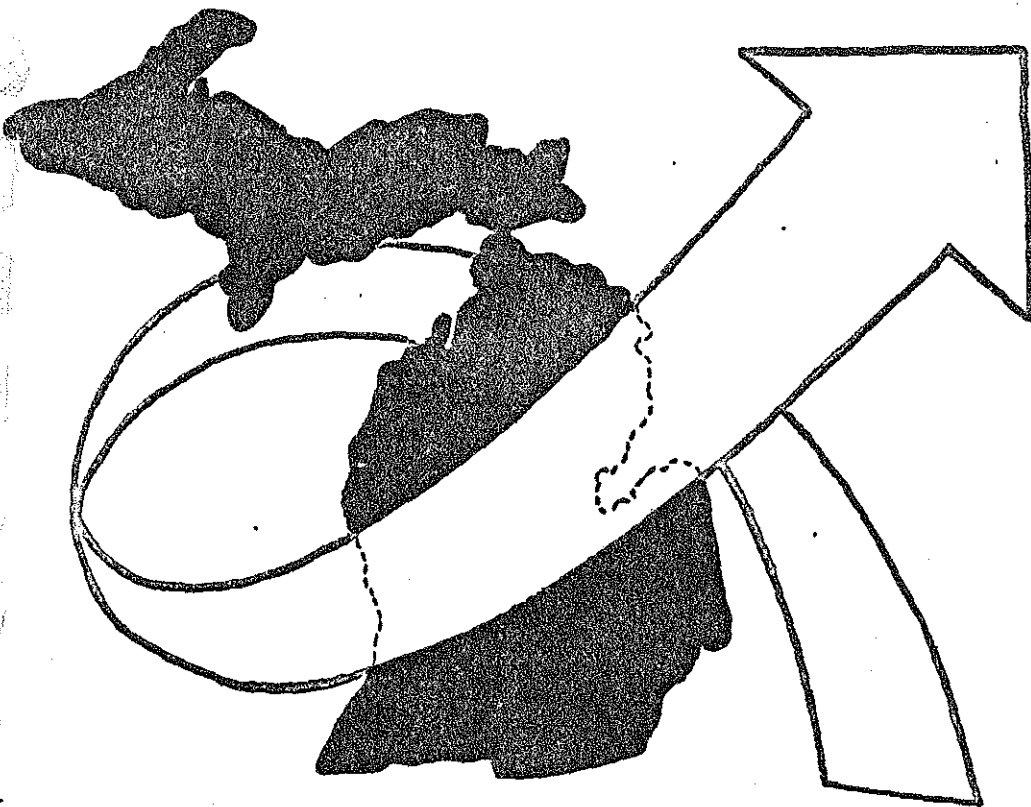
INTRODUCTION

As indicated in previous reports, the size of zone
and network systems used in the transportation planning
analysis process has increased rapidly in the last 10 years
to the point where systems of 1200 - 1500 zones are not
uncommon. This is particularly true for most regional trans-
portation studies and statewide traffic forecasting models.
In selected situations, systems of 2500 zones are also presently
in existence. These systems often require networks of 10,000 -
15,000 network links and 5000 to 8000 nodes. In addition
to travel model networks, there is also a demand for very
large highway network development for needs and functional
classifications studies as well as traffic accident location
systems.

Many organizations who have taken on the task of
developing systems of this size often tend to overlook
one of the more tedious tasks necessary to complete a
project of this magnitude--coding of the initial highway
network.

Even though this is one of the more tedious phases in
the transportation planning process, it is also one task
which often is the cause of many project difficulties.

The last report (Vol. 3) in the Michigan Statewide
Traffic Forecasting Model series discussed a traffic fore-
casting tool which would allow any government agency to

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make efficient daily use of very large highway network systems. This report will direct its attention at a process developed by the Statewide Studies Unit in the M.D.S.H. which will:

1. Drastically reduce network coding time by replacing manual tasks with machine operations.

2. Elimination of a tedious task through use of a Thompson Pencil follower which is a fascinating piece of peripheral computer equipment.

3. Improve network reliability by reducing coding errors.

Typical Large Network Coding Process Using Manual Techniques
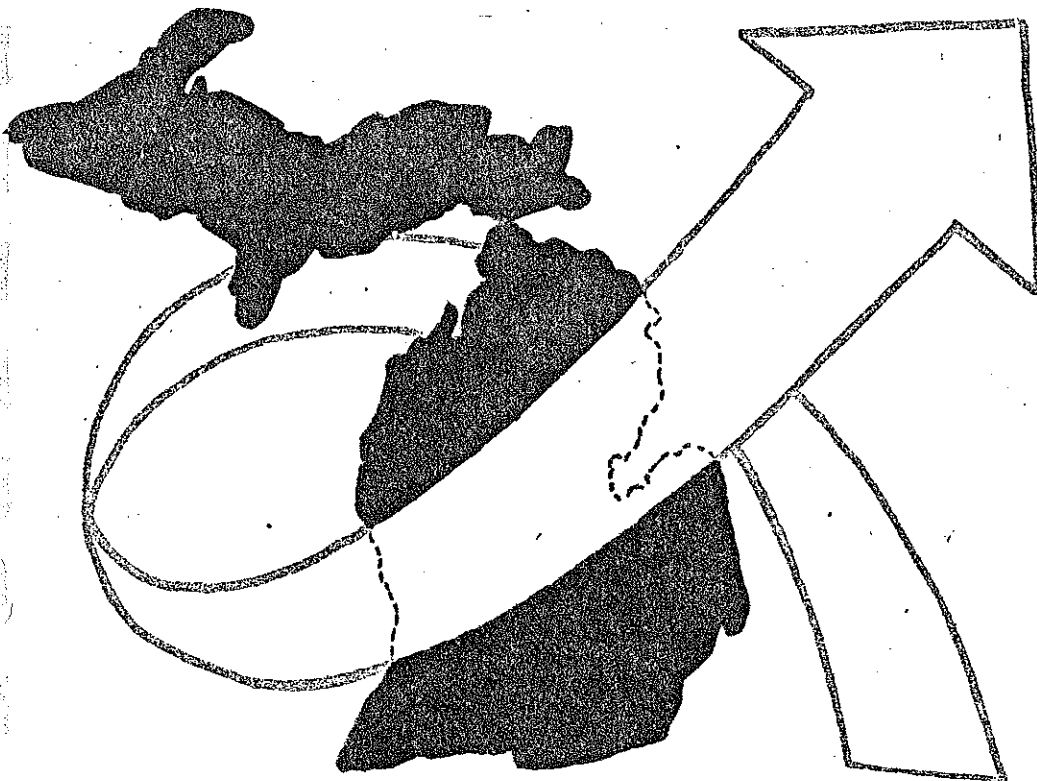
TYPICAL LARGE NETWORK
CODING PROCESS

This section of the report is included only as a brief resume of a typical large network manual coding process so that any potential user of the proposed "automatic network generator" program will have something to use as comparison.
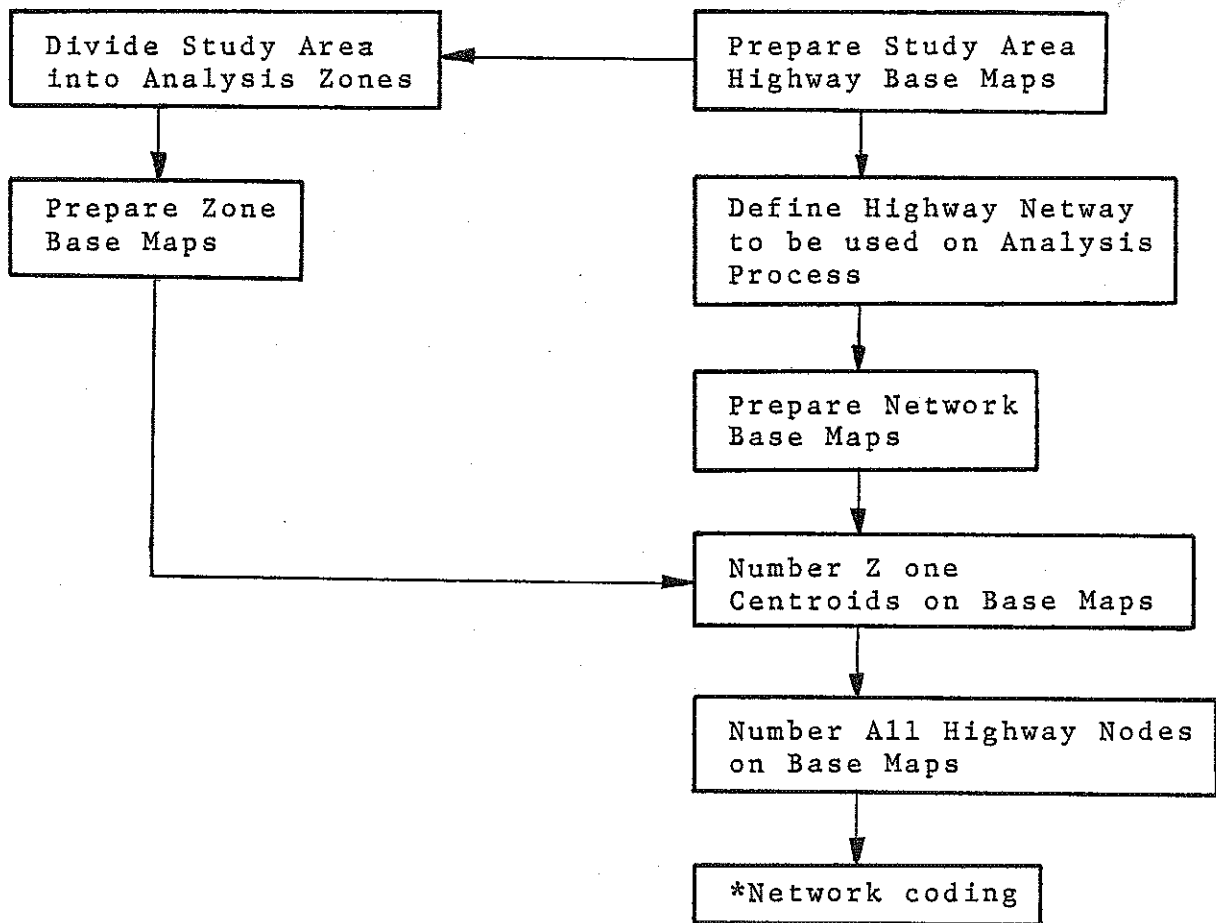
A simplified flow chart of a typical network coding process is presented in figure 1.

If a network coding process were directed toward obtaining a computerized statewide highway network file, one of the initial steps would be to obtain individual county base maps similar to the one displayed in figure 2. The study area in this case is the state and each of the state's individual counties will have to be sub-divided into individual traffic analysis zones. The result of this zonal definition process appears in figure 3.

The next task in this process is the actual selection of highways which are to be included in the computer analysis process. This is referred to as network definition and the number of highways included in the final network is directly related to the zone structure. During the network definition process, the connections between the zone system and the highway system are also completed using highway links called centroids. A final highway network base map appears in figure 4.

Once the network definition process has been completed, each of the highway links must be identified by a system of

4

```
┌─────────────────────┐              ┌─────────────────────┐
│  Divide Study Area  │◄─────────────│  Prepare Study Area │
│  into Analysis Zones│              │  Highway Base Maps  │
└─────────────────────┘              └─────────────────────┘
           │                                    │
           ▼                                    ▼
┌─────────────────────┐              ┌─────────────────────┐
│  Prepare Zone       │              │  Define Highway Netway│
│  Base Maps          │              │  to be used on Analysis│
└─────────────────────┘              │  Process            │
           │                         └─────────────────────┘
           │                                    │
           │                                    ▼
           │                         ┌─────────────────────┐
           │                         │  Prepare Network    │
           │                         │  Base Maps          │
           │                         └─────────────────────┘
           │                                    │
           │                                    ▼
           │                         ┌─────────────────────┐
           └────────────────────────►│  Number Z one       │
                                     │  Centroids on Base Maps│
                                     └─────────────────────┘
                                                │
                                                ▼
                                     ┌─────────────────────┐
                                     │  Number All Highway Nodes│
                                     │  on Base Maps       │
                                     └─────────────────────┘
                                                │
                                                ▼
                                     ┌─────────────────────┐
                                     │  *Network coding    │
                                     └─────────────────────┘
```
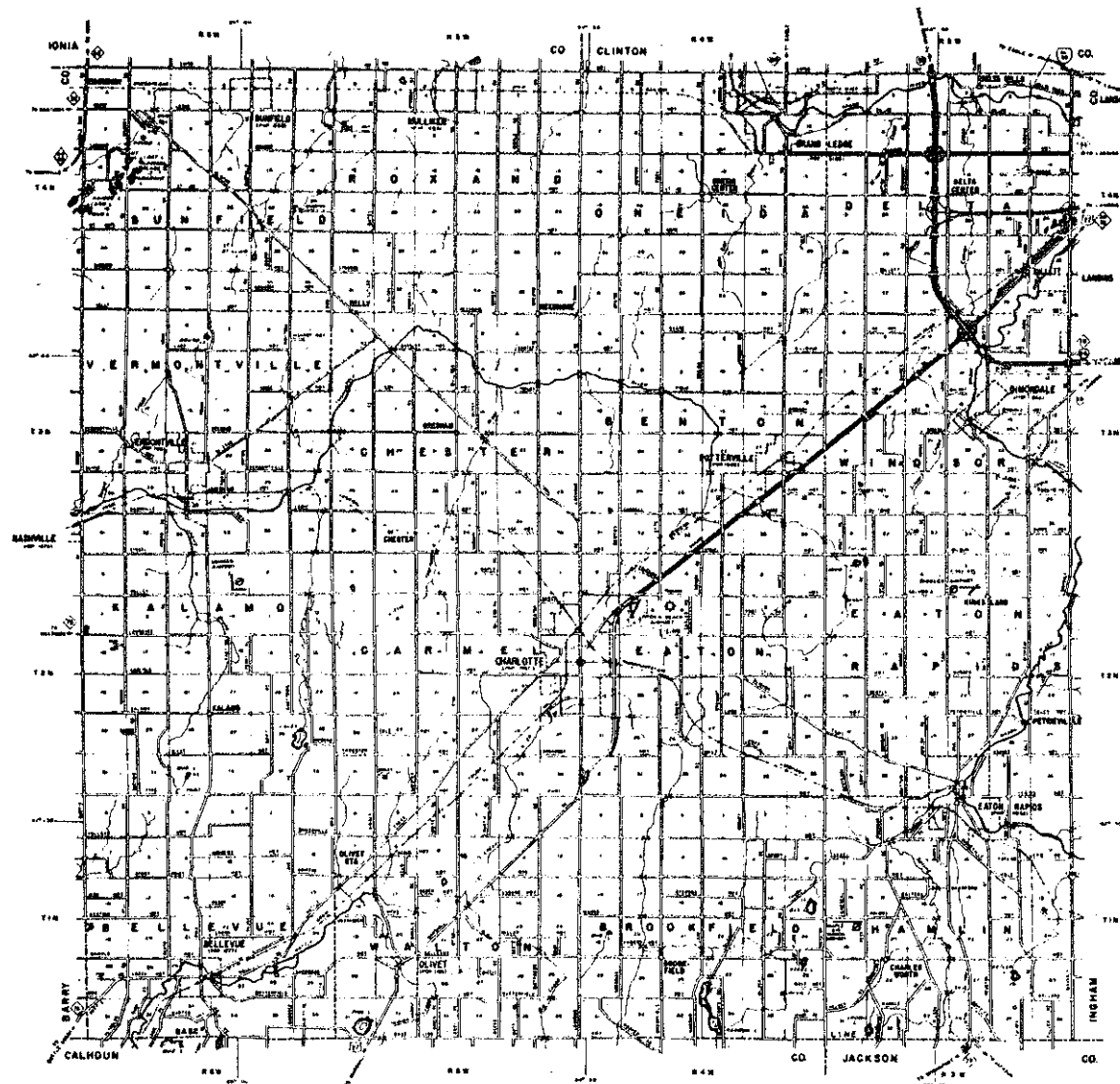
* This process must be repeated for each highway network
link - - - in some cases as many as 15,000 links.
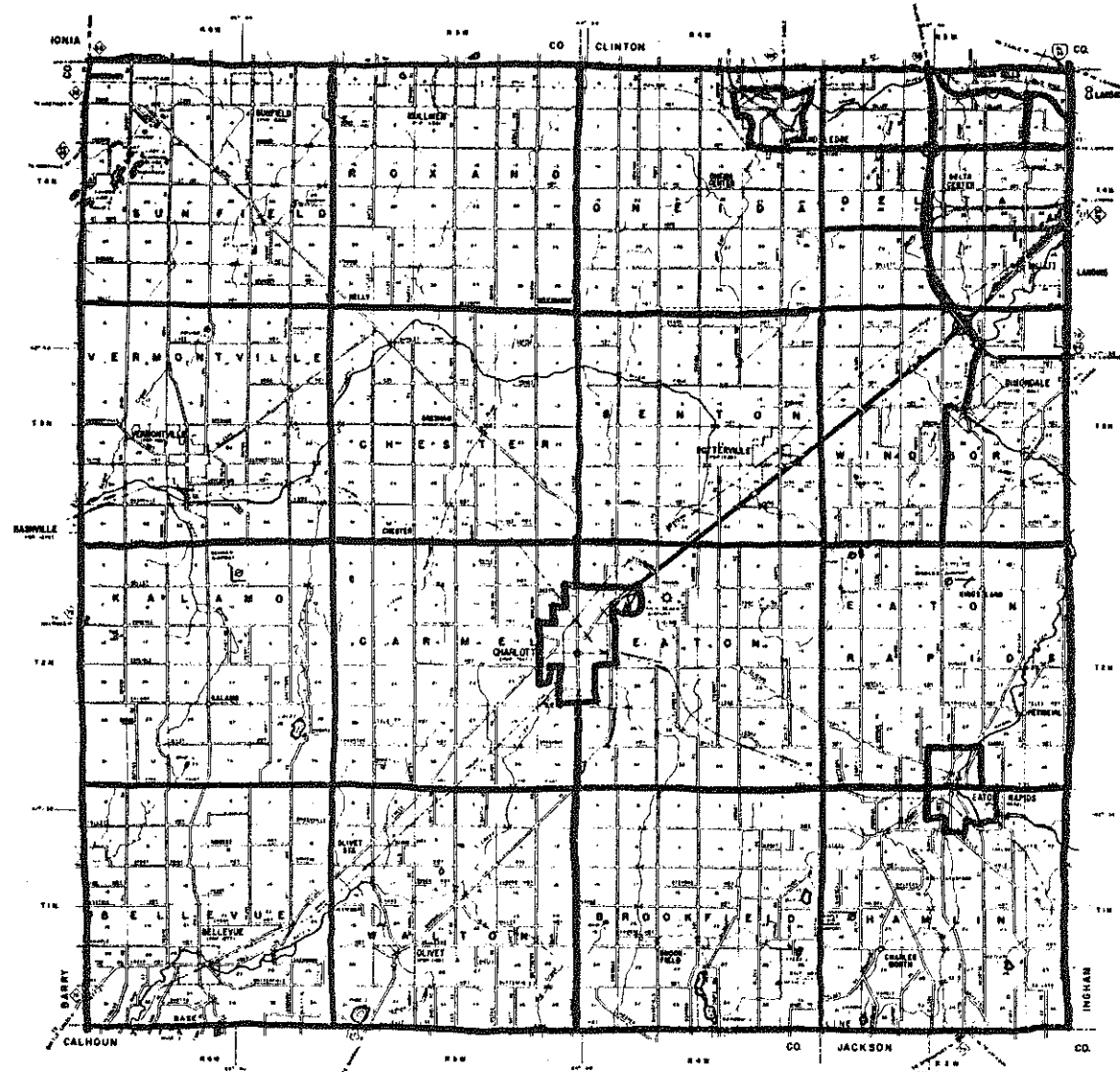
SIMPLIFIED MANUAL

NETWORK CODING PROCESS

Figure 1

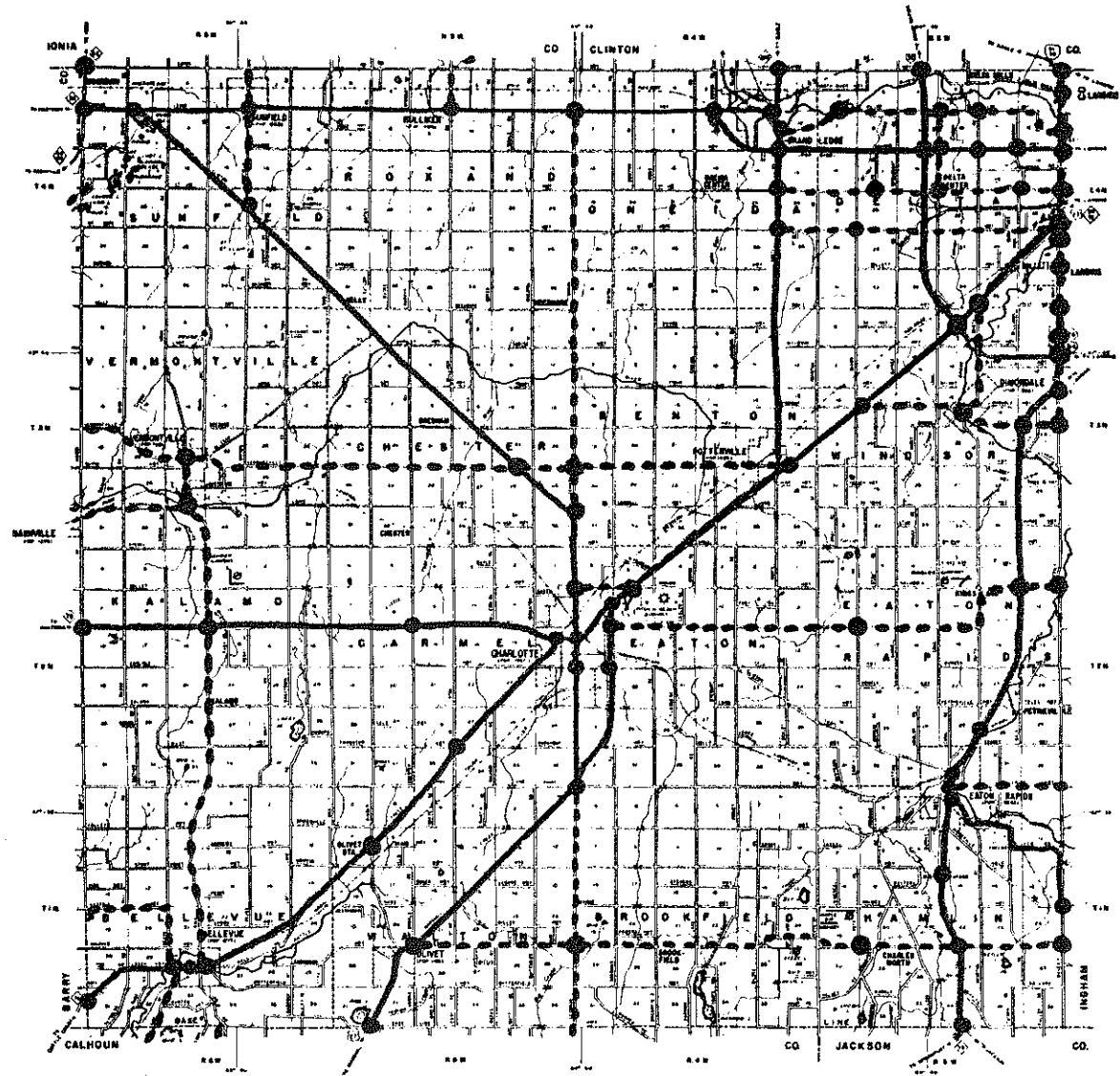# EATON COUNTY BASE MAP

FIGURE 2

EATON COUNTY
MICHIGAN
STATE HIGHWAY COMMISSION
DEPARTMENT OF STATE HIGHWAYS

DATA OBTAINED FROM

HIGHWAY PLANNING SURVEY

CONDUCTED IN COOPERATION WITH
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
BUREAU OF PUBLIC ROADS

EATON COUNTY ZONE MAP

FIGURE 3

HIGHWAY NETWORK BASE MAP

FIGURE 4

A and B nodes. Each link is defined by the node (black dot in figure 4) at each end of the link. Therefore, all nodes must be identified by assigning individual numbers to each one in the system. The user should note that with systems that contain upwards of 7000 or 8000 nodes this becomes a very tedious operation and one which often generates signif- icant network errors.

All zone centroids must also be assigned sequential numbers generally starting with the number one and contin- uing until all zones are numbered.

At this point the actual coding process begins by completing highway network coding forms similar to the sample in figure 5. The individual doing the coding must enter the A and B node of each link which will be used in the highway network computer model on the code sheet. Next the actual link distance must be annually determined and entered on the code sheet. If speed is used as a measure of separation for various areas throughout the state, the user must select a speed for each link and enter this on the code sheet. These speeds could be determined as a result of a complex process of analysis for actual route conditions. They might also be selected from a simplified chart which indicates which route types are to be coded at what speeds depending on specific locations. Either way, this process still requires several manual steps before the speed is entered on the code sheet.

STATE OF MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

B-5500 LINK DATA CARD

Form 1720

CARD TYPE	A NODE	B NODE	DISTANCE XX XX	TO B'S	TIME OR SPEED X XX / XX X			CAPACITY IN 10 S	COUNT		DIRECTION Y OR S	TIME OR SPEED X XX / XX X			CAPACITY IN 10'S	COUNT		LINK TYPE	LINK JURISDICTION	CAPACITY CLASS		DELETE
					AM	PM	OFF					AM	PM	OFF								

Figure 5

PRACTICAL *LANE CAPACITIES
PER 12' LANE V.P.H.

104(b)5 Study

	URBAN		SUBURBAN		RURAL	
% Comm.	LEVEL	ROLLING	LEVEL	ROLLING	LEVEL	ROLLING
0	1500	1500	1200	1200	1000	1000
1	1486	1466	1189	1272	991	977
2	1472	1432	1178	1244	982	954
3	1458	1398	1167	1116	973	931
4	1444	1364	1156	1088	964	908
5	1430	1330	1145	1060	955	885
6	1416	1296	1134	1032	946	862
7	1402	1262	1123	1004	937	839
8	1388	1228	1112	976	928	816
9	1374	1194	1101	948	919	793
10	1360	1160	1090	920	910	770
11	1349	1138	1081	903	902	756
12	1338	1116	1072	886	894	742
13	1327	1094	1063	869	886	728
14	1316	1072	1054	852	878	714
15	1305	1050	1045	835	870	700
16	1294	1028	1036	818	862	686
17	1283	1006	1027	801	854	672
18	1272	984	1018	784	846	658
19	1261	962	1009	767	838	644
20	1250	940	1000	750	830	630

*For urban, suburban and rural possible capacity double the figures
under rural practical capacity.

Figure 6

The next element that often is coded for each link is
the capacity of that link. This may be determined through
the use of a series of mathematical operations which could
determine capacity similar to suggestions in the HRB Highway
Capacity Manual. It also might be determined through
the use of a chart similar to the one in figure 6. Once
the capacity has been established, it must then be entered
on the code sheet.

Present traffic volume data is also very necessary when
defining a new highway network. This is the value the model's
test results are compared to during the calibration process.
Traffic volumes are available from traffic count records
or yearly traffic flow maps. After obtaining the count, this
must be coded in the appropriate space on the code sheet.

With some highway network definition processes, the
type of highway link and area or location of the link is
also determined and coded for each link. Most of this infor-
mation is generally available from the county base map.

The previous discussion deals with the coding of a
single highway link. The user should keep in mind the
fact that many manual operations were necessary just to
complete coding for a single link. This link coding
process may have to be repeated as many as 10,000-15,000
times depending on the size of the original network.
Therefore, as a result of this process, several problems
often occur.

1.   Human errors are quite prevalent because of
     the sheer size of a network coding operation.

2.   Most operations are manual; therefore,
     network coding is quite lengthy. (4 to 8 months)

3.   Boredom often occurs on the part of the coding
     staff thereby generating additional errors.

These are the problems that confronted the Michigan Depart-

ment of State Highways' staff on each network coding project.

As networks tend to become larger, the problems compound

themselves.   Therefore, the Statewide Studies Unit began

to look for solutions to these problems.   One of the possible

solutions to the above mentioned problems will be discussed

in a later section of this report.

The new network coding process depends on the use of a

piece of peripheral computer equipment often referred to as

a "digitizer."   The Michigan Department of State Highways'

"digitizer" is a Thompson Pencil Follower model PC-10.

A brief resume about the Thompson Pencil Follower has been

included in this report for those individuals not familiar

with this type of equipment.

THOMPSON PENCIL
FOLLOWER
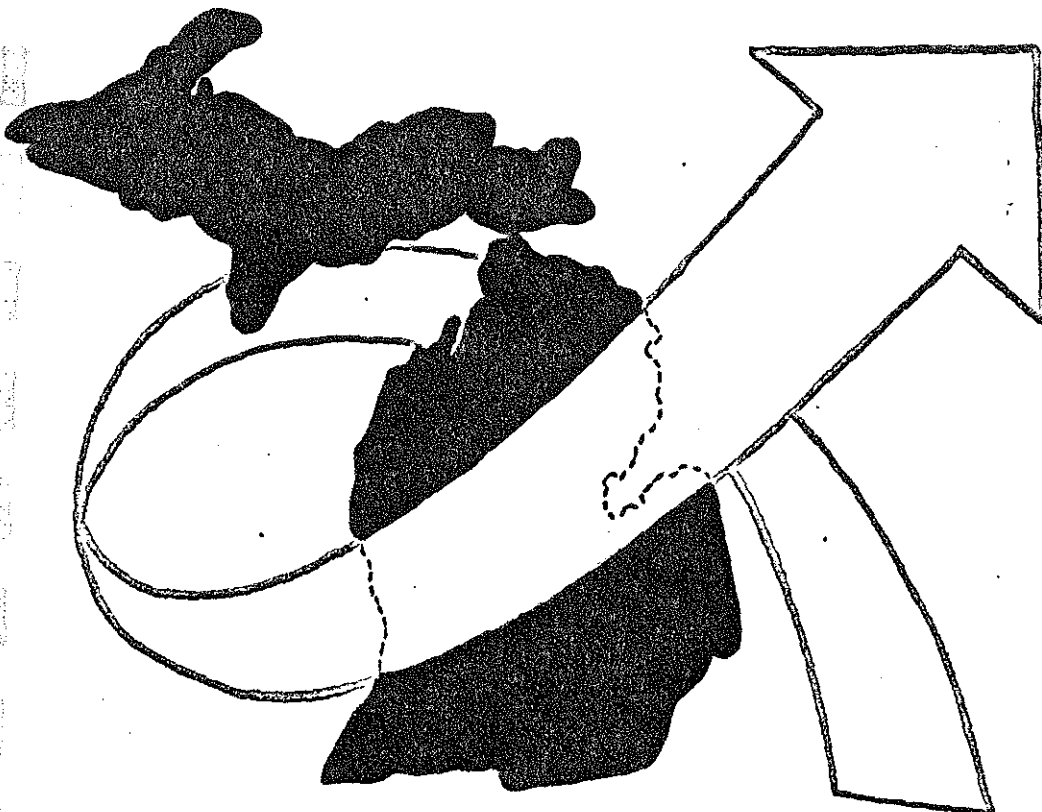
THOMPSON PENCIL FOLLOWER
(DIGITIZER)

This piece of peripheral computer equipment is used
to obtain the coordinates of specific locations or points
on base material without actually manually measuring
their location. These coordinates are punched out on
paper tape along with an identification number for each
location. For those persons who might be interested in
additional details, a copy of Edwin Industries Corporation
brochure on the Thompson Pencil Follower is included in
this section.

The basic components of this systems are:

1. Table on which to place material to be digi-
    tized.
2. Keyboard which allow users to enter data on
    punched tape in addition to actual coordinates.
3. Console which creates the punched paper tape
    output.
4. Pencil which is used to physically locate each
    point for which coordinates are required.
5. Foot Control is the switch mechanism which is
    pressed after the pencil has been properly
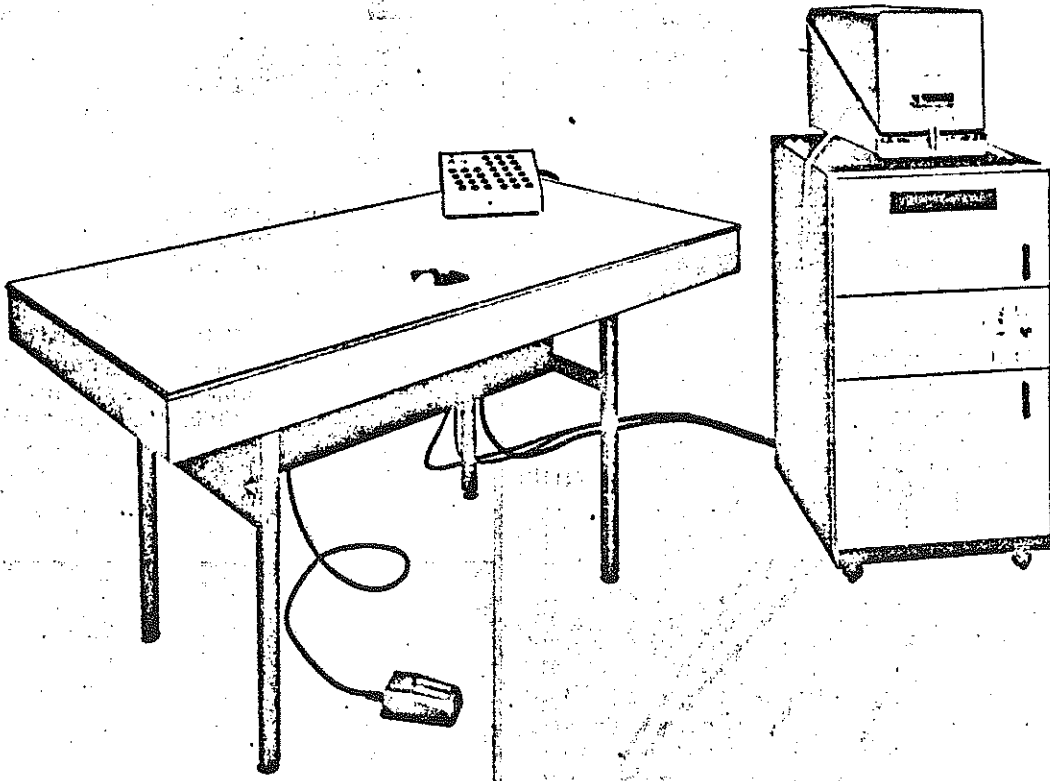   placed over the location for which coordinators
    are to be determined.

Each of the basic elements is identified in figure 7.

Figure 8 is a blow-up of an actual punched paper
tape. This sample also indicates the standard set of
punches used to represent the various keyboard characters.

THOMSON DIVISION
PF 10

PENCIL FOLLOWER

EDWIN INDUSTRIES CORP

PICKARD BLDG   5858 EAST MOLLOY ROAD
SYRACUSE NY 13211   (315) 454-4407

FIGURE 7

FIGURE 8

APPLICATIONS

STRIP CHART RECORDS
Pen recorders, galvo recorders, potentiometric recorders, UV recorders, hot styles, multi-point. Single or multi trace.

FILM RECORDS
Continuous or frame by frame. Galvo recorders, kine-theodolite, high speed motion studies. Boresight records.
Widely used for preliminary digitising of bubble chamber photographs and complete digitising of spark chamber photographs.

MAPS AND CHARTS
Positions of towns, contours and coast lines, volumes and area calculations.

ENGINEERING DRAWINGS
For correlating information and correcting errors. Preparation of tapes for machine tools. Programming automatic wiring machines.

ARCHITECTURAL DRAWINGS
For quantity surveys. Estimates for electrical, mechanical trades. Highway cross section, cut and fill calculations.

ACCURATE LOCATION OF IMAGES AND PAPER
The projected image or strip chart can be set exactly in position for each set of readings but it is much simpler to take a number of fiducial points and programme the computer to make the necessary adjustments. Automatic correction for scale variations eliminate operator error.

NON LINEAR RECORDS
For either paper or film records any non linear corrections are carried out in the computer by appropriate programming. The elimination of critical adjustments or extra operator operations keeps errors to a minimum.

ANGULAR POSITION READOUT
The analysis of kinetheodolite films to give the attitude of missiles or film records of aircraft attitude on landings is easily accomplished by using a square plastic which will output the centre and one end of the line to provide in effect a double readout which the computer will easily interpret.
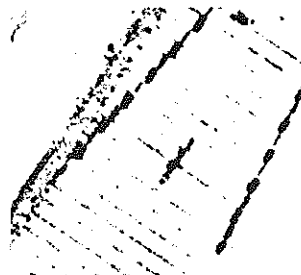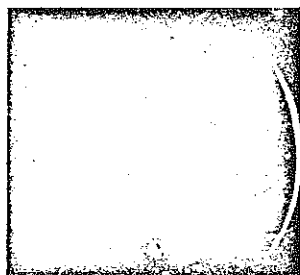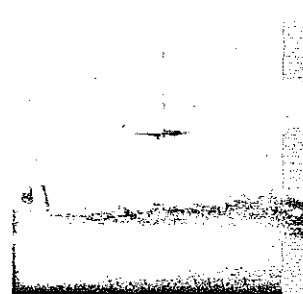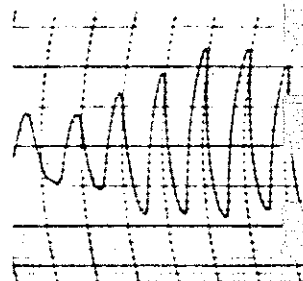
PROJECTED IMAGES
For projected image analysis the pencil is replaced by a white flat square engraved with cross hairs The intersection can be viewed clearly and accurately without parallax and may be located rapidly at the required position.

GRADIENT AND "BEST FIT LINE" READOUT METHC?
Paper or film containing noisy traces are rapidly analyzed by the "best fit" method in which a ruler is used instead of a pencil. Each end of the ruler contains a locating coil which is energized in turn to produce X_1, Y_1 and X_2, Y_2 which defines the slope.

TABLE

CONSOLE
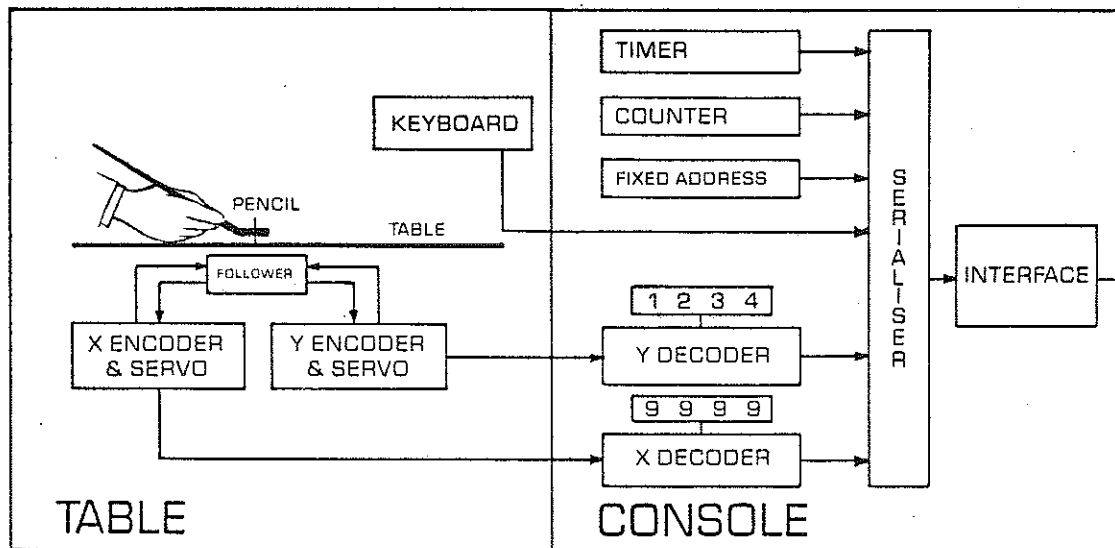
FEATURES

DIGITIZE
Drawings, maps, strip charts, projected films, any plane surface

WORKING AREA
18 x 40 inches (45 x 100 cm)
Larger on special order

RESOLUTION
0.1 mm/digit

FOLLOWING SPEED
High accuracy 1 in/sec
Lower accuracy 4 in/sec

DIGITIZING SPEED
Up to 20X-Y Coordinates per second

OUTPUT
Customer specified any 5 to 8 level code or single line true (IBM 526) suitable for punch tape typewriter, magnetic tape

KEYBOARD INPUT
Manual up to 30 keys

OPTIONS

COUNTER
A digit counter totalizes output readings

FIXED ADDRESS
10 switches each 0 to 9 called individually by output serializer or as a group.

MANUAL PAPER REEL UNITS
May be added at either end of table to accommodate most types of chart paper.

PROJECTOR
A projector is available to handle 16 or 35 mm film with accurate and automatic frame advance. Spool sizes up to 1000 ft. Fast or slow forward or reverse. Automatic frame count.

DUAL READOUT
This provides the rapid automatic sequential read out of X_1, Y_1, and X_2, Y_2 for determining slope.

DESCRIPTION

IT IS UNIQUE
The Pencil Follower is a unique device which eliminates the complex mechanism of other analysis machines.

Operation is as simple as pointing a pencil at the coordinates to be digitized. It is equally easy to use on maps, charts, projected images or any two dimension presentation. A line is digitized by simply tracing and selecting either continuous readout or read on command. Continuous readout gives the significant advantage of recording more information when tracing intricate features such as peaks. The coordinates of any point over the whole area are immediately displayed and recorded to an accuracy of ±0.2 mm and a resolution of ±0.1 mm.

MOST IMPORTANT USE
Its most important use is to put shapes into a digital computer.

WHY NOT AUTOMATIC SCANNING OR DIRECT DIGITAL RECORDING?
Automatic analysis of charts requires traces of great clarity. Digitizing a "line of best fit" automatically is not too practical. Direct digital recording is expensive and allows no discrimination so that wasteful information has to be digested by the computer. Recognition of colour shading or symbols automatically is not practical. An unskilled operator easily, rapidly and economically selects the required information. The Pencil Follower quickly digitizes it.

HOW DOES IT WORK?
The "free" pencil eliminates the effort of adjusting cross hairs or other methods of coordinate alignment. The work is done by a servo mechanism below the reading surface which accurately follows every movement of the pencil.

The pencil generates an alternating magnetic field. Below the work surface four sensor coils mounted on an XY mechanism pick up any error signal which in turn cause the respective servo motors to seek a null. The X and Y servos are attached to shaft position encoders which drive a visual display. The encoder output is also available in either serial or parallel, one of ten or any 5 to 8 level code. A variety of interface units are available for punches, tape units, typewriters and computers. The manual keyboard is provided to identify or insert commands in the recorded output. Automatic identification can be selected by a format select switch.

ACCURACY

The static accuracy of digitizing is approximately ±0.1 mm. Due to the inherent error required for servo movement the dynamic accuracy will be less. For normal accurate line tracing of about 1" per sec. errors may be ±0.2 mm and for rough digitizing while tracing at 4" per sec. errors of ±1.0 mm may be observed.

Orthogonality and linearity are such that static accuracy of ±0.1 mm may be obtained over the working surface.

OUTPUT FORMAT

A wide variety of outputs are available in parallel or serial form. The output serializer is a 20 position ring divided into groups A and B as selected by the user. For example Group A output may be X coordinate, space, Y coordinate, space. Group B may be, count number, CR, LF, LF. A format switch selects the number of times Group A is called before one call of Group B. Group A may be called 8 times for an 8 channel recording followed by Group B once.

SPECIFICATIONS

Working Area
18 x 40 inches (45 x 100 cm)

Resolution of Position Readout
0.004 inches per digit (0.1 mm)

Resolution of Matrix
10,000 x 4,500 digits

Servo Positioning Accuracy
±0.004 inches (±0.1 mm)

Servo Dynamic Accuracy
±0.008 inches @ 1" per second
±0.04 inches @ 4" per second

Maximum Speed of Movement
10 inches per second

Maximum Lock On Distance
4 inches (10 cm)

Maximum Digitizing Rate
20 per second, higher to order

Servo System Frequency
400 cps internal generator

Power Supply
117v 4a / 235v 2a ±10%   50/60 cps

Dimensions
Table 29½ x 54 x 33 inches
Console 20 x 19 x 37 inches

Weight
Table 140 lb (63 kg)   Console 125 lb (56 kg)

ADDITIONAL FEATURES

X-Y Encoders	Electromechanical, brush contact type, mono-strophic code shaft position encoders convert the pencil position to an unambiguous digital code.
X-Y Storage	Storage registers are used in order to provide read-out "on the fly" with continuous line output capability.
X-Y Display	Provides visual digital readout with projector type display. Gives continuous position of pencil or keeps reading of last position encoded, for point work.
Interfaces	The appropriate interfaces are fitted within the output serialiser. The following are available. Punched Paper Tape Westerex BRP11 and Creed 25HS Punched Cards IBM 024 026 056 Typewriter IBM solinoid operated Any 5 to 8 level code can be supplied Other interface units in development
Keyboard	Normally supplied with ten digits also carriage return, plus, minus, decimal point, space, and tape or card out. Up to 30 keys may be supplied.
Table Top	Hard white plastic
PRICE	From $14,500 depending on options required. Refer to detailed price list.

DIGITIZER CONTROL PACKAGE

Raw digitizer coordinates require certain basic conversion steps before one obtains x and y coordinates in the units of any given map, chart, or graph. The digitizer control package is designed to carry out these operations. It consists of seven FORTRAN subprograms. One subprogram, DCONT, acts as a monitor, sensing the scale and unit specifications for a given job and calling the appropriate routines in proper sequence. Another, INP12, initializes DCONT and enters the specified computer input and output units. The other five, DSCAL, DROTA, DSCSH, DOVER and DINTE, are secondary routines which perform single conversion steps when called by DCONT. The entire package may be used as in integrated system, or any one of the five secondary subprograms may be called independently. If core storage is a limiting factor it may be convenient to use only those routines which directly apply to a specific job.

Makeup of Input Decks

A job, as defined by the logic of this package, includes all x and y coordinates digitized from a single chart or graph. The entire chart or graph may fit within the working area of the digitizer table, in which case the whole job may be effected without changing the position of the chart on the table. Long strip charts or large sheets may require successive shifts in position with the accompanying changes in boundary specifications.

A frame, as defined herein, includes all x and y coordinates digitized from a chart or graph while it remains in the same position on the table.

An input deck consists of a job specification card followed by one or more frames of digitizer coordinates, each preceded by 1-2 frame header cards. When the scale shift option is used, all frames are headed by two cards, the first containing frame corner coordinates in the units of the chart or graph and the second containing frame corner coordinates in the units of the digitizer table. When the scale shift option is used, only the first frame is preceded by both header cards, with all succeeding frames being headed only by a card containing the frame corner coordinates in the units of the digitizer table.

JOB SPECIFICATION CARD

Column(s)

1-3   Tolerance for overwrite option. Units: .01 cm. to
               the nearest unit. For example, the number "27" would
               specify that, for any two successive digitized points
               closer together than 0.27 cm. on the digitizer table,
               the latter point would be deleted. A "0" specifies
               that this option is not required.

4-5   A "0" specifies that the scale shift option is not
               to be used.
               A "1" shifts the graph or chart corner coordinates
               to the right when the end of each frame is sensed.
               A "2" shifts the graph or chart corner coordinates
               upward when the end of each frame is sensed.
               A "3" shifts the graph or chart corner coordinates
               to the left when the end of each frame is sensed.
               A "4" shifts the graph or chart corner coordinates
               downward when the end of each frame is sensed.

6-7   A "0" if scaling constants are to be based on the
               number of graph or chart units per inch.
               A "1" if scaling constants are to be based on the
               number of graph or chart units per centimeter.

8-17   Scaling constant in the x direction. The number of
               graph or chart units per centimeter or per inch as
               specified in cols. 6-7. Needs 4 digits to right of
               decimal.

18-27   Scaling constant in the y direction. The number of
               graph or chart units per centimeter or per inch as
               specified in cols. 6-7. Needs 4 digits to right of
               decimal.

28-37   The interval, in graph or chart units, between each
               successive x coordinate when linear interpolation for
               coordinates having equal spacing of x values is desired.
               A "0" bypasses this option. Needs 4 digits to right of
               decimal.

38-39   A "1" if correction for rotation of the graph or chart
               on the table is to be applied. When this option is
               specified, the horizontal line of a chart or graph may
               be positioned on the digitizer table at up to 90 degrees
               above or below the horizontal of the table. A "0" if
               this option is to be bypassed.

-2-

FRAME HEADER CARDS

First card   (Used with the first frame only, if the scale shift
              option is used)

Column(s)

1-10   The x value, in the units of the graph or chart, of
              the left boundary of the frame.

11-20   The x value, in units of the graph or chart, of the
              right boundary of the frame.

21-30   The y value, in units of the graph or chart, of the
              top boundary of the frame.

31-40   The y value, in units of the graph or chart, of the
              bottom boundary of the frame.

              (NOTE: all the above variables require 4 digits to
              the right of the decimal point)

Second card   (Precedes every frame in every case)

1-8   The x and y digitizer coordinates, obtained via direct
              digitization, of the frame origin.

9-16   The x and y digitizer coordinates, obtained via direct
              digitization, of the lower right corner of the frame.
              Not used except when rotation correction is applied.

              (NOTE: When the rotation correction is to be applied,
              the frame origin must be the lower left corner, and all
              coordinates must lie within the area defined by lower
              left and lower right boundaries. When the rotation correc-
              tion is not to be applied, the frame origin does not have
              to be the lower left corner, so long as the digitizer table
              origin corresponds with the intersection of the left and
              bottom boundaries of the graph or chart, as given by the
              first and last constants on the first frame header card,
              and the scale shift option is not used.

DIGITIZER COORDINATES CARDS

These cards constitute the body of the input data. They contain the x and y digitizer coordinates of each automatically digitized point. The first x-coordinate on the card appears in columns 1-4, and the first y-coordinate appears in columns 5-8. This order is repeated so that a maximum of 10 digitized points are contained in a single card.

The end of a block of coordinates is designated by a code number entered by the operator in the 4 columns immediately succeeding the last y-coordinate of the block. If the last y-coordinate completely fills out the last card, then the code is punched in the first 4 columns of the next card. Succeeding data in both cases begin on the following card.

Code   Specification

-111   Denotes a logical break between two successive blocks
                of data within the same frame, as when two or more
                curves appear on the same graph. The coordinates
                of the next block of data follow on the very next card.
                There is no change in the frame boundary specifications.

-222   Denotes the end of a frame. Frame header card(s) for
                the next frame follow.

-333   Denotes the end of a job. If jobs are stacked in
                succession, the next card would be a job specifi-
                cation card.

CALLING THE ROUTINES

<u>DCONT</u> --   At the beginning of each job it is necessary to
initialize this subprogram by calling INP12, which initializes
DCONT and supplies it with the input unit numbers. The call
statement is as follows:

<div align="center">

CALL INP12 (M,N)

</div>

where M is the logical number of the input unit from which the
job specification card or input record is to be read, and N is
the logical number of the input unit from which raw digitizer
data are to be read (see section on input formats). If M equals
N all input is read in from the same unit.

DCONT supplies one set of x and y coordinates to the main
program each time it is called by the statement:

<div align="center">

A = DCONT (1,X,Y)

</div>

where A represents any integer or real variable set equal to
DCONT, DCONT is a code number signaling the end of a block of
data, and X and Y are the coordinates of a single point in the
units specified by the user. If DCONT equals zero, more coor-
dinates follow. If DCONT equals 1, X and Y are the last coor-
dinates in a single section of data when two or more sections of
data on the same map, chart, or graph require separation by a
logical break. One or more sections follow. If DCONT equals 2,
X and Y are the last coordinates from a given frame. If DCONT
equals 3, X and Y are the last coordinates from a given job.

When DCONT is called, it is not necessary to call any of
the secondary routines. The previous two statements represent the
only call statements necessary to activate the entire package.
Descriptions of the secondary routines. The previous two statements
represent the only call statements necessary to activate the entire
package. Descriptions of the secondary routines are applicable only
when those subprograms are to be used independently.

SECONDARY ROUTINES

<u>DSCAL</u>--   At the beginning of each frame DSCAL must be initialized
by the statements:

           CALL   DSCAL (I, XO, YO, XS, YS)

and

           CALL   DSCAL (4, XL, YB, 0.0.0.0)

When I equals zero, the scale of the chart or graph is to be specified
in number of units per inch. When I equals 1, the scale of the chart
or graph is to be specified in number of units per centimeter. XL and
YB are the coordinates of the origin of the chart or graph, in the units
of the chart or graph. This origin need not be the lower left corner.
XS and YS express scale of the chart or graph, specified in number of
units per inch or per centimeter as given by I, in the X and Y directions,
respectively. XO and YO are the raw digitizer coordinates of the graph
or chart origin (XL, YE).

        Each set of raw digitizer coordinates is converted to the scale
of the chart or graph when DSCAL is called by the following statement:

           CALL   DSCAL (2, DX, DY, X, Y)

with DX and DY representing the raw digitizer coordinates of a point
and x and y representing the same point converted to the scale of the
chart or graph.

<u>DROTA</u>--   At the beginning of each frame DROTA must be initial-
ized by the statements:

           CALL   DROTA (4, XL, YB, XRT, YRT)

and

           CALL   DROTA (I, XO, YO, XS, YS)

where I, XO,YO,XS,YS,XL, and YB are as defined in the description
of the subprogram DSCAL, and XRT and YRT are the x and y raw digi-
tizer coordinates of the lower right corner of the chart or graph.
XL and YB, in contrast to their use in DSCAL, must define the extreme
lower left corner of the frame.

SECONDARY ROUTINES continued

DROTA continued

Each set of raw digitizer coordinates is corrected for rotation of the sheet on the digitizer table and converted to the scale of the chart or graph when DROTA is called by the statement:

CALL   DROTA (2,DX,DY,X,Y)

where DX,DY,X, and Y are as defined in the description of the subprogram DSCAL.

DSCSH-- This routine shifts the boundaries at the end of a frame when automatic scale advance is desired. At the beginning of each job it must be initialized by the statement:

CALL   DSCSH (0,XL,YB,XR,YT)

where XL and YB are the coordinates of the origin of the frame, in the units of the chart or graph, and XR and YT are the coordinates of the top right hand corner of the frame, in the units of the chart or graph.

To effect a scale shift, DSCSH is called by the following statement:

CALL   DSCSH (ISH,XL,YB,XR,YT)

where XL, YB, XR, and YT are the boundary coordinates of the next frame, as defined in the previous statement, and ISH is the code number which specifies in which direction the scale is advanced. If ISH equals 1, advance is to the right; if ISH equals 2, advance is upward; if ISH equals 3, advance is to the left; and if ISH equals 4, advance is downward.

SECONDARY ROUTINES continued

DOVER--   This routine rejects coordinates if successive points
are spaced more closely than the specified tolerance. It must be
initialized by the following statement:

Q= DOVER (T,-10000.,-10000.)

where T specifies the tolerance in units of .01 cm. of distance on
the digitizer table.

As each set of coordinates is to be tested for spacing
with respect to the last set, DOVER is called by the following state-
ment:

R= DOVER (-1.,X,Y)

where X and Y are the raw digitizer coordinates of the point, and
R is a code indicating whether the tolerance is exceeded. If R
equals zero, X and Y are too close to the last set of coordinates
and should be deleted. If R equals 1, X and Y are a sufficient dis-
tance from the last set of coordinates and should not be deleted.

DINTE--   At the beginning of each logical block of data DINTE,
which calculates interpolated coordinates in equal intervals of x,
must be initialized by the following statement:

Q= DINTE (0,XX,YY, XNT, 0.0)

where XNT represents the specified interpolation interval in the
units of the graph or chart, XX and YY represent the x and y coor-
dinates, already converted to the units of the chart or graph, of
the first point in the logical block of data, and Q is a dummy
variable.

As each succeeding set of x and y coordinates in the
units of the chart or graph are obtained, DINTE should be called by
the following statement:

IF(DINTE) (1,XX, YY, XI,YI)) a,b,a

where XX and YY are the x and y coordinates as defined in the pre-
vious statement, XI and YI are the x and y coordinates interpolated
for equal intervals of x, if new coordinates have been calculated,
and a and b are statement numbers. The value of DINTE indicates
whether or not new interpolated coordinates have been calculated. If
DINTE equals 1, new coordinates have been calculated which should be
collected as dimensioned variables and the routine called again to
determine if more than 1 set of interpolated coordinates between the
last two sets of original coordinates is to be accumulated. This
loop continues until DINTE again becomes zero.

SEMI AUTOMATIC
NETWORK CODING
PROCESS
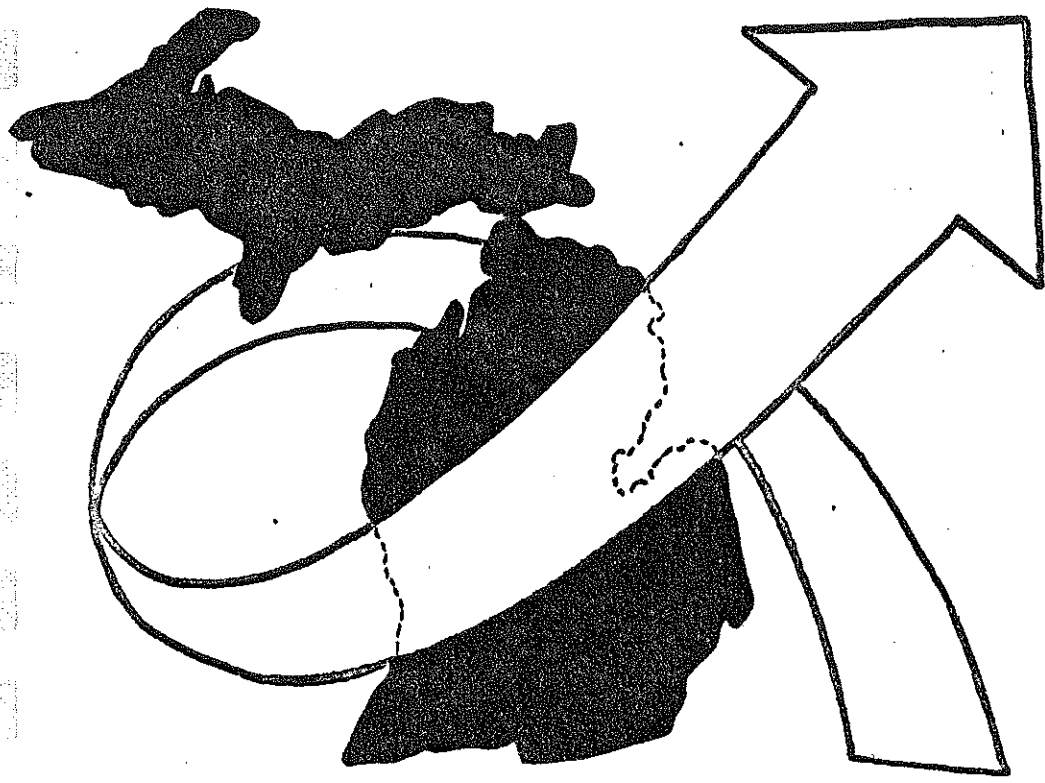
SEMI-AUTOMATIC
NETWORK CODING
PROCESS

Because of many of the problems continuously encountered
with the "typical" network coding process discussed in the
previous section, the following process was defined and
tested with hopes of eliminating many of the existing
difficulties inherent in the present manual techniques.

This process is based on an application of the Thompson
Pencil Follower. Details of this piece of equipment were
briefly discussed in a previous section. With this new
technique, the user will still need to select the highway net-
work and complete the initial highway network base maps, but
from that point forward, the process has been improved and
drastically modified.

In order to explain the details of the semi-automatic
network generation technique, a sample network has been
described in figure 9. This is a gross simplification of
a typical network coding situation, but this network was
used as the initial network for testing this preliminary
computer program process.

Let the user assume that this is a single county or
township network map separated out of a very large highway
network. Note that no node numbers have been assigned to
any of the highway intersections for this sample. First
the user places this map over the pencil follower table

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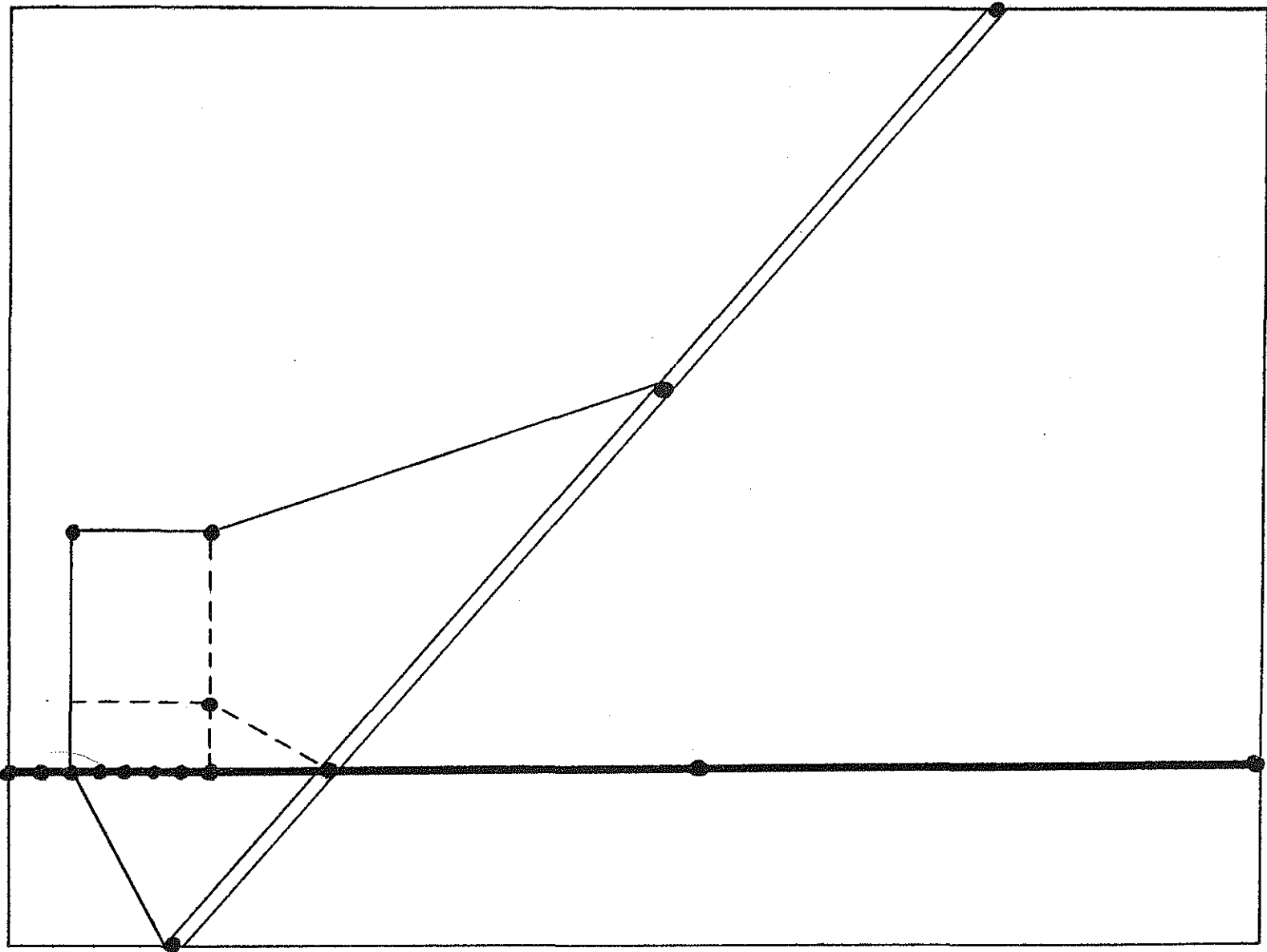
SAMPLE NETWORK

	INTERSTATE
	INTERSTATE BUSINESS ROUTE
	STATE TRUNKLINE
	CITY STREETS OR BORDERLINE

FIGURE 9

similar to the one displayed in figure 7. At this point

each of the actual steps required to digitize this sample

network will be described using figure 9 as a reference.

Because this was a test network, the programmer identi-

fied each link in this network with a link number to

eliminate any initial confusion. The link numbers appear

in figure 10. This would normally not be necessary but

is useful when referring to computer listings later in this

section. When coding each link using the "digitizer"

concept, there are basically two parts. (1) The deter-

mination of necessary information defining each link and

(2), the identification of the A and B nodes for each link.

The first portion of link coding is accomplished using

the keyboard. A diagram of the keyboard arrangement appears

in figure 11.

For those who might not be familiar with the "digitizer,"

the following information is punched in the paper tape

initially before identifing the A and B node of each link

using that keyboard.

Link # / Dir / Jur / Lk Type / Cont. Sect.

  (3)   (1)   (2)   (2)   (2)

After entering this information the user would then place

the pencil pointer, Figure 7, at the location marked start

(A node) in figure 10, depress the foot control, move the

pencil pointer to the opposite end of the link (B node)

and depress the foot control. This operation identifies
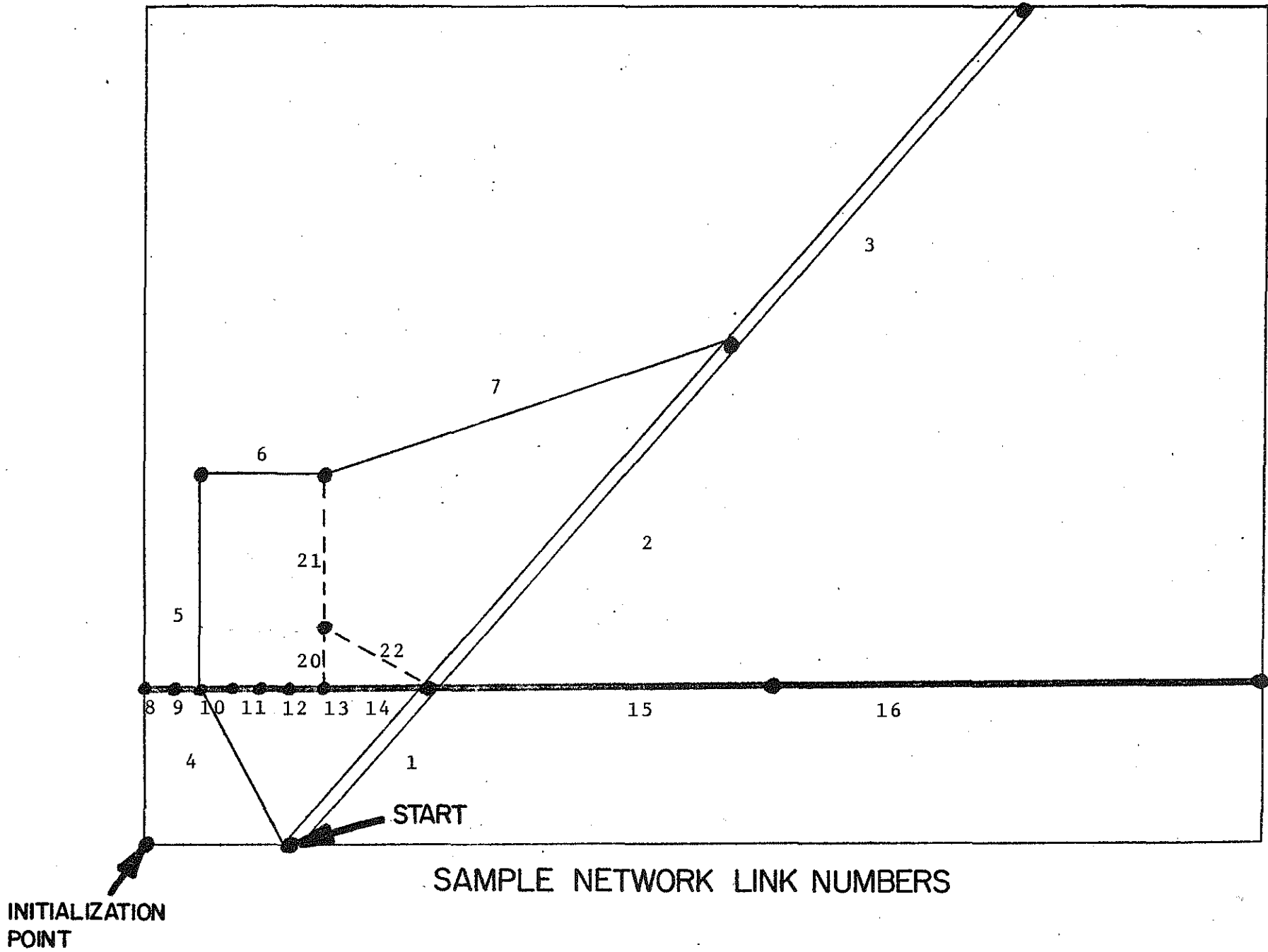
SAMPLE NETWORK LINK NUMBERS

INITIALIZATION
POINT

START

INTERSTATE
INTERSTATE BUSINESS ROUTE
STATE TRUNKLINE
CITY STREETS OR BORDERLINE

FIGURE 10

KEYBOARD

THOMPSON PENCIL FOLLOWER
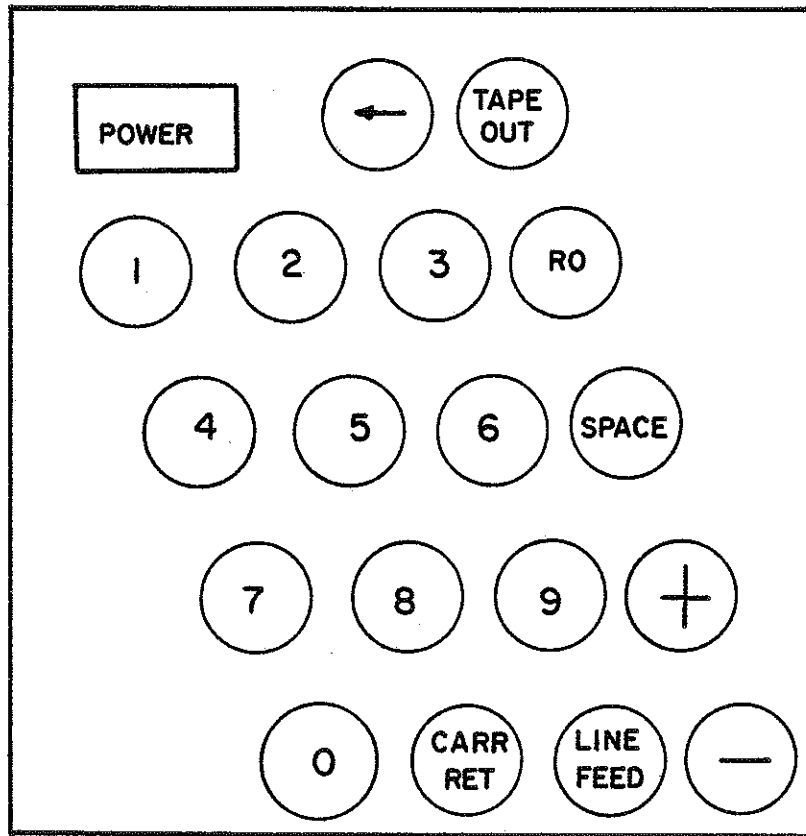
FIGURE 11

both the A and B node of a link. By repeating this operation

for each link in the system, all links would then be identified

with six relatively simple pieces of information. A sample

of the "digitized" information, after it was been removed

from paper tape, is displayed in the upper portion of figure

12. This information is a sample listing of the test network

in figure 9 after the "digitizing process." At this point

there is no resemblance between this network link file and

the actual highway network format which appears in figure 5.

After completion of the network identification pro-

cess, which has produced a punched paper tape using the

"digitizer," the next major portion of this new network coding

process is initialized. The second portion of this process

involves a computer program which was defined to convert

the "digitizer" output into a standard network format.

This program accomplishes much more than simple format

changes. The discussion which follows is an attempt to

explain the problems which were encountered during the develop-

ment of this process and just how the computer program was

defined to overcome these problems.

With most large scale highway networks such as those

used in statewide models, the network may be defined on as

many as one hundred county maps. Therefore, when placing each

map on the "digitizer" table and identifing the links for

each county, there would be no difference in the coordinates

from one county to the next. This would require each

county to be treated as an individual entry or highway

network. This problem was overcome by using an initiali-
zation point for each county such as the point identified
in figure 10. When starting each county highway "digitizing"
process, the user would place the pencil point over this
point after the county has been aligned on the table and
record the initial master coordinates of this point. The
master coordinates for the initialization point for each
county could be previously determined through the use of a
state map. The coordinates of the initialization point
for the test network is the first line in the upper part
of figure 12.

The computer program uses this coordinate to adjust the
original base coordinates so that each county has an indi-
vidual coordinate system. In the test case this coordinate
would be used to modify all of the actual coordinates which
follow below it in figure 12. The initialization point is,
therefore, used to relate each piece (county) to the whole
(state).

A second problem appears after the user has completed
the identification of the first link. Note that in figure
10 the B node of link number one is the same point as the A
node of link number two and, therefore, should retain the
same coordinates. In this situation there is no problem
as the user may leave the pencil follower at the B node
location after completing link one. The identifier infor-
mation for link two may be entered with the keyboard and by
depressing the foot control without touching the pencil

```
  000000000010002341,0461,2270,1984          ◄◄ LINK NUMBER
  00120101910012594,0478,2838,0780,          ◄ INITIALIZATION POINT
  00220101910022836,0778,3348,1427,
  00320101900033348,1427,3850,2066,
  00410102910212593,0475,2427,0756,
  00510102900222427,0757,2408,1139,
  00630102910232409,1138,2637,1152,
  00730102910232638,1154,3345,1424,
  00840201900112326,0752,2375,0755,
  00940201910112375,0756,2428,0763,          ◄ ACTUAL COORDINATES
  01040201910112428,0763,2475,0766,
  01140201910112475,0765,2525,0767,
  01240201910112525,0766,2580,0768,
  01340201910112579,0768,2656,0773,
  01440201110112655,0773,2838,0780,
  01540201910112838,0780,3421,0815,
  01640201910133420,0815,4348,0866,
  02010404000002654,0767,2648,0871,
  02110404000002648,0872,2638,1152,
  02240404000002651,0872,2835,0783,
  03030404000002425,0862,2651,0872,
  9999999999999999999999999999999999
  ?END
   WAIT.
```

Figure 12

RUNNING

A-NODE	B-NODE	DIST	LIND	DJIURR	TYPE	CONT SECT
0100 0002	0201 0116	0152	001	20	10	191001
0201 0116	0413 0361	0324	002	20	10	191002
0413 0361	0622 0040	0458	003	20	10	190003
0100 0002	0039 0116	0129	004	10	02	91021
0039 0116	0039 0265	0149	005	10	02	90022
0039 0265	0129 0267	0090	005	30	02	91023
0129 0267	0413 0361	0299	007	30	02	91023
0000 0115	0019 0115	0019	008	40	20	190011
0019 0115	0039 0116	0020	009	40	20	191011
0039 0116	0058 0117	0019	010	40	20	191011
0058 0117	0078 0117	0020	011	40	20	191011
0078 0117	0100 0116	0022	012	40	20	191011
0100 0116	0129 0116	0029	013	40	20	191011
0129 0116	0201 0116	0072	014	40	20	111011
0201 0116	0431 0119	0230	015	40	20	191011
0431 0119	0796 0122	0365	016	40	20	191013
0129 0116	0129 0156	0040	020	10	40	400000
0129 0156	0129 0267	0111	021	10	40	400000
0129 0156	0201 0116	0082	022	40	40	400000
0040 0156	0129 0158	9089	030	30	40	400000

SAMPLE
COMPUTER
LISTINGS

follower, the coordinates of the A node for the second link
will be the same.   Therefore, no problem.

Now as the user continues to digitize the network, he
will find that a problem does exist, the minute digitizing
begins on another route.   For example, to digitize link number
ten in figure 10 it becomes difficult to obtain the same
A node for link number ten as for the B node of link num-
ber one because the pencil follower has been moved in the
interim.   Therefore, a network problem is created as these
two points would not have the same coordinates using this
process.   It would be only by coincidence that the user
happened to return the pointer to the exact same location
as was the case with link number one and fifteen in figure
12.   The B node of one is 2838, 0780 and the A node is also
2838,0780.   In most cases a problem will occur. For example,
link number fifteen A node and link number twenty-two B node
(Figure 12) are different when in fact they are the same point.

The computer program eliminates this problem by applying
tolerances when comparing node numbers in order to determine
whether two different node numbers are, in fact, the same
point.   Using this sub-routine in the program, the A node
of link twenty-two would be identified as the same point.
This process can be verified by turning to the listing
in figure 12 at the top.   Using the network diagram figure 10,
it can be determined that links 1, 2, 14, 15 and 22 all have
a common node some place around 2838,0780.   These nodes are
underlined in this listing and in the highway network link

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list in the lower part of figure 12. Note that in the lower part of the figure all nodes carry the same number.

Some problems still exist before the digitized network links are acceptable as direct input into a network builder program.

One of these problems is the fact that all nodes should very probably be assigned sequential four-digit node numbers. Most transportation planning computer packages will not handle node numbers larger then four and certainly not eight digit node numbers as is the case with the numbers generated by this "digitizer process." Therefore, the computer program defined for this project sorts the A-node B-node generated by the "digitizer," applies the node tolerance limits to determine which points are in fact the same point and finally, sequentially renumbers all nodes using a four-digit number.

When creating a highway network using manual techniques, the following items are also coded into each network link record: Speed, Capacity, Count, Distance.

With this process, the speed is determined by using a speed chart which is part of the program and the speeds are determined using the link type and jurisdiction. The potential user should note that by using this new technique, these items need not be determined manually any more.

The capacity and count information can be placed in the link record by using the control section number which was originally entered through the digitizer keyboard. The control section number allows the user to enter other

master highway network data files and move data to the
highway network link record.

Distance on each link is the final element which must
be determined before the highway network link file is com-
plete enough to use as input for a network builder program.
The distance would be determined using the coordinates
generated for each end of a highway link when using the
digitizer.

Finally, the task of determining coordinates for each
of the nodes in a large highway network can easily be accom-
plished. When this program is assigning four-digit node
numbers, the original "digitizer" eitht-digit node numbers can
be used as the coordinates of each node and a node coordinate
list could be generated.

CONCLUSIONS
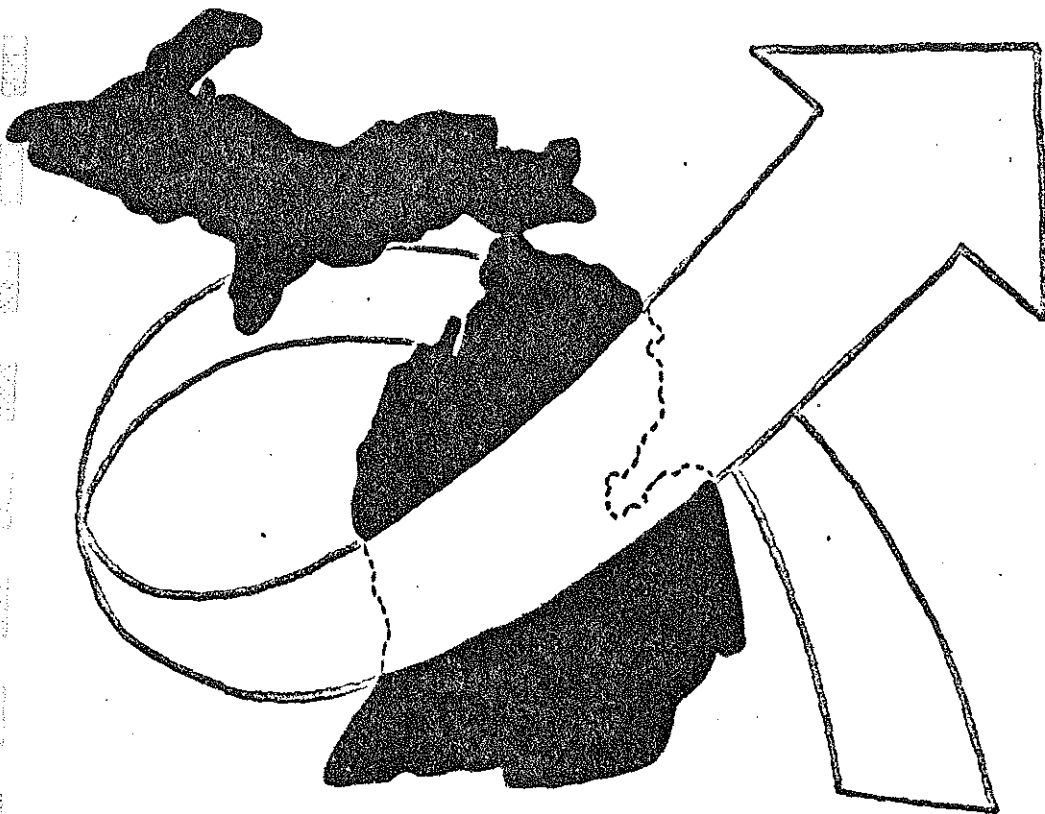
CONCLUSIONS

This process appears to have the following advantages.

1. It converts a relatively boring manual network coding process into a more fascinating task by using a "digitizer" which is an interesting piece of peripheral computer equipment. This by itself would tend to eliminate human error generated by the boredom of the original manual process.

2. By using the digitizer and this computer program, the manual task of assigning node numbers is completely eliminated thereby removing another source of error.

3. With a manual network coding operation, the coder had to sort through a mound of maps and listings in order to determine the following.

   a. Link Distance
   b. Speed
   c. Direction
   d. Capacity
   e. Count
   f. Link type
   g. Jurisdiction
   h. Control section

   Using this process, the user need only enter those items underlined in the above list using the keyboard on the digitizer. The computer program automatically selects or calculates the remaining items.

4. Most present day network coding processes involve the using of a network plotting package. In order to use a plotting package, the user must previously determine the coordinates for all nodes in the network. As indicated in a previous section this is a tedious, time-consuming, error-generating task. With these techniques the node coordinate file or list is an automatic process requiring no manpower whatsoever.

Therefore, the present day network coding process now

becomes a reasonably efficient process through the use of

a "digitizer." Most of the tedious manual operations such

as node numbering and coordinate determination, which tend to

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generate network errors, have been completely eliminated.

The manual task of determing link speed, distance capacity

and count have also been automated. The only task which

the user need complete is the identification of link type,

jurisdiction, direction and control section for each link

in a network - - - - the rest has been automated using

a Thompson Pencil Follower and a single computer program.

The Michigan Department of State Highways would sincerely

appreciate any suggestions which might improve this pro-

cess.