REMOTE SENSING IMPACT ON CORRIDOR SELECTION AND PLACEMENT

L-15

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ABSTRACT

In recent years, the National Environmental Protection Act (NEPA) legislation has required and will require that major developments such as pipeline, powerline, and highway corridors be done at low environmental cost (impact). The anticipated Land Use Policy and Planning Assistance Act (Jackson-Udall Bill) will also probably lead to the requirement that such development be done in a manner consistent with existing land use development plans. In the case of NEPA, environmental impact statements are required for major developments utilizing federal funds. Many states have similar environmental laws with environmental impact statements for other developments.

These legal developments have put additional pressure on planners to locate corridors using objective and defensible procedures and to consider environmental, social and economic impacts as well as construction costs. Computer-aided corridor selection techniques, utilizing digitized data bases of socio-economic, census, and cadastral data, have been developed for highway corridor routing (ref. 1). At ERIM, under sponsorship of the NASA Office of University Affairs Code Y program, we have generated land resource data from various remote sensing data sources, and have, in cooperation with Richard Esch of the Michigan Department of State Highways and Transportation, successfully merged the land resource data generated from LANDSAT-1 with the ancillary data files of Esch's corridor selection model, and designed proto-type highway corridors using the combined data set.

From our point of view, land resource data derived from various remote sensing data, (LANDSAT, aircraft MSS, or photography) when merged with ancillary data and used as input to digital computer corridor location algorithms, represents a powerful and important use of remote-sensing-derived information for operational planning needs. We feel that methodologies of this type will become increasingly important in the future.

In this paper we discuss the types of remote-sensing-derived information we feel are useful for highway corridor location, special considerations in geometric correction of remote sensing data to facilitate merging it with ancillary data files, and special interface requirements. Hopefully our experience with this case will be of help to others contemplating similar activities.

1. INTRODUCTION

Over the past six years, citizen awareness of environmental issues has increased markedly and has resulted in a number of pieces of federal and state legislation (e.g., National Environmental Protection Act of 1970) which require projects developed with public funds to be preceded with environmental impact statements stating the expected impacts of proposed developments and showing that the project has been designed to minimize environmental impact. At the same time the Federal Highway Administration of the Department of Transportation has required all states to develop "action plans" identifying the planning processes used for highway projects which use federal funds.

All these developments have made it imperative that highway and other corridor routes (e.g., pipelines and powerlines) be selected by objective and defensible procedures. Highway planners are turning to new technology such as computer data bases with associated corridor routing algorithms to provide more objective corridor routing.

Michigan has advanced highway corridor routing methodology and has been examining the potential of various remote sensing sources to provide up-to-date land cover information to supplement its computerized file of census and socio-economic data. The Environmental Research Institute of Michigan (ERIM), under funding from the NASA Office of University Affairs (Grant NGR-23-005-552, technical monitor Mr. Joseph Vitale) has cooperated with the Statewide Studies Unit (SSU) of the Michigan Department of State Highways (MDSH) to explore the uses of LANDSAT and RB-57 high-altitude color infrared (CIR) photography for obtaining current land cover information. The LANDSAT efforts are the subject of this paper.

While the discussion of the use of LANDSAT data and the case study presented here focus on the highway planning process, we believe that similar procedures could be used for other corridor routing tasks. LANDSAT and other remote sensing data, when properly processed to yield appropriate information, will have impact on those tasks as well.

2. HIGHWAY PLANNING IN MICHIGAN

Highway planning in Michigan occurs in three distinct phases. The first phase is a "reconnaissance study" to determine the need for a new highway link and the areas the link is to serve. Alternative corridors are also generated. The second phase is a detailed examination of each alternative corridor and the selection of a corridor. The third phase is a detailed engineering study of the placement of the road within the selected corridor.

Remote sensing technology can impact all three stages of highway planning in Michigan, and it does. For reconnaissance studies, the subject of more detailed discussion in the next section, general land cover information (of a degree of complexity of Level I the U.S.G.S. Circular 671 - although not precisely those classes) is useful, along with substantial information regarding traffic volumes, accident rates, population, and services availability (e.g., hospitals or schools). For corridor selection from various equal construction-plus-environmental cost alternatives generated by the reconnaissance study, more detailed land cover information (about Level II) is required. In pilot studies (ref. 2) this information has been obtained by photointerpretation of RB-57 CIR data. No doubt this information could be obtained by computer processing of data from satellites whose sensors are more optimized for land cover sensing than the current LANDSAT-MSS, e.g., the Thematic Mapper.

In the third level of planning, the MDSH currently uses color photography collected over the corridor of interest both as an information source for more detailed land cover information (about Level III) and as a data base.

In the next section, we discuss in detail a case study of the use of land cover information derived from LANDSAT data to the reconnaissance planning of a hypothetical highway corridor. The work reported was a cooperative project between ERIM and Mr. Richard Esch of MDSH-SSU.

3. A HIGHWAY CORRIDOR ROUTING CASE STUDY

Richard Esch, of MDSH-SSU has developed a highly versatile statewide transportation model shown in figure 1 (see also ref. 1). While figure 1 shows all model capabilities, and is therefore complex, there are three generic types of modules which make up the overall model. First, there are a set of files - Statewide Network File, Statewide Socio-Econ File, and Statewide Facilities File - containing basic information. In the middle of figure 1 are a set of models which use data from the files to make calculations. At the bottom is a graphics display battery for displaying model calculations. Figures 2, 3, and 4 show some of the information present in the basic data files.

Corridor location has been done with only the data from the files shown, although for optimum results, land resource data should be used in conjunction with the existing data files. The general situation is illustrated in figure 5. We hope to be able to create a natural characteristics data file to supplement the existing data files. Remote sensing will be able to supply many but not all of the natural characteristics data, and possibly some of the cultural characteristics required for effective corridor location.

3.1 THE CASE STUDY

As a demonstration of the ability of the existing model to use land cover information extracted from ERTS-CCT's by computer processing, a case study was performed. ERIM acquired and processed data from the Munising, Michigan area in the north center of the Upper Peninsula. An eight category recognition tape was prepared, with the classes shown in Table I. The tape was further processed by Richard Esch. Since the model operates on a cell basis, the cells are larger than the 1.1 acre LANDSAT resolution element, the first step was an aggregation of the recognition tape data. Data were aggregated over 8 x 16 arrays of LANDSAT resolution elements, yielding a grid size of 140.8 acres. The percentage of each land cover class was computed for each 110 acre model grid cell. Example maps (representing an area of 5 x 9 mi) showing the percentage of water and urban are presented in figures 6 and 7. The large water area at the top of figure 6 is Lake Superior, while smaller aggregations of water down the left hand side of figure 6 are other lakes. In figure 7, Munising is at the upper right center. Using the digital tape recognition file, Richard Esch first preapred a location determinant composite file from the land cover data. This location determinant shown in figure 8 was, in this case, a composite of urban and water, although it could have been created from a linear sum of all classes. The weight for water was -10 and that for urban +10, as shown in figure 9.

Figure 9 also shows the relative weights given to the location determinants (in this case only LANDSAT-derived land cover information) and the link distance (related to cost of highway construction) in selecting the corridor. In practice, the model would be exercised with different sets of relative weights to generate several alternative corridors. Land cover as well as highway construction costs were used in this example, and thus the location of corridors can be done to minimize overall cost of construction plus environmental cost.

For this case study, the optimal corridor from the start, at the top, to the end, at the bottom is shown by the line in Figure 10. Notice that near the top the line passes through cells with relatively little water, rather than through cells which are predominantly water. This occurs because of the (assumed) high environmental cost of building a highway over water. (The construction cost would obviously be large.)

3.2 REMOTE SENSING SYSTEM CONSIDERATIONS

There are at least three remote sensing system considerations important when preparing land cover information to be used in models such as the MDSH-SSU corridor selection model. The three most important considerations are the type of information required and its accuracy, the format of the information supplied, and the geometric quality of the supplied information.

We have previously discussed the idea that reconnaissance corridor routing can be done with fairly coarse land cover information, as shown in figure 5. The accuracy requirements for this information have not yet been precisely defined, but the current machine processing capabilities of LANDSAT data are such that information derived by this means would probably be very useful for initial tests of corridor selection using land cover information.

Since most models are implemented on digital computers, having a digital format input of land cover information is a necessity. Machine processed LANDSAT data is inherently digital format information, and thus has advantages over photointerpreted products which must be digitized before they can be used by the model. Accuracy checking the machine processed data is conveniently done with the information in pictorial format. But the availability of digitally controlled ink jet printers such as that sent by Mead Technology Labs or available on ERIM's MIDAS (Multivariate Interactive Digital Analysis System) (ref. 3), make creation of pictorial output from digital tape much easier to do than to digitize pictorial data.

Geometric correction must be performed on the raw LANDSAT data in order to be able to merge the land cover information with other information sources. The accuracy with which this is done depends on the number and sizes of the grid cells in the model and the accuracy with which the information needs to be registered. Some measure of the size of grid cells may be gained from figure 11. This figure shows the old 547 cell system for the State of Michigan. Recently, the model has been expanded to 2300 cells, and there are plans to go to a larger number of cells. All cells are not the same size, as can be seen from the figure. If we assume a 4:1 variation in cell size and 58,000 sq miles for the State of Michigan, then the smallest zone is 6.3 sq miles or about 23 km on a side if the zone is square. Assuming a registration accuracy to $\pm 1\%$ of the width of the zone, the required geometric accuracy is ± 230 m. This is well within the range of LANDSAT capabilities. Of course, the reference grid used in many state studies is not UTM or latitude-longitude, but a state plane coordinate system. Michigan is no exception. Fortunately, in Michigan's case there is only one grid system, which makes the registration job somewhat easier.

4.0 CONCLUSIONS

Ability of current LANDSAT data processing technology to provide land cover information to upgrade satewide reconnaissance corridor routing has MDSH very interested. Continued development of this capability will require further inflow of federal dollars, because new technology research is low on Michigan's State Budget priority list as it is with nearly every state.

We feel that our case study has generated interest and holds promise for upgrading highway and other corridor planning. We look forward to taking the next step.

REFERENCES

1. R. E. Esch, "Michigan's Statewide Traffic Forecasting Model", Michigan Department of State Highways, September 1972.

2. I.J. Sattinger, et al., "Remote sensing in Michigan for land resources management: Annual Report, 1 June 1972 to 1 June 1973" Report 193400-2-F, Environmental Research Institute of Michigan, Ann Arbor, Michigan, July 1973.

3. F.J. Kriegler, et al., "MIDAS, Prototype Multivariate Interactive Digital Analysis System - Phase I", Report 195800-25-F, NASA CR-132463, Environmental Research Institute of Michigan, Ann Arbor, Michigan, August 1974.

TABLE I

CLASSES OF THE EIGHT-CATEGORY
RECOGNITION TAPE

Urban

Open

Hardwood Forest

Water

Conifer Forest - Jack Pine

Marsh

Conifer Forest - White Pine

Managed Hardwood Forest

STATEWIDE MODELING SYSTEM COMPONENTS

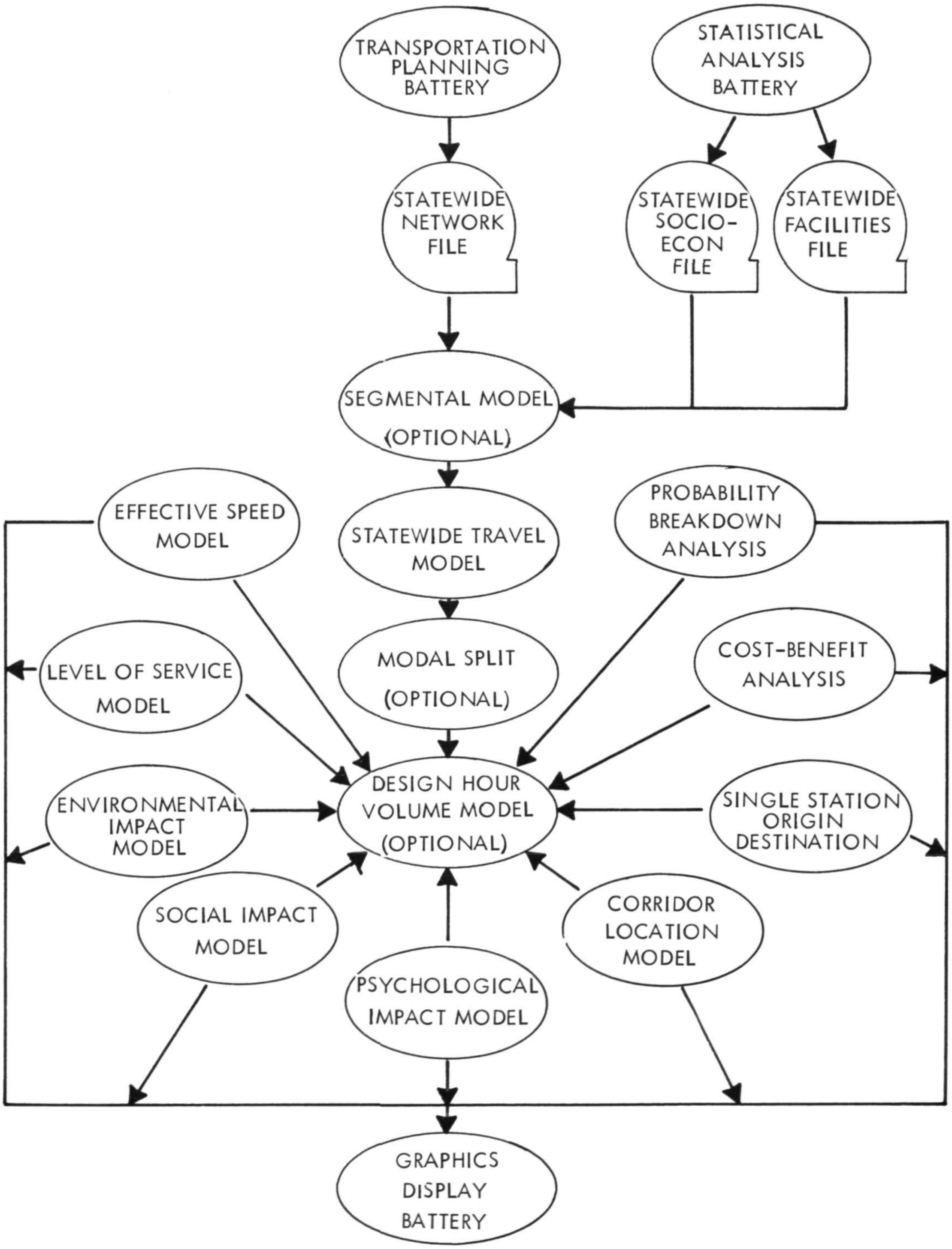

Figure 9

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 2

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 3

STATEWIDE FACILITY FILE

HISTORIC SITES
HOSPITALS
AIRPORTS
WHOLESALE TRADE CENTERS
MAJOR PARKS
NON-PUBLIC COLLEGES
PUBLIC COMMUNITY COLLEGES
CITIES OVER 30,000 POPULATION
UNEMPLOYMENT OFFICES
MENTAL HEALTH CENTERS
CERTIFIED INDUSTRIAL PARKS
MICHIGAN'S UNIVERSITIES
SKI AREAS
SNOWMOBILE TRAILS
CBD w/5,000 POPULATION
TRUCK TERMINALS
STATE POLICE POSTS
DAILY NEWSPAPERS
WEEKLY NEWSPAPERS
SEWAGE TREATMENT FACILITIES
TOURIST ATTRACTIONS
BUS TERMINALS
MANUFACTURERS
CAMPSITES

FIGURE 4

CORRIDOR LOCATION VARIABLES

(1) NATURAL CHARACTERISTICS

WATERS - STREAMS, RIVERS, LAKES, ETC.

VEGETATION - BARREN LAND, FORESTS, NATURAL AREAS

TOPOGRAPHY - ORIENTATION, DIRECTION, SLOPE, ELEVATION CHANGE

SOIL CONDITION - SURFACE AND SUBSURFACE SOIL TYPES

(2) CULTURAL CHARACTERISTICS

LAND USE - EXISTING AND PLANNED RESIDENTIAL, COMMERCIAL, INDUSTRIAL, AGRICULTURAL, RECREATIONAL AREAS

POPULATION DISTRIBUTION - URBAN CENTERS OF VARIOUS SIZES

COMMUNICATION SYSTEM - LOCAL ROADS, ARTERIALS, FREEWAYS, UTILITY LINES

FIGURE 5

% WATER

94	94	94	94	94	94	94	51	0	0	36	0	0
100	100	100	100	74	98	100	100	26	0	37	0	0
100	100	100	100	79	83	100	100	99	85	3	0	0
100	100	100	100	100	100	100	99	100	100	20	0	0
100	100	100	100	91	84	97	91	100	100	56	0	0
100	98	42	13	1	0	2	86	100	100	84	2	0
100	54	0	0	0	0	0	2	30	90	100	97	41
100	26	0	0	0	0	0	0	0	13	43	31	2
100	38	0	0	0	0	0	0	0	2	0	0	0
59	13	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	3	0	0
26	25	0	0	0	0	0	0	0	4	19	11	0
98	45	0	0	0	0	0	0	0	0	0	2	0
53	2	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	2	0	0
0	1	0	1	0	0	0	0	0	0	0	0	0
0	0	1	0	0	4	5	0	0	0	0	0	0
0	0	13	0	0	0	0	0	0	3	0	0	3
0	1	32	1	0	0	0	0	0	15	38	2	0
0	26	13	0	0	25	0	0	0	18	38	1	0
0	19	20	0	2	1	0	0	0	0	0	0	0
0	1	48	0	0	0	0	0	9	0	0	0	2
0	0	57	13	0	0	0	0	11	7	0	2	13
0	0	15	73	5	0	0	0	2	0	38	1	0

FIGURE 6

% URBAN AREA

0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	2	0	0	0	0	0	0	2	0	0	1
0	0	2	0	0	0	6	5	2	19	23	4	1
0	0	6	7	5	8	12	4	0	2	4	2	5
2	3	2	1	7	0	11	5	0	0	1	0	0
9	1	0	0	1	0	0	1	0	2	3	1	0
0	0	0	0	0	0	1	12	0	3	2	2	0
0	0	0	0	0	0	0	0	2	6	0	1	0
0	0	0	0	0	0	0	2	2	6	6	2	2
0	2	0	0	0	1	5	0	2	9	17	5	2
0	2	0	0	0	3	0	2	9	1	1	5	17
0	7	0	1	0	0	0	2	2	16	19	23	4
5	0	0	0	0	0	3	13	16	13	2	0	8
[illegible]	3	1	0	0	0	0	2	9	2	1	1	0
31	21	0	0	1	0	0	0	1	1	0	0	0
18	23	0	0	0	0	0	1	5	2	1	1	0
9	9	0	1	0	2	11	1	0	0	1	2	1
8	2	0	7	0	4	59	35	2	0	0	0	3
6	22	9	9	2	4	12	13	2	0	1	0	1
33	49	26	2	5	2	6	2	0	0	0	0	0

FIGURE 7

LOCATION DETERMINANT--COMPOSITE

-94	-94	-94	-94	-94	-94	-94	-51	0	0	-36	0	0
-100	-100	-100	-100	-74	-98	-100	-100	-26	0	-37	0	0
-100	-100	-100	-100	-79	-83	-100	-100	-99	-85	-3	0	0
-100	-100	-100	-100	-100	-100	-100	-99	-100	-100	-20	0	0
-100	-100	-100	-100	-91	-84	-97	-91	-100	-100	-56	0	0
-100	-98	-42	-13	-1	0	-2	-86	-100	-100	-84	-2	0
-100	-54	2	0	0	0	0	-2	-30	-88	-100	-97	-40
-100	-26	2	0	0	0	6	5	2	6	-20	-27	-2
-100	-38	6	7	5	8	12	4	0	1	4	2	5
-58	-9	2	1	7	0	11	5	0	0	1	0	0
2	1	0	0	1	0	0	1	0	2	0	1	0
-26	-25	0	0	0	0	1	12	0	-1	-16	-9	0
-98	-45	0	0	0	0	0	0	2	6	0	-1	0
-53	-2	0	0	0	0	0	2	2	6	6	2	2
-5	2	0	0	0	1	5	0	2	9	17	5	2
0	2	0	0	0	3	0	2	9	1	-1	5	17
0	6	0	0	0	0	0	2	2	16	19	23	4
5	0	-1	0	0	-4	-2	13	16	13	2	0	8
34	3	-12	0	0	0	0	2	9	-1	1	1	-3
31	20	-32	-1	1	0	0	0	1	-14	-38	-2	0
18	-2	-13	0	0	-25	0	1	5	-16	-37	0	0
9	-10	-20	1	-2	2	11	1	0	0	1	2	1
8	2	-48	7	0	4	59	35	-7	0	0	0	2
6	22	-48	-3	2	4	12	13	-9	-7	1	-2	-12
33	49	11	-71	-1	2	6	2	-2	0	-38	-1	0

FIGURE 8

HIGHWAY LOCATION DYNAMICS
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MICHIGAN STATEWIDE STUDIES
PROPOSED HIGHWAY IN MUNISING AREA
LAND DATA FROM ERTS RECOGNITION TAPE

STUDY AREA SIZE 25 CELLS BY 13 CELLS
CELL SIZE 140.8
NUMBER OF LOCATION DETERMINANTS 9

LOCATION DETERMINANT		WEIGHT
1	URBAN AREA	10.0
2	OPEN AREA	0.0
3	HARDWOOD FOREST	0.0
4	WATER	-10.0
5	CONIFER FOREST JACK PINE	0.0
6	MARSH LAND	0.0
7	CONIFER FOREST WHITE PINE	0.0
8	HARDWOOD FOREST MANAGED	0.0
9	NOT CLASSIFIED	0.0

LINK VALUE COMPONENT	WEIGHT
LOCATION DETERMINANTS	10.0
LINK DISTANCE	10.0

ALPHA	0.1
TOLERANCE	0.0

FIGURE 9

OPTIMAL ALTERNATIVE 1

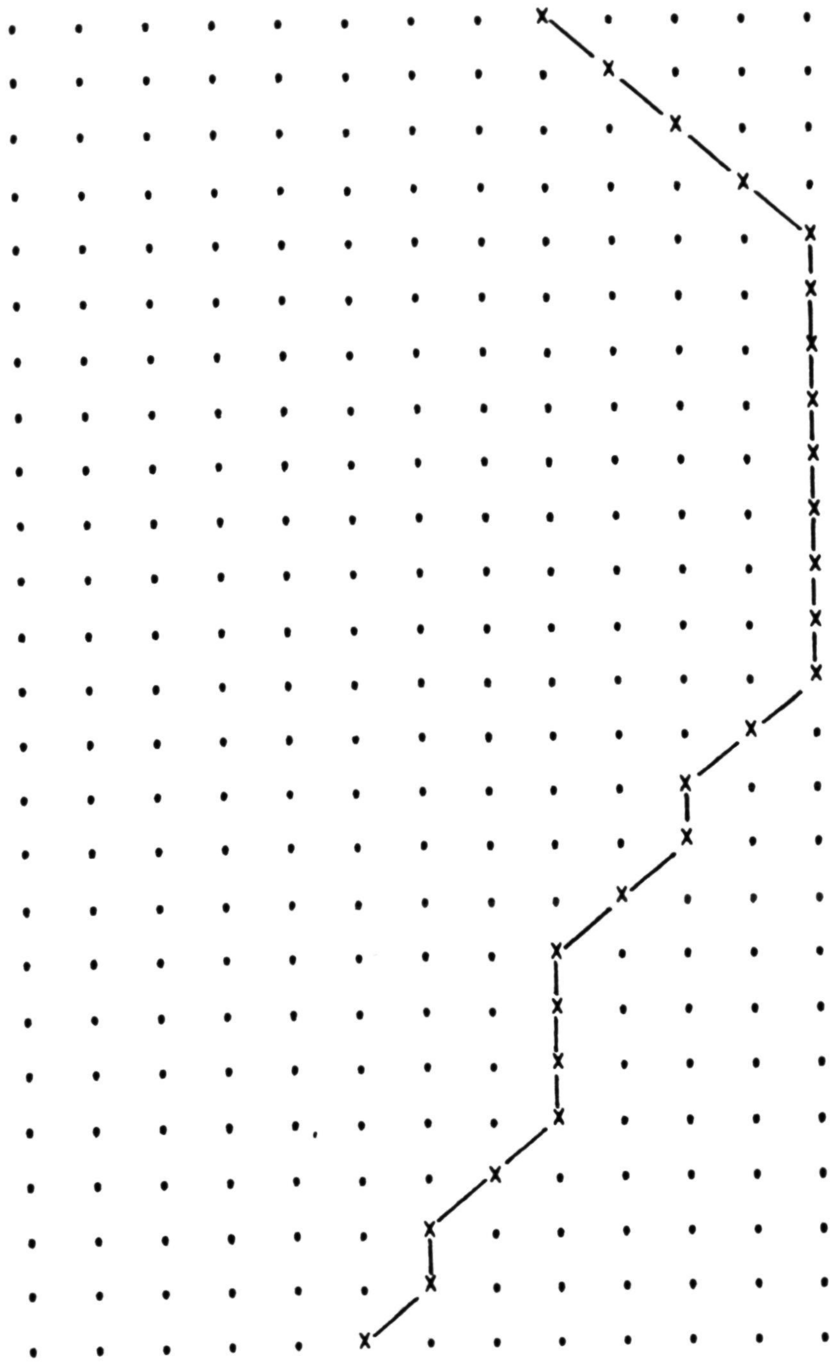

FIGURE 10

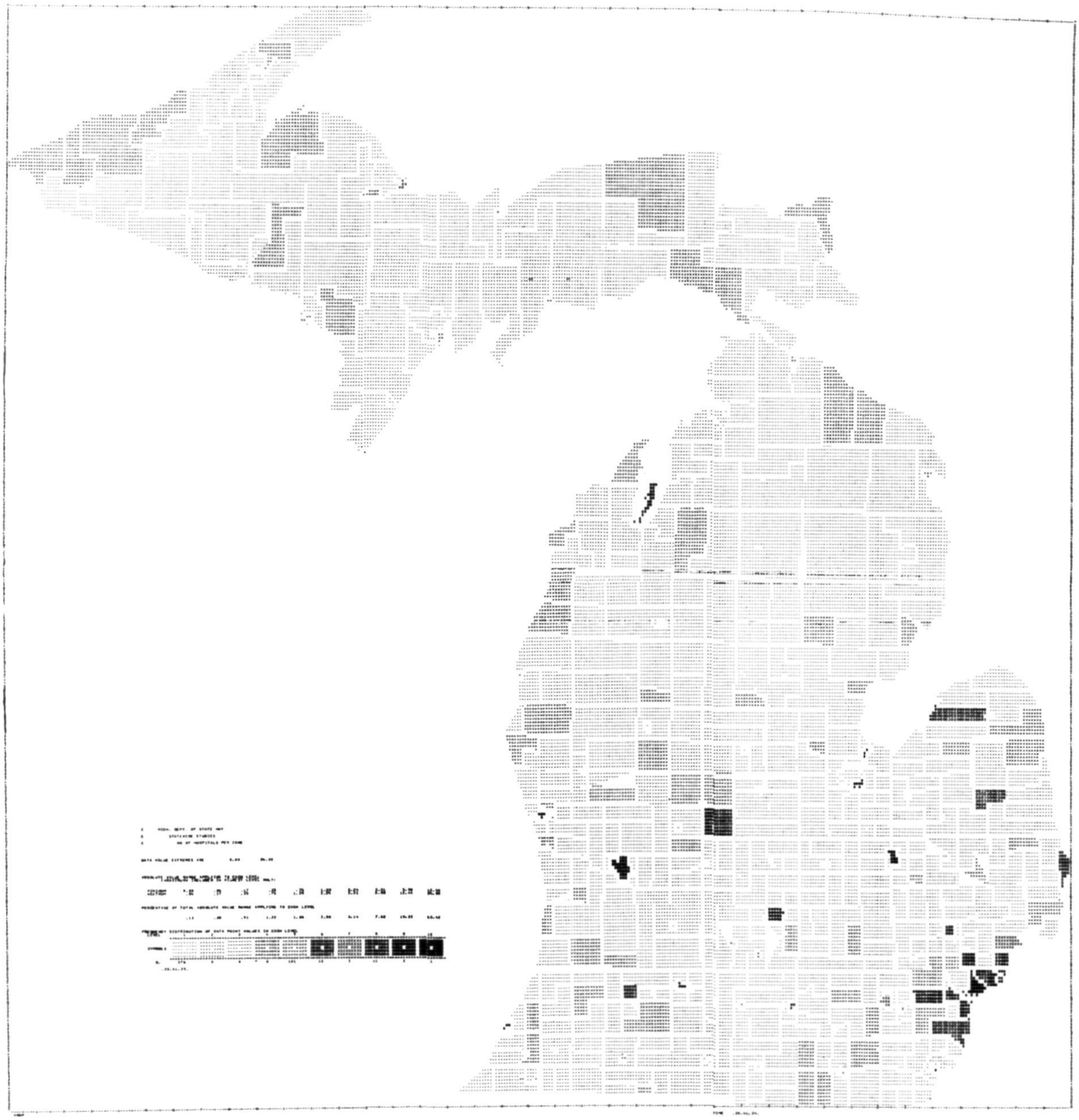

FIGURE 11