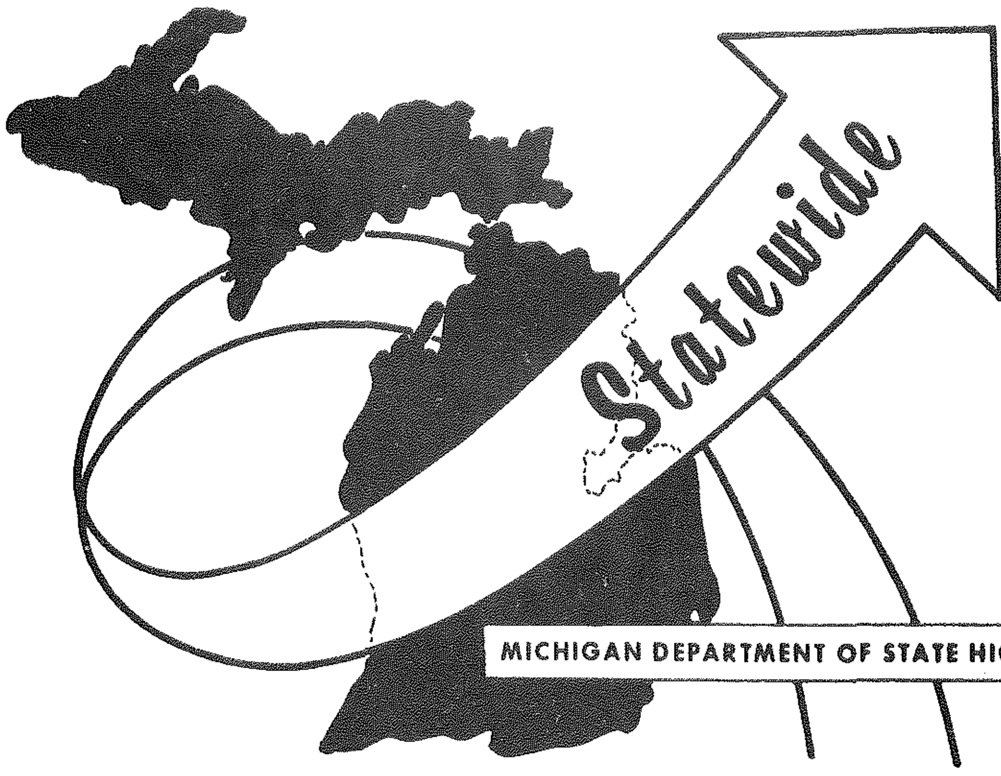
Statewide Transportation Analysis & Research

MICHIGAN'S STATEWIDE
TRAVEL MODELING
SYSTEM
VOL. VI

CORRIDOR LOCATION DYNAMICS

STATEWIDE TRANSPORTATION PROCEDURES

November 1972



MICHIGAN DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

MICHIGAN DEPARTMENT

OF

STATE HIGHWAYS AND TRANSPORTATION

MICHIGAN'S STATEWIDE
TRAVEL MODELING
SYSTEM
VOL. VI

CORRIDOR LOCATION DYNAMICS

STATEWIDE TRANSPORTATION PROCEDURES

November 1972

STATE OF MICHIGAN

WILLIAM G. MILLIKEN, GOVERNOR

DEPARTMENT OF STATE HIGHWAYS

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

November 22, 1972

Mr. Sam F. Cryderman
Engineer of Transportation Planning
Transportation Planning Division

Dear Mr. Cryderman:

Our recent discussion on "action plan" pointed to two increasingly important requirements for the decision process of future highway locations:

1. It must be based on broad socio-economic and envrionmental considerations, and

2. It must have full public participation.

With that in mind, we feel the Corridor Location Dynamics Model recently developed by George S. Liu of the Statewide Studies Unit may be of timely interest to you.

The Model takes any socio-economic and environmental goals set by the planner as input and generates the optimal route(s) between two points using a mathematical technique. It has three important differences from the conventional process for choosing a highway alternate:

1. It allows goals to be quantified and weighed by various interest groups,

2. It yields logically exhaustive, mathematically determined optimal solution(s) according to any set of goals, and

3. It is fully automated, requiring little or no human labor.

MICHIGAN THE GREAT LAKE STATE

The Model is therefore not only a powerful tool for highway location design, but allows solutions based on different goals and issues to be quickly generated and compared, thus uniquely suited to answer the "action plan" requirements mentioned above.

There are at present, as far as is known, only two other similar attempts in the Nation, both using a less efficient mathematical technique. The Model, as it stands, is also fully operational. However, future modification is envisioned to increase the problem size it can accommodate.

We await your response and comment.

Sincerely,

Keith E. Bushnell

Keith E. Bushnell
Engineer of Transportation Survey
and Analysis Section

PREFACE

This is the sixth in a series of reports dealing with the development of a Land Use - Transportation Planning System for the State of Michigan. The System, when completed, is to comprise an extensive set of both existing and new models to be used in all phases of statewide planning, including economic and population forecasting, future traffic and land use simulation and combined land use - transportation system design. Each model of the system may be used either in conjunction with others or separately as an independent program.

One such model just completed is the Highway Location Dynamics Model described in this report. Its function is to generate optimal highway corridor location(s) according to a specified set of planning goals. The generated corridor(s) may then be incorporated into the existing statewide network via another program for additional impact analysis. This allows the planner to select the optimum corridor, update the highway network and complete traffic forecasts all in a single operation.

The previous reports in the series are:

Volume I	Objectives and Work Program
Volume IA	Workshop Topic Summaries
Volume IB	Traffic Forecasting Applications Single and Multiple Corridor Travel Analysis
Volume IC	Model Application Turnbacks
Volume II	Development of network Models

Volume	III	Multi - level Highway Network Generator
Volume	IIIA	Semi-Automation Network Generation using a "Digitizer"
Volume	IV	Total Model Calibration-547 Zone Process
Volume	VA	Travel Model Development Reformation-Trip Data Bank Preparation
Volume	VB	Socio-Economic Data Bank Development

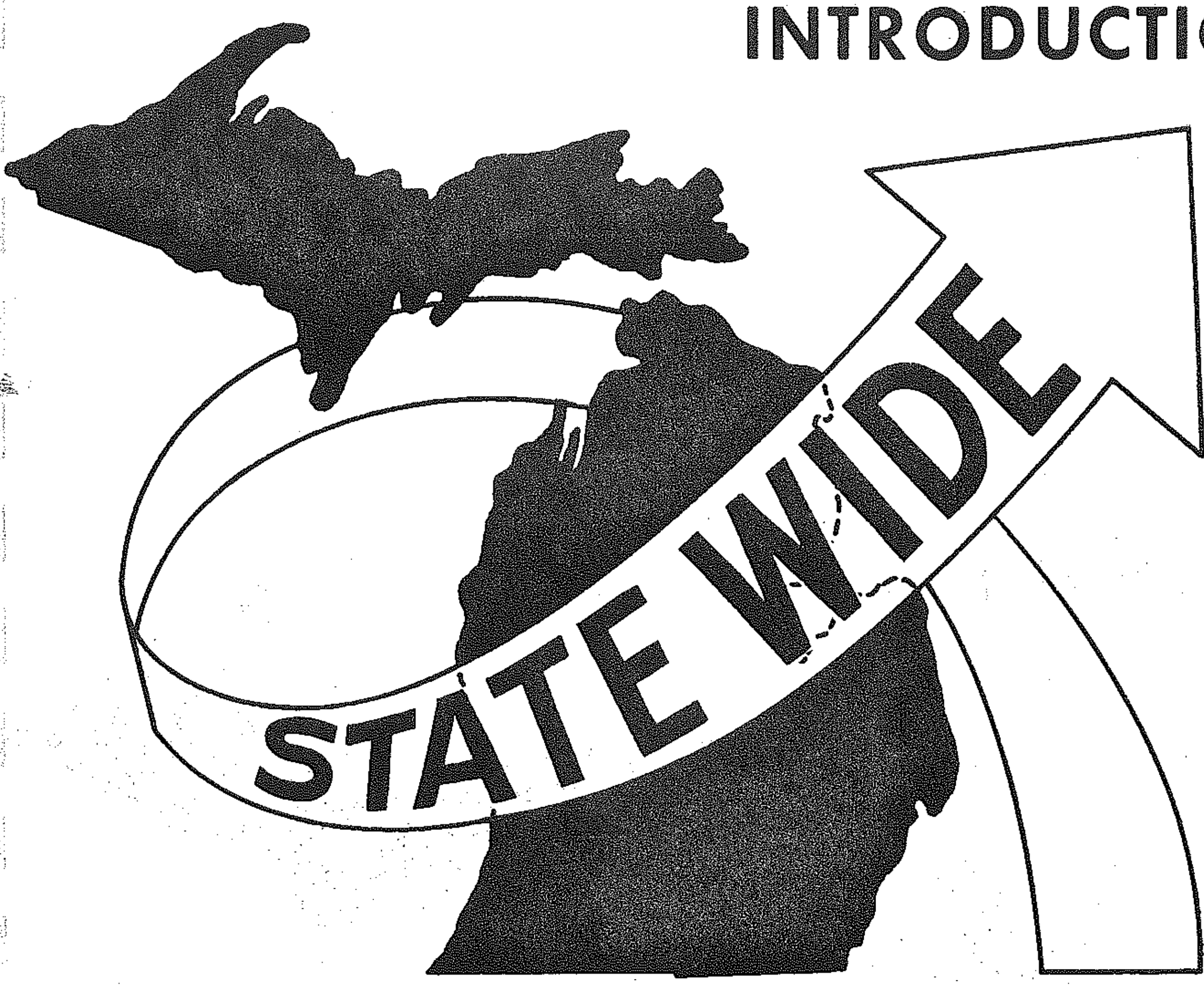
ROUTE LOCATION DYNAMICS

By

GEORGE S. LIU

TABLE OF CONTENTS

INTRODUCTION



INTRODUCTION

Highway Location and Planning

There is a growing awareness among many sectors today of the important role transportation systems, expecially major highways, play in shaping our total environment. A highway is, first of all, the only physical artifact large enough to function as the structure of a region. Its durability makes it, once built, a permanent and unalterable feature of the landscape. Furthermore, it exerts a far reaching influence not only on the natural environment but on the land use and population distribution pattern of a large area comprising many communities, towns and cities. Not surprisingly, the highway is no longer considered as an engineering project answering transportation needs, but as an organizing and generating force that can be either beneficial or detrimental, depending entirely on how thoughtfully and imaginatively its route is designed in a total planning context.

The Limitations of Evaluation Process

This awareness has prompted both the government and the public to require that any major highway construction, once its desirability is established, be preceded by:

(1) The definition of goals and their order of priority, both regional and subregional.

(2) The determination of various feasible alternative routes.

(3) The evaluation and comparison of alternative routes according to how each satisfies the stated goals, so that the best one can be chosen.

Much work has been done in regard to the above process.

Governments of various levels have defined many planning goals and set up guidelines for evaluation. Action plans are devised to involve public participation to help define and resolve conflicting goals. There is also a continuing research effort by both public and private organization to study the environmental effects of highway. The process itself, however, is seriously limited.

In any sizable area, the number of feasible routes that may join two points is, for all practical purposes, inexhaustible. Lacking any better means, the process merely chooses a few alternatives for evaluation, somewhat randomly or intuitively. However, the best route out of ten or a hundred alternatives is obviously not necessarily the same as the best route out of all alternatives. It can happen only if the chosen alternatives are themselves the best ones, which is most unlikely. The process therefore will not in general yield the best route sought by planner according to a set of goals.

Furthermore, planning goals are not only generally difficult to define, but may vary with different subregions or segments of population. Planners too have different design philosophies which are almost always implied but rarely stated. The largely intuitive and manual process does not allow a wide variety of solutions to be readily generated for comparison based on different goals or philosophies. As a result, solutions all too often reflect only local interests or partial views of the planner.

The Need for a New Methodology

We therefore need a new process which can:

(1) Logically determine the best one or several alternatives out of all feasible alternatives, based on a set of goals, and

(2) Readily generate a wide variety of alternatives for comparison based on different sets of goals.

Such a process will have two uses:

(1) As a planning tool, it puts both goal formulation and method of solution on a totally quantified basis. Philosophical opinions aside, the insight gained from carrying out such a process as well as both the quality and variety of solutions it produces cannot but be helpful. It should at the least supplement, and if used with care and understanding may totally replace, the conventional evaluation process.

(2) As a tool for public participation, it provides a quick translation of any goal formulation to non-arbitrary solutions. Thus the planner can involve the public in an active planning process to define and resolve conflicting goals by comparing and discussing the solutions implied by these goals. In a democracy, such participation is obviously not only desirable but essential for success.

It remains to be seen whether such a process is feasible. The following Methodology is therefore developed.

METHODOLOGY

METHODOLOGY

The Methodology is based on mathematical optimization. We may state the route location problem as follows:

To find the route between two points via a connecting network such that the route value, i.e. the sum of link values, is maximum, where link values are values associated with the links reflecting the planning goals.

The description of the Methodology is therefore divided into three parts, following their operational sequence:

(1) Problem Definition and Data Collection

(2) Link Value Computation

(3) Route Location Optimization

Problem Definition and Data Collection

The starting point of the Methodology is to define the study area, the end points for any route, and the transportation and environmental planning goals. Data pertaining to the characteristics of the area that are relevant to the environmental goals can then be collected accordingly.

A. Study area and End Points

The end points for a proposed highway are usually given. The study area in which the end points and all feasible routes lie however must be defined by the planner.

A grid of appropriately sized square or rectangular cells are then superimposed onto the study area. End points and intermediate nodes of a route are represented by the centers of the cells. The boundary of the area may be irregular but should be convex. (Fig. 1).

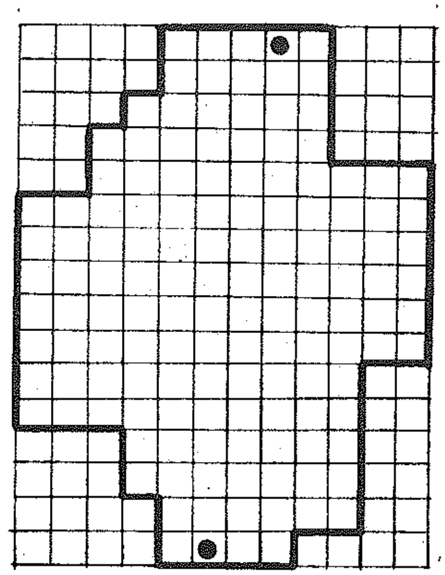


FIGURE 1

The irregular shape allows any obviously unfeasible area, such as rough terrain, dense urban centers, etc. to be excluded, thus minimizing the data collection effort.

B. Goal Formulation

Goals for route location should be formulated by the planner to reflect both public and private interests in the region. There are two major considerations for any route:

The consideration of a route as an efficient means of transportation implies that it should be as short or as direct as possible in terms of the total distance of the route. On the other hand, the consideration of a route as a positive influence on the environment means that the transportation goal must be balanced by a set of environmental goals. These goals may be classified as follows:

(1) Natural Environmental Goals

- Least pollution of water system
- Least disruption of forests and natural areas
- Best conformity with topography
- Best utilization of soil conditions

(2) Cultural Environmental Goals

- Best coordination with existing and planned land uses.
- Least disruption of existing population centers
- Best coordination with existing and planned communication systems.

The relative importance or priorities of all planning goals are to be determined and subject to change. The goal formulation process therefore involve the following:

(1) The choice of a set of environmental goals

(2) The specification of weights for the various environmental goals corresponding to their relative importance, and

(3) The specification of weights for the transportation goal and the composite environmental goal corresponding to the relative importance between the two major goals.

C. Data Collection

Corresponding to environmental goals, data for each cell may be classified into Natural and Cultural characteristics each consisting of several subgroups:

(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

The above listing aims to provide a framework for data collection, and may be augmented or simplified depending on data availability, detail level desired and other considerations. For long term purposes, however, it may be advisable to make the collection process as part of a larger data bank development, so that the data collected may be used for other planning activities. In that case, both cell size and types and detail level of data should be considered with the view of maximum flexibility and ease for future expansion.

Link Value Computation

The values associated with all feasible links within the study area must reflect, besides transportation, the environmental goals as specified by the planner. A corridor width delimiting the highway influence on environment must therefore be assumed. The computation procedure is as follows:

A. Cell Values

For each cell, compute:

(1) Cell Environmental Values

Cell environmental values, each corresponding to a cell characteristic, e.g., topography, population distribution etc., are scaled between -100 and +100 with -100 representing the greatest disruption, or the least cell environmental value, and +100 representing the greatest compatibility, or the highest cell environmental value.

(2) Composite Cell Environmental Value

A composite cell environmental value is computed as the weighted average of various cell environmental values above. The weights used correspond to the relative importance of the environmental goals.

B. Link Values

For each feasible link, compute:

(1) Link Environmental Value

A highway link connects the center of a cell in a row with that of another cell in a contiguous row (Fig. 2). Cells affected by the link corridor are shown shaded in the figure. The link

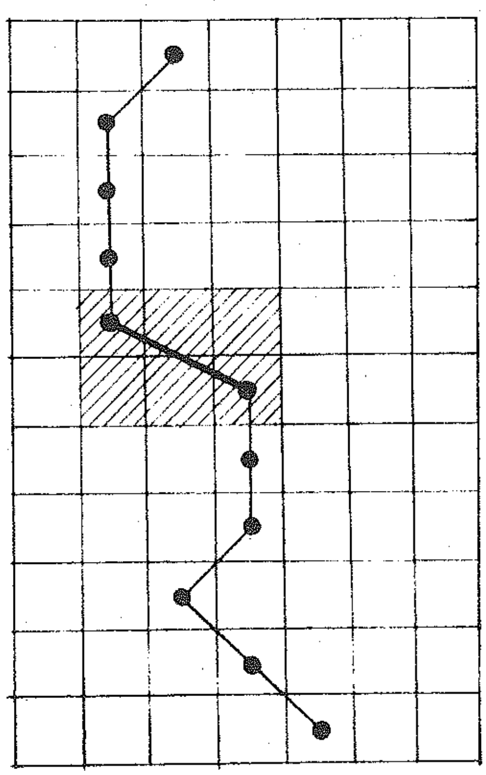


FIGURE 2

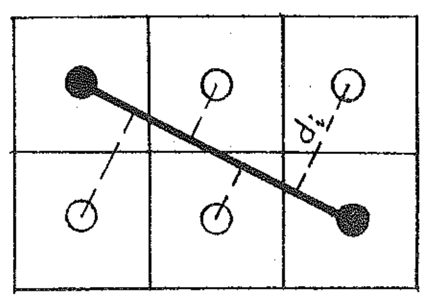


FIGURE 3

environmental value is the weighted sum of the composite environmental values of the cells. The weights f_i are computed as follows:

$$f_i = e^{-\alpha d_i}$$

where d_i is the distance from the center of an effected cell i to the link (Fig. 3), and α is a parameter to be determined or given. The link environmental value thus computed is scaled between -100 and +100.

(2) <u>Link Distance Value</u>

Straight line link distance is computed and scaled between -100 and 0, with -100 representing the longest distance and 0 zero distance.

(3) <u>Composite Link Value</u>

A composite link value, or simply, link value is computed as the weighted average of the link environmental value and the link distance value. The weights used correspond to the relative importance between the environmental goal and the transportation goal.

Route Location Optimization

After all link values are computed, mathematical techniques may be employed to find the optimal route(s). The following briefly compares the dynamic programming technique with the shortest route technique. Also discussed is the generation of alternative solutions by allowing value tolerances.

A. Optimization Techniques

The choice of an optimization technique largely depends on the assumption of a network which defines all the feasible routes.

Let the centers of the square or rectangular cells in a study area be represented by a set of equally spaced nodes in a place. Consider the following two networks:

(1) A network which oonsists of only vertical, horizontal and diagonal links. All links are two-directional, i.e., undirected (Fig. 4).

(2) A network which consists of links that connect one node in a row to any node in the next row in the direction of destination. All links are therefore one-directional, i.e., directed (Fig. 5).

The problem is to find the optimal route between two points via either one of the above networks.

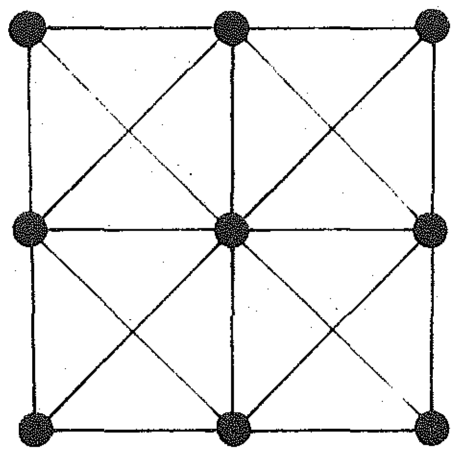


FIGURE 4

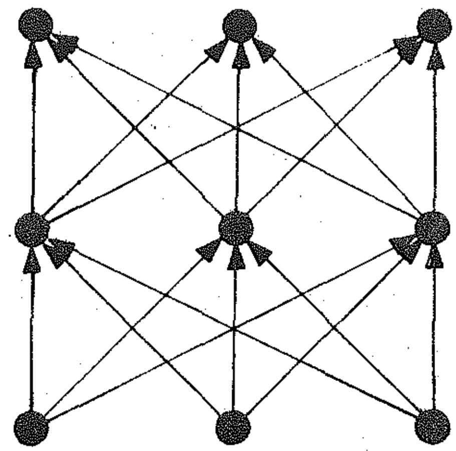


FIGURE 5

If the first network is assumed, then the problem is the shortest route problem in graph theory. If the second is assumed, then it is a dynamic programming problem. Both can be readily solved by standard techniques. We shall not go into the details here. A comparison of the two networks, however, shows the following:

(1) The first network allows more directional freedom, i.e., links may be directed away from the destination. Thus a feasible route may involve adverse travel or overshooting. In actual practice, these are relatively special and infrequent situations. The "destination directed" rule for the second network therefore is not very restrictive.

(2) On the other hand, the first network allows less freedom for link orientations, i.e., links can be

oriented only vertically, horizontally or diagonally. Links of other orientations which may be represented by a single link of the second network must be approximated by several links of the first network. The shortest route technique is therefore likely to be both slower and less accurate. To achieve more accuracy in the above approximation, smaller cell size may be used. However, this will besides making the process even slower require more data collection effort.

Dynamic programming technique is therefore adopted.

B. Alternative Solutions

Generally, unless by coincidence, only one optimal route is generated under a set of goals and their relative weights. With a slight change of data or weights, it is possible that an entirely different solution is generated. This sensitivity or instability cannot be justified by the nature and precision level of our problem. Means therefore must be available to:

(1) Test the stability of a solution, and

(2) Generate "near optimum" solutions if the solution is unstable.

To accomplish the above, we allow some tolerance, specified at the discretion of the planner, for the computed link values. Two link values are considered to be equal if the magnitude of their difference is less than the specified tolerance. Thus for the same set of weights, several alternative solutions, all "optimal", may be generated for evaluation. The number of alternatives will depend on the magnitude of tolerance allowed.

For a given set of environmental goals, alternative solutions therefore may be generated by varying any or all of the following:

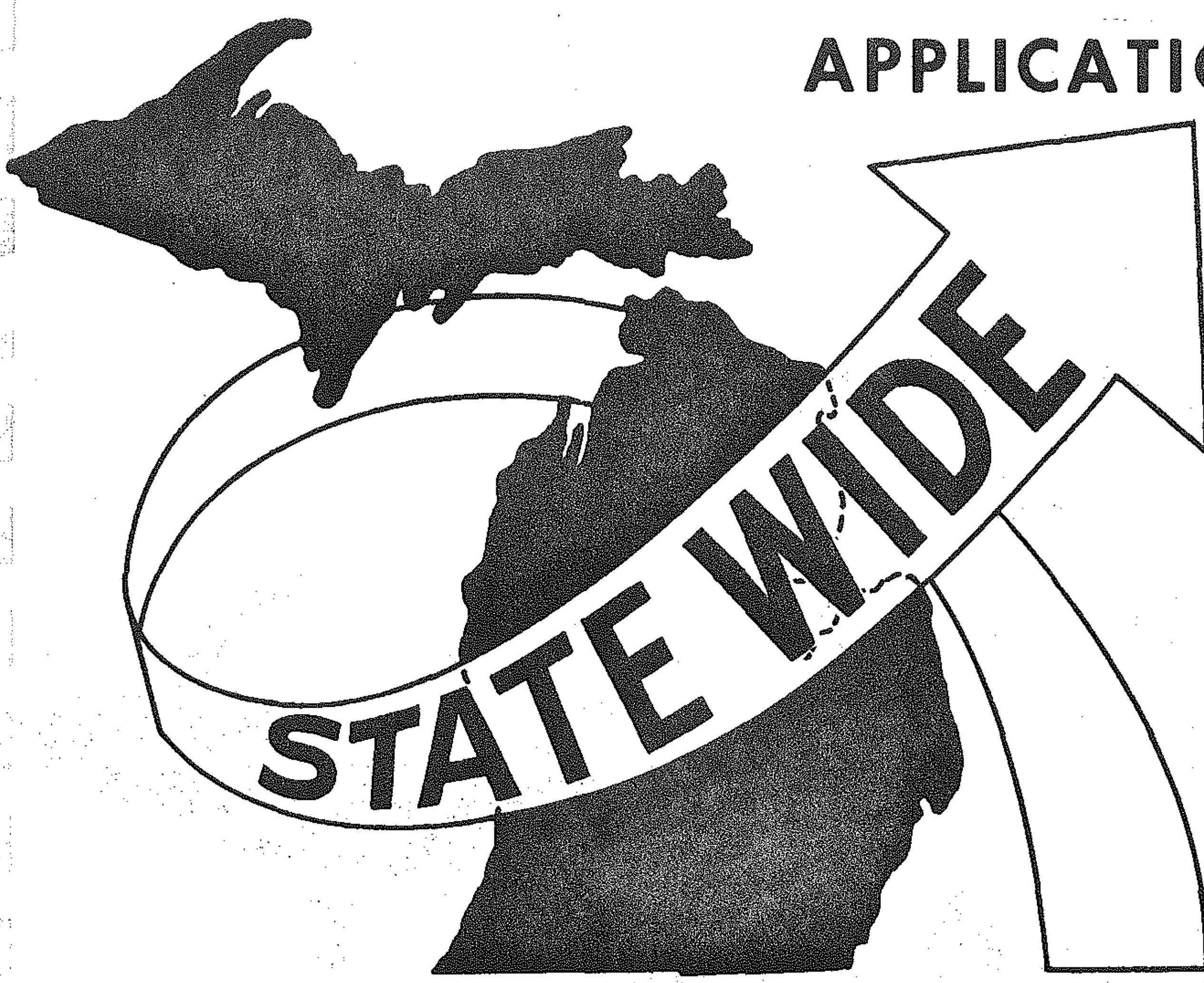
(1) The relative weights for the individual environmental goals

(2) The relative weights for the transportation and the composite environmental goal

(3) Parameter α (see P. 2-7) and

(4) Tolerance allowed for the computed link values.

MODEL TESTING AND APPLICATION



MODEL TESTING AND APPLICATION

A computer model was developed based on the Methodology described above. With given study area boundary, end points and cell environmental values as input, the model will for user specified goals and their relative weights as well as allowable tolerance, generate a set of alternative optimal routes for evaluation.

Test Examples

The following test examples (Figs. 6-12) illustrate to some extent the workings of the model. No realism is intended for the simple inputs:

(1) Study area boundary and end points: as shown

(2) Number of environmental goals: two

- Compatibility with topography
- Coordination with existing land use

(3) Cell environmental values

The study area consists of three types of cells with environmental values as follows:

Type 1: shown shaded

+100 for topographic considerations

0 for land use considerations

Type 2: shown cross-hatched

+100 for land use considerations

0 for topographic considerations

Type 3: 0 for both considerations

(4) Tolerance allowed: 0

Seven cases were run, using different weights for the two environmental goals and distance. One optimal route is generated for each case.

Case 1 weighs the two environmental goals against each other, with no weight given to distance. It shows a route widely zigzagging between the cells of desirable topography and the cells of compatible land use. The unrealistic shape is due both to the simplistic environmental values and the fact that no importance is attached to distance. Case 2, with no weight given to either topography or distance, the route expectedly follows the cells of compatible land use.

The last five cases weigh topographic consideration against distance, with no weight given to land use considerations. Cases 3, 4, and 5 show that as distance is given more weight for each successive run, the route starts to straighten out and depart from the cells of desirable topography. Cases 6 and 7, with one of the end points redefined, show the same effect with

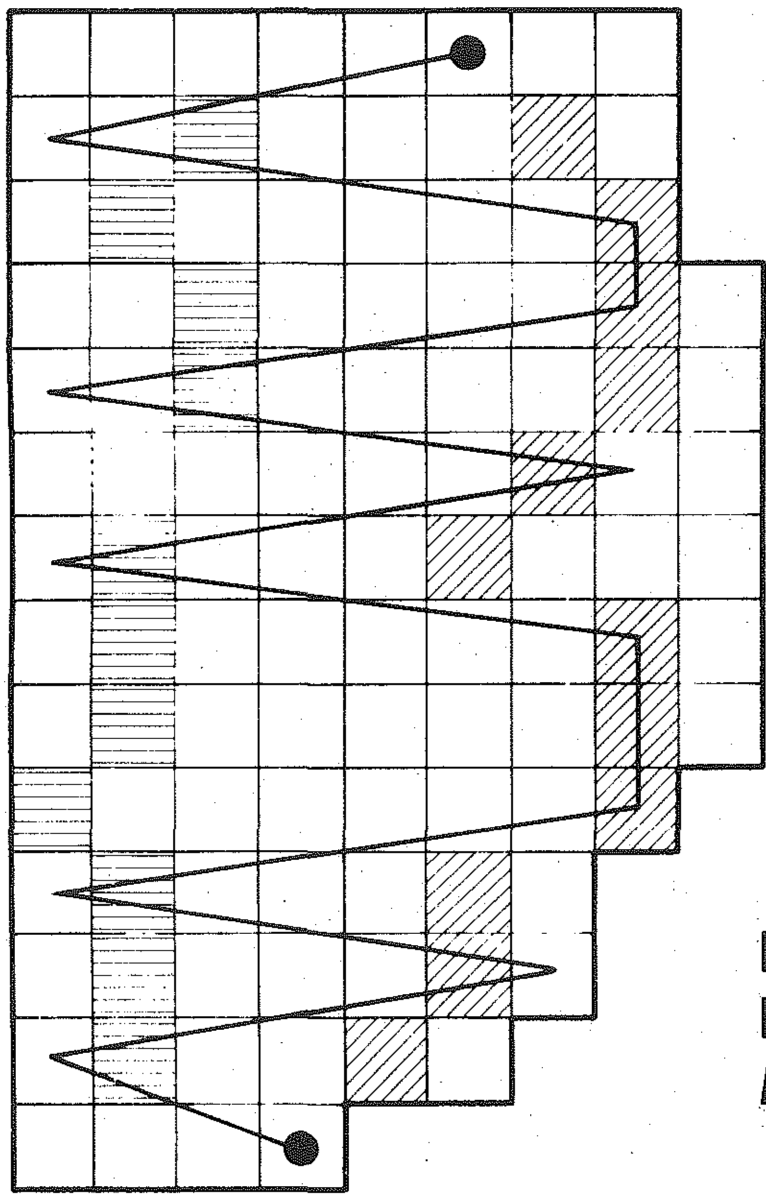
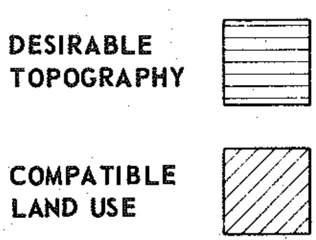


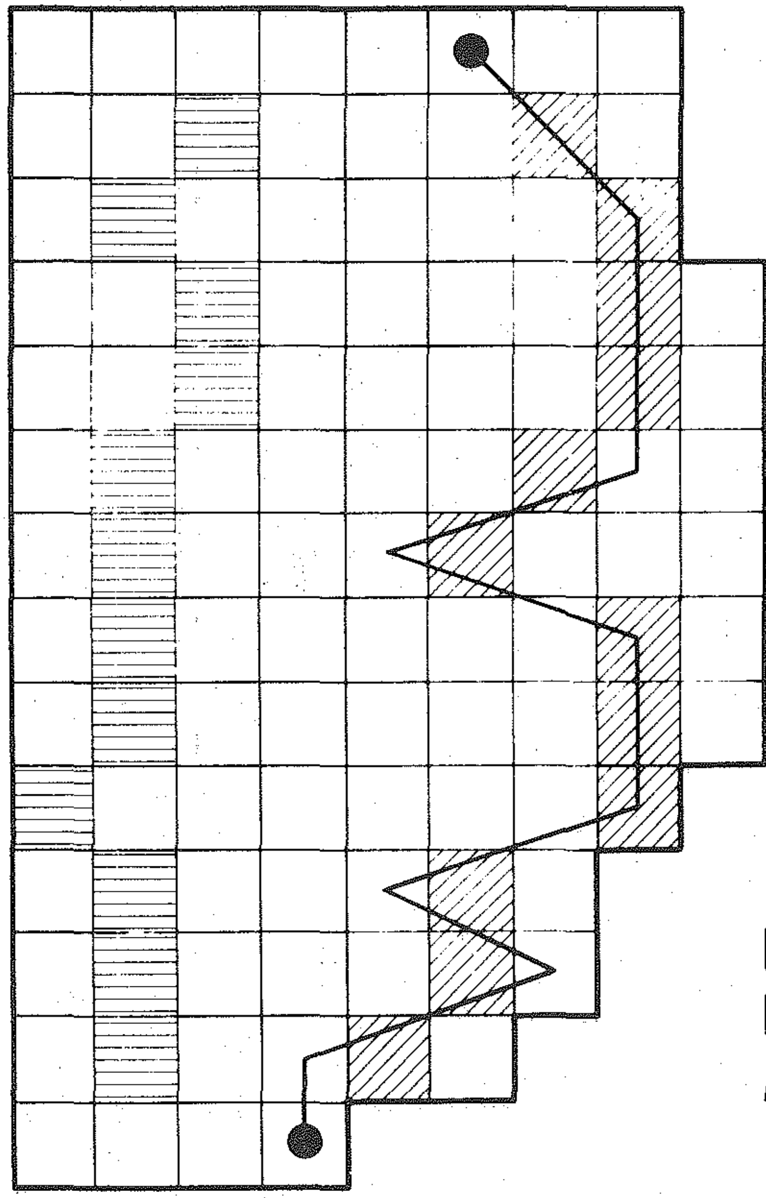
FIGURE 6



ROUTE LOCATION MODEL TEST

CASE 1

	WEIGHT
ENVIRON GOALS	
TOPOGRAPHY	1
LAND USE	3
COMPOSITE ENVIR. GOAL	1
DISTANCE	0



ROUTE LOCATION MODEL TEST

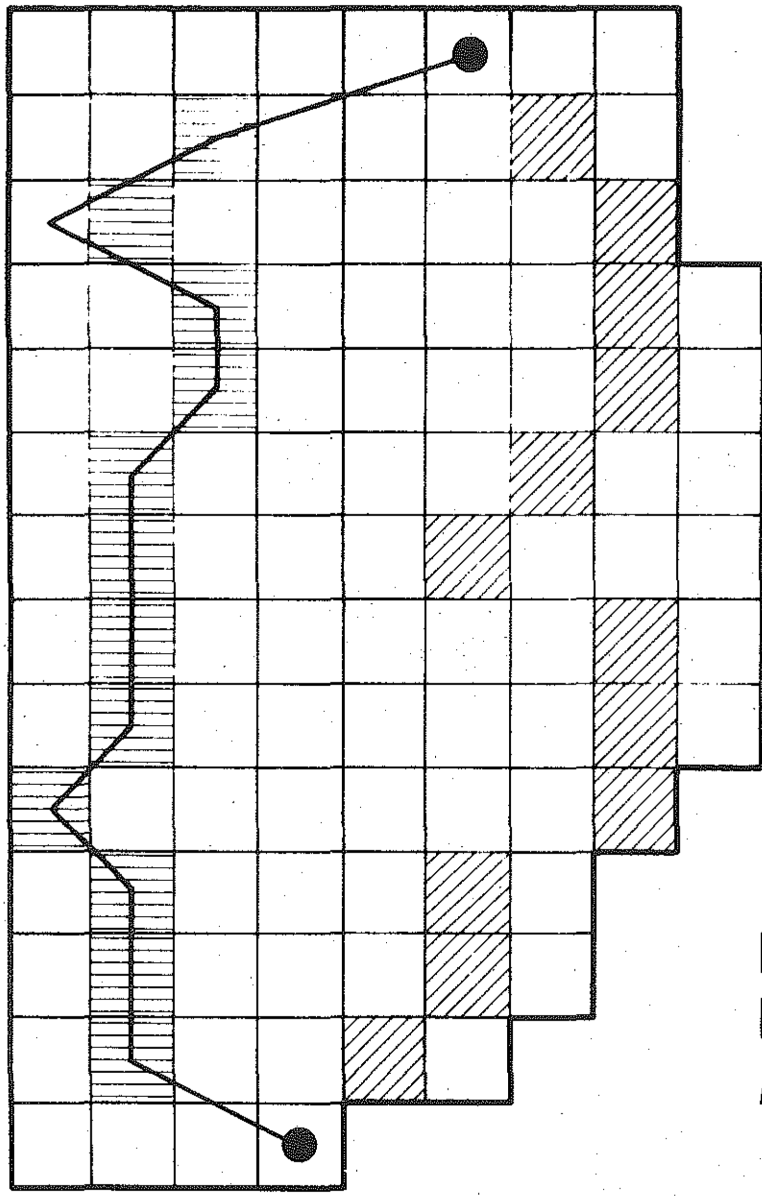
CASE 2

FIGURE 7

	WEIGHT
ENVIRON GOALS	
TOPOGRAPHY	0
LAND USE	1
COMPOSITE ENVIR. GOAL	1
DISTANCE	0

DESIRABLE TOPOGRAPHY

COMPATIBLE LAND USE



ROUTE LOCATION MODEL TEST

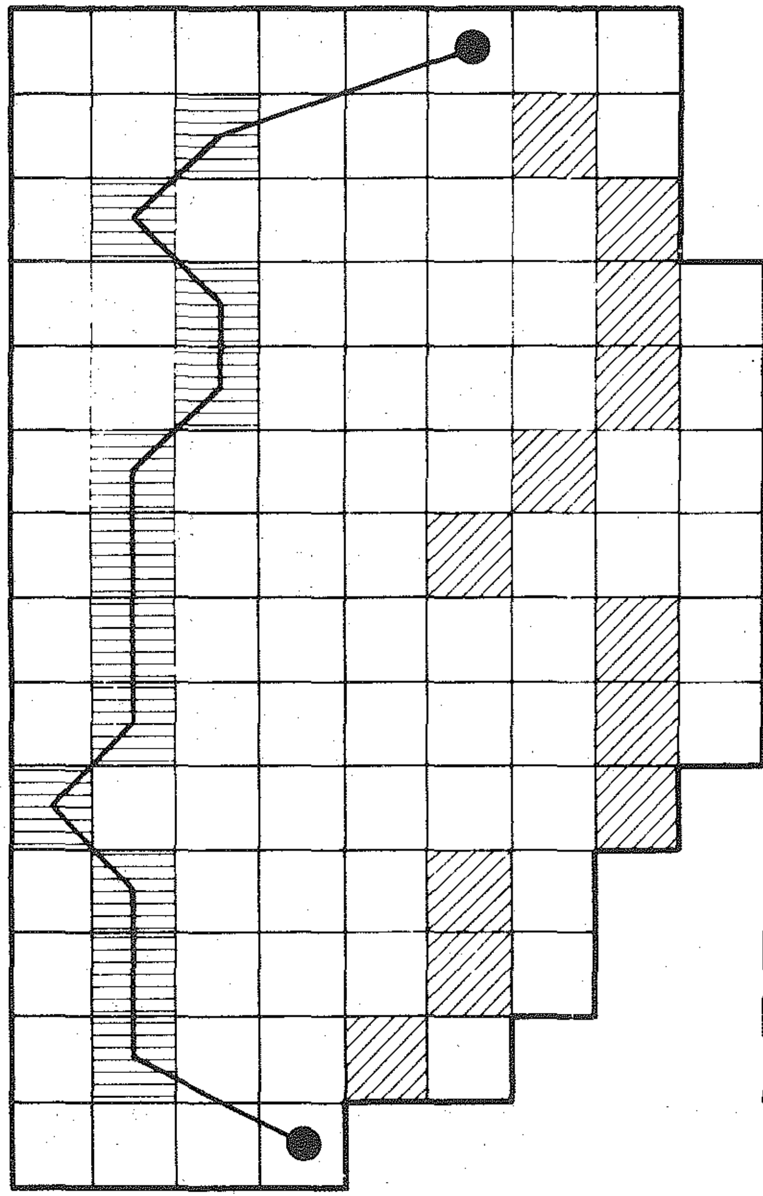
CASE 3

FIGURE 8

	WEIGHT
ENVIRON GOALS	
TOPOGRAPHY	1
LAND USE	0
COMPOSITE ENVIR. GOAL	1
DISTANCE	1

DESIRABLE TOPOGRAPHY

COMPATIBLE LAND USE



ROUTE LOCATION MODEL TEST

CASE 4

	WEIGHT
ENVIRON GOALS	
TOPOGRAPHY	1
LAND USE	0
COMPOSITE ENVIR. GOAL	1
DISTANCE	2

FIGURE 9

DESIRABLE TOPOGRAPHY

COMPATIBLE LAND USE

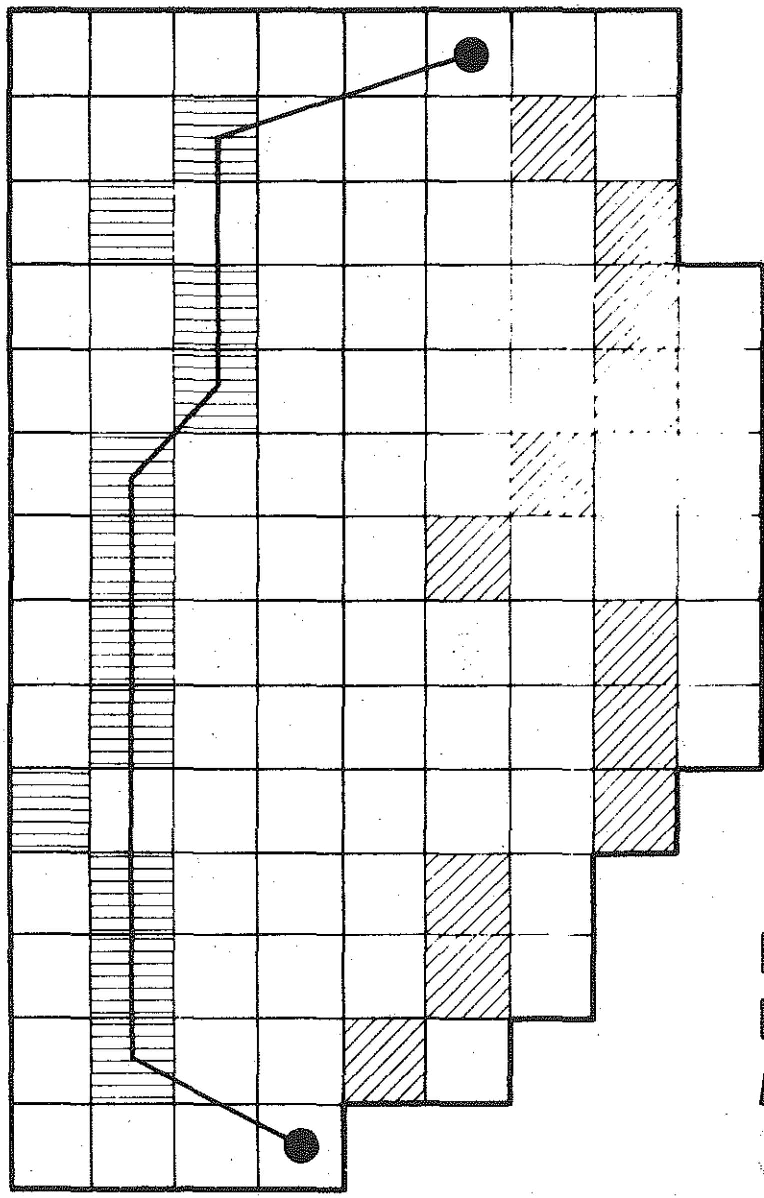
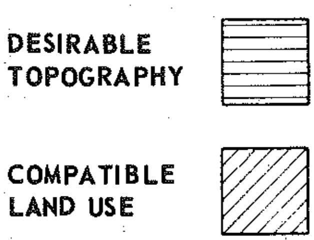


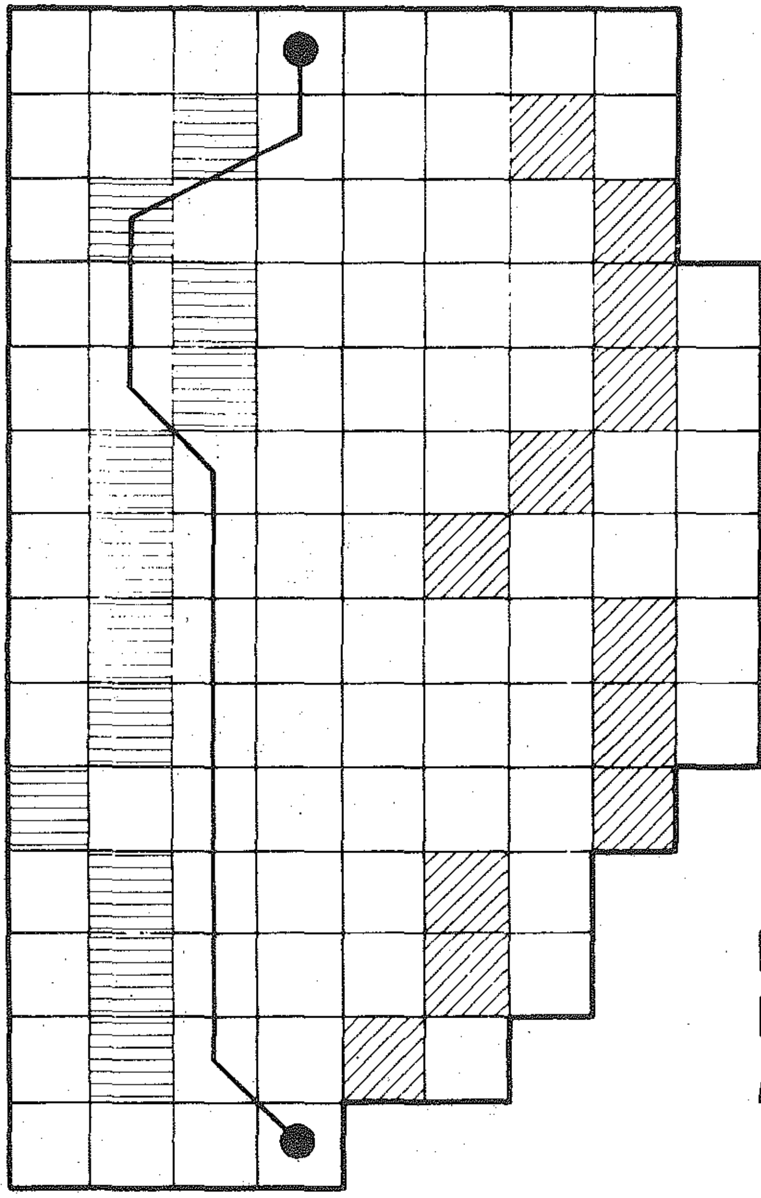
FIGURE 10



ROUTE LOCATION MODEL TEST

CASE 5

	WEIGHT
ENVIRON GOALS	
TOPOGRAPHY	1
LAND USE	0
COMPOSITE ENVIR. GOAL	1
DISTANCE	4



ROUTE LOCATION MODEL TEST

CASE 6

FIGURE 11

		WEIGHT
ENVIRON GOALS		
	TOPOGRAPHY	1
	LAND USE	0
COMPOSITE ENVIR. GOAL		1.5
DISTANCE		2.0

DESIRABLE TOPOGRAPHY 

COMPATIBLE LAND USE 

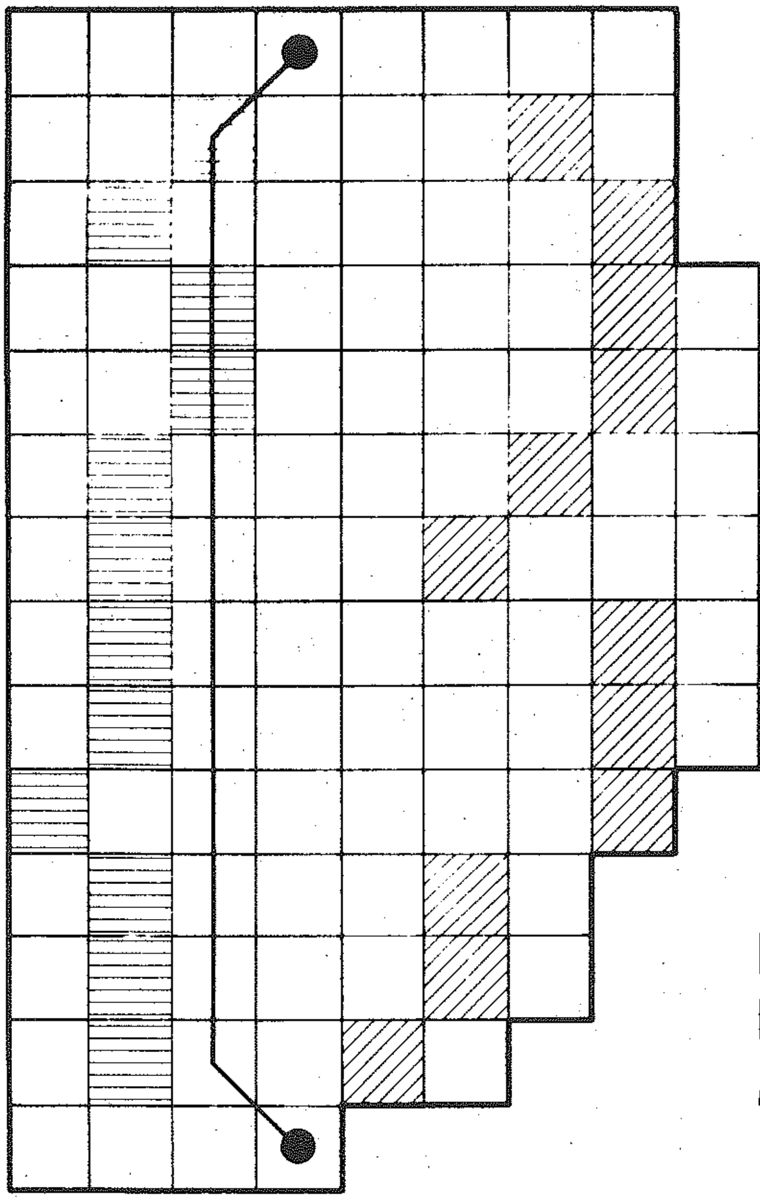


FIGURE 12

DESIRABLE TOPOGRAPHY	(horizontal hatching)
COMPATIBLE LAND USE	(diagonal hatching)

ROUTE LOCATION MODEL TEST

CASE 7

	WEIGHT
ENVIRON GOALS	
TOPOGRAPHY	1
LAND USE	0
COMPOSITE ENVIR. GOAL	1
DISTANCE	2

a more pronounced degree. We thus observe that, if necessary, distance may be weighted to prevent excessive zigzagging of route.

With tolerance given some positive values, more than one alternative route may be generated for each of the seven cases.

The Use of ERTS Data

It would be both interesting and instructive to see how the model may be applied in a real-world situation.

Perhaps the main difficulty in such applicaiton is the great amount of work required to collect pertinent land-use data. A significant portion of the information is recorded photographically by the Earth Resources Technology Satallite (ERTS) and then interpreted by pattern recognition techniques. One research laboratory is able to identify nine possible land types for each pixel at 1.10 acres as follows*:

1. Urban Area
2. Open Area
3. Hardwood Forest
4. Water
5. Conifer Forest (Jack Pine)
6. Marsh Land
7. Conifer Forest (White Pine)
8. Hardwood Forest (Managed)
9. Not Classified

---

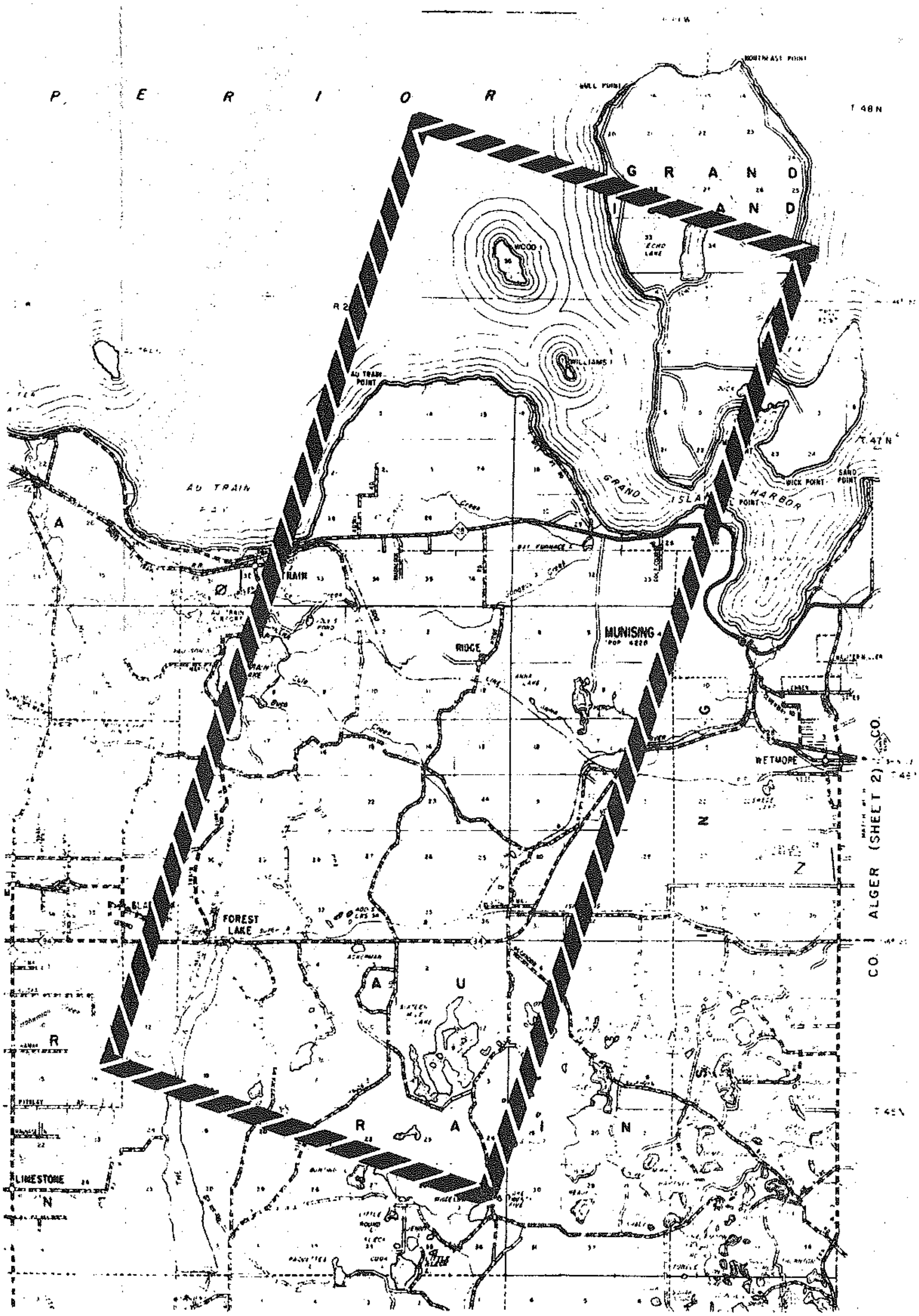
* Environmental Research Institute of Michigan, "Land Use Mapping for the State of Michigan", Final Report.

It is obvious the classification above does not provide a complete data base for general application. For such application we need also socio-economic data such as population density and land uses--commercial, residential, industrial, etc., as well as land characteristics such as topography and soil types. These must be obtained by other means. However, for land areas that are largely rural, open and flat, the use of ERTS-collected data is not only adequate, but provides wide geographical coverage and continues updating capability.

A Real-World Example

Let it be proposed that a highway be built in the Upper Peninsula of Michigan near the Munising Area (see approximate location on map). Since the area is rural, open and flat, ERTS-collected data may be used adequately.

The area is divided into 25 x 13 rectangular cells each consisting of 16 x 8 pixels at 1.10 acres. The cell area is thus 16 x 8 x 1.10 or 140.8 acres. Within each cell the area percentages of the nine different land types may be easily obtained. These percentages are used as surrogates for cell values (P. 2-5) or "location determinents". The composite cell value or "composite location determinant" of each cell is then computed as the weighted average of the percentages. The weights given may be either positive or negative and reflect the relative desirabilities or non-desirabilities for a highway to traverse the corresponding land types.



P E R I O R
GRAND ISLAND
NORTHEAST POINT
T 48 N
AU TRAIN POINT
AU TRAIN BAY
GRAND ISLAND HARBOR
T 47 N
MUNISING
RIDGE
WETMORE
FOREST LAKE
LIMESTONE
ALGER (SHEET 2) CO.

The two following illustrative runs are made using same weighting for location determinants. Run 1 puts more importance to distance than Run 2. It therefore generates a slightly shorter route compared to those from Run 2. One alternative is given by Run 1 with zero tolerance, while ten are given by Run 2 with 0.5 tolerance. It is interesting to observe that all alternatives from the two runs correspond well to what intuitively would be "good" routes.

RUN 1

HIGHWAY LOCATION DYNAMICS

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

STUDY AREA SIZE   25 CELLS BY 13 CELLS
CELL SIZE   16 BY 8 ERTS POINTS AT 1.10 ACRES
NUMBER OF LOCATION DETERMINANTS 9

LOCATION DETERMINANT	WEIGHT
1 URBAN AREA	20.0
2 OPEN AREA	5.0
3 HARDWOOD FOREST	-5.0
4 WATER	-10.0
5 CONIFER FOREST JACK PINE	-5.0
6 MARSH LAND	-2.0
7 CONIFER FOREST WHITE PINE	-5.0
8 HARDWOOD FOREST MANAGED	-5.0
9 NOT CLASSIFIED	0.0

LINK VALUE COMPONENT	WEIGHT
LOCATION DETERMINANTS	4.0
LINK DISTANCE	10.0

ALPHA	0.1
TOLERANCE	0.0

% 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	12	16	12	2	0	8
34	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

% OPEN 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	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	3	0	9	7	0	0
0	0	0	0	1	0	9	2	0	1	1	1	1
0	0	0	0	4	0	13	5	0	0	0	0	0
1	0	0	0	0	0	0	0	1	0	1	0	0
0	0	0	0	0	0	4	13	0	0	2	0	0
0	0	0	0	0	0	0	0	0	2	0	0	0
0	0	0	0	0	0	0	0	0	1	0	0	2
0	0	0	0	0	0	2	0	0	1	4	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	3	0	2	0
0	0	0	0	0	0	1	1	0	4	0	0	3
12	0	0	0	0	0	0	0	2	1	0	0	0
12	5	0	0	0	0	0	0	0	0	0	0	0
5	10	0	0	0	0	0	0	0	0	0	0	0
2	1	0	0	0	0	4	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	3	2	1	0	0	1	0	0	0	0	0	0
1	34	32	0	7	0	0	0	0	0	0	0	0

% HARDWOOD FOREST

0	0	0	0	0	0	0	0	3	0	0	6	9
0	0	0	0	0	0	0	0	2	1	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	0	0	2	0
0	0	0	0	2	0	0	0	0	0	0	7	3
0	0	3	7	10	0	0	2	0	0	0	2	2
0	0	42	23	8	4	2	2	2	3	0	0	2
0	1	45	12	12	21	33	15	29	27	8	6	5
0	9	48	20	45	47	59	36	55	25	24	17	8
11	23	40	41	43	70	49	48	53	16	29	20	27
13	20	8	52	65	30	37	21	59	67	35	57	20
3	0	1	55	56	32	14	37	38	24	30	45	18
1	0	9	52	46	25	56	97	95	77	83	67	36
8	24	23	46	26	66	47	67	73	84	84	61	37
44	30	51	11	37	78	70	72	69	85	52	78	45
88	52	39	37	30	62	49	79	82	80	71	47	12
70	60	55	61	52	15	74	60	50	51	45	45	21
71	56	41	70	55	26	51	41	23	12	9	14	5
36	83	43	55	14	45	46	9	16	32	49	64	15
15	57	30	58	30	49	73	26	66	25	9	66	29
11	20	68	53	45	39	34	73	83	27	27	76	30
58	45	47	45	47	67	80	90	63	25	41	59	12
80	91	27	26	12	13	23	44	24	25	25	42	27
73	60	20	48	3	10	39	33	22	25	10	13	10
54	11	16	8	9	32	51	24	20	14	7	20	9

% 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	12	43	31	2
100	38	0	0	0	0	0	0	0	2	0	0	0
59	12	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	12	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	37	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	12	0	0	0	0	11	7	0	2	12
0	0	15	73	5	0	0	0	2	0	38	1	0

% CONIFER FOREST JACK PINE

0	0	0	0	0	0	0	12	0	0	18	23	0
0	0	0	0	8	2	0	0	3	5	14	12	9
0	0	0	0	6	7	0	0	0	4	23	5	0
0	0	0	0	0	0	0	0	0	0	27	12	0
0	0	0	0	2	5	2	6	0	0	7	10	0
0	2	5	9	9	5	9	4	0	0	2	20	5
0	12	9	4	16	19	12	41	16	1	0	3	5
0	16	9	33	19	20	20	36	27	4	5	16	12
0	13	7	26	5	0	2	16	20	33	17	20	5
12	21	7	16	8	2	2	12	11	7	22	12	2
27	20	37	10	2	16	18	18	4	2	9	2	5
11	16	47	9	20	16	44	14	17	34	11	18	8
1	13	66	20	21	28	15	0	1	2	5	10	5
12	13	35	20	37	18	29	5	9	0	0	20	4
23	25	16	34	34	5	2	16	14	0	2	4	2
2	29	19	26	50	5	13	4	1	5	5	2	0
18	26	21	5	26	49	6	6	5	2	5	1	2
2	23	35	7	30	39	14	2	4	9	2	1	0
0	3	26	16	26	20	8	12	9	8	4	2	10
10	2	30	8	29	16	7	5	3	15	20	8	8
28	6	10	6	23	15	30	6	1	13	9	1	3
14	10	19	23	32	10	1	0	1	17	10	3	5
3	2	14	24	34	29	1	2	17	15	27	17	5
6	2	5	4	8	6	3	13	12	15	20	40	12
1	0	0	9	4	2	12	44	20	38	17	40	16

% MARSH LAND

0	0	0	0	0	0	0	9	0	0	30	2	0
0	0	0	0	12	0	0	0	9	4	34	4	4
0	0	0	0	9	2	0	0	1	5	14	0	0
0	0	0	0	0	0	0	1	0	0	21	0	0
0	0	0	0	1	4	0	3	0	0	29	7	0
0	0	12	3	7	5	9	2	0	0	11	34	2
0	16	5	3	2	18	7	32	13	0	0	0	0
0	21	2	16	1	2	3	17	4	0	6	31	19
0	5	0	0	0	0	0	2	0	1	2	9	2
2	8	2	1	0	3	0	0	1	0	2	0	0
2	2	4	2	2	5	26	32	1	0	2	0	0
4	26	23	0	3	8	9	9	32	5	7	2	1
0	30	5	2	6	38	18	0	0	0	0	0	0
3	2	1	2	13	6	12	6	0	0	0	0	0
3	2	0	2	3	0	0	4	0	0	2	0	0
0	0	2	1	3	1	4	0	0	0	1	0	0
2	1	0	1	0	10	2	3	3	0	0	1	1
0	0	0	0	3	2	3	5	6	17	16	2	3
0	0	0	0	12	0	2	12	12	12	3	1	0
10	0	0	4	5	1	1	14	0	0	3	1	2
22	0	0	10	9	3	9	1	0	0	0	0	0
2	5	0	6	5	0	0	0	0	0	0	0	0
0	0	0	6	20	14	0	0	2	0	10	3	1
0	0	0	1	17	0	0	0	1	3	10	18	3
0	0	0	2	7	0	0	0	2	4	11	20	6

% CONIFER FOREST WHITE PINE

0	0	0	0	0	0	0	25	97	100	16	68	41
0	0	0	0	6	1	0	0	60	90	16	84	33
0	0	0	0	6	9	0	0	0	6	59	95	50
0	0	0	0	0	0	0	0	0	0	32	86	50
0	0	0	0	4	6	2	0	0	0	8	76	47
0	1	37	67	73	89	80	4	0	0	3	41	42
0	18	42	70	75	59	80	23	36	2	0	0	1
0	36	42	39	69	57	34	20	37	19	3	8	9
0	34	34	45	41	42	15	39	25	37	52	52	30
9	31	48	39	36	26	23	23	35	77	45	68	22
37	56	52	35	30	50	18	28	36	27	47	38	25
56	33	30	34	20	44	27	10	12	26	29	18	21
0	12	21	25	25	9	9	1	1	3	8	20	7
21	58	41	31	23	5	8	2	2	0	1	12	2
25	39	33	54	25	9	13	5	11	2	13	4	0
9	18	39	37	16	28	32	14	4	12	17	34	2
9	5	24	31	22	26	16	24	40	16	17	11	19
10	20	23	23	12	29	18	33	47	45	70	83	30
1	4	16	29	48	35	43	65	48	39	43	31	17
9	5	7	29	35	34	19	55	30	38	15	23	11
12	4	7	30	23	18	27	19	9	36	26	21	13
9	3	15	24	11	19	2	7	36	58	47	36	32
5	1	9	34	33	38	4	10	43	60	37	37	12
13	3	0	16	70	78	39	31	52	50	59	27	10
3	1	6	2	60	62	24	28	55	43	27	20	20

% HARDWOOD FOREST MANAGED

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	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	2	2	1	5	2	2	2
0	0	4	2	2	3	4	0	0	0	0	0	0
5	1	1	2	2	0	1	7	0	0	1	0	0
3	2	0	1	0	0	2	0	0	2	1	2	0
0	0	0	2	0	0	2	4	1	1	0	4	2
0	0	0	0	2	0	2	2	2	9	4	1	2
0	0	0	0	0	5	4	17	13	9	9	5	5
0	2	0	0	0	7	8	3	3	2	10	8	2
0	0	1	0	0	1	2	1	5	2	3	12	20
0	1	0	0	0	0	2	4	0	12	15	16	4
12	1	0	0	0	0	5	5	3	2	2	0	1
17	7	2	0	0	0	1	0	4	0	0	1	0
13	9	0	1	0	0	0	0	1	1	1	1	1
3	8	2	0	0	0	0	1	2	2	0	1	3
6	8	0	2	1	1	2	2	0	0	1	0	0
3	2	1	3	1	2	12	9	4	0	1	0	0
2	10	2	9	1	2	6	9	0	0	0	0	1
9	5	4	1	2	2	7	2	1	1	0	0	0

% NOT CLASSIFIED

6	6	6	6	6	6	6	3	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	1	1	0	0	0	2	0	0	0	0	0
0	0	0	0	0	0	0	0	2	2	0	0	1
0	0	0	0	0	0	1	1	0	4	2	2	0
0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	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	1	0	0	0	0	0	0	0	3	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	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	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	2	0	0	5
0	0	1	0	0	0	0	0	0	5	13	0	0
0	3	0	0	0	0	0	0	0	2	0	0	0
0	2	0	0	3	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0
0	0	5	0	0	0	0	0	1	0	0	0	0
0	0	1	4	0	0	0	0	0	0	0	0	0

LOCATION DETERMINANT--COMPOSITE

-47	-47	-47	-47	-47	-47	-47	-36	-25	-25	-29	-25	-13
-50	-50	-50	-50	-42	-49	-50	-50	-30	-24	-29	-24	-12
-50	-50	-50	-50	-43	-45	-50	-50	-50	-46	-24	-25	-13
-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-27	-25	-13
-50	-50	-50	-50	-48	-46	-49	-47	-50	-50	-35	-24	-13
-50	-49	-34	-28	-24	-24	-24	-46	-50	-50	-44	-20	-12
-50	-36	-22	-25	-25	-22	-24	-21	-30	-44	-50	-49	-21
-50	-28	-22	-23	-25	-25	-16	-14	-22	1	-1	-23	-9
-50	-34	-17	-16	-18	-15	-6	-19	-25	-22	-19	-21	-6
-37	-23	-22	-24	-14	-25	-5	-16	-25	-25	-24	-25	-13
-15	-24	-24	-25	-24	-24	-21	-19	-24	-22	-21	-24	-12
-31	-27	-22	-25	-25	-24	-21	-2	-20	-21	-25	-24	-12
-50	-32	-24	-25	-24	-19	-22	-25	-23	-16	-25	-24	-13
-37	-25	-25	-25	-23	-24	-23	-21	-23	-17	-17	-22	-10
-26	-22	-25	-25	-25	-24	-18	-24	-22	-13	-1	-18	-11
-25	-23	-25	-25	-25	-21	-24	-22	-14	-24	-24	-19	9
-25	-16	-25	-24	-25	-23	-25	-22	-23	-3	-2	6	-7
-19	-25	-25	-25	-25	-26	-21	-8	-4	-5	-21	-25	-1
23	-21	-27	-25	-23	-25	-25	-21	-12	-20	-24	-24	-12
21	4	-33	-25	-23	-25	-25	-23	-24	-26	-31	-25	-12
3	4	-28	-23	-24	-31	-24	-24	-19	-26	-33	-24	-12
-12	-17	-30	-23	-24	-22	-9	-24	-25	-25	-24	-23	-12
-15	-22	-37	-15	-22	-18	49	19	-25	-25	-23	-25	-9
-17	4	-27	-16	-20	-20	-10	-8	-25	-26	-22	-23	-14
16	53	20	-39	-16	-23	-17	-22	-25	-24	-33	-22	-12

STUDY AREA BOUNDARY

. = CELL OUTSIDE OF BOUNDARY
X = CELL INSIDE OF BOUNDARY

```
.  .  .  .  .  .  .  .  X  .  .  .  .
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
X  X  X  X  X  X  X  X  X  X  X  X  X
.  .  .  .  .  X  .  .  .  .  .  .  .
```

OPTIMAL ALTERNATIVE 1

```
.  .  .  .  .  .  .  .  X  .  .  .  .
.  .  .  .  .  .  .  .  .  X  .  .  .
.  .  .  .  .  .  .  .  .  .  X  .  .
.  .  .  .  .  .  .  .  .  .  .  X  .
.  .  .  .  .  .  .  .  .  .  .  .  X
.  .  .  .  .  .  .  .  .  .  .  .  X
.  .  .  .  .  .  .  .  .  .  .  .  X
.  .  .  .  .  .  .  .  .  .  .  .  X
.  .  .  .  .  .  .  .  .  .  .  .  X
.  .  .  .  .  .  .  .  .  .  .  .  X
.  .  .  .  .  .  .  .  .  .  .  .  X
.  .  .  .  .  .  .  .  .  .  .  .  X
.  .  .  .  .  .  .  .  .  .  .  .  X
.  .  .  .  .  .  .  .  .  .  .  .  X
.  .  .  .  .  .  .  .  .  .  .  .  X
.  .  .  .  .  .  .  .  .  .  .  .  X
.  .  .  .  .  .  .  .  .  .  .  X  .
.  .  .  .  .  .  .  .  .  X  .  .  .
.  .  .  .  .  .  .  .  X  .  .  .  .
.  .  .  .  .  .  .  .  X  .  .  .  .
.  .  .  .  .  .  .  .  X  .  .  .  .
.  .  .  .  .  .  .  X  .  .  .  .  .
.  .  .  .  .  .  X  .  .  .  .  .  .
.  .  .  .  .  .  X  .  .  .  .  .  .
.  .  .  .  .  X  .  .  .  .  .  .  .
```

RUN 2

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

STUDY AREA SIZE   25 CELLS BY 13 CELLS
CELL SIZE   16 BY 8 ERTS POINTS AT 1.10 ACRES
NUMBER OF LOCATION DETERMINANTS   9

LOCATION DETERMINANT	WEIGHT
1 URBAN AREA	20.0
2 OPEN AREA	5.0
3 HARDWOOD FOREST	-5.0
4 WATER	-10.0
5 CONIFER FOREST JACK PINE	-5.0
6 MARSH LAND	-2.0
7 CONIFER FOREST WHITE PINE	-5.0
8 HARDWOOD FOREST MANAGED	-5.0
9 NOT CLASSIFIED	0.0

LINK VALUE COMPONENT	WEIGHT
LOCATION DETERMINANTS	10.0
LINK DISTANCE	10.0

ALPHA	0.1
TOLERANCE	0.5

LOCATION DETERMINANT--COMPOSITE

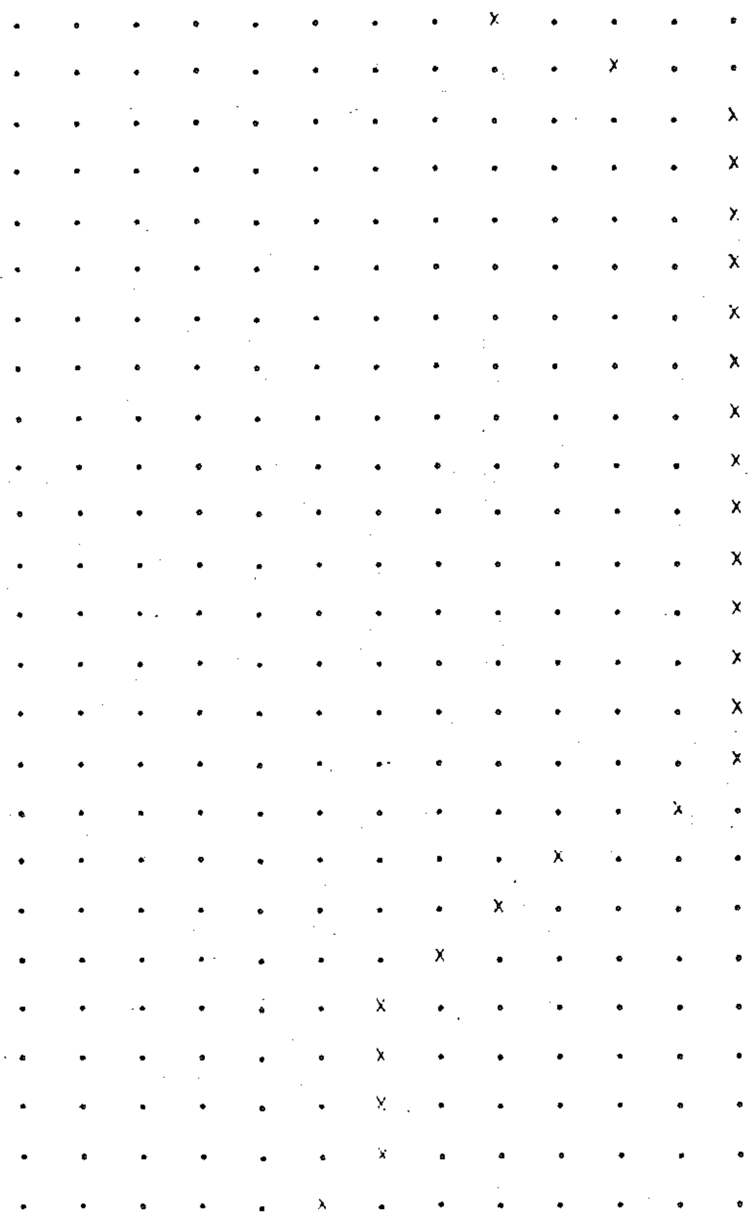
-47	-47	-47	-47	-47	-47	-47	-36	-25	-25	-29	-25	-13
-50	-50	-50	-50	-42	-49	-50	-50	-30	-24	-29	-24	-12
-50	-50	-50	-50	-43	-45	-50	-50	-50	-46	-24	-25	-13
-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-27	-25	-13
-50	-50	-50	-50	-48	-46	-49	-47	-50	-50	-35	-24	-13
-50	-49	-34	-28	-24	-24	-24	-46	-50	-50	-44	-20	-12
-50	-36	-22	-25	-25	-22	-24	-21	-30	-44	-50	-49	-21
-50	-28	-22	-23	-25	-25	-14	-14	-22	1	-1	-23	-9
-50	-34	-17	-16	-18	-15	-6	-19	-25	-22	-19	-21	-6
-37	-23	-22	-24	-14	-25	-5	-16	-25	-25	-24	-25	-13
-15	-24	-24	-25	-24	-24	-21	-19	-24	-22	-21	-24	-12
-31	-27	-22	-25	-25	-24	-21	-2	-20	-21	-25	-24	-12
-50	-32	-24	-25	-24	-19	-22	-25	-23	-16	-25	-24	-13
-37	-25	-25	-25	-23	-24	-23	-21	-23	-17	-17	-22	-10
-26	-27	-25	-25	-25	-24	-18	-24	-22	-13	-1	-18	-11
-25	-23	-25	-25	-25	-21	-24	-22	-14	-24	-24	-19	9
-25	-16	-25	-24	-25	-23	-25	-22	-23	-3	-2	6	-7
-19	-25	-25	-25	-25	-26	-21	-8	-4	-5	-21	-25	-1
23	-21	-27	-25	-23	-25	-25	-21	-12	-20	-24	-24	-12
21	4	-33	-25	-23	-25	-25	-23	-24	-26	-31	-25	-12
3	4	-25	-23	-24	-31	-24	-24	-19	-26	-33	-24	-12
-12	-17	-30	-23	-24	-22	-9	-24	-25	-25	-24	-23	-12
-15	-22	-37	-15	-22	-18	40	19	-25	-25	-23	-25	-9
-17	4	-27	-16	-20	-20	-10	-8	-25	-26	-22	-23	-14
16	53	[illegible]	-39	-16	-23	-17	-22	-25	-24	-33	-22	-12

STUDY AREA BOUNDARY
----- ---- --------

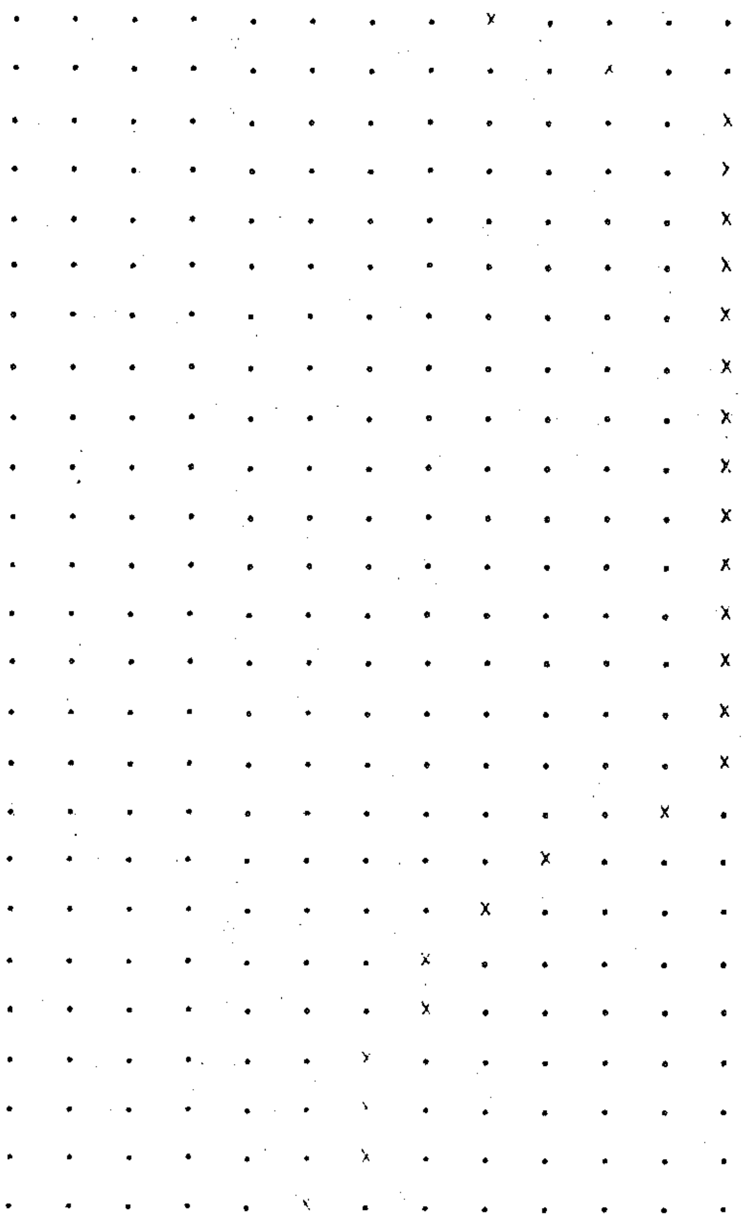
. = CELL OUTSIDE OF BOUNDARY
X = CELL INSIDE OF BOUNDARY

.	.	.	.	.	.	.	.	X	.	.	.	.
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X
.	.	.	.	.	.	.	.	.	.	.	.	.

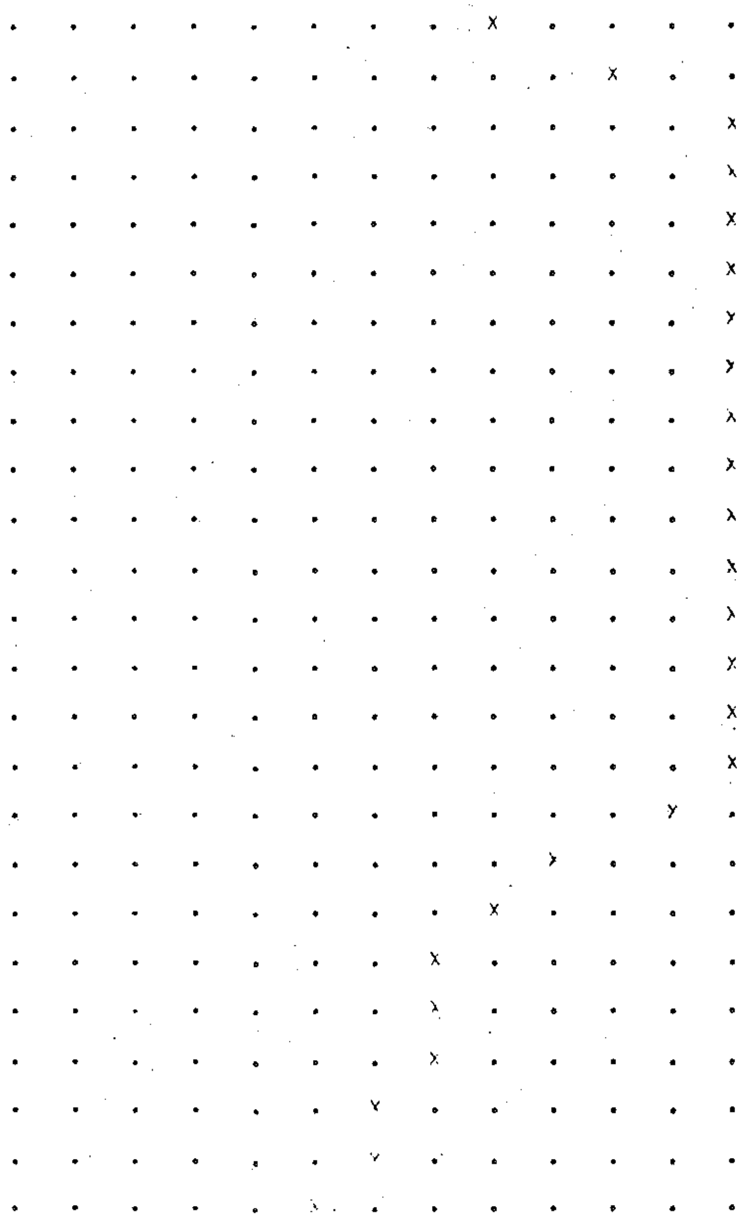
OPTIMAL ALTERNATIVE 1



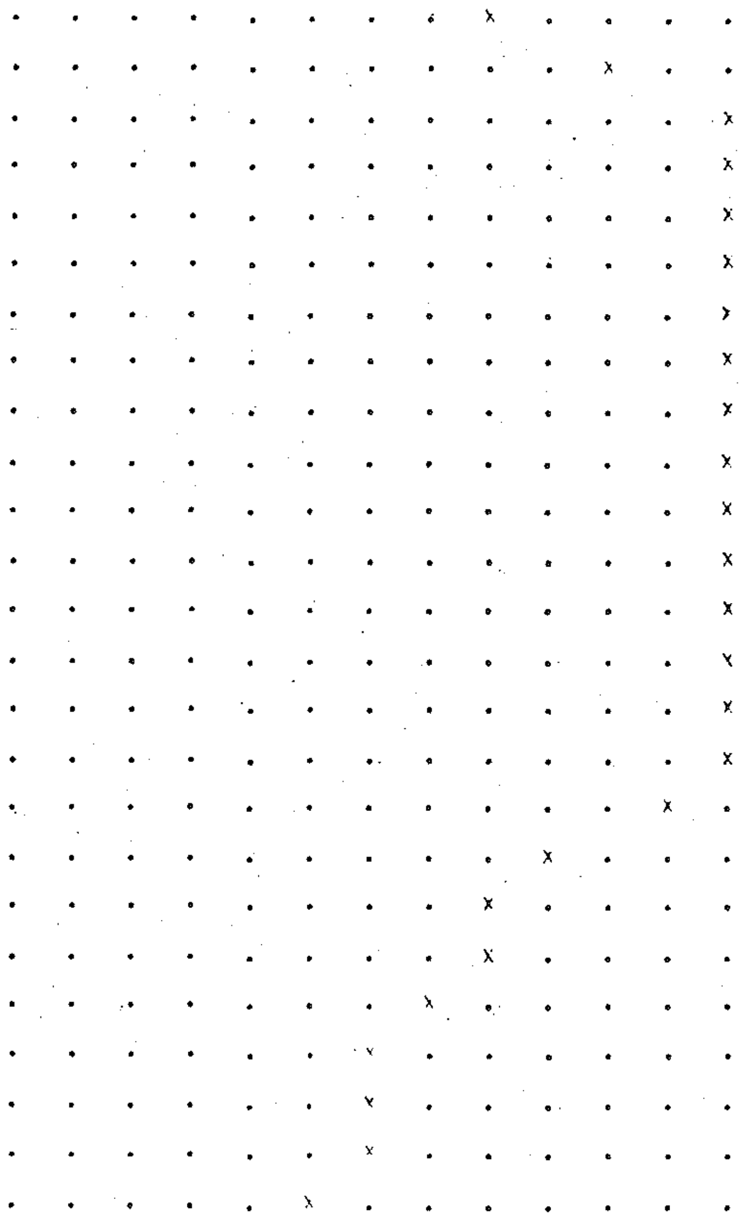
OPTIMAL ALTERNATIVE 2



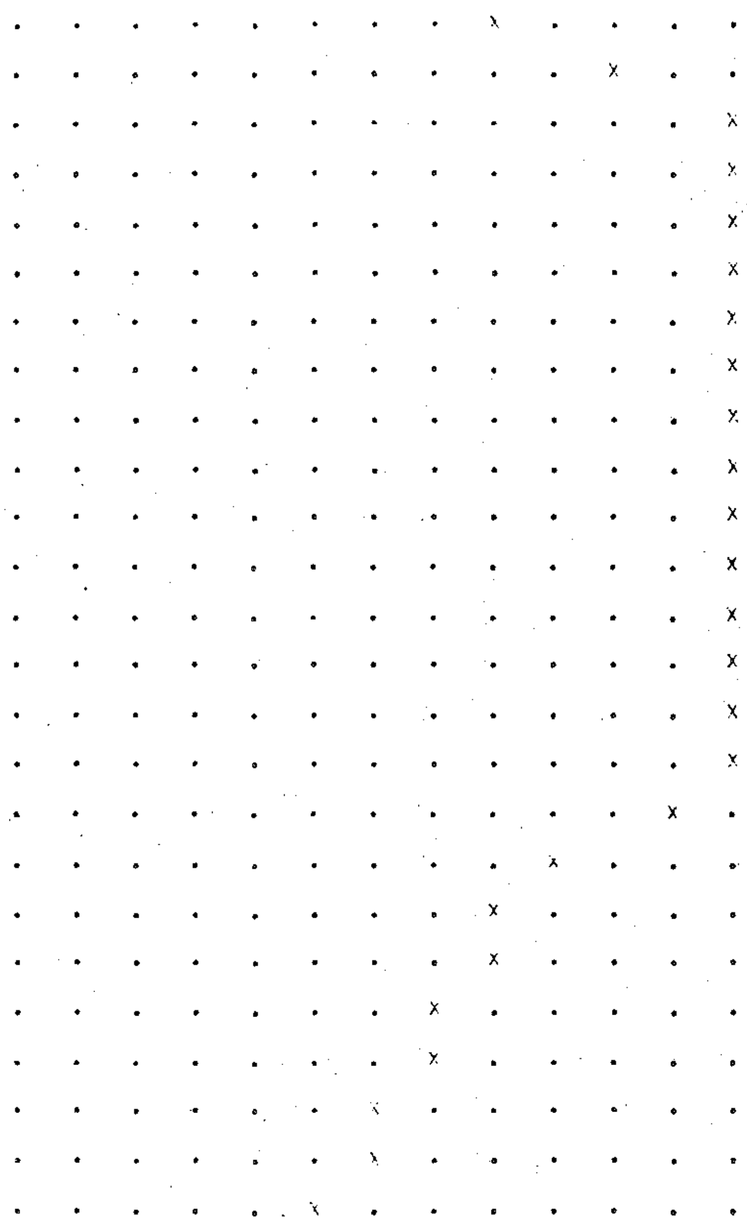
OPTIMAL ALTERNATIVE 3



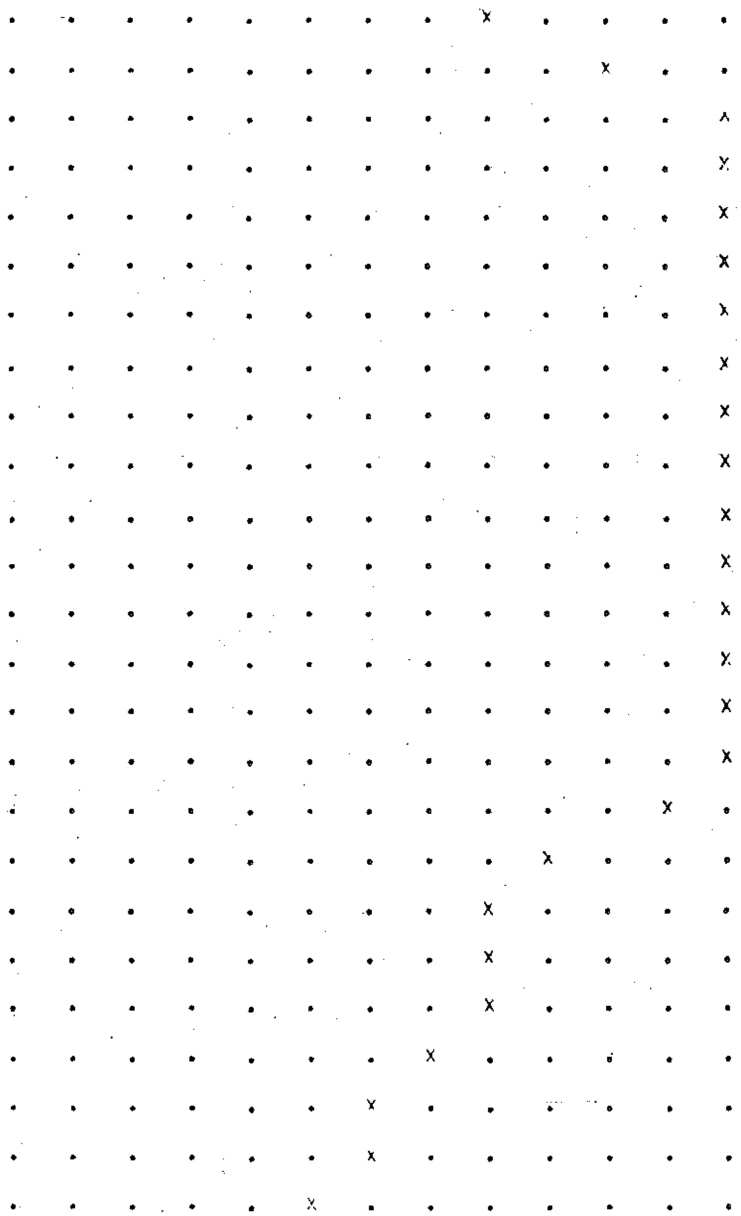
OPTIMAL ALTERNATIVE 4



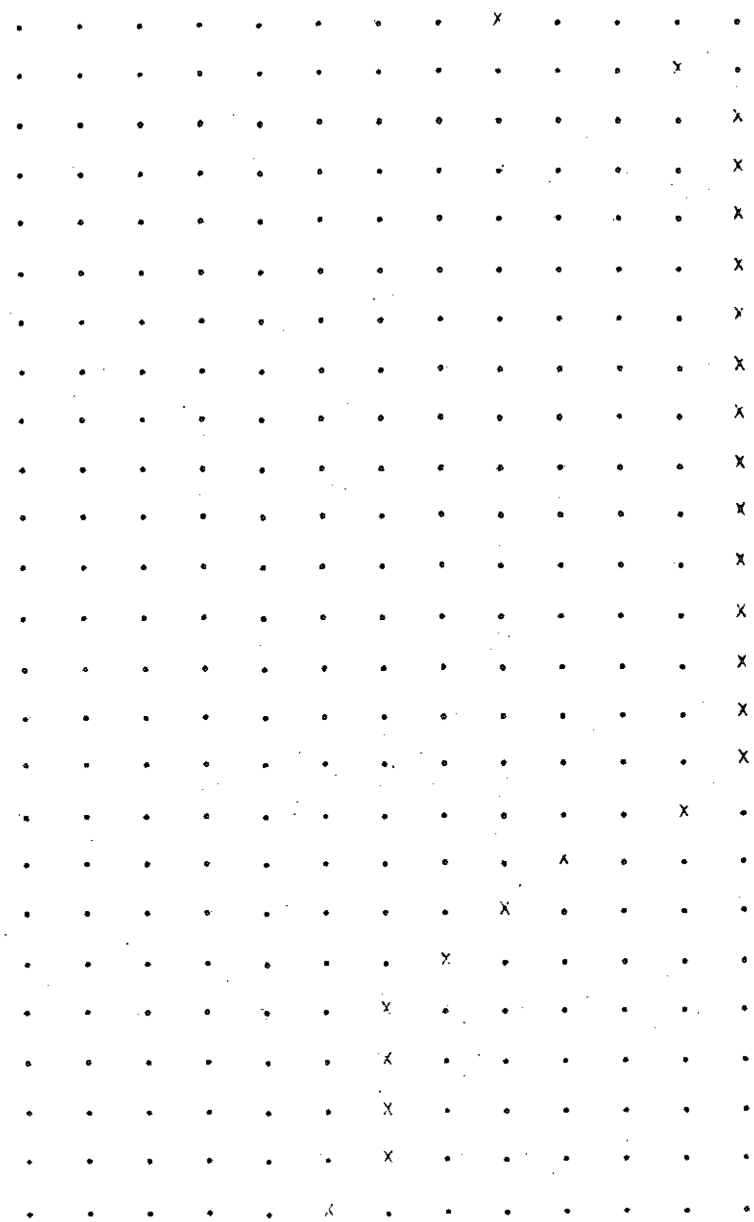
OPTIMAL ALTERNATIVE 5



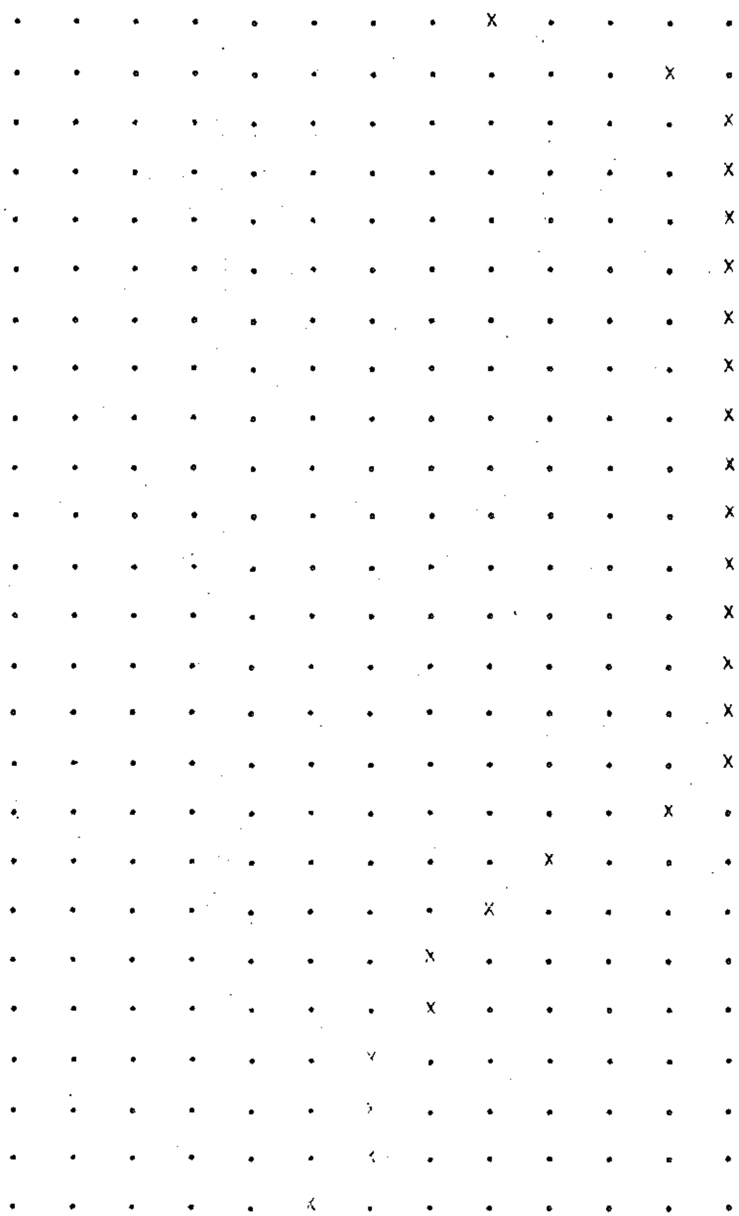
OPTIMAL ALTERNATIVE 6



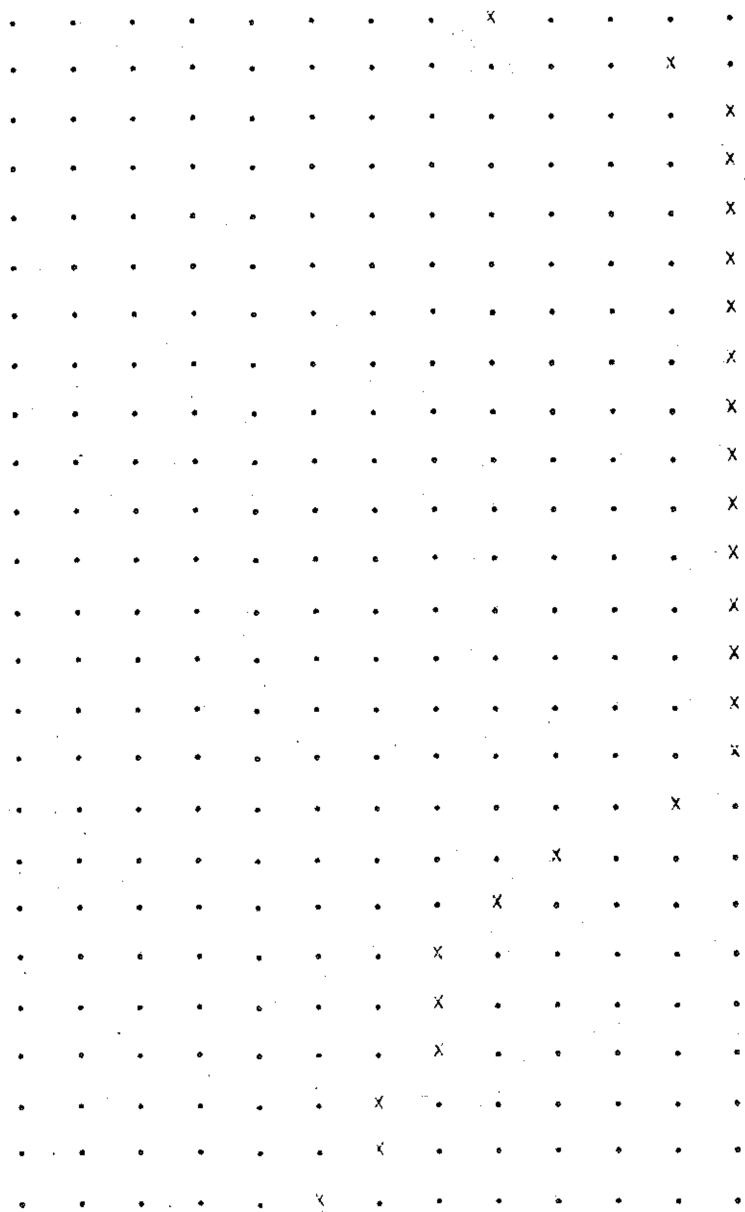
OPTIMAL ALTERNATIVE 7



OPTIMAL ALTERNATIVE 8



OPTIMAL ALTERNATIVE 9



OPTIMAL ALTERNATIVE 1[illegible]
------- -----------

```
.   .   .   .   .   .   .   .   X   .   .   .   .
.   .   .   .   .   .   .   .   .   .   .   /   .
.   .   .   .   .   .   .   .   .   .   .   .   X
.   .   .   .   .   .   .   .   .   .   .   .   X
.   .   .   .   .   .   .   .   .   .   .   .   X
.   .   .   .   .   .   .   .   .   .   .   .   X
.   .   .   .   .   .   .   .   .   .   .   .   X
.   .   .   .   .   .   .   .   .   .   .   .   X
.   .   .   .   .   .   .   .   .   .   .   .   X
.   .   .   .   .   .   .   .   .   .   .   .   X
.   .   .   .   .   .   .   .   .   .   .   .   X
.   .   .   .   .   .   .   .   .   .   .   .   X
.   .   .   .   .   .   .   .   .   .   .   .   X
.   .   .   .   .   .   .   .   .   .   .   .   X
.   .   .   .   .   .   .   .   .   .   .   .   X
.   .   .   .   .   .   .   .   .   .   .   .   X
.   .   .   .   .   .   .   .   .   .   .   X   .
.   .   .   .   .   .   .   .   .   X   .   .   .
.   .   .   .   .   .   .   .   X   .   .   .   .
.   .   .   .   .   .   .   .   X   .   .   .   .
.   .   .   .   .   .   .   /   .   .   .   .   .
.   .   .   .   .   .   X   .   .   .   .   .   .
.   .   .   .   .   .   X   .   .   .   .   .   .
.   .   .   .   .   .   ^   .   .   .   .   .   .
.   .   .   .   .   X   .   .   .   .   .   .   .
```