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Statewide Transportation Analysis & Research

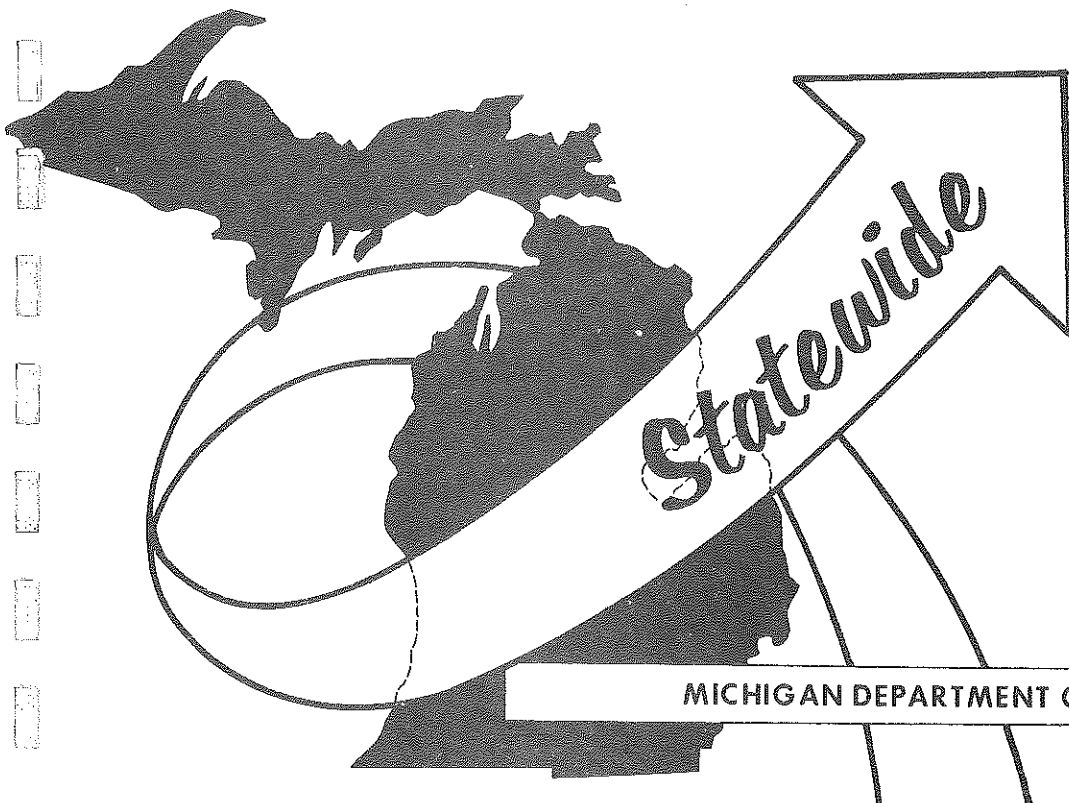
Michigan's Statewide
Transportation Modeling System

Volume VI-B

SECONDARY IMPACT MODEL

February 1983

Transportation Planning
Procedures Section



MICHIGAN DEPARTMENT OF TRANSPORTATION

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BUREAU OF TRANSPORTATION PLANNING

Michigan's Statewide
Transportation Modeling System

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Procedures Section

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TABLE OF CONTENTS

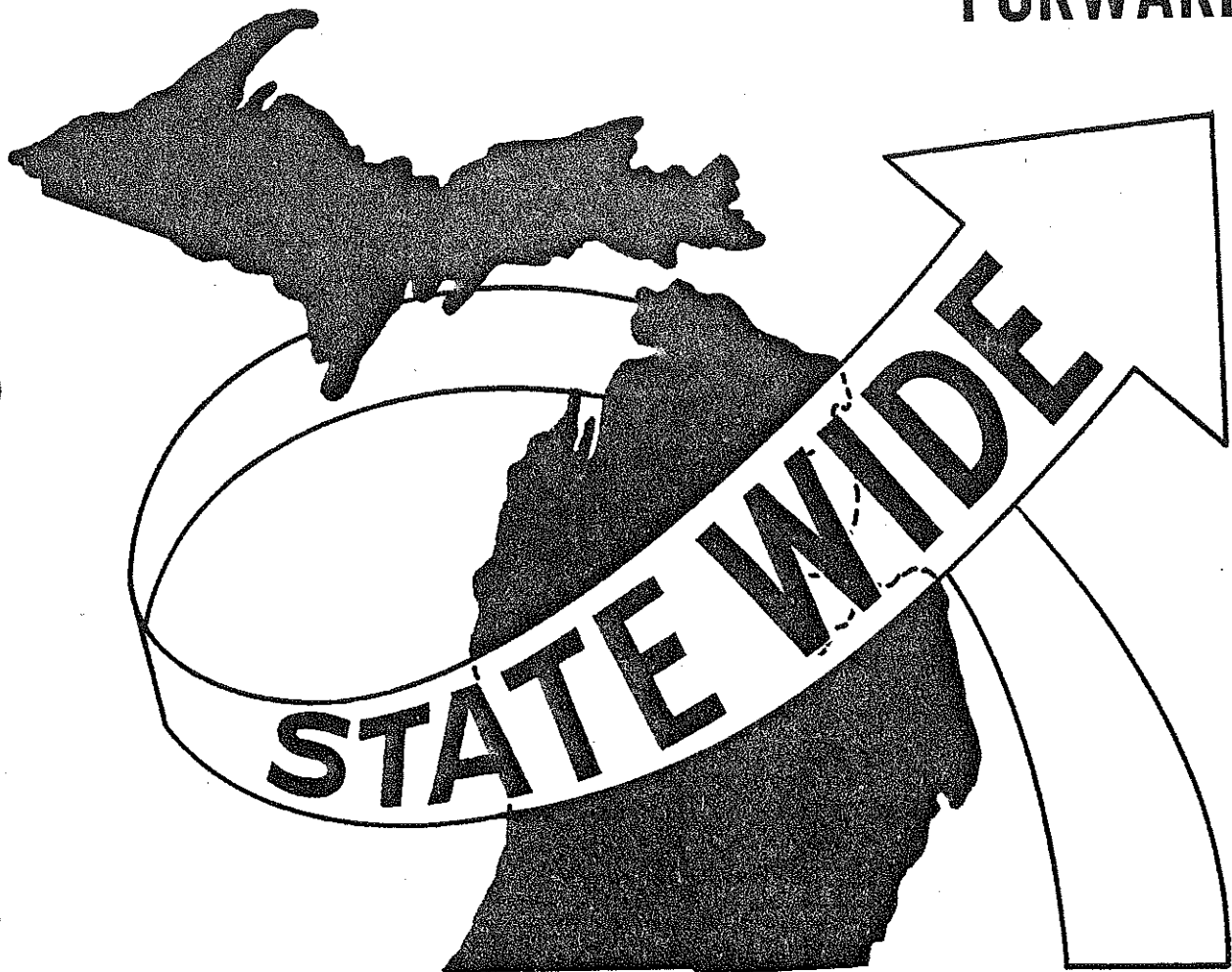
SECONDARY IMPACT MODEL

GEORGE S. LIU

	<u>Page</u>
Forward	1
I. Introduction	2
II. The Process	4
A. Environmental Impact Study	4
1. Data Classification	4
2. Data Resampling	6
3. Environmental Impact	8
4. Composite Impact	8
5. Impact Maps	9
B. Accessibility Study	9
1. Data	9
2. Accessibility for Data Points	10
3. Accessibility for Cells	12
4. Accessibility Map	13
C. Overlap Map	14
D. Summary	15
III. Case Study	16
A. Project Description	16
B. Environmental Impact Study	16
1. Data Resampling	16
2. Environmental Impact	18
C. Accessibility Study	18
1. Data	18
2. Accessibility for Data Points	19
3. Accessibility for Cells	19
D. Overlap Map	19
IV. Conclusion	20

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FORWARD



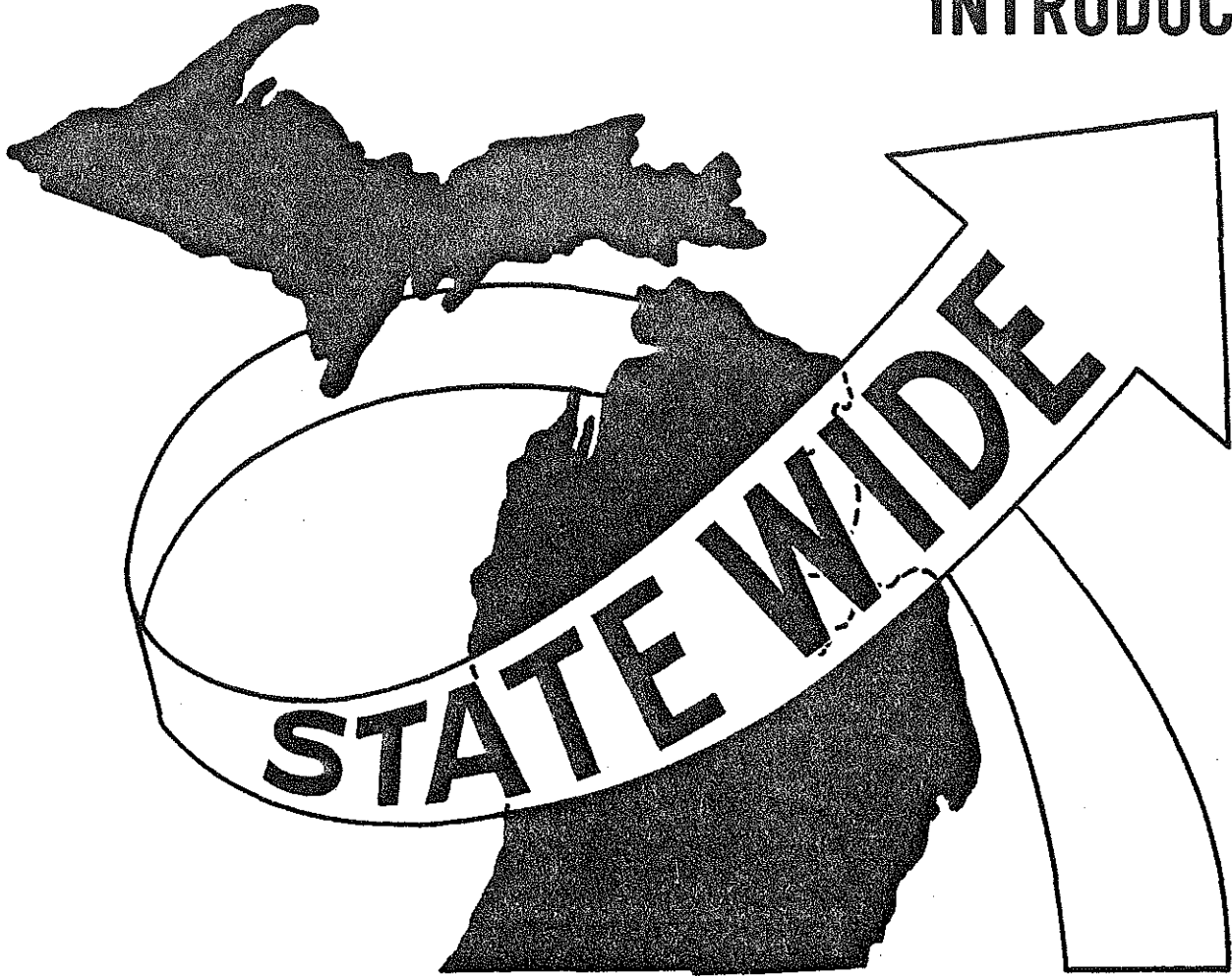
FORWARD

The Action Plan Guide of the Michigan Department of Transportation specifically recommends three levels of impact study for any construction or improvement of the Michigan transportation system. The three levels of impact, known respectively as primary, secondary, and tertiary, are defined in the Action Plan.

The primary impact study has long been part of a standard procedure within the Department. The task has been carried out by tools such as the Statewide Transportation Modeling System and the Corridor Location Model -- both computer models. The secondary impact study, while being recognized for its importance and specifically recommended by the Action Plan, does not as yet have an efficient or totally computerized procedure. Using part of the existing models and some additional new concepts and programs, the Department has been able to put together a procedure that hopefully will be useful in that direction.

We welcome any comments or suggestions.

INTRODUCTION



INTRODUCTION

It has long been recognized, though not always followed, that any man-made structure should be designed and built in harmony with the overall environment. The largest single such structure is the land transportation system, mainly the highways. It is also the most permanent. The time has long past when highways were built to improve transportation, period. Their effect on the environment was not only ignored, but was probably not even recognized. We are now bombarded by literature, and indeed required by law, to consider seriously such effects.

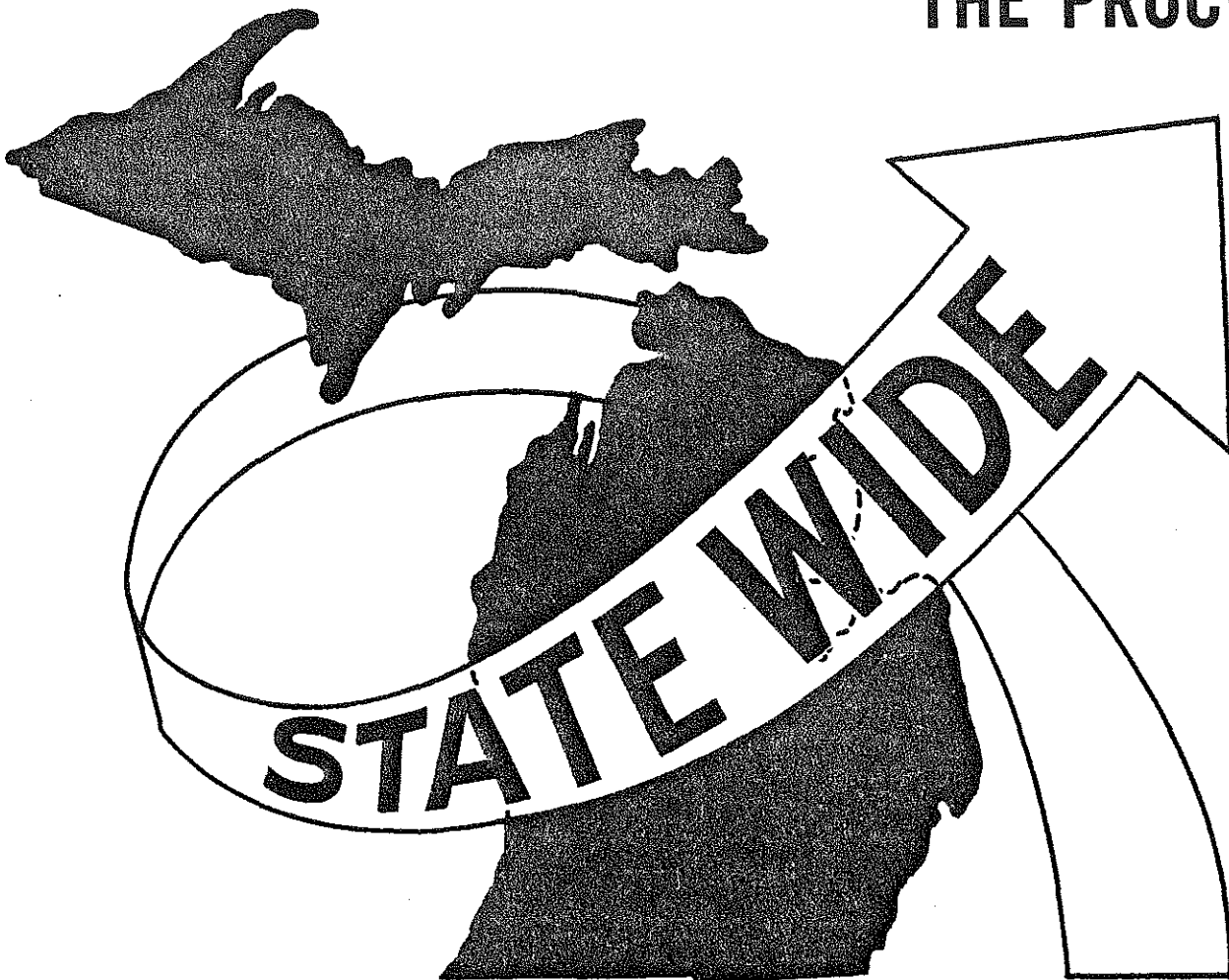
The most obvious effect is the physical destruction or pollution by a highway of valuable environments such as forest, water, neighborhoods, clean air, etc. This is known in planning as the primary impact. It is extensively researched and dealt with in literature and about which various levels of government and the public have been most concerned. In fact, it is now a standard procedure, legally required, to consider such impact before any construction is to start. Several alternatives have to be considered before one with little, or the least such impact, can be approved.

Here comes the surprise. Once a highway is approved and built, it stands not as an isolated structure, but becomes a part of the total transportation system. This may have major changes on the accessibility picture of the region, not necessarily only the area neighboring the new highway. Areas which were previously undeveloped now become relatively more accessible and, therefore, may attract tremendous development. With development, it brings impacts on the environment which were not even

envisioned or considered. Such secondary impact on an environmentally sensitive area becomes, therefore, a crucial issue. Its importance may be equal to, if not more than, that of the primary impact.

This study attempts to help address the above issue.

THE PROCESS



THE PROCESS

The basic objective of this study is to find where high accessibility areas may overlap environmentally sensitive areas with alternative highway construction. To do this, the following process is adopted. First, divide the study area into square cells by laying a grid over it. Second, rate each cell by environmental impact, on a scale from zero through nine, creating an "impact map". Third, rate each cell by accessibility to population on a similar scale, creating an "accessibility map". Last overlay the "accessibility map" on the "impact map" to identify where high impact areas overlap high accessibility areas. The accessibility map is re-calculated for each new transportation corridor alternative, so that the one with the least amount of such overlaps may be chosen.

A. Environmental Impact Study

1. Data Classification:

Land cover/use data may be classified by the following system. It consists of a four-level hierarchy. Level I, the top level, consists of nine categories. Levels II, III, and IV follow successively. To each level, a land cover/use number is attached, with one, two, three, and four digits for Levels I, II, III, and IV respectively. For example:

Level I (1 digit)	1	Urban and Built-Up
Level II (2 digits)	11	Residential
Level III (3 digits)	111	Multi-family, medium to high rise

TABLE 2.1

Proposed Levels I & II * Michigan Land Cover/Use Classification System

- 1 URBAN & BUILT UP
 - ⌢ 11 Residential
 - ⌢ 12 Commercial, Services, & Industrial
 - ⌢ 13 Industrial
 - ⌢ 14 Transportation, Communication & Utilities
 - ⌢ [15] Map Industrial Parks under appropriate category in Commercial Services & Institutional (12) or Industrial (13)
 - ⌢ 16 Mixed
 - ⌢ 17 Extractive
 - ⌢ 19 Open & Other
- 2 AGRICULTURAL LAND
 - ⌢ 21 Cropland, Rotation & Permanent Pasture
 - ⌢ 22 Orchards, Bush-Fruits, Vineyards & Ornamental Horticulture Areas
 - ⌢ 23 Confined Feeding Operations
 - ⌢ [28] Inactive Land (These plant communities will be mapped under herbaceous rangelands (31).
 - ⌢ 29 Other Agricultural Land
- 3 RANGELAND
 - ⌢ 31 Herbaceous Rangeland
 - ⌢ 32 Shrub Rangeland
- 4 FOREST LAND
 - ⌢ 41 Broadleaved Forest (generally deciduous)
 - ⌢ 42 Coniferous Forest
 - ⌢ 43 Mixed Conifer-Broadleaved Forest
- 5 WATER
 - ⌢ 51 Streams & Waterways
 - ⌢ 52 Lakes
 - ⌢ 53 Reservoirs
 - ⌢ 54 Great Lakes
- 6 WETLANDS
 - ⌢ 61 Forested (wooded) Wetlands
 - ⌢ 62 Non-Forested (non-wooded) Wetlands
- 7 BARREN
 - ⌢ 71 Salt Flats (not applicable to Michigan)
 - ⌢ 72 Beaches & Riverbanks
 - ⌢ 73 Sand Other than Beaches
 - ⌢ 74 Bare Exposed Rock
 - ⌢ 75 Transitional Areas
 - ⌢ 79 Other
- 8 TUNDRA (not applicable to Michigan)
- 9 PERMANENT SNOW & ICE (not applicable to Michigan)

Level IV (4 digits)	1111	High Density
	1112	Medium Density
	1113	Low Density

The complete Level I and II system is shown in Table 2.1.

2. Data Resampling:

Land use data in whatever format must be resampled to cell data, i.e., percentages of land uses in each cell. For example, the original data file available for the study area is as follows.

The study area is divided into subareas or simply "areas". Each record in the "areas file" describes a uniquely defined land use area. Each record in the "segments file" describes a segment of the total boundary of two defined areas. That is, a segment is the separating boundary between two land use areas of differing type or classification (Figure 2.1).

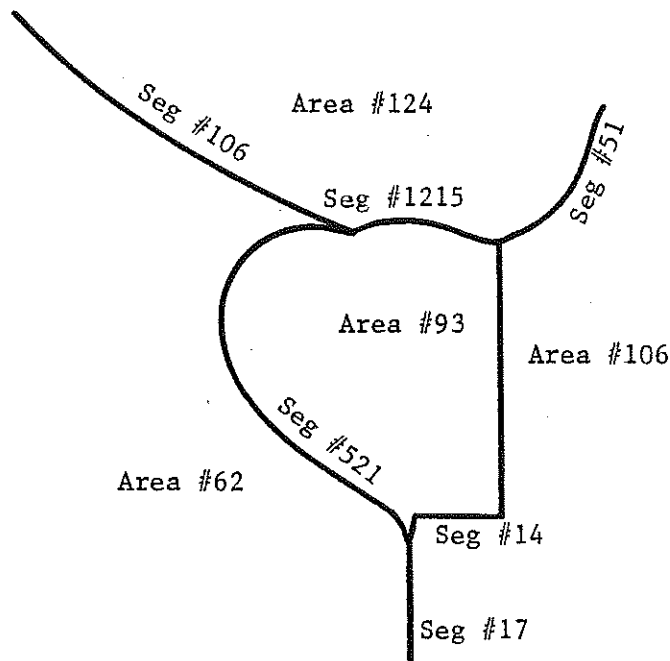
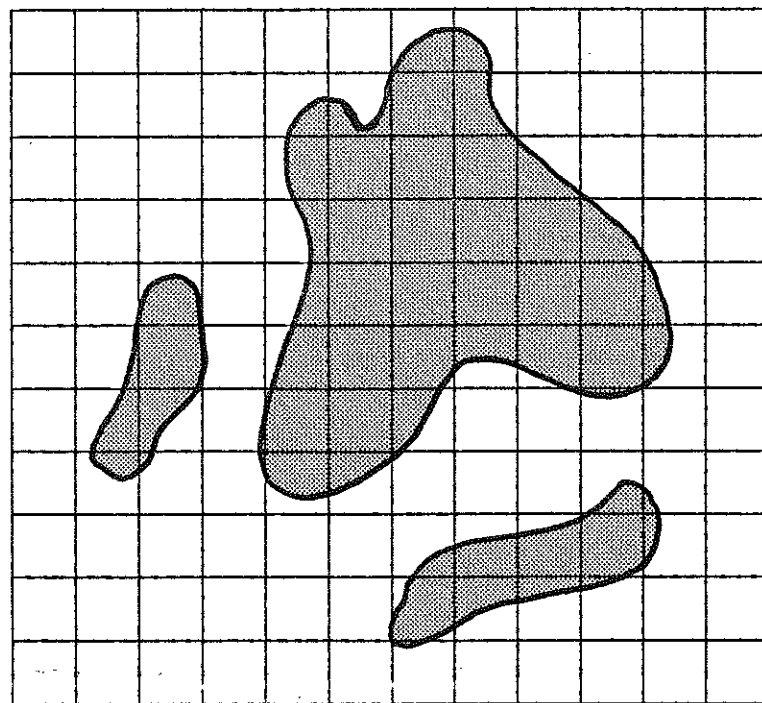


FIGURE 2.1

To convert the above to cell data, lay a grid of square cells with desired cell size over the study area. The areas or percentages of all land uses in each cell are then computed. This can be done land-use by land-use (Figure 2.2) as follows:

- a. Define boundaries for all areas of one land use.
- b. Pass horizontal scan lines through the study area.
- c. Find all the intersections of the scan lines with the boundaries of the areas of the land use.
- d. Given the distance between the scan lines, the intersections above and the locations of the grid lines, compute the amount of area of the land use within each cell.
- e. Repeat the same steps for other land uses.

FIGURE 2.2



3. Environmental Impact:

The environmental impact or sensitivity of a land use, e.g., forest, in a cell relative to that of the same land use in other cells is in direct proportion to its area or percentage of area in the cell. Thus, for each land use m , its relative impact U_{mi} of cell i may be scaled from zero through nine as follows:

<u>% Area in Cell</u>	<u>Relative Impact</u>
0 to 0.5	0
0.5 to 1.5	1
1.5 to 2.5	2
2.5 to 3.5	3
3.5 to 4.5	4
4.5 to 5.5	5
5.5 to 6.5	6
6.5 to 7.5	7
7.5 to 8.5	8
8.5 to 10.0	9

4. Composite Impact:

Let U_{mi} be the relative impact of land use m in cell i . Then the relative composite impact, V_i , of cell i is defined as the linear combination or the weighted average of U_{mi} 's:

$$V_i = \sum_{m=1}^M a_m U_{mi} \quad (2.1)$$

where M is the number of land uses and $a_m, m=1, 2, \dots, M$ are the weights assigned to the land uses corresponding to their relative importance as determined by the user. The values of V_i may also be scaled from zero through nine with zero corresponding to low and nine to high values.

5. Impact Maps:

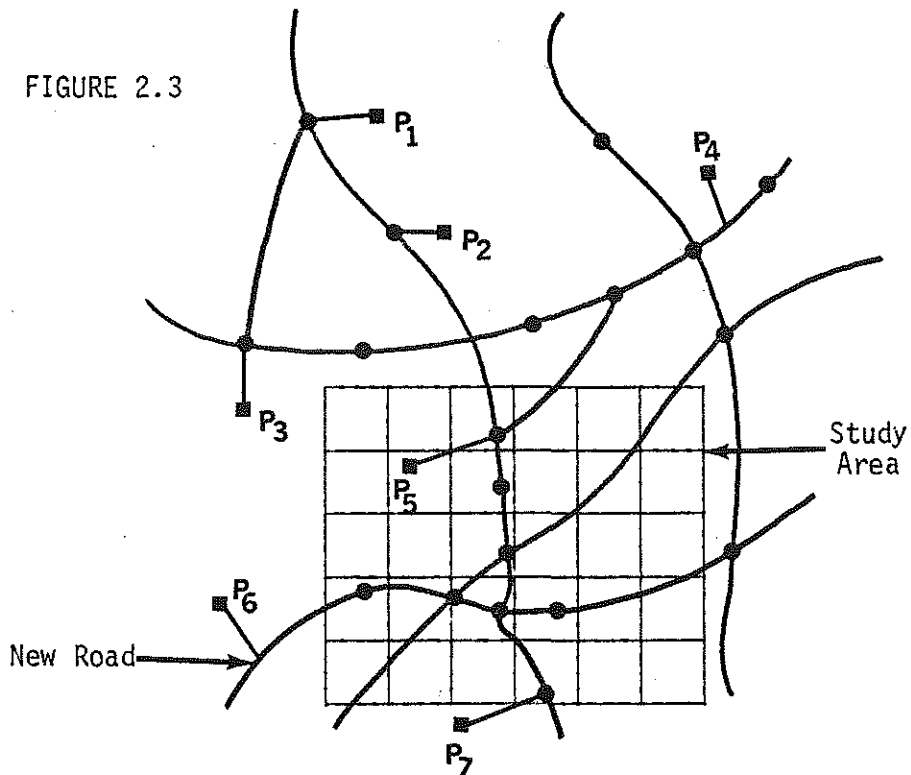
The maps of any individual land use impact or the composite on a scale from zero through nine may be displayed by assigning ten single-digit integers in one-to-one relation with the ten impact levels or value classes. Digit zero will give blank output. For example, assigning (0 1 2 3 4 5 6 7 8 9) will display the ten impact levels as is; assigning (0 0 0 0 0 0 0 1 1 1) will display the high levels (7, 8, 9) as ones (1's) and the rest blank; assigning (0 1 1 1 2 2 2 3 3 3) will display low levels (1, 2, 3) as ones (1's), medium levels (4, 5, 6) as twos (2's), and high levels (7, 8, 9) as threes (3's); and so on. Using this approach, the user may group or blank out impact levels any way he chooses for display.

B. Accessibility Study

1. Data:

Let the study area be included in a region which is subdivided into K zones with centroids at (x_1, y_1) , (x_2, y_2) , ... (x_K, y_K) and zonal population $P_1, P_2 \dots P_K$. The centroids are connected by a transportation network defined by nodes numbered from N_1 through N , $K < N_1$, with coordinates at $(x_{N_1}, y_{N_1}) \dots (x_N, y_N)$ and links each connecting two nodes with given distance and travel time. The network is obtained from major existing roads and any new proposed corridor.

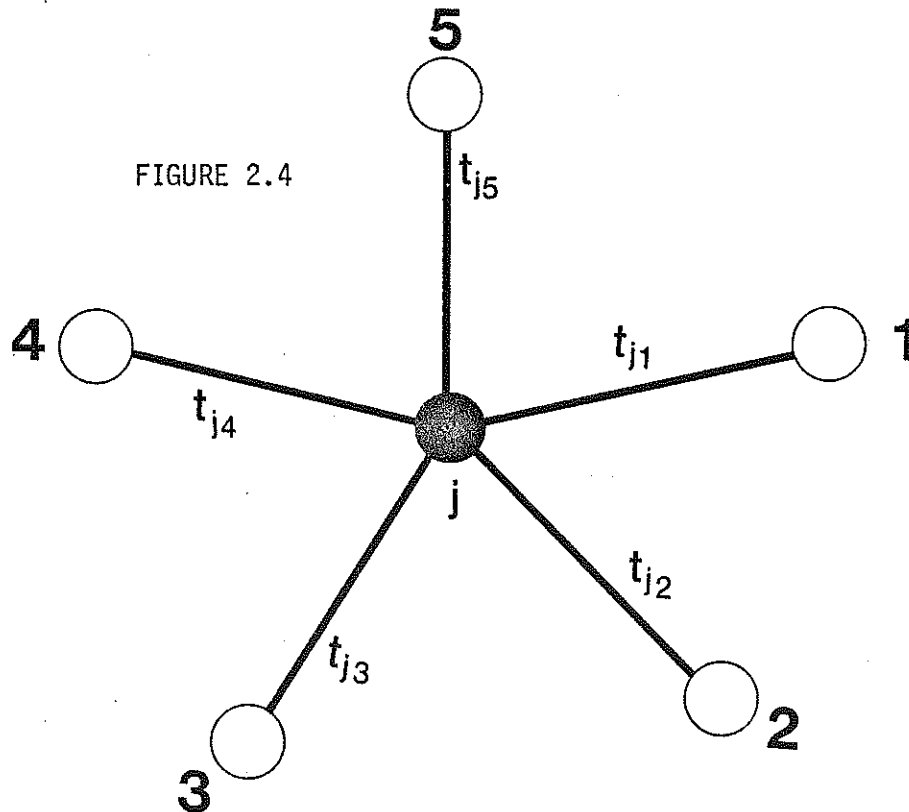
Let $J < N$ be the number of data points, i.e., the nodes included in the study area, with corresponding node numbers and x-y coordinates (Figure 2.3). To obtain accessibility values of cells in the study area, we first compute the accessibility values for the data points and then use interpolation.



2. Accessibility for Data Points:

Given the above data, we can construct a $J \times K$ skim tree table of minimum travel times t_{jk} from data point j , $j=1, 2, \dots, J$ to centroid k , $k=1, 2, \dots, K$. The accessibility value A_j for data point j may be defined as:

$$A_j = \sum_{k=1}^K \frac{P_k}{t_{jk}^2} \quad j=1, 2, \dots, J \quad (2.2)$$



An alternative definition is as follows: Using zonal population and skim tree table above, we can compute the total population within different time bands to each data point. Let T_l be the travel time in minutes corresponding to time band l and S_{jl} be the population within time band l to data point j . Then the accessibility A_j of data point j may be defined as follows:

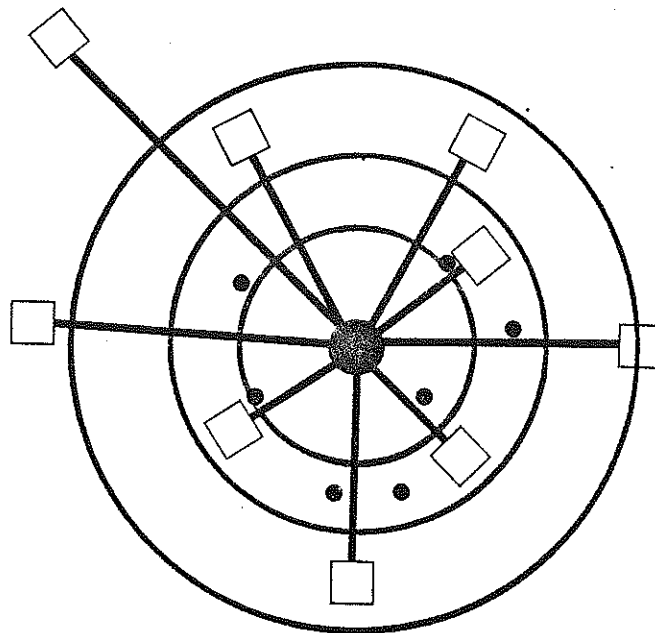
$$A_j = \sum_{l=1}^L \frac{S_{jl}}{T_l^2} \quad j=1, 2, \dots, m \quad (2.3)$$

Where L is the total number of time bands considered. For example, let us choose three time bands: 10 minutes, 20 minutes, and 30 minutes. Then:

$$A_j = \frac{S_{j1}}{10^2} + \frac{S_{j2}}{20^2} + \frac{S_{j3}}{30^2} \quad j=1, 2, \dots, m \quad (2.4)$$

All A_j 's, after computed, are scaled from zero through nine.

FIGURE 2.5



3. Accessibility for Cells:

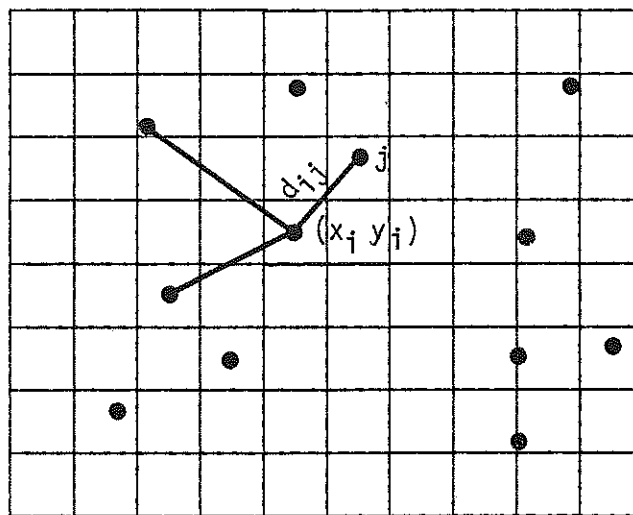
The accessibility values for all cells within the study area may be obtained by interpolations, using A_j 's computed and scaled above and the coordinates of the J data points.

Let the coordinates of the center point of cell i be (x_i, y_i) and the straight line distance between cell i and data point j be d_{ij} . Then the accessibility value Z of cell i is:

$$Z_i = \sum_{j=1}^J A_j e^{-\theta d_{ij}} \quad (2.5)$$

where θ is a positive number to be chosen by the user (see below). The Z 's, after computed, are scaled from zero through nine.

FIGURE 2.6



4. Accessibility Map:

The accessibility map is based on the Z_i 's computed and scaled above and displayed graphically by the same approach as the impact maps. Each choice of θ value in Equation 2.5 will result in a different map. Large values of θ will produce steep decay in Z_i 's, while small values will produce flatter decay. The

former is assumed to correspond to weak and the latter to strong link between the cells and the data points. By examining several such maps, the user may judiciously chose a \emptyset value to roughly reflect the existing secondary road system, which basically links the cells to the data points.

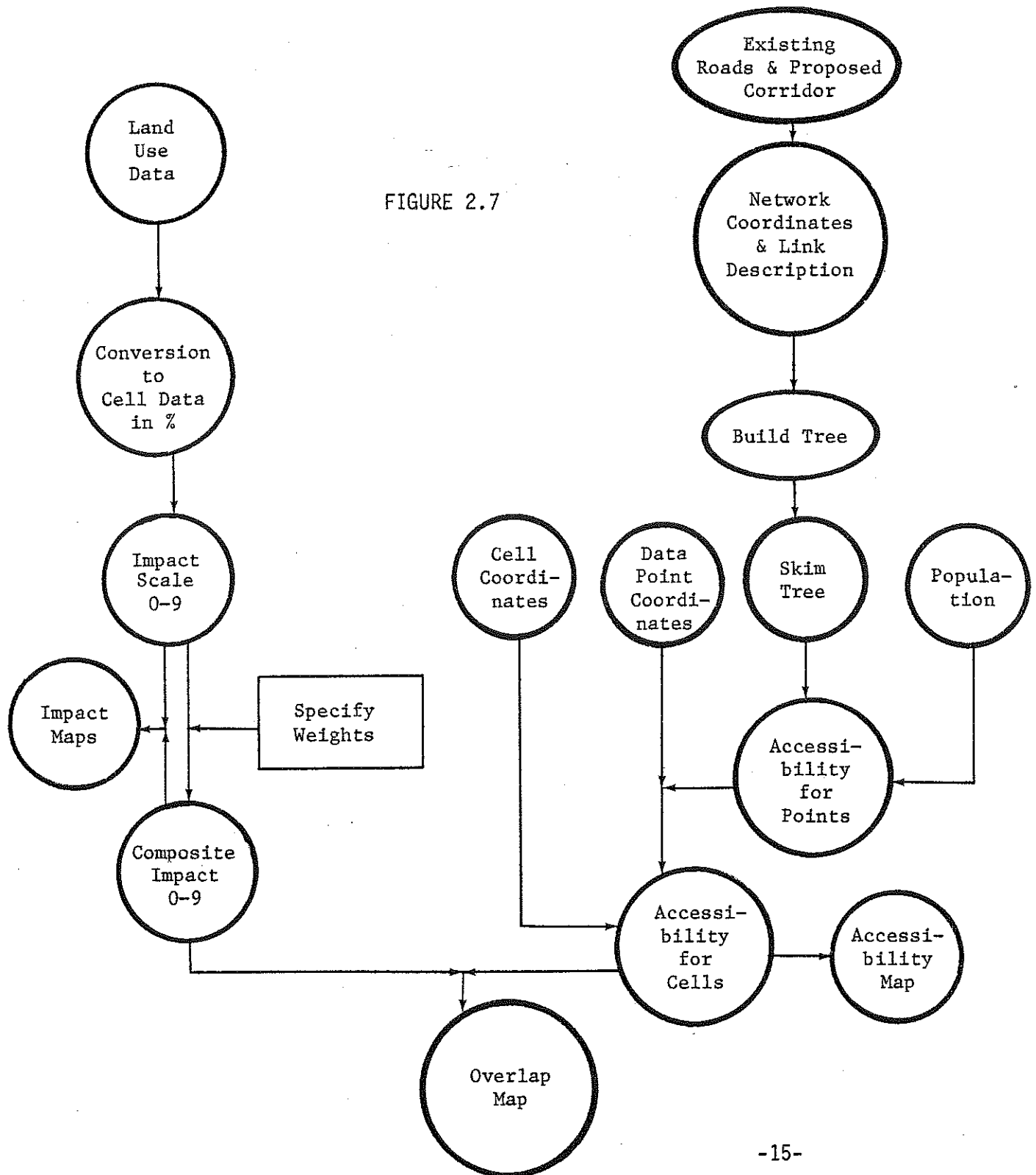
C. Overlap Map

As stated in the beginning, the objective of the whole study is to find where high accessibility areas may overlap environmentally sensitive areas with any given highway construction. With the accessibility map and the individual and composite impact maps computed above, it is simple to display any overlap of interest to the user by defining the ranges for impact and accessibility. For example, specifying impact range (7, 9) and accessibility range (7, 9) will display all cells with impact levels 7, 8, or 9 and accessibility levels 7, 8, or 9; specifying the ranges (5, 8) and (4, 6) will display all cells with impact levels 5, 6, 7, or 8 and accessibility levels 4, 5, or 6; and so on. The cells displayed have impact levels indicated.

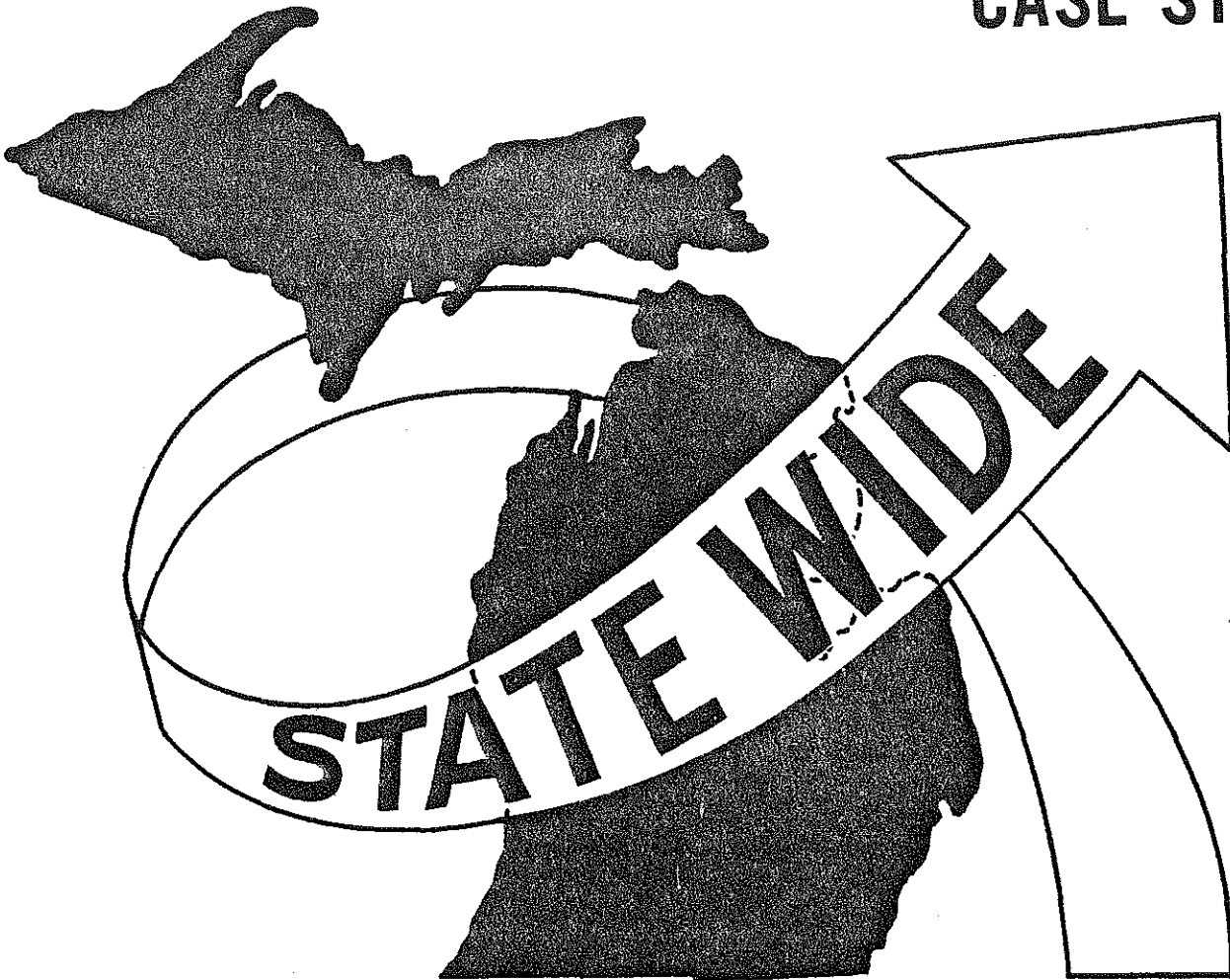
Generally, the composite impact map is used for such studies. But individual impacts may often be of great interest; for example, to see whether high accessibility areas may overlap forest areas. In such cases, the individual impact maps can be used.

D. Summary

The whole process may be summarized by the following flow chart:



CASE STUDY



CASE STUDY

A. Project Description

The possibility of building a new highway linking the cities of Cadillac and Manton in Michigan is contemplated. Secondary impact studies for different alternatives including the "no-build" are required. The "no-build" alternative is often the first one to examine and is chosen for our case study.

The study area includes Cadillac (population 9,990) and Manton (population 1,107) and measures approximately 8½ miles by 20 miles (Figure 3.1).

B. Environmental Impact Study

1. Data Resampling:

Land use/cover data for the study area is given by a data file known as the Environmental Information System (EIS), which actually consists of two inter-related files: an "area" file and a "boundary" file. The nature of these two files and the land use classification system for the files are briefly described in Section II-A.

To convert the above file to a cell data file which gives the number of acres (or percentage) of each land use for each cell, we lay a grid over the study area and specify:

- (a) numbers of row and column of the grid desired,
- (b) number of scan lines desired for the conversion, and

(c) land use types desired.

In the above, input (a) defines the cell size of the overlaying grid; input (b) defines the accuracy of the conversion process; input (c) allows the user to choose any combination of land use for the study. We may, for example, specify the following land uses:

- 1 (Level 1): Urban and Built-up
- 21 (Level 2): Agriculture - Cropland, Rotation, and Permanent Pastures
- 22 (Level 2): Agriculture - Orchard, Bush Fruits, and Vineyards
- 23 (Level 2): Agriculture - Confined Feeding Operations
- 29 (Level 2): Agriculture - Other
- 31 (Level 2): Rangeland - Herbaceous
- 32 (Level 2): Rangeland - Shrub
- 4 (Level 1): Forest Land
- 5 (Level 1): Water
- 61 (Level 2): Forested
- 62 (Level 2): Non-Forested
- 7 (Level 1): Barren

For this study, the grid chosen is 32 rows by 15 columns of nearly square cells. The land uses chosen for all of Level 1 are:

- 1 - Urban and Built-Up
- 2 - Agriculture (Figure 3.2a)
- 3 - Rangeland (Figure 3.2b)

4 - Forest Land (Figure 3.2c)

5 - Water

6 - Wetlands

7 - Barren Land

2. Environmental Impact:

After the cell data file is obtained, we may, following the procedure outlined in Section II-A:

- (a) compute the different land use impact for the cells, scaled from zero through nine,
- (b) specify the weights assigned to the land uses (Figure 3.3) and compute the composite impact, scaled from zero through nine, and
- (c) display graphically any individual land use impact on the composite impact (Figure 3.4).

C. Accessibility Study

1. Data:

The region in which the study area is included is the State of Michigan which is divided into 2391 zones with given centroid locations and zonal populations. The accessibility study follows the procedure described in Section II-B with one minor modification: in order to increase the accuracy of interpolation (Equation 2.5), the study area is temporarily enlarged to include more nodes, still called data points. The new area includes 62 data points (Figure 3.5) and is covered by a grid of 45 rows by 22 columns, with the old grid imbedded (Figure 3.7).

2. Accessibility for Data Points:

Given the network file defining the nodes and links of the transportation system and the 62 data points, we can construct a 62 by 2391 skim tree table of minimum travel times from all data points to all centroids.

We use the definition given by Equation 2.3 for the accessibility values of data points and choose three time bands for each data point: 10 minutes, 20 minutes, and 30 minutes. The population within the time bands is computed for each data point. Then the accessibility values for the data points are computed according to Equation 2.3 scaled for graphic display (Figure 3.6).

3. Accessibility for Cells:

The cell accessibility values are interpolated using Equation 2.5 from data point accessibilities computed above. For this study, θ is chosen to be 0.99. The values are displayed (Figure 3.7) and "cropped" to conform to the original study area (Figure 3.8).

D. Overlap Map

We can now display the cells with various impact and accessibility ranges by overlap maps. The numbers indicated in the maps are the actual impact levels. Three such maps are displayed (Figure 3.9). In all three, ranges for impact levels are (1, 9) and that for accessibility levels are (6, 9), (4, 9), and (2, 9).

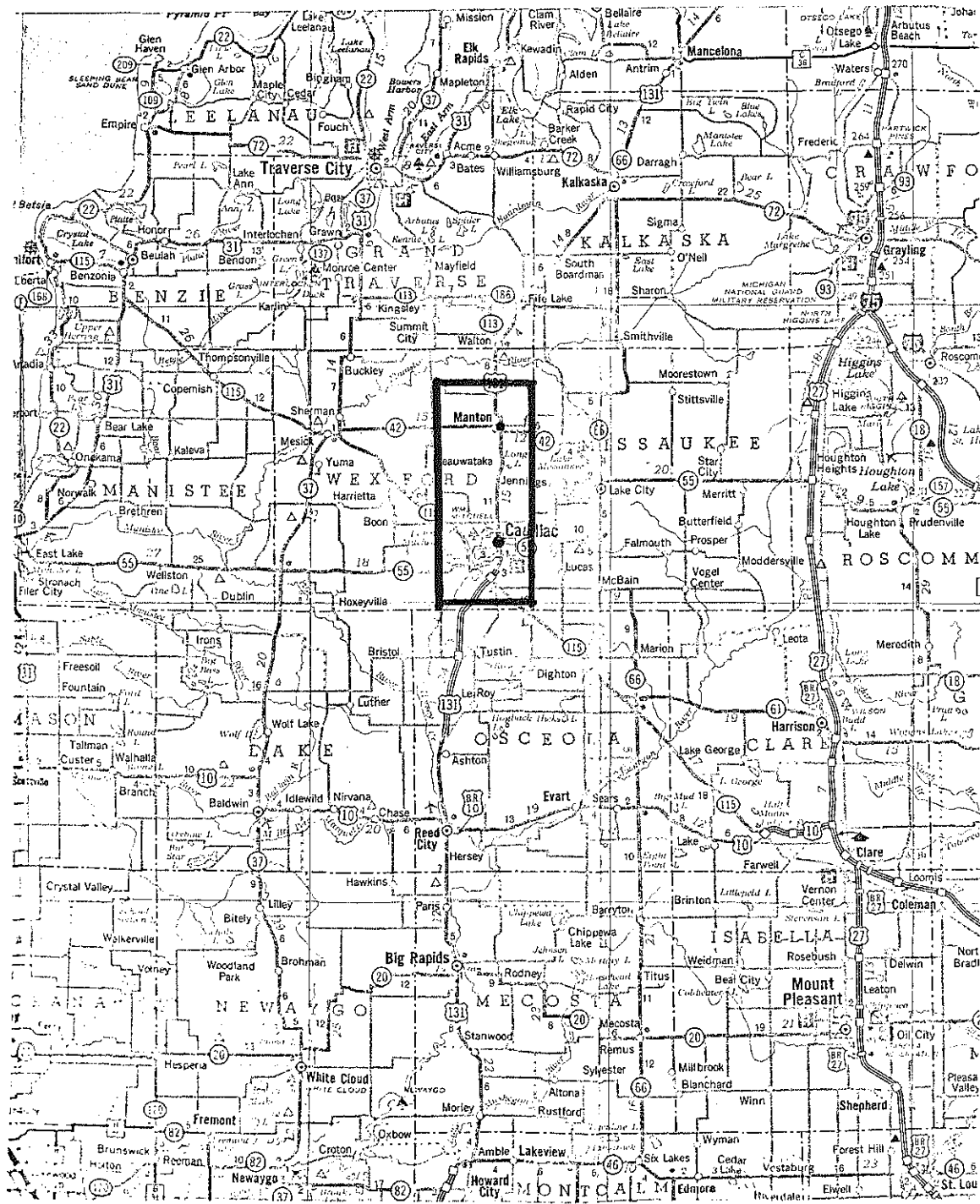
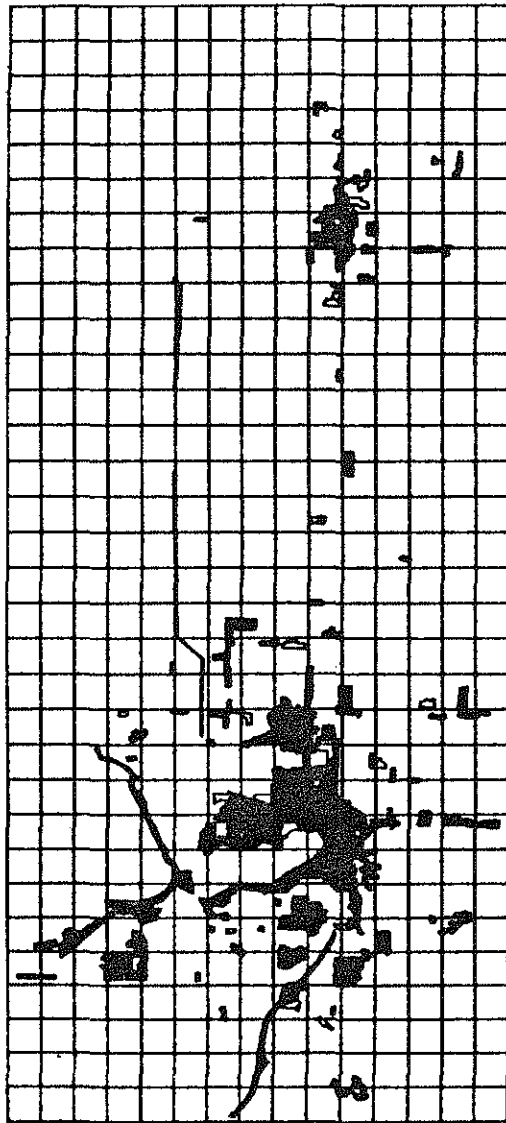
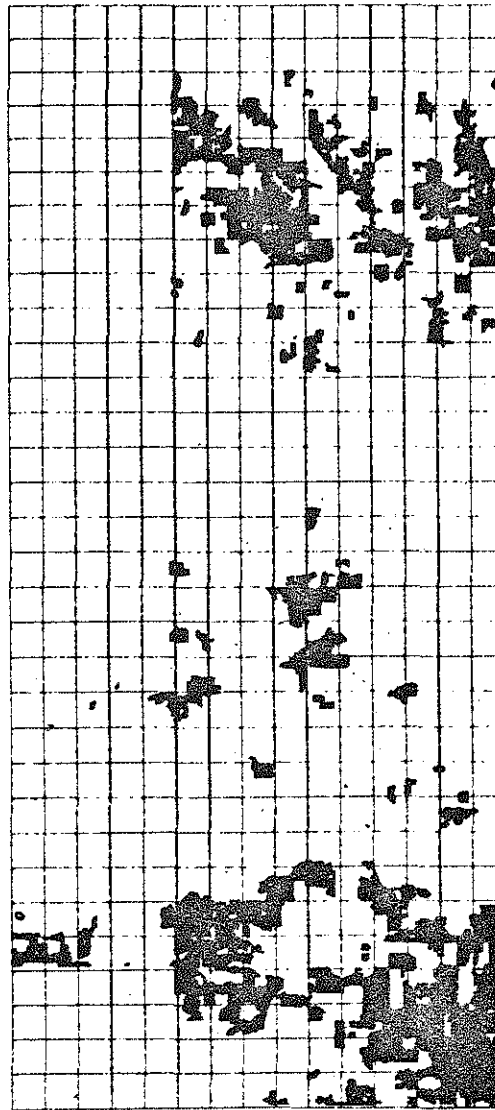


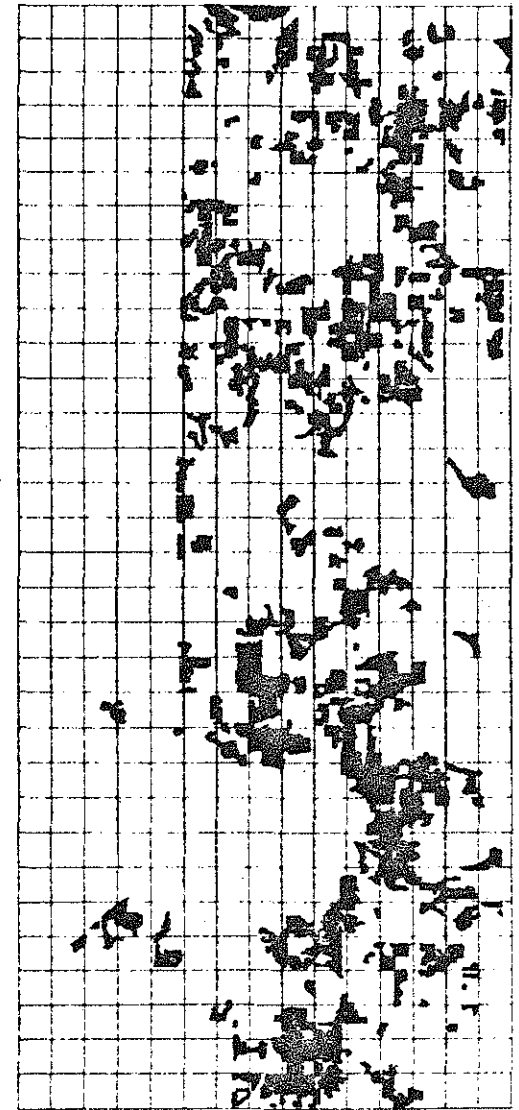
FIGURE 3.1 - Study Area



(a) Urban & Built Up



(b) Agricultural Land



(c) Rangeland

FIGURE 3.2: Land Use Resampling

PLANNING CRITERIA		
IMPACT		WEIGHT
(1)LU 1	URBAN AND BUILT UP	10
(2)LU 2	AGRICULTURE	60
(3)LU 3	RANGELAND	50
(4)LU 4	FOREST LAND	30
(5)LU 5	WATER	30
(6)LU 6	WETLANDS	10
(7)LU 7	BARREN LAND	10

FIGURE 3.3: Land Use Impact Weighing

7	6	7	8	8	8	8	8	8	8					
8	8	5	7	7	8	8	8	9	8					
7	9	7	4	7	8	8	7	8	7					
7	8	7	6	6	7	6	7	7	6					
6	7	7	6	6	7	7	8	6	5					
8	7	7	6	6	4	6	7	6	5					
6	6	6	6	2	5	7	7	7	5					
7	7	7	7	6	5	6	7	7	5					
7	8	8	7	7	7	7	7	8	5					
1	8	7	8	7	7	6	8	7	8	5				
1	8	7	7	7	7	8	7	8	9	6				
8	8	8	8	8	8	7	8	9	7					
8	8	8	8	7	8	9	9	9	7					
1	9	9	9	9	8	8	9	9	8	5				
1	8	9	9	8	8	9	8	9	7	5				
1	8	9	9	7	8	8	9	8	8	6				
1	8	9	9	8	7	7	7	9	8	6				
1	8	7	7	6	6	6	8	8	9	7				
1	6	6	7	5	5	8	9	9	8	6				
1	6	6	6	6	5	6	6	7	8	6				
4	7	7	7	7	4	1	4	6	8	8	8	6		
1	6	9	9	7	5	3	2	6	8	8	9	6		
1	8	9	6	4	1	1	5	6	6	7	6			
5	8	2	2	4	3	2	5	7	6	5				
1	7	9	9	6	2	2	5	8	9	6				
3	1	1	2	4	3	5	4	5	4	6	6	7	6	
7	5	2	3	4	6	5	6	4	5	7	5	7	5	4
5	5	3	2	5	6	6	7	4	5	4	6	6	6	5
7	7	6	4	7	7	6	7	7	4					
3	5	6	6	6	7	6	6	5	4					
4	6	6	5	7	6	7	6	4						
3	6	6	5	5	6	6	6	4						

FIGURE 3.4: Composite Impact

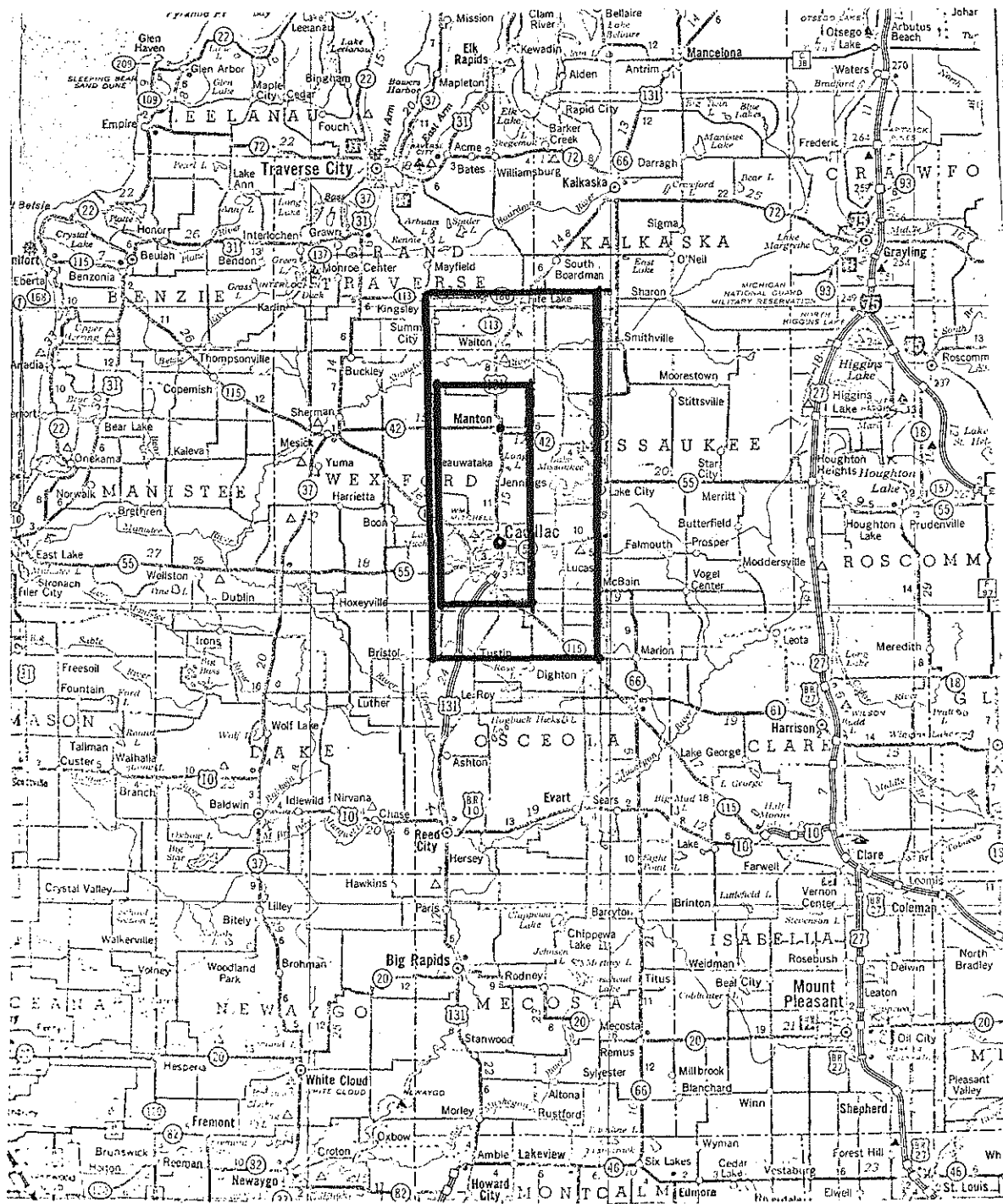


FIGURE 3.5: Accessibility Study Area

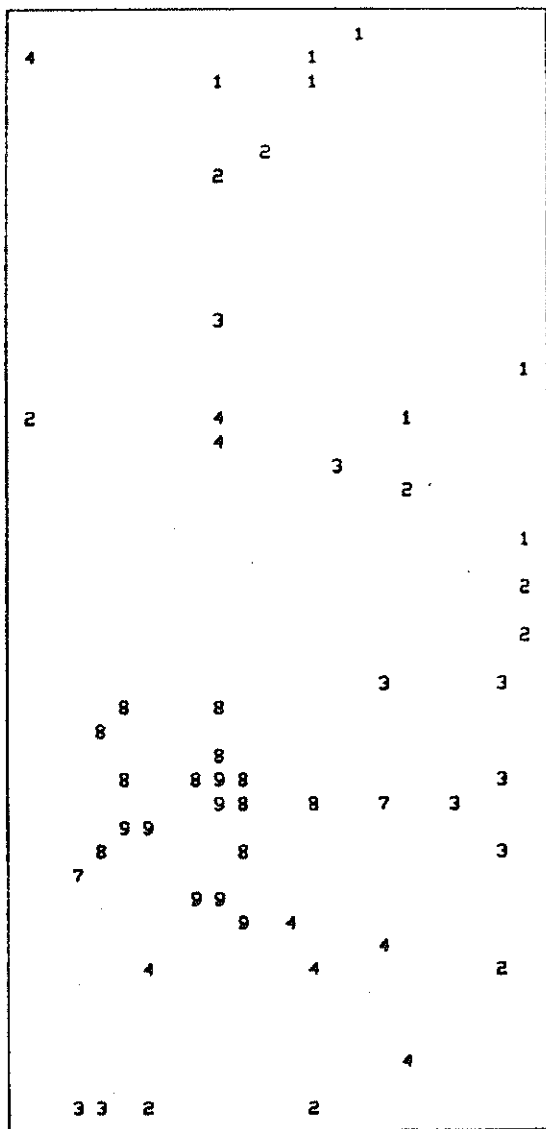


FIGURE 3.6: Node Accessibility

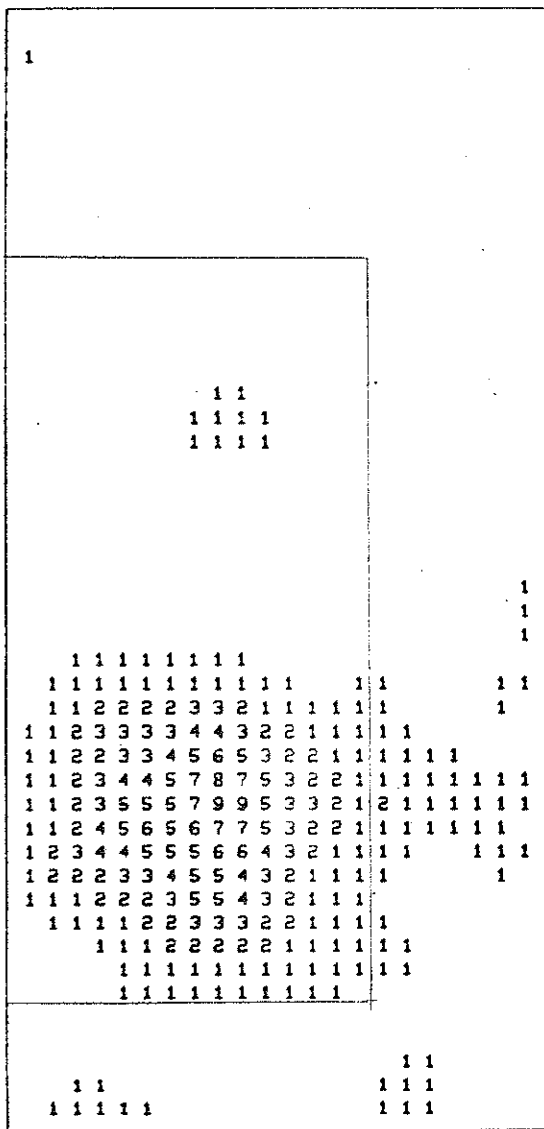


FIGURE 3.7: Cell Accessibility (Uncropped)

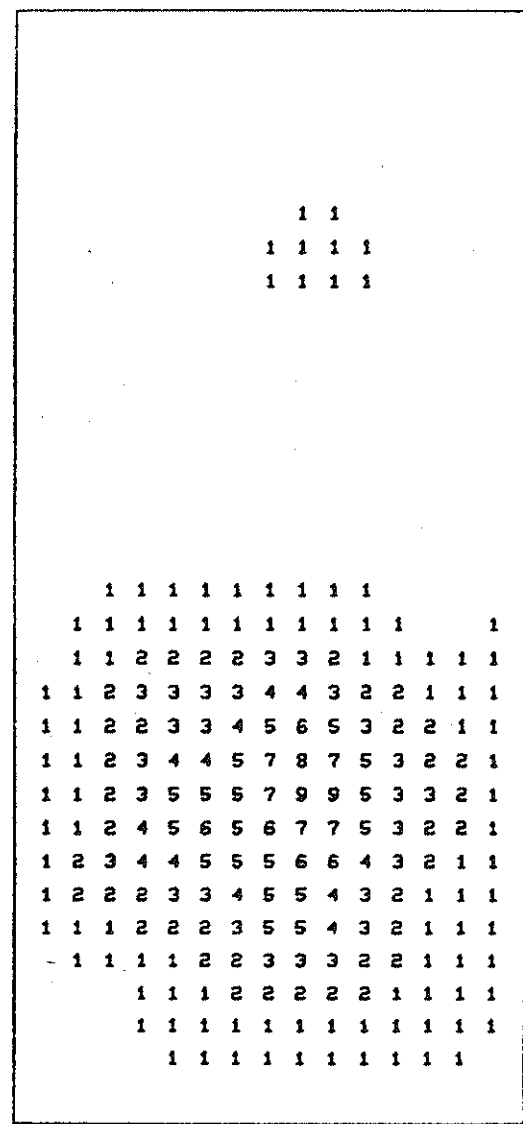
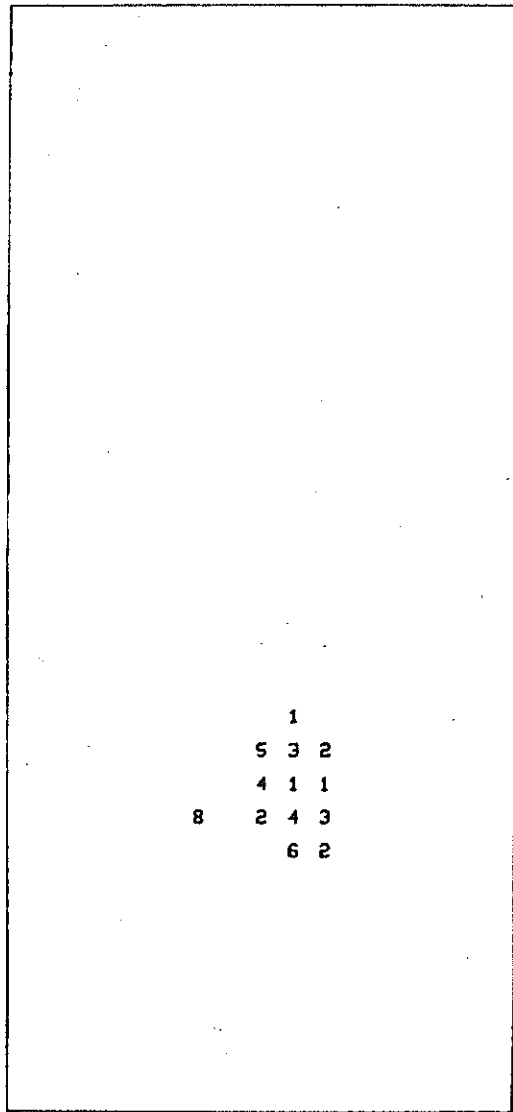
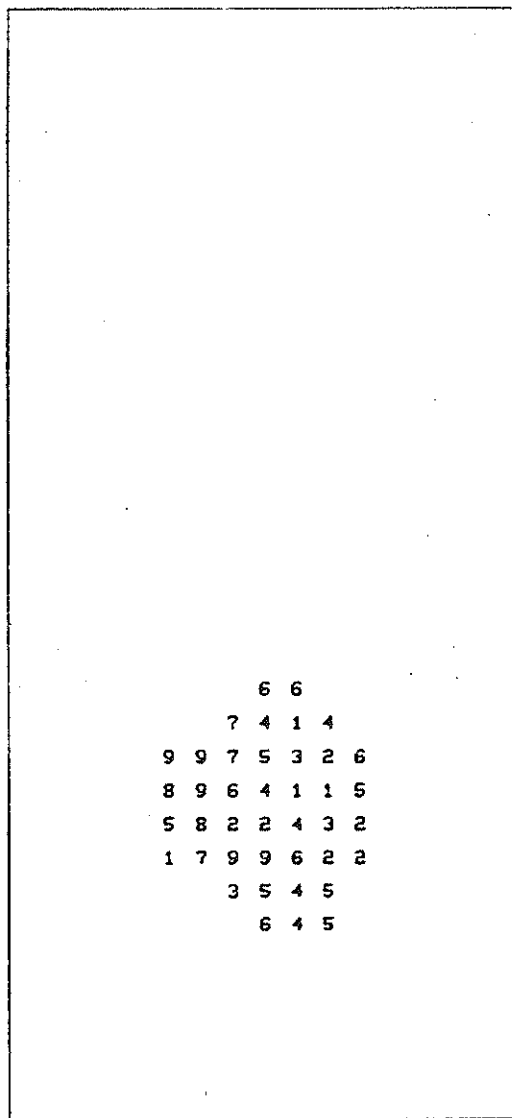


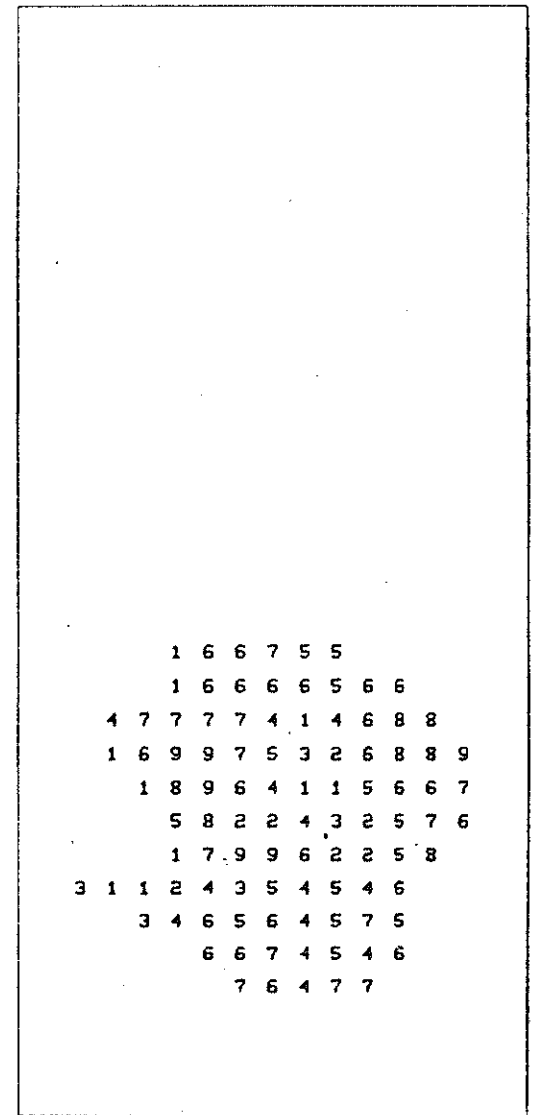
FIGURE 3.8: Cell Accessibility (Cropped)



(a) Impact (1,9)
Accessibility (6,9)



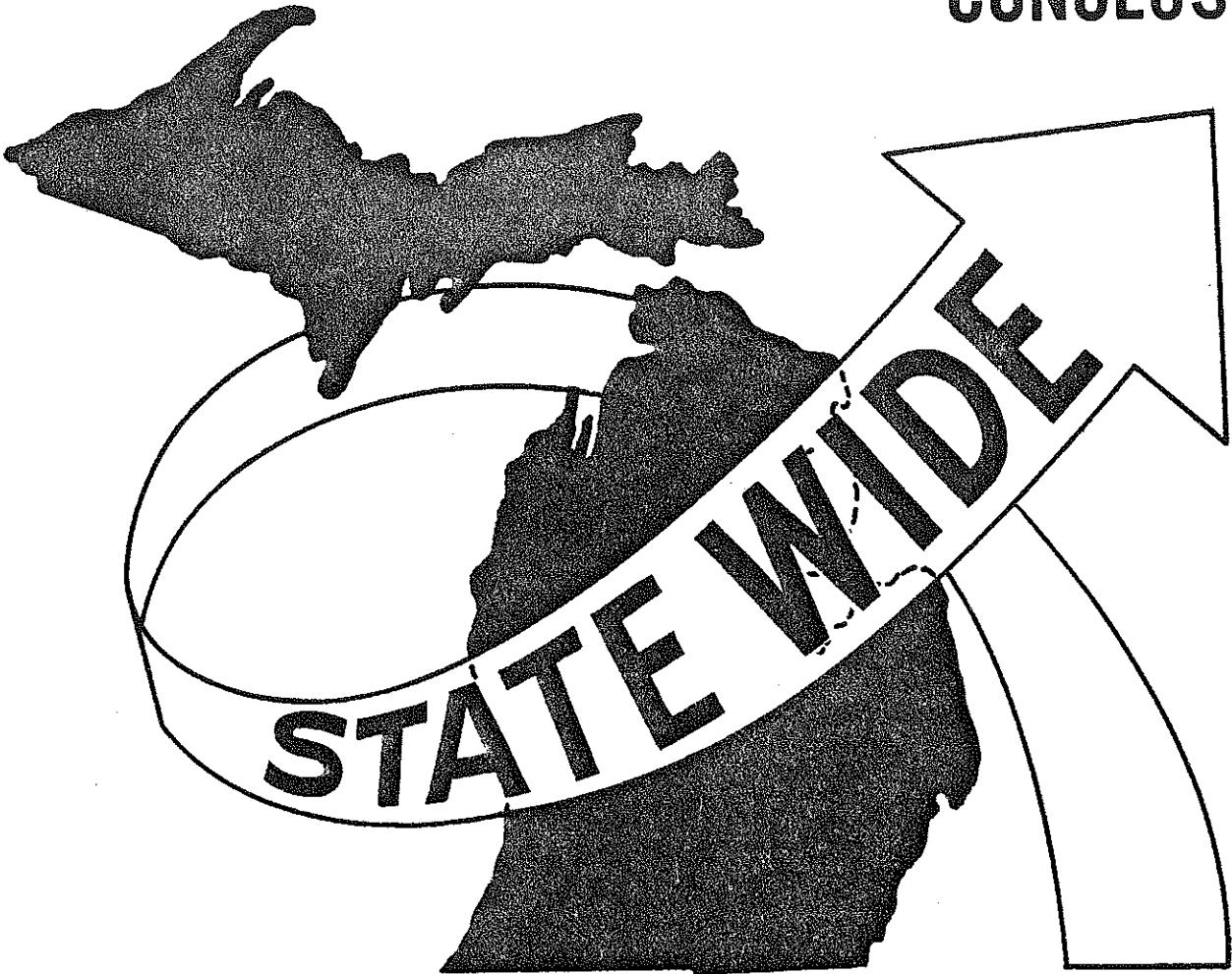
(b) Impact (1,9)
Accessibility (4,9)



(c) Impact (1,9)
Accessibility (2,9)

FIGURE 3.9: Overlap Maps With Various Ranges

CONCLUSION



CONCLUSION

It appears that the process outlined above can be quite a useful one in studying secondary impact on environmentally sensitive areas. Doubtless, as time goes on, there will be many improvements. Not only certain parts of the process may be refined, but the process may be carried further. While changing accessibility is the basic cause for urban growth and, therefore, secondary impact, it still remains to predict such growth and impact precisely.

Nevertheless, we feel it is an important first step toward such a goal as well as a useful tool in its own right.