A REVIEW AND EVALUATION OF THE TRI-COUNTY REGIONAL PLANNING COMMISSION HOUSEHOLD DISTRIBUTION MODEL

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A REVIEW AND EVALUATION
OF THE
TRI-COUNTY REGIONAL PLANNING COMMISSION
HOUSEHOLD DISTRIBUTION MODEL

By

James Remie Verougstraete

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ABSTRACT

A REVIEW AND EVALUATION OF THE TRI-COUNTY REGIONAL PLANNING COMMISSION HOUSEHOLD DISTRIBUTION MODEL

By James Remie Verougstraete

"From its very beginning, early in this century, urban planning in the United States has become progressively more "quantative" through growing uses of numerical data and introduction of large scale information-handling procedures and mathematically formulated analytical techniques. In the past few years significant new needs and capabilities have quickened that trend to the point of a methodological revolution."[1]

As planners become more aware of the complexities of the urban regional environment, an ever increasing need will be felt to better quantify, analyze and understand the intricate components of urban change and their causal relationships. Planners in recent years have found that by using electronic digital computers they can greatly enhance their understanding of the environment. Moreover, the data handling capabilities of the computer can free the planners to perform more important functions and undertake tasks which before were physically impossible.

Freund, Eric C. and Goodman, William I., Principles and Practices of Urban Planning, Municipal Management Series, Washington, D.C., International City Managers Association, 1968, p. 227.

James Remie Verougstraete

Comprehensive plan preparation is one of the most important areas of planning to which the computer has been applied. Various modeling techniques have been formulated which take advantage of the data handling capabilities and speed of the computer to improve the quality and utility of the comprehensive plan. These techniques have enabled the planner to objectively view the community, identify its components, develop and test his theories, and formulate future development schemes based on realistic controls and policies.

In 1963, the Tri-County Regional Planning Commission undertook an extensive land use -- natural resource -- transportation study which culminated in a Comprehensive Regional Development Plan. Several transportation and land use models were developed for this purpose which relied on the extensive use of computers. These models formed the core of the study and were devices that were used to generate the basic ingredients of the comprehensive plan.

The overall purpose of this thesis will be to review and evaluate the household distribution model which was developed and used by the Tri-County Regional Planning Commission. In so doing, attention will be given to the technical, theoretical and operational aspects of the model as well as the role it played in the planning process.

Background material for this study was obtained from various published and unpublished reports as well as the personal involvement in the study on the part of the author. Much of the data and information contained herein were derived from various inventories and interviews conducted by the Commission.

The scope of this thesis was limited to a case study of the household distribution model. Consideration was given in this review and evaluation to a description of the area under study, highlighting the major features which influenced the models' design; a review of the procedures, considerations, and techniques used to create the model; and an evaluation of the model concerning its theoretical base, the variables which were used, and its technical and operational features.

ACKNOWLEDGMENTS

The successful completion of this thesis stems from the concern and encouragement of many people. A special thanks is gratefully extended to Assistant Professor Effat Mansour who provided encouragement and guidance throughout this project and offered valuable advice and criticism at every stage. Professor Keith Honey and Assistant Professor Richard Anderson are commended for their review and critique of this manuscript.

Finally, my parents and wife deserve special recognition and thanks for their patience and faithful support.

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CHAPTER I

INTRODUCTION

DESCRIPTION OF THE STUDY AREA

The study area, Lansing Tri-County Region, consists of three counties, Ingham, Eaton, and Clinton (Figures 1 and 2). This region is located in the south-central part of Michigan's lower peninsula and contains the capital city of Michigan. The neighboring cities of Lansing and East Lansing are the two largest urban communities in this region. In total there are 75 cities, villages and townships in this tri-county area and when combined, they form a total land area of 1,700[1] square miles.

There are three main components of the region's economy which are largely responsible for the historical growth and development of the area. The first of these components to come to the Lansing area was the capitol of the State of Michigan in 1847.[2] In 1855, Michigan Agricultural College was established in East Lansing and later became Michigan State University.[3]

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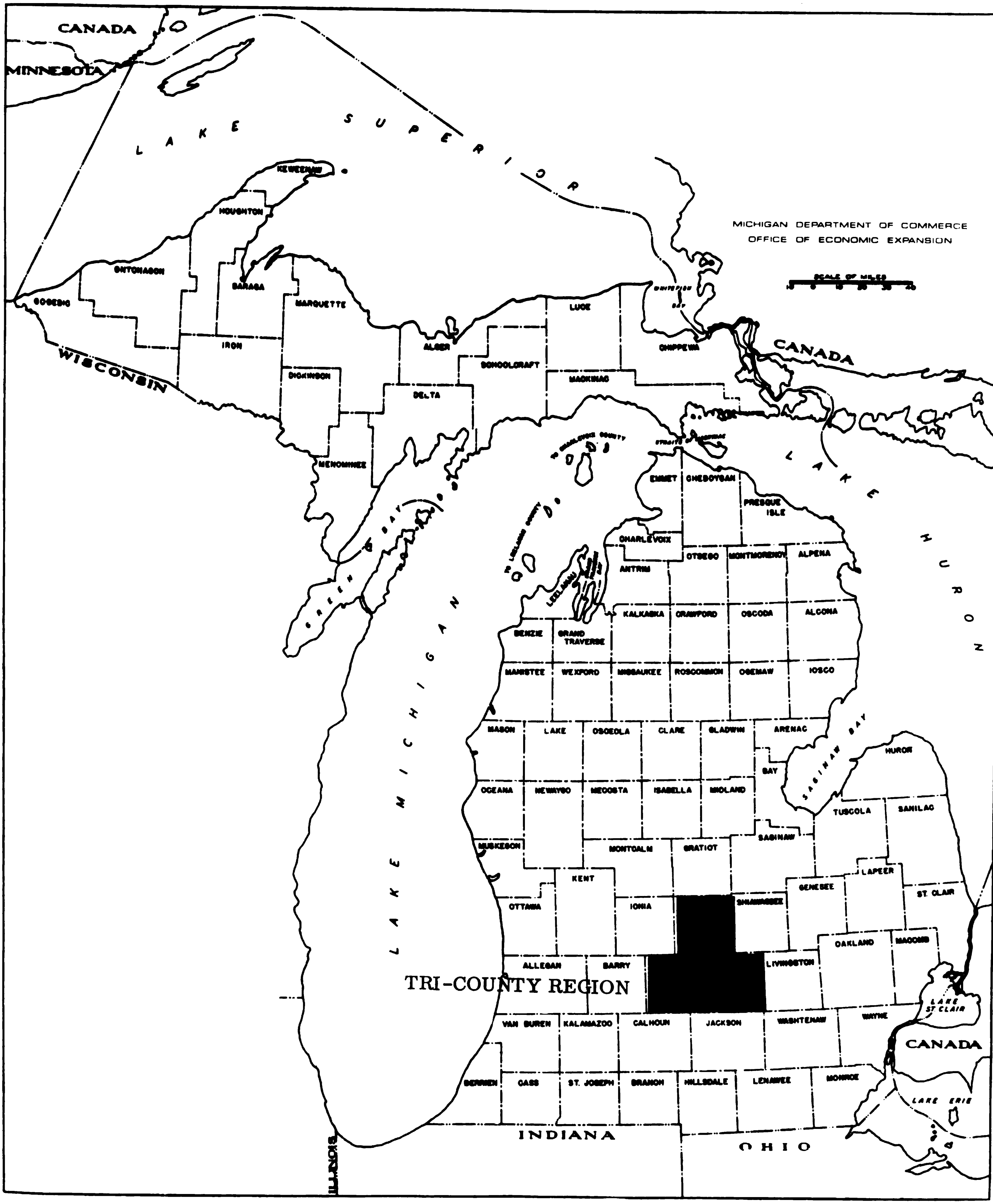
[1]Tri-County Regional Planning Commission. Mass Transportation in the Tri-County Region. Lansing, Michigan: Tri-County Regional Planning Commission, April, 1969, p. 3.

[2]Bureau of Business and Economic Research, College of Business and Public Service. Economic and Population Base Study of the Lansing Tri-County Area. East Lansing, Michigan: Michigan State University, July, 1958, p. 6.

[3]Tri-County Regional Planning Commission. "History of the Tri-County Region; Information Report #7". Lansing, Michigan: Tri-County Regional Planning Commission, 1966, p. 25.

MICHIGAN COUNTIES AND THE TRI-COUNTY REGION



LANSING TRI-COUNTY REGION

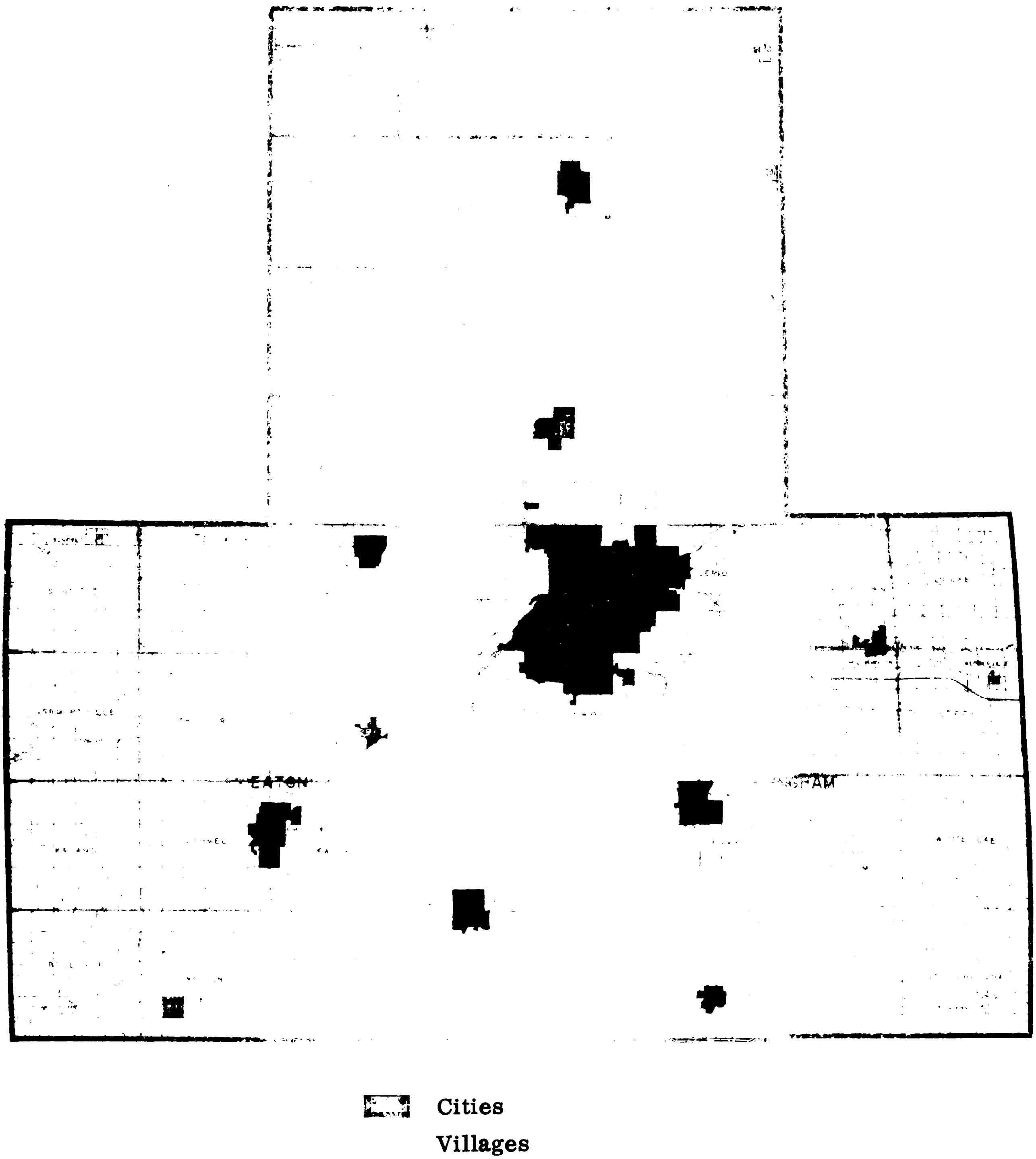


PLATE 2

Lastly, the Oldsmobile Corporation located its primary base of operations in the City of Lansing in 1886.[1] Each of these major employers has experienced large scale growth and thereby provided the catalysis for dramatic change in the development of the region.

[1] Bureau of Business and Economic Research, College of Business and Public Service, op. cit., p. 7

The following table provides a general indication of the relative historical growth rates for ingham, Eaton and Clinton Counties from 1900 through 1960.[1] The population forecasts for 1965 through 1990[2] are considered to be rather conservative estimates of the regions growth potential.

TOTAL POPULATION

Year	Clinton County	Eaton County	Ingham County	Total Region
1900	25,136	31,668	39,818	96,622
1910	23,129	30,499	53,310	106,938
1920	23,110	29,377	81,554	134,041
1930	24,174	31,728	116,587	172,489
1940	26,671	34,124	130,616	191,411
1950	31,195	40,023	172,941	244,159
1960	37,969	49,684	211,296	298,949
1965	42,175	57,725	242,325	342,225
1970	48,565	66,595	278,610	393,770
1975	54,360	75,605	309,765	439,730
1980	58,540	87,800	341,530	487,870
1985	70,100	102,480	366,820	539,400
1990	77,825	113,175	399,650	590,650

As mentioned earlier, the region consists of 75 separate but related functional governmental units all of which vary in size, levels of activity and areas of influence.

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[1]U.S. Bureau of the Census. Census of Population and Housing: 1840-1960. Washington, D.C.: U.S. Government Printing Office, Department of Commerce.

[2]The population forecast from 1965 through 1990 were obtained from the Tri-County Regional Planning Commission Cohort Survival Model.

In order to establish a logical framework for analysis and description of the region and its characteristics, each community has been classified according to four major community types. The criteria used to establish this classification scheme was based on various measures which define the level of influence and role of each community. Included in this analysis are different measures of population, employment, levels of urban services, areas served by local newspapers, local trade areas, school districts and residential densities.[1] The following four major categories of community types were developed:

1. Urbanized Core Area
2. Major Urban Communities
3. Urban-Rural Centers
4. Agricultural Areas

The study area consists of a single dominate urban core (Central Urbanized Area), six Major Urban Communities, eighteen Urban-Rural Centers, and a large unincorporated Agricultural Area. The following is a brief description of the study area in terms of these community types and their characteristics, roles and level of influence.

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[1]Tri-County Regional Planning Commission. The House We Live In; A Comprehensive Growth Plan. Lansing, Michigan: Tri-County Regional Planning Commission, September, 1968, p. 44.

THE URBANIZED CORE AREA

The urbanized core area, as shown in Figure 3, consists of the Cities of Lansing and East Lansing as well as Meridian, Delta and Dewitt townships. The relative togetherness of this area is in part reflected by the fact that this was the only portion of the entire region which was tracted by the Bureau of Census in 1960.

The most notable characteristic of this area is that it contains 85 percent of the region's employment base.[1] As mentioned earlier, this is due largely to the presence of Michigan State University, Michigan State Government, and the Oldsmobile Corporation. However, there are many other large employers in this area which have assisted in establishing this fact.

There are more jobs, with a wider range of diversification, available in the Urbanized Core Area than anywhere else in the region. Moreover, the level of educational attainment of the area's residents is much greater than elsewhere in the region. The presence of many students at Michigan State University and the highly-trained personnel that are attracted to the State Government employment base contribute heavily to the phenomenon.

Tri-County Regional Planning Commission. Regional Data Book; Information Summary by Metro Center Type by Jurisdiction. Lansing, Michigan: Tri-County Regional Planning Commission, May, 1969.

COMMUNITY TYPES

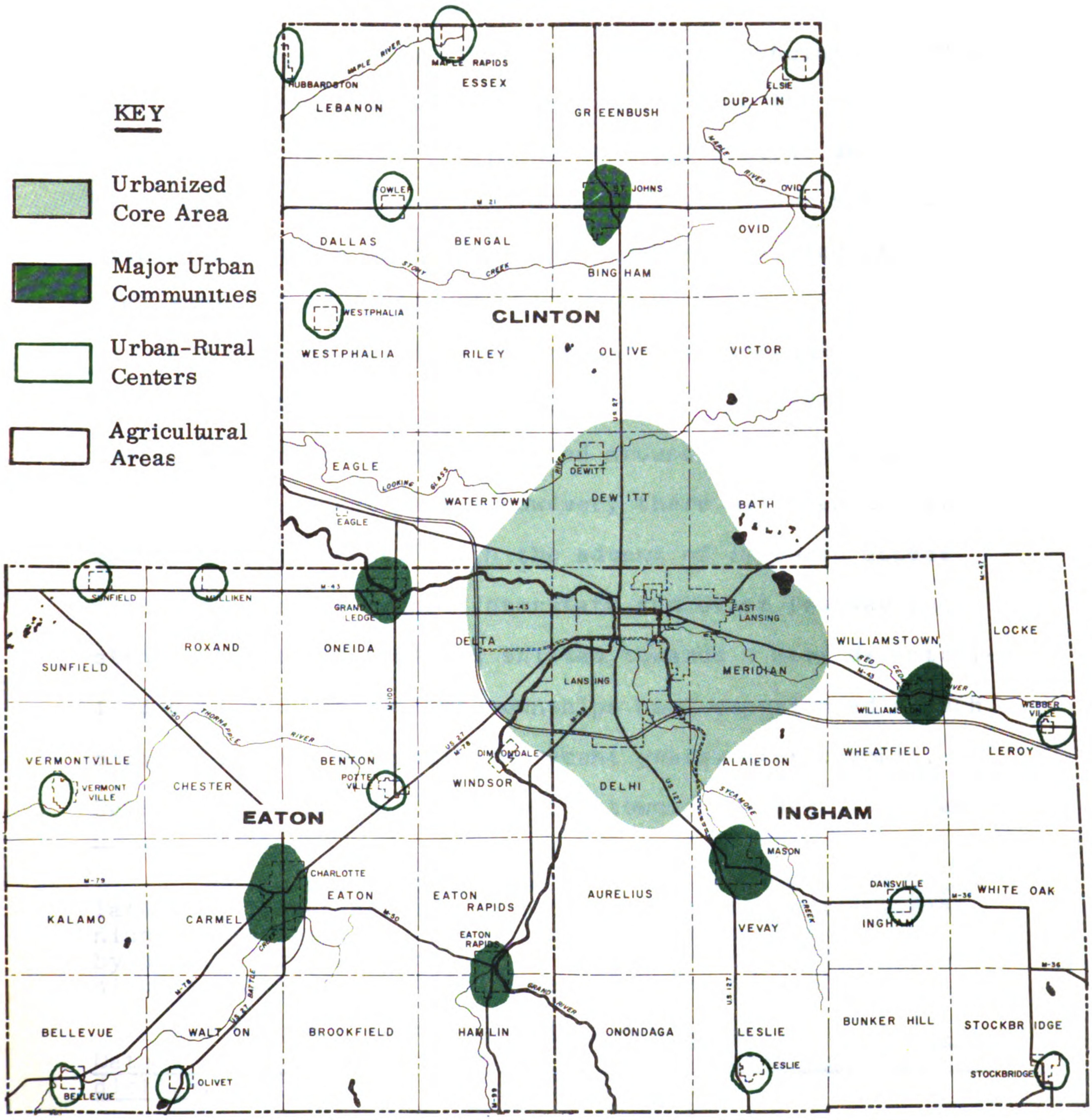

FIGURE 3

Although the Urbanized Core Area is relatively small in total area, when compared to the entire region, it contains 70[1] percent of the total regional population. Moreover, 72[2] percent of the total households in the region can be found in this area. Although the residential density of this area is significantly higher than all other sub-units within the region when compared to other urbanized areas of comparable size, it is quite low.

Historical development patterns throughout the region have tended to be compact and centralized because past development has concentrated around existing urban centers. In recent years, however, there has been a shift away from this trend. With the advent of improved access made available by recent interstate and other freeway construction, development has shifted towards a more decentralized pattern. The fringe townships have experienced a much more rapid rate of growth in recent years. For example, Delta, Delhi, Meridian and Dewitt townships have increased in

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[1]The above population data was obtained from population estimates derived from the Tri-County Regional Planning Commission data files. These estimates were provided by updated household counts by census tract and household size estimates from a 1965 Home Interview Survey.

[2]Tri-County Regional Planning Commission. Regional Data Book; Information Summary by Metro Center Type by Jurisdiction, op. cit.

total population by 32[1] percent from 1960 to 1965 as compared to an increase of only 16[2] percent from 1955 to 1960.

The racial composition of the Central Urbanized Area varies quite significantly from the balance of the region. For example, of the region's total non-white population in 1965, 97 percent lived within the Central Urbanized Area.[3] Moreover, 80 percent of the non-whites live within the corporate limits of Lansing City.[4] The general economic status of the non-white is significantly less desirable than that of the white population. For example, the median family income of a non-white in the central Lansing area is $5950, whereas the balance of the community enjoys a median income of $7382.[5]

Single-family detached homes, on large lots, are the predominate housing style of the Urbanized Core Area. It was not until the early 1960s that any significant level of apartment development became known to the area. Michigan State University has maintained a policy of providing all the neces-

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[1]The above population data was obtained from population estimates derived from the Tri-County Regional Planning Commission data files. These estimates were provided by updated household counts by census tract and household size estimates from a 1965 Home Interview Survey.

[2]Ibid

[3]Ibid

[4]Tri-County Regional Planning Commission. Regional Data Book; Information Summary by Metro Center Type by Jurisdiction, op. cit.

[5]T.C.R.P.C. 1965 Home Interview Survey.

sary housing facilities for both married and single students on the campus. However, in the early 1960s, private developers began an ambitious program of building off-campus apartment units in large quantities. From 1960 to 1965, 3547 new apartment units were added to the housing stock of East Lansing as compared to a total of 7607 units that were available prior to that time.[1] This trend has since been carried over into the City of Lansing.

The Urbanized Core Area is the financial and trade center of the region. This area has a complete set of both public and private urban services. For example, nearly all of the City of Lansing and East Lansing are presently served with both public sewer and water facilities. The central business district, located in the City of Lansing, is the only facility in the entire region which can be considered a regional-type shopping facility.

Due to the rapid growth rates in the fringe areas and the inability of these townships to meet the demands of this increased urbanization, serious development problems are beginning to become apparent. These townships are not financially capable of meeting the demand for such services as sewer and water facilities. As a result, they are characterized by

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[1] Mason, Jackson, and Kane, Inc. Housing in Lansing. Lansing, Michigan: Mason, Jackson, and Kane, Inc., Architects, 1968.

over-taxed sewer systems, inadequate streets, and the general lack of coordinated and sound development control practices.

MAJOR URBAN COMMUNITIES

As illustrated in Figure 3, there are a total of six communities which are classified as "Major Urban Communities;" Williamston City, Mason City, Eaton Rapids City, Charlotte City, Grand Ledge City, and St. John's City. The most distinguishing feature that sets these communities apart from the rest of the region is simply that each has a major and independent economic base. Although it is not comparable in terms of size and diversity to that of the Central Urbanized Area, it is nevertheless self-sufficient. For example, three of these communities are the seat of their respective county governments. Also, each has some measure of industry which provides a local demand for various job skills.

The retail services provided by these communities are relatively large in proportion to the size of the communities themselves. The primary reason for the disproportionate size is that the rural areas which surround each of these communities are highly dependent upon them to satisfy many of their basic retail and service needs. The type of retail facilities that are located in these communities are oriented towards convenience-type goods. Although some comparison goods are offered, it is not of the scale that would seriously compete with the central business district of the Urbanized Core Area. Therefore, these communities rely very strongly on the City of Lansing to provide comparison goods and supply special regional-type services.

Another form of the reliance of these communities upon the Central Urbanized Area is for employment opportunities. Many of these residents find it desirable to live in the outlying communities and work in the Urbanized Core Area because of excellent transportation linkages.[1] Thus, they are able to enjoy the pleasures associated with small town living and at the same time, avail themselves of the employment advantages offered by the larger city.

In summary, these communities represent very pleasant and quiet satellite communities with their own economic base which enables them to be somewhat independent of the Urbanized Core Area's influence. They range in population size from 2325 to 8425.[2] The predominate housing types consist of single-family dwellings at a very low density with a notable lack of multi-family units. These communities have little or no racial

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[1] Tri-County Regional Planning Commission 1965 Land-Use, Natural Resource, Transportation Study.

[2] Tri-County Regional Planning Commission data files, updated household counts by census tract and household size estimates from a 1965 Home Interview Survey.

mix. The median family income is $6523 as compared to the regional median of $7047.[1]

URBAN-RURAL CENTERS

Throughout the region there is a total of eighteen small incorporated places which are referred to as "Urban-Rural Centers." The population of these communities range from 100 to 2,000 people.[2] The most distinguished feature of these centers, which separates them from all others, is the strong orientation toward the rural element of the region. Most of the communities are rather isolated from the other major centers as they are scattered throughout the fringe of the regions. Secondary roads are their only transportation link with other major urban areas.

From 1960[3] to 1965,[4] the total population of these communities grew by 2032 persons as compared to a 2811[5] population increase for the "Major Urban Communities" and a 32,333[6]

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[1] Ibid

[2] Ibid

[3] U.S. Bureau of the Census. U.S. Census of Housing and Population: 1960. Washington, D.C.: U.S. Government Printing Office, Department of Commerce, February, 1962, pp. 13-42.

[4] T.C.R.P.C. Data Files, op. cit.

[5] U.S. Bureau of the Census, op. cit.

[6] T.C.R.P.C. Data Files, op. cit.

population increase for the "Urbanized Core Area" for the same period. (Most of this change has been a direct result of natural increase--births exceeding deaths.) The younger-age groups have found it more advantageous to establish residence in the larger cities because of better employment opportunities. As a result of this out-migration, many of these communities have experienced very low growth rates and some even a net loss of population.

In these areas there is a general lack of all types of urban services; for example, most of these communities cannot afford full-time police or fire department personnel. Also, some of the communities do not have any public sewer facilities.

The retail base of these centers is limited to a very small number of establishments which offer strictly convenience-type goods. For example, the average number of retail employees in 1965 for an Urban Rural Center was 41.[1] It is obvious that the residents must depend on other larger communities to fulfill their needs.

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[1] Tri-County Regional Planning Commission. Regional Data Book; Information Summary by Metro Center Type by Jurisdiction, op. cit.

AGRICULTURAL AREAS

The balance of the region consists largely of agricultural and undeveloped land. This portion of the study area is composed of approximately 966,000 acres or 87 percent of the total regional land area.[1] The total population of this area is 17,695 or 5 percent of the regional total.[2] Twenty-four percent of the people who live in this area are employed in agricultural and related jobs.[3] The remaining 76 percent of those employed have jobs in the cities throughout the region. The median family income in 1965 was $6400, which is substantially lower than the regional average.[4]

DESCRIPTION OF THE TRI-COUNTY REGIONAL PLANNING COMMISSION LAND-USE, NATURAL RESOURCE, TRANSPORTATION STUDY

Following is a brief discussion of the Tri-County Regional Planning Commission's program. This discussion is intended to set the stage for a more detailed description of the household distribution model which was developed as a part of this study. It is hoped that this will be accomplished by placing the model in the context of an ongoing organization

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[1] Tri-County Regional Planning Commission 1962 Land Use Inventory.

[2] T.C.R.P.C. Data Files, op. cit.

[3] T.C.R.P.C. 1965 Home Interview Survey

[4] Ibid

and focusing on specific studies that have particular importance to the model.

In 1964, the Tri-County Regional Planning Commission began a rather extensive land-use, natural resource, transportation study, which was to culminate in a well-organized comprehensive regional development plan. The study consisted of six major phases.[1] The initial phase of the program was the undertaking of several inventories. The purpose of these inventories would provide a sound basis for estimating future changes by identifying and quantifying various trends, relationships, standards and problems. The data produced from these inventories were to become the statistical base for the models.[2] The analysis phase of the study was intended to examine the inventory data to determine which variables were best suited to describe the region in terms of change, travel, and land-use activity. The analysis was also to be used to formulate goals and objectives concerning regional development policies.[3] The forecasting portion of the study was intended to provide realistic estimates of future growth and its characteristics and to

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Tri-County Regional Planning Commission. <u>Tri-County Regional Land-Use, Natural Resource, Transportation Study; Study Design</u>. Lansing, Michigan: Tri-County Regional Planning Commission, November, 1964, p. 14.

<u>Ibid.</u>, p. 8

<u>Ibid.</u>, p. 11

provide an opportunity to relate desired goals to expected development.[1]

The policy plan formulation phase provided a well-defined set of goals and objectives. These would be presented to the community leaders for their opinions and recommendations in order to reach a general agreement on future growth proposals for the region.[2] The plan preparation phase was designed to provide an opportunity to test the models which were developed concerning the limits and effects of policy decisions on the development patterns of the region. The product of this phase was to be a short and long-range comprehensive plan which represented a realistic and desirable set of policy decisions and assumptions.[3] The plan implementation phase of the program proposed to develop and use techniques to secure public awareness, acceptance and understanding of the plan. This plan was to be related to existing financial and legal capabilities of local governmental units.[4]

It was recognized throughout this study that a great share of the data being collected would eventually be used in either the transportation model or the household distribution model which would be developed later. Therefore, a serious

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[1] *Ibid.*, p. 13.

[2] *Ibid.*, p. 15.

[3] *Ibid.*, p. 16.

[4] *Ibid.*, p. 18.

effort was made to store these data on machine-readable cards or magnetic tapes to facilitate quick and accurate utilization.

The Commission, upon recognizing the relative importance of the transportation system in shaping the economic and physical characteristics of the region, chose to use the most sophisticated tools available for dealing with this element of the plan. Essentially, this meant the use of modeling techniques at a level that was within the economic grasp of the program. The services of Allan Voorhees and Associates were obtained as consultants to assist in the performance of this task.

The Transportation Model used in this study consisted of four major elements: trip generation; trip distribution; traffic assignment; and modal split analysis.[1]

The trip generation model was designed to establish a mathematical relationship via the regression analysis technique, between the number of trips produced in or attracted to a specific traffic zone and the characteristics of that zone. Generally, the characteristics used to estimate trip generations were such elements as median family income, total households, residential densities, auto ownership, and employment types. Once a correlation was derived between trips and characteristics, this model was used to forecast future trips based on expected, programmed, or projected characteristics of each zone.

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[1] Ibid., p. 13.

The trip distribution model was used to determine the exchange of these trips between 411 different traffic zones in the region. This model was essentially a gravity model which determined future trip distributions based on the types of activities performed in each zone and the spatial distance from each zone to all other zones. This distance is a function of time and is expressed as an accessibility factor.[1] The traffic assignment model was used to assign all the trips among zones to available transportation routes. All trips were assigned to the network along those routes which would require the least travel time.

The modal split analysis was used to divide all the trips between auto and transit travel modes. This division was accomplished by factors which described the demands for transit, using costs, travel time, convenience, and various other factors which influence the choise between the private automobile and mass transit.

The household distribution model, as will be discussed in much more detail in Chapter II, was based on the same principles as the transportation model. That is, the distribution model was essentially a regression model which produced population distribution allocations based on a mathematical relationship between the number of households attracted to an area and the physical, social and economic characteristics of that area. These characteristics included such variables

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[1]Tri-County Regional Planning Commission 1965 Home Interview Survey.

as levels of community services, elementary schools, residential densities, median family incomes, holding capacities, accessibility to employment centers and shopping facilities, and types of land-use activities. In addition to providing many of the inputs required by the transportation models, this model was intended to be a guide to decision-makers in evaluating the impact that certain policies have upon the social and economic character of the study area.

CHAPTER II

REVIEW OF THE TRI-COUNTY REGIONAL PLANNING COMMISSION HOUSEHOLD DISTRIBUTION MODEL

CHAPTER II

REVIEW OF THE TRI-COUNTY REGIONAL PLANNING COMMISSION HOUSEHOLD DISTRIBUTION MODEL

INITIAL DESIGN CONSIDERATIONS

The initial task in preparing the household distribution model was to determine its function and role within the total planning process of the commission. First, it was decided that the model should yield household allocations for relatively small geographic units in order to satisfy the data needs of the transportation models, and more importantly, provide data at a level of detail required to prepare a comprehensive development plan. As the size of the geographic area for which forecasts are made decreases, the probability of error increases significantly. Therefore, it was felt that there was an urgent need to develop a regional population forecast which would serve as realistic regional control totals of population in order to maintain control over any errors that might result from the model's small area allocations. Prior to the preparation of a household distribution model, population forecasts were prepared for the total region using the Cohort Survival technique.[1] The output from this model thereby became the control total for the household distribution model.

The second phase was to undertake an extensive review

[1]A Cohort Survival model was written for the IBM 1401 computer and used to generate forecasts of total population by five-year age-sex groups and five-year increments from 1960 through 1990.

of existing modeling techniques. These techniques will be discussed in more detail in Chapter III. At the conclusion of the review, it was determined that the regression analysis techniques were best suited to the needs and financial resources of the study. Given the framework, limitations and constraints of this technique, a series of initial design decisions were made which influenced the content and form of the model. The initial task was to define the dependent variable; that characteristic or element that is to be forecasted. Although the output from the cohort survival model was to be used as the forecast variable, it was determined that it would be more desirable to allocate households rather than individual persons. Since location decisions are made collectively as a group of persons which constitute a household, it is more logically correct to allocate households rather than individuals.[1]

The model was further designed to produce allocations of households for relatively short periods of time; five-year increments. It was felt that a five-year span of time would best suit both long-range and short-range planning needs. Under this type of system, the output from each period would become, in part, the input for the next forecasting period. There are two basic advantages to this type of short

[1]Tri-County Regional Planning Commission. Small Area Population Forecasting Models. Lansing, Michigan: Tri-County Regional Planning Commission, March 1, 1966, p. 11.

cycle system--first, it is possible to better update the characteristics (inputs) of the region as close as possible to the time when these events or programs are expected to occur. The programs and events referred to include such activities as highway plans and programs, urban renewal projects, sewer and water extensions, and public land acquisition programs. Secondly, it is also easier to calibrate the model because the patterns of development and growth are clearer and more obvious.[1]

It was also decided to use the model as a tool for evaluating various policy decisions concerning their impact on development patterns. Therefore, it was necessary to incorporate various forms of these policies into the model as independent variables. These policy variables included such land use controls as zoning constraints, which influence residential densities and land uses, as well as measures of public services such as transportation facilities, schools, and sewers.[2] In order to achieve desirable development patterns, the planner, by including variables which are effected by public policy, would be able to determine the types and extent of various policies.

In selecting a time period upon which to formulate the model, it was felt that a current period would be most desirable. In an effort to make the initial regression per-

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[1] _Ibid._, p. 12.

[2] _Ibid._, p. 12.

iod as current as possible, the time interval from 1960 to 1965 was selected. Although this placed serious demands on data gathering aspects of the study, benefits far exceeded the added costs. A regression analysis model assumes that the relationships that are determined from the period on which the regression analysis was performed will remain constant throughout the forecast period. In order to achieve a regression equation which is representative of current development influences, it is both logical and necessary to perform that regression on as recent a time period as possible.

CENTRAL HYPOTHESIS OF THE DISTRIBUTION MODEL

In its simplest form, this distribution model is built on the hypothesis that each sub-area in the region has a set of identifiable and measurable characteristics which have a significant influence on collective household location decisions. In other words, the model assumes that households are attracted to various areas within the region because these areas have specific amenability characteristics which directly or indirectly exert an influence on where they will locate. These characteristics included some measure of the physical and social environment such as total vacant land and existing developed acreage, policy characteristics of urban services such as the level of sewer and water services, and an indication of the functional relationships between areas such as accessibility to work and shopping. It was felt that there are several types of characteristics within each of these categories that have influenced development in the past and will continue to influence residential development patterns in the future.

Planners have maintained for many years that the social, economic and physical characteristics of an area is greatly responsible for the way in which an area grows and develops. In an attempt to encompass some of these planning principles in the model, various environmental characteristics were selected as factors which influence household location decisions. For example, it was felt that median age of housing and the percent of dilapidated houses would provide a measure of the attractiveness of an area for future development; whereas such measures as housing value, median family income, and average historical lot size would provide some indication of the prestige and attractiveness associated with an area. Various types of non-residential development such as industry in an area may indicate the undesirable qualities which would repel the future development. Lastly, the holding capacity of an area which is a function of the amount of vacant land and the lot size controls placed on that land will have a direct impact on the amount and character of future development.

Planners have maintained that levels of urban services such as public sewer and water facilities have a significant impact on future development rates. Moreover, the amount and quality of elementary school facilities has always been regarded as an important location factor. Therefore, various measures of these variables were incorporated into the regression analysis in an effort to test and measure their actual influence.

Transportation facilities have been held to not only serve but also shape land use patterns. A measure of accessibility was incorporated in the regression analysis in order to include and test this principle. The primary transportation system was used to determine accessibility factors for each census tract to all other census tracts. Two types of accessibility were used--accessibility to work to reflect a person's desire to locate within a reasonable distance from his place of employment, and accessibility to retail employment facilities to indicate a householders need to be conveniently close to shopping facilities. Accessibility is defined here as a function of travel time and a particular set of friction factors which are associated with a person's tolerance level to travel certain distances for various purposes.[1]

DEFINITION OF DEPENDENT AND INDEPENDENT VARIABLES

DEPENDENT VARIABLE

The final definition of the dependent variable was expressed as the total change in households from time T to T&5. (Δ households 1960-1965). Although many other combinations of definitions were tested in the regression analysis,

[1]T.C.R.P.C. 1965 Land-Use, Natural Resource Transportation Study.

it was found that this was the most logical and representative definition. For example, a regression analysis was performed with the dependent variable defined as the absolute number of households in T&5 (total 1965 households). It was found that the regression analysis could not account for the total historical growth of each tract with any degree of accuracy. In essence, by defining the dependent variable as total households rather than the change in households, the assumption is made that a measure of the independent variables at some point in time could account for all the historical development that had occurred in that census tract. This assumption is illogical for many reasons, among which is the fact that past growth is not a function of current land development. For example, a park that was added to a particular area in 1955 obviously could not have effected the household growth in that tract, say in 1940.

INDEPENDENT VARIABLES

The initial effort in selecting a set of independent variables was to prepare an extensive listing of all possible variables which may have some influence on household location decisions. This list was generated without regard for the availability of this data or the costs associated with data collection. Moreover, it was generally understood that it would be impossible to use all of these data in a regression analysis and that it would be too costly to collect or develop many of these items. This listing was to serve as a summary of all the different variable types which would be considered as candidates for further consideration based on their availability and relevance to the problem.

Upon undertaking an extensive review of the possible sources for these data, it was found that many of these items had to be discarded for one or more of the following reasons:

1. Data was simply not available.
2. Data was aggregated to geographic units which were not compatible with Census tracts.
3. Data was available only for portions of the total study area.
4. Data was defined and/or collected in a manner which either made it unusable or inaccurate.
5. Data was available but too costly and time consuming to gather.

Upon reviewing all the available data and sources, the list of candidate variables was modified and trimmed considerably. The final independent variables which were tested in the regression analysis consisted of well-defined and logical inputs. It was generally felt that it would be better to concentrate on fewer variables and allocate more effort to accurate data measurement than to collect all the possible variables which may be remotely usable and helpful in the model. Serious consideration was also given to the fact that each independent variable which was found to correlate well with the dependent variable and, thereby, remain in the equation would have to be estimated for each census tract and for each forecasting period. Therefore, serious attention was given to those independents variables which were of obvious intuitive importance and would lend themselves to rational methods of forecasting.

A complete listing of the independent variables which were tested in the regression analysis is provided in Appendix A.

MODEL FORMULATION

REGRESSION ANALYSIS

The regression analysis was used as a tool to determine which of these variables were significant indicators of growth and to establish a mathematical relationship between these variables and the dependent variable. Once each of these characteristics were defined and measured for each census tract in the region in 1960, they were introduced to the regression analysis as independent variables. The regression analysis attempts to explain the dependent variable for each tract (household growth from 1960 to 1965) using a single equation which includes these independent variables in various combinations. The extent to which it is successful in explaining the dependent variable is, in part, expressed by the correlation coefficient. A high correlation coefficient implies that these independent variables do correlate well with the change in households from 1960 to 1965. Moreover, the mathematical equation derived from the regression analysis contains each of the significant variables and a corresponding coefficient, all of which form the central core of the model. In other words, given a measure of each of these variables for any census tract at any future point in time, it is possible to forecast the change in households for that tract of the next five-year period via the regression equation. As will be discussed in more detail in Chapter III, this assumes that the relationship that existed between the dependent variable and the independent variables will remain constant throughout the entire forecasting period. Generally, it is this assumption which is most frequently attacked in evaluating any regression model of this type.

The first phase in the development of the household distribution model was to perform a series of regression analysis on the pre-defined independent variables (see Appendix A). Several regressions were performed using different combinations and various definitions of variables in order to determine which would best correlate with household growth.

All the regression analysis were performed on the Control Data Corporation (C.D.C.) 3600 computer at the Michigan State University Computer Center. The regression program that was used performs multiple regression analysis by a method of least squares.[1] An important feature of this program is that it automatically deletes independent variables from the regression equation until all equation coefficients are determined to

[1]The multiple regression analysis program used the LSDEL routine which was prepared by the Agricultural Experimentation Station at Michigan State University as part of a statistical program series.

be significantly different from zero by the F test at some pre-specified significance level.[1] This feature enables the model builder to include a large number of independent variables and allows the computer to determine which combination of variables will yield the most desirable results.

DISAGGREGATION

The basic approach used in the earlier regression analysis was to perform this test on all of the 124 census tracts. Moreover, all the independent variables listed in Appendix A were included in the analysis in order to determine those which were most productive. It was found, however, that the best correlation attainable under this arrangement was a multiple correlation coefficient of (R^2) at .42 and with all independent variables at the 0.005 level or better. After further investigation it was decided that the reason for this poor correlation was that the range of characteristics (values for independent variables) for each observation (each census tract) in combination with the tremendous variation of values for the dependent variable (change in household 1960-1965) was too great to be accurately explained by a single equation. In other words, there was a significant variation in the relative values for each dependent variable and their corresponding independent variables for each individual census tract. As mentioned in Chapter I, there is a significant difference in the

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[1]The pre-specified level of significance used was 0.005.

historical growth rates from one community type to another within the Region. For example, the Urbanized Core Area has received large scale development whereas the Urban-Rural Centers have grown at a very moderate and gradual rate. Moreover, the type and amount of employment, public facilities, vacant land, and transportation facilities vary substantially from one to another. It is also quite apparent that the attitudes and values of the residents of these various areas vary considerably.

It was with this added perspective of the region and its communities that measures were taken to proceed with the regression analysis. In order to more accurately account for the various differences between sub-areas of the region, the total 124 observations (census tracts) were disaggregated into two groups, "Rural Areas" and "Urban Areas". Essentially, the Urbanized Core Area and the Major Urban Communities were grouped to the Developed Area. This meant combining all the census tracts that comprised the five township areas with the Cities of St. Johns, Eaton Rapids, Mason, Grand Ledge, Charlotte and Williamston. Likewise, the Urban-Rural Centers and Agricultural Areas were combined to form the Rural Area. This disaggregation of observations enabled the model builder to perform two separate regression analysis on two independent sets of data. In effect, this step constituted the formulation of two separate models; one for the rapidly growing areas (Urban Areas) having 60 observations, and the other for the rural-oriented areas (Rural Areas) having 64 observations.

The initial results of this disaggregation was very encouraging. The Rural Area produced a multiple correlation coefficient (R^2) of 0.86 while the Developed Area generated an (R^2) of 0.80 each at 0.005 significance. (See Rural Area regression analysis in Appendix B.)

DELETION OF SELECTED OBSERVATIONS

Although an (R^2) value of 0.80 is considerably better than that achieved prior to disaggregation of the data, it was felt that improvements were still required in the Development Area. Upon comparing the values which were estimated for each individual census tract via the regression equation to the known change in household from 1960 to 1965, it was found that the equation was consistently inaccurate in dealing with certain census tracts. Certain census tracts in central Lansing and East Lansing Cities were consistently over or under allocated. Moreover, it was obvious that these tracts, for one reason or another, were unique to the rest of the region in terms of development practices, land ownership, types of land uses and economic pressures for development. These specific tracts either make up the CBD's of Lansing, Michigan State University, or large industrial areas which are surrounded by older residential areas.

In the case of central Lansing, the model seriously over-estimated the residential growth potential of this area.

The particular tracts in question make up what is presently the Central Business District and surrounding areas. The general character of this area is essentially non-residential. It was felt that the model did not adequately account for the land values associated with available vacant acreage in this area. Moreover, because of recent urban renewal plans in these areas, rather unusual development and change has occurred.

There were two Census Tracts in the City of East Lansing which combined to form the Michigan State University campus. The campus area is unquestionably a unique situation in that all the development in this area is totally controlled by the University. The only household development that has taken place in this area during the study period has been in the form of married housing units which were built by the University. Moreover, the University has acquired a substantial amount of land which, under the present land use classification system, has been defined as vacant. By including these two tracts in the regression analysis, the regression equation was being asked to explain the development of households in this area which was a function of the University's policies and the number of married students and not a matter of free choice as in the case with the rest of the Developed Area. In summary, the regression equation over-estimated the household growth in these areas simply because the independent variables indicated there was a substantial amount of vacant land available and many of the other desirable characteristics which would normally indicate a significant growth rate. Moreover, the model was being designed to reflect private household location decisions and not the University's policies regarding the supply of on-campus married housing.

The presence of several large industries immediately adjacent to the CBD of Lansing also represents a rather unique situation. Over the past few years many of these industries have felt the urgent need to expand their facilities. However, they have found that they are completely surrounded by residential development. The Oldsmobile Corporation as well as several others have decided that it is better to expand in their present location rather than to relocate outside the developed area. As a result, several acres of residential land has been converted to either new industrial and related buildings or parking facilities for employees which has resulted in a net decrease in the number of households in these areas from 1960 to 1965. Here again, the regression equation was not suited for this type of situation. This was not regarded as a serious problem, however, because the model was not designed to anticipate overall residential development patterns.

In an effort to improve upon the multiple regression coefficient for the Developed Area, several of these unique tracts were removed from the observations to be considered by the regression analysis. It was felt that this would be a better approach to the formulation of a regression equation as opposed to option of introducing adjustment factors which are applied to individual tracts to artificially compensate for their unique characteristics. The deletion of selected observations is a statistically valid undertaking provided that there is sound reason for doing so. Given the unusual characteristics of this limited number of select tracts, it was felt that this course of action was justified.

As shown in Appendix C, by reducing the total number of observations for the Developed Area, it was possible to improve the multiple correlation coefficient (R^2) to 0.97 with all independent variables having a significance of 0.005 or better. The primary reason for this improvement was that the regression equation was no longer being asked to account for several unusual dependent and independent variables which were a result of unique characteristics in certain tracts.

REGRESSION EQUATIONS

The following is a complete listing of each independent variable and its definition finally used in the Developed Area model and the Rural Area model:

DEVELOPED AREA MODEL

A. Environmental Independent Variables

(1) Median Family Income (i) $= \left(\text{Median Family Income (i)}\right)$

(2) Median Family Income $(i)^2 = \left(\text{Med. Family Income (i)}\right)^2$

(3) Median Family Income $(i)^3 = \left(\text{Med. Family Income (i)}\right)^3$

(4) % of Total Area Industrial$(i)^2 = \left(\frac{\text{Industrial Acres (i)}}{\text{Total Acres (i)}}\right)^2$

(5) Average Net Residential Density (i)^3 = $\left(\frac{\text{Households (i)}}{\text{Total Residential Acres(i)}}\right)^3$

(6) Residential Holding Capacity^3 = (Average Net Residential Density(i)) x (Vacant Developable Land (I))^3

(7) Total Households (i) = Total Number of Households(i)

(8) Total Households (i)^2 = (Total No. of Households(i))^2

NOTE: All variables were measured at time "t" (1960
(i) = Census Tract

B. Public Service Variables

(1) Water Service Area(i)^2= $\left(\frac{\text{Total Acres Served by Water(I)}}{\text{Total Developed Acres (i)}}\right)^2$

(2) Water Service Area(i)^3= (Same)^3

(3) Sewer Service Area(i)^2= $\left(\frac{\text{Total Acres Served by Sewers (i)}}{\text{Total Developed Acres (i)}}\right)^2$

(4) Elementary School Service Density (i)^2 = $\left(\frac{\text{Total Grade School Classrooms(i)}}{\text{Total Households (i)}}\right)^2$

(5) Elementary School Service Density (i)^3 = (Same as Above)^3

(6) Total School Services (i) = Total Number of Schools (i)

(7) Total School Services (i)^2 = (Same as Above)^2

(8) Total School Services (i)^3 = (Same as Above)^3

(9) Park Services (i) = Total Number of Parks (i)

(10) Park Services (i)^2 = (Same as Above)^2

(11) Park Services (i)^3 = (Same as Above)^3

(12) Golf Course Services (i) = Total Number of Golf Courses (i)

(13) Golf Course Services $(i)^2$ = $(\text{Same as Above})^2$

(14) Golf Course Services $(i)^3$ = $(\text{Same as Above})^3$

C. Functional Relationships Variables

(1) Accessibility to Retail Employment(i) =

$$\frac{\sum_J \left[\text{Retail Employ.}_{(j)} \times \frac{\text{Shopping Trip}}{\text{Friction Factor (i to j)}} \right]}{\sum_J (\text{Above})}$$

(2) Accessibility to Retail Employment$(i)^2$ = $(\text{Same})^2$

(3) Accessibility to Retail Employment$(i)^3$ = $(\text{Same})^3$

RURAL AREA REGRESSION

Dependent Variable

(1) Change in Households (i) (t to t+5) = (Total Households (i) 1965-(Total households (i) 1960)

Independent Variables

(A) Environmental Variables

(1) % of Total Area Industrial (i) = $\frac{\text{Industrial Acres (i)}}{\text{Total Acres (i)}}$

(2) % of Total Area Industrial $(i)^2$ = $(\text{Same as Above})^2$

(3) Average Net Residential Density$(i)^3$ = $\frac{\text{Households (i)}^3}{\text{Total Residential Acres (i)}}$

(4) Vacant Developable Land (i) = Total Useable Vacant Acres (i)

(5) Vacant Developable Land $(i)^2$ = $(\text{Same as Above})^2$

(6) Total Households $(i)^3$ = Total Number of Households $(i)^3$

The following is the final regression equation for the developed area portion of the region:

$$(\Delta HH) =$$

$$2754.4089 + 6250.6670 (X_1) -61423.3531 (X_1)^2 + 210696.8255(X_1)^3$$

$$-9739.6367 (X_2) = 13892.2649 (X_2)^2 -6318.2269 (X_2)^3 +20.0254 (X_3)$$

$$-.2412 (X_3)^2 + .0007 (X_3)^3 + .0068 (X_4)^2 +32377.8862 (X_5)$$

$$-544772.4467 (X_5)^2 + 11873.0669 (X_6)^2 -884.2492 (X_7)$$

$$+292.2136 (X_7)^2 -25.7260 (X_7)^3 -267.3199 (X_8) - 198.9417 (X_8)^2$$

$$-28.0618 (X_8)^3 + 190.6626 (X_9) -336.7404 (X_{10}) +20.4101 (X_{10})^2$$

$$-.2029 (X_{10})^3 + .375.0658 (X_{11})^3 + 6583.1332 (X_{12})$$

$$-18470.0699 (X_{12})^2$$

Where:

(ΔHH) = Change in Households from T to T + 5

(X_1) = Accessibility to retail employment at time T

(X_2) = Median family income at time T

(X_3) = Water service area at time T

(X_4) = Sewer service area at time T

(X_5) = Elementary school services at time T

(X_6) = Percent industrial at time T

(X_7) = Total school services at time T

(X_8) = Park services at time T

(X_9) = Golfing services at time T

(X_{10}) = Average net residential density at time T

(X_{11}) = Holding capacity at time T

(X_{12}) = Total households at time T

The following is the final regression equation for the rural area portion of the region:

$$(\Delta HH) = 20.1554 + 42.8468\,(X_1) + 1860.6113\,(X_2) - 63987.1537\,(X_2)^2 - 25524.2582\,(X_3)^2 + 4.2812.6878\,(X_3)^3 + 3856.2989\,(X_4) - 15488.7101\,(X_4)^2 - .1467\,(X_5)^3 + 80.5945\,(X_6) - 32.7948\,(X_6)^2 + 21491.4862\,(X_7) - 146064.4196\,(X_7)^2$$

Where:

(ΔHH) Change in households between T and T - 1

(X_1) Accessibility to total employment at time T

(X_2) Accessibility to retail employment at time T

(X_3) Elementary school services at time T

(X_4) Percent industrial at time T

(X_5) Average net residential density at time T

(X_6) = Vacant developable land at time T

(X_7) = Total households at time T

B. Public Service Variables

(1) Elementary School Service Density $(i)^2 = \left(\frac{\text{Total Grade School Classrooms } (i)}{\text{Total Households } (i)}\right)^2$

(2) Elementary School Service Density $(i)^3 =$ (Same as Above)^3

C. Functional Relationship Variables

(1) Accessibility to Total Employment$(i) = \left[\frac{\sum_j \text{Total Employ.}_{(j)} \text{Work Trip Friction Factor}_{(i \text{ to } j)}}{\sum_j \text{(Same as Above)}}\right]^2$

(2) Accessibility to Retail Employment$(i)^2 =$ (Same as Above)

MODEL COMPONENTS

The equations which were derived from the regression analysis actually represent a portion of and not the total distribution model. These equations are, in fact, the mathematical core of the model. In the total algorithim for the model, these equations are fitted into a set of operational procedures which enable the model to perform logical and useful allocations. The bulk of the computer program in terms of program statements and computation time, is actually taken up by bookkeeping operations.

The first portion of the model is devoted to the manipulation of raw data inputs. It was intended that the model be so designed as to allow easy and efficient use with a minimum amount of involvement of the planner in manual preparation of data inputs. The initial portion of the model performs several mathematical operations on the incoming raw data to get it into a form which is required by the regression equations. These calculations include such operations as converting vacant land acreage and gross residential densities into a form representing holding capacities (households per acre). It is in this manner that the model user is saved the responsibility of manually calculating all the independent variables. Moreover, the input data could be expressed in a form which more closely resembles existing data files and thereby eases the problem of data preparation.

In addition to the raw data inputs required for the independent variables, the model required a pre-defined set of household control totals for both the Development Area and the Rural Area equations. These consisted of two separate figures which were expressed as the total change in households that could be expected to occur in each of these areas over the next five-year period. These controls were derived from the cohort survival model and represent total household forecasts for the entire "Developed Area" and "Rural Area". Each of these data are stored in memory for future use.

The procedure used by the model to generate a household distribution begins with the insertion of each independent variable for an individual census tract into the appropriate regression equation (Developed or Rural Area equation). The regression equation is solved for that particular set of values which results in an initial estimate of the household growth for that specific tract. This process is continued until a household forecast is achieved for each individual census tract. Upon reaching this point, these household estimates are summarized and compared to the appropriate household control (Developed or Rural). If the sum of the individual forecasts exceeds or falls short of the pre-established control, each tract is adjusted proportionately. The individual allocations for each tract are then printed out as "attempted change in households" as shown in an example of the model output provided in Appendix D. This is not, however, the final household forecast. Due to the nature of the regression equation, account is not taken of the fact that there may not be sufficient vacant land in each of the tracts to accommodate the indicated household growth. Therefore, the "attempted change in households" listing only represents the potential of each tract for development based on the assumption that sufficient land is available.

In the next step, the model compares the holding capacity of each census tract to the amount of household growth it has been allocated. If a particular tract has received more development than it can support, then the allocation is set equal to the holding capacity and the excess households are set aside for general allocation in the next cycle. A re-allocation of excess households is made via the regression equations in the following model cycle to all those tracts which have sufficient land to support additional development. This process is continued until all conditions are satisfied at which time the final household allocation to each tract is printed out.

MODEL CALIBRATION AND TESTING

Once the algorithim had been developed and the computer program written, it was necessary to test the model to eliminate all procedural or internal programming errors. In order to facilitate quick and efficient de-bugging, the program was written in FORTRAN and in a direct and simple manner. As a result, many of the early operational programming difficulties were overcome with relative ease.

A test deck of input data was prepared for use in de-bugging. The deck consisted of sample independent variables from eight census tracts; four from the Developed Area and four from the Rural Area. These tracts were selected so as to provide the widest range of possible values. The initial test of the program was to compare the model's output for these tracts to that derived from manual calculations using the same equations, procedures, and 1960 inputs. Secondly, the values for the independent variables were altered to test the system's reaction to fluctuations in inputs.

MODEL CALIBRATION

Model calibration represented something of a problem in that the most current statistical period has been used to develop the regression equations. Being that the period from 1960 to 1965 was used in the regression analysis, it would have made little sense to calibrate it based on this same time period. The model, however, was not completely developed until early 1968. It was felt that it would be logical to use the period from 1965 to 1970 for calibration. Being that the commission had already collected a great deal of data on the residential development from 1965 to 1968 and the time span between 1968 and 1970 was relatively short, it was felt that sufficiently accurate 1970 household estimates could be prepared.

All the important data dealing with zoning petitions, subdivision plats, building permits, local population estimates, and major development proposals were quickly assembled and a 1970 household estimate was prepared. The household distribution model was then used to generate a 1970 household allocation which was compared to the 1970 estimate derived from local development trends and proposals. As a result of this comparison, it was found that the model allocation was surprisingly close to the probable household distribution. With the exception of two census tracts, the model's allocations were within ± 2% of the actual change of households for any given tract.

MODEL APPLICATION

MODEL USE AND POLICY DECISION

"Planning is oriented towards ensuring a better future. The process of pursuing this objective involves three basic problems. The first of these is predicting the outcomes of alternative actions so as to determine what kind of future will eventuate on the basis of available possible planning decisions. The second problem is that of determining an operational definition of "better"; such a definition should not only reflect community values so as to facilitate acceptance of a plan, but should also provide guidelines in the planning process itself. The third problem is that of end reduction--finding amongst the very large number of possible combinations of factors those which give some promise of being the most effective in providing a better future."[1]

In other words, the planning process that is used to generate a plan involves the statement of community goals, objectives, and desires; the development of alternative plans which could meet these goals and objectives; the selection of an alternative plan based on an evaluation of how well it meets the broad objectives, lends itself to implementation, is likely to be received by the community as a whole.

The household distribution model was intended to provide the means for evaluating alternative policy plans and

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[1]Britton Harris. "Organizing the Use of Models in Metropolitan Planning". This paper was prepared for a seminar on Metropolitan Land Use Models at Berkeley, California, March 19, 1965, p. 2.

to assist in determining which set of policies would be most effective in achieving a desirable land use configuration. To this end, the Commission undertook an extensive program directed at identifying community goals and objectives. An extensive set of broad regional goals were established as a result of this study. With these goals in mind, a set of alternative policies and design principles were formulated which represented alternative approaches to achieving the goals. Three alternative sketch plans were prepared which represented different types of population and employment distributions that could be achieved within the framework set by the alternative policies of principles.

It was at this point that the household distribution model and the transportation model were to evaluate these alternative plans. The basis upon which these alternatives were to be evaluated rested on a judgment of how effectively the alternative policies of each plan could be used to effect a desirable distribution of population. That is, the models were to attempt to develop a land use pattern which was called for in each alternative plan by varying the policy inputs (residential densities, holding capacities, transportation system plans, urban renewal plans, policies regarding public acquisition of land, etc.). Each alternative would then be evaluated based on the final land use configuration, the types of policies used in achieving that pattern, and the extent to which these policies had to be enforced or pressured in order to adequately direct future development patterns.

Unfortunately, neither the transportation model nor the household distribution model were ready in time to undertake this evaluation task. As a result, it was necessary to undertake this evaluation in the traditional manner. That is, "to look at variation in the physical arrangements which express the planner's understanding of what conditions are best apt to satisfy an imperfectly defined set of goals."[1]

These three alternatives (Satellite Cities, Corridor Towns, and Contained Growth) were published and widely circulated throughout the region.[2] Local planners and interested agencies were contacted and asked to comment on each alternative. Moreover, questionnaires were distributed as widely as possible, which, in effect, asked that the respondent select a particular alternative which he felt best fit his interests. Based on the comments and suggestions which were received, the Commission felt that none of these alternatives really provided the type of plan that best suited the entire region. It is for this reason that a fourth policy plan was developed which attempted to incorporate the most desirable features of the other three alternatives. This policy plan most closely represented the "Contained Growth" concept. It

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[1]Ibid., p. 4

[2]Tri-County Regional Planning Commission. The Tri-County Regional Planning Commission Policy Plan - A Prelude to the Regional Development Plan. Lansing, Michigan: Tri-County Regional Planning Commission, 1967, p. 2.

was intuitively felt that this "Metro Center Concept" would most easily lend itself to both implementation and public acceptance. The Metro-Center policy plan became the general policy guideline needed to run the household distribution model. That is, for each model forecast, the policy inputs such as residential densities, distribution of employment, the types and location of major transportation arteries, and the timing of public acquisition of land were geared to reflect the overall development guidelines set forth by the Metro-Center policy plan. Each five-year forecast consisted of several model runs. Policy variables were altered several times during each forecast period in order to better approximate the development patterns invisioned by the policy plan.

There were two primary household allocation targets; 1975 for the short-range plan, and 1990 for the long-range comprehensive development plan. The intermediate years 1970, 1980, and 1985 were used as convenient points at which to update the independent variables concerning development policies and physical land uses.

The general approach used in preparing the model inputs for the short and long-range plans were significantly different. It was felt that there was relatively little that could be done to drastically alter the major capital improvements that were presently scheduled or underway since the target year 1975 was only eight years away. For example, most of the freeway construction plans that were to be undertaken for this period had already been approved and most of the land had been purchased. The general process used to prepare the inputs for the 1965-1970 and 1970-1975 model allocation periods was to collect as much information as possible concerning the approved and scheduled capital improvements and to introduce them into the model where appropriate. With this data on committed plans and programs as a base, a realistic 1970 and 1975 household distribution was accomplished.

The degree of flexibility was far greater for the period from 1975 to 1990. This is primarily due to the fact that there are very few public or private agencies which undertake long-range planning of this magnitude. Therefore, it was during this period that the policy plan could most directly influence the household distribution pattern. The emphasis during this period was taken off of existing plans and programs and put on the policy decisions as called for by the policy plan. Sewer and water extension programs were more strongly geared to containing development in and around already existing urban centers. Residential densities became more restrictive in the fringe areas of the region in order to discourage residential development through large lot zoning which limited the holding capacities of these areas. The transportation pattern was geared to interconnect major urban centers in order to increase their accessibility to each other and thereby make them more desirable for future development. In general, it was during this 15-year period that policy input decisions were heavily geared towards the achievement of policy plan objectives.

Many of the model input variables and other data items necessary for the preparation of a comprehensive Regional Development Plan were derived through the traditional methods of applying general standards. For example, the amount of land consumed by non-residential uses was, in part, determined by applying a ratio of employees per acre by type of land use. A comparative table was prepared which related gross residential densities to net residential densities. This table was used to determine the amount of land that would be required per household for such local uses as residential street right-of-way, churches, elementary schools, neighborhood parks, and local retail facilities.

Special attention was given to the problem of estimating the distribution of different categories of employment, by place of work. Attempts were made to develop a crude regression model which would allocate regional employment or larger geographic areas. All efforts in this direction were totally unsuccessful. It was found that the best possible correlation coefficient attainable was (R^2) at 0.28. The conclusion drawn from this analysis was that there was no apparent direct or indirect pattern to the distribution of employment in the region. Therefore, an alternative approach was used to deal with this matter. The approach used to allocate regional employment was first to determine the most logical and desirable locations for these various types of employment activities. Various local planners as well as the Lansing Metropolitan Development Authority were contacted to collectively analyze potential locations for industrial and commercial facilities. As a result of a series of meetings on this topic, several specific sites began to emerge as having the highest potential for development. Regional control totals for employment were derived, in part, from the cohort survival population forecast. This employment was allocated to these sites based on employees per population and employees per acre for commercial and industrial uses respectively.

A second supplementary model was also attempted with considerably more success. In light of the relative difficulties and complexities in estimating median family incomes, a regression model was developed to provide this independent variable required by the household distribution model. The independent variables used in this model include such items as past income levels, total change in households over the past five-year period, and indicators of historical net residential densities. The model was based on an aggregation of data at the analyzes area level; a combination of two or more census tracts. A correlation coefficient of (R^2) at 0.72 was achieved with all variables significant at .04 or better. Rather than prepare a computer program to house this simple model, all calculations were performed manually on a desk calculator.

MODEL DISTRIBUTION RESULTS

It is generally felt that the household distribution model was successful in that it accomplished nearly all of its objectives. Although minor difficulties were incurred in specific tracts throughout the region, the overall distribution of households appears to be well within the confines of reasonableness. Moreover, the configuration of development very closely resembles that called for by the Metro-Center policy plan. It is important to note that this configuration of households was, in fact, accomplished without the need to over-emphasize any policy variables or development constraints.

The household distribution model was used as a tool to assist the planner rather than control him. Output from the model was regarded as a general indication of the development potential of a particular census tract and not the final estimate of growth. The planner was at all times free to manually change the distribution of households if for some reason he felt that the model was over or under emphasizing certain areas. Moreover, the output from the model was expressed in terms of households. It was the planner's responsibility to transform households into population. This was accomplished with the use of household size forecasts (population per household) which were derived independently from the model and applied manually.

CHAPTER III

A CRITICAL EVALUATION

CHAPTER III

A CRITICAL EVALUATION

TRADITIONAL PLANNING VS. MODELING

One of the first issues which must be investigated in order to properly evaluate the Tri-County Regional Planning Commission's model is one which strikes at the heart of their program. That is, "why pursue the formulation of a plan via modeling techniques as opposed to the traditional planning approach?" It is only through considering this question that progress can be made towards a more detailed and technical evaluation of the model itself.

It is commonly agreed that "planning is oriented toward ensuring a better future."[1] In pursuing this planning, the world will continue to change and develop. However, without some coordinative and cooperative attention, some of this development and change may be generally undesirable. According to Britton Harris, "the planner, therefore, attempts to devise policies which will influence the development in desired directions, by means and at costs which are acceptable to the community as a whole."[2]

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[1] Britton Harris, op. cit., p. 2.

[2] Britton Harris. "New Tools for Planning", Journal of the American Institute of Planners, Vol. XXXI, No. 2, (May 1965), p. 91.

If we are willing to accept this general description of planning, then the planning process will involve the following steps:

"1. The projection of probable future development.
2. The identification of objectionable and undesirable features of this development.
3. The identification of desirable alternative patterns and directions of development.
4. The invention of policies and public actions which may influence development in desirable directions.
5. The generation of plans reflecting various combinations of these policies and actions.
6. Testing these plans for effectiveness, feasibility and costs.
7. Choosing, or assisting in the choice, among alternative sets of policies, and initiating still further improvements."[1]

There are basically two different views as to the manner of following through this planning process in order to arrive at a "better" future state. This discussion is commonly referred to as "traditional planning" and the other "growth models". Each of these methods encompass the same

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[1] Ibid., p. 91.

objectives and agree on the same basic processes in achieving these objectives. The difference between these two approaches is apparent in the specific techniques used to progress through each of the steps outlined above.

It is pointed out by Harris that, "the traditional planning method has been to look for variations in the physical arrangements which express the planner's understanding of what conditions are best apt to satisfy an imperfectly defined set of goals. Much of this planning in its most general form has been what might be termed configurational. That is, considerable emphasis has been laid on the overall shape and form of the metropolitan area and the major transportation elements which are believed to help determine this form."[1] Although somewhat brief, this description of traditional planning methods strikes at the basic approach and considerations involved. The main point is that traditional planning is concerned with the physical arrangements of land use activities to the extent that they influence the future state of the region. Essentially, this approach states that the future shape and form of the area is controlled by the transportation systems and open space policies. According to Harris, an inherent weakness of this approach is that, "the definition of a desirable future state is not related to the predication

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[1]Britton Harris. "Organizing the Use of Models in Metropolitan Planning.", op. cit., p. 3.

of the effectuation of any policies except for certain direct controls over development."[1] That is to say, outside of such measures as zoning, subdivision regulations, and urban renewal programs, this method does not take into account the far reaching impact of other important factors which will also influence the over-all development pattern. As a result of this feature, "it cannot be known whether the future state hypothesized is in fact on a feasible line of development from the present. Equally serious, even if it is feasible, the process of reaching such a state may involve costs of implementation which react seriously on the evaluation of the plans desirability."[2]

The basic weakness of the traditional planning method of plan preparation is that it is conducted on an intuitive basis. That is, the planner uses his expert knowledge to transform policies into physical land use arrangements which hopefully reflect a "better" future state. The traditional planner can call on little more than "expert judgment" to know how costly or realistic his plan is to effectuate.

There are a number of reasons why the traditional planning method experiences serious difficulties in preparing an objective and realistic plan. Among these are:

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[1]Ibid., p. 3

[2]Ibid., p. 3

"1. The metropolitan area is a complex functional entity in which people, business, and institutions interact vigorously. Much development takes place under private initiative, not completely subject to direct public control, and in response to influences which are not fully understood.

2. The range of policies with which planners at various levels are able to influence development is growing. It includes not only traditional direct controls, but indirect influences, such as transportation development, urban renewal, taxation, and many other programs. Coordinating the effects of related policies in all these fields over an entire metropolitan area strains both the competence of the planning professional and existing administrative and governmental arrangements."[1]

By virtue of the physical limitations of the human mind, man is capable of considering a relatively small number of different elements simultaneously. Upon looking realistically at the total metropolitan environment, the number of interrelationships among and between activities and the space which they occupy becomes overbearing. Even though the plan-

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[1]Britton Harris. "New Tools for Planning", op. cit., p. 91.

ner is becoming more and more sophisticated at understanding these interrelationships, he does not have the capacity to study and understand them all in any degree of detail.

Modeling techniques are, in essence, an alternative approach to assist in the preparation of alternative comprehensive plans. Stuart Chapin defines a model as "a mathematical representation of a phenomenon previously conceptualized in verbal and logical form of theory."[1] Growth models, as discussed here, are simply mathematical abstractions which describe the metropolitan area. In particular, growth models address themselves to the complexities and interrelationships of change or growth.

In contrast to the traditional planning method, "this approach to planning examines the consequences of policy determinations by simulating directly the effects which these determinations will have upon the growth of the metropolitan area."[2] It is this simulation which is expressed as a single or series of mathematical relationships which enables the model to deal with an astronomical number of factors in a relatively short period of time. It is pointed out by Harris that "Most of the problems of comprehensive planning involve in the first instance very large amounts of detailed infor-

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[1]Freund, Eric C., Goodman, William I., Principles and Practices of Urban Planning, Municipal Management Series; International City Manager's Association; Washington, D.C., 1968, p. 475.

[2]Britton Harris. "Organizing the Use of Models in Metropolitan Planning", op. cit., p. 3.

mation regarding land, buildings, public services, and activities. This information must be handled and processed quickly, accurately, and consistently."[1]

As pointed out earlier, the traditional planner would quickly become overwhelmed by the amount and detail of this information. Moreover, his ability to study and analyze this data is seriously limited by conventional means. It is only with the advent of the electrical computer that planners have been able to maximize the use of this data and apply it accurately and quickly to the matter at hand. Moreover, because of the speed and accuracy of the computer, planners have been able to devise methods (models) to both test their theories and account for more of the complexities of the urban environment.

Donald M. Hill points out that: "The essence of the model's development is the scientific method comprising theoretical reasoning and emperical observations. The rationale of the model is premised on the following observations:

1. That the logical preferences of population, employment, and other activities are highly interrelated;
2. That the development of land for various uses is influenced by numerous exogenous factors.

A model in this context is a mathematical technique capable

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[1]Britton Harris. "New Tools for Planning", op. cit., p. 91.

of predicting detailed subregional development patterns of urban activities based on existing urban development, on externally forecasted regional growth, and on exogenous policy considerations concerning transportation, open space, zoning policies, public utilities and regional growth."[1]

It is considered to be standard procedure to first determine a broad set of goals and objectives. From these goals, alternative sets of policies are established which reflect different ways of attaining these goals. Moreover, these policies are formulated hand-in-hand with design principles which ultimately effect the character and form of the urban environment. As a general rule, from these goals, objectives, policies and design principles, alternative development plans are created which are a graphic representation of what the metropolitan area would be provided these rules were followed. A basic criticism of the sketch planning technique outlined above is pointed out by Harris as follows: "The search in this case is, in the first instance, for optimal future arrangements of the metropolitan area without regard to the possibility of reaching this future state from present conditions by a combination of normal growth processes with feasible choices."[2]

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[1] Donald M. Hill. "A Growth Allocation Model for the Boston Region", Journal of the American Institute of Planners, Vol. XXXI, No. 2, (May 1965), p. 112.

[2] Britton Harris. "Organizing the Use of Models in Metropolitan Planning", op. cit., p. 4.

As a result, it is extremely difficult to attempt to evaluate alternatives which are prepared under this type of process. The basic problem is that there is no direct way to know if in fact the urban form proposed by any one of these alternatives is, in reality, achieveable. Moreover, the costs involved remain a mystery because of the neglect of the planner to specify in any detail the difficulties incurred in effectuating a plan of this type. As a result, the evaluation of alternative sketch plans is, at best, subjective and intuitive.

The amount of time that is required to prepare a comprehensive regional development plan under the process outlined above is indeed enormous. It is further pointed out by Harris that: "So long as the generation and spelling out of plans remained an arduous and slow process, opportunities to compare alternative plans were extremely limited. In this case, the evaluation of plans became largely subjective and the subjective nature of the evaluations led to many difficulties in achieving a consensus."[1]

One of the most important advantages offered by the modeling techniques is that once the initial investment in model development is made, it is possible to generate large numbers of alternative development schemes, logically, objectively, quickly, and at a relatively low cost. The basic vehicle for accomplishing this is through the model and

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[1] Britton Harris. "New Tools for Planning", op. cit., p. 92.

its inputs. Different policies and design standards in effect are transformed into specific inputs to the model. As mentioned earlier, the model is so designed as to react differently to changes in the input data. Thus, by altering the allocation of utilities as an input, for example, one can objectively determine the impact that this constraint has on the overall development pattern of the metropolitan area. It is through reiterations of this type that one is able to generate large numbers of alternative plans.

Both the process of designing alternative plans as well as understanding and evaluating these alternatives depends very heavily on an intimate understanding of how a metropolitan area functions and grows. Harris supports this argument by stating that: "This is necessarily so because the consequence, direct and indirect, of planning decisions are the most direct elements entering into an evaluation, while changing these consequences by changing proposed policies is the central aim of planning design."[1]

There are two basic benefits which are a direct result of modeling techniques which have an effect on plan design and evaluation. First, through using the modeling approach, one gains a better understanding of the consequence of alternative policies and assumptions. Consequently this improved understanding ultimately effects the design of the

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[1] Ibid., p. 92.

plan. Secondly, by better understanding how the system functions and reacts, the planner can formulate new restraints to be imposed on the design problem. This again only leads to an improvement in results.

In summarizing the basic advantages and disadvantages of traditional planning vs. modeling, one must recognize that each approach has certain qualities which make it desirable. Harris points out that: "The use of the growth model offers the greatest advantage of realism and provides output which may be presumed to be feasible in terms of locational behavior as it influences urban development over time. Future state "traditional" planning provides the planner with an opportunity to experiment with arrangements which might conceivably have much higher levels of performance than those which would ordinarily be discovered by planning through the use of growth models. With the growth model, the planner has to filter his intuitions about future desirable configurations through the process of trying to reach these configurations by the application of policy and then evaluating the result. In future state planning, the planner may go directly to an expression of his intuition and determine immediately how effective that intuition is, but he will then be very much up in the air as to the possibility of achieving this state by normal means or as to the cost of achieving it through added controls and incentives."[1]

Although not stated directly above, one of the most important benefits to the planner as a professional is that of education. By undertaking a program which calls for the use of models, one will become far more deeply acquainted with the metropolitan area and its functional relationships simply because he will be forced to "think through" these processes and relationships. As stated by Ira S. Lowry: "Above all, the process of model-building is educational. The participants invariably find their perceptions sharpened, their horizons expanded, their professional skills augmented. The mere necessity of framing questions carefully does much to dispel the fog of sloppy thinking that surrounds our efforts at civic betterment."[2]

REGRESSION VS. OTHER MODELING APPROACHES

The single most important element which must be considered in an evaluation of any model concerns the particular modeling technique used. In order to properly evaluate the model, therefore, attention will be given here to a comparison of the regression model used in the creation of the Tri-County Regional Planning Commission (TCRPC) house-

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[1] Britton Harris. "Organizing the Use of Models in Metropolitan Planning", op. cit., p. 5.

[2] Ira S. Lowry. "A Short Course in Model Design", Journal of the American Institute of Planners, Vol. XXXI, No. 2, (May 1965), p. 165.

hold distribution model and the other modeling alternatives that are available.

The criteria used by the Commission to select a particular modeling technique consisted of the following considerations.[1]

1. Model accuracy as a forecasting tool.
2. System understanding.
3. Equipment and data processing requirements of each alternative.
4. Data Requirements of each method.
5. Development costs in terms of overall time and professional staff skills.

In light of the Commission's limited budget and staff, each of these factors had to be carefully considered prior to committing a substantial amount of money and time to the project.

Upon reviewing various approaches that had been or were currently being used in the planning field, it was found that there were three basic types or categories of models -- regression, opomization, and simulation. Although these are often referred to by different names, such as analouge, symbolic, deterministic, stocastic, descriptive, predictive,

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[1]Tri-County Regional Planning Commission. Small Area Population Forecasting Models, op. cit., pp. 8-10.

heuristic, and recursive,[1] they can generally be reduced to these three basic types.

According to Michael Stigman, "there is the deterministic model (regression model) which is commonly, but not always, based on correlation analysis and, in general, includes one dependent variable and one or more independent variables."[2] These models, in which class the TCRPC model falls, are based on a definite knowledge of past trends and relationships and on the assumption of their continuation into the future.[3] It is quite obvious, therefore, that the validity of this technique is based on the accuracy and stability of the relationships investigated and used.

Optimization models are firmly based on a technique of analysis known as linear programming.[4] This process involves the definition of a mathematically definable objective or goal which the linear program will seek to maximize. An optimization model, according to Robert Boguslaw, "calculates the best plan for achieving stated objectives in

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[1]Michael Allen Stegman. "An Analysis and Evaluation of Urban Residential Models and Their Potential Role in City Planning", A Dissertation in City Planning, University of Pennsylvania, 1966, pp. 1-2.

[2]Donald M. Hill, op. cit., p. 11.

[3]Penn Jersey Transportation Study. An Introduction to Mathematical Models, PJ Paper #8, 1964, p. 5.

[4]Donald M. Hill, op. cit., p. 11.

a situation in which resources are limited."[1] Linear programming models have received rather widespread application in the private sectors of our economy. This is particularly true in single firms where linear programming techniques are used to economize a specific operation or process. Urban planners have found this tool useful in model building where specific goals can be defined and maximized. Examples of this application in the planning environment include such problems as minimizing total travel time or maximizing the amount of services received per unit of income. When applied to urban problems, optimization models have difficulty relating to an imperfect social environment. For example, the urban system differs from the clear-cut physical sciences in that human error and free choice are the basis upon which the system functions. A linear programming solution to a particular urban problem is based on the assumption that the human components of that system have perfect knowledge of the environment. Moreover, linear programming has often been used to achieve an equilibrium where, in fact, no equilibrium exists. The essential problem is that the human component of the urban system is not perfect; acts, on occasion, in an irrational manner; and under a democratic society, cannot be forced to follow an optimum course of action.

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[1] Robert Boguslaw. The New Utopians, Englewood Cliffs, Prentice Hall, Inc., 1965, p. 52.

Harris defines a simulation model as "one in which real world processes are imitated."[1] In other words, a simulation model is one which is designed to resemble the system under study. The emphasis of this model is not in providing realistic and highly accurate forecasts or output about the system, but rather to act as the system would react to various exogeneous and indogenous stimuli. The primary use of a simulation model is to gain insights into the interrelationships of the system via building the model and taking part in its use to test different system reactions. An example of a simulation model is one which employs the "monte carlo" technique by, in effect, rolling dice to determine a course of action or make a decision on a matter which is purely random or is based on the law of probability or chance.

It appears that the optimization model has potentially the greatest assurance of accuracy. This is true because the system is dependent upon defining what the goals of the system are and not necessarily the mechanics by which these goals are achieved.[2] It is logical to assume, therefore, that the optimization model will continue to provide realistic results even though technology may alter the mechanics by which these goals are achieved. The major problem

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[1]Britton Harris. "A Gloss of Lacklustre Terms", Journal of the American Institute of Planners, Vol. XXXI, No. 2, (May, 1965), p. 94.

[2]Tri-County Regional Planning Commission. Small Area Population Forecasting Models, op. cit., p. 8.

that faces optimization when this technique is applied to urban problems is that the goals of society are not easily definable. Moreover, optimization models have difficulty in satisfying all goals especailly when these goals are in conflict with each other. It was concluded, therefore, that the optimization model represented a high-risk return alternative.[1]

It also appears that the simulation technique would seriously compete with the regression model for overall accuracy, especially for long-term forecasts. The essential reason for this is that the system interactions are represented individually rather than collectively which is the case in the regression model. It is assumed here that elemental representations will be more stable over long-time periods.[2] According to Keith Crane, "The technique (simulation) is more sensitive to error, because errors compound through succeeding steps in each simulated chain of events."[3]

It appears that the simulation model is a far superior teaching tool than are either of the other techniques. This is due to the fact that it provides insights into "how" the system reacts to various stimuli. The optimi-

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[1] Ibid., p. 8.

[2] Ibid., p. 8.

[3] Ibid., p. 8.

zation model, on the other hand, tends to resemble a "black box" to anyone who was not deeply involved in its creation. The regression approach is a useful tool for providing insights into the historical relationship between its variables. It is important to note, however, that the regression technique does nothing to define what in fact these casual relationships are. It is important, therefore, to exert caution in selecting variables as it is possible to encounter meaningless correlations between variables.[1]

All three models require rather large capacity computers and are large consumers of data. Generally, the regression model's data requirements are less demanding than that of the simulation model. On the other hand, optimization models require a different type of data than the other two. That is, optimization requires data on the "attitude of the system" whereas the other needs data which describes the "state of the system".[2]

The most serious consideration in selecting between alternative techniques was that of developmental costs. It was this characteristic of the regression model which was most impressive and outstanding above the other alternative approaches. It was found that regression models

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[1] _Ibid._, p. 9.

[2] _Ibid._, p. 9.

required less of an investment for development both in terms of manpower and computer costs.

Upon reviewing all of the advantages and disadvantages of each alternative modeling technique as well as the data and financial resources available to the Commission, the regression analysis model technique was selected as the basis upon which to develop this model. It is quite obvious that the prime concern was not to select a technique which was of mathematical or theoretical elegance; for the regression model is lacking in both. The two most limiting and important forces which came to play were that of time and money.

The Commission had access to a relatively large computer (CDC-3600) as well as very detailed and accurate data derived from inventories of land use, population, recreation, transportation and natural resources. These facilities and data were probably sufficient to support the development of either an optimization or simulation model. However, it became particularly clear quite early in the program that the available funds were insufficient to support even a token development of either the optimization or simulation approach. Moreover, this is especially clear in that the primary objective of the Commission's program was to prepare an operating and accurate model and not to foster a research effort directed at "advancing the state of the art."

AN EVALUATION OF VARIABLES USED IN THE MODEL

The choise of variables, both dependent and independent, can greatly influence the theoretical and logical core of the model. Attention, therefore, must be given to the criteria used in variable selection, the way they are defined and measured, and the rationale for including certain variables and excluding others. Included in this discussion will be detailed review of the results of both a sensitivity and performance test which were applied to the model. Important points will also be raised concerning the model's consistency and the relationship of the dependent variable to the independent variable.

AN EVALUATION OF THE DEPENDENT VARIABLE

The most obvious consideration involving variables centers around the selection of a dependent variable. As mentioned in Chapter 2, the dependent variable was defined as the total change in households from t to t&5. It is the author's opinion that the basic decision to use households as a dependent variable was a wise choice. Britton Harris supports this opinion in his statement that there are two basic reasons for using households as a lowest common denominator of urban growth. "First, residential land is the main space consumer in any metropolitan area, and it seems likely that the market for residential land in most instances is the price-setting market which therefore indirectly influences all other locations."[1]

It is also important to realize that a larger percentage of all vehicle miles traveled in our urban areas are home-based trips. Therefore, it is logical to assume that one of the most important ways to understand and plan for future transportation needs is by accurately defining the distribution of households to be served. "Second, in a very general sense, perhaps the most important criterion in plan making is some measure of the differences in welfare levels for the resident population which may somehow be observed or measured as between two different plans."[2]

A more basic characteristic of the household which makes it suited for use as a dependent variable is that it can readily serve as the basic unit of population movement. People, for example, do not usually migrate as individuals. That is, the vast majority of overall population growth is a result of people who migrate as a family unit and not as a group of unrelated individuals. Households are increasingly more attractive as a basic unit of measurement because it is quite simple to determine residential land consumption given some measure of the number of households. Chapin and Weiss point out that "Land use can be derived or inferred from such predications (households). Social status however, cannot easily be inferred from a land

[1]Britton Harris. "Organizing the Use of Models in Metropolitan Planning", op. cit., p. 17.

[2]Ibid., p. 17.

use prediction."[1]

Even though the definition of the dependent variable is such that it addresses the most important single aspect of metropolitan growth, this all-inclusive definition, in itself, is a serious weakness of the model. That is, one basic weakness of this model is that all households are grouped into a single category. It is quite evident that there are a wide range of different types of households which are best defined by the social-economic status of its members. For example, younger families tend to have children who are living at home that are of school age; therefore, they tend to place a high value on the availability and quality of schools and parks. Moreover, because of their relative position in the family cycle, their needs for living space are quite different from that of older, more established families.

Household income levels are another important characteristic which influences household location preferences. Higher income families are better able to absorb various costs that are associated with different residential locations. For example, families of higher income status do not need to rely on public transit as a means to get to and from work as do lower income groups. Moreover, higher income groups tend to place more value on prestige as a locational consideration.

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[1]Stuart Chapin, Jr., Shirley F. Weiss. "Factors Influencing Land Development", Journal of the American Institute of Planners, Vol. XXXI, No. 2, (May, 1965), p. 176.

The level of educational attainment and the type of job in which the household head is employed will also greatly influence the value system of the household. Higher education groups, for example, tend to seek residential locations in areas where it is possible to associate with persons of similar backgrounds and interests.

An obvious weakness of the TCRPC distribution model is that all of these different types of households of varying value systems and preferences were grouped into a single category in the dependent variable. This problem has a solution through the stratification of households by type. That is, the general category of "households" would be divided into several sub-categories based on different measures of income, family size, racial composition, type of employment, education level, and age groupings. Britton Harris points out that "Hopefully, such a stratification would reflect the dimensions of variation between households which influence residential choice."[1] By stratification, one would simply categorize households based on a set of characteristics which apparently will have some influence on household behavior patterns regarding locational preferences. In effect, in place of a single regression equation which encompasses all households, several equations would be generated for each household type.

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[1]Britton Harris. "Organizing the Use of Models in Metropolitan Planning", op. cit., p. 17.

In this manner, households would be allocated to sub-areas within the study area based on their own particular preference.

There are several problems associated with this approach, however, which warrant attention. As sighted by Harris, "Any complete stratification on these dimensions would, however, create a generally unmanageable number of household location groups. Paralleled with this problem there exists the problem of stratifying housing types so that the number of areas dealt with in the model will not be unmaneageable, yet will remain relatively homogenous."[1]

Although the possibility of stratification was considered in the early development of the TCRPC distribution model, it was decided that it would be better to avoid household typologies. The primary reason for this decision was two-fold. First, the associated problems of complexity of model design and use would have been too difficult under a stratified household condition. More importantly, however, the obvious lack of data made this approach unquestionably prohibitive. The 1960 Census was the primary data source for model development. To obtain stratified household types via special Census tabulations would have been exceedingly costly and time consuming in that there is considerable time delay between the submission of a special request and the actual delivery of this data from the Bureau of the Census.

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[1] Ibid., p. 18.

It is recommended that if any further modeling is undertaken by the Commission, serious consideration should be given to the possibility of using household types rather than a single household category. The U. S. Bureau of the Census will be undertaking a significantly different approach in the 1970 Census than has been taken in previous Census of population and housing. The most important change, with regard to the availability of 1970 Census data, is that the Bureau will provide any local user with a machine readable copy of detailed 1970 data summaries. This data will be available at cost and upon request shortly after the Census is taken. These tapes will contain a wide range of detailed Census data which is aggregated to geographic areas which range in size from Census blocks to Census tracts and minor civil divisions. The model builder, therefore, will be given maximum flexibility to allow him to obtain data on household types from the 1970 Census without having to purchase these data and services from the Bureau.[1]

AN EVALUATION OF THE INDEPENDENT VARIABLES

"In today's computer technology, this technique (multiple regression analysis) is a handy "filter" through which one can toss into a pot all kinds of factors which

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[1]U.S. Department of Commerce/Bureau of the Census. 1970 Census User Guide, Government Printing Office. Washington, D.C., April, 1962.

might be remotely connected with urban development. The multiple regression analysis will very neatly separate the wheat from the chaff and serve up only those which are in statisticians terms, "significant"."[1]

If one were to undertake the building of a regression model under this philosophy, the odds are that certain factors would come out of the regression analysis with a high correlation to the dependent variable, even though there is no direct or indirect relationship between the two.

In pursuing a regression model, one does not simply generate a list of variables that he feels may somehow influence household location decisions and test them via a regression analysis. The process, in order to be valid, must stem from some source of theory or logic. The approach taken in this study was to assume that households tend to locate in various areas because these areas have some measurable quality which renders them desirable or attractive to residential development. Likewise, certain characteristics have the reverse effect on households (repulsion). Based on this assumption, independent variables were identified, defined, measured and tested. Each variable was selected

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[1]Thomas G. Donnelly, F. Stuart Chapin, Jr., Shirley F. Weiss. "A Probabilistic Model for Residential Growth", Journal of the American Institute of Planners, Vol. XXXI, No. 2, (May, 1965), p. 177.

because of its expected influence on the potential of an area for attracting or repelling development. This expectation was based on the region's characteristics and intuitive judgment, and supported by previous theories.

The criteria which was used in selecting each variable was in harmony with most of the basic planning theories and principles regarding locational needs, standards, and preferences. In the following statement, Stuart Chapin sights a convenient example of some traditional planning principle concerning residential location preferences which are considered to be basic to all planning practices. "Living area should be located in convenient proximity to the work and leisure time areas where there are nearby transit and thoroughfare routes to insure easy access back and forth. They should be in convenient proximity to large open spaces and should include smaller open spaces to insure an open-order character of development. They should be located in easy walking distance to accessory community facilities. They should be located in areas protected from traffic and incompatible uses, and in areas where desirable residential densities with a range of choice can be insured."[1]

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[1]Freund, Eric C., Goodman, William I., op. cit., p. 372.

Of course there are many more basic principles which have been and are presently held to be important factors regarding the location of residential areas. The important point here is that, in a modeling situation, one is forced to specify these principles in a manner which will allow them to be measured and analyzed in order to test their validity and simulate the urban environment. Another example of this is provided by the commonly held principle that the availability, quality, and location of school facilities is an important consideration to the individual householder upon selecting an area in which to locate. In order to use this as a variable in the model, it must be clearly defined and measured. In the case of the TCRPC model, this principle was introduced and tested in several different ways. For example, the total number of elementary school buildings in each census tract was used as a specific independent variable. Other measures included such definitions as the total number of classrooms, a ratio of classrooms per school-age child, and a ratio of classrooms per household. It was in this manner that it was possible to test the validity and applicability of this principle using several different definitions.

Another principle which is close to the heart of accepted planning practices is that public utilities and services both serve and shape urban development. Water and sewer facilities are held to be two of the most important public services which influence residential growth. However, it has long been difficult to determine how important these variables really are. Again, these two variables were introduced as independent variables into the regression analysis using several different definitions for each.

Chapin points out that "Transportation is essentially a service which enables people, firms, and various other entities to carry on activities at sites selected for these purposes in separated locations. Just as sanitation systems with their water supply and waste disposal facilities represent another necessary service, thoroughfares and transit systems and their terminal facilities exist to make it possible for connections of people, firms, and other human institutions to carry on their activities in different locations in space."[1]

It is commonly known that a major consideration in location decisions center around the matter of accessibility. As pointed out by Harris, "the pattern of land uses is thus a large dependent system in which choice of location of an establishment is made in terms of spatial distributions of others with which it interacts."[2] The individual household is by no means excluded from this behavioral characteristic.

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[1] Ibid., p. 339.

[2] Britton Harris. Preliminary Note on Aspects of Equilibrium in Urban Growth Models, Philadelphia, Pennsylvania, Institute for Environmental Studies, August, 1966, p. 17.

It has been well established that the vast majority of trips which have their origin or destination at a household are to or from either places of work or shopping facilities. In other words, the two most important movement variables which influence household location decisions are concerned with accessibility to work and accessibility to shopping facilities. If this is accepted as basically a sound assumption, then the problem becomes one of definition. The Tri-County Regional Planning Commission chose to incorporate the measure of accessibility as provided by the standard gravity modeling approach. It is stated by the Bureau of Public Roads that "In essence, the gravity model says that trip interchange (accessibility) between zones is directly proportional to the relative attraction of each zone and inversely proportional to some function of the spatial separation between zones. This function of spatial separation adjusts to the relative attraction of each zone for the ability, desire, or necessity of the trip maker to overcome the spatial separation involved."[1] Mathematically, the gravity model equation is expressed as follows:

$$T_{ij} = \frac{P_i A_j F_{ij} K_{ij}}{\underset{j=1}{N} A_j F_{ij} K_{ij}}$$

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[1] U.S. Department of Transportation/Bureau of Public Roads. Calibrating and Testing A Gravity Model for Any Size Urban Area, U.S. Government Printing Office, November, 1968, pp. 1-2.

"Where:

T_{ii} = trips produced in zone and attracted to zone

P_i = trips produced by zone

A_j = trips attracted to zone

F_{ij} = emperically derived travel time factor which expresses the average area-wide effect of spatial separation on trip interchange between zones which are apart

K_{ij} = a special zone-to-zone adjustment factor (friction factor) to allow for the incorporation of the effects on travel of defined social or economic linkages not otherwise accounted for in the gravity model formulation."[1]

Another important variable which exerts influence on household location decisions is concerned with the holding capacity of the area. Holding capacity, as defined here, is a function of available developable vacant land and the current gross residential density. In other words, it is a measure of the total number of households that can ultimately locate in a census tract given a specific density restraint. The support for using this as an independent variable is varied and overwhelming. Some measure of holding capacity has been used in one form or another in nearly every major

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[1] Ibid., pp. 1-3.

distribution model throughout the country. Imperically, holding capacity serves as both a policy constraint and an indication of the potential of an area to accept development. In other words, the planner can alter the holding capacity of an area both in the real world and in the model sense through the adjustment of residential density. Moreover, the distribution of developable vacant land in a metropolitan area has definite impact on development patterns. An example of this influence can be found in or near the core of most metropolitan centers. As the amount of vacant land decreases, the cost of that land increases. At some point in time, land values increase to the point where it is no longer economically feasible to consider residential development. At the same time, an abundance of vacant land generally indicates that an area is too far removed from the residential land market and, therefore, has a reverse effect on the desirability of that area to attract new development.

Median family income measures have enjoyed widespread applications in many urban models to date. Income data has many qualities which reveal pertinent information about the characteristics of the urban systems and its components. For example, median family income can provide many key insights into such complex issues as consumer preferences for housing types, locational preferences, and consumption rates. Moreover, different levels of income are directly related to varying auto ownership, trip productions and attractions, and household mobility rates.

Median family income, as used in the TCRPC distribution model, was found to be one of the most important variables in terms of its net impact on the dependent variable. Because of its relative importance in this equation, a separate model was formulated which simply addressed itself to the problem of forecasting future income levels throughout the study area. This income forecasting model, like the household distribution model, was based on a multiple regression analysis.

As mentioned in Chapter 2, an extensive listing of potential independent variables was prepared without regard for the problems of collecting these data from the various Federal, State and local sources. This list included a wide range of possible independent variables and was based on common planning principles and theories. As the study progressed and various data sources were identified, this initial list was trimmed and modified considerably. It was generally felt that the initial list included an excessive number of variables; many of which were either not available or were too costly to obtain. It was also felt that it was beyond the financial limitations of the Commission to obtain all the data listed. Moreover, many of the variables initially considered were deemed unnecessary or as having a low probability of exerting serious influence on the dependent variable. Lastly, the Commission felt that it would be more desirable to concentrate on developing very accurate measures of a limited number of very important variables rather than crude measures of a large number of variables. That is, they did not want to sacrifice quality in measurement for quantity in variables.

It is the author's opinion that the decision to reduce the total number of independent variables in favor of increasing the accuracy of input measurement may have had an undesirable effect on the model. Modeling techniques in general, and specifically regression analysis techniques are, at best, crude approximations of the "real world". That is, the inherent weaknesses in the basic theory underlying a regression model, the assumption and generalizations which must be made in order to formulate a model of this type, and the logical inconsistencies which exist, provide little assurance that the model will be a highly accurate allocation tool. That is not to suggest that regression models are useless tools because they are grossly inaccurate. Rather, while regression models are among the best techniques available, they have several weaknesses for which accurate measurement of data inputs will do little to correct or eliminate.

A more important criticism of the Commission's decision to emphasize accurate input measurement at the expense of the number of variables used concerns the purpose for which these inputs are intended. In any regression analysis, the independent variables are used to describe the changes in the dependent variable. In the case of the household distribution model under discussion, the independent variables are intended to describe various characteristics of a census tract that will have an influence upon household location decisions. That is, they represent some measure of a specific quality of an area that will either attract or repel households. Most of these variables represent some sort of physical property of the tract which local householders value as being desirable or undesirable. For example, the more accessible an area is to various employment centers throughout the region, the more theoretically desirable that area becomes. Accessibility to work, therefore, is introduced into the model as an independent variable and defined in such a manner as to approximate the collective attitude of all types of households. Although accessibility to employment is defined very specifically in terms of an equation, in reality it is nothing more than a crude approximation. First of all, it approximates the collective attitudes of all the households regarding the importance that is placed on accessibility, while in reality, different households of varying size, income, and social status view accessibility with varying importance. Secondly, since accessibility is a physical measure of a social value, it is by definition an approximation.

In summary, it is the author's opinion that it makes little sense to stress the importance of obtaining accurate measurements of the independent variables in a regression equation. This is clearly evident from the fact that these precise measurements are to be used in a very general and un-precise model. Moreover, there is no point in obtaining exceedingly accurate measures of the independent variables when the variables themselves are nothing more than approximations of what a householder deems important. It is suggested that it would have been more worthwhile to focus on the inclusion of additional independent variables. In so doing, the model would have been greatly enhanced by including more variables which deal with a wider range of social and economic characteristics. It is further suggested that this list of independent variables could have been expanded through the use of "proxy" variables rather than precise measurements and without any loss of model accuracy.

MODEL TESTING

There were two different methods which were used to test the model to determine its accuracy and utility: a performance and sensitivity test. Ira S. Lowery points out that "The appropriate test of a predictive model is to run a prediction and verify the details of its outcome."[1] He further points out that the basic procedure for undertaking a performance test is to "take the state of the world in 1950 as a starting point and apply the model by forecasting for 1960, then compare the forecast values to the observed values for 1960."[2]

PERFORMANCE TEST

The TCRPC model was formulated with data from the period from 1960 to 1965. The initial model allocation of households, therefore, was from 1965 to 1970. With the target date (1970) only two years away, there was a wealth of data upon which a fairly sound independent estimate of 1970's household distribution was developed. Once the model was used to generate a 1970 household allocation, the results were compared to this independent estimate of 1970 population. As mentioned in Chapter 2, it was found that the model approximated the probable 1970 distribution pattern with considerable accuracy.

It is the author's opinion, however, that this approach is not totally acceptable. Since these independent estimates were based on the planner's knowledge of the area, known and anticipated development plans, and traditional population forecasting techniques, the end product may be

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[1] Ira S. Lowery, op. cit., p. 164.

[2] Ibid., p. 164.

subject to considerable error. The ideal procedure is to compare the model's allocation to an existing statistical base where more exact measures of the household distribution is known. Although this was impossible in the case of the TCRPC model, it is recommended that model's 1970 household allocations by Census tract are compared to the 1970 Census data once it becomes available to obtain a clearer measure of the model's performance.

SENSITIVITY TEST

After completing the performance test, the model was given an extensive sensitivity test. It is pointed out by Lowery that sensitivity tests have several advantages which are not provided by performance tests: "Sensitivity testing is sometimes urged as a more accessible substitute for the performance test; although it is easy to perform, and applicable to a wide variety of models, sensitivity testing elicits indications of the "strength" of a model design rather than of a descriptive on predictive or evaluative accuracy."[1]

Lowery goes on to point out that the procedures involved in sensitivity testing are as follows: "By varying the value of a single parameter (or even an input variable) in successive runs of the model, one can measure

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[1] Ibid., p. 165.

the difference in outcome associated with a given parametric change. If the model's response to wide differences in the parametric values is insignificant, this may be an indication that the parameter - and the associated network of functional relationships - is superfluous. On the other hand, extreme sensitivity of outcomes to parametric changes indicates either that the parameter in question had better be fit with great care, or that some further elaboration of this component of the model is in order."[1] The procedure used to test the TCRPC household distribution model was to hold the correlation coefficients constant and vary the values for each independent variable. In this manner, it was possible to observe the fluxuations in the dependent variable which were caused by variations in each individual independent variable. The following three pages (Plates 4, 5, and 6) provide a graphic analysis and summary of the results of this sensitivity testing on both the Developed Area and Rural Area models.

For purposes of analysis, the "y" axis of these graphs are expressed in terms of actual change in households. The "x" axis is always expressed as a unit change in the relative value for the independent variable. This unit change is expressed as a reasonable range in values for each independent variable, beginning with the smallest value and progressing to the largest reasonable value for that

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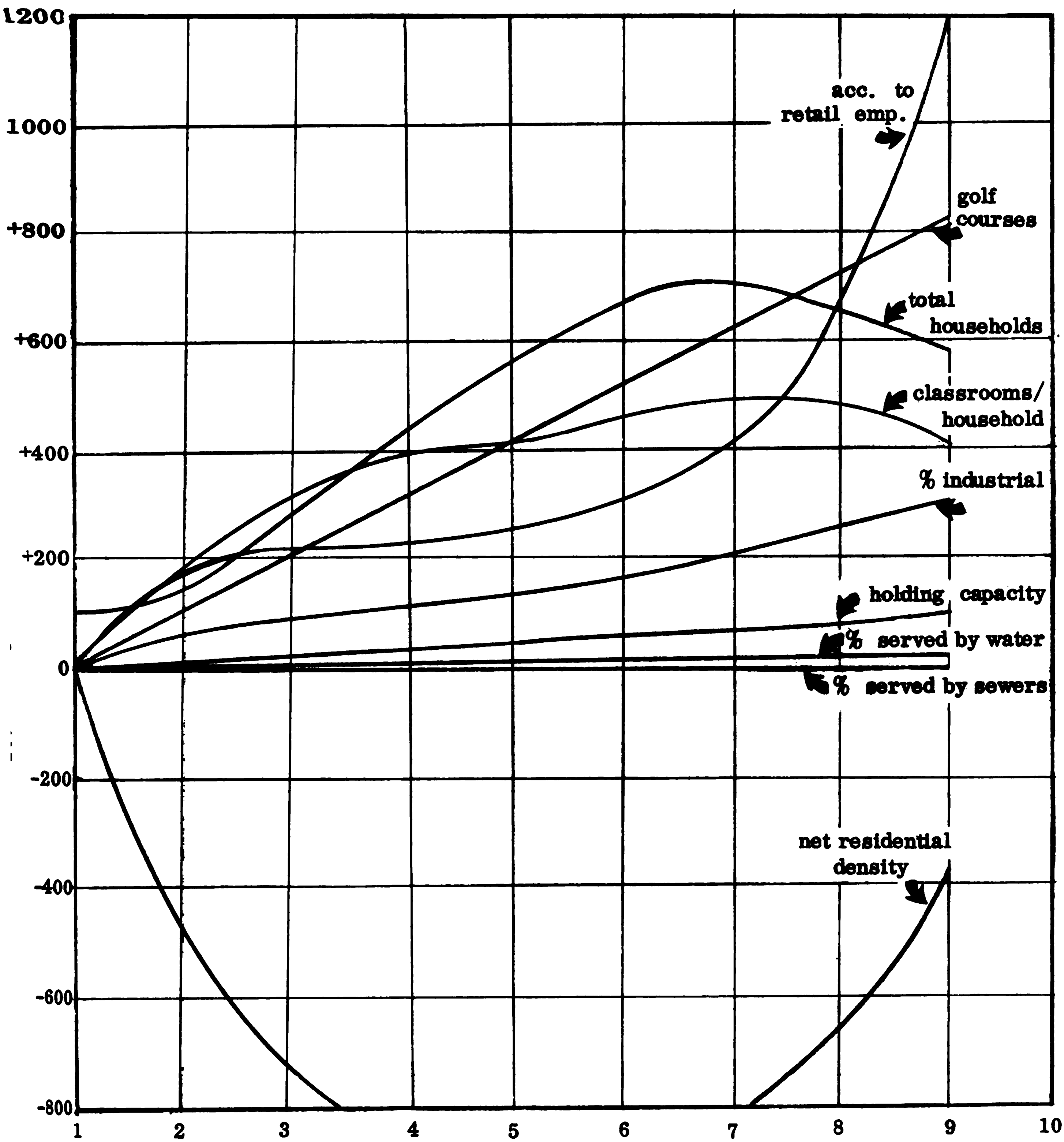
[1] Ibid., p. 164.

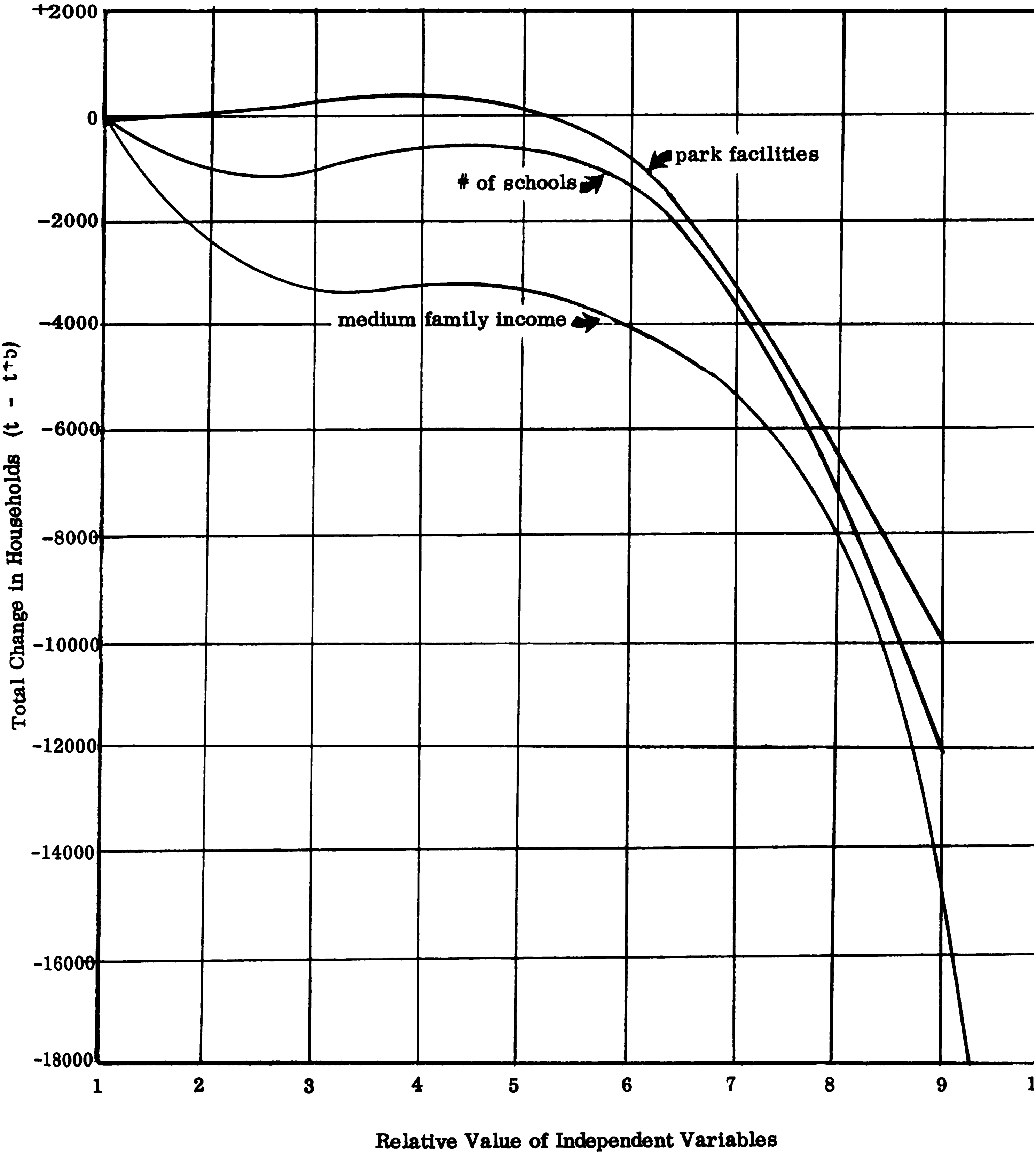
Total Change in Households (t = 11.6)

GRAPHIC ANALYSIS OF SENSITIVITY TESTS ON THE INDEPENDENT VARIABLE IN THE DEVELOPED AREA REGRESSION MODEL

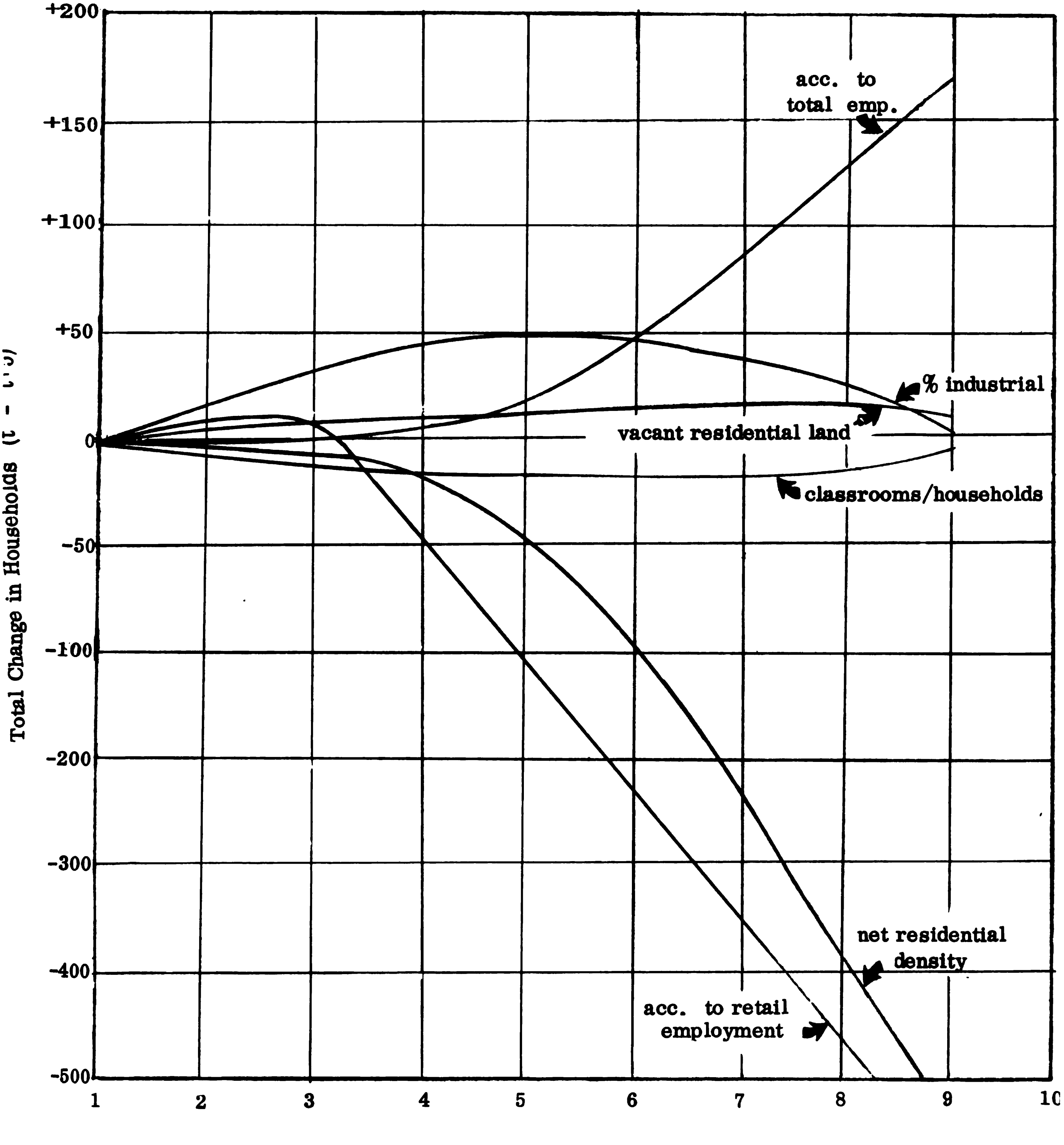


Relative Value of Independent Variables

GRAPHIC ANALYSIS OF SENSITIVITY TESTS ON THE INDEPENDENT VARIABLES IN THE DEVELOPED AREA REGRESSION MODEL



GRAPHIC ANALYSIS OF SENSITIVITY TESTS ON THE INDEPENDENT VARIABLES IN RURAL AREA REGRESSION MODEL



variable.

The following table consists of a ranking of independent variables based on their partial correlation coefficients. From this ranking, it is possible to determine which of the independent variables correlated most highly with the dependent variable.

Developed Area Model Independent Variables

Rank	Independent Variable
1	Residential density
2	Number of schools
3	Area served by water
4	Elementary school classrooms per household
5	Number of parks
6	Number of golf courses
7	1960 households
8	Median family income
9	Percent developed industrial
10	Percent of area served by sewers
11	Vacant land acreage
12	Accessibility to retail employment

Rural Area Model Independent Variables

Rank	Independent Variable
1	Accessibility to retail employment
2	Accessibility to total employment
3	Vacant land acreage
4	1960 households
5	Percent developed industrial
6	Number of elementary school classrooms
7	Current net residential density

Lowery has suggested that a model must not be insensitive nor overly-sensitive to changes in values of the independent variables. It is suggested that model sensitivity is a matter of balance wherein rational shifts in parameters cause rational changes in household distributions.

As a result of these sensitivity tests, two independent variables were found to be overly-sensitive to small changes in values. Both of these variables appear in the Developed Area model; the number of schools and the number of parks. Although it does not clearly appear in the graphic analysis of these variables, very minor changes in either variable will cause serious changes in the household distribution patterns. Fortunately, the sensitivity of these variables was discovered prior to the model's application. As a result, the necessary adjustments were made to reduce the undesirable unfluence of these variables on the distribution of households. It should be pointed out, however, that this problem was not dealt with in a satisfactory manner. It is the author's opinion that, upon discovering that there were two overly-sensitive independent variables, a new regression analysis should have been performed on the Developed Area, excluding both the total number of parks and schools. The basis for this opinion stems from the fact that, whenever an independent variable is either added or removed from a regression analysis, there is a resultant change in the regression coefficients for the remaining variables. That is, the relative importance of the remaining independent variables, concerning their impact upon the dependent variable, is altered.

The approach that was taken by the Commission, however, was to eliminate any undesirable influence that these two variables might have had on the distribution of households by holding them constant. In effect, neither of these variables were used throughout the allocation period. It is the author's contention that, if in fact these two variables should have been excluded from the equation, a new regression equation should have been obtained which was based on the actual exclusion of these variables. Without becoming deeply involved in a detailed discussion regarding the relative impact and correlations of these variables, it should be mentioned that a high correlation between an independent variable and the dependent variable does not always mean that the independent variable will be important in terms of its relative influence. A case in point is that concerning the independent variables in the Developed Area model which involve the "area served by water" and "median family income". Area served by water is ranked third in correlation with household change, whereas median family income ranks eighth. However, the influence of the income variable far exceeds that of water service variable in effecting the dependent variable.

It is also possible to begin to draw some conclusions regarding various pre-conceived theoretical notions about the independent variables and their effect on the dependent variable. As mentioned earlier, the selection of variables was, in part, based on criteria provided by basic planning principles regarding household location preferences. The testing and ranking of these variables should provide some insights as to how realistic these principles and assumptions actually are, in relation to the study area.

One of the most obvious findings strikes at the basic planning principles which state that transportation facilities exert a heavy influence upon household location decisions in the metropolitan area. It was found that accessibility to work in fact was not an important variable in the developed area. In fact, this variable was completely deleted from the equation because of its poor correlation with the dependent variable.

It may be concluded that accessibility to work is not an important determinant of household growth in the Lansing area. Although this statement may be difficult to accept, there are several valid reasons which support this conclusion. It should first be realized that the developed area model addressed itself to what is considered the urbanized and urbanizing areas of the region. Moreover, it is within this area that one can find the greatest number of available jobs as well as the widest choice of residential sites. In addition, this area constitutes a very small percent of the total area of the region. As a result, a person can live virtually anywhere within this area and travel to any other point with relative ease and within a very short period of time. It has been determined from the transportation study that a person can drive from any remote point in the fringe of this area to any other point within a total travel time of 10 to 20 minutes.[1] It may be concluded, therefore, that accessibility to work is not a serious consideration. Moreover, it is logical to assume that other factors are considerably more important to local householders.

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[1]TCRPC 1965 Land-Use, Natural Resource Transportation Study.

In the case of the Rural Area Model, accessibility to work emerges as a very significant variable. This is totally consistent with the theoretical constructs of this model. The rural component of the region constitutes a very large geographic area which is generally lacking in high speed transportation facilities. Moreover, the employment base is limited and scattered. The relationship of the household to place of work becomes increasingly more important because the factors of time and distance are far greater.

It is this author's opinion that the selection of all variables, not only those of accessibility, should be heavily influenced by the characteristics of the particular area under study. As has been pointed out in the discussion of work trip accessibilities, this variable has limited importance in the Lansing area. This is not to suggest that accessibility is not an important variable in other situations and studies. It is suggested, however, that the size, scale, form and social-economic character of the local area will, for the most part, determine whether or not a particular factor is important. For example, accessibility to work would logically become a very important factor in household location decisions in a metropolitan area such as Detroit or Cleveland. It is in metropolitan areas of this size where travel time, traffic congestion during peak hours, as well as trip distance, increase to the point where the local householder is forced to limit his range of possible residential locations to those areas which are reasonably close to his place of employment. It is possible to further broaden this statement by stating that each community has a different set of conditions, values, or circumstances which will have varying effects on the relative importance of different basic planning principles. It is the model builder's first responsibility to educate himself concerning the unique qualities of his area prior to identifying specific independent variables.

Another important criticism of the model concerns the matter of disaggregating observations (census tracts). Although the techniques that were used by the Commission to disaggregate the Region into a "Developed Area" and a "Rural Area" for modeling purposes were well thought out and factually based, the overall approach was somewhat subjective and largely traditional in nature. It is the author's opinion that several measures could have been employed to provide a more rational basis for disaggregation. Specifically, much of the community attitude data which was obtained in the 1965 Home Interview Survey would have been useful to determine various geographic aggregates of households based on similarities in their particular values regarding location factors.

There are three general categories of independent variables in both the Developed and Rural Area models; those which have a significant positive impact on the dependent variables, those which have little or no influence, and those which have a major negative influence on the change in households. As indicated on Plates 4, 5, and 6, these variables are listed as follows:

Developed Area Model	Rural Area Model
A. Variables with a positive influence	
1. Accessibility to retail employment	1. Accessibility to total employment
2. Total number of golf courses	
3. Total historical households	
4. Classrooms per household	
5. % of total area in industrial uses	
B. Variables which have little or no impact	
1. Residential holding capacity	1. % industrial
2. % of area served by sewers	2. Total vacant acres
3. % of area served by water	3. Classrooms per household
C. Variables with a serious negative influence	
1. Total number of parks	1. Net residential density
2. Total number of schools	2. Accessibility to retail employment

Many of the relationships that are apparent from this type of graphic analysis can be explained by common planning theories or beliefs. Others are more difficult to justify in the absence of a thorough and detailed analysis. Unfortunately, any attempt to either defend or attack any one of these relationships must be based on intuitive judgment or theoretically-based arguments. For example, total households, as shown on Plate 5, indicate that the greater the number of households that already exist in a census tract, the more attractive that tract becomes. However, once a certain point is reached, there is a marked shift in this relationship. That is, once the total number of existing households reaches a certain level, that tract becomes less desirable to new households. This relationship can be supported by several observable and theoretical arguments. For example, once an area reaches a certain level of development, a number of factors come into play which can influence the attractiveness of the area. The holding capacity may be reduced to the level where little or no vacant land is available to support additional residential development. Land values may have reached a point where residential development is no longer a feasible use for the remaining available land. Lastly, the area may become less attractive to new development because of a large number of older homes.

At the other end of the scale, median family income (Plate 6) indicates that as incomes increase, the fewer number of households are attracted to the area. Once median family income reaches the upper middle class level, however, there is a noticeable downward shift in this trend. This can be explained by the economic principle that higher income families tend to seek the more desirable and expensive residential sites in the area. Moreover, the prestige that is associated with higher income residential areas tends to inflate the development and land costs. Finally, most income distribution curves indicate that there is a generally small number of households in the higher income categories relative to the total distribution of incomes. There are very few households, therefore, that can afford to locate in these prestige areas.

In summary, it should be pointed out that the relationship of each independent variable to the dependent variable appears to be logical and consistent. That is, since there is a logical explanation for most of these relationships, the model itself is generally consistent with existing planning theories and principles.

As a final note, attention should be drawn to the fact that there are two independent variables in the Developed Area model which, although intuitively felt to have a great deal of importance, in fact have little or no effect on the distribution of households. These variables are the "% of the area served by sewers" and the "% of the area served by water". As illustrated on Plate 4, these variables have very little impact on the dependent variable. Moreover, each of these variables were completely deleted from the regression analysis for the Rural Area. This can be partly explained by the fact that, except for a few tracts, nearly all of the Developed Area is directly or indirectly served by water and sewer facilities. In the Rural Area, however, public water and sewer facilities are nearly non-existent. Moreover, since past development control practices have placed little or no emphasis on either of these two services as a control, past development has not been responsive to the availability of these facilities. It is the author's opinion that the unimportance of these variables may be considered to be a serious weakness of the model. It is felt that public water and sewer facilities will become increasingly more important as controls over future development. With the advent of increased development pressures and the resultant problems of water pollution due to poor sewer facilities, more legislative and social emphasis is being placed on the importance of this problem. As a result, planning policies regarding the extension of sewer and water facilities will become among the most crucial and powerful development control measures available to the planners.

Unfortunately, no attempt was made to account for this trend in the TCRPC model. That is, the coefficients for sewer and water variables were held constant, as were all others, throughout the allocation period. It is the author's opinion that these coefficients could have been changed at each allocation interval to approximate the increased importance of these variables.

<u>OPERATIONAL CONSIDERATIONS</u>:

Another important area which is equally deserving of consideration concerns the area of operational and administrative problems that are directly related to the type and scope of the study. To undertake a modeling approach to comprehensive planning without giving attention to such matters as personnel, technical skills, consultant services and special equipment and facilities is not only foolhardy but potentially disasterous.

One of the most important matters which warrants immediate consideration deals with the type and training of personnel that are required to undertake this job. An important facet of this problem centers around the issues of whether or not highly skilled and technically competent personnel should be secured as part of the regular planning staff or acquired through the services of a consultant. Although this problem faces any agency, regardless of the approach they are taking, the complexities and seriousness become far greater when computer programming and models are involved.

There are relatively few planners available that have the necessary skills and background to perform the kinds of services needed to successfully complete a modeling effort of this type. Moreover, the salaries demanded by these people are often times greater than the budgetary limitations of the planning agency. However, it is usually quite costly to acquire the services of a qualified consultant for a project of this nature and usually the time loss because of coordinative problems is considerable. Harris points out that "Many consultants are highly skilled on the technical side but lack substantive knowledge of planning and urban problems, and consequently must to some extent be educated as to the content of the work. On the other hand, traditionally trained planners and urban analysts are familiar with the problem but not in the techniques and must be educated in them."[1] It has been found that a technical person is more flexible to adapting to social problems than the planner is capable of obtaining the technical skills. Either way, however, considerable time is lost with a resultant increase in overall project costs.

In the case with the Tri-County Regional Planning Commission, the work was performed by agency staff members who worked closely with the Community Systems Foundation, through which technical consultant services were obtained. In order to minimize the problems of coordination which re-

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[1]Britton Harris. "Organizing the Use of Models in Metropolitan Planning", op. cit., p. 19.

sult from this type of arrangement, CSF personnel were given office space at the Commission. In this manner the regular staff and the consultants were better able to exchange ideas and develop the model with a minimum lack of coordination.

The type, quality and amount of data that is required to support a study of this type is another important consideration. In a traditional planning office, data demands are of a general, standard, and of an obvious nature. That is, the program does not require that extensive, fine-grained information be acquired. More general types of data are usually required which describe the overall physical, natural, social, and economic characteristics of the metropolitan area. The model, however, will demand detailed information aggregated to very small geographic areas. As a result, the time and effort that is needed to collect, store, and analyze this data is considerable. Britton Harris points out that "The early establishment of policies and determinations of methods with regard to data collection and data file management is absolutely essential for any large study. Delay and indecision in this field will involve the study staff in a major emergency measure at a later date and result in overwhelming attribution of the staff capability of dealing with more substantive problems."[1] The primary reason for Harris'

[1] Ibid., p. 20.

concern over the early establishment of data collection programs stems from the fact that much of the information that will be required is extremely difficult to obtain. It is very easy to underestimate the size of the task because it requires a great deal of foresight to anticipate all the operational problems that could result.

This is not to suggest that an agency should immediately run out and begin to gather data. It is still a good rule to wait on data collection activities until the study design, program objectives and model components have been well established. In fact, this rule is somewhat more important in this type of program. In addition to general purpose type of data that is gathered by most planning agencies, the model usually calls for a class of data which may be titled "special purpose data".[1] That is, data which will have a specific role or place in the model program. Included in this category are data on such items as origins-destinations, household typologies and type of employment by place of work. Data to be used in the model should be identified and defined at as early a date as possible. Moreover, procedures should be established for collecting, storing and using this information as efficiently as possible. Due to the large volumes of data that are

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[1] Ibid., p. 21.

required, new and better data processing techniques should be employed to assure that this information is handled accurately, quickly and consistently. That is, electronic data processing equipment is a necessity for insuring a well-organized and functional system for information storage, manipulation and retrieval.

RECOMMENDATIONS FOR MODEL IMPROVEMENT

Based on the experience gained from formulating, designing and applying this model, it has become quite clear that a number of improvements could be made to enhance its theoretical base as well as its applications. The following is a summary of recommendations for improving the model and its use:

(A) Given all the pros and cons of various modeling techniques, it is recommended that the Commission again use the regression technique as the theoretical base of the model. It is felt, however, that several changes should be made to wherein the feasibility and utility of the model would be greatly enhanced.

(B) As mentioned in the previous evaluation, the fact that the model grouped all households into one single category was a serious weakness. It is recommended, therefore, that an effort be made to incorporate household typologies into the model based on such variables as income, school years completed, employment types and age composition.

This approach will be much more feasible after 1970 when summary tapes and special tabulations will be available from the Census Bureau at substantially lower costs and with less time delays.

(C) The basic geographic unit of aggregation which was used in the original distribution model consisted of 1960 Census tracts. It is felt that these areas, being arbitrarily defined for purposes of conducting a census, did not adequately define homogenious areas having like socio-economic characteristics. With the advent of the 1970 Census, it will be possible to ignore tract boundaries and formulate special purpose geographic areas for model use. Moreover, local areas will be given copies of 1970 Census summary data containing information which is aggregated to the block level. It is recommended, therefore, that special areas be defined which bear a closer relationship to the model's needs and better approximate areas having similar social-economic characteristics.

(D) It is further recommended that the Commission undertake the development of an information system wherein the Dual Independent Map Encoding (DIME) file to be developed by the Census Bureau would serve as the key for preparing various local data. This would facilitate the quick and efficient geographic identification of data in a manner which would be compatible with both Census and locally defined areas. Moreover, this system would aid in the development of a data base for the model as well as other studies.[1]

(E) A serious effort should be made to expand upon the independent variables used in the model. That is, more variables should be included in the regression equation. Among other things, these variables should be directed at measuring the economic influences of the Region. Included should be such measures as land values, housing costs, rental rates, and tax rates.

(F) It is recommended that various supporting models be developed for providing estimates of the independent variables wherever feasible. These models should be interfaced with the household distribution model in order to achieve an interactive system for allocating growth.

(G) The distribution model should be further developed to include the ability to automatically convert households to total population. A supplementary model should be prepared which estimates family size given data on household types and various local and national trends. Moreover, the model should be capable of generating estimates of non-residential land consumption given such measures as household growth, employment by type and place of work, and standards which indicate the land area needs for such neighborhood facilities as streets, parks, schools

[1] George Farnsworth. Dual Independent Map Encoding, A Geographic Base File. This is an internal staff paper prepared for the Census Use Study.

and local shopping facilities.

(H) A more obvious recommendation is that the model serve as a device for both formulating and evaluating alternative development schemes. That is, the model should be used to assist the planner in formulating policies, testing the policies relative to their influence on development patterns, and selecting a specific set of policies which are most feasible and desirable to insure a better future state.

(I) Another recommendation which is directly related to Point G mentioned above concerns the involvement of the Commission staff and local decision makers in plan formulation and evaluation. The local and Regional planners as well as various decision and policy makers from the public and private sectors should be encouraged to participate in setting goals, formulating specific policies, translating these policies into values for the independent variables, and reviewing the outcome of these decisions as provided by the model. There is a significant educational value to this approach to plan formulation as well as an opportunity to secure the local support and understanding that is necessary for better and later implementation of the final plan.

(J) Lastly, it is recommended that the household distribution model be better interfaced with the transportation models. This could be accomplished by using compatible geographic areas in both models rather than Census tracts in one and unrelated traffic zones in the other. Moreover, both models should be allowed to interact with one another.

APPENDIX A

"POTENTIAL INDEPENDENT VARIABLES"

APPENDIX A

The following is a general listing of all the potential independent variables that were tested in the regression analysis:

A. 1960 Accessibility (functional relationship variables)

1. Work trip accessibility to total employment.
2. Shopping trip accessibility to total employment.
3. Shopping trip accessibility to retail employment.
4. Shopping trip accessibility to households.

B. 1960 Environmental Variables

1. Developed land acreage.
2. Vacant developable land acreage.
3. Historical net residential density.
4. Historical gross residential density.
5. Current net residential density.
6. Holding capacity (1960)
    a. Vacant developable land x current density.
    b. Vacant developable land x historical net density.
    c. Vacant developable land x historical gross density.
    d. Adjusted vacant land acreages.
    e. Adjusted vacant land x historical net residential density.
    f. Adjusted vacant land x current net residential density.
7. Total industrial acres.
8. Percent of total area developed industrial.

C. <u>Public Service Variables</u> (1960)

1. Sewer service area.

   a. Total land area serviced.

   b. Percent of total land area served.

   c. Percent of developed land area served.

   d. Percent of undeveloped land area served.

2. Water service area (1960)

   a. Total land area served.

   b. Percent of total land area served.

   c. Percent of developed land area served.

   d. Percent of undeveloped land area served.

3. School service area (1960)

   a. Total number of elementary schools.

   b. Ratio of households per school.

   c. Total number of elementary school classrooms (1960).

   d. Ratio of households per elementary school classrooms (1960).

4. Recreation Service Levels (1960)

   a. Total recreational land.

   b. Percent of total area in recreational land.

   c. Households per acre of recreational land.

   d. Total number of parks.

   e. Total number of golf courses.

APPENDIX B

"RURAL AREA REGRESSION ANALYSIS"

(UNRESTRICTED LEAST SQUARES)

DEPENDENT VARIABLE--X(64) HHDPVAR1

VARIABLE DELETED BY CRITERION 4 WAS X(83) SEWER X2

VARIABLES IN ORDER DELETED

60RESDEN	SCHOOLS	60ACTEX3	SWR SERV	IND X3	PARKS X2	SCHLS X2	RMSPERHH	60RDENX2	SCHLS X3	H2O SERV	H2O X2
115	91	72	82	90	95	92	85	116	93	79	80
H2O X3	60WTACTE	60INC X3	60INC X2	60INCOME	60HH	GOLF	60ACREX3	VACX3	PARKS X3	SEWER X3	SEWER X2
81	70	78	77	76	133	97	75	132	96	84	83

SIGNIFICANCE CRITERION MET,

RESULTS REQUESTED EVERY ITERATION.

AOV FOR OVERALL REGRESSION

	SUM OF SQUARES	DEG OF FREEDOM	MEAN SQUARE	F	SIG
REGRESSION (ABOUT MEAN)	52027.05201817	12	4335.58766818	26.1537	<0.0005
ERROR	8288.66226673	50	165.77324533		
TOTAL (ABOUT MEAN)	60315.71428490	62			

OBSERVATIONS	MULTIPLE CORR COEFS R2	R	R BAR 2	R BAR	S STANDARD ERROR OF ESTIMATE
63	0.8626	0.9288	0.8296	0.9108	12.87529593

	VAR	REGRESSION COEFFICIENTS	STD. ERRORS OF COEFFICIENTS	BETA WEIGHTS	STD. ERRORS OF BETAS	TB	FB	SIG	PARTIAL CORR COEFS	R2 DELETES
CONSTANT	0	-20.15542919	9.32600759			-2.1612	4.6708	0.035		
60ACTEX2	71	42.84684642	7.57691416	0.67306	0.15439	5.6549	31.9781	<0.0005	0.62456	0.77469
60STACRE	73	1860.61134586	553.92721623	0.66918	0.19922	3.3589	11.2825	0.002	0.42908	0.83157
60ACREX2	74	-63987.15374091	10805.41303015	-1.17380	0.19822	-5.9218	35.0673	<0.0005	-0.64205	0.76620
CLRMS X2	86	-25524.25817680	7402.17237425	-0.98420	0.28542	-3.4482	11.8902	0.001	-0.43831	0.82990
CLRMS X3	87	412812.68784332	119472.86619949	1.03157	0.29855	3.4553	11.9390	0.001	0.43904	0.82977
IND PCT	88	3856.29893375	1114.43006637	0.69014	0.19944	3.4603	11.9739	0.001	0.43956	0.82967
IND X2	89	-154588.71011353	48606.62039661	-0.58751	0.18473	-3.1804	10.1150	0.003	-0.41020	0.83478
60RDENX3	117	-0.14674297	0.06051706	-0.22442	0.09255	-2.4248	5.8798	0.019	-0.32438	0.84642
VAC	130	80.59247636	17.50887835	2.40511	0.52251	4.6029	21.1871	<0.0005	0.54555	0.80435
VACX2	131	-32.79467732	7.25266577	-2.13296	0.47171	-4.5217	20.4461	<0.0005	-0.53874	0.80638
60HH	134	21491.48612223	4797.01699030	1.68516	0.37614	4.4802	20.0720	<0.0005	0.53521	0.80741
60HH	135	-146064.41955948	37000.15800476	-1.42686	0.36195	-3.9477	15.5841	<0.0005	-0.48746	0.81975

HHOPPAV1

	OB	Y = X(64)	ESTIMATED Y	Y - ESTIMATED Y
45	1	46.00000000	39.13524906	6.86475094
50	2	99.00000000	97.39424098	1.60575902
51	3	67.00000000	82.64638506	-15.64638506
52	4	73.00000000	67.61378678	5.38621322
66	5	110.00000000	72.67533128	37.32466872
68	6	12.00000000	20.99312532	-8.99312532
69	7	15.00000000	9.29982457	5.70017543
70	8	30.00000000	37.46320237	-7.46320237
71	9	40.00000000	46.34765698	-6.34765698
72	10	116.00000000	106.63050504	9.36949496
75	11	35.00000000	49.36376612	-14.36376612
76	12	45.00000000	43.02333486	1.97666513
77	13	50.00000000	62.69162033	-12.69162034
79	14	27.00000000	40.89458612	-13.89458612
80	15	26.00000000	15.02661315	10.97338685
81	16	21.00000000	23.40105331	-2.40105331
82	17	9.00000000	18.29953303	-9.29953303
83	18	16.00000000	38.31260580	-22.31260580
84	19	27.00000000	29.09622643	-2.09622643
85	20	5.00000000	31.12616446	-26.12616446
86	21	29.00000000	31.66497347	-2.66497347
231	22	9.00000000	21.21836940	-12.21836940
232	23	9.00000000	8.10095990	0.89904010
233	24	8.00000000	2.06403825	5.93596174
234	25	15.00000000	16.82662570	-1.82662570
236	26	69.00000000	64.15059408	4.84940592
238	27	26.00000000	29.21203482	-3.21203482
239	28	124.00000000	117.21738607	6.78261393
240	29	26.00000000	33.46621879	-7.46621879
241	30	5.00000000	8.16054634	-3.16054634
242	31	17.00000000	19.01605749	-2.01605749
243	32	5.00000000	13.86052751	-8.86052751
244	33	12.00000000	2.33934020	9.66065980
245	34	15.00000000	16.80516260	-1.80516260
246	35	35.00000000	20.45237456	14.54762544
248	36	72.00000000	44.41111625	27.58888375
249	37	51.00000000	54.68498123	-3.68498123
251	38	58.00000000	33.26822204	24.73177796
252	39	16.00000000	18.80555881	-2.80555881
253	40	15.00000000	20.67348977	-5.67348977
254	41	24.00000000	18.26421389	5.73578611
255	42	20.00000000	24.28122724	-4.28122724
256	43	20.00000000	-1.13125211	21.13125211
402	44	26.00000000	23.71000335	2.28999665
403	45	10.00000000	8.97703218	1.02296782
404	46	19.00000000	16.42778095	2.57221905
405	47	30.00000000	34.58517733	-4.58517733
406	48	31.00000000	35.58997225	-4.58997225
407	49	11.00000000	3.92828790	7.07171210
408	50	4.00000000	6.38869021	-2.38869021
409	51	20.00000000	36.15104615	-16.15104615
410	52	40.00000000	32.64588227	7.35411773
412	53	14.00000000	10.53801749	3.46198251
413	54	11.00000000	17.94559585	-6.94559585
414	55	8.00000000	9.90954650	-1.90954650
415	56	7.00000000	13.65056357	-6.65056357

416	57	21.00000000	15.66079305	5.33920695
417	58	49.00000000	52.92919986	-3.92919986
418	59	27.00000000	35.68320120	-8.68320120
419	60	109.00000000	116.45687338	-7.45687338
420	61	110.00000000	114.13335681	-4.13335681
423	62	83.00000000	54.03821300	28.96178700

SUM Y		SUM RES
2196.00000000		0.00000000
SSY	SS(Y - MEAN Y)	SS RES
136862.00000000	60315.71428490	8288.66226673
R2	D.W. STAT	SS(R - PREV R)
0.86257873	1.97668489	16384.07343435

APPENDIX C

"DEVELOPED AREA REGRESSION ANALYSIS"

(UNRESTRICTED LEAST SQUARES)

DEPENDENT VARIABLE--X(64) HHDPVAR1

VARIABLE DELETED BY CRITERION 1 WAS X(87) CLRMS X3

VARIABLES IN ORDER DELETED

SEWER X3	IND X3	IND PCT	SWR SERV	60ACTEX2	60ACTEX3	VL 60D	VL 60DX3	60WTACTE	60HH	CLRMS X3
84	90	88	82	71	72	121	123	70	135	87

SIGNIFICANCE CRITERION MET,

MINIMUM ERROR MEAN SQUARE CRITERION MET,

RESULTS REQUESTED EVERY ITERATION,

AOV FOR OVERALL REGRESSION

	SUM OF SQUARES	DEG OF FREEDOM	MEAN SQUARE	F	SIG
REGRESSION (ABOUT MEAN)	2199232.90832520	26	84585,88108826	21.1492	<0,0005
ERROR	63991.69632435	16	3999,48102027		
TOTAL (ABOUT MEAN)	2263224.60461426	42			

OBSERVATIONS	MULTIPLE CORR COEFS R2	R	R BAR 2	R BAR	S STANDARD ERROR OF ESTIMATE
43	0,9717	0,9858	0.9258	0,9622	63.24145018

	VAR	REGRESSION COEFFICIENTS	STD. ERRORS OF COEFFICIENTS	BETA WEIGHTS	STD. ERRORS OF BETAS	TB	FB	SIG	PARTIAL CORR COEFS	R2 DELETES
CONSTANT	0	2754.40891111	882,82608819			3,1200	9,7343	0,007		
60STACRE	73	6250.66699445	1979,42635468	1.28832	0.40798	3,1578	9,9718	0,006	0.61963	0,95410
60ACREX2	74	-61423.35305691	22540,47160769	-2,29820	0.84337	-2,7250	7,4258	0,015	-0.56302	0,95860
60ACREX3	75	210696.82545090	75677,30154037	1,41134	0.50692	2,7841	7,7515	0,013	0.57128	0,95803
60INCOME	76	-9739.63667750	3494,80296254	-6,82491	2.44893	-2,7869	7,7668	0,013	-0.57166	0,95800
60INC X2	77	13897.26791620	4417,98136342	15,30112	4.86602	3,1445	9,8878	0,006	0,61802	0,95425
60INC X3	78	-6318.22694969	1801,72194099	-8,73341	2.49044	-3,5068	12,2974	0,003	-0,65923	0,94999
H2O SERV	79	20.02541517	2,42184342	4,81334	0.58212	8,2687	68,3708	<0,0005	0,90020	0,85090
H2O X2	80	-0.24123818	0,03495957	-8,61892	1.24903	-6,9005	47,6168	<0,0005	-0,86516	0,88758
H2O X3	81	0.00067456	0,00013711	3,72632	0.75740	4,9199	24,2053	<0,0005	0,77591	0,92895
SEWER X2	83	0.00677536	0,00198762	0,34268	0.10053	3,4088	11,6198	0,004	0,64862	0,95119
RMSPERHH	85	32377.68622713	4271,96810198	1,92673	0.25421	7,5791	57,4435	<0,0005	0,88439	0,87021
CLRMS X2	86	-544772.44673157	68559,04070854	-1,69026	0.21272	-7,9460	63,1395	<0,0005	-0,89321	0,86015
IND X2	89	11873.06692362	3464,55645239	0,21214	0.06190	3,4270	11,7444	0,003	0,65062	0,95097
SCHOOLS	91	-884.24928790	66,98359149	-6,67524	0.52076	-12,8183	164,3077	<0,0005	-0,95460	0,68137
SCHLS X2	92	297.21357268	23,04493461	13,70952	1.06118	12,6802	160,7866	<0,0005	0,95367	0,68759

PARKS	94	-267.31991304	[illegible]	4.07730	0.74082	5.2038	30.2917	<0.0005	[illegible]	[illegible]
PARKS X2	95	198.94171087	36.14633358	-2.60957	0.49978	-5.2215	27.2637	<0.0005	-0.79384	0.92355
PARKS X3	96	-28.06182791	5.37431906	-2.60957	0.49978	-5.2215	27.2637	<0.0005	-0.79384	0.92355
GOLF	97	-190.66259138	39.67720803	-0.33809	0.07036	-4.8053	23.0913	<0.0005	-0.76857	0.93092
60RESDEN	115	-336.74041222	22.50082135	-17.61686	1.17715	-14.9657	223.9720	<0.0005	-0.96609	0.57593
60RDENX2	116	20.41013333	1.47485004	87.61234	6.33093	13.8388	191.5120	<0.0005	0.96067	0.63329
60RDENX3	117	-0.20289664	0.01508263	-70.78502	5.26191	-13.4523	180.9655	<0.0005	-0.95852	0.65193
VL 60DX2	122	375.06582280	117.52065555	0.21307	0.06676	3.1915	10.1856	0.006	0.62368	0.95373
60HH	133	6583.13324022	1455.54890564	1.46107	0.32305	4.5228	20.4556	<0.0005	0.74907	0.93558
60HH	134	-18470.06992769	5580.41361451	-1.03564	0.31290	-3.3098	10.9548	0.004	-0.63751	0.95237

R E S I D U A L S (UNRESTRICTED LEAST SQUARES)

	OB	HHDPVAR1 Y = X(64)	ESTIMATED Y	Y - ESTIMATED Y
9	1	4.00000000	-2.40125716	6.40125716
11	2	94.00000000	80.04347288	13.95652712
12	3	23.00000000	75.68263153	-52.68263153
13	4	37.00000000	12.00130140	24.99869860
14	5	9.00000000	8.99992650	0.00007350
16	6	13.00000000	-4.93007138	17.93007138
17	7	317.00000000	312.12533633	4.87466366
20	8	207.00000000	212.05170764	-5.05170765
21	9	27.00000000	35.53500753	-8.53500753
22	10	10.00000000	-23.93714329	33.93714329
23	11	34.00000000	41.10042332	-7.10042332
28	12	195.00000000	145.88085851	49.11914149
29	13	37.00000000	102.52182361	-65.52182361
30	14	0.00000000	-21.59398070	21.59398070
31	15	909.00000000	888.04396221	20.95603778
32	16	41.00000000	21.79219975	19.20780025
33	17	214.00000000	196.62711990	17.37288010
34	18	231.00000000	202.58682825	28.41317174
35	19	56.00000000	132.19314441	-76.19314441
36	20	1253.00000000	1237.65114942	15.34885056
37	21	106.00000000	126.68148048	-20.68148048
38	22	329.00000000	326.24331349	2.75668651
39	23	356.00000000	342.09079862	13.90920137
40	24	67.00000000	60.78817061	6.21182939
43	25	323.00000000	356.36046300	-33.36046301
44	26	155.00000000	180.66093985	-25.66093985
46	27	147.00000000	106.98635538	40.01364462
47	28	79.00000000	104.24120159	-25.24120159
48	29	110.00000000	227.61473422	-117.61473422
49	30	267.00000000	329.37544707	-62.37544708
53	31	290.00000000	317.31672832	-27.31672832
54	32	144.00000000	46.89600751	97.10399249
55	33	134.00000000	124.64036106	9.35963894
67	34	86.00000000	114.96788367	-28.96788367
101	35	188.00000000	126.58703389	61.41296611
102	36	164.00000000	156.22372087	7.77627913
201	37	451.00000000	414.14485534	36.85514466
202	38	91.00000000	132.43426694	-41.43426695
203	39	343.00000000	307.47435866	35.52564133
235	40	159.00000000	191.93589329	-32.93589329
247	41	259.00000000	234.99872150	24.00127850
250	42	164.00000000	155.66359026	8.33640974
411	43	109.00000000	95.69923362	13.30076638

APPENDIX D

"HOUSEHOLD ALLOCATION MODEL PROGRAM AND SAMPLE OUTPUT"

```
      PROGRAM DISTMODL
      DOUBLE PRECISION Y
      DIMENSION FIRST TRY(125),
     A LOCATION(125),DAM RAM(125),VACNT RD(125),VACNT NRD(125),
     B RESIDENT(125),OTHER DEV(125),TOT ACRES(125),PCT H20(125),
     C PCTSEWRD(125),CLASSRMS(125),SCHOOLS(125),PARKS(125),GOLFING(125),
     D AC TOT EMP(125),AC RET EMP(125),HOUSEHLD(125),INCOME(125),
     E CUR GR DEN(125),CUR NT DEN(125),AVG NT DEN(125),EX HLD CAP(125),
     F VACNT ND(125),Y(40),HH GROWTH(125),DISP HH(125),
     G INDLAND(125),IND PCT(125),DONE(125)
      TYPE REAL IND PCT
      TYPE INTEGER  DAM RAM,VACNT RD,VACNT NRD,RESIDENT,OTHER DEV,
     A TOT ACRES,PCT H20,PCT SEWRD,CLASSRMS,SCHOOLS,PARKS,GOLFING,
     B AC TOT EMP,AC RET EMP,HOUSEHLD,EX HLD CAP,VACNT ND,HH GROWTH,
     C DISP HH,FIRST TRY,BASE YEAR,FORE YEAR,UPDATE,TOT1 DHH,TOT2 DHH,
     D TOT1 RHH,TOT2 RHH,REDEVELP,EXTRA VRD,
     E EXTR VNRD,FORECAST,GRS DEVLP,TOT HSHLD,DONE
      READ 5, NUM LOC,BASE YEAR,TOT2 DHH  ,TOT2 RHH,UPDATE
    5 FORMAT (I4, I5, 2I6, I3)
      PRINT 5,NUM LOC,BASE YEAR,TOT2 DHH  ,TOT2 RHH,UPDATE
      FORE YEAR= BASE YEAR+ 5
      DO 35 I=1,NUM LOC
,44       16613
     A LOCATION(I),DAM RAM(I),HOUSEHLD(I),INCOME(I),CUR NT DEN(I),
     B CUR GR DEN(I),PCT H20(I),PCT SEWRD(I),CLASSRMS(I),SCHOOLS(I),
     C PARKS(I),GOLFING(I),AC TOT EMP(I),AC RET EMP(I),RESIDENT(I),
     D OTHER DEV(I),VACNT RD(I),VACNT NRD(I),TOT ACRES(I),INDLAND(I)
   10 FORMAT (I3,I1,I4,I5, 2F4.2,6I3, 8I5)
      ACRE IND= IND LAND(I)
      IND PCT(I)= ACRE IND/ TOT ACRES(I)
      EX HLD CAP(I)=VACNT RD(I)*CUR GR DEN(I)
      DONE(I)=0
      HSHLD= HOUSEHLD(I)
      AVG NT DEN(I)= HSHLD/ RESIDENT(I)
      VACNT ND(I)= TOT ACRES(I)- RESIDENT(I)- OTHER DEV(I)- VACNT RD(I)
     A -VACNT NRD(I)
      IF(DAM RAM(I).EQ.1) 15,20
   15 TOT1 DHH= TOT1 DHH+ HOUSEHLD(I)
      GO TO 21
   20 TOT1 RHH= TOT1 RHH+ HOUSEHLD(I)
   21 CONTINUE
      IF(I.EQ.1 .OR. I.EQ.51 .OR. I.EQ.101)25,30
   25 PRINT 40
      PRINT 45, BASE YEAR,FORE YEAR
      PRINT 50
   30 PRINT 55, LOCATION(I),DAM RAM(I),HOUSEHLD(I),INCOME(I),
     A AVG NT DEN(I),               CUR NT DEN(I),CUR GR DEN(I),
     B PCT H20(I),PCT SEWRD(I),CLASSRMS(I),SCHOOLS(I),PARKS(I),
     C GOLFING(I),AC TOT EMP(I),AC RET EMP(I),RESIDENT(I),OTHER DEV(I),
     D VACNT RD(I),VACNT NRD(I),VACNT ND(I),TOT ACRES(I),INDLAND(I)
   35 CONTINUE
   40 FORMAT (1H1,38X,*H O U S E H O L D   D I S T R I B U T I O N*,
     A *   M O D E L*,/ )
   45 FORMAT ( 9X, *B A S E   Y E A R   D A T A   F O R   T H E*,
     A *   F O R E C A S T I N G   P E R I O D   F R O M   *, I4,
     B *   TO   *, I4, /)
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50 FORMAT (11X,
  A *        C                AVG  CUR  CUR  0/0  0/0 ELEM              *,
  B *     WORK SHOPG          DEVLP        VACNT*,/, 11X,
  C *        G          MEDN  NET  NET GRSS AREA AREA SCHL  NUM  NUM  *,
  D *NUM ACCES ACCES DEVLP (NON- VACNT (NON- UNUSE*,/, 11X,
  E *  LOCA D HOUSE FAMLY  RES  RES  RES WITH WITH CLSS   OF   OF  *,
  F * OF TOTAL  RETL (RES) (RES) (RES) (RES)  ABLE TOTAL*,/, 11X,
  G *  TION E HOLDS INCME DENS DENS DENS  H20 SEWR  RMS SCHL PARK G*,
  H *OLF  EMPL  EMPL ACRES ACRES ACRES ACRES ACRES ACRES INDTL*,/)
55 FORMAT (11X,I6,I2,2I6  ,3F5,2,6I5  ,9I6)
   DAM HSHLD= TOT2 DHH- TOT1 DHH
   RAM HSHLD= TOT2 RHH- TOT1 RHH
   TOT HSHLD= TOT2 DHH+ TOT2 RHH
60 IF( UPDATE,GT,0)65,75
65 UPDATE =  UPDATE- 1
   READ 80, NTRACT,REDEVELP,EXTRA VRD,EXTR VNRD
   DO 75 I=1,NUM LOC
   IF(LOCATION(I),EQ,NTRACT) 70,75
70 DISP HH(I)=  REDEVELP* AVG NT DEV(I)
   HOUSEHLD(I)= HOUSEHLD(I)- DISP HH(I)
   IF(DAM RAM(I),EQ,1) DAM HSHLD= DAM HSHLD+ DISP HH(I)
   IF(DAM RAM(I),EQ,0) RAM HSHLD= RAM HSHLD+ DISP HH(I)
   VACNT RD(I)= VACNT RD(I)+ EXTRA VRD
   VACNT NRD(I)=VACNT NRD(I)+ EXTR VNRD
   RESIDENT(I)= RESIDENT(I)- REDEVELP
   EX HLD CAP(I)=VACNT RD(I)*CUR GR DEV(I)
   GO TO 60
75 CONTINUE
80 FORMAT(I3,3I5)
   FORECAST= 0
100 FORECAST= FORECAST+ 1
   SUM DAM= SUM RAM= 0
   DO 120 I=1,NUM LOC
   IF(DONE(I).GT,0)GO TO 120
   Y( 1)=AC TOT EMP(I)/ 10000.0
   Y( 2)= Y( 1)* Y( 1)
   Y( 3)= Y( 1)* Y( 2)
   Y( 4)=AC RET EMP(I)/ 10000.0
   Y( 5)= Y( 4)* Y( 4)
   Y( 6)= Y( 4)* Y( 5)
   Y( 7)=INCOME(I)/ 10000,0
   Y( 8)= Y( 7)* Y( 7)
   Y( 9)= Y( 7)* Y( 8)
   H20= PCT H20(I)
   Y(10)=(H20* TOT ACRES(I))/ (RESIDENT(I)+ OTHER DEV(I))
   Y(11)= Y(10)* Y(10)
   Y(12)= Y(10)* Y(11)
   SEWRD= PCT SEWRD(I)
   Y(13)= (SEWRD* TOT ACRES(I))/ (RESIDENT(I)+ OTHER DEV(I))
   Y(14)= Y(13)* Y(13)
   Y(15)= Y(13)* Y(14)
   CLASS= CLASSRMS(I)
   Y(16)= CLASS/ HOUSEHLD(I)
   Y(17)= Y(16)* Y(16)
   Y(18)= Y(16)* Y(17)
   Y(19)=IND PCT(I)
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      Y(20)= Y(19)* Y(19)
      Y(21)= Y(19)* Y(20)
      Y(22)=SCHOOLS(I)
      Y(23)= Y(22)* Y(22)
      Y(24)= Y(22)* Y(23)
      Y(25)=PARKS(I)
      Y(26)= Y(25)* Y(25)
      Y(27)= Y(25)* Y(26)
      Y(28)=GOLFING(I)
      Y(29)=AVG NT DEN(I)
      Y(30)= Y(29)* Y(29)
      Y(31)= Y(29)* Y(30)
      Y(32)=AVG NT DEN(I)* VACNT RD(I)/ 10000.0
      Y(33)= Y(32)* Y(32)
      Y(34)= Y(32)* Y(33)
      Y(35)=VACNT RD(I)/ 10000.0
      Y(36)= Y(35)* Y(35)
      Y(37)= Y(35)* Y(36)
      Y(38)=HOUSEHLD(I)/10000.0
      Y(39)= Y(38)* Y(38)
      Y(40)= Y(38)* Y(39)
      IF(DAM RAM(I).EQ.1) 105,110
  105 CONTINUE
      HH GROWTH(I)= 2754.40891111D0+6250.66699445D0*Y(4)
     A -61423.35305691D0*Y(5)
     B +210696.82545090D0*Y(6)-9739.63667750D0*Y(7)
     C +13892.26791620D0*Y(8)-6318.22694969D0*Y(9)
     D +20.02541517D0*Y(10)-.24123818D0*Y(11)
     E +.00067456D0*Y(12)+.00677536D0*Y(14)+32377.88622713D0*Y(16)
     F -544772.44673157D0*Y(17)+11873.06692362D0*Y(20)
     G -884.24928790D0*Y(22)+292.21357268D0*Y(23)
     H -25.72601444D0*Y(24)-267.31991334D0*Y(25)
     I +198.94171087D0*Y(26)-28.06182791D0*Y(27)-190.66259138D0*Y(28)
     J -336.74041222D0*Y(29)+20.41013333D0*Y(30)-.20289664D0*Y(31)
     K +375.06582280D0*Y(33)+6583.13324022D0*Y(38)
     L -18470.06992769D0*Y(39)
      IF(HH GROWTH(I).LT.0) HH GROWTH(I)= 0
      SUM DAM= SUM DAM+ HH GROWTH(I)
      GO TO 120
  110 CONTINUE
      HH GROWTH(I)= -20.15542919D0+42.84684642D0*Y(2)
     A +1860.61134586D0*Y(4)-63987.15376091D0*Y(5)
     B -25524.25817680D0*Y(17)+412812.68784332D0*Y(18)
     C +3856.29898375D0*Y(19)-154588.71011353D0*Y(20)-.14674297D0*Y(31)
     D +80.59247636D0*Y(35)-32.79467732D0*Y(36)+21491.48619223D0*Y(39)
     E -146064.41955948D0*Y(40)
      IF(HH GROWTH(I).LT.0) HH GROWTH(I)= 0
      SUM RAM= SUM RAM+ HH GROWTH(I)
  120 CONTINUE
      DO 150 I=1,NUM LOC
      IF(DONE(I).GT.0) GO TO 150
      IF(DAM RAM(I).EQ.1)125,130
  125 HH GROWTH(I)= HH GROWTH(I)*(DAM HSHLD/ SUM DAM)
      GO TO 135
  130 HH GROWTH(I)= HH GROWTH(I)*(RAM HSHLD/ SUM RAM)
  135 IF(FORECAST.EQ.1) 140,150
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140 FIRST TRY(I)= HH GROWTH(I)- DISP HH(I)
150 CONTINUE
    IF(FORECAST .GT. NUM LOC) GO TO 180
    NOVER CAP= 0
    DO 165 I=1,NUM LOC
    IF(DONE(I).GT.0)GO TO 165
    IF(HH GROWTH(I).GT. EX HLD CAP(I)) 160,165
160 HH GROWTH(I)= EX HLD CAP(I)
    IF(DAM RAM(I).EQ.1) DAM HSHLD= DAM HSHLD- HH GROWTH(I)
    IF(DAM RAM(I).EQ.0) RAM HSHLD= RAM HSHLD- HH GROWTH(I)
    NOVER CAP=NOVER CAP+ 1
    EX HLD CAP(I)= 0
    DONE(I)= 1
165 CONTINUE
    IF(NOVER CAP.GT. 0) GO TO 100
180 DO 210 I=1,NUM LOC
    HOUSEHLD(I)= HOUSEHLD(I)+ HH GROWTH(I)
    NET DEVLP= HH GROWTH(I)/ CUR NT DEN(I)
    GRS DEVLP= HH GROWTH (I)/ CUR GR DEN(I)
    VACNT RD(I)= VACNT RD(I)- GRS DEVLP
    RESIDENT(I)= RESIDENT(I)+ NET DEVLP
    EX HLD CAP(I)= VACNT RD(I)* CUR GR DEN(I)
    OTHER DEV(I)= OTHER DEV(I)+ GRS DEVLP- NET DEVLP
    HH GROWTH(I)= HH GROWTH(I)- DISP HH(I)
    HSHLD= HOUSEHLD(I)
    AVG NT DEN(I)= HSHLD/ RESIDENT(I)
    IF( I.EQ.1 .OR. I.EQ.51 .OR. I.EQ.101) 190,200
190 PRINT 40
    PRINT 300, FORE YEAR, TOT HSHLD
    PRINT 310, BASE YEAR, BASE YEAR
200 PRINT 320, LOCATION(I), HOUSEHLD(I), HH GROWTH(I), FIRST TRY(I),
   A RESIDENT(I), OTHER DEV(I), VACNT RD(I), AVG NT DEN(I),
   B EX HLD CAP(I)
210 CONTINUE
300 FORMAT ( 9X,*F O R E C A S T S    F O R    Y E A R   *, I4,
   A *   B A S E D    U P O N    *, I5, *   R E G I O N A L    *,
   B *H O U S E H O L D S*, /)
310 FORMAT (16X, 35X, *ATTEMPTED*, /,16X,
   A *                          CHANGE IN   CHANGE IN      NET        O*,
   B *THER        VACANT    AVERAGE NET   EXCESS*, /,16X,
   C *              FORECASTED  HOUSEHOLDS  HOUSEHOLDS  RESIDENTIAL  DEV*,
   D *ELOPED  RESIDENTIAL  RESIDENTIAL   HOLDING*, /,16X,
   E *LOCATION  HOUSEHOLDS   FROM *,I4,*   FROM *,I4,*     ACRES    *,
   F *   ACRES       ACRES        DENSITY    CAPACITY*, /)
320 FORMAT (16X, I6, I11,2I12, I13,2I12, F13.2, I11)
    END
RUN,5, 1000

EXECUTION STARTED AT   0902 -10
104 1965 5/152 27510  0
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LOCATION	CODE	HOUSE HOLDS	MEDN FAMLY INCME	AVG NET RES DENS	CUR NET RES DENS	CUR GRSS RES DENS	O/O AREA WITH H2O	O/O AREA WITH SEWR	ELEM SCHL CLSS RMS	NUM OF SCHL	NUM OF PARK	NUM OF GOLF	WORK ACCES TOTAL EMPL	SHOPG ACCES RETL EMPL	DEVLP (RES) ACRES	DEVLP (NON- RES) ACRES	VACNT (RES) ACRES	VACNT (NON- RES) ACRES	UNUSABLE ACRES	TOTAL ACRES	INDTL
9	1	698	8940	8,95	10.60	5,60	80	70	18	1	2	1	37562	2233	78	238	20	17	0	353	0
11	1	1957	5521	13,31	15.50	7,60	80	100	43	4	1	0	27523	1169	147	238	10	19	0	414	0
12	1	1068	6333	8,97	10.80	5,60	100	100	28	1	3	0	29390	1565	119	109	26	10	0	264	4
13	1	927	4605	16,85	15,00	7,40	100	100	0	1	1	0	31885	1479	55	230	15	0	16	316	13
14	1	252	3569	84,00	65,00	2,70	0	100	0	0	0	0	23417	762	3	172	4	4	12	195	4
16	1	556	10714	6,18	7.00	4,00	60	100	14	3	1	0	36825	1511	90	117	14	3	0	224	0
17	1	641	13125	2,92	4.80	2,80	75	85	26	2	3	1	21787	773	288	408	261	40	85	1082	0
20	1	2059	5814	13,91	25.00	10,20	100	100	24	1	0	0	27597	982	148	217	10	3	19	397	59
21	1	1097	6000	9,38	9.00	5,00	50	80	15	1	1	0	34121	1532	117	237	28	10	16	408	38
22	1	765	9250	6,59	6.50	3,80	75	100	16	1	2	1	30296	1339	116	229	9	0	43	397	1
23	1	1594	6777	7,52	9.40	5,20	100	100	24	2	4	0	17776	483	212	178	19	0	0	409	10
28	1	1026	7886	5,86	25.00	10,20	95	100	24	1	3	0	15283	451	175	159	45	38	1	418	12
29	1	502	8000	2,13	6.50	3,80	0	40	16	2	2	0	22309	768	236	772	1645	117	141	2911	162
30	1	301	6800	8,14	8.00	4,50	65	100	0	0	2	1	23605	1313	37	231	20	42	6	336	1
31	1	1437	9522	4,94	5.00	3,00	55	40	12	0	2	0	20635	1143	291	316	757	173	20	1557	55
32	1	776	6307	3,88	6.50	3,80	95	95	0	0	0	0	8559	305	200	182	334	61	44	821	27
33	1	1401	8982	3,80	5.00	3,00	80	90	30	3	2	0	23681	880	369	247	381	26	12	1035	8
34	1	975	9646	4,41	6.50	3,80	70	100	35	2	0	0	27713	1128	221	246	75	100	7	649	47
35	1	1194	6220	3,95	5.00	3,00	85	100	18	2	1	1	29843	1392	302	380	181	122	0	985	46
36	1	1973	8085	3,73	6.00	3,50	30	40	21	1	1	0	18967	805	529	228	90	0	0	847	4
37	1	1371	8138	4,22	5.00	3,00	70	80	49	4	1	0	19297	1502	325	240	190	209	0	964	15
38	1	473	12999	2,94	8.00	4,50	60	50	12	1	1	0	23679	1014	161	95	880	0	0	1136	0
39	1	1290	12500	3,59	4.80	2,80	60	50	54	5	1	0	16669	644	359	260	355	0	0	974	1
40	1	1250	11666	5,14	13.00	6,70	100	100	11	1	2	0	31462	1879	243	113	28	0	0	384	0
43	1	1345	9437	4,57	9.00	5,00	100	100	0	0	0	0	17296	515	294	127	1	0	1	423	0
45	0	352	7562	2,30	3.70	2,20	0	35	0	2	0	1	21796	738	153	139	666	0	1	959	0
46	1	654	9181	2,56	2.80	1,70	2	50	25	1	0	1	15540	791	334	427	1474	0	299	2534	63
47	1	608	5666	3,47	9.00	5,00	2	30	0	0	1	1	12002	383	175	158	1323	0	642	2298	0
48	1	781	7666	2,75	4.00	2,40	5	25	36	5	1	1	10241	328	284	251	974	1175	236	2920	1
49	1	1425	12307	2,03	2.50	1,60	10	70	14	3	1	0	15775	561	703	469	1139	1562	169	4042	11
50	0	463	7500	1,79	2.80	1,80	2	15	0	1	0	0	11941	254	258	388	7528	0	71	8245	6
51	0	638	6000	2,50	4.00	2,40	5	0	10	0	0	0	18459	688	255	190	885	0	0	1330	2
52	0	753	7000	5,79	5.00	3,00	30	10	34	2	1	1	12512	321	130	239	2021	0	0	2390	3
53	1	1568	7984	2,76	4.80	2,80	30	20	28	3	2	0	16009	905	568	896	1153	2483	32	5132	89
54	1	1465	7375	2,65	5.00	3,00	0	45	32	3	1	0	13248	469	552	236	771	0	2	1561	8
55	1	763	7322	1,95	2.50	1,50	0	10	13	2	2	0	5610	66	392	758	4101	7486	139	12876	160
66	0	648	7300	1,82	2.00	1,30	0	0	0	0	0	0	2767	20	357	632	14803	0	1028	16820	5
67	1	780	5909	3,79	3.65	2,10	75	88	22	5	2	1	6632	397	206	161	318	0	49	734	4
68	0	319	7428	1,07	1.20	0,80	0	0	0	0	0	0	2275	17	298	678	21617	0	581	23174	0
69	0	216	6210	6,00	5.70	3,30	20	0	14	3	0	0	3244	97	36	59	68	0	0	163	1
70	0	339	6008	1,27	1.00	0,60	0	0	0	0	0	0	2762	32	267	968	20013	0	613	21861	45
71	0	281	5714	1,25	1.00	0,60	0	0	1	1	0	0	3239	29	225	637	16739	0	696	18297	48
72	0	672	7666	1,43	2.60	1,70	0	0	14	1	0	0	13149	287	469	721	21673	0	556	23419	1
75	0	487	6779	1,30	1.70	1,10	0	0	15	1	1	0	3469	22	376	713	21168	0	1123	23380	57
76	0	1356	6749	3,47	5.00	3,00	60	65	32	5	3	0	4835	76	391	517	1289	0	23	2220	53
77	0	426	7862	1,29	1.70	1,10	0	0	0	0	1	1	3371	62	331	1161	18592	0	1074	21158	127
79	0	384	7500	1,42	1.50	1,00	0	0	16	2	0	0	2900	20	271	3606	16181	0	890	20948	30
80	0	270	5335	1,14	1.00	0,60	0	0	0	0	0	0	1726	8	237	655	21980	0	578	23450	25
81	0	336	6797	1,45	1.20	0,80	0	0	0	0	0	0	629	4	231	555	20909	0	724	22419	7
82	0	336	6537	3,46	3.00	1,90	70	70	18	2	1	0	1126	170	97	118	443	0	0	658	6

B A S E   Y E A R   D A T A

LOCATION	CODE	HOUSEHOLDS	MEDN FAMLY INCME	AVG NET RES DENS	CUR NET RES DENS	CUR GRSS RES DENS	0/0 AREA WITH H2O	0/0 AREA WITH SEWR	ELEM SCHL CLSS RMS	NUM OF SCHL	NUM OF PARK	NUM OF GOLF	WORK ACCES TOTAL EMPL	SHOPG ACCES RETL EMPL	DEVLP (RES) ACRES	DEVLP (NON- RES) ACRES	VACNT (RES) ACRES	VACNT (NON- RES) ACRES	UNUSEABLE ACRES	TOTAL ACRES	INDTL
83	0	335	6444	1,38	1,00	0,60	0	0	0	0	0	0	981	3	242	2398	17556	0	915	21111	3
84	0	360	6300	0.97	1,40	0,90	0	0	0	0	0	0	1160	4	372	854	20129	0	1268	22623	5
85	0	548	6300	4.25	2,80	1,70	75	65	14	3	0	0	3353	149	129	146	432	0	0	707	4
86	0	404	4000	1.46	1.00	0,60	0	0	3	1	1	0	2025	14	276	1179	5000	15882	1077	23414	11
101	1	960	7316	2.00	2.20	1.40	0	5	14	5	1	0	9800	344	481	952	752	12971	337	15493	13
102	1	1445	7187	2.36	2,50	1,50	15	0	11	5	1	0	16011	430	611	1426	600	5536	-315	7858	85
201	1	1519	9134	2.06	3,50	2,20	50	20	50	6	1	0	15367	479	736	793	725	1711	79	4044	3
202	1	499	6571	1.60	2,50	1,50	3	0	4	2	1	0	18609	453	311	551	385	6435	176	7858	69
203	1	907	11176	1.43	1.80	1,20	0	0	13	1	0	0	11431	204	636	1018	2550	10711	103	15018	3
231	0	272	5375	1.03	1,10	0,70	0	0	0	0	0	0	1733	35	264	777	21290	0	591	22922	7
232	0	180	5937	5.00	2,50	1,50	35	0	0	0	0	0	1870	76	36	70	395	0	0	501	6
233	0	143	5937	3,04	2,50	1,50	0	0	7	1	0	0	3009	18	47	64	551	0	0	662	11
234	0	317	5562	1.12	1,10	0,70	0	0	1	1	0	0	1663	4	283	616	21738	0	102	22739	1
235	1	1642	6444	4.46	5.00	3,00	85	80	41	5	1	0	4632	54	368	340	491	0	46	1245	40
236	0	562	8000	1,25	1,50	1,00	1	1	1	1	2	0	4749	62	466	34	19938	0	1444	21882	52
238	0	285	7385	2,85	2,80	1,70	0	0	13	1	0	0	9423	141	100	69	393	0	16	578	15
239	0	756	7385	1,41	2,40	1,50	0	0	4	1	0	0	11486	228	537	1151	2000	17978	577	22243	38
240	0	341	7856	1,20	1,30	0,90	0	0	3	3	0	0	3651	32	285	690	20812	0	472	22259	31
241	0	291	7913	3,73	2,40	1,50	50	0	14	2	1	0	7849	221	78	101	324	0	0	503	1
242	0	328	5500	1,12	1,00	0,60	0	0	7	6	0	0	2607	20	293	701	21270	0	834	23098	20
243	0	222	7941	2,31	1,20	0,80	0	0	0	1	0	0	1224	14	96	517	21235	0	782	22630	7
244	0	251	5937	1,16	2,00	1,30	50	0	15	2	0	0	1224	27	217	120	451	0	0	788	4
245	0	323	7000	1,13	1,00	0,60	0	0	1	1	0	0	976	11	285	660	22023	0	658	23626	5
246	0	357	6889	1,16	1,50	1,00	0	1	3	4	0	0	1004	4	308	684	21065	0	212	22269	8
247	1	2656	6256	4,38	5,00	3,00	80	85	44	6	4	1	2937	51	607	876	1145	0	44	2672	66
248	0	449	8000	1,24	1,20	0,80	0	0	4	5	1	0	2213	55	362	992	19798	0	517	21669	36
249	0	486	7681	1,39	1,70	1,10	0	0	0	0	0	1	4927	41	350	789	19942	0	1064	22145	22
251	0	421	6001	1,38	1,50	1,00	0	0	1	1	1	0	1323	10	306	771	20576	0	1695	23348	22
252	0	305	5333	1,24	1,00	0,60	0	0	0	0	0	0	1355	7	245	654	21482	0	941	23322	9
253	0	315	6685	1,14	1,20	0,80	0	0	23	1	1	0	1159	11	276	830	20236	0	1255	22597	43
254	0	297	6302	3,26	3,20	2,10	50	5	0	1	1	0	1840	87	91	158	380	0	15	644	4
255	0	300	6301	1,27	1,20	0,80	0	0	1	1	0	0	16	16	236	674	21305	0	548	22763	35
256	0	413	6302	4,09	4,00	2,40	70	15	20	3	2	0	955	167	101	133	356	0	83	673	1
402	0	207	4332	1,26	1,00	0,60	0	0	0	0	0	0	309	0	164	2872	18493	0	1200	22729	6
403	0	211	6561	3,35	2,90	1,80	35	0	0	0	0	0	925	5	63	186	606	0	32	887	16
404	0	201	7078	1,08	1,00	0,60	0	0	3	1	0	0	750	3	186	882	20574	0	309	21951	71
405	0	386	7750	1,25	1,00	0,60	0	0	7	4	0	1	1208	42	310	1039	21278	0	399	23026	140
406	0	335	6879	1,09	1,00	0,60	0	0	2	3	0	0	1075	66	306	726	20766	0	210	22008	45
407	0	311	6603	3,46	2,70	1,70	50	0	0	1	0	0	1254	354	90	71	506	0	0	667	7
408	0	452	6603	4,43	2,00	1,30	50	0	26	2	0	0	1974	28	102	136	353	0	0	591	13
409	0	374	4934	1,19	1,20	0,80	0	0	4	3	1	0	2560	51	315	751	20745	0	631	22442	20
410	0	381	8874	1,23	1,50	1,00	0	0	7	7	1	0	3230	91	310	652	20656	0	66	21684	14
411	1	1818	6457	4,31	5,20	3,10	80	90	49	7	1	0	6070	758	422	576	638	0	0	1636	49
412	0	238	7750	1,04	1,00	0,60	0	0	3	3	0	0	2662	34	228	637	22586	0	123	23574	20
413	0	238	6561	6,80	2,50	1,50	50	35	17	3	0	0	1648	14	35	120	495	0	0	650	7
414	0	221	665	1,02	4,10	0,60	0	0	0	0	1	0	1163	4	217	646	21628	0	220	22711	1
415	0	170	6567	2,36	2,50	1,50	50	0	0	2	0	0	2220	83	72	66	704	0	0	842	5
416	0	227	5828	1,05	1,20	0,80	0	0	12	1	0	0	2921	16	216	593	21367	0	152	22328	8
417	0	297	7428	1,09	1,00	0,60	0	0	5	5	0	0	4063	27	273	629	21946	0	112	22960	1
418	0	427	6071	1,23	1,50	1,00	0	0	8	5	0	0	7324	117	346	664	21481	0	489	22980	2

B A S E   Y E A R   D A T A   F O R [illegible]

LOCATION	CODE	HOUSE HOLDS	MEDN FAMLY INCME	AVG NET RES DENS	CUR NET RES DENS	CUR GRSS RES DENS	O/O AREA WITH H2O	O/O AREA WITH SEWR	ELEM SCHL CLSS RMS	NUM OF SCHL	NUM OF PARK	NUM OF GOLF	WORK ACCES TOTAL EMPL	SHOPG ACCES RETL EMPL	DEVLP (RES) ACRES	DEVLP (NON-RES) ACRES	VACNT (RES) ACRES	VACNT (NON-RES) ACRES	UNUSEABLE ACRES	TOTAL ACRES	INDTL
419	0	350	6399	1.20	1.30	0.90	0	0	1	2	0	0	4272	30	291	651	19895	0	2253	23090	13
420	0	1100	6333	1.95	2.00	1.30	0	0	19	3	2	0	7770	114	565	1520	19313	0	2510	23908	50
423	0	665	7000	1.31	1.60	1.00	0	0	9	1	1	1	12659	261	508	1163	20248	0	816	22735	47
424	0	418	6400	1.50	1.20	0.80	0	0	1	1	0	0	6232	57	279	1165	20877	0	982	23303	181

LOCATION	FORECASTED HOUSEHOLDS	CHANGE IN HOUSEHOLDS FROM 1955	ATTEMPTED CHANGE IN HOUSEHOLDS FROM 1965	NET RESIDENTIAL ACRES	OTHER DEVELOPED ACRES	VACANT RESIDENTIAL ACRES	AVERAGE NET RESIDENTIAL DENSITY	EXCESS HOLDING CAPACITY
9	810	112	204	88	248	0	9,20	0
11	2033	76	250	151	244	0	13,46	0
12	1173	105	95	128	118	8	9,16	46
13	950	23	21	56	232	12	16,96	88
14	252	0	0	3	172	4	84,00	10
16	556	0	0	90	117	14	6,18	56
17	841	0	0	288	408	261	2,92	730
20	2161	102	230	152	223	0	14,22	0
21	1151	54	49	123	241	18	9,36	90
22	765	0	0	116	229	9	6,59	34
23	1638	44	39	216	182	11	7,58	57
28	1256	230	208	184	172	23	6,83	234
29	843	341	309	288	809	1556	2,93	5912
30	301	0	0	37	231	20	8,14	90
31	2329	892	807	469	435	460	4,97	1380
32	918	142	128	221	198	297	4,15	1128
33	1690	289	261	426	286	285	3,97	855
34	1260	285	278	264	278	0	4,77	0
35	1194	0	0	302	380	181	3,95	543
36	2288	315	367	581	266	0	3,94	0
37	1794	423	382	409	297	49	4,39	147
38	878	405	366	211	135	790	4,16	3555
39	1349	59	54	371	269	334	3,64	935
40	1250	0	0	243	113	28	5,14	187
43	1350	5	465	294	128	0	4,59	0
45	352	0	0	153	139	666	2,30	1465
46	1393	539	487	526	552	1157	2,65	1966
47	995	387	350	218	192	1246	4,56	6230
48	1356	575	520	427	347	735	3,18	1764
49	1872	447	404	881	570	860	2,12	1376
50	603	140	140	308	415	7451	1,96	13411
51	643	5	5	256	191	883	2,51	2119
52	841	88	88	147	251	1992	5,72	5976
53	2171	603	545	693	986	938	3,13	2626
54	1731	266	240	605	271	683	2,86	2049
55	1124	361	327	536	854	3861	2,10	5791
66	744	96	96	405	657	14730	1,84	19149
67	945	165	149	251	194	240	3,76	504
68	344	25	25	318	689	21586	1,08	17268
69	216	0	0	36	59	68	6,00	224
70	389	50	50	317	1001	19930	1,23	11958
71	343	62	62	287	678	16636	1,20	9981
72	809	137	137	517	753	21593	1,56	36708
75	535	48	48	404	728	21125	1,32	23237
76	1390	34	34	397	522	1278	3,50	3834
77	512	86	86	381	1189	18514	1,34	20365
79	435	51	51	305	3623	16130	1,43	16130
80	289	19	19	256	667	21949	1,13	13169
81	364	28	28	254	567	20874	1,43	16699
82	361	25	25	105	123	430	3,44	817

LOCATION	FORECASTED HOUSEHOLDS	CHANGE IN HOUSEHOLDS FROM 1965	ATTEMPTED CHANGE IN HOUSEHOLDS FROM 1965	NET RESIDENTIAL ACRES	OTHER DEVELOPED ACRES	VACANT RESIDENTIAL ACRES	AVERAGE NET RESIDENTIAL DENSITY	EXCESS HOLDING CAPACITY
83	380	45	45	287	2427	17482	1,32	10489
84	396	36	36	397	869	20089	1,00	18080
85	590	42	42	144	155	408	4,10	693
86	451	47	47	323	1210	4922	1,40	2953
101	1480	520	471	717	1087	381	2,06	533
102	2284	839	759	946	1650	41	2,41	61
201	2283	764	691	954	922	378	2,39	831
202	715	216	196	397	609	241	1,80	361
203	1177	270	245	786	1092	2326	1,50	2791
231	298	26	26	287	791	21253	1,04	14877
232	186	6	6	38	72	391	4,89	586
233	143	0	0	47	64	551	3,04	826
234	337	20	20	301	626	21710	1,12	15197
235	1750	108	98	389	355	455	4,50	1365
236	673	91	91	526	65	19847	1,28	19847
238	316	31	31	111	76	375	2,85	637
239	899	143	143	596	1187	1905	1,51	2857
240	384	43	43	318	704	20765	1,21	18688
241	312	21	21	86	107	310	3,63	465
242	353	25	25	318	717	21229	1,11	12737
243	238	16	16	109	524	21215	2,18	16972
244	264	13	13	223	124	441	1,18	573
245	343	20	20	305	673	21990	1,12	13194
246	385	28	28	326	694	21037	1,18	21037
247	2888	232	210	653	907	1068	4,42	3204
248	512	63	63	414	1018	19720	1,24	15776
249	559	73	73	392	813	19876	1,43	21863
251	465	44	44	335	786	20532	1,39	20532
252	327	22	22	267	668	21446	1,22	12867
253	382	67	67	331	858	20153	1,15	16122
254	323	26	26	99	162	368	3,26	772
255	328	28	28	259	686	21270	1,27	17016
256	418	5	5	102	134	354	4,10	849
402	235	28	28	192	2890	18447	1,22	11068
403	219	8	8	65	188	602	3,37	1083
404	225	24	24	210	897	20535	1,07	12321
405	437	51	51	361	1072	21194	1,21	12716
406	380	45	45	351	755	20692	1,08	12415
407	314	3	3	91	71	505	3,45	858
408	463	11	11	107	139	345	4,33	448
409	418	44	44	351	770	20690	1,19	16552
410	428	47	47	341	668	20609	1,26	20609
411	1943	125	113	446	592	598	4,36	1853
412	252	14	14	242	646	22563	1,04	13537
413	238	0	0	35	120	495	6,80	742
414	232	11	11	219	662	21610	1,06	12966
415	191	21	21	80	72	690	2,39	1035
416	237	10	10	224	597	21355	1,06	17084
417	319	22	22	295	643	21910	1,08	13146
418	494	67	67	390	687	21414	1,27	21414

F O R E C A S T S   F O R   Y E A R   1970 ...

LOCATION	FORECASTED HOUSEHOLDS	CHANGE IN HOUSEHOLDS FROM 1955	ATTEMPTED CHANGE IN HOUSEHOLDS FROM 1965	NET RESIDENTIAL ACRES	OTHER DEVELOPED ACRES	VACANT RESIDENTIAL ACRES	AVERAGE NET RESIDENTIAL DENSITY	EXCESS HOLDING CAPACITY
419	400	50	50	329	668	19840	1,22	17856
420	1235	135	135	632	1556	19210	1,95	24973
423	822	157	157	506	1222	20091	1,36	20091
424	506	88	88	352	1202	20767	1,44	16613

EXECUTE : 0 HOURS 0 MINUTES 06,620 SECONDS
SETUP : 0 HOURS 0 MINUTES 03,580 SECONDS
FTN : 0 HOURS 0 MINUTES 17,431 SECONDS
LOADER : 0 HOURS 0 MINUTES 02,468 SECONDS
*OTHER : 0 HOURS 0 MINUTES 00,000 SECONDS

ELAPSED TIME: 0 HOURS 0 MINUTES 30,099 SECONDS
264 WRITE OPERATIONS ON LU 61 WERE DONE DURING EXECUTION,
SEQUENCE NUMBER 104164:000C FINISHED AT 090218 DATE 01/19/68

BIBLIOGRAPHY

BIBLIOGRAPHY

Becker, Joseph and Hayes, R.M. Information Storages and Retrieval, John Wiley and Sons, New York, 1966.

Boguslaw, Robert. The New Utopians, Englewood Cliffs, Prentice Hall, Inc., 1965, p. 52.

Bureau of Business and Economic Research, College of Business and Public Service. Economic and Population Base Study of the Lansing Tri-County Area, East Lansing, Michigan, Michigan, Michigan State University, July, 1958, pp. 6-7.

Chapin, Jr., Stuart and Weiss, Shirley F. "Factors Influencing Land Development", Journal of the American Institute of Planners, Vol. XXXI, No. 2, May, 1965, p. 176.

Chapin, Jr., Stuart and Donnelly, Thomas G. and Weiss, Shirley F. "A Probabilistic Model for Residential Growth", Journal of the American Institute of Planners, Vol. XXXI, No. 2, May, 1965, p. 177.

Community Systems Foundations. "Models for Predicting Employment, Population, and Land Use (Exclusive of Transportation Networks)", Community Systems Foundations, Ann Arbor, Michigan, 1964.

Duke, Richard D. and Meier, Richard L. "Gaming Simulation for Urban Planning", Journal of the American Institute of Planning, Vol. XXXII, No. 1, January, 1966, pp. 3-17.

Farnsworth, George. Dual Independent Map Encoding, A Geographic Base File. An Internal Staff Paper prepared for the Census Use Study.

Feldt, Allen G. "Operational Gaming in Planning Education", Journal of the American Institute of Planners, Vol. XXXII, No. 1, January, 1966, pp. 17-23.

Freund, Eric C. and Goodman, William I. Principles and Practices of Urban Planning, Municipal Management Series, Washington, D.C., International City Managers Association, pp. 475, 372, 339.

Gibbs, Jack P. Urban Research Methods, Princeton, New Jersey, D. Van Nostrand Company, Inc., 1961.

Gladstone, Robert and Associates. "Technical Memorandum Report Tri-County Region Housing Outlook and Issues, Washington, D.C., Robert Gladstone and Associates, Economic Consultants, 1966.

Graves, Charles H. "Forecasting the Distribution of 1985 Population and Employment to Analysis Zones for Plan A, Staff Report No. 15", Seattle, Washington, Puget Sound Regional Transportation Study, 1964.

Hansen, Walter G. "Urban Transportation and Urban Growth Patterns". Paper presented at Highway Planning and Research Conference, Chapel Hill, North Carolina; By the author, March, 1963.

Harris, Britton. Preliminary Note on Aspects of Equilibrium in Urban Growth Models, Philadelphia, Pennsylvania, University of Pennsylvania, Institute for Environmental Studies, August, 1966, p. 17.

Harris, Britton. "A Gloss of Lackluster Terms", Journal of the American Institute of Planners, Vol. XXXI, No. 2, May, 1965, p. 94.

Harris, Britton. "New Tools for Planning", Journal of the American Institute of Planners, Vol. XXXI, No. 2, May, 1965, pp. 91-92.

Harris, Britton. "Organizing the Use of Models in Metropolitan Planning". Paper was prepared for a seminar on Metropolitan Land Use Models, Berkeley, California, March 19, 1965, pp. 2-4, 17-18.

Harris, Britton. "The Uses of Theory in the Simulation of Urban Phenomena", Journal of the American Insititute of Planners, Vol. XXXII, No. 5, September, 1966, pp. 258-272.

Heilbron, Thomas H. "An Analysis of Land Use Models". Prepared for Professor Marquis, Michigan State University, East Lansing, Michigan, by the author, 1964.

Hill, Donald M. "A Growth Allocation Model for the Boston Region", Journal of the American Institute of Planners, Vol. XXXI, No. 2, May, 1965, pp. 11,112.

International City Managers' Association. Local Planning Administration, Municipal Management Series, The International City Managers' Association, Chicago, Illinois, 1959.

Isard, Walter. Methods of Regional Analysis: An Introduction of Regional Science, Cambridge, Massachusetts, The M.I.T. Press, 1960.

Kent, Jr., T.J. The Urban General Plan, San Francisco, Chandler Publishing Company, 1964.

Levin, Bernard M. and Schofer, Ralph E. "The Urban Transportation Planning Process", Journal of Social-Economic Planning Science, Vol. I, 1967, pp. 185-197.

Lowery, Ira S. "A Short Course in Model Design", Journal of the American Institute of Planners, Vol. XXXI, No. 2, May, 1965, pp. 164-165.

Mason, Jackson and Kane, Inc. Housing In Lansing, Lansing, Michigan, Mason, Jackson, and Kane, Inc., Architects, 1968.

Pedersen, Poul Ove. "Multivariate Models of Urban Development", Journal of Social-Economic Planning, Vol. I, 1967, pp. 101-116.

Penn Jersey Transportation Study. An Introduction to Mathematical Models, Penn Jersey Paper, No. 8, 1964, p5.

Stegman, Michael Allen. "An Analysis and Evaluation of Urban Residential Models and Their Potential Role in City Planning". A dissertation in City Planning, University of Pennsylvania, 1966, pp. 1-2.

Study Commission on Metropolitan Area Problems, appointed by Governor G. Mennen Williams, Michigan; "Final Report Governor's Study Commission on Metropolitan Area Problems", State of Michigan, July, 1960.

Tri-County Regional Planning Commission, The Tri-County Regional Planning Commission Policy Plan - A Prelude to the Regional Development Plan, Lansing, Michigan, Tri-County Regional Planning Commission, 1967, p. 2.

Tri-County Regional Planning Commission. Mass Transportation in the Tri-County Region, Lansing, Michigan, Tri-County Regional Planning Commission, April, 1969, p. 3.

Tri-County Regional Planning Commission. "History of the Tri-County Region; Information Report No. 7", Lansing, Michigan, Tri-County Regional Planning Commission, 1966, p. 25.

Tri-County Regional Planning Commission. "History of the Tri-County Region", Tri-County Regional Planning Commission, Lansing, Michigan, 1965.

Tri-County Regional Planning Commission. The House We Live In; A Comprehensive Growth Plan, Lansing, Michigan, Tri-County Regional Planning Commission, September, 1968, p. 44.

Tri-County Regional Planning Commission. Regional Data Book; Information Summary by Metro Center Type by Jurisdiction, Lansing, Michigan, Tri-County Regional Planning Commission, May, 1969.

Tri-County Regional Planning Commission. Small Area Population Forecasting Models, Lansing, Michigan, Tri-County Regional Planning Commission, March 1, 1966, pp. 8-12.

Tri-County Regional Planning Commission. Tri-County Regional Land-Use, Natural Resource, Transportation Study; Study Design, Lansing, Michigan, Tri-County Regional Planning Commission, November, 1964, pp. 8, 11, 13-15, 18.

U.S. Department of Commerce, Bureau of the Census. 1970 Census User Guide, Government Printing Office, Washington, D.C., April, 1962.

U.S. Bureau of the Census. U.S. Census of Housing and Population: 1960, Washington, D.C., U.S. Government Printing Office, Department of Commerce, February, 1962, pp. 13-42.

U.S. Bureau of the Census. Census of Population and Housing: 1840-1960, Washington, D.C., U.S. Government Printing Office, Department of Commerce.

U.S. Department of Transportation: Bureau of Public Roads. Calibrating and Testing A Gravity Model for Any Size Urban Area, U.S. Government Printing Office, Washington, D.C., November, 1968, pp. 1-2.