A REVIEW OF LAND USE MODELS AS DEVELOPED FOR TRANSPORTATION STUDIES - THEIR USE AND IMPLICATIONS TO URBAN PLANNING

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ABSTRACT

A REVIEW OF LAND USE MODELS AS DEVELOPED FOR TRANSPORTATION STUDIES - THEIR USE AND IMPLICATIONS TO URBAN PLANNING

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The determination of future land use distribution is a primary problem to both urban and transportation planners. Urban transportation studies during the past decade have sought to increase the efficiency and effectivness of land use forecasts in order mainly to provide a basis for estimating future traffic demand. A major advancement toward this end was the development of mathematical models designed to forecast and allocate urban growth to small geographical areas. As individual transportation studies were initiated, the design of these models became more refined and their application broadened. Chapter One traces this development in a general way, pointing out the significant advances and limitations of each study's approach to determining future land use distribution.

From the analysis of past and present land use models, an investigation is made of the uses and implications of these models to the field of urban planning. Later, the limitations of forecasting with the use of mathematical models and problems of forecasting in general

are enumerated in order to point out the research that is still needed in this field of study.

From the analysis contained herein, it is concluded that there is good reason why the future can not be predicted far enough ahead to be particularly significant. This uncertainty about the future is simply the corollary of the freedom of human beings to make their own decisions, and until a means is devised to predict human behavior fairly accurately, it may never be possible to predict the future state of an urban area. However, the results need not be perfect in order for land use models to be useful. If they can be used to measure the relative merits and effects of policy decisions and development alternatives, then a significant tool for planning will be available.

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INTRODUCTION

Early attempts to alleviate transportation problems in urban areas either dealt only with existing traffic demands and made no forecasts, or expanded all traffic movements uniformly according to past trends. A major breakthrough in this limited methodology occured about 1952 when urban travel patterns were related to the intensity of use and the spatial separation of different types of land use. [1] It followed that in order to determine future transportation needs, it was necessary to determine future land use distribution.

Urban planners have always been concerned with making accurate land use plans, but the almost sudden need and vast amounts of available money for urban transportation studies accelerated the demand for better methods of determining future land use needs and arrangements, especially in the larger metropolitan areas. To fulfill this demand, urban and transportation planners tried to find regularities in urban development processes which would lend themselves to mathematical relationships that could be helpful in the preparation and testing of development proposals. These mathematical relationships are commonly called models.

A model can be defined in broad terms as an imitation or a design for action. There are several types of models in common usage today. They are: abstract, symbolic, physical and mathematical. [2] An abstract model is perhaps the most versatile and most commonly used of the four. It can be as simple as a representation of an atom for instructional purposes, or be as complicated and ill-defined as a thought process. The latter is used unconsciously every-day by everyone. Simple acts such as tying a shoe or more complicated processes such as weighing alternatives in an emergency situation are both examples of abstract models. A symbolic model consists of replacing actual plysical lengths, locations, and angles with mathematics. A common use would be the prediction of eclipses by scientists. The physical models are used in engineering and science and usually represent, to scale, a structural project or an experiment. A physical or scale model of a drainage basin, for example, is very useful in predicting potential flooding as a result of precipitation somewhere in the drainage basin.

Mathematical models, with which this thesis is basically concerned, consist of formulations expressing observed or hypothesized relationships in mathematical terminology. A formula such as X + Y = Z is actually a simple mathematical model. However, the mathematical models discussed in this thesis are much more complex and are usually solved with the aid of an electronic computer. Mathematical models have many uses, but the models discussed throughout this thesis were all designed to describe the processes of urban development so that future land use arrangements of urban areas could be predicted. It is for this reason that they are often referred to as land use models. All future use of the word "model" in this paper will mean mathematical land use models, unless otherwise stated.

At this point one might wonder why models are developed. In answer to this common query the following paragraphs briefly point out the more obvious advantages of models.

In the first place urban areas can not be designed in a straightforward and controlled manner as a bridge or section of highway. Urban areas are constantly changing as a result of a myraid of unrelated decisions by individuals, business firms, and government. To cope with the ever broadening problem, the urban planner's field of interest has expanded to include many disciplines other than the traditional physical sciences. Because of the vast subject matter contained in these various disciplines, and the interrelated effects of changes in one or the other, the planner (urban or transportation) needs help in assimilating and evaluating data. Herein lies the basic advantage of models. That is, a model is a device for systemizing knowledge in a useful and managable form to increase its user's awareness. The ramifications of development proposals are so widespread that awareness of effects can not be left solely to intuition. [3]

Another major advantage of a model is that while being formulated, or upon completion, it provides a frame of reference for consideration of the problem. In other words, before one can adequately mathematize a phenomenon such as the urban environment or a scientific experiment, he must have a good understanding of the contributing factors and their interrelationships.

Immediately one can say of the above that it is not known how all factors behave or are related. This is true, but it also brings up another advantage of using models -- they suggest information gaps. Thus, when a model is being formulated it brings out the need for more information, and it also makes for a better understanding of the factors that are used.

Another advantage, which is somewhat related to the above, is that a model, when tested, may show its deficiencies. These deficiencies could be either in the data or mathematical expressions themselves. This suggests that perhaps models and data inputs can be more and more refined.

Once a problem or situation is defined in symbolic language, the various factors and relationships can be manipulated at great speeds resulting in a high degree of efficiency. Efficiency is achieved in another way by the use of models. They provide a cheap way to predict the outcome of a particular set of circumstances, and one does not need to have the actual operation or physical facilities at his disposal to see what will happen. [4]

The more technical bodies of knowledge, such as astronomy, physics, and mathematics have long since recognized the value of formulizing concepts, and as a result, have made many significant advances in their fields.

It is relatively recent that models have been used in disciplines such as economics, psychology, and now urban planning. The advantages of models which were briefly discussed above reflect why there has been such enthusiasm and interest in the development of mathematical land use models. Throughout the following chapters, models will be analyzed as to their uses, implications to urban planning, limitations, and needs.

FOOTNOTES

1. Robert B. Mitchell, *Urban Traffic, A Function of Land Use* (New York: Columbia University Press, 1954), p. 2.

2. W. T. Bross, *Design for Decision* (New York: Macmillan Co., 1953), pp. 162-167.

3. Arthur T. Row and Ernest Jurkat, "The Economic Forces Shaping Land Use Patterns," *Journal of the American Institute of Planners*, XXV (May, 1959), 79.

4. Bross, loc.cit., p. 169.

CHAPTER I

HISTORICAL REVIEW OF MAJOR TRANSPORTATION STUDIES

During the last ten years transportation studies have been initiated in scores of urban areas ranging in size from a few thousand persons to nearly fifteen million. As will be brought out in this chapter, the larger of these studies have become progressively more sophisticated in their approach to determining future land use distribution. The review and analysis emphasizing this fact include the following features for each study:

1. General organization - including when the study started, population, and area covered.
2. Objectives of the studies - in terms of land use relationships and their function in transportation planning.
3. Study methodology - including assumptions and concepts used, general procedure or functioning of the models, and types of land uses projected.
4. Particular significance of the study - in regard to its contribution to the development of the transportation planning process.

In selecting studies to be analyzed, data on all major urban areas that have completed or initiated transportation studies were grouped in a chronological order as to their initiation date. Upon review of this data, it was found that several studies were very similar and others had not progressed enough to afford sufficient analysis and were consequently omitted from this chapter. As a result, the studies which are included in the following pages are felt to represent a non-repetitious chronological development of land use projection methods as used by major transportation studies.

Detroit Metropolitan Area Transportation Study

In 1953 the Michigan State Highway Department, county of Wayne and City of Detroit established a policy committee which was responsible for the conduct of the Transportation Study. J. D. Carroll, Jr. was the director of the study which covered an area of 709 square miles and contained just under three million people in 1953. [5]

The purpose of the Detroit study was to develop traffic projections and highway improvement plans. [6] To accomplish this purpose a significant assumption was made as to the importance of land use in determining traffic generation, and was stated in the following manner: "Separation of places in space and the need for travel to overcome this separation is best reflected in the usage of land. Specification of land uses and their arrangement in space are basic causal factors creating traffic." [7] Thus, this linkage of land use to traffic generation marked a new era of transportation planning.

The planning process developed by the Detroit study was fairly simple, but unique for transportation planning at that time. The first step in this process was a population and economic forecast of the total study area. The second task was a forecast of the total amount of land for various uses which was based on the population and economic forecasts. The third step was the distribution of the future population and land use. [8] This latter step, for the Detroit study, was greatly simplified by the fact that the City Planning Commission had prepared a master plan in 1951, and the Metropolitan Area Regional Planning Commission also had a plan for the metropolitan area outside the city of Detroit. Carroll, the study director, recognized the significance of these plans when he stated: "The land use distribution must reflect local master plans and must account for redevelopment plans. Close cooperation with the public planning agency must be maintained as the future land use distribution is the most critical step in the transportation planning process, because the future origins and destinations are based on it."

Having future land use plans available was fortunate, but in order to adequately plan and stage transportation facilities it was necessary for the staff to determine when land would be developed. Therefore, priority ratings were applied to available land, designating when it would probably be developed. [9] However, there was no mention as to how these ratings were established.

Several important assumptions and procedures were utilized in this study. The assignment of trip generation rates for land uses was done manually on a zone by zone basis - observing past trends and patterns. In this way the established tendency for trips per acre to decline with distance from central business district was taken care of automatically. On the surface it appears that this assumption anticipated no change from existing conditions.

Another important assumption was that improvements in traffic facilities would be evenly distributed in any future plan. Therefore, the friction between zones would remain relatively the same in 1980 as in 1953. This assumption seems rather poorly founded since so much is being done with future accessibility in the more recent transportation studies.

In summary, it can be said that the Detroit study was a pioneer in several areas of transportation planning. It was the first large comprehensive study that crossed many political subdivision boundaries. It was also the first study to use electronic data processing to simulate traffic flows from land use projections, and the first to use land use projections as a basis for total metropolitan traffic flow analysis. [10]

Washington D. C. - Mass Transportation Study
National Capital Region

The Washington D. C. study was organized in 1955 under authorization of the 84th Congress which stated that the

National Capital Planning Commission and the National Capital Regional Planning Council were to jointly conduct a survey of the present and future mass transportation needs of the region. Kenneth M. Hoover directed the study which contained approximately two million people.

The planning process utilized in this study was very similar to the Detroit method in that future land use distribution was the result of intuitive or professional judgement based on the traditional planning approach. More specifically, the future population and economic growth in the region was estimated for 1980 and then distributed to local areas on the basis of existing local trends. Two basic assumptions were made in regard to this distribution. First, it was assumed "... that local governments would not be willing or able to significantly change this trend in growth. It was further assumed that the local governments would be able to exercise only a limited influence on the pattern of development and growth." [11] These two assumptions were significant because they precluded any variation in present trends and the introduction of community policies as to how growth should occur. Of course the federal government is the greatest factor affecting growth in Washington, and it is not subject to local control. However, this excuse is not available in other cities where similar conservative or short-sighted assumptions are made.

The projections in the Washington D. C. study were defended as being realistic on the grounds that the approach took into account the variety and diversity among communities within the region in a way that could not be done through reliance on quantitative relationships. [12]

The unique feature of the Washington study which contributed to the evolution and development of transportation planning was the application of future full-scale simulated traffic flow methods to several radically different transportation system alternatives. This study, unlike the Detroit study which developed only highway plans, analyzed several systems which varied mainly in respect to the mixtures of modes of transportation used in each. One was rail dominant, another bus dominant, and a third automobile dominant. However, all three simulations were calculated from a single land use projection. Thus, the Washington study fully demonstrated the value of designing and analyzing a range of major transportation alternatives, even though the validity of the actual projection appears limited by the overly simple assumptions about future land use. [13]

Chicago Area Transportation Study

The Chicago study was organized in 1955 by a special agency which functioned in an advisory capacity to the participating governmental units. J. D. Carroll, Jr. directed the study which covered 1,326 square miles and included 6.8 million people. [14]

The basic objectives of this study were enlarged over previous studies in that it proposed to devise a long range plan for needed highways and for mass transportation facilities, to carefully design information so that it could be re-examined and used for updating, and to develop a future land use projection on which to base future travel patterns.

Unlike the previous two studies which used conventional planning techniques to determine future land use distribution, the Chicago study staff used a more deterministic method which could be classified as a semi-mechanical model. One of the main reasons for this approach was that there was no metropolitan plan available, nor a planning agency that could prepare one. Because very few metropolitan areas have master plans, transportation planners try to develop a means (mechanical or otherwise) of determining future land use patterns. Therefore, the Chicago Area Transportation Study staff made land use projections which were based on the assumption that the forces operating presently will determine largely the land development pattern expected by 1980. [15] The C.A.T.S. report makes no pretentions, however, as to the projections being a plan. The study staff clearly distinguishes between the two in the following statement. "A land use forecast based upon historical trends and current relationships, is not the same as a land use plan. A land use forecast makes estimates as to how land is most likely to be used, e.g., that the trend toward low density, single family home construction will continue and will have a spatial pattern quite similar to the pattern of densities observed in 1956. It does not consider whether this is good or bad or ought to be encouraged. It is an attempt to state what the future will be like if present trends continue." 16

Following this line of thinking, the Chicago study staff found significant relationships between several variables and the distance from the central business district. In other words, their basic thesis was that the distribution of activities and the intensity of land usage are highly related to accessibility. It is important to note that the accessibility of a parcel of land in the Chicago study was measured as being directly proportional to the distance of that parcel from the central business district. Another relationship showed the peak population density was moving outward at a rate of 1.6 miles per decade. These and similarly complex relationships were used to project future land usage based on past trends.

The distribution of each type of land use was determined differently. "For residential land use, the capacity of each zone was determined initially on the basis of existing densities and vacant land. The change in population density, population density per developed acre, and non-white population were analyzed as a function of time and distance from the central business district. Certain zones were analyzed separately because of special considerations. Commercial forecasts were obtained by considering both planned projects and a fixed ratio of commercial acreage to residential acreage. Public land uses were broken into local uses such as grade schools and into non-local used such as federal or state buildings. A fixed ratio of local public land use acreage to residential acreage was used, but no orderly relationship for non-local usage was found. The acreage in streets remained constant, except in zones where more than 10% of the land was undeveloped. In these cases, a percentage of land was set aside for streets, depending on the acres of undeveloped land and the type of land use in the zone. Open spaces such as parks and golf courses were forecasted on the basis of past trends, community goals, and likely available acreage." [17]

In summary, this technique was based on the assumption that urban growth is essentially a movement of densities in a concentric pattern, declining as distance from the center increases. As a model, the Chicago method does very little in describing how the processes which shape the urban pattern actually work. [18] It neglects to envision changes in trends and, most important, that the transportation systems will change the projected growth pattern. Carroll recognized this latter fact, but rationalized his method in the following way. "The fact the accessibility will be altered may not be significant on a regional scale. Besides there are legal, geographic, financial and other factors that influence land use, so changes in the transportation network may not have significant effect on the ultimate development." [19]

The major importance of C.A.T.S. lies in the fact that it was a pioneer effort in describing urban growth in mathematical language. It was also the first to relate development potential to accessibility in a comprehensive way.

Hansen Model

Following the Chicago Area Transportation Study there was a rash of model developing and initiating of transportation studies. The Pittsburg Area Transportation Study was one such major study, but it followed C.A.T.S. procedure so closely it contributed little to the evolution of model development. However, Walter Hansen hypothesized a model for distributing urban population growth (residential only) based on growth data of the Washington, D. C. metropolitan area between 1948 and 1955. Hansen's model is termed a potential or gravity model because it is an extrapolation of the gravity concept of physical science. The basic thesis of this model is that forecasted population can be distributed to small zones using the accessibility of these zones to other land uses and the amount of vacant land in the zone. The accessibility in this model differs extremely from that used in the Chicago study where accessibility was assumed to be directly proportional to the distance from the C. B. D. Here accessibility is calculated by the following formula:

$$A_1 = \frac{S_2}{T_{1-2}^{x}} + \frac{S_3}{T_{1-3}^{x}} \cdots + \frac{S_n}{T_{1-n}^{x}}$$

where A = accessibility
S = size of the activity ie. employment in a zone
T = time for travel between zones
X = exponent - the value of this is very difficult to determine and creates many problems.

Hansen calculated the accessibility for all zones and by applying a couple of constants and simple ratios of vacant land to total forecasted growth could estimate future residential development in a zone. [20]

The model obviously has several weaknesses which are acknowledged by Hansen, but it also has several important advantages over previous types of projections. First, it has greater behavioral content because how families choose their locations is related to access to employment and to the locational opportunities (vacant land) available in various parts of the city. This measure of access also takes into account the economies and diseconomies of a transportation system to a limited degree. Secondly, this method takes into account the distributive effects of the transportation system and the spatial array of employment. Third, the output of this model is not as preconceived as the Chicago model which was based on what someone thought the area should look like. [21]

The results of this research were fairly accurate considering accessibility and vacant land were the only two variables used. The significance of this study is that it paved the way for research to isolate more factors or variables and measure their effect on land development. It also further emphasized the importance of accessibility on land development.

Baltimore-Washington Interregional Study

The Baltimore-Washington study was a continuation of previous studies conducted independently by the two metropolitan areas. It was organized as a joint project in 1957 under the technical advisorship of Alan M. Voorhees, and the region studies contained nearly four million people.

The major objective of the study was to project and analyze future distribution patterns of population, employment, and automobile traffic growth in the Baltimore-Washington region. While previous studies of these cities had dealt with this objective, several changes were made in this one. This study was to treat the Baltimore-Washington area, not as two independent areas, but as one interrelated region. The previous studies relied upon more or less conventional techniques for estimating population and employment distribution. This study introduced more recently developed methods of population and employment projections for small areas in the region. It also considered alternative patterns of regional growth, lending equal emphasis in analysis to: a) potential form and extent of land development; and b) requirements for transportation systems.[22]

The actual process employed by this study expanded the gravity model concepts developed by Hansen, and used separate models for distributing population growth and manufacturing employment. Where Hansen used only accessibility and vacant land as variables in his model, the Baltimore-Washington study staff added a "K" factor which was to take into account socio-economic factors.

More specifically, the population growth model included three factors: 1) available population capacity; 2) accessibility to employment; and 3) a group of socio-economic and development factors reflecting the character of the land, utilities, and established developments. The growth index representing the actual or predicted growth for any particular zone was determined by the following equation:

Growth Index (G) = Capacity (C) x Accessibility (A) x other growth factors (K)

This study area was divided into zones, and the "K" factor for each zone was determined empirically from data on growth between 1948 and 1957 by the following formula:[23]

$$K = \frac{G}{CxA} = \frac{\text{actual growth (1948-1957)}}{\text{theoretical growth}}$$

The unique feature of this study was in the analysis of the "K" factors for each zone. Several component factors were found to be contributing to the "K" values. They were grouped into four categories, and in each category a number of individual factors were listed as contributing to the major category. These individual factors were assigned weights and their sum made up a total weight for each major group. The values of the four major groups were then multiplied together, and the result was said to be equivalent to the "K" value for each zone.

The four major groups and their individual factors are listed below to give an indication of the analysis procedure used at the time of this study.

1. Utilities - deficiencies in water or sanitary sewers reduced the K factor.

2. Land and Development Factors - low land cost, attractive land, poor subdivision practice, policies of land owners.

3. Community Factors - prestige, established communities, quality of local government services.

4. Special Factors - not really known. [24]

After these factors were indentified deductively or subjectively, they were analyzed in regards to their effect on future growth. At times they were changed because of significant variables pertinent to a zone. This was an important aspect because it showed a tendency to get away from blindly following past trends.

In order to establish population capacities, and therefore make the model work, future densities had to be assumed. By varying the density groupings within the region it was possible to derive alternative growth patterns for analysis.

Manufacturing land use was projected by using the same model with different variables comprising the "K" factor and accessibility to population was used instead of accessibility to employment. Commercial employment as well as other land uses were more or less distributed in direct proportion to the population distribution.

The significance of the Baltimore-Washington study rests in the fact that it further developed mathematical models to include a variety of factors, and that it briefly examined alternative land use patterns as well as alternative transportation systems. The interesting conclusion of the study was: "Transportation is not the dominant or controlling factor in shaping our cities. With the mobility provided by the automobile, the urban dweller has for all practical purposes been freed of distance limitations in his choice of a place to live." [25] This conclusion may not be applicable to other areas because it seems that accessibility was almost equal in all parts of this study area.

Los Angeles Regional Transportation Study

The L.A.R.T.S. was organized in 1959 under the general coordination of the California Division of Highways and was directed by Edward T. Telford. The study, the largest in the world at that time, contained 7.5 million people in a 9,000 square mile area. This study has yet to be completed.

Therefore, the following analysis is based on reports which describe what is hoped to be accomplished.

The purpose of the study is to develop the travel patterns of people and goods for use in determining the present and future transportation needs of the five county area. These patterns will be related to present and projected land use, population, employment and other socio-economic factors affecting traffic. Furthermore, the study staff proposes to test alternative freeway systems, different concepts of mass transit usage, alternative land use plans, and various rates of economic growth. [26] Besides this objective, which is obviously more inclusive that that of any previous study's, the L.A.R.T.S. staff further stressed the following: "The land use models developed in this study will provide powerful tools to the local communities for testing and evaluating alternatives of existing and future land use and transportation plans. The study in itself will not make any recommendations as to street and highway improvements, freeway locations, or public mass transportation. Its prime responsibility is to provide information which the various agencies and their legislative bodies, in the study area, can use in their planning and decision making." [27] This is a new approach used in a transportation study and may have significant effects in allowing for local policies and objectives to be implemented to a greater degree than previously.

The general procedure in regards to land use distribution is very similar to that used in the Baltimore-Washington study, in that it proposes a gravity type land use model which will distribute population change throughout the area. Industrial and other uses will each be distributed by separate models. The population-land use model is based on competition for projected growth. This competition is based on a multiple correlation analysis of many factors which include water, sewers, highways, public transit, land suitability, average vacant land cost per acre, average topo conditions, accessibility to jobs, and types of dwelling units. These factors are the same as those usually used throughout the United States in similar studies. However, their individual weights or importance will vary with city and regional differences. Therefore, each city which undertakes this type of study will have to determine the relative importance of the factors which affect their growth.

An observation made of this study and previous studies brings out a problem much discussed today; that is, how can you determine the interrelated effects of land use and transportation systems? Previous models used existing accessibility to determine future land use distribution, but the L.A.R.T.S. staff proposes to lay out a future highway net to determine future travel times, then use them in the model to predict land use distribution. Neither method seems completely satisfactory because they are basing land use distribution on transportation networks instead of vice versa or some combination of the two.

The Los Angeles Regional Transportation Study's unique features are the broader objectives and the utilization of the services of various planning jurisdictions within the study area. Questionnaires were sent out requesting various information on land development and land use plans. Therefore, the final result of the Study will represent a culmination of many ideas and will give the local areas a basis on which to make decisions.

Penn-Jersey Transportation Study

The Penn-Jersey study was initiated in 1959 by joint agreement of the highway departments of Pennsylvania and New Jersey and the City of Philadelphia. The study was designed to include an area which contained over 4.3 million persons. By far the most complex to date, this study, directed by Henry Fagin, produced several innovations to transportation planning.

The scope of the objective exemplifies the deviation from previous studies to some degree. It was stated that the study intended not only for the recommended transportation system to provide convenience and economy of travel, but also that its influence on the development of the area should tend toward facilitating a desired pattern of regional development. Stress is laid on the development of alternative patterns, both of possible transportation systems and of the future regional development likely to be associated with each system. [28]

Previously, transportation plans have been based on assumptions as to the future distribution of people and activities. Some consisted of informed judgment while others consisted of projecting past trends. In both these methods one single projection of land use had been made, and various transportation schemes were evaluated in relation to serving that pattern. The Penn-Jersey staff developed a regional growth model whereby land use projections can be made for varying sets of assumptions and policies. These include influences of land use change on alternative transportation schemes.

Another basic difference in the Penn-Jersey study is that an effort has been made to identify the behavioral process which results in the distribution of new households and employment opportunities. Previous models have inferred that the factors influencing new development will be similar to those of the past. However, the elements which generate new development tend to be only partially identified, and the assumptions identifying these variables are rarely tested. Because of these reasons and the inherent stress on quantitative relationships, economic models have been introduced by the Penn-Jersey staff to explain the "maximizing" behavior of individuals and business firms within a region. [29] The basic thesis behind the model is that if there is a consistency, it is not in the pattern per se, but in economic and social behavior of the individuals who locate their houses and business places.

The behavioral content of the model depends upon the propensity of household locators to maximize the difference between what they annually allocate to the purchase of their residences (and all its attributes i.e. site size, public services, age of area, views etc.) and what they actually have to pay exclusive of site cost. This difference is defined as the households rent paying ability, and it is unique for each type of household, the particular parcel of land associated with that household, and the area where the site is located. The exact form of the model is a linear program.

The interaction between this behavioral model and the traffic model in the Penn-Jersey scheme depends upon how "accessibility" as a variable influences household location decisions. The accessibility of each household to other land uses is defined in terms of trip making costs instead of distance or time. Each location in the area has a particular accessibility or cost of traveling from that location to other locations. Thus, a resident must consider this cost along with the housing and site costs. Therefore, decisions to spend money for housing as compared with other items in the family budget.

The actual regional growth model is made up of several sub-models, each of which is complex and beyond scope of this paper to explain. Let it suffice to generally list four basic inputs to the regional model:

1. Initial state of the system - all present artifacts.
2. Projections of external factors i.e. population and economy.
3. Alternative policies in regard to transportation systems or alternative levels of service. This may include public policies as to land development, zoning, taxation and provision of services.
4. Assumed relationships of the model itself which consist of functions and parameters. (The functions describe the form of relationships - the way the real world is assumed to work. The parameters are constants of the functions which define the quantitative nature of the relationships.) [30]

The function of the model is to estimate changes in the present condition which result from changed factors in the above and other variables. The model begins with existing 1960 conditions as the given, and proceeds to simulate changes in five year iterations. The pattern at the end of the first five years is the given for the next iteration.

The Penn-Jersey staff states that the mere passage of time does not in itself lead to changes in patterns. These changes result from some prior cause which ought to be identifiable. If changes in pattern were related only to the passage of time, or growth of population, then they would be the same no matter what public policies were pursued. (This is what Washington assumed.) The Penn-Jersey staff proposes that the tastes and desires of people for residential space and the economic behavior of individuals and commercial locators remains unchanged in its essential character. However, changes in trip making behavior would result from 1) changes in the environment which affect the opportunities open to locators (trip makers); 2) from changes in the capacity of people to satisfy their desires; or 3) from changes in the composition of the population seeking such satisfaction. The changes in environment result from growth processes and public policy decisions, and changes in the capacity of people result from changes in income. [31]

The foregoing discussion brings out some of the significant features of the Penn-Jersey Study. It is the most complex study of behavior and the variables affecting it, and the inclusion of policy variations and their resulting effects on development patterns produced significant advances in this phase of planning. The involvement in specifying the interrelated effects of land use and transportation on one another is also a significant step forward in transportation planning. The process of "watching the region grow" by five year periods was advanced more thoroughly than previously.

Tri-State Transportation Study

The Tri-State study was initiated by the governors of Connecticut, New Jersey and New York in August of 1961. The study area was, for the first time, to envelop three states totaling 11,000 square miles and containing 14.7 million people. Roger H. Gilman, the director of the study, was given a twofold objective of formulating a long range transportation plan and program that will promote the orderly and desirable development of the region during the next two decades, and secondly, to plan solutions for the most critical immediate problems. In regards to land use projections the Prospectus stated that a specific method had not been settled upon as yet, but that they intended to study previous methods and then devise a model suitable for the Tri-State region. [32]

The general procedure to be followed encompassed most of the advancements of transportation planning to date. In the first place, the inter-relationship between the region's land development and transportation system is to be studied so that recommendations can be made for achieving the optimum development of the region. Furthermore, it was proposed to study the area in a series of incremental growth periods - much like the Penn-Jersey study. The local areas are to work out their own plans and policies of a subregional nature in order to involve local objectives. [33]

Southeastern Wisconsin Regional Transportation Study

This study was initiated in 1962 and is set up as a project of the S.E.W.R.P.C. (Southeastern Wisconsin Regional Planning Commission) which is charged with the responsibility of developing a regional master plan. Sanford Farness originally directed this study whose organization is ideal for the true integration of land use and transportation planning. The primary objective of the agency is to develop alternative regional transportation plans and development patterns. In order to do this, the region will be described in a systems approach and land use models will be developed.

The land use model, like the Penn-Jersey model, is a process model. "It will be used to test the effectiveness of various ways of achieving desired land use plans. The model contains variables such as water and sewer location, zoning, etc., which are under governmental control. By adjusting these controlled variables in the model and observing the resulting forecasts of land use, the best way to achieve a desired plan can be determined.

"The land use model is divided into five nearly independent simulations, each one dealing with a different category of land use, namely, residential, industrial, commercial, agricultural, and special (such as park and open spaces). The forecasts of agricultural and special land uses in each zone is made in an 'ad hoc' fashion. These forecasts are then used with other data to forecast residential, industrial, and commercial land uses.

"As an example, consider the operation of the residential model. Initially, households are divided into categories according to structure, market value, and owner versus renter status. The actual categories are made on the basis of empirical data so that all the households in a given category live mostly in a few categories of housing. In addition, zones are categorized according to taxes, water, sewers, and accessibility to work, shopping, and population. Then the desirability of a particular housing type for a zone type is determined from empirical data by assumming that current housing types are located in desirable zones.

"Growth occurs then as follows. First, a yearly turnover rate is empirically determined for each category of households. These 'turning-over' households move into vacant housing types desirable to their category of household. If more than one zone contains such vacant housing, the zone with the highest accessibility to facilities is moved into by the turning over household. Land developers and builders produce new housing types. The quantity of each housing type is determined by past sales. The location is determined by finding zones that are desirable for these housing types, subject to constraints of available land and zoning restrictions. The model is then iterated from one year to the next to simulate the growth of the region." 34

There are several significant features of the S.E.W.R.P.C. study. Besides including many features of other studies, it stresses the fact that this will be a regional plan instead of metropolitan in scope. By this they mean to include the rural fringe in the development analysis. Furthermore, the transportation study was launched by an existing planning agency which can make plans, integrate land use and transportation plans, and implement them on a continuing basis. Another significant feature is that this is the first time alternative transportation plans and regional development plans will be evaluated in light of a comprehensive assessment of effect on the natural resources, the ecological balance, and on the resulting total environment, as well as the overall costs of developing and operating the combined regional land use-transportation system. [35]

Summary

The preceding analysis has necessarily been limited to only an overview of transportation studies and their land use models, as dwelling on details would have lengthened this chapter without adding substantially to its basic purpose. A review of the studies contained herein illustrates the general development and sophistication of land use models and the broadening of study objectives.

These objectives reflect to a great degree upon the models' form and use.

The Detroit Area Transportation Study was the first to use future land use as a basis for planning transportation facilities. Its objective was to develop highway plans in accordance with an existing master plan. As other studies were initiated, broader objectives, new concepts, and new procedures were introduced. Today, many transportation studies utilize mathematical models that are designed for use in simulating urban development, testing alternative policies, and describing the interrelated effects of land use and transportation facilities.

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CHAPTER II

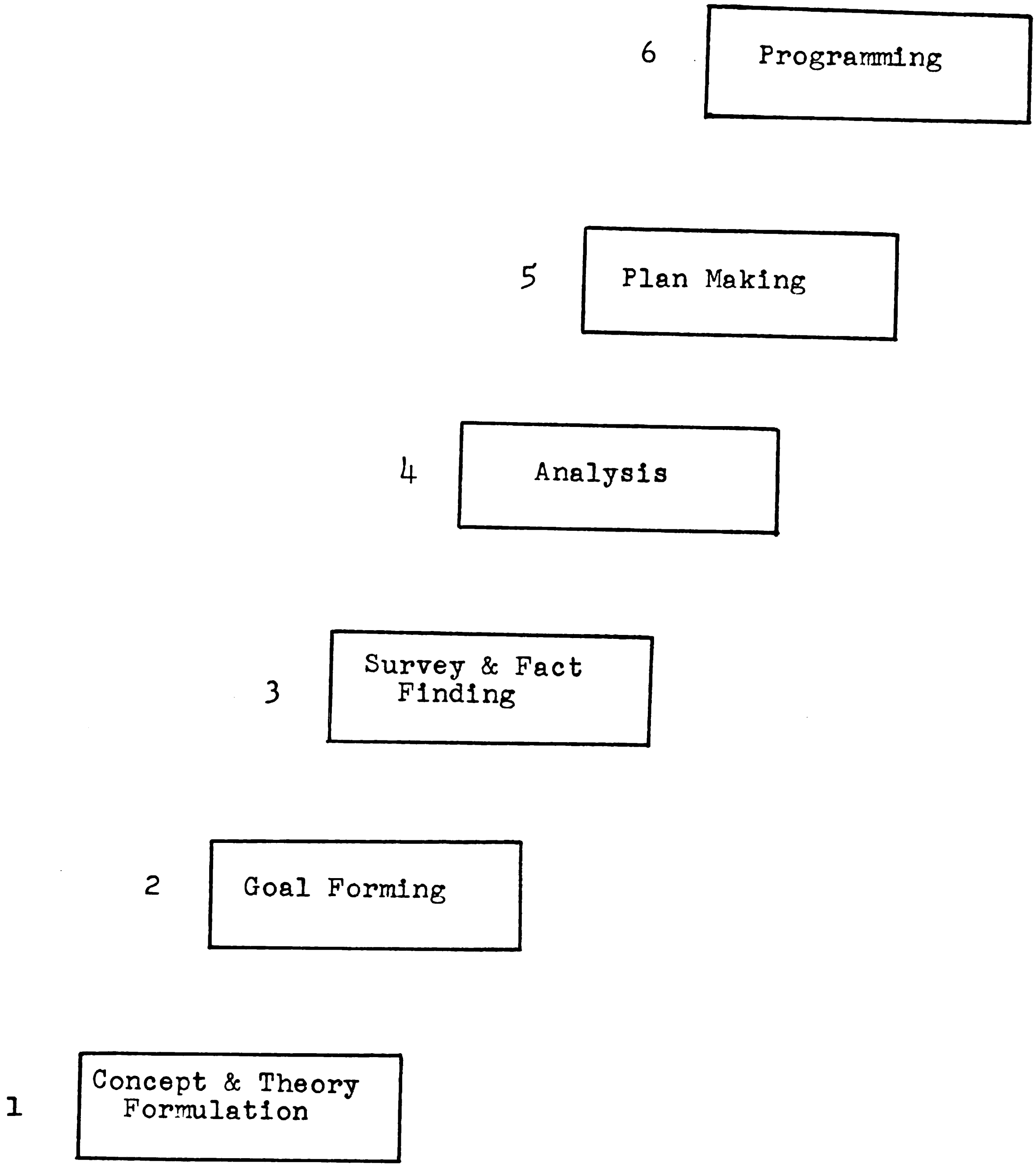
USES AND IMPLICATIONS OF LAND USE MODELS

As was shown in Chapter One, the use of models has spread from strictly transportation planning to urban and regional planning as well. It is the purpose of this chapter to define the potential use of models in the permanent planning process, and to point out the implications which the use of models may have to planning.

Uses of Models in Planning

It has been said that the validity or usefulness of a model should be judged by its suitability for a particular purpose.[36] The purpose of land use models to date has been to aid in predicting future land use arrangement. Assuming that this purpose can be accomplished with an existing model, many uses related to the planning process can be visualized. The planning process, diagrammed on the following page, consists of the following steps: 1) concept and theory formulation; 2) goal forming; 3) survey and fact finding; 4) analysis; 5) plan making; and, 6) programming.[37] The remainder of this section describes the uses that present day models could perform in each step of the planning process.

PLANNING PROCESS



Concept and Theory Formulation

This initial step of the planning process is not subject to mathematical formulization because it is here that basic ideas are born. It could be said that this is where mathematical land use models are developed.

Goal Forming

This is one of the most important steps in the planning process. It is here that the framework for remaining actions is established. A model could be of significant value at this stage if it were well defined, and the type that could be used to test alternative policies and their resultant effects. If models were well defined as to the inputs needed and outputs that could be expected, planners (or decision makers) would be more encouraged to form goals and objectives. For example, consider a model that has as an input some measure of sewer extension possibilities. This would necessitate a policy decision which presumably would be based on goals and objectives. Following this line of reasoning, the use of models would provide for a better consensus of area goals and policies. In fact, alternative policies have been inputs to several models to date.

Survey and Fact Finding

Once a model has been developed for a particular area, it seems obvious that the types and form of data to be collected would be well defined. Also, since the data would usually be used on a computer, it could be collected in a manner which would facilitate its being transferred to IBM cards or magnetic tapes for easy storage. Thus, efficiency could be achieved in the handling of data, and in data collection by knowing beforehand precisely the kind of data needed.

This is a commendable use for models, assuming that one has been developed for the planning area in question. This assumption is necessary because at the present state of knowledge it does not seem possible to use a model which was developed for a city in one section of the country for a city elsewhere, due to the fact that each city is unique in its particular patterns of growth, etc. As a result, much data is necessarily collected for use in constructing the model -- sometimes in a trial and error fashion. Therefore, much of the efficiency is lost in the initial planning efforts. Consequently today's models can offer only a rough guide to the survey and fact finding phase of planning. The real advantage comes in the continuing and updating processes which follow the initial plan making.

Analysis

This phase of the planning process is often nebulous and hard to define. In many respects it overlaps with the plan making phase. However, for definition reason, analysis can be said to consist of evaluating and synthesizing data in order to identify problems. The models today that are used for predicting are of little value in identifying existing problems. Their usefulness lies in training the observer to examine the city as a whole by requiring, as inputs, total area effects of individual developments. Also, the analysis stage could afford the opportunity for the model and its data to be tested on known past growth.

Plan Making

It has been said that the ultimate purpose of all planning work is to recommend decisions. A decision involves a choice, and the probability of choosing the correct alternative depends on the manner in which the alternative is stated, and the amount of data that is taken into account.[38] If through the use of models much data and many alternative solutions can be analyzed, then the probability of making the right decisions is increased. To digress for a moment, consider an investment of one billion dollars, which is not too uncommon in a complex urban area. If the probability of choosing the correct alternative, concerning this investment, is increased by as little as one per cent, a savings of ten million dollars could result. Herein lies the justification for the expenditure of time and money on the development of computer models.[39]

In regard to the plan making phase of the planning process, perhaps the first use to which models can be put is projecting existing trends and policies into the future.

This enables the identification of future problem areas if existing trends are followed. Also, in the initial stages of plan formulation, models can be used as a substitute for actual experiment. Growth can be tested under various assumptions, and the effects of various policies on development can be shown. Environmental changes can be hypothesized and their effects demonstrated. All of these can result in the identification of problems, pressures, and a future range of choice.

With the use of models, planners can better weigh alternatives in terms of goals or their achievability, and the government investments, policies and other actions, including transportation facilities, needed to implement them. In the various alternatives that may be presented, the degree to which objectives are achieved in each can be measured. Besides testing the achievability of certain objectives, more detailed needs such as schools, recreation areas, and transportation facilities could be identified by comparison to specific standards.

In summary it can be said that planners can not make sound recommendations, and public officials can not intelligently decide issues unless a clear understanding exists of the nature and magnitude of the issues involved in each case. The purpose of models is to enhance the decision making ability by providing a means of studying the implications and consequences of various alternatives.[40] In this respect it is obvious that models, contrary to some suspicions, supplement not supplant the planner and his functions.

Programming

Once a plan is decided upon, a series of steps and actions are necessary for its implementation and continual updating. The use of a model can help formulate such a series of steps or program. With problems and needs of the future identified in quantative terms, the planner can program both community and professional resources to solve these problems. One could argue that conventional planning techniques offer this advantage. The difference, however, occurs in the way in which the future and its problems are predicted. Through the use of models it is possible to age the city in a series of iterations under various hypotheses. Thus a much better idea of when, and under what circumstances a particular action or expenditure will be needed. This has great potential when it comes to effecting policies, programming capital improvements, and programming staff operations. In light of the above uses, it follows that as a result of using models, planning can more easily be turned into a program of action.

In summarizing the uses of models in planning, several conclusions can be drawn. Land use models today are designed for the purpose of predicting the future distribution of urban activities. It is generally conceded that this purpose has not yet been demonstratably achieved, and consequently models are considered by many as being useless. However, the sole criterion for usefulness should not rest on this near-impossible to achieve objective. The final results need not be perfect for a model to be useful because it can serve a significant purpose if it enhances our understanding of the city and how it functions. For example, consider t he use in the plan making stage where the results of specific alternative policies were simulated. The accuracy of the forecast in this instance would not be as important as the identification of the effects of various policies. Another example is evident in the data collection phase. The ability to predict with a model does not enter into the determination of the processes and data that shape the urban form. Only the structure of the model and its necessary inputs need to be known. This line of reasoning can be applied to many of the uses described in this section.

Therefore, it can be said of present models that even though they are not yet able to predict, they are performing a useful purpose in helping to identify urban functioning, and defining the scope of planning, as well as serving the other purposes listed in this section. These uses will become more apparent and acceptable as models are more refined - as they inevitably will be. Perhaps, as is suggested in a following section, models will be developed which will not be aimed solely at predicting the future state of development.

Implications of the Use of Models to Planning

Reflection on the development and use of land use models to date suggests several implications regarding urban planning. In this section, the implications felt to be of significant consequence are discussed.

As shown in Chapter One, the early transportation studies were organized on an ad hoc or independent basis. The only relation to the urban planning function occurred through the basing of transportation plans on land use projections, which may or may not have been prepared by the local planning agency. During the evolution of these transportation studies, technical and organizational sophistication has taken place. Today, it is not uncommon for a transportation study to be organized on a continuing basis, or as part of a permanent regional planning operation. This advancement was due partly to the recognition that transportation facilities not only serve land use but are a major force in shaping its distribution.

Assuming that a model were operational for a particular urban area, several implications can be visualized resulting from an integrated organizational structure. For instance, at the outset of the planning processlong range data needs could be established by knowing the necessary inputs to the model. Consequently, other governmental departments could be more efficiently brought into the planning process and better cooperation obtained. The most important implication, in regard to organization, is that transportation facilities can be more effectively used as a means for implementing desired plans or goals because transportation facilities do shape the urban environment more that any other single factor.

Aside from organizational implications, the size of the area for which models are effective indicates another implication. From past experience models seem to be more applicable to larger areas because behavioral actions and other inputs to the models must be handled on a gross basis to be statistically reliable. Therefore, metropolitan and regional planning tend to benefit from the use of models more than the small community or neighborhood type of planning. The advantage of this situation is that a broader, more encompassing regional viewpoint is established, whereas the disadvantage lies in the possibility that the more detailed neighborhood interests may be obscured.

Because of the vast complexity of metropolitan planning, and the advent of data processing and computer models, it seems inevitable that many steps in the planning process will become more computerized. The trend in this direction is obvious today. Established data banks can be of significant use to model development, and the use of models can help establish and supplement these efforts toward more efficiency. As a result of this increased efficiency in data handling, the planner will have more time to devote to analysis and the more human aspects of planning. Another implication in relation to data and the use of models is that a greater stress will be put on research to determine the factors that affect growth. This data would be necessary before a model could be made operational. Also, the kind of research or data to be collected in the future for evaluating methods on a continum can be identified by the use of models.

With the vast amount of data that could be available, many coordinated functions of planning, besides transportation, would benefit through the use of these data and models One such function would be urban renewal. Models could simulate how the market operates under given assumptions and pressures. Thus, more effective housing and reuse of cleared areas could be accomplished.

Perhaps the most important implication of model usage is in the area of policy making. Since models are now designed to simulate area growth under various alternative assumptions and policies, it is imperative that the decision makers in the region, or community adopt a set of policies. This implies that policy planning may become more important. There is certainly a need for such a step because, traditionally, policies are seldom mentioned, seldom identified and even less often adopted. Policy planning and achieving community objectives could be made to work hand in hand through the use of models. Different policies regarding zoning, taxes, the extension of services, and others could be tested with the use of models to see which combination best implements community objectives.

Another implication of using models in planning can be visualized in planner education. Specialization in model development and research in the behavioral aspects of urban processes is a must if better models are to be developed. Perhaps metropolitan and regional planners could forego detailed studies of such aspects as zoning and concentrate on studies involved with model development. On the other hand, it may be desirable to have a detailed knowledge and then study model development as an advanced interest or degree.

Finally, it must be mentioned that models do not seem able to predict industrial land use patterns to the same degree of accuracy as residential land uses. [41] (Commercial uses are directly related to residential, therefore they can be derived from or after residential uses have been distributed.) Major industrial uses are difficult to locate, and because they are usually the basis on which residential uses are distributed (via accessibility to work areas), they become the foundation for future land use pattern. The implication here is that conventional planning methods will be necessary to locate large industrial uses at least until a better method of specifying their location is developed.

In conclusion, many implications exist in the present state of model development. A more powerful planning operation can be undertaken through the integration of transportation and urban planning and through the use of models. If development factors and actions needed are identified along with their results, then perhaps more imaginative and broader planning can be achieved, as well as some degree of implementation of plans through transportation facility layouts.

FOOTNOTES

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CHAPTER III

LIMITATIONS OF EXISTING LAND USE MODELS

In Chapter One it was shown how transportation studies have progressed from merely designing transportation facilities to serve a projected land use to the present stage, where it is realized that transportation facilities, to a large extent, determine urban form. Consequently, transportation planners are putting more emphasis on the study of factors which shape present, and especially, future urban patterns.

Urban planners have been confronted with the problem of determining future urban form for many decades, but are still struggling with many of the original problems and several new, more complex ones. With the relatively recent advent of large scale transportation planning and its obvious far reaching effects, the problems of forecasting or "planning for the future" have been brought to a head. The design of land use models has been an important step in trying to solve these problems by predicting future urban form on both a comprehensive and skillful level. However, there are still many basic limitations to forecasting in general, as well as limitations to the more refined level of model structure. This chapter will point out these limitations which must be considered before we can honestly plan for the future. The purpose here is not to debate the issues which will be raised, but merely to point them out for consideration.

Upon analyzing the many limitations, it was felt that they could be categorized in the following manner: conceptual problems; unknown variables or informational gaps; and problems of model structure. In the following pages these categories are further broken down into sub topics for discussion purposes.

Conceptual Problems

One might consider conceptual problems as inappropriate to models per se, but the understanding of the fundamental issues raised here is a prerequisite to any type of long range planning. It is felt that until this understanding is accomplished and to some extent incorporated in models, model building is little more than a mathematical exercise.

Values - Goals - Policies

The formulation of goals and objectives is the most fundamental aspect of any planning process, yet it is often ignored or overlooked. If one accepts the fact that transportation facilities do affect the structure or pattern of the city, then it is evident that transportation planners should consider what the desirable pattern should be. It is felt that this most fundamental question - "what objectives do we want to accomplish and how?" - has not been answered to date. If this is true, then billions of dollars as well as less tangible things are being wasted and lost by blindly following past trends when planning for the future. Is the general population too entrenched in past and present cultural traits to foresee or envoke change? Just what do people really want? These questions are the ones that must be answered, however difficult. One might say that it is impossible to determine the values and goals of such a pluralistic society as ours, but in response it can be said that this only emphasizes the basic contention that we do not know what we are planning for.

One of the reasons for this uncertainty lies in the fact that metropolitan areas are fairly new formations. At first, small scale planning principles (i.e. neighborhood theory) were applied to the metropolis, but it was soon realized that a new concept was needed. Many concepts are presently in existence or are being formulated, but none are widely accepted as yet. Several questions arise regarding basic issues and concepts which have limitless effect on the urban structure. A few of these are given as examples: 1) Do we need a single central business district, or are several subcenters the answer? 2) Should families with higher incomes locate nearer the central business district? They are the most productive, and therefore should they not live near the most productive area in order to minimize travel distance? [42] 3) Should we plan for an "efficient" metropolis? If so, what is "efficiency", and who determines it? 4) Do people actually like living in the city or is it a necessity? If they do like it, why are the approaches to big cities always crammed with people on Sunday evenings who are trying to get back home after a weekend "away"?

The above questions are intended to illustrate that before we dash headlong into planning transportation facilities, values, goals, and objectives need to be formulated. This is no easy task if done thoroughly, but the result may well be worth the effort. Consider a new type of machinery that is first conceived in the minds of men, then designed and built. Could this not apply to metropolitan structure? [43]

A corollary to the need for formulating objectives is the statement of policies by the governing bodies. Traditionally this phase of planning has been left out, and as a result, there has been little implementation of plans. The early transportation studies did little with "policy planning." Recently, however, several studies have made this phase very important and are to be commended. They have realized that the assumption of weak policies means poor long range planning. Finally, if there can not be a theory of city structure, because of constant changes in our society, then the formulation of long range goals and policies can provide the necessary guide to follow.

Assumptions and Bases of Forecasting

Assumptions play a major role in forming the basis of forecasting and model construction. In the first chapter, several limitations concerning assumptions were brought out while discussing the evolution of transportation studies. For illustration purposes a few of these will be reiterated here: 1) Detroit assumed the travel friction between zones would be equal in the future because future transportation facilities would be evenly spaced; 2) Washington D.C. assumed that local agencies would effectuate no policies to induce change in the existing trends; 3) Hansen assumed that people would react as molecules do in the gravitational theory; and 4) Penn Jersey had to make many assumptions about human behavior before their model could be formulated. With a little reflection, it should be evident that assumptions have far reaching effects, and an error in this stage could be disasterous.

It is conceded that there could be little activity, be it planning or other, without making assumptions. However, in examining the bases for these assumptions many limitations become apparent. First, present models and other forecasting methods are based on data derived from metropolitan areas in the United States, many of which have had roughly the same population and economic compositions, the same institutions and the same technology. The similarity in land use patterns is a result of these cultural traits. What would happen if one or more of these traits

were changed? In South American cities the high income families live near the center of the city and the low income groups on the periphery -- exactly opposite of the pattern in this country. This is a result of different cultures. The main theme of this discussion is to point out that there is no law of urban form, but only a consistency in the behavior of culturally conditioned peoples. Therefore, any forecast which is based on past trends and does not examine the differences in cultural characteristics existing at that time and the ones most likely to exist in the future, is worthless.

Another weakness of present forecasting is the underestimating of society and individuals and their ability to effectuate change. As an example, consider the models that are based to some extent on land values. Can not the local governments manipulate these land values since they are merely manifestations of our culture? Also, the models based on the gravity theory underestimate the mobility of industry and residences. They could, conceivable, turn the city inside out. [45]

Another limitation can be seen in models which take the existing city and add increments of growth onto it. These models overlook, except for immediate projects, the possibility for drastic change in the existing structure from urban renewal, or more basic cultural changes.

Unknown Variables and Informational Gaps

In the preceding section it was pointed out that values, goals and the basis for several assumptions are relatively unknown. Proceeding in a similar vein, this section is designed to point out types of information that are very important in shaping future urban patterns, but are for all practical purposes, unknown. It was felt that these unknowns could be grouped into the following four areas for discussion: 1) behavioral; 2) technological; 3) general information; and 4) model structure.

Behavioral Unknowns

Data on human behavior in many respects, particularly in regards to transportation planning needs, is very limited. In observing time trends where data is available, it is usually impossible to hold constant the environmental forces over a period of years, and thus impossible to derive a true picture of the behavior itself.

Since behavioral data is difficult to obtain and forecast, it has been necessary to delineate behavior patterns with reference to cross sectional data. The models which simulate behavior are limited in their accuracy to what can be scientifically foreseen from the study of the interrelationships of this cross sectional data, and to what can be measured or inferred from urban statistics. [46] Since behavior itself can not actually be determined, and only a cursory relationship between it and certain other variables can be made, a definite limitation exists, and a problem arises as to which variables to project and how.

It can be said that little is known about the fundamental elements expressed in the choices people now make. Neither theory nor data is available to help anticipate human behavior under various hypothesized conditions of the future. Therefore, before more planning is done, or an adequate theory of metropolitan growth and structure is developed, assimilation of considerably more knowledge as to the behavior of locational decision makers and the effects of various policies on their behavior is needed.

Technological Unknowns

It is generally agreed that advances in technology are mighty forces in shaping our living patterns. (Witness the automobile for a much used example.) There exists a great myth that technological advances come about as if by magic, under no control of humans. Most people do not realize that such advances are the product of men and our culture. The problem or limitation of most forecasting today is the complete lack of trying to determine these advances. Planners in general sit back and make plans kmowing that changes in technology will occur, but falling back on the excuse that no one can foresee technological change. Thus when the future arrives and plans are completely antiquated, there is no remorse because "technology" caused the failure.

It is conceded that technological innovations are very difficult to foresee, and often impossible to predict. This in itself can be viewed as a limitation, and will continue to be one until man learns to either control or predict these advances. However, a more serious limitation of most long range planning is the ommission of technological advances which are figuratively, "just around the corner." Inclusion of these and their alternative effects would not require too much foresight since many technical advances are in the process of development now. As an example, consider the emphasis by several studies on the requirement that sewer service be available before development occurs. This is valid now, but how will chemical toilets, that burn the sewage on the spot, affect development? Another example is the development of very small individual cars that would require less than half the lane space now needed and therefore double existing street capacities. One area which has great potential and far reaching influence is that of communications. The substituting of communications for transportation could drastically reduce travel and alter development patterns. [47]

Therefore, the need in planning and model building is to anticipate technological advances, and to explore their implications so that projections are not in considerable error when the future arrives. Planning today should be of dynamic, revolutionary methods - not based on the extension of past trends and outdated empirical methods.

General Informational Gaps

It is acknowledged that models are no more accurate than the data which goes into them. This data, in many instances, is relatively unknown and therefore assumed, or it needs to be forecasted, and is consequently subject to all the conventional problems of present day forecasting methods. Without belaboring this latter point, which has been discussed to some degree previously, the remainder of this section will be devoted to listing several areas in which more data and research are needed before adequate projections can be made.

Research needs to be focused on the metropolis as a functioning, evolving process in order to answer the following questions:

1. What are the effects of size, dispersion, or areal specialization on the functioning of the metropolis?
2. How does the metropolis work at any point in time? How does it change? Can this change be controlled and directed?
3. What are the significant differences in various types of urban form?
4. Exactly how does the city respond to transportation? Will the future metropolis take one form if certain arrangements are made, and

another if not?

Listed below are many other general questions that need to be answered in order to properly anticipate the future:

1. How will people behave with larger levels of income?
2. How would modern business react to increased or decreased mobility?
3. How would home buyers react to a more liberal, mortgage policy on used housing?
4. Some experts have said there is a lack of information on non-residential land use and its distribution. [48] Another has said there exists adequate information on industry and commercial uses, and what is needed is more information on residential distribution. [49] Contradictions like this emphasize the need for more research.
5. More information is needed on the effects of aesthetic and social factors, and a meaningful measuring device for these needs to be developed.
6. Locators may wait varying lengths of time before incurring the expense of moving, even though other factors are present which make relocation optimal at that time. Therefore, there is a need for long term information to determine how to anticipate this behavioral lag. [50]
7. What actually are the formative factors that shape

the metropolitan region? Assuming that transportation is one of them, where does it belong in the hierarchy of other forces?

Many more data needs could be listed, but the above examples are enough to indicate that there is a need for much inter-disciplinary research before forecasts can be made with a substantial degree of accuracy.

Model Structure

Most of the previous limitations discussed were applicable to any type of forecasting. This section is devoted to pointing out those weaknesses which are unique to models. The following limitations are of a general nature, and are not detailed in regards to mathematical and statistical methodology for the following two reasons: 1) the author's knowledge and experience in this specialized field does not qualify him for such an undertaking; and 2) the model builders themselves do not really know the reliability of their formulations until the results are evaluated at the end of the forecast period.

Generally, there are several disadvantages which are applicable to all types of models. In the first place, land use models often oversimplify the problem and solution. Akin to this is the fact that the symbolic language which computers use is limited. Another type of problem arises when one becomes too engrossed in the mathematical model and feels that it is actually the real world. When this happens the model loses its usefulness as a tool and its user loses sight of reality. [51] Also, present day models that are designed for use in prediction have not had sufficient time to test their results, even though some models were tested on past data and results compared to the present situation. The results of this type of procedure are usually accurate, but they should be because the models were designed using this data.

In order to more fully relate the limitations of models it is necessary to classify the various types of models and identify their individual limitations. Anthony Tomazinis states in Penn Jersey Paper # 8, "An Introduction to Mathematical Models", that models can be classified in three general types according to the nature of the resultant product. [52] These are deterministic, stochastic and optimal. Subsequently, each of the above can be divided into two kinds according to the method in which the model functions. Thus, for deterministic and stochastic, there are analytic and numerical models, and for optimal there are plain optimal and twin goal optimal models. A brief discussion of each follows.

Deterministic - Numerical Models

Models of this type express graphically instead of mathematically the relationship between variables. This is valuable when the behavior of variables is not well

known and can not be formulated. The Chicago Area Transportation Study used this type in defining the relationship between distance from the central business district and density of development. These models have by nature limited predictive ability, but are valuable in tracing historical data. The technical limitation lies in its inability to combine relationships involving more that two or three variables in a satisfactory manner.

Neither deterministic model can be used to describe the processes which shape the urban pattern. Their users can not be concerned with processes of change or the willful redesign of land use patterns, and they essentially assume development takes place outside human control.

Stochastic - Analytic Model

This type of model indicates both a non-linear relationship and a degree of probability of the occurrence of a certain event. The Chicago Area Transportation Study staff applied a form of this in determining trip distribution. Because of the probabilistic and statistical problems of this type of model, none have been used for land use projections. This holds true for stochastic numerical models also.

Plain Optimal Model

This type of model is a simple form of linear programming which requires its inputs to be linear in nature. No model of this type has been used in urban planning for several reasons; one being the inability of the social sciences to provide clear cut objective functions, input coefficients, and a list of the important variables and constraints needed.

Twin - Goal Optimal Model

This type of model is also part of the linear programming concept, but is more complex than the previous type. Penn-Jersey is pioneering the use of this type of model and it looks promising because of comprehensiveness of the concept. Where the previous type of model was concerned with only one process of achieving a result, this model type can maximize or minimize a function in response to a second consideration which could include an allocation of resources according to both the total output and a preference schedule according to the availability of resources in the area. However, the mathematical complexities and the newness of this concept are limiting factors. Also this "...linear programming approach is questionable as a simulating technique because of its property of maximizing or minimizing some aggregate function (such as total rent paying ability of all residential locators). Economic theory holds that each individual is trying to maximize his economic position so that a linear program can not be said to simulate locational behavior unless it can be shown that the sum of all actions to maximize individual economic position is synonymous with maximization of the aggregate economic position. Such a relationship does not seem to be readily demonstratable, either for residential or industrial locators. Land use models based on linear programs may also be questioned because of their reliance on economic motivations and their consequent exclusion of all input variables which can not meaningfully be translated into economic terms." 53

To summarize, many limitations have been expressed in this chapter. All of them have not dealt with models particularly, but with diverse areas of the social and physical sciences. However, the issues raised herein can neither be forgotten nor excluded from consideration when developing a model, as they are basic to determining possible future development patterns.

FOOTNOTES

42. Richard Weistmantal, "Dantes Inferno - The First Land Use Model," Journal of the American Institute of Planners, XXV(Nov. 1, 1959).

43. Guthiem, "Integration of Transportation and Land Use Planning Through Quantitative Models", Transportation Design Considerations (Woods Hole Conference: NAS - NRC, 1961).

44. Melvin M. Webber, "Transportation Planning Models", Traffic Quarterly, (July, 1961) pp. 373-389.

45. Weistmantel, loc. cit.

46. R. M. Zettel and R. R. Carll, Summary Review of Metropolitan Area Transportation Studies in the U.S. (University of California, 1962).

47. Frederick W. Memmott III, The Substitutability of Communications for Transportation, Technical Paper, Niagara Frontier Transportation Study, pp. 1-12.

48. Wingo, loc. cit.

49. Review of Existing Land Use Forecasting Techniques, loc. cit.

50. Zettel, loc. cit.

51. Bross, loc. cit.

52. Tomazinis, loc.cit., pp. 3-16.

53. Review of Existing Land Use Forecasting Techniques , loc. cit., p. 78.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

The development of land use models during the last decade has been viewed with both enthusiasm and skepticism by planners as well as members of other professions. As brought out in this thesis, there are justifications for these opposite views, depending on the manner of analysis. If one approaches present day models with the thought that more insight can be obtained on the sensitivity of urban areas to changes in policy and behavior and that a better overall understanding of urban development can be achieved, then there is a valid purpose to which existing models may be put. However, if one expects to successfully predict a future urban development pattern, then there is much room for skepticism. In either case the progress of this particular subject to date, and the great potential it has for the future should be considered.

The Chicago Area Transportation Study isolated various indices identifying land development. However, these indices were not the actual forces causing development patterns, but only the results of certain forces. More recent studies have tended to identify these forces or causal factors which have created certain development patterns. However, there are still vast areas of research needed to better substantiate present concepts and to provide more reliable data as inputs to models. Some of these research and data needs are: 1) Forthcoming policy decisions that are likely to affect the pattern of growth for the region and smaller areas need to be identified, as well as the nature and costs of various alternative policies, plans, and programs that are to be tested in the model; 2) Also needed is a better identification of factors expressing the interrelationships among the elements of the metropolis. Since each region has different climate, topography, resources, and historical period in which it was developed, it is necessary to evaluate each metropolis independently; 3) The effect of transportation on land development and land development on transportation has been researched a great deal, but the interrelationships are still not well known. 4) Consideration must be given to the respective needs and programs of the various industrial, commercial, and social organizations in the region since they constitute a major force in development; 5) The whole gamut of behavioral characteristics and their potential change is poorly defined and needs research; 6) Technological changes which may rapidly affect the economy or efficiency of transportation should be investigated; 7) Analysis of the political structure of regions is necessary to determine coordination and implementation possibilities.

In reviewing existing models, there are a number of concepts which should be included or at least considered, for use in all models. These include: 1) a modelwhich can be used to forecast changes rather than absolute values; 2) the use, whenever possible, of exogenously determined region-wide control totals; 3) a model which can deal with all variables simultaneously; 4) a model which contains as many behavioral relationships as may feasibly be utilized without an inordinate amount of mathematical complexity; 5) a model which is sensitive to accessibilities as measured by travel times and/or costs by all major modes; and 6) models should be flexible so that they can accomodate changes in information and technology. [54] To date no model has all the desired properties listed above, but perhaps as more experience is gained, a truly comprehensive model may be constructed.

To date, many models have been developed for use in transportation and land use planning. Most of these are quite diverse in their methodology and concepts, but they are all aimed at predicting some future state of land use development in the metropolitan area. This objective is very commendable, and if realized, could be most useful. But the big question which arises is whether or not this objective of predicting a future state of development can be achieved by using models, or any other means.

The validity of any type of model depends on its suitability for a particular purpose. If predicting the future state of a system is the purpose, then the behavior of that system must be fairly constant and well defined. A good example is the solar system whose future state can be described rather accurately because its behavior is not affected to any extent by outside forces, and is not likely to change on its own accord. The city and its functioning are not as stable as the solar system. Even if it were, it would be subject to changes of the type Forrester expresses:

> "If a model could predict specific events far enough ahead to allow action to be taken as a result of the prediction, there may be sufficient time intervening for random events to alter the predicted values.
>
> If random disturbances do not exist, if the model is sufficiently near to perfect, and if the momentum of the system is not strong enough to inhibit action in anticipation of the predicted events, then the action taken is itself highly likely to affect the predicted outcome. The prediction procedure would then need to be a system decision function incorporated so that the model recognized the effect of the prediction on other decisions." 55

Since the city is not stable, but subject to many changes, it can be concluded that a final predicted state of development is not possible. However, this does not rule out the use of models in urban planning. It merely suggests that the basic purpose or objective of models be changed to that of predicting the behavior of the city as a system. In other words, models should be developed with the express purpose of enhancing the understanding of the forces and their results which ultimately shape the urban environment.

A model which could achieve the above purposes would indeed be complex, but cities themselves are no less complex.

The major difficulty of models today is that they do not, and perhaps can not include adequate descriptions of the changing metropolis. For the most part, planners abstract a few variables and constants, and formulate a model. A major breakthrough is needed in this field so that more complexity, and therefore better results can be obtained. As a proposal in this direction, it is conceivable that the city could be described in terms of a dynamic open system with many subsystems interacting to bring about the urban development. It is important to realize that one can talk about the behavior of systems as well as the behavior of individuals. Therefore, "behavior models" could be the basis for more complex and complete models. It is not the intent here to present a lengthy dissertation of systems, but in order to give a little insight on the topic a brief explanation of the city as a dynamic open system is presented in the following paragraph.

Within open systems, change takes place according to the unfolding of developmental potentials which are actually in the system at its inception. The inputs which give rise to this change tend to be of a developmental, non-recurring type, and as they continue to invade the system, the total system continues to change, the result being a sequence of systems which build upon and take from its predecessor. As this process takes place, changes of varying kinds and degrees of magnitude are continually occuring so that there is never a particular, uniquely identifiable system. The system can never be made to stand still, but can only be represented as such in abstraction for analytical purposes. [56]

The developmental potential mentioned above could be any given piece of land in a city. Presumably it has a potential for use according to the state of the city system at any one time, and it will obviously have a different potential resulting from changes caused by inputs into the system. As long as the city remains an open system, then model makers are going to have to view the city as an evolving continuous process. The best tool for this seems to be a systems approach where, hopefully, the city system could be broken down into several subsystems and their actions and interactions within and upon the total complex could be identified.

If one could design a systems model which simulated the urban process it would necessarily involve the interactions between many subsystems in the community. Some of these would be the household subsystem, developer subsystem, builder subsystem, bank subsystem, real estate subsystem, local government subsystem, transportation subsystem, and others. In order to relate all of these a common denominator must be found. Gifford suggests that "These elements are related by rules which have evolved for their interaction and coordination towards a maximization of individual profit and the general welfare. And, in general, these elements and rules may be conceived as having their basis in the optimization of the survival of the individual personal systems of the inhabitants of the city, as this is accomplished through a combination of individual and socially organized actions." 57

Whether the common denominator which Gifford suggests is the most valid is not the question here. The manner in which the subsystems are specifically related will depend on results of much research. It does seem, however, that the description of these systems will be based on their behavior under varying circumstances, and under each of these circumstances decisions will need to be made by representatives of each subsystem. Since decisions are usually based on previous decisions or their results, it would seem that the sequence of decisions by subsystems would be of primary importance. Therefore, a "sequential decision model of the city system" is suggested as a means of understanding the city, and as a result, provides a better basis for planning.

FOOTNOTES

54. Review of Existing Land Use Forecasting Techniques, loc. cit., p. 128.

55. Forrester, loc. cit., p. 128.

56. John V. Gifford, The Nature of the City as a System, A paper presented before the Bay Area Systems Group of the Society for General Systems Research, San Francisco, 1961, p. 7.

57. Ibid., p. 9.

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