zumindest gleichwertig die ungestörte Information der Planer durch die Leute gegenüber

(29) Sherry R. Arnstein beschreibt in einem Aufsatz "The Ladder of Citizen Participation" eindrücklich das weite Kampffeld von Partizipationsvorstößen und Gegenmaßnahmen. Sie stellt eine Stufenleiter zur Beurteilung von Bürger-Partizipation auf: 1. Manipulation, 2. Therapie (beide Nichtpartizipation), 3. Information, 4. Konsultation, 5. Besänftigung (Stufen der Schein-Zugeständnisse), 6. Partnerschaft, 7. Delegierte Entscheidungsgewalt, 8. Bürgerkontrolle (Stufen der Bürgerkontrolle)

(30) etwa W. Hartenstein und K. Liepelt, Man auf der Straße, Frankfurt 1963

(31) Alan A. Altschuler, Transit Subsidies: By Whom, for Whom? in: AIP Journal, Nr. 2, March 1969

(32) Heide Berndt, Das Gesellschaftsbild bei Stadtplanern, Frankfurt 1965, Stuttgart 1968

(33) siehe dazu L. Burckhardt, Artikulation heißt Partizipation, in: Stadtbauwelt 23, September 1969, Berlin; und zusammen mit W. Förderer, Bauen ein Prozeß, Teufen 1968

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Die beiden folgenden Beiträge sind zwei Kapitel eines Werkes, das 1970 unter dem Titel "Urban Analysis" erscheinen soll. Wir danken Professor M. Kilbridge für die Genehmigung zum Vorabdruck.

Wir drucken die beiden Artikel ab, da aus ihnen die Praxis der gegenwärtigen Stadt- und Regionalplanung in den USA ohne viel Interpretation ablesbar ist: In erster Linie die (wertfreie) Theoriebildung mit Hilfe von Modellen derjenigen Entwicklung, die dem Zeitpunkt der Modellbildung unmittelbar vorangeht, in zweiter Linie die Entscheidungshilfe für die politischen Instanzen, und zwar durch die Möglichkeit, Alternativen anhand der Modelle durchrechnen zu können.

Vgl. dazu den Beitrag von C. Alexander im letzten Heft, in dem aus einer Unzufriedenheit mit dieser Praxis ein anderer Ansatz vorgeschlagen wird, sowie die Kritik dieses Beitrages am Schluß des vorliegenden Heftes; und den Beitrag von K. Pfromm im vorliegenden Heft, in dem nach einer kritischen Analyse der neueren Stadtplanungspraxis über die Advozierende Planung berichtet wird, die in den USA als mögliche Gegenpraxis verstanden wird.

Maurice Kilbridge, Robert O'Block, Paul Teplitz

THE ROLE OF MODELS IN URBAN PLANNING

INTRODUCTION

Planning, in its broadest sense, is ordering the relationships of means to ends. To plan for our cities in this sense we would first establish goals, then select from among alternative policies and programs those means considered most likely to achieve them. Once ordered in time and space, such means would constitute a plan. The role of theory in this process is essential: It explains the causal relationships of means and goals, thus providing the rationale for selection among alternatives.

This is obviously not the world of urban planning as we know it today: a world in which the means available frequently determine the goals chosen, in which grand decisions can rarely be taken, in which we must play guessing games on the consequences of policies and programs for lack of explanatory theory, and in which little plans grope incrementally toward elusive goals. Perhaps in a free and pluralistic society urban planning can never be otherwise; but unless we take improvement as our premise and search for order and understanding, we will never know.

Theory is the key to the search for order, for without it we cannot predict the consequences of alternative means and so are unable to systematically influence trends of growth and change. Current theory explains only a small fraction of urban phenomena; if the meaning of urban planning is to be fulfilled, more and better theory must be generated.

Our working definition of the term model is somewhat narrow: a set of symbolic representations of relationships. In this instance, of course, we will be referring to abstracting urban phenomena to symbolic form and relating these in a structural and mathematically operational way (1).

This paper argues that analytic methods, and particularly symbolic models, can assist greatly in the development of theory. We believe that this is the major role of urban models today. We suggest that their secondary role is to help policy makers sharpen their judgment through more explicit statement of the assumptions and consequences of alternative means, thereby limiting subjectivity in selection from among alternative policies and programs.

We describe the relationship of models to theory in some detail and show how symbolism can serve to develop and purify theory. We also discuss powers and limitations of analytic techniques in urban planning. Later we will explain the development and use of urban models, emphasizing the value of the process rather than the value of the product. Finally, we will venture into the prospects for urban models and offer some suggestions.

THEORY, MODELS AND URBAN PLANNING

One measure of the development of a field of knowledge is the extent of its structured theoretical base which, we shall argue, is partially equivalent to saying the extent to which it employs abstract models for analysis and prediction. These abstract models need not be fully mathematical in form: they may, for example, be block diagrams or such representations as the psychological concepts of id, ego and superego. Although the language of symbolism is not rich enough to allow translation of all propositions into precise notation, it is usually sufficiently subtle and varied to express the important elements of reality when these elements are precisely and logically formulated. A theory which cannot be abstracted to symbolic representation is more likely suffering from imprecision than from the inadequacy of symbolism.

Theory and Symbolism

There are four substantial advantages to symbolic representation of a theory; the summation of these advantages generally outweigh disadvantages associated with oversimplification or distortion of reality:

1. Conceptual clarity - conversion of a theory to a model, or a set of symbolic representations, forces precise definition, clearly delineated elements and explicit statements about the nature of its relationships. Ambiguities of words and vaguely specified relationships cannot be tolerated in a model formulation.
2. Improved comparability with known theories - viewed abstractly, theories of quite different phenomena sometimes can be seen to be structurally equivalent. This similarity of form may identify the model as one of a class of models for which theoretical enrichment and solution methods already exist. This advantage is

illustrated in the use of "gravity" (2) models for urban planning: by reference to Newtonian physics, urban gravity models have been developed to an extent not likely without the existence of this structural equivalence.

3. Simplified deduction - a model facilitates deductive reasoning and so points to implications previously not suspected. Consequences of the propositions and assumptions of the underlying theory can be formally and rigorously traced.

4. Empirical framework - formulation of a theory in symbolic terms establishes a framework for empirical investigation, the results of which can be structured for meaningful statistical analysis. The model establishes data categories and suggests verification tests. This framework for inquiry allows comparison of the results from logical argument and empirical analysis. A professional field develops its theoretical base through just such interplay of deduction and induction, which can be considerably enhanced by the use of models.

Our goal is to formulate models which are subtle and rich enough to adequately reflect reality, yet not so complex as to defy manipulation. Practical problems which arise at this stage are admittedly difficult, but most turn out to be of a computational nature and so eventually solvable.

Many complex urban situations, however, are not tractable by ordinary analytic techniques: the mathematics may become too difficult or the exact nature of the functional relationships may not be fully understood. These difficulties can be circumvented by using computer simulation which can handle problems beyond the effective grasp of mathematical analysis and which has considerable tolerance for unverified assumptions and unexplained relationships. Models too complex even for simulation can be broken into submodels and solved sequentially. Models that overrun the capacity of the largest computers can be handled by interrupted simulation, in which the model user stops the computer at decision or judgment points, chooses from among alternative courses and sets the computer on that course (3). Imperfect models containing relationships not sufficiently understood for reduction to mathematical form can be similarly handled.

Models and Theory Development

Models are more than simply the end products of theorizing. The relation of theory to model during the process of discovery is extremely subtle and involves constant alternation between inductive and deductive reasoning. The process is a varied as snowflakes, but the following will serve to illustrate its complex nature.

Random observations of a class of events give rise to suspicion of a pattern of regularity which, stated as a crude generalization, becomes a working hypothesis. This hypothesis is used to formulate classes of relevant data necessary for its testing and data are gathered systematically and analyzed with reference to the hypothesis. The hypothesis is found to be partially wrong - as are most hypotheses - so it is changed and extended to fit the data. The new hypothesis, which we may now call a theory, is converted to a model; its clarity is improved in the process. In this form it is seen to be similar to an established class of models about which considerable theory already exists. By analogy with that theory, the theory under development is broadened. The new model is now ready for test as a prediction tool.

To test the predictive powers of the model, its parameters are fitted using historical data; the model is then "solved" with current data to "predict" the present. This process of retrospective prediction by manipulating parameters continues until the model can accurately predict the present. At this point the model represents a current theory and is ready for use in prospective prediction: it must now be tested over time and under varying conditions. The theory cannot be "proved" but only supported or strengthened by empirical evidence; its generality can be denied by a single contrary example.

The theory can now be stated once more in plain language. Its justification, its model, and the account of its development, when they appear in print, almost always sound very different from the actual development process. More than one write-up leaves the erroneous impression that the theory sprang full-blown from the analyst's brow, and that the model is but a symbolic recapitulation.

We stated earlier that one measure of the development of a field of knowledge was the extent of its structured theoretical base. We promised to argue that this is partially equivalent to saying the extent to which it employs abstract models for analysis and prediction. We have now shown the relationship of modeling to the development of theory; we have not yet, however, explained the qualification implied in the phrase, " partially equivalent".

The qualification stems from the concept of structure, for a structured theoretical base requires more than just the use of models in theory development: it also requires the accumulation of many theories - narrow and broad, special and general, ranging over the science, overlapping, contributing and conflicting - until enough has accumulated for articulation into a structured base. Clearly, the structuring process can be greatly facilitated if the component theories are expressed in symbolic form. The field of urban planning is only now beginning to develop theory; it will be many years before it possesses a structured theoretical base comparable to that of, for instance, economics.

Simulation

Unlike the laboratory scientist, the urban planner can seldom manipulate the objects of his study to find their best arrangement or to discover their natural properties or laws. The scales of cost and time are usually too large to allow for experimentation with the physical elements of planning, and controlled experimentation with the social elements is rarely a possibility.

By building a simulation model (4) to represent urban functions, the planner can create an artifical environment for experimentation. He can then test his hypothesis and translate his results into statements about the urban environment. Just as this process of simulation can serve as a laboratory for the development of theory, so it can be used to test the consequences of alternative public policies and programs.

The power of simulation rests in its ability to accept weak and inelegant theory, a class into which most urban theory currently falls. Descriptive statements which can be reduced to the logic of a computer program can constitute the model; precise equations are not necessary.

We can identify four distinct stages of abstraction in the development of a simulation model. Each stage moves one step further from the real world, thus introducing the possibility of interpretive and judgmental error. Simulation model building starts with the real world situation, and proceeds through identification of an area of analysis and establishment of model criteria to specification of the outputs required for model corroboration and decision-making.

The first abstraction is from reality to a general theory of how the world operates. This is the kind of intuitional knowledge urban planners have developed about the economic, physical and social relationships of cities. It tends to be vague, qualitative, comprehensive and full of uncertainties; yet it is usually all we have to start with. This is too "soft" even for a simulation, so a second level of abstraction - which we shall call "manageable" theory - must be made. Our very general theory of the real world is narrowed in scope, the least certain elements are dropped, irrationality is set aside, only relationships which demonstrate logical connections are retained, and the quantitative is preferred to the qualitative. This manageable theory is the foundation of the model, but is not the model itself. As an example, if we choose to study the movement of people around an urban center, general mobility could be narrowed to include only work trip patterns, excluding the less certain shopping and social mobility patterns.

The third level of abstraction is the model itself - an explicit statement of all relationships in an internally logical framework. Those aspects that are too complex, defy measurement or relate in an unknown fashion are quite simply dropped. In the example above, for instance, a single gravity equation might be used to describe work trip patterns.

Converting this model to an appropriate language and form for the computing machinery available is the fourth abstraction from reality. Further exclusion and simplification may be required for practical programming; computing machinery often imposes computational constraints - continuous functions may have to be treated as discrete, data rounded off to satisfy storage limitations, and so forth.

After all this abstraction, one may well ask, "What does the computer output mean in terms of the real world? How valid is its forecast?" And since a simulation model is established as an experimental laboratory, "How much faith can I put in the experiments?" In reply we can say that the urban model must:
- be internally consistent
- contain no logical errors
- produce reasonably accurate forecasts.

Beyond this, one can check the soundness of the reasoning on which the computer program is based by going through the four stages of abstraction in reverse order. The simulation program is compared successively with each of the lower levels of abstraction in order to identify and explain differences.

A final test of the model and its computer program can be carried out by inserting artificial data and checking that the pattern of output is consistent with the model's theory.

Models for Urban Planning

The use of such analytic techniques for urban planning is not without challenge. Four arguments are put forth:

- urban phenomena are too complex and disorderly for reduction to systematic models
- the indeterminacy of human behavior makes social prediction impossible
- the nature of technological change is unpredictable although the fact of such innovation is certain.
- the rate of social and economic change is accelerating particularly in highly developed countries

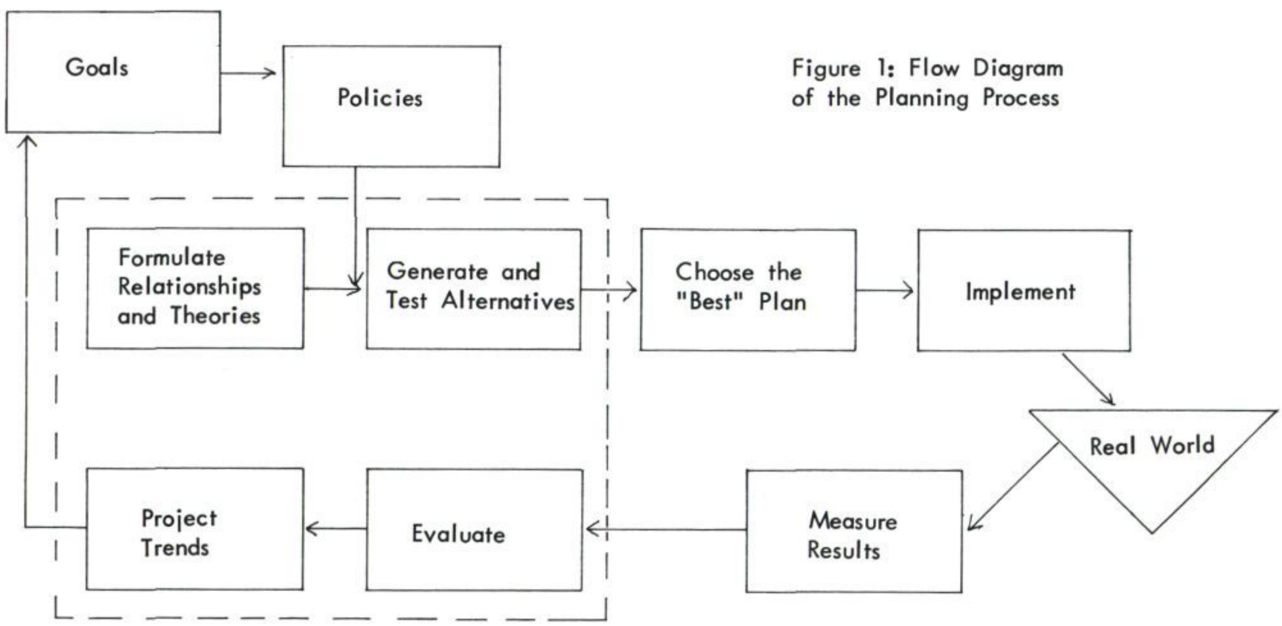

Figure 1: Flow Diagram of the Planning Process

Recognizing the merit of these arguments, we emphasize again our contention that the process of modelling, not the model itself, is often the most valuable aspect of this effort. - The planner who is involved in the development of a model can gain new insight into urban phenomena and relationships. The above arguments present issues to be studied, problems to be met and attacked, not excuses for chaos.

This is not to argue that planners should try to model the world. The appropriate role of models in urban planning today is admittedly limited and qualified.

But that role is important:
- to assist in the development of theory
- to provide a laboratory for testing policies and programs
- to emphasize evaluation of short-term relationships
- to provide predictions and projections

Figure 1 is a general schematic representation of the urban planning process. We believe that the greatest potential for models and modeling today lies in the area of theory development and project evaluation, represented by that part of the diagram within the dotted box.

DEVELOPMENT AND USE OF URBAN MODELS

While much can be learned from observing a finished model, or by scanning a computer printout of its application, *more can be learned from the discipline of being* required to state assumptions and theories explicitly, and by the opportunity to test one's ideas of urban relationships while groping for the model's parameters and form. The recurring theme of this section will be the value of the modeling process; we will carry it through our discussion of model development, validation, and appraisal, and use it as the essential principle in our argument for the involvement of certain people in the effort.

Model Development

In an earlier paper (5) we described the four elements central to the development of a model:
- model subject - what is the model about?
- model function - what is the model to do?
- model theory - on what theory is the model based?
- model method - how does the model use its theory?

Defining these elements in response to the above questions is the first step of a modeling effort.

Roughly speaking, the subject of the model is that entity or activity which is projected, allocated, or manipulated by the model. There are four essential classes of subject matter in current urban models: land use (6), transportation (7), population (8) and economic activity (9). The function of an urban planning model is usually to project or allocate the subject, or to derive new subjects from it; most models perform two or more functions in varying combinations. The theory underlying the model is that set of relationships - stated or implied - assumed to prevail between the model subject and the larger environment. Distinguished on this basis, models generally can be sorted into two classes: micro-analytic behavior or "choice" models, and macro-analytic growth-forces or "index" models. The operational method of the model is the mathematical or symbolic form used to carry out the projection, allocation, or derivation.

To these thought, and without repeating the content of the earlier paper, we would add some general observations on the availability of data and on the number of factors or variables included in the model. Clearly, the purpose for which the model is being developed is basic to decisions about data and factors included. If the model is to be a generalized or research effort designed for the examination of relationships between urban phenomena, or to state a general theory in symbolic and manipulative form, its essential purpose is to increase knowledge and insight about the processes studied. For such models hypothetical or generalized data can be used, and the number of factors or variables can be limited by assumptions. On the other hand, if the model is to be applied in an ongoing planning effort, accuracy in depicting the real world is desirable. A specific set of data generally must be used, and simplifying assumptions cannot be easily made.

Although an applied or practical model is usually developed for a particular city and used only in its planning activities, the time has probably come when we should try to generalize these models by extending them to other cities. If these models do not seem to "fit" when tested in other, similar cities, their validity - even for the city for which they were built - may be challenged. It would seem that data from one city should apply to other cities, at least within certain class categories. For instance, differences in natural setting such as topology, climate, spatial distribution, and so forth, should not affect functional data. Moreover, we should be able to rely on the stability of large numbers: the social and economic behavior of large groups are relatively invariant and predictable. (This is fortunate indeed, since the physical construction that planners undertake based on this behavior is quite durable.)

In the development of applied models the data available frequently determines the nature of the model and this is sometimes detrimental to the effort. In a practical situation, with time and money constraints, most analysts begin by surveying the available data. They then attempt to shape the model to make the best use of these data and avoid as much as possible the expense of gathering new data. This approach can severely restrict the choice of theory and method employed in the model. For example, if a model depicting market behavior were planned and a look at the data showed that information about market suppliers would have to be specially gathered, the analyst might well reconsider his approach and select a gravity model instead. This is understandable; little is to be *gained by developing a model meant for practical application*, for which there is no data.

The level of aggregation of the subject matter also will depend to some extent on the availability of data. If the necessary data are available on municipal divisions only, the analyst is well advised to structure the model on this basis and not on census tracts - unless, of course, he is prepared to generate his own census tract data.

The seriality of data may also determine the form of model used for if the analyst can obtain data for only one point in time - and few areas have data for more than two or three points - he may be forced to develop an equilibrium model rather than a time-series or growth-forces model.

Model developers who gather their own data encounter the fearful problem of lack of comparability over time and from place to place. Housing assessments, for instance, vary with time and among municipalities; zoning and housing-condition standards differ widely from one community to the next; the list could fill this page.

The analyst must usually yield to practical constraints when deciding on the number of factors or variables to be included in an applied model. Computer running time and storage requirements often increase quadratically or exponentially with an increase in variables, while the model's predictive capability does not grow proportionately. The analyst must decide whether a simple model explaining most of the variance, say 50 to 70 %, is preferable to a more complex model explaining, say 90 %, of the variance.

Each variable added to the model must count; and while each brings further information and precision to the model, some bring more than others. There are statistical procedures available to the analyst, such as factor analysis and discriminant analysis, to help select from among many variables those with the highest information content.

Model Validity

There is no such thing as a perfectly valid model in the sense that it is a perfect representation of the real world. As an abstraction from reality it leaves part of reality behind. This is, of course, both its power and its weakness. The power lies in clarity of essentials and the manipulative nature of symbols; the weakness lies in some necessary degree of invalidity. One of the critical task of the analyst is to understand, minimize, and control the degree of invalidity of the model.

Most models contain parameters in the form of coefficient or exponents that cannot be determined by statistical tests or from past experience, but must be established by a form of trial and error. Examples in urban situations would be the rate at which new households are formed, or the rate at which a certain class of household will move to new locations. The fitting of parameters is done by running the model repeatedly with various assumed values of the parameters until the resulting output of the model agrees with actual experience.

This process, called calibration, can rarely be done well enough the parameters frequently interact in unknown ways, and it is difficult to isolate the effects. In most applied models there are too many parameters to adjust them one at a time while holding all others constant. Among other limitations computation costs would be prohibitive. So to the extent that there is residual failure of fit from inaccurate parameters the model does not reflect the real world and is to that extent invalid.

During the process of developing any applied model, simplifying assumptions are made to make it possible to bring the real world into abstraction in a manageable form. It is essential that these assumptions be made explicit and tested with reference to the model when it is finished. Simplifying assumptions, once made, must not be set aside or forgotten; the significance of each assumption must be tested against the completed model. This is an essential validation procedure, called sensitivity testing. Alternative assumptions are tried in the model to see how each affects the approximation to reality in the model's output.

Any appraisal of model validity must take into account sources of error in the data itself. A study undertaken by the U.S. Department of Commerce (10) to assess the statistical validity of the 1960 Census of Housing revealed that many statistics were both unreliable and inaccurate. They estimated that if another group of enumerators had been sent back to rate the housing units, only about one-third of the units would have been rated the same by both groups of enumerators. Some categories of housing conditions were underestimated by at least one-third. The study recommended that statistics should: represent the real rather than the apparent state of affairs; reflect real trends; be built up from disaggregate data; and be geographically comparable.

One further consideration in the validation of urban planning models is the selection of appropriate validation tests. The results of standard statistical tests can be misleading if the peculiar purposes and design of the model are not fully appreciated. Consider, for instance, an attempt to determine the predictive accuracy of an urban model by the least squares method. It is inappropriate to use this method in a point-by-point test comparison of a model's prediction with observed location patterns. The test generates the coefficient of determination, R^2, a measure of the number of areas in which actual and predicted locations agree. But it does not consider patterns of growth or change, and the model's ability to predict patterns may be more important than its ability to predict absolute magnitudes. Such a test could give a very low validity measure to a model which predicted location patterns perfectly, but happened to shift all location areas slightly in one direction. Unless the predictions were actually plotted on a map, the analyst would not recognize the real validity of the model.

Involvement

Involvement of the right people during the design and construction of an applied urban model can determine ultimate success or failure of the project. Expert assistance is almost always required since few urban planning departments can provide the variety of specialized skills needed for a modelling effort. However, modelling is not the kind of effort that can be delegated or done at arm's length resulting only in a summary report to the sponsor. It is a process involving repeated decistion, tests, reviews of test results, evaluation, and new decisions. Throughout this process many people - the right people - should be fully involved. To be fully involved means to follow the development of the model, to understand in a general way its assumptions and the theories on which it is based, to compare these against one's own experience and intuition. Full and ideal involvement is that of the analysts themselves. For others, involvement implies a continuing working relationship, in varying degrees, with the modelling effort.

Who are the "right people"? Those directly responsible for the planning efforts in which the model will be used - the professionals of the planning department, certain policy makers, elected and appointed public officials, the managers of some municipal departments. These people must understand the general theory of the model if their decisions are to be aided by it.

To the extent that models provide an indication of patterns of growth, or patterns of response to public actions, public officials should be involved in their development. It is unrealistic to expect public officials to devote as much time to understanding the model as the professional planners. But they certainly can be introduced to its assumptions, theories, and limitations and the uses to which it can be put.

TECHNIQUE: SOME SUGGESTIONS

Models of Systems and Subsystems

As a practical matter in the development of applied urban models it is generally wise to start with independent submodels for the smallest functional units and later to combine these into larger models. The development of submodels allows a division of labor among specialists in various aspects of urban growth and change. For instance, one group can work on a traffic submodel while another group attacks an employment or housing submodel. Independently constructed submodels must be designed and built with great care so that ultimately they will be comparable and additive. The variables that connect the submodels merit special attention. Those that do not fit directly into any submodel are sometimes in danger of slipping through the cracks, never to be seen again.

An inherent problem in the development of submodels is the maintenance of comparable quality across the submodels. Some subjects - traffic analysis, for example - are more analytically advanced than others. Efforts have to be allocated among the tasks so as to bring the greatest incremental gain to the total model.

The concept of marginal analysis can provide a way of considering systematically the costs and contributions of submodels. As far as possible, relative accuracy of the submodels should reflect their relative importance to the predictive process of the full model.

An important consideration, of course, is the selection of subsystems sufficiently critical to warrant development of a submodel. Most of the remarks we have made about selection of factors and variables for inclusion in the model apply here as well.

We should note that the decision is frequently made to include more variables for analytic purposes than will be necessary for prediction. Quite simply, it is easier and better to delete variables than to add them at some later date. Some may not be projectable, but still can be useful for analysis.

Extending the Use of Urban Models

It is somewhat premature to speculate on the extension of urban models to new applications when the areas to which they have been applied thus far - land use, transportation, population, economic activity - have been scarcely influenced by the process. These are still the prime areas for applied urban models, and it is hoped that the second generation of models, now being developed, will be more useful than were their predecessors.

Nevertheless, speculation on possible new areas of application brings to mind planning for recreational facilities (11). Different people have different needs, but we do not yet have a systematic way of analyzing or comparing them. Another application would be planning for the location of schools, particularly high schools or community colleges. The placement of such facilities is governed by multiple objectives, including accessibility, area development plans, and contribution to racial integration. Rational evaluation of objectives such as these could be facilitated by application of planning models.

Similarly, planning for the location of other city functions such as hospitals, parking facilities, airports, water and sewage treatment plants, and so forth, could well profit from the use of a model. Further applications might be possible in air and water pollution control programs, and in the development of urban indicators which could tell, on a continuing basis, what critical changes were taking place in various zones or neighborhoods of a city.

Another potential use of models is for the evaluation of other models. Computer simulation, while certainly far less costly than real-world experimentation, is nevertheless expensive. Complex and comprehensive models contain far too many variable and parameters to permit test of all reasonable combinations. One solution to this dilemma is to run a model for a few key input combinations, and use a second model to interpolate between those key points; that is, to study the difference between established objective and forecast. The latter model would contain only those variables vital to the test area.

Some new modeling techniques are yet to be applied to urban models. For instance, Bayesian decision theory can be used for sequential planning decisions made under uncertainty and with limited information. A planner can assess a *prior* probability distribution of events, and use such a model to choose from among alternatives. After implementation of the plan or project, new data are gathered from which a *posterior* distribution of events is developed. This updated distribution gives the planner an indication of how accurate his original estimates were and form the basis for the second round of decisions. As this cycle is repeated, the probability distribution should approach the actual distribution of events. The planner's ability at prediction improves correspondingly.

This approach could be quite valuable in a planning situation involving a housing project, where the reaction of the residents is not known. A planner would make initial estimates of the location, design and size which will be acceptable to the public. With these assessments he decides whether or not to initiate action, make efforts to acquire land and so forth. As the public is heard from, their reactions serve to modify the original assessments if necessary. The Bayesian approach, as illustrated here, presents a formal method for accumulation of knowledge and experience. Actual experience can be compared with predicted experience and the deviation used to determine subsequent action.

Future models must pay closer attention to the dynamics of response to public programs, and to the intricate interconnection between segments of our society. Even now, highway planners are becoming interested in short-term, transient effects of new roads, as well as long-termin impact. Similarly, most of the recent air and water pollution programs have concerned themselves with the timing and phasing of action.

A current research project (12) is attempting the development of mathematical models to describe the macroeconomic growth and decay of cities. The city is viewed as a dynamic process susceptible to analysis by the classical solution methods for differential equations. A set of econometrically derived equations, whose parameters are fitted by statistical measurements, will be developed to describe the manner in which cities change over time. Since the fundamental concern is effective public policy, the project will emphasize analysis of those parameters which can be linked to available policy options.

The concepts of systems theory have crept into our everyday thinking. Planners, and indeed the general public, no longer view slums simply as areas with dirty run-down buildings, but recognize them as complex interrelated systems of people, schools, housing, business and government, all with critical problems. To cope with this kind of system urban models undoubtedly will draw more upon the notion of feedback control theory, recognizing situations of positive feedback (vicious cycles) as well as negative-feedback (stabilizing influences). Already several projects are underway to build urban models more cognizant of the dynamic interactions between urban systems.

In the next decade, the field of urban planning must assume the staggering simultaneous burden of developing its theoretical base while providing leadership and guidance as if that base were already full grown. We believe that analytic methods, and especially symbolic models, will prove invaluable both in the development of the theory on which increasingly effective action can be based, and as an aid to the decision-making which must proceed concurrently if our cities are to flourish.

(1) The Annotated Bibliography following this paper presents descriptions of the major urban models developed to date
(2) Items 2, 7, 12, 15, 16 und 21 of the Annotated Bibliography give reference to several types of gravity models
(3) Items 9, 16 and 20 of the Annotated Bibliography refer to models employing this technique
(4) The most comprehensive simulation models developed for urban planning are referred to in items 9, 10, 13, 19 and 21 of the Annotated Bibliography
(5) M. Kilbridge, R. O'Block, P. Teplitz, "A Conceptual Framework for Urban Planning Models", Management Science (Application Series), February 1969
(6) See models referenced as items 3, 6, 7, 9, 10, 13, 14, 15, 20 and 21 in the Annotated Bibliography
(7) See models referenced as items 2 and 3 in the Annotated Bibliography
(8) See models referenced as items 1, 3, 8, 9 and 17 in the Annotated Bibliography
(9) See models referenced as items 1, 3, 8, 9, 12, 16 and 17 in the Annotated Bibliography
(10) U.S. Bureau of Census. Measuring the Quality of Housing: An Appraisal of Census Statistics and Methods. Working Paper 25, 1967
(11) See e.g., Jack B. Ellis, Herman E. Koenig, & David N. Milstein, Physical Systems Analysis of Socio-Economic Situations, Michigan State University, October 1964
(12) By Professor Jay Forrester of the Sloan School of Management of the Massachusetts Institute of Technology

ANNOTATED BIBLIOGRAPHY OF URBAN MODELS

1. Berman, Barbara R., Chinitz, Benjamin, and Hoover, Edgar M., Projection of a Metropolis, Cambridge, Harvard University Press, 1960

New York City
Input-output used to forecast for 1965, 1975, 1985 employment, output, and value added by 43 industry classes. Demographic, employment and population forecast made sequentially. Inputs, coefficients, functional relations, industry classifications and output tables presented. 22 counties in New York Metropolitan Region.

2. Bevis, Howard W., "A Model for Predicting Urban Travel Patterns", Journal of the American Institute of Planners, Volume XXV, Number 2 (May 1959), pp. 87-89

Gravity model and linear programming used experimentally to predict residential and nonresidential traffic volumes. "Travel functions" minimized subject to trips generated (using gravity concept) which must equal interchange volumes, which must be greater than or equal to zero. More powerful than simple gravity model trip projections.

3. Brand, Daniel, Barber, Brian, and Jacobs, Michael, "A Systematic technique for Relating Transportation Improvements and Urban Development Patterns", 46th Annual Meeting of Highway Research Board, January 1967

Empiric Land Use Model
Simultaneous equations (derived using regressing techniques) forecast activities (population and employment characteristics, number of automobiles and school enrollments) for 626 traffic zones in Eastern Massachusetts. Fifty variables, data required, and model sequence presented. Accessibility theory implied

4. Donnelly, Thomas G., Chapin, F. Stuart, Jr., and Weiss, Shirley F., A Probabilistic Model for Residential Growth, Chapel Hill, North Carolina, Institute for Research in Social Science, May 1964

This experimental model's regression equation determines land "attractiveness", which is used to assign new residential locations (using random numbers) to land. Simplifying assumptions, inputs, specifications, program components and test results presented.

5. Doxiadis, C.A., Emergence and Growth of an Urban Region, The Developing Urban Detroit Area, Vol. II: Future Alternatives, Detroit, Detroit Edison Company, 1967

Distributes population on the basis of accessibility to employment. Projects and allocates transportation needs on the basis of population distribution. Methods are regression equations and other analytic forms.

6. Graybeal, Ronald S., A Simulation Model of Residential Development, Berkeley, California, University of California, 1966

New residential land development formulated, employing user and space interaction, growth and response to policy (land use controls, transportation, etc.). Parameter definition, 18 equations, algorithm, calibration criteria (maximize fit), experimental tests, and land use described.

7. Hansen, Walter G., "How Accessibility Shapes Land Use", Journal of the American Institute of Planners, Volume XXV, Number 2 (May 1959), pp. 73-76

Hypothetical accessibility model distributes future residential development to metropolitan zones. Accessibility defined and discussed. Empirical testing. The equations, parameters, and an illustration are presented.

8. Hill, Donald M., "A Growth Allocation Model for the Boston Region", Journal of the American Institute of Planners, Volume XXXI, Number 2 (May 1965), pp. 111-120

Model forecasts population and employment using existing patterns of development, external forecasts, policy changes. 1950-1960 data used for parameter estimation using simultaneous regression techniques. 2300 square miles of Boston Metropolitan Area, 29 subregions. Calibration, validation and projected results included

9. Irwin, N.A., "Review of Existing Land-Use Forecasting Techniques", Highway Review Board Record, No. 88, pp. 187-189

Chicago Area Transportation Model
Judgment and mathematics employed to project population, manufacturing employment, and major land uses. Curve fitting, plotting, accounting-type processing and extrapolations simulate Chicago-1980. Accuracy, procedure, and assumptions discussed

10. Irwin, N.A., "Review of Existing Land-Use Forecasting Techniques", Highway Review Board Record, No. 88, pp. 184-187

Penn-Jersey Transportation Study
Linear programming used to simulate residential development by maximizing aggregate rent paying ability subject to constraints. Household aging, migration, income changes and transportation costs utilized. Disaggregation extensive, data collection intense. Other submodels proposed

11. Irwin, N.A., "Review of Existing Land-Use Forecasting Techniques", Highway Review Board Record, No. 88, pp. 194-199

RAND Model
Research technique to study transportation - land-use linkage Functional relationships, flow chart and derivation of parameters presented. Six month periods. No calibrations or testing to date. Other RAND work described; locational rent functions, J.F. Kain's papers.

12. Lakshmanan, T.R., and Hansen, Walter G., "A Retail Market Potential Model", Journal of the American Institute of Planners, Volume XXXI, Number 2 (May 1965), pp. 134-143

Retail trade centers in Baltimore area selected using gravity model concept of sales potential, size and number, purchasing power and proximity of residents. Data requirements, outputs, criteria for evaluation, and results discussed

13. Lamb, Donald D., Research of Existing Land Use Models, No. 1045 Pittsburgh, Southwestern Pennsylvania Regional Planning Commission, March 1967, pp. 42-46

Activities Allocation Model
Six submodels: residential locating, residential space consumption, manufacturing locating, nonmanufacturing locating, nonresidential space consumption and street area. Model uses 6 multiple regression equations to convert and allocate activities to 192 districts in greater Philadelphia. Fifty minutes of IBM 7094 time needed to simulate a five-year period.

14. Lamb, Donald D., Research of Existing Land Use Models, No. 1045 Pittsburgh, Southwestern Pennsylvania Regional Planning Commission, March 1967, pp. 50-54

Connecticut Land Use Model
Model allocates growth to 169 towns covering 5.000 square miles in Connecticut. Nine simultaneous equations describe shifts in employment and population. Ten-year projections made. Index of accessibility implicit. 1950 data base used

15. Lathrop, George T., and Hamburg, John R., "An Opportunity-Accessibility Model for Allocating Regional Growth", Journal of the American Institute of Planners, Volume XXXI, Number 2 (May 1965), pp. 95-103

This opportunity-accessibility model tests policy by manipulating holding capacity, access and density while allocating residents to 200 square mile Buffalo area. Theoretical and empirical shortcomings recognized, output given to traffic assignment model. Developed and tested by New York State Department of Public Works

16. Lowry, Ira S., A Model of Metropolis, RM-4035-RC, Santa Monica, California, The RAND Corporation, August 1964

"Instant metropolis" created using basic, retail and household sectors. Structural equations presented along with derivation, calibration, and testing of gravity principle allocation rule. Density constraints, iterative procedures, inputs, outputs for 420 square mile Pittsburgh area, and the author's appraisal included

17. Niedercorn, John H., An Econometric Model of Metropolitan Employment and Population Growth, RM-3758-RC, Santa Monica, California, The RAND Corporation, October 1963

Metropolitan employment (manufacturing, wholesaling, retailing, etc.) and population, forecast for ten-year periods. Three zones (SMSA, central city, metropolitan ring). Parameters estimated using cross-section data from 41 SMSA's. Several "partial" theories, inputs, assumptions, predictive power (coefficients of determination), and conclusions presented.

18. O'Block, Robert P., "An Economic Model for Low-Cost Housing Projects, Program and Policy Evaluation", Proceedings of Association for Computing Machinery Symposium on the Application of Computers for the Problems of Urban Society, New York City, October 1969

Land, construction and other cost estimates used to calculate project replacement cost, investor's equity, mortgage, debt service charges, operating expenses and minimum economic rent. Economic theory employed. Flow diagrams, case examples and the model's use for project, program and policy decisions presented. Programmed for time-sharing equipment

19. San Francisco Community Renewal Program. Model of San Francisco Housing Market, C-65400, Cambridge, Arthur D. Little, Inc., January 1966

    Model matches households and housing supply to simulate residential development. Markov aging model, location characteristics, neighborhood classification, "fracts", space pressures and housing types employed. 35.000 computer instructions, 15.000 data items, 2 1/2 hours IBM 7094 running time rquired. Will test policy when operable

20. Schlager, Kenneth J., "A Land Use Plan Design Model", Journal of the American Institute of Planners, Volume XXXI, Number 2 (May 1965), pp. 103-111

    Economic preference theory underlies a linear programming matrix minimizing aggregate investment costs subject to locators (residents, industries, etc.) demand requirements; 30 zones, 400 variables, 60 constraints, 20 minutes of IBM 7090 running time. Input requirements and the planners role in formulating, guiding and forecasting land development are discussed. Research model

21. Steger, Wilburg A., "The Pittsburgh Urban Renewal Simulation Model", Journal of the American Institute of Planners, Volume XXXI, Number 2 (May 1965), pp. 144-150

    Policy testing model developed and tested to project residential locations using job locations, commercial activity. Factor analysis used to derive multiple regression parameters. Input-output, linear programming submodels, 30 computer routines, 30 minutes running time. Articulates structure of simulation models, information requirements, data collection and management

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