SPECIAL REPORT 97

URBAN DEVELOPMENT MODELS

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SPECIAL REPORT 97

URBAN DEVELOPMENT MODELS

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PREFACE

This volume constitutes the record of a Conference on Urban Development Models held in June 1967 at Dartmouth College, Hanover, New Hampshire. The Conference was sponsored by the Bureau of Public Roads, the Department of Housing and Urban Development, and the Automotive Safety Foundation. The Conference was conducted by the Highway Research Board. Organization and direction of the Conference was the general responsibility of the Land Use Evaluation Committee of the Department of Urban Transportation Planning of the Highway Research Board, and the specific responsibility of an Advisory Committee consisting of Britton Harris, Chairman, Charles H. Graves, Walter G. Hansen, Joseph R. Stowers, and Lowdon Wingo, Jr., and *ex officio* members John Hamburg, Chairman of the Land Use Evaluation Committee and George C. Hemmens, Conference Secretary. James A. Scott of the Highway Research Board assisted as staff liaison.

With several exceptions the papers in this volume were originally prepared for and served as a basis for subsequent discussion at the Conference. The exceptions are the paper by Britton Harris summarizing the Conference, and the papers by John R. Hamburg, Roger L. Creighton and Robert S. Scott and David Boyce which were commissioned by the Conference Advisory Committee to complement Conference discussion and achieve comprehensive coverage of issues related to the development and use of models in urban planning.

The organization of this volume follows generally the organization of the Conference except that papers presented at sequential Conference sessions have been grouped under common themes to which they are addressed. Prepared discussions of these papers, where available, are presented with the papers. General, open discussion at the Conference has been summarized, where appropriate, under these general themes. One of the objectives of the Conference was to promote free discussion of issues raised in the presentations, and drawn from the agency and research experience of all participants. It has not been possible to reproduce all of that discussion in this report. The sense of the discussion has been excellently reported by Britton Harris in his paper. The summaries of the discussion presented in the report attempt to document the principal comments, concerns, agreements, and disagreements of the participants, and have been selected and condensed from the Conference transcript. The editor accepts responsibilities for any errors or misinterpretations which may have resulted, and begs the indulgence of the participants.

George C. Hemmens,
Editor

May 1968

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PART I

Introduction

CONFERENCE SUMMARY AND RECOMMENDATIONS

BRITTON HARRIS *

A major objective of the Conference on Urban Development Models was a state-of-the-art evaluation of land use modeling. The fundamental approach, however, was designed to be more than a didactic review of the past work; the aim was to discuss and open up new perspectives. This paper reviews the background of the Conference, summarizes the conclusions reached, and presents the Conference recommendations.

The Dartmouth Conference on Urban Development was held against a background of rapid but uncoordinated growth in the field of land use and urban development modeling. The expansion of "modeling" in the physical, social, and management sciences has had a long and respectable history, but its more recent explosion is largely a consequence of the advent of the computer. Transportation planning had employed an expanded battery of models which were largely developed in the decade 1945-55, before computers became available, and was consequently in the position to take major advantage of the computer facility, beginning in the middle of the last decade. Transportation-based modeling and planning were given a distinguished landmark appraisal in the publication of the May 1959 issue of the *Journal of the American Institute of Planners,* under the editorship of Alan M. Voorhees.

Land use planning models developed, first of all, as an adjunct of transportation planning. This position eventuated because metropolitan transportation studies had both need and resources for the preparation of land use models. At the same time, the land use planning profession was in general not well equipped by training and past practice to take full advantage of computers and of the methods of mathematical models.

With the growing complexity of urban problems and with stimulus coming from many different directions, land use modeling began to develop rapidly in the 1960's, but with a pattern of healthy diversity which reflected a diversity of sources of inspiration. Some of the progress and quality of this development was captured in a seminar at the University of Pennsylvania in October 1964, the proceedings of which were embodied in another special issue of the *Journal of the American Institute of Planners* in May 1965.

The Land Use Evaluation Committee judged that, by the middle of 1967, the time was ripe for another assessment of work in the field which could ren-

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der advice to Federal agencies and could stimulate the work of individuals and research groups throughout the country. With the agreement of the sponsoring agencies and the Highway Research Board, the Conference was planned and carried out.

BUILDING AND OPERATIONALIZING MODELS

As a part of the preparations for the Dartmouth Conference, the Land Use Evaluation Committee circulated two questionnaires to agencies and individual model-builders concerned with the questions to be discussed at the Conference. While these surveys were designed to have general coverage, the Committee undoubtedly missed a number of important efforts, and the unevenness of the responses may have limited somewhat the generality of the results.

The responses of agencies were somewhat more uniform than the responses of individuals, and have lent themselves to a more coherent summary and report. The excellent paper by George Hemmens which was circulated at the Conference and which is a part of this volume draws many interesting generalizations about agency operations and experiences.

In this introductory section, I will attempt a brief summary of some of the outstanding characteristics of individual modeling efforts.

As may have been suggested by my earlier remarks, the influence of transportation studies on model-building has persisted, at the least in providing an institutional setting for the activities of individuals. During the past five years, however, the growth of combined transportation and land use studies has rendered this distinction less clear-cut.

The notable exceptions to the transportation base for modeling efforts have been the Pittsburgh CRP Study conducted by the University of Pittsburgh and CONSAD Research Corporation, the San Francisco CRP conducted by Arthur D. Little, Inc., the ensemble of research activities at the University of North Carolina under the direction of F. Stuart Chapin, Jr., and Brian Berry's studies of retail trade. From a slightly different point of view, it also may be noted that the San Francisco study and most of the North Carolina studies are unique in that they do not make use of concepts of transportation cost, location, and accessibility.

More recent work under my direction at the University of Pennsylvania and other work in a number of scattered academic centers have dealt with these problems only partially under transportation study auspices. In general, I think it would be fair to say that, over the past five years, there has been some expansion in university based research in this field.

One of the outstanding features of the somewhat impressionistic descriptions which we have received of the process of model-building is a confirmation of Thomas A. Edison's dictum that "genius is two percent inspiration and ninety-eight percent perspiration." In one case, for example, it was reported that the conceptualization of a model took three days, and its implementation two years. The phenomenon of a flash of inspiration followed by considerable drudgery and hard work in making a model operational indeed seems to be the general case in many instances reported prior to the Conference. I will discuss some of the elements of the drudgery below.

We may point out, in contrast with this general type of experience, two other and quite different possible routes which have had an influence in particular cases or trends of model-building. The first of these is developing a larger picture through careful and successive empirical investigations, each of which builds to some extent on previous work. This historically in some ways describes the long-term development of transportation modeling, and in land use modeling is particularly applicable to the work of Chapin and his colleagues. The opposite approach is a deductive one requiring the careful construction of theory in advance of model-building. Contrary to some impressions, such theory construction generates its own types of perspiration, and is not altogether inspiration. In the transportation modeling field, the work of Morton Schneider perhaps best exemplifies the deductive approach, and a brilliant example of the extension of his ideas into land use modeling is provided by his paper in this volume. Similar examples connecting land use and transportation may be found in the work of Alonso, Wingo, and Stevens. It is quite likely that the flashes of inspiration which have been reported by a number of model-builders represent, at a particular point in time, the union of a combustible mixture of empirical and theoretical insights.

If we now turn to examine briefly the sources of ideas for model-building, we may note a strong but not exclusive emphasis on certain transportation concepts as applied to land use development. At the same time, we should note, I think, the fairly obvious but important fact that the basic ideas behind models each suggest some consistency and constancy in the behavior of people which underlie the regularity of metropolitan development. The most general basic idea to be found in models, not surprisingly, is some concept of the constancy of travel behavior. This idea underlies the Lowry model and the Lakshmanan-Hansen, Fidler, and Harris models of retail trade. In a few cases, ideas of constancy of demographic phenomena have been used as a basis for model construction. Another class of models, typified by the EMPIRIC model and certain migration models, assumes some form of constancy in shift behavior. Finally, a substantial class of models, mostly not yet operational, searches for a constancy in consumer preferences for housing and other sources of utility. Models of all these classes, with certain exceptions, make use of ideas of location and accessibility as they have been developed in transportation models.

Operationalizing Models

The ninety-eight percent of perspiration which intervenes between an inspiration for a model and making it operational contains a number of ingredients, one of the more important of which is the general problem of programming, computation, and computer facilities.

Nearly all of the models discussed and reported in our preliminary survey were geared for computer operation on machines of a variety of types and sizes. In general, there were two styles of computer programming—that done by the deviser of the model, and that done by independent programmers under his supervision. In perhaps somewhat more than a majority of the cases, the model designer himself undertook the programming, in some cases actually learning to program in order to resolve his problems. Programming efforts as short as one month (Morton Schneider's 704 machine code for tree-tracing and assignment) have been reported, but more typically the completion of operating programs in polished form has taken upwards of a year. In most cases, this programming was not the sole concern of the model-builder or his programming associates.

Programming time and effort have been influenced by a number of factors other than the experience and sophistication of the programmer. By far the largest factor is probably the difficulties of calibration; models which, for one reason or another, do not need to be calibrated require substantially smaller amounts of programming. A second influence is the sophistication and polish embodied in the output of programs. For private, exploratory purposes, simple output formats may be useful, but for wide discussion, for the export of programs, and for publicly presentable results, a few models have been designed to produce extensive and elaborate output, including, for example, computer-generated maps. The extent to which models have to be embodied in a larger package in line with present tendencies toward the production of modular models dealing with different parts of the urban development process also has influenced programming effort; modular models require more effort than isolated exercises. Finally, of course, the whole allocation of programming effort is influenced not only by the skill of the programmers involved, but also by the shop environment and the availability of a wide variety of computer software support, which in some cases has obviated the necessity on the part of the model-builder to program a number of difficult operations.

A special case arises in the event that model development requires the invention and application of new mathematical methods. Contrary to the general impression, this is not usually the case; the mathematics used in transportation and land use modeling is fairly conventional and not, in its direct application, very difficult. Undoubtedly, as modeling sophistication grows and as the problems become better understood, the level of mathematical innovation will increase. In this event, very difficult and protracted programming problems may arise. This has been the case in recent experience in the incomplete development of the POLIMETRIC model for Boston by Karl Dieter, and in the development of mathematical programming techniques to be used in a planning model for the Southeastern Wisconsin Regional Planning Commission by Kenneth Schlager.

By far the most substantial obstacle to the operationalizing of models has been the delay and frustration involved in assembling, organizing, and utilizing the necessary and relevant data.

In the environment of much land use modeling (and especially in transportation studies), data collection and data availability have not always been planned with model-building in mind. This has presented the model-builder with the difficult choice of modifying his models or encountering delay and expense while additional data are collected. Quite aside from these problems, the process of data clean-up, data reduction, and preliminary analysis as it proceeds in a large study is inherently lengthy and time-consuming.

In practice, therefore, it frequently happens that the process of model-building as geared to data availability may, in the average case, extend over a period of more than two years in any large metropolitan study. In the extreme case, with especially difficult data problems, such as those encountered in the final calibration of the EMPIRIC model, which required small-area employment data for 1950, this period may be extended. Special purpose studies, studies conducted in the milieu of an established data base, and modeling efforts which do not require calibration may be more fortunate. Again, the typical case, the long time span required for data utilization in the process of model-building, does not occupy the full time of the model-builder, and it would be an unfortunate exaggeration to draw conclusions from these remarks as to the number of man-years spent in model construction.

On the basis of experiences reported and observed, only very general statements can be made about the data input requirements for models. These requirements vary considerably from study to study, but certain basic requirements and the main dimensions of variation from them can be distinguished. In the majority of models which use transportation concepts, some definition of the transportation system is necessary. This usually takes the form of zone-to-zone times, distances, or other impedances, by mode of travel. Relatively little use ordinarily is made of zone-to-zone interchanges for different trip purposes, and other detailed transportation planning data. There are important exceptions, however, in which the parameters of transportation behavior are derived from such trip data and fed into locational models. The concepts of accessibility and connections between place of work and place of residence ordinarily require for the majority of models information in moderate detail as to the location of employment and population. The prediction of location requires the same information at various levels of detail, depending on the model concepts. While some models may deal with total retail trade employment, for example, others use four-digit data which are very rarely available. The location of public facilities, and especially public open space, is frequently required for model construction and calibration. Detailed land use information ordinarily is desirable; detail in this field may extend to the type of construction and the condition of buildings. There are two directions in which serious problems arise beyond the already formidable ones which I have sketched. Shift type models require whatever information is used for at least two points in time, and presently available data, aside from population data, does not meet this requirement. Behavioral models frequently require not only that all data be disaggregated, but that it be cross-classified. Massive basic data—disaggregated and cross-classified, and recorded over time—often should be used for other purposes than model-building, but it is seldom available in any event.

Given a model concept which has grown out of previous thought and experience, plus a first pass at the arduous work of preparing computer programs and assembling data, the analyst and model-builder usually becomes involved in a lengthy process of calibration and adjustment of the models.

Of the two parts of this process, calibration proper may occupy a relatively short period of time, but is altogether more exigent and time-consuming than the actual operation of the model. Once data are available, for example, a multiple regression analysis takes a relatively short period of time, even if more sophisticated econometric techniques such as were employed in the fitting of the EMPIRIC model are used. These same processes will become more difficult and complex as an increasing number of nonlinear models are devised. This, however, is only a part of the story. Even the simplest process of calibration is apt to involve a long search for optimal combinations of variables, optimal definitions of the variables themselves, and the most satisfactory functional forms to meet the general needs of the model. Not only does the process of calibration thereby become much longer, but at some point it becomes confused with the different process of adjustment of the model.

It is of course not surprising that the first tests on a new model confront the analyst with a number of surprises in terms of the way the model works and the effects which it predicts. This may be true even though, as frequently happens, the formulation of the model itself is preceded by extensive experimental and exploratory work, as has occurred in numerous cases brought to our attention. It is usually the case, then, that model-builders find themselves engaged in an extensive period of tinkering, adjustment, and further exploration. This exploration is undoubtedly greatly sharpened by the injection of the modeling ideas which give rise to the experiment, but it nonetheless may be time-consuming.

Overview of Modeling Experience

My impressionistic review of the experiences of model-builders who reported prior to and at the Dartmouth Conference may have conveyed the impression that very large resources have been devoted to an intrinsically difficult process. It is our general impression that, while this may be true in a few selected cases, it is not a general situation. Not only is the number of active model-building projects extremely, perhaps disappointingly, limited, but the individuals engaged in model-building have frequently discharged a very large spectrum of additional responsibilities. They are apt to be engaged in teaching, agency and corporate management, transportation planning and analysis, and the collection of data for more general planning purposes. In effect, many of the difficulties which they have encountered, as outlined above, arise precisely out of the meager resources devoted to land use modeling itself.

The participants in the Dartmouth Conference arrived with a very personal knowledge of these problems, which contributed greatly to the relevancy and penetration of the discussions which followed.

SUMMARY AND RECOMMENDATIONS

The following sections of this paper constitute an attempt to assess the general conclusions and sense of the Dartmouth Conference, which may serve as a guide to practitioners in the field and to the sponsoring agencies in developing further their research programs. Most of the conclusions and recommendations in this section do not stem from specific actions of the Conference by direct vote, since this mode of operation was judged to be cumbersome and counterproductive. We make here an effort to summarize the sense of the Conference, noting areas in which there were significant minority opinions. The sense of the Conference is derived, first, from the content of the papers presented and from preliminary materials submitted by a number of researchers to the Conference organizers; second, from the progress of the discussions of the papers; and third, from a final Conference session which discussed the problems of directions and emphases, with a remarkable degree of unanimity. This paper originated as my own statement on these conclusions, based on the sources just outlined plus individual discussions with a number of members of the Advisory Committee and other selected members of the Land Use Evaluation Committee. The views of the discussants and an emerging unanimity from the floor discussion at the Highway Research Board meetings in January 1968, have been incorporated in this final version.

Current Strength of Land Use Modeling

The state of the art of land use modeling, as the Conference recognized, has progressed rapidly over the last ten years, and currently exhibits a number of substantial strengths. These constitute the background for a discussion of problems which currently exist in the field.

The first strength of land use modeling practice is the emerging emphasis on the systems view of urban metropolitan problems. For historical as well as theoretical reasons, land use simulation is to a greater or less extent integrated with transportation simulation, and most views of urban development take into account not only the interactions of transportation and land use, but also the interactions between different land uses.

The second strength arises from an extension of the systems view to include many aspects of public policy either within the system or, more usually, as explicit inputs into the simulation and as variables which directly or indirectly affect developmental behavior. The present land use development simulation capability is therefore in a position to project the effects of alternative policies. This capability can be used as an instrument in the exploration of policy choices facing the decision-makers.

A third strength lies in the interaction between modeling capabilities and data availability. These two factors obviously influence each other. Present modeling capabilities, on the whole, make effective use of available data and exert a judicious influence in the expansion of data availability and data handling capacity.

In the fourth place, land use modeling has proved to be an effective bridge between the practical problems facing public agencies in the middle and long term, and the scientific problems of understanding and thus controlling the urban environment. The locus of a large proportion of all model-building has been in decision-oriented agencies, and this situation has inevitably injected a practical flavor into model-building efforts. At the same time, both the successes and failures of model-building and model utilization have provided insights into the nature of urban function and urban change, and have suggested avenues of theoretical and empirical investigation into the true nature of urban phenomena.

Major Problems in the Field

Against this background of positive achievement, the Conference identified a number of problem areas which deserve serious attention.

In the present generation of models, the outputs are limited to a relatively narrow class of phenomena having to do mainly with the response of the transportation system to demands upon it and with the gross locational characteristics of aggregates of population. These limitations are generally recognized as not providing an adequate basis for decision-making. The problem of expanding this basis may be identified as consisting of two subproblems.

By far the most important subproblem is the expansion of modeling capability to deal with social processes and to measure the achievement of social goals. This also implies that many aspects of modeling will require disaggregation so that the effects of policies on subpopulations and client groups of various government programs can be more accurately predicted. The emerging style of modular model-building lends itself to this approach and permits the absorption of the results of research efforts dealing with specific problems into the general modeling capability.

When an expansion of modeling capability proceeds along these lines, the expanded outputs, while more relevant to decision-making, may at the same time provide an overwhelming volume which cannot be readily assimilated. This indicates the additional importance of evaluative models which can summarize more readily the results of predictions for the use of decision-makers. The development and importance of evaluative methods in a relatively new and unexplored field suggest an increasing sensitivity in the model-building profession both to social goals and to decision-making behavior. Such increased sensitivity is a necessary concomitant of and stimulus to the solution of many difficult technical problems in this field.

Another major area of concern in the exercise of model-building has to do with the confidence of the general public, the decision-makers, and the model-builders themselves in the accuracy and reliability of their work. A whole area of this problem has to do with decision-making under uncertainty, including uncertainty as to tastes and technology. Present modeling efforts perhaps have taken these too much for granted, especially in the design phase of planning. A discussion of this problem will be deferred to a later point. Two other sources of possible error in the construction of models merit immediate attention.

The current demands of policy-oriented decision-making require increasingly disaggregated projections. At the same time, the long-run projections required for urban development and transportation planning, combined with the desire to examine the possible growth paths of the city, lead to the consideration of long chains of interconnected events. It has been suggested that these long and disaggregated chains introduce the possibility of the propagation and amplification of error. Further experience is needed to evaluate the interaction between detail in projections over time, and their reliability—especially as this interaction may or may not be modified by the self-equilibrating tendencies of metropolitan growth.

A second possible source of error is the fact that descriptive models may not capture true cause and effect relationships, and that the impacts of these relationships may change over time. There is a strong but not unanimous feeling among model-builders that one direction for improving the accuracy with which models reproduce the real world lies in the expansion of studies of the behavior of decision units. In certain cases, the appropriate object of study may be a social group rather than a decision unit, and in other cases the study of aggregates properly defined may be just as realistic as the study of decision units. There are many other questions which arise in the study of decision units regarding the availability of data at reasonable cost, the methods of aggregation in constructing a model, and the validity and stability of relationships at a small scale. Here the profession and the sponsoring agencies face serious dilemmas which must be carefully explored.

The modeling activity currently in progress faces difficulties in the larger planning context which revolve around the generation of alternative plans for testing. At a number of points, emphasis was placed on the desirability of developing and testing "backward-seeking" models, design models, or planning models. Such models would take a statement of objectives, and through the use of optimum-seeking methods, would generate plans or policies which would be optimal in terms given to the model by the user. The advantages of such models would be not only the increased facility with which plans could be generated, but also the sharper focus upon social goals and objectives. In principle, this procedure also might be used to permit goals to define technological requirements rather than the converse; unfortunately, technological possibilities as presently perceived strongly influence and restrain the achievement of goals.

An alternative approach which was not widely discussed at the Conference is the development of heuristic computerized methods for generating alternative plans. Such models could greatly reduce the burden of plan preparation.

The Conference regarded the relative uniformity and unimaginativeness of plans currently being tested by models as one of the limitations on extensive model development and model testing. The extension of model-building into the design and planning field is in general not an accomplishment of this generation of model construction, but remains a serious future problem which the Conference identified but on which it did not make any clear recommendation.

Data limitations received substantial Conference attention. These may be recognized as extending in two directions.

The need for individual data on decision units, serving the behavioral thrust of some current model development, did not receive detailed Conference consideration. Such a need with respect to households might well be served by the implementation of controversial proposals for national or local data banks containing individual household information. Alternatively, the needs might be served as at present by specially designed sample surveys (including O and D surveys), strengthened by the availability of adequate universe data regarding the total urban environment.

Questions regarding universe data, data banks, and data utilization received moderate Conference attention. It was unanimously agreed that, building on present methods of utilizing data, additional clearly defined directions of immediate development can be identified. In the long run, it was agreed that the validation and testing of models will require not only statistical tests, but also their application in urban areas over time and in different cities. It was the sense of the Conference that in selected metropolitan areas an effort should be made to secure and maintain data regarding the urban environment and urban locational patterns on a time-series basis. Desirably, with respect to selected data items, an effort might be made to achieve uniformity not only over time, but also between cities. Such data files, properly organized, would be data banks. The Conference also recognized the existence of a general class of difficulties having to do with the nonuniformity and *ad hoc* nature of arrangements which are made for contact between the analyst and his data base.

Insofar as public policy is coming to deal increasingly with social goals regarding public welfare, social organization, and the natural environment, present concepts of the desirable content of data banks are recognized as being in need of expansion. Definitions of meaningful and measurable variables in these areas still are being developed, and recommendations as to their inclusion in data banks may be regarded as premature.

A repeated theme in Conference discussion revolved around the responsibility of the model-building profession to provide usable results which would meet the needs of a variety of local and national agencies involved on a continuous basis in the decision-making process. Two distinct sources of impediments to meeting this responsibility were identified. There are serious difficulties of communication, time, and resources which face the model-builder in preparing a completely documented report and an exportable set of models. These difficulties are compounded by disparate operating situations and disparate data availability. In the second place, it appears likely that some recently developed models are too complex for wide-spread agency use. In part, this complexity reflects the rapidly changing and developmental character of the land use modeling effort; greater simplicity may at a later point actually reflect greater sophistication. At the same time, however, it must be recognized that the staff capability of agencies to use even relatively simple models is severely limited.

The Conference recognized in general a condition of undue limitation of resources in the field of urban modeling. This recognition should not be construed as the usual plea for additional research which customarily proceeds from many research conferences. The difficulties recognized take a number of different forms, and efforts to remedy them, it is believed, will benefit other aspects of urban planning and decision-making in addition to research.

Overcoming the limitations which have already been discussed regarding data availability will not only facilitate research, but will provide a much broader base for planning and for monitoring the progress of various government programs. These administrative requirements must be met in any event.

The existing practice of BPR and HUD of attaching major research efforts to operational projects in the form of major urban transportation studies, community renewal program studies, and 701 studies has the advantage of bringing research into contact with realistic decision-making problems, but it has the disadvantage of funding research at inadequate scales and of failing to provide continuity. Not only continued research, but also the actual functioning of agencies have suffered from the consequent lack of capacity to capitalize on previous research progress.

At the agency level, there is inadequate staff capability for organizing, conducting, and supervising both research and applied activities in the model-building field. This deficiency has not been offset (as may be the case, for example, in the field of public health) by the appointment of advisory committees and boards from within the disciplines involved and from related disciplines.

It is recognized that any effort, public or private, to overcome the various difficulties under which this field now is working will encounter serious manpower difficulties. Most practitioners and professionals now active in the field have greatly augmented their professional and academic training in a variety of fields by private effort and by experience. It is believed that the agencies requiring model-building expertise are not exerting adequate efforts to sponsor and stimulate the training of the necessary personnel.

Conference Recommendations

The recommendations of the Conference arise naturally out of the foregoing identification of problems in the field of modeling land use development for decision-making purposes.

A. The first general class of recommendations has to do with the institutional setting for model-building and analysis:

1. It is recommended that the sponsoring agencies expand their in-house capability for designing, guiding, and evaluating research efforts in the field of land use projection and model-building, in relation to their respective needs for this capability.
2. It is recommended that a distinction be drawn between long-term model development and short-term applications, and that the institutional and contractual arrangements of the sponsoring agencies take this distinction into account by providing long-term support for developmental work and by judiciously isolating it in part from the exigencies of the operating milieu. Conversely, it follows that operational procedures should be more widely available through institutional channels, so as to relieve operating projects of the necessity for developmental work; this availability of results may require in-house and contract support, at least for a period of time.
3. As an immediate step in the direction of raising the level of research in this field, the sponsoring agencies should follow the example of the Public Health Service and the National Science Foundation in involving related professions and academic disciplines in the formulation of research policies and in the evaluation of research actually undertaken.
4. The sponsoring agencies should review and act systematically, either directly or through other appropriate government agencies, to relieve the present and immediately foreseeable shortage of trained research and development personnel in this field.

B. The second area of Conference recommendations deals with questions of data availability, which affects general levels of planning capability as well as developmental efforts in land use modeling:

1. The sponsoring agencies should take early steps to guarantee the installation and operation of urban data banks in a limited number of selected areas over a substantial period of time. This effort should be designed to produce a basic array of

data for land use planning purposes, which is comparable between cities and which, over the next ten years, generates time-series data for analysis and for model-building purposes. Data bank efforts should be closely correlated with the increased availability of data which will result from the 1970 Census. Efforts should be made to transfer the results of selected transportation and land use studies into data banks in machine-processable and accessible form.

2. Research should be accelerated and action taken at the national level to adapt or create a general data-handling capability which would relieve future studies and analysts of onerous programming problems connected with accessing and utilizing extensive data bases of the type described in the preceding paragraph.
3. Coordinated attention should be given in selected cases and in connection with special studies, to the generation or capture for widespread use of special surveys dealing with such topics as residential mobility, industrial mobility, environmental influences on location, social dynamics, and changing patterns of consumption. These are specialized topics for which data collection is very expensive and on which considerable detailed research may be anticipated in the future.

C. The third general area of recommendations has to do with immediate broad-scale emphases in the field of model-building which the Conference believed to be immediately feasible:

1. It is recommended that more conscious effort be devoted to the simplification or standardization or both of land use models, with a view to more widespread agency utilization. Avenues of development which could be explored in this context include (a) the design and preparation of simplified models for exploratory purposes, and (b) the structuring of sets of models in a hierarchical fashion so that truncated subsets of these models could be used in various planning situations. In any event, greater effort should be made to circulate and make generally available the results of model-building efforts.
2. It is recommended that immediate emphasis be given in larger studies and as permitted by data availability to the behavioral aspects of individual decision units. As a long-term problem, the relation between individual decision-making behavior and aggregative modeling efforts should be explored explicitly. Recommendations for long-term policy in this area are presently premature.
3. It is recommended that modeling efforts take a broader view of social goals in two specific ways: (a) optimizing and eval-

uative models for transportation and land use must take into account not only user costs and benefits, but the direct and indirect effects of facilities and policies on the larger community and on a complete spectrum of social goals; and (b) the present style of land use modeling must be greatly expanded so as to be able to model social and environmental processes related to education, health, poverty, social tensions, and environmental degradation.

4. It is recommended that immediate attention be devoted to the development of evaluative methods which will bridge the gap between present and future model outputs and the actual decision-making process.

D. The fourth group of recommendations is concerned with matters of relatively substantial importance identified by the Conference which, it is believed, can be solved only over the long term and with selective attention. These recommendations are perhaps no less urgent than earlier ones, but the prospect of solution of the problems to which they refer is clouded by more serious difficulties.

1. It is recommended that explicit attention be given to the design process by which plans are generated. In the short run, efforts should be devoted to facilitating the planning process and to laying a basis for more imaginative, more consequential, and less technology-bound alternatives to present and foreseeable conditions. For the longer run, a consistent but selective effort should be made to develop increasingly general and flexible "backward-seeking" or optimizing models and flexible methods of defining social goals for input into such models.
2. It is recommended that over the long run the profession be encouraged to develop standards for the design, calibration, and use of models. The emergence of such standards will require the support for much wider interchange of models, data, and professional views It will also require extensive testing of models over time and across cities on the basis of data which are not yet available. Finally, it will probably require a substantial refinement of statistical and econometric techniques and the development of supporting theories in the general field of spatial dynamics and urban development patterns.
3. It is recommended that the agencies explore, over time, channels for the support of the development of basic research in this field. Such a research capability on a national basis does not yet exist, in the first instance, because of a general inadequacy of resources devoted to other than operational objectives. Perhaps more important, the field of urban analysis and

modeling has lacked focus because of a failure of communication among a number of disciplines and among a number of operating agencies, as well as between the disciplines and the agencies. Consequently, no clear definition of basic research needs in this field exists, and agency attention must be directed toward developing such a definition. This can be followed by support for appropriate research efforts.

OPENING STATEMENTS

EDWARD H. HOLMES, *Director of Planning, Bureau of Public Roads*

The two principal purposes of the conference are to review the state of the art in land use modeling and to develop guidelines of research in the areas of greatest need. It is evident that a proper utilization of money and effort demand that this evaluation be undertaken. I wish to emphasize the importance of full participation and discussion in this conference.

As a transportation planner, I am interested in a number of land use models being developed in some of the different transportation planning processes that are being carried on about the country. There are different theories involved in the development of the models and the way they are being applied, and differences also in the manner in which they are being received. In the Department of Transportation we hope that we may be able to develop some sort of criteria to measure the usefulness of models and their adaptability to various needs. We also hope that an agreement on priorities may lead to a more efficient allocation of research money and effort. It also seems to me that we need to examine how accurately models being developed in the land use and transportation planning process reflect the real world.

But perhaps most important is the need to convince the decision-makers in cities and the decision-makers where the research is being carried on that the objective of the planning process is not just the development of a plan. It is the development of a continuing program and the implementation of that program. Usually we think that implementation of plans results from capital improvement programs of some sort or another, and in our area of transportation, we get right back to the Federal Highway Administration and the implementation of transportation programs by the state highway departments. But we must first convince the highway departments that our plans are sound and that the recommendations for the future are soundly based. The projections, if they are made through the simulation models which we use generally now, must be based on models that reflect what is actually happening in the present.

We have been accused many times in the highway field of doing only highway-oriented planning. But it has always been my contention that the planning has not been highway oriented, but that the implementation has been because the highway departments, charged with implementing the programs, have been satisfied that the plans were soundly based and that the projections made from them were realistic projections of future need. However, our experience in projecting future need has not always been good, and usually the need has turned out to be much greater than was projected. Gradually we are achieving sufficient skill sophistication to the point where we can project transportation needs with reasonable assurance provided we know how to project land use trends and develop the probability of land uses with which these transportation needs are associated. There again, we can say that in nearly all state highway departments (there are only two states in which we do not have formally required planning processes in operation; those two not having a city of as much as 50,000 population) we have achieved the acceptance of the simulation model as the means of projecting travel in the future. We have achieved this by our ability to demonstrate to the skeptical highway officials that the model does reproduce what is now on the ground.

We presently have the means of proving that a model which involves and relies on non-travel related data can produce a picture of travel in an urban area which reflects reasonably well the facts of the transportation situation. The men who implement these programs, whether state highway officials, mayors of cities or city managers, are elected or appointed officials who have the responsibility of spending public funds, and they must be skeptical of any proposals that are made to them by planning groups or by their own agencies. We have achieved something when we can convince properly skeptical people that we have a rational and useful method for solving their transportation problems.

When it comes to land use, however, we have to convince a different group of people. Implementation of a plan is not simply a matter of capital improvement programs. The officials who are responsible for the control of land use must carry out their part of a transportation-land use plan if the highway transportation plan, the total transportation plan, is to succeed. And here is where we seem to have more difficulty. Of course we know that we have various land use controls, notably zoning. Zoning is always subject to economic pressures and usually succumbs to them if the economic pressures become heavy. But there must be some way to implement a land use plan, and perhaps the trouble is that we do not know enough about it to be realistic.

I recall one conference in which a description was given of a land use planning model and a comment from one of the participants from another state was as follows: "The trouble with land use models is that the growth does not seem to come the way the planners thought—the way the land use was projected." For example, in the city to which he was referring, the highest priced development came in the area where that type of development was the least desirable. In my view, this comment revealed that whoever developed the land use model could not have had a very good idea of what was a desirable area for high priced real estate development. I doubt that people would put big money into an area that they thought was undesirable. Somehow the land use planner was not able to capture the real desires of the people who were about to spend money. Thus it seems that we need to evaluate our assumptions about what really does make people tick—both the people who build residences and those who build commercial or industrial centers.

We must remember that it is very difficult to convince the planning officials of the validity of land use projections, and part of the reason is that the land use models we have seen thus far do not have within them the capability of demonstrating that they can reflect the real world to the extent that the transportation models have.

The second objective of the conference is to produce guidelines for future research. This has very broad application because there certainly will be increasing funds available for research in this area. There is every indication in the Federal Government and in our Department of Transportation of a realization of the importance of the urban area, and I feel very sure that the Bureau of the Budget will take a liberal view of proposals by various government agencies to do research in this area, provided that an intelligently oriented and organized research program is proposed to them.

Research is presently being done; certainly in the Bureau of Public Roads we have been putting quite a little money into research in urban transportation and urban land use. In fact, one of the budget examiners was questioned as to why research on land use was not begun in HUD, and the answer is that this is important to the Public Roads program.

To me it is almost unimportant whether research funding is through one department or the other, provided we can work together in the future as closely as we have done in the past, and I can see no reason to think that we shall not. From the point of view of our Department, I can foresee increasing opportunity to finance research, and I think that other agencies outside of government will probably follow suit, and that there will be an increase in research in the modeling field. Thus, it seems to me very timely and important that this conference produce some guidelines as to what can be done to our best advantage in producing the type of research that will produce acceptable models. I also hope that the conference will come up with some solid accomplishments in the directions of evaluation of current research efforts.

I agree with Mr. Harris that the ultimate purpose of the model is to aid in decision-making, and I am sure that those here from Public Roads will agree with that statement. But frankly, I am not sure that we can get total agreement on this point because I do not believe that there are very many decision-makers who can be convinced by the highly technical descriptions of processes and models contained in the conference papers. The technicalities are important to people who can understand them, and I suspect that most of the people who can understand them are probably here in this room. One important thing that must come not only out of this Conference but out of our land use planning models is an ability to convince the people who must accept the results of these models as to the soundness and the value of work that is done. They will not be convinced unless the description of the models can be presented to them in a language that they can understand and that can be supported by some proof that it does measure something which they can get out and see. I would hope that in pursuing theory and bringing into it the many variables that are involved, we do not bring into these equations the requirement of input data that cannot be collected. It has been said that it sometimes takes several years to get the input data needed for the models. I have seen some models that have been proposed, and I know very well that the necessary data cannot be collected. So let us be as theoretical as we can, but let us also have some restraint in expanding this theory beyond its practical use and beyond its acceptability. I should hope that land use modeling will parallel the development of transportation models in which we have found a means of improvement as we go along. As Alf Johnson likes to say, we seem to improve as we get better. I would hope that in land use modeling we can be practical as we go on in theory, so that everyone can take advantage of these models as they develop and will not have to wait for many years to take advantage of the perfect model if one can ever be developed.

WILLIAM B. ROSS, *Deputy Under Secretary, Department of Housing and Urban Development*

The first thing I discovered when I started reading the papers for this Conference was that my knowledge of the state of the art and the state of the literature was inadequate, and that probably the more time I spent listening at this Conference and the less time talking, the better off we all would be. It is very obvious from reading the papers that at least half the people here have reached the point of realistic and brutal honesty about the shortcomings and deficiencies of their work. By now, we must admit that much of the easy fun-poking at simplistic models and their results is irrelevant; and we also have to admit that some of the rudimentary criticisms are just obsolete.

One of the first things one finds when getting into a new agency, such as the Department of Housing and Urban Development, is the attitude of the professional research groups and the proprietory research organizations toward their building and our buying models "of the real world." They said, in effect, if you will throw enough money into it and will give us a big enough computer and enough data, we will not only predict all the trips, but also everything else that will happen in "Gotham City."

Hopefully, we have now recognized that there is a clear distinction between what I call analytic research models and the operating models with which we are very concerned because they represent the bread-and-butter of our client agencies at the local level. Mr. Holmes and I both represent agencies which have a great deal of interest in what other people do, and the interests of our agencies are quite similar. We are still interested in the execution of functions which are carried out by other people. We are concerned with operational models because they have utility to our customers, and we would have to admit that we do not necessarily fully understand what that function takes in the way of data and relationship functions or what issues are most applicable to local operating agencies. I would like to hear the operating people speak up on that subject very clearly in this week. We are interested in supporting operational models, in doing whatever we can to broadcast the successes and to heed the warnings of the deadends — those technological and conceptual difficulties that render further pursuit of a particular line of inquiry useless.

When it comes to analytic models, I think we have a direct interest ourselves but also still some uncertainty as to what we are looking for. We have an immediate and clear interest in models at the metropolitan level in rather aggregative cases like a macro-housing market. These models offer a great deal of hope for improving our operating performance in such areas as insurance underwriting and the allocation of federally assisted housing. But, to be practical, we cannot necessarily wait for other and more scientific systems. We are using implicit straight-line extrapolation models now, and we are going to continue to use them to make required day-to-day decisions. But we would be very much interested in additional research and additional developments in analytic models as well as in the distributive land use models which have a primary use in the local operating agencies.

Although we are still in a very primitive stage of research formulation in HUD, it is clear that we will be more interested in the future in a clearer distinction between the research and the operating models than we have had in the past. We were quite proud to have funded the San Francisco Housing Market Study, but it is still a disappointment to find that it had no relation either to the community renewal program or to the process of renewal in the city of San Francisco. We would like to change that situation.

We have heard that there is a tremendous translation gap between policy-maker and technician. If policy-makers either cannot read integral signs or take them on faith, the model-builders must try to explain their work. And some of us, whether we like it or not, are stuck with some aspects of that translation job.

We find ourselves doing a lot in the way of strategic intervention in the land use change process at the local level. We do that not merely to be busybodies, but because someone has decided for an intuitive, straight-line, (or totally wrong) reason that there is a form of intervention which helps produce more optimal land uses than would occur otherwise. As a result, we have had a good many programs which are heavily involved in influencing land use change processes—renewal, urban beauty and parks, advance land acquisition, open space acquisition and development, and many others. It would be very interesting to us, and very helpful, to have more in the way of analytic research work, including models, on how land use and land use change processes work in various aspects of the urban condition; and we would be much more interested in these than in speculation on where the world would end up in a frictionless society.

Now, there is one other very important aspect which has been touched on by both Mr. Harris and Mr. Holmes. The Bureau of Public Roads, the Department of Transportation, and the Department of Housing and Urban Development represent a major part of the non-demographic interest in what the Census Bureau does, and in what kinds of data the Federal Government invests its resources. We need theories, backed up by models or reflected in models, to help us argue for the selection of data that will be useful, either for a national collection as part of the inputs to workable operating models or for the fairly sizable special data collections that we can produce or acquire if we do not make too many mistakes in the first round and lose our credibility with those who pass on the uses of Federal funds.

I think these comments indicate that we have an open mind; certainly we are desperately in need of the kind of guidance that this Conference was convened to give. We hope very much that the conference will not disappoint us.

AGENCY EXPECTATIONS FROM PREDICTIVE MODELS

CHARLES J. ZWICK *

I am told that the mood of this Conference is to be introspective. We are to air disagreements, document agreements, and in general, to stop and assess where we are after an initial flurry. My intention is to be optimistic, but I will also be frank and blunt.

When I first agreed to this address, I wrote down on a piece of paper—one piece—some things which went through my mind. They were the following:

- What models are we talking about?
- Models for what purpose?
- Models are useful in making what kinds of decisions?
- Models are amoral.

By the last point, I mean that models are neither right nor wrong, except in a specific context. I believe we have to focus on what we are trying to do and what decisions we are trying to make. Only against some criterion, some decision, do models become correct or incorrect. These ideas will be woven into my discussion today.

Enough time has passed since the big flurry of urban development models in the early 1960's for introspection to be appropriate for this Conference. We have had a number of successes as well as a significant number of failures and disappointments from both the research side and from the decision-makers' side. On the other hand, this work is expanding and growing. Undoubtedly, there will be more money available for urban development models. Clearly, this is a growth industry. Despite the failures and disappointments, we will continue to expand these efforts.

Progress also can be measured by the technical competence of the people attending this conference. Without trying to be Pollyannaish about it, I think this is a fairly impressive collection of people. We could not have gotten together a group with this technical competence four or five years ago. In this sense progress has been made.

Still another index of progress to me, looking at some of the papers distributed at this Conference, is the fact that both Britton Harris [1] and Jack Lowry

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[1] Britton Harris, "Quantitative Models of Urban Development," a paper prepared for a Conference of the Committee on Urban Economics, January 1967, Washington, D.C.

have tried to classify urban development models. A first step in any scientific inquiry is that of taxonomy. I happen not to like either one of the classification schemes they propose, but that is irrelevant to the desirability of trying to classify the various models.

In his classification, Britton Harris talks about model attributes; micro versus macro models, static versus dynamic models, and deterministic versus probabilistic models. Jack Lowry's categorization is more a process approach to the problem; land use models, migration models, and land use succession models. I think that a classification focused on end-use—on what kinds of decisions models aid us in making — would be more useful, as I hope will become clear as the Conference proceeds.

To sum up these introductory remarks, we do have some work behind us; good people are working in the area; it is a growth industry; and people are beginning to try to classify various models. So introspection *is* in order. It is important to step back now and assess our status before we take the next leap forward. To aid in this process, I would like to ask several questions.

The first question is, *what models are we talking about*? This is a conference on urban development models. However, in fact, we are interested at this meeting only in a subset of all urban development models. These are — to use Jack Lowry's phrase — quantitative models of spatial aspects of urban development. There are obviously other models of urban development, including, for example, models of changes in political institutions and social attitudes. The key terms with which we are concerned are quantitative and spatial aspects of urban development.

We are also talking about large models with land use, transportation, and other submodels within these large models. Ted Holmes made the point that we need to build some feedback loops into the larger model so as to reflect clearly how one of these subsystems affects the other subsystems. I believe it is important to define clearly the models we are talking about as we go forward.

The next question is, *models for what purposes*? In his paper, Britton Harris says the purpose of models is to aid decision-making. I would argue that this only clouds the issue — what decisions, what time frame? There has been a lack of clarity on the purpose of models. I once wrote a paper setting forth at least three purposes for models which I still think are valid. I would like to restate them for your consideration.

First, models can be used as an *aid in forecasting*; that is, to make conditional statements. If *a* changes under certain conditions, *b* will result. This is a typical predicting or forecasting objective.

A second related, but really quite different, purpose for models is their use as research tools or techniques for *studying the process of urban change*. The objective here is understanding the underlying system in order to identify and measure relationships. We can come out of a study of the process of urban change with forecasts, but if we are interested only in predicting or forecasting we might use a much different model than if we are interested in studying the underlying components of a system. This relates to the whole business of structural versus nonstructural models, with which we are all familiar. Any predictions resulting from a large, complicated model are subject to large uncertainty and error. Partial equations usually allow us to forecast a narrower range. Thus, I think that the distinction between a forecasting tool and a research device to get at the underlying relationships in a very complicated system is an important one to keep clearly in mind.

A third purpose for models, obviously, is their use as *an educational device,* a teaching aid, to instruct people about an underlying structure. This, of course, assumes we understand the underlying structure and that we are using the model or the simulation to display the various interactions and relationships. The model in this case is clearly a teaching aid. I would argue that this is a very different purpose than the other two I have identified.

Our thinking should be clear as to which of these three purposes we have in mind when we undertake to build a model. Bill Ross came close to making this point when he said he wanted a clear distinction between operational models and research models. These distinctions have been clouded up in work statements by both government agencies and research organizations. A model is not going to do all things for all people. Life is not quite that simple.

This session is labeled "Agency Expectations from Predictive Models." Predictive models, I assume, means the first of these purposes, namely models as an aid in forecasting. From my vantage point this is probably the least important of the three purposes for models. The models to date have been more important as research vehicles and as educational devices than as aids in forecasting specific land use patterns or transportation requirements. This raises the question of whether this will continue to be the case over the next decade. I suspect it will. Over the next decade, I predict that if we are interested in forecasting specific land use patterns or specific transportation requirements, we will be able to do this more accurately and efficiently by undertaking partial analyses. I will develop this idea further as I go along.

I would now like to turn to *what kinds of decisions must be made* in the area of urban development. There is obviously a whole spectrum of decisions, ranging from fairly detailed questions of the alignment of streets to very broad questions such as the desirable spatial distribution of the population. Ted Holmes and Bill Ross have indicated how some of these decisions are viewed from their respective agencies. I assume that others will focus on decisions they face in their presentations in succeeding sessions of this Conference. I will limit my discussion of decisions to those we face in the Bureau of the Budget—an agency perspective, if you will.

Of necessity, decisions at the Bureau of the Budget level tend to be gross, global, "big" decisions. Bureau decisions influence the amount of money available for research in broad areas or for specific major capital investments of the Federal Government.

The best way to get at this decision question, I am sure, is to illustrate it with a few examples. I will do it in the transportation area. These are decisions which I believe will be of critical importance, and I would like to point out the relevance of specific land use, transportation models to these decisions. I will argue that specific models are not very relevant as forecasting vehicles, but they are useful in helping us understand the process of urban development. Therefore, to repeat a point I have already made, models will be very useful for educating people. They will be less useful in providing specific answers to questions that need answering.

The first point I would make is that most urban development models tend to be global and consider all modes of transportation in an attempt to define either a preferred transportation system, or several alternative transportation systems. A typical approach is to take as given an existing transportation complex and talk about a process of evolution towards a "desirable transportation system" sometime in the future. It is a matter of fact that now and for the foreseeable future, most important transportation decisions are made partially, involving usually only one mode of transportation. Let me give some examples.

The first one that comes to mind is the question of airport facilities. There is a need for a major expansion of airport facilities in the United States over the next decade. Billions of dollars will be spent over the next five years on airport facilities — the terminals, the runways, the whole process of getting people on and off airplanes. It is asserted that the financial requirements are so large that state and local governments cannot afford to undertake the expansion by themselves and that Federal financial assistance is needed. There is a potential conflict between "the national airport plan," which views this problem as a national air transportation system, and the land use desires of local communities. We are going to make decisions which will involve billions of dollars, and which will have major impacts on other modes of transportation, as well as major impacts on land use within our metropolitan areas.

What planning requirements should the Government impose if Federal money is going to support this expansion of airport facilities? How do we force an integration of these plans and these expenditures with other plans of the Federal, state and local highway departments, local mass transit plans, and so forth? Do we build big terminal facilities at the airports, or, as some people have proposed, should we expand on the "Dulles" solution and have a number of mobile terminals that can pick up people around the metropolitan areas and move them directly to the planes? Is a fourth airport needed in New York City? Or, in the New York case, can the nonscheduled portion of the traffic be moved to Floyd Bennett Field and thereby relieve LaGuardia and Kennedy airports so that they can serve the scheduled airline needs for the foreseeable future?

These are really quite basic decisions. Important issues of land use and intermodal transport problems are involved. We need people who understand this process much better than we now have to help us develop realistic options. I know of no particular model that I can take off the shelf to help me with this. Individual models do, however, give insights into particular aspects of the bigger issue.

A second example that comes to mind is referred to as the post-1972 highway system — what do we do after the Interstate System is complete? This is probably the most important of all the transportation decisions that are going to be made in the next couple of years. The Interstate System, which is a specific system in terms of highway miles, is supposed to be completed in October 1972. Undoubtedly, there is going to be a follow-on system. The implications of this follow-on system for urban planning and land use are obviously of utmost importance. It is quite clear without any deep analysis that in contrast with the present Interstate System most of the new system is going to be in either urban areas or in high-density corridors that serve the urban areas. What is it going to look like? Is it going to be more of the same? What procedures are going to determine its characteristics? The same old ones, or will there be new rules of the game? If so, how do we evolve new procedures? These decisions must be made fairly soon.

A specific question involved here is whether highway funds should be used for parking facilities. This is an issue that is already under debate in Washington. There is one group that argues that parking facilities are obviously part of the highway system, and therefore, it is appropriate to use highway funds to construct parking facilities. Another group agrees that parking facilities should be built with highway funds, but only in the suburbs and not downtown in the central business areas. Involved in this debate are some implicit assumptions about the relationship of parking facilities to travel and land use patterns. We simply do not have enough good information to provide a well-considered answer to this question. Here we have a major issue with strong views on all sides not backed by good analysis. We do not know yet what would happen under the various alternative parking facility locations. Yet, within a short time, the Congress will pass a law which will influence urban transportation and land use patterns for another decade or more.

Let me just make an aside at this point. I think in this area we need a little more focus on particular groups within our society and within our urban areas, rather than on "the urban transportation problem" *per se*. For the most part, the urban transportation debate today has been a middle class exercise concerned with getting relatively well-to-do people in and out of the city or to their place of employment.

If we start asking questions about how we meet the transportation requirements of particular social groups, we start changing the focus of the urban transportation discussion quite a bit. There is a great deal to be gained by working on some of these problem areas in urban transportation — the problems of the minority groups living in ghettos and their particular work-trip patterns and the concomitant cross haul and extra transport costs. At the other extreme are the problems of the high-income commuters who are most concerned with getting to airports so that they can commute as quickly and as effectively as possible and who are willing to pay a high price for this service.

These are examples of the kinds of decisions which the Bureau of the Budget will be facing over the next several years. I believe it is clear that there is no one existing model that will generate answers to these issues. There are, however, a number of models that can provide insights into parts of these issues, and there are some analytic efforts which can be brought to bear on these problems so that we will be in a better position to make informed decisions.

This brings me to the question of *the time-frame for decision-making.* The issues that I have just described will be resolved better if analytically trained people will attempt to influence the legislation that will be required. Alternatively, as research workers, we can ignore these issues and continue our longer-term effort of accumulating general knowledge. Now, it seems to me that if we want to influence these near-term decisions, we will have to narrow our models, carry out partial analyses, work with inadequate data bases, and, in general, compromise what we would consider to be a professionally competent piece of work.

We do not have to face up to these problems, however. I know of no overriding ethic that says we are better off working on long-term problems, or alternatively, on more immediate problems. It is a choice all of us have to make, and having once made the choice we have to live with its consequences. If we get too close to the decisions, we may find we are not research workers any longer, but decision-makers. This is a fate to which a number of us have succumbed. This question of time-frame is critical and tends to be obscured in our discussions. Remember, if we want to influence some of the important issues coming along in the next few years, we are going to do different research work than if we want to accumulate general knowledge about urban development and urban change.

Let me end with a comment or two about the environment of public attitude concerning these research efforts. As I see it, public attitude is mixed. On the one hand the analytic approach is in vogue. The Bureau of the Budget is pushing for all agencies of the Government to employ a system called the Planning, Programming, and Budgeting System. The people that are coming to Government—as undersecretaries, deputy undersecretaries, assistant secretaries—have different backgrounds from those who came into Government ten years ago. More money is being spent on research, and there is every prospect that even more money will be spent. Better trained people are working on key problems. Certainly social scientists, particularly economists, have more influence than they previously had.

On the other hand, there are clearly signs of impatience and calls for action. "Let's get things done. Let's not worry about all this fancy analysis." The more sophisticated will point out that formal studies have not been convincing enough to form a public consensus around particular urban development plans, and to move communities in a direction that these studies recommended. They argue that all we need to do is spend money, and spend it quickly, and get on with the job.

This impatience should influence the type of research we do. We can develop models which can be used in conjunction with action. Model City activities in HUD, mass transit and other demonstration programs, need to be conducted within a backdrop of hypotheses which can be tested and with plans which can be changed in light of new information. This ability to react often is missing from today's *ex ante* efforts which stress careful planning before a decision is made—do the analysis, think through the consequences, make your plans and then make a decision. Unfortunately, I am suggesting that the real world is not going to stand still for this. If we believe there is going to be an impatience and a drive for action, we must modify our research plans to build models which recognize this fact of life.

At a recent meeting of the National Academy of Engineering, I suggested that there are currently in vogue two methods of evaluating transportation plans One is the systematic, analytic approach in which we at this Conference have a vested interest. The other I labeled the "oracle" approach. The oracle approach is doing very well these days. Simply find a wise man or a lady as the case may be, and she or he will tell you what to do. I would hope, in this debate between the oracle and the systematic/analytic approach to problems, that our side will win. On demographic considerations alone we might get numerous enough to outvote those who prefer the oracle approach.

In any event, I would hope that this Conference will help support the systematic/analytic approach. To do so, we must focus on: What models are we talking about? Models for what purpose? What kinds of decisions must be made? And, lastly, models are amoral.

PART II

Planning, Decision-Making, and The Urban Development Process

What is the planning and decision-making framework in which urban development models are to be used? What are the factors and forces influencing development patterns and how can they be incorporated into urban models? These two related questions were the central focus of the second, third, and fourth sessions of the Conference. The two questions are joined in a common concern which was a major preoccupation of the Conference: what is an appropriate strategy for model design that will meet the demands placed on the structure and output of models by the requirements of the planning and decision-making process, and which will also meet the requirements for model reliability in replication and conditional prediction of real world events.

The paper by Steger and Lakshmanan discusses the requirements placed on models by the decision-making process Their focus is the evaluation of plans, and their presentation is designed to reveal the existing gaps between the requirements of rational decision-making in the public sector and the current capabilities of analysts to meet these requirements. In assessing the current state of the art of plan evaluation in terms of the requirements they outline, the authors conclude that the current practice is quite weak and suggest strategies for improving modeling and plan evaluation.

The papers by Chapin and Leven are examples of alternate approaches to development of urban theory. Chapin describes his micro-level research on the daily activities of individuals and households in the city and on the policies and preferences which govern the location behavior of households. He discusses approaches to modeling the daily activities of households in an urban area and argues for the development of land use models based on fine-grained, behavioral analyses and theoretical development. Leven presents the case for a macro approach to understanding land development patterns He argues for a theory of the city based on aggregate functions of the city as a unit and land development models based on such a level of generality

PLAN EVALUATION METHODOLOGIES: SOME ASPECTS OF DECISION REQUIREMENTS AND ANALYTICAL RESPONSE

WILBUR A. STEGER AND T. R. LAKSHMANAN *

In recent years, urban developmental and transportation planning has been in flux: as policy-makers and planners come to grips with the problems posed by planning for complex urban systems open to change in many directions, they have become aware of new and broader sets of issues. The analytical framework for posing these planning issues also is trending away from simplistic end-state orientations to more appropriate functionalist foundations.

Thus, the issue and policy space in physical planning is broadening beyond earlier focus on efficient arrangements among activities in space having close functional links, to policy issues of varying dimensions at different levels of government oriented to assuring appropriate levels of public service and harmonious relations among spatially juxtaposed, if functionally unrelated, activities. At the same time, planning analysts who have emphasized a desired future state are focusing on the processes by which that state is reached, combining thereby an interest in process and a desire for goals. Transportation planners have also moved away from narrow notions of transportation system efficiency to an evaluation of externalities of transportation investments in considering the feedback effects of transportation on development patterns.

The legislative and institutional response and to some extent initiation of these changing trends have been the various Highway Acts, Mass Transit Act, the Community Renewal Program, Model Cities and Metropolitan Development Act and the creation of the U.S. Department of Housing and Urban Development. The full impact of these decisions has yet to be realized, although a basis for a continuing, comprehensive, and cooperative land use and transportation planning process has emerged.

In the same period, several metropolitan studies carried out under the auspices of these legislative decisions have pioneered the development of certain aspects of the analytical and computational technology addressed to urban land use and transportation planning. However, in the prevalent fourfold view [1] of the planning process [Goal Identification–Policy and Plan Design–

* CONSAD Research Corporation.

[1] This adds one to the trichotomy cited by Britton Harris in "The City of the Future: The Problem of Urban Design," paper presented at the Thirteenth U.S. Annual Meeting, Regional Science Association (St. Louis, November 1966).

Impact Estimation (plan testing or simulation)–Evaluation and Choice] these new techniques have been almost solely addressed to the impact estimation phase. The contextual (goal setting), synthetic (alternative plan development) and evaluation phases have received scant attention, partly because of their inherent complexities. In the evaluation area, there have been parallel developments in the areas of water resources (benefit-cost), and defense analysis (cost-effectiveness). Some attempts have been made recently to apply these concepts and techniques in developmental and transportation planning.[2] Exploratory attempts have been also evident to perceive in full the relationships between plan design, plan evaluation and goal setting and to identify the conceptual and technical problems therein.[3]

At this stage, a set of crucial questions is in order. What are the issues and policy space in current urban and regional planning? What are the emerging concerns and their dimensions? What philosophical views exist of the planning process (and its dimensions) in which to frame these issues and arrive at appropriate instrumentalities? What is the content, scope and nature of current methodologies of plan evaluation and the related plan design technology? How are control or policy variables identified and expressed? How are the effects or impacts identified and estimated in terms of magnitude and the different dimensions of incidence stratification?

Focusing on plan evaluation technology, what is the gap between the best current supply of evaluation technology and prevalent practice? What measures or procedures would most effectively bridge this gap? In another sense, what is the gap between the conceptually satisfactory requirements for plan evaluation and the capability of our public institutions and technology to meet these requirements? What would be the most promising research strategies to close this gap and what priorities can be discerned in this future research?

These are some of the challenging and complex questions before this Conference. They serve as a backdrop to this paper which is addressed to the

[2] For example, see Robert Dorfman (ed.), *Measuring Benefits of Government Investments* (The Brookings Institution 1965), in particular the papers by Herbert Mohring and Jerome Rothenberg; CONSAD Research Corporation, *Design for Impact Studies,* prepared for the Office of High Speed Ground Transportation, 1965 James C. T Mao, "Efficiency in Public Renewal Expenditures Through Benefit-Cost Analysis," *Journal of the American Institute of Planners,* XXXII (March 1966), pp. 95-106.

[3] See Britton Harris, "The City of the Future: The Problem of Optimal Design," paper presented at Regional Science Association Meeting at St. Louis, November 1966. CONSAD Research Corporation, *Impact Studies,* Prepared for Northeast Corridor Transportation Study, January 1967, Chapter IV Marvin Manheim, "Highway Route Location as a Hierarchically Structured Sequential Decision Process," (Ph.D. Dissertation, M.I.T., 1964). Edwin N. Thomas and Joseph L. Schofer, *Toward the Development of More Responsive Urban and Transportation Models,* Research Report (The Transportation Center, Northwestern University, April 1967).

problem of evaluation. It attempts to locate the evaluation phase (or decision modeling) in the planning process, derive requirements for evaluation, identify gaps between these requirements and capabilities, and suggest appropriate long-run and short-run analytical devices addressed to these gaps.

Of the four facets of the overall planning process, evaluation is perhaps the least amenable to objective professional investigation. All citizens of a democracy have views — both descriptive and normative — of the public evaluation process. The disciplines with the most professional expertise to describe this process — the public administrators, political scientists, sociologists, and urban historians — provide us with some insights to abstract the necessary ingredients for our needs.[4] But their views are decidedly still in this very formative stage.

The subject matter does not lend itself to simplification. At a very general level, metropolitan plan alternatives must be evaluated in terms of the human ends (or benefits) they will serve, the other ends forgone (opportunity costs) and the differing means (or costs) required to achieve these ends. Each of the alternatives of an urban area is a bundle of goods with an associated set of values and life styles and a specific price tag. But as Wurster points out, it is a hypothetical package, and in the present state-of-the-art evaluation, it is very difficult to know exactly what the goods are or what the cost may be.

The objectives or ends can be compared in proximate goal statements such as housing choice, job accessibility, income or racial distribution. But the deeper indirect socioeconomic benefits are not easy to identify or assess: individual opportunity, productive efficiency, family welfare, privacy, security, cosmopolitan character and stimulus, flexibility to further change, etc. Attitudinal research informs us that we know very little about peoples' tastes and

[4] Nathan D. Grundstein, "Urban Information Systems and Urban Management Decisions and Control," paper prepared for the Third Annual Conference on Urban Planning Systems and Programs, Chicago, 1965; Alan Altshuler, "Rationality and Influence in Public Service," Public Administration Review, XXXI (September 1965); Wilbur R Thompson, "Toward a Framework for Urban Public Management," *Planning for a Nation of Cities,* ed. S. B. Warner, Jr (M I.T Press, 1966), Gilbert F. White, "Formation and Role of Public Attitudes," *Environmental Quality in a Growing Economy,* ed. Henry Jarrett (Johns Hopkins Press, 1966); Norton E. Long, "New Tasks for All Levels of Government," *Environmental Quality in a Growing Economy, ibid,* Charles E Lindblom, *The Intelligence of Democracy* (Free Press, 1965), Morton L. Isler, "Selecting Data for Community Renewal Programming," *Journal of the American Institute of Planners,* XXXIII (March 1967); David A Grossman, "The Community Renewal Program: Policy Development, Progress and Problems," *Journal of the American Institute of Planners,* XXIX (November 1963); "Process Planning· Symposium on Programming and the New Urban Planning," entire issue, *Journal of the American Institute of Planners,* XXXI (November 1965); N. Beckman, "The Planner as a Bureaucrat," *Journal of the American Institute of Planners,* XXX (November 1964)

needs, and we need conceptual frameworks to pose relationships between attitudes, tastes, needs, and behavior.

Appropriate cost comparisons among the plan alternatives may deal with private and public expenditures for major items such as transportation, housing, open space and redevelopment. Again, the forms and degrees of public power, institutions needed, and social costs of dislocation and plan enforcement all have to be assessed. In a general and rough manner, some of these cost differences among plans are estimated, while others do not lend themselves to quantitative evaluation.

If we wish to be able to progress in the assistance we provide to public decision-makers and to planners who advise decision-makers, we require a manipulable abstract view of this process, while at the same time acknowledging the breadth and variety of types of public decisions and methods to deal with them. We propose to structure our view of this evaluation process around the nature of gaps between what we want to achieve and can achieve in the evaluation area.[5] No one can really hope, at least not in the near future, to evaluate the evaluation methodologies, in theory and practice, with the precision demanded for gap-unit measures.[6]

In summary, this paper evidences a preoccupation with basic conceptual problems in plan evaluation, such as issue relevance, process context, plan design and identification of impacts and preference vectors. The neglect of technical issues, such as a choice of an appropriate discount rate, that loom large in water resource program evaluation discussions, is a measure of the novelty and youth of the field of urban plan evaluation and the challenges that lie ahead for its development.

From this perspective, we have resisted the temptation of a too innocently positivist approach. The search for feasible techniques in an area with a perplexing multiplicity, fluidity and conflict of values, the quicksand complexity

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[5] R. M. Rauner defines "gaps" as "the mediate goals against which budgets can be assigned and performance measures computed," p. 16 in "Regional and Area Planning: The EDA Experience," prepared for presentation at the Institute of Management Science Annual Meeting, April 1965; see also, R. A. Levine, "Program Budgeting for an Interagency Program," Program of the Thirty-Sixth Conference of Southern Economic Association, November 1966.

[6] Except on rather particular grounds; *e.g.*, a test of statistical validity. See D. E. Boyce and R. W. Cote, "Verification of Land Use Forecasting Models· Procedures and Data Requirements," Forty-fifth Annual Meeting of the Highway Research Board (Washington, January 1966); W. A. Steger, "Review of Analytic Techniques for the C.R P.," *Journal of the American Institute of Planners*, XXXI (May 1965); Traffic Research Corporation, "Review of Existing Land Use Forecasting Techniques," Boston Regional Planning Project, Massachusetts Transportation Commission, July 1963; and Donald D. Lamb, "Research on Existing Land Use Models," Southwestern Pennsylvania Regional Planning Commission, March 1967.

of control and effect variable dimensions, and shifting criteria, has the quality of a mirage. Consequently, we resolved to thread our way through the network of premature generalizations abounding in the field with the intent of preliminary identification of broad strategies of analytical development. It has been very sobering experience.

METROPOLITAN AND URBAN PLANNING IN CONTEXT

Two major interrelated trends in the last decade or so have been crucial in the evolution of the demand for metropolitan and urban planning. They are the evolution of national transportation policy and the evolution of national urban policy. The planning issues and frameworks resulting from these trends and the issues confronting metropolitan planners and public decision-makers are briefly surveyed in this section.

National Transportation and Urban Policy

In the area of national transportation legislation, there are two major milestones, the National Defense Highway Act of 1956 and the Federal Highway Act of 1962. The National Defense Highway Act brought to a close the era in which planning and highway planning in particular could be based on the aggregation of small locally based decisions. The planning of a large highway system required greater knowledge of urban structure and processes and required planners to become more concerned with benefits and costs of highways. The techniques of economic analysis were deployed to select a transportation plan alternative that involved the lowest transportation cost and the highest ratio of user benefits to costs.[7] Minimizing costs became the most important objective in transportation planning. The process of obtaining individual, institutional, or societal goals did not explicitly enter the planning process. Further, the indirect effects of transportation in terms of improved spatial organization or social dislocation were not considered in the evaluation of plans. Simple projections of demand coupled with a reliance on cost minimization placed the planner in the position of following trends rather than leading them.

The disaffections with the planner's function as projecting rather than planning [8] were sought to be alleviated by the 1962 Highway Act and the associated executive memoranda.[9] The establishment of an explicit metropolitan planning process intended to be continuing, comprehensive and cooperative

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[7] See Chicago Area Transportation Study *First Report*, Vol. II and IV, Chicago, 1962.

[8] See Britton Harris, "Plan or Projection," *Journal of American Institute of Planners*, XXVII (November 1960), pp. 265-272.

[9] Bureau of Public Roads, Instructional Memoranda, 50-2-63(1), Urban Transportation Planning (10 basic elements), September 13, 1963; HHFA, "Guidelines for Five Critical Points in Transportation Planning," December 29, 1964.

was required. The plans envisioned are to be characterized by consideration of all transportation modes, comprehensive interaction of transportation factors with demographic, social and economic factors, transportation system characteristics, a need for large-scale gathering of data to support the planning process, and the representation of communities in the area on the plan evaluation aspects. Public policy-makers are becoming cognizant of the fact that transportation systems serve as key controllable variables in guiding future desired economic and social postures of the region. This new approach to transportation planning has stimulated the efforts to the development of alternative policies to be derived from the goals of society. Emphasis is shifting from a projection of impacts of transportation policies to an evaluation in a broad framework of those impacts. This development has been accompanied by the development of "backward seeking" policy evaluation model framework (see below). Thus, if a shorthand description of the emphasis in planning process in the 1950's was projection, in the 1960's the corresponding term would be evaluation.[10]

The traditional approach to metropolitan planning, borrowed from planning at lesser (*i.e.,* architectural and urban) scales and focusing on the development of a master plan in the sense of a discrete guide to future development, has been undergoing substantial modification among planners and governmental practitioners. In part, this is a recognition of the urban community as a complex web of diverse and functionally interdependent interacting parts, with the parts evolving over time as they attempt to adapt to constantly changing contexts around them. An increasing emphasis on processes by which changes are introduced that will affect future character of the city and the effectiveness with which persons and activities will be able to interact in the future has become evident. The metropolitan transportation studies, particularly the Penn-Jersey (Delaware Valley) Transportation study, concerned with interactional flows among activities, played no mean part in this evolution. About the same time the enactment of legislation for Community Renewal Programs, though not explicitly concerned with metropolitan planning, vastly expanded the functional scope of urban land use planning and set the stage for identifying alternative policies whose consequences could be estimated and evaluated.[11] The recent establishment of the Department of Housing and Urban Development has provided a further impetus to metropolitan planning.

Thus, in summary, metropolitan planning today has both an interest in process and a desire for identifying goals. Alternative policies and plans are derived from these goals and their impacts estimated and evaluated. An emphasis on a broad range of impacts (magnitude and several dimensions of

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[10] See J. L. Schofer and F. J. Wegman, *A Transportation System Plan Design Model* (Northwestern Technical Institute, March 1966), Chart I.

[11] See Wilbur A. Steger, "Review of Analytic Techniques for the CRP," *Journal of the American Institute of Planners,* XXXI (May 1965).

impact stratification) of alternative policies and a focus on a multidimensional evaluation of these impacts are emerging in urban planning today.

Emerging Metropolitan Policy Issues

Emerging metropolitan issues, naturally, assume many forms: to Wilbur Thompson, "Urban-regional economics is just now coming into its own . . . [having] more than its share of the gut-issues of the day."[12] To Wingo, the issue is primarily a problem engaging "the whole institutional machinery for land allocation," so as to rationally consider "the spatial dimension of the accelerating urban revolution."[13] It assumes many forms, the clichés carrying their share of the objective truth: quality of the environment, slums and suburbs, the white noose, high central densities and amenities, magnetic vibrant downtowns, chaotic urban responsibility, total (national) responsibility for the ghettos and public welfare, no quick cures for congestion, the neighborly life, etc.

For a significant part, the issues revolve about the costs, benefits, and incicence of public investments and/or private investments affected by public actions in urban areas. These include the short and long-term effects of these investments on the stability, growth, and well-being of the combined private and public sectors.[14]

That we are speaking of enormous magnitudes is obvious. A recent study by TEMPO for the Executive Committee of the National League of Cities estimated that the total revenue needs for local governments in the decade to 1975 would exceed one trillion dollars, or an implied revenue gap, even extrapolating today's sources, of more than one-quarter of this total. The *Nation's*

[12] Wilbur R. Thompson, "Programs for Metropolitan Area Economic Growth," a paper prepared for the Third Regional Accounts Conference, November 1964.

[13] Lowden Wingo, Jr., "The Uses of Urban Land: Past, Present, and Future," Resources for the Future, Reprint No. 39, July 1963.

[14] No suggestion is being made here that these issues are entirely novel. Concern with improving the quality of our environment associated with the benefits of compact habitation is cited in literature of the eighteenth and nineteenth centuries. See O. C. Herfindahl and Allen V Kneese, *Quality of the Environment,* Resources for the Future, 1965, pp 53-54. Also, nineteenth and early twentieth century public concern for the slums, the poor, the market for low-income housing, and the role of inferior uses of land, are cited by Lowden Wingo, Jr., "Urban Renewal: Objectives, Analyses and Information Systems," a paper prepared for the Third Regional Accounts Conference, November 1964, pp. 7-8. Nevertheless, what is novel is the scale of public investment and the concern that the costs and benefits have an explicit and agreeable incidence. Also novel is concern with the *total* environment. "The formulation of an ideal environment should take into consideration all aspects of man's life including his emotional needs and the development of his civilzations." René Dubos, "Promises and Hazards of Man's Adaptability," *Environmental Quality in a Growing Economy,* ed. Henry Jarrett (Johns Hopkins Press, 1966), p. 37.

City special report, "What Kind of City Do We Want?" estimated that, between now and the year 2000, in real terms, "the money needed to build and rebuild our cities twice as big and twice as good will average out to over $100 billion a year": almost one-third would be for all new and better community facilities of all types.[15] Estimates of public service investment for each new household in the New York region is anticipated to be $16,800 in real terms.[16]

Viewing metropolitan issues in a framework of public investment concerns, at least three dimensions of issues are apparent.

Public Investments and the Geographic Hierarchy Issues. Public investments in urban regions of a mature, developed nation play a many-faceted role in the pursuit of development and distributional objectives. A direct impact of public investments is their income generation role through their stimulation of demand for goods and services.[17] These projects also have effects on human capital, improving its productivity and thus augmenting the regional production of goods in the long run. Again, by reducing factor costs, these projects generate internal economies for many sectors, thereby fostering external economies for all sectors. Further, public investments in certain regions, by generating growth in new sectors, may result in larger urban functions, in upgrading of the centers in the urban hierarchy, and in consequent urbanization economies that spur further growth.

Thus, the public investments generate a wide range of benefits, other effects, and incur attendant costs. An identification and measurement of these consequences and costs must be done through an overall appreciation of the economic panorama in the affected metropolitan areas, among regions, and the nation. Such an analytical framework, following Hoover, would investigate the impacts of public investments from:

- the *locational* viewpoint: the role of public investments in improving the comparative advantage for specific industries, population groups, etc.;
- the *regional* view: the interrelations among projects in terms of their impacts within the region over time; and
- The *interregional* view: the economic interrelationships among sectors, between regions, over time, resulting from these projects.

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[15] "What Kind of City Do We Want?" *Nation's City,* April 1967.

[16] Regional Plan Association (New York), Bulletin 100, "Spread City," September 1962; see, also, the National Planning Association Study on national goals by Louis Lecht.

[17] These effects are relatively easier to trace at the national level as payments for domestic factors of production. At the regional level, they are a function of interregional, interindustry linkages that determine the proportion of local productive inputs in the region.

This specifies one dimension of the issues' space, the geographical hierarchy: the Federal, interregional, subregional, urban and intraurban. This spatial hierarchy can be used to exhaust a wide variety of issues: the growth and cyclical stability, in relevant economic and social activities, at different levels of the geographical hierarchy. Similarly, comparative advantage theory can be applied to study the relative impacts of alternative mixes and quantities of public investment at different area levels. Most of the spatial, that is external, effects of location can be isolated within the spatial dimension.

The Public Versus Private Sector Issues. Another very important issues' dimension is that of the public versus private nature of infrastructure investment. If the geographical hierarchy issue is directed to what is to be done, this issue's area raises basic questions of how it is to be done.

There is nothing, *per se,* inviolate about the private nature of existing private sector investments. The line can, and has recently, moved across the spectrum of infrastructure investment types, as has the role of the various levels of government within the public sector. The latter involves the choice of revenue and expenditure incidence, and thus, client group redistribution, which is, of course, another important issues' dimension.

The public-naturedness of an investment is rarely a planning issue at the urban or regional level although it almost certainly should be a major one. The parameters of this dimension include:

- *The presence or absence of externalities,*[18] and the degree to which these can be measured, their incidence discovered, and redistributions accomplished or explicitly denied.[19] This latter possibility should be of particular interest to the urban-regional planner, since his expanding tool kit of analytic methods and information availability could substantially alter the previous externalities' determining equilibrium point.

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[18] O. A. David and A. S. Whinston, "The Economics of Complex Systems: The Case of Municipal Zoning," *Kylos,* 1964, pp 419-446; James W. Buchanan and William Craig Stubblebine, "Externality," *Economica,* 29 (1962); Ralpha Turvey, "On Divergences Between Social Cost and Private Cost," *Economica,* 30 (August 1963); A. Breton, "Towards an Economic Theory of Pollution Control and Abatement," London School of Economics, *Background Paper,* D29-1, 1966; O. A. Davis and A. B. Whinston, "Some Notes on Equating Private and Social Cost," *The Southern Economic Journal,* 31 (October 1965); J. M Buchanan, "Joint Supply, Externality, and Optimality," *Economica,* 33 (November 1966).

[19] G. M. Neutze, *Economic Policy and the Size of Cities* (The Australian National University of Canberra, 1965); J. A. Stockfish, "External Economies, Investment and Foresight," *Journal of Political Economy,* 63 (1955), pp. 446-449; R. N. McKean, "Some Problems of Criteria and Acquiring Information," in H. Jarrett, ed., *op. cit.,* pp. 63-65

- *The presence or absence of structural effects,* due to "the response in parameter changes in the technological, social, and economic organization of the metropolitan region."[20] At the very least, improved knowledge of the structural processes in the private sector can improve the planning and development achieved for public sector investment. At the other extreme, the structure can be manipulated by public investment and/or by converting previously private investments into the public category.
- *The feasibility and desirability of introducing, for external cost or net social benefit reasons, regulatory and/or pricing mechanisms.*[21] This is a major policy issue and yet it is rarely the subject of the planner's choice space. This is surprising because the choice frequently depends on the comprehensiveness, interrelatedness, and complexity of the urban-regional system under consideration, a subject matter quite familiar and important to the planner.
- *The feasibility and desirability of determining public demand, in the absence of a price system* Interpretation of voting statistics, budget-constrained time preference surveys, sociological and cultural interpretation, price-system proxies, and other methods: these have all been suggested as methods for estimating present and future public demand. These are recommended as short cuts for the difficulties of (a) interpreting individual preference functions, (b) aggregating them, or (c) predicting what they will be. Planners rarely enter this issues area systematically, although they do attempt to help communities explicitly state their competing goal structures.
- *The presence and extent of scale economics.* This should be a major dimension structuring the planner's view of the urban management functional systems, by area and subarea. Certainly at the regional level, the system of cities and supporting areas should be highly sensitive to the presence and extent of these economies. Furthermore, these economies can assume many forms, *e.g* transportation effects (intercity, intracity, parking, etc.); public sector goods and services effects (utilities

[20] L Wingo, Jr, "Urban Renewal· Objectives, Analysis, and Information Systems," *op. cit.*, p. 14; also, W. Thompson, "Programs for Metropolitan Area Economic Growth," *op cit.*, p. 12

[21] Davis and Whinston, "The Economics of Complex Systems," *op. cit*, pp 442-443; Allen V. Kneese, "Research Goals and Progress Toward Them," in H. Jarrett, ed., *op. cit*, pp. 72, 87.

and other); private sector goods and services effects; and other effects (land values, design potential, information and coordination potential, etc.). Nevertheless, planning information systems have not been geared to assist in this most important determinant of public-naturedness, our costing systems being totally inadequate for even Planning-Programming-Budgeting Systems, let alone the determination of total systems cost (capital plus operating, properly discounted).

This general lack of involvement of planners in the arena of public-private sector debate is particularly unfortunate because the following trends toward increased rationalization of planning activities [22] call for an intelligent, informed view of this issues area:

- With immense changes of real income, per capita anticipated, *e.g.*, a fivefold increase in 70 years, there is great need for responsible, long-run planning for changes in the tastes of the public, both for public and private goods;[23]
- With the intensification of jurisdictional interdependence, there is increasing need for an appropriate multiple hierarchy (in an areal sense) pricing system, or other relatively automatic and impersonal rationing devices;[24]
- With the decline of blue-collar workers, the urban environment will exist almost exclusively for decision-making, information processing and communication functions,[25] and with the increasing socialization of problem solving,[26] the *productivity* of decision-making and private and public planning will become increasingly recognizable and measurable;
- With the increasing cost of defining alternatives to examine, and collecting and processing the relevant information, there is recognition that a major role of planning is to choose those is-

[22] Donald N Michael, "Urban Policy in the Rationalized Society," *Journal of the American Institute of Planners,* XXXI (November 1965), pp. 283-288.

[23] W. A. Steger, "The Management Sciences: The Future Users," a paper presented at the Institute of Management Sciences Annual Meeting (Boston, April 1967).

[24] William Wheaton, "Metro-Allocation Planning," *Journal of American Institute of Planners,* XXXIII (March 1967), pp. 103-107

[25] R. L. Meier, *Communications Theory of Urban Growth* (*M.I T. Press,* 1962).

[26] H. G. Johnson, "The Social Sciences in the Era of Opulence," *Canadian Journal of Economics and Statistics* (November 1966)

sues to which planning and study resources are to be allocated;[27]

- With planning, design and architectural inputs so labor intensive, productivity is not likely to increase in these sectors at the same rate as other urban-oriented sectors, and planning will have to assume a vocal role to ensure that savings generated from the productivity increasing sectors are passed on to the planning sector;[28] and
- With increasing emphasis upon the economies and productivity due to concentrating human capital in dense urban areas, there will be greatly increasing attention paid to the allocation of scarce land resources — "space" being the major "urban-peculiar" intensively utilized factor of production.[29]

All of these offer reasons for the planning profession to be engaged more actively in important public-private area controversies, in addition to the spatial, physical, economic and social consequences of alternative public investment plans.

Incidence Issues. The final issues' dimension, briefly alluded to above, is that of the incidence of the effects of public and/or private investment choices, *i.e.,* the distribution and redistribution consequences. A major weakness of planning studies is their scant attention to the question of incidence of benefits. Public investment projects are often prepared for different client groups and also may affect a variety of other client groups in an indirect manner. For many planning projects, a basic focus is the effect that public investments may have, directly or indirectly, on low-income or high-unemployment subgroups of the population.

Several issues are important here. The characteristics of the local community where the public investments are located influence to a great degree the incidence of the benefits. Thus, the employment status, occupational or industrial affiliation, of the persons in the community may be highly relevant to them capturing the benefits occurring from a public investment project.

Again, there are spread effects of public investments from the locales which receive the investments to a few areas in the vicinity. No empirical evidence is available to infer these spread effects. However, public investments in some

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[27] M. Webber, "Comprehensive Planning and Social Responsibility," *op. cit.;* L Wingo, Jr., "Urban Renewal: Objectives, Analysis and Information Systems," *op cit.* pp. 5-6.

[28] This argument is due to William Baumol's discussion of planning for urban growth in an "unbalanced" economy.

[29] H. Liebenstein, "Long-Run Welfare Criteria," *The Public Economy of Urban Communities,* ed. Julius Margolis (Resources for the Future, 1965).

urban areas or urban growth poles improve their comparative advantage vis-à-vis other places, thereby resulting in spread effects from that growth pole to adjacent areas — suburban or otherwise. Such spread effects may not be incident to a great degree in lagging regions. An investigation of these differential spread effects involves explorations of different characteristics of the communities in growth poles versus lagging regions. On the other hand, the spread effects may be understood in terms of interindustry linkages among different regions.

The delineation of these types of incidence is no easy matter. One set of estimates required is the change in number of families in different income groups in areas where public investment projects are made. However, certain aspects of incidence, for instance the temporal aspect, are even more difficult to discover. For these, what is required is the development of a framework posing the problem of incidence of project benefits. These frameworks then may suggest further analytical work into this problem. An example of this formulation may be a three-dimensional array of benefit incidence, the dimensions being the different income groups, types of public investments, and temporal — temporary or permanent — benefits.

In summary, the metropolitan policy issues requiring in-depth planning consideration and evaluation are all concerned with infrastructure investment: first, the geographical distribution, for growth, stability and comparative advantage reasons; second, the responsibility of the public sector; and third, the distribution effects. These are the classical economic issues of efficiency, equity, and non-competitive system effects.

VIEWS OF THE PLANNING PROCESS

This section is addressed to a description of the planning process in some detail, to help locate the role of evaluation in this process.

Models of the Planning Process

In general, the metropolitan planning program (Fig. 1) is one in which: (a) future regional needs and challenges are anticipated, (b) alternative strategies addressed to these issues are forced, (c) the crucial impacts or outcomes of each of the alternative planning strategies stated above (in b) estimated, and (d) the evaluation of alternative plans or designs based on more or less general criteria applied to the delineated impacts.[30]

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[30] We borrow most heavily, here, from knowledge of the following studies: Detroit Land Use and Transportation, Bay Area Transportation; Penn-Jersey (now Delaware Valley) Transportation; Southwestern Pennsylvania; Southeastern Wisconsin; Baltimore Regional Planning Council, and several (previous and existing) Community Renewal (and Analysis) Programs, in particular, Los Angeles, New York City, Pittsburgh, San Francisco and St. Louis

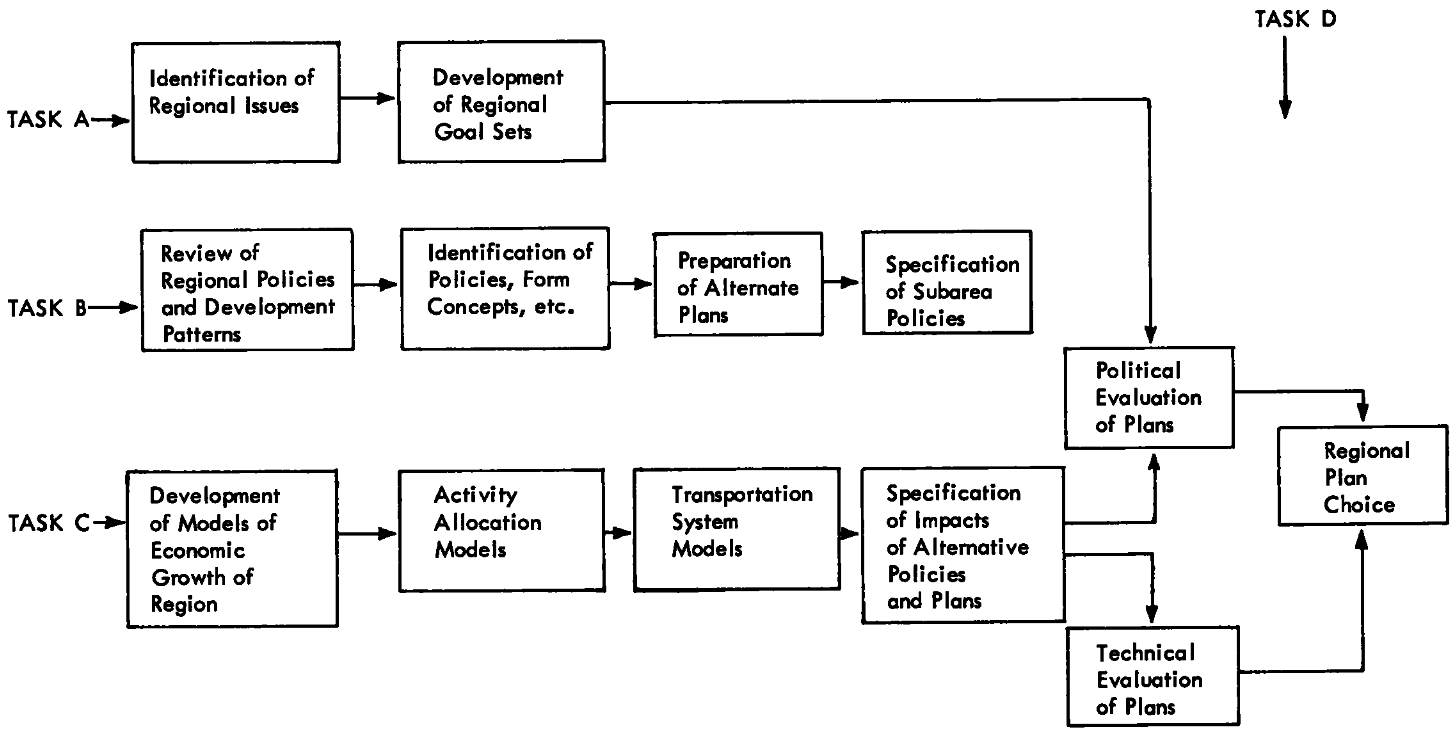

Figure 1. A simplified model of a regional planning work program.

This process is largely to be regarded as cyclic and continuous. The impacts and evaluation of one set of metropolitan plans may well suggest a return to the process of synthesis for fresh generation of alternatives. Again, the evaluation criteria themselves derive from regional goals that influence the development of alternative plans and indeed may guide the choice of the policy or instrumental variables appearing in these alternatives. Further, as future regional needs are reassessed, the process feeds back into itself. Thus, planning must be viewed truly as a continuing comprehensive process.

Such a process by its nature calls into play a creative, subjective, and synthetic thought process on the one hand and an analytic and objective effort on the other. Thus in contextual (goal setting) and synthetic (development of plan alternatives) phases of planning, a great deal of imagination and subjectivity are called for in identifying what goal sets are desired and how existing or new structural and form elements can be combined to produce desired metropolitan futures. However, in the phase of "plan testing" or estimating the impacts of outcomes of alternative policy bundles, analytical techniques play a crucial part.

The last statement needs some elaboration. The impact estimation phase involves essentially the establishment of the functional relationship between the control or instrumental or policy variables which are crucial to plan selection. These interrelationships are often very complex and difficult to trace and understanding of these underlying relationships is the focus of many land use or regional growth models.

The process of evaluation ideally involves the establishment of an overall criterion for evaluation and selection from among alternative plans in terms of their impacts (benefits and costs) This implies that various types of impacts would have to have weights attached to them relative to one another to help in this grand choice. It must be obvious that a sophisticated knowledge of the value system and its dynamics is called for if such a task is to be undertaken fruitfully. Such knowledge should embrace estimates of tradeoffs among values and the degree of satisfaction of these values in a commensurate fashion.

The planners can hope to elucidate this problem in cooperation with social scientists in developing over time a greatly enriched and multidimensional benefit-cost analysis that explores peoples' goals and desires in their plurality and communality. The set of interacting values that are mediated by societal and technical relationships (determining the rates of tradeoff) are expected over time to be exposed for the public consideration and decision-making. In this way, decision-making is anticipated to be assured considerable objectivity and a broader participation.

Such are the theoretical underpinnings of the planning process of the more sophisticated metropolitan studies. They suggest techniques that are in many respects futuristic and non-operational. Consequently, as mission-oriented agencies, the work program describes the essentials of an operational strategy to plan development and evaluation from the complex (and at places intractable) planning methodology, outlined above. Such strategies are designed to reflect the resolution of the tradeoffs among various complex aspects of goals definition, design, and evaluation of the future regional plans.

The planning process poses a number of very imposing demands for the policy-maker. Such requirements include a specification of goals and values and agreement in advance, wide canvassing of plan alternatives addressed to these objectives, a similarly systematic analysis of consequences of each alternative, and for policy choices to be evaluated against the selected goals. In practice, the selection of goals is a very tricky and difficult political process; complete information on relevant measures of all consequences is not always possible to develop and, when developed, difficult to comprehend; and, finally, the requirements of evaluation pose conceptual and technical problems. These considerations have persuaded some theorists, including Braybrooke and Lindblom, to suggest a strategy of "disjointed incrementalism" such as the following: [31] describe the metropolitan system; identify problems in the system; establish short-term objectives; generate alternative plans for problem solution; and evaluate plans in terms of short-term objectives.

It is believed that decision-makers focus on incremental alterations of existing social states rather than an erection of rationalist, deductive, long-run metropolitan system.

In this process, one begins by using a descriptive model of the metropolitan system without making long-run predictions because it is assumed that decision-makers in the political milieu will tend to seek solutions which ameliorate existing problems rather than allow an approach to a set of predetermined goals. For this reason, although one wishes to use the most comprehensive, most accurate and most precise descriptive models available, almost any incremental description is suitable for getting to the next step provided that it is generally believed to be a reasonable description of reality.

This next step is the step in which we identify problems in the system. Identification of problems implies value structures and goals, but here one is able to side-step the problem of goal setting because very often two individuals or groups with conflicting goals will agree to the existence of a problem and call for its solution or eradication. Problems will appear as misallocations, gaps, and functional misfits. Most problems lend themselves also to be broken down to smaller problems.

Having identified problems, it is necessary to establish some very short-term objectives for problem solution. These objectives would be problem avoidance or problem amelioration objectives rather than positive goals.

Then one generates alternative plans to meet these objectives. Since an incremental approach is being taken to generally agreed upon problems, plans can be developed problem by problem and interdependencies between problems can be considered after solutions are found. The important thing is to

[31] David Braybrooke and Charles E Lindblom, *A Strategy for Decision Policy Evaluation as a Social Process* (New York· The Free Press of Glencoe, 1963).

generate plans which cover the full range of feasible choices open to decision-makers.

In the evaluation stage a more limited view of the scope of evaluation is adopted. Again, plans must be evaluated in terms of problem-oriented objectives for the comparison between plans. The evaluation of the plans can then continue by applying the rather less sophisticated evaluation techniques which are less demanding than the social welfare functions implied in the previous model. The incremental planning process is intended for some of the problems which have been identified for which the relevant variables in the process can be forecast. This portion can be performed on a limited and selective basis.

Dimensions of the Planning Process

These two models obscure many of the underlying dimensions of the metropolitan planning-decision process. Identifying those "dimensions" should help in clarifying the choices planners and analysts have already made in establishing the process as described. It should also indicate choices which remain to be made in improving this process.

The nature of this process, in each instance, is conditioned by the relative emphasis that a planning effort places upon each of the following approaches [32]

Forward Versus Backward-Seeking Processes.[33] Backward-seeking processes automatically precalculate, in a time-phased manner, all that is required to achieve an end state, optimally. The appropriate land use forms, socioeconomic changes, and transportation links are staged endogenously within the process. If models are involved, these analytically create, for instance, the set of networks which produce alternative desired regional configurations for any given multiple-goal objective function.[34] Most current studies are forward seeking, where alternatives for manipulating the modeled environment toward an implicitly or explicitly stated set of goals are chosen carefully for test.[35]

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[32] These dimensions are not completely orthogonal with respect to one another, nor are they listed in order of importance.

[33] H. W. Bruck, "Problems of Planning for the Future: The Marriage of the White Queen and Tiresias," paper presented at the National Transportation and Railroad Symposium (San Francisco, May 1966)

[34] H. W. Bruck, S. H Putman, and W. A Steger, "Evaluation of Alternative Transportation Proposals: The Northeast Corridor," *Journal of the American Institute of Planners*, XXXII (November 1966), pp. 322-333.

[35] A notable exception, with its emphasis on transportation and land use design optimization, is the Southeastern Wisconsin Study. Report No. 7, *Forecasts and Alternative Plans, 1990* (Southeastern Wisconsin Regional Planning Commission, June 1966).

Multiple Versus Single Goals. With the advent of the writings and thinking of Carroll,[36] Holmes,[37] Garrison,[38] Fagin,[39] and Bureau of Public Road manuals and other publications,[40] a number of transportation related, economic, social, regional planning, aesthetic design, and general criteria are now essential parts of the overall process. Various measures are recommended such as benefit-cost ratios and rates of return for transportation efficiency, qualitative measures for performance and design, accessibility and cost measures for economic efficiency, cost and accessibility measures for social criteria.[41] Arbitrary, but explicit, weighting schemes are then applied to these multiple measures. The trend in existing studies is, of course, towards the multiple criteria and multiple measures.[42]

Planning Versus Policy Making. While, at one time, it was generally accepted that urban and metropolitan planning should be non-political, there is increasing communication between the professional planner and the policy-makers of governmental units. The criticism of their non-political role and responsibility has led to a number of proposals, including a variety of new political forms. The preparation and review of metropolitan issues; the development of goal sets; the development of alternatives; the review of regional policies and development patterns; the generation of policies, form concepts and structural aspects; and the preparation of alternative plans and subarea policies: these all will be affected by the subtle changes already taking place in the planner-politician relationship.[43]

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[36] J. Douglas Carroll, Jr., *Urban Transportation Research,* HRB SR69, 1962

[37] E. H. Holmes, "Why Transportation Planning?", Bureau of Public Roads, May 1964.

[38] W Garrison, *et al*, *Studies of Highway Development and Geographic Change* (University of Washington Press, 1959) See, also, N Irwin, "Criteria for Evaluating Alternative Transportation Systems," a paper prepared for Highway Research Board, Forty-Fifth Annual Meeting, January 1966.

[39] H. Fagin, "Urban Transportation Planning Criteria," The Annals of the American Academy of Political and Social Sciences, March 1964.

[40] *Guide for Highway Impact Studies,* 1959; *Manual 9, Social and Community Value Factors,* prepared for the Ohio Department of Highways by Vogt-Ivers and Associates, 1966; Jacob Silver and Joseph R. Stowers, "Population, Economic and Land Use Studies in Urban Transportation Planning," July 1964.

[41] Southeastern Wisconsin, *Volume II, op. cit;* also, Bureau of Public Roads, *Manual 9, Social and Community Value Factors, op. cit.*

[42] Alan A. Altshuler, "Rationality and Influence in Public Service," *op. cit.;* also, Altshuler, "The Goals of Comprehensive Planning," *Journal of the American Institute of Planners,* XXXI (August 1965).

[43] Bernard J. Frieden, "Toward Equality of Urban Opportunity," *Journal of the American Institute of Planners,* XXXI (November 1965); Melvin M. Webber, "Comprehensive Planning and Social Responsibility," *Journal of the American In-*

Planning Versus Functional Control Operations. In contrast to most planning problems, which are concerned with determining whether or not feasible solutions exist, governmental control and control theory concerns itself mainly with findings and optimal solution, assuming that feasible solutions exist. Thus, to the degree that planning assumes a more backward-seeking theoretical base, the more control aspects it will assume as responsibilities. Furthermore, planning is becoming more concerned with changing (or advocating changes in) goals and restrictions which make certain plans unfeasible, which is a complement to the control process. Other dimensions related to planning versus control are feasibility versus optimality, where the objective function can or cannot be defensibly constructed, acceptable to all members of society, and the duration over which the plans are to be effective. Most transportation and land use plans are designed to be effective over a medium to long range; however, there is increasing emphasis placed on short-term planning requirements, with advocates calling for explicit requirements for short-term programs and concrete provisions for short-term action, such as is imposed (or proposed) for urban mass transportation, water and sewer facilities, and open space land program planning Another related dimension is that of planning versus functional management decisions; clearly, most planning has not been and will not be involved with the operational aspects of managing currently operating metropolitan service facilities. Nevertheless, there is increasing realization that many of the cost, benefit, effects, and incidence data are an important by-product of current functional agency operations, and planning familiarity is necessary for planning to make correct operational and control assumptions. One consequence is that the transportation and land use planning process frequently has ignored important and relevant functional areas, such as housing, where the operational and current management decisions are so crucial and frequent as to overshadow the true merits of longer-range planning. Increasingly, functional areas such as housing and recreation are being considered as detailed subject matter for regional planning studies, along with transportation and land use

Comprehensive Versus Particular Problem-Solving. The first four dimensions are aspects of the overall "degree of comprehensiveness" dimension. This takes many forms, all of which are tied to the planner's concept of the metropolitan region as a complex social system, for which public resource allocation has to be performed "as a whole." Nevertheless, the degree of "wholeness" — the number of functions to be viewed as interacting simultaneously and rele-

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stitute of Planners, XXIX (November 1963); Paul Davidoff, "Advocacy and Pluralism in Planning," *Journal of the American Institute of Planners,* XXXI (November 1965); U S. Senate Committee on Government Operations, Subcommittee on Intergovernmental Relations, *The Effectiveness of Metropolitan Planning,* June 1964 vant to a specific problem — is, itself, increasingly viewed as a subject for cost-effectiveness analysis. The lack of intensive use of the largest of the models — the Pittsburgh model and the San Francisco model — is partially due to the large cost (computer time for the San Francisco model) or, in the view of the current head of Pittsburgh City Planning, the overambitious nature of the Pittsburgh model which seeks to account for so many individual decisions.[44] Problem-solving efficiency increasingly is being seen as a process to be rationalized, itself, and planning agencies are learning to better "package" problems and problem-solving mechanisms to take advantage of joint costs and benefits.

Physical Versus Social Planning. Planning has learned to extend interests beyond physical locational arrangements so as to avoid the imposition of disproportionate costs upon one client group in order to benefit another unless suitable compensation is or can be made. Increasingly, planning programs—particularly Housing and Urban Development 701 Programs — are subject to criticisms if they lack substantial reference to the social or economic impacts the plans might have, and the incidence of these impacts.[45] The obsolescence of merely locational planning is particularly relevant to transportation planning in a developed economy, since several recent studies, in particular the Penn-Jersey land use models, confirm the earlier observation that "today highway improvements are effected in a developed economy which has an extensive transportation system and where improvements continue to whittle away at spatial imperfections and further reduce the value of situs . . . one should no longer expect gargantuan dislocations because of improvements providing access to land of greater productive capacity . . . nonspatial relationships appear to be of even greater importance."[46] Analogous reasoning has extended to critical evaluation of the use of quantitative cost-benefit indices in social planning; *e.g.*, planning resource allocation for the poverty program.[47]

Automation Versus Manual Operations. Naturally, the trend is toward increasing use of computers in the entire process. It is possible to characterize

[44] The Planning Commission apparently also believes that relatively "narrow objectives," such as developing a strategy for racial balance in the school system, or extensive clearance in one area, could be assisted through the use of the model and that, eventually, a large-scale testing of numerous alternatives could ultimately be achieved. Bernard Fuchs, "Federal Comprehensive Urban Planning Grants," U.S. Bureau of the Budget Memorandum, November 1966

[45] See the contributions by Ira M. Robinson and Harvey S. Perloff in the *Journal of American Institute of Planners,* XXXI (November 1965)

[46] Robert H. Stroup and Louis A. Vargha, "Reflections on Concepts for Impact Research," a paper presented at the 40th Annual Meeting of the Highway Research Board (Washington, January 1961).

[47] Martin Rein, "Social Science and the Elimination of Poverty," *Journal of the American Institute of Planners* XXXIII (May 1967).

their role in a forward-seeking process by examination of the shaded areas of Figure 2.[48] Here, much of the estimated impact and incidence information is calculated for each alternative investigated by the use of a computerized land use-transportation systems simulation effort, drawing upon a partially or wholly automated stored information source. Much of the process is manual in this forward-seeking version. However, development of methods for calculating efficient sets of choice possibilities,[49] estimating community needs and values,[50] and determining "optimal" project-program mixes[51] are all the targets of analytic methods of the next decade but are clearly not yet available for practical application, across the board, in forward-seeking processes. The backward-seeking process, on the other hand, also will lend itself to automation of these features, leaving only the decision-makers' *ad hoc* information sources and confidence checkout techniques of Figure 2 free from the influence of automation.

EVALUATION METHODOLOGIES

This section provides a description of the framework for articulation of the evaluation problem, the requirements for evaluation and some previous attempts at grappling with this problem. This discussion essentially focuses on conceptual and fundamental issues in evaluation and turns to questions of detailed method and technique only minimally.

Goal Identification

Crucial to the process of successful regional planning is a clear understanding of regional goals. Far too often, planning has been beset with difficulties resulting from a failure to use an explicit consensus of goals and objectives as a base. The more sophisticated studies are extremely conscious of this and engage in the task of delineating realizable goals. The opportunities and challenges for developing the region are viewed in the aggregate and a broad set of general region-wide goals developed. Some goals of the region are implicitly understood by each citizen and by the community forces that comprise the

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[48] This is a modification of a figure developed by Nathan Grundstein for the Pittsburgh simulation effort See Grundstein, "Urban Information Systems and Urban Management Decisions and Control," *op. cit.*, p. 5.

[49] Marvin L. Manheim, *Hierarchical Structure: A Model of Design and Planning Processes,* M.I T. Report No. 7 (M.I.T. Press, 1966)

[50] William C. Birdsall, "A Study of the Demand for Public Goods."

[51] W. A. Steger, "Analytic Techniques to Determine the Needs and Resources for Urban Renewal Action," Proceedings of the IBM Scientific Computing Symposium on Simulation Models and Gaming, December 1964; Robert C. Meier, "The Application of Optimum Seeking Techniques to Simulation Studies: A Preliminary Evaluation," *Journal of Financial and Quantitative Analysis,* 2 (March 1967)

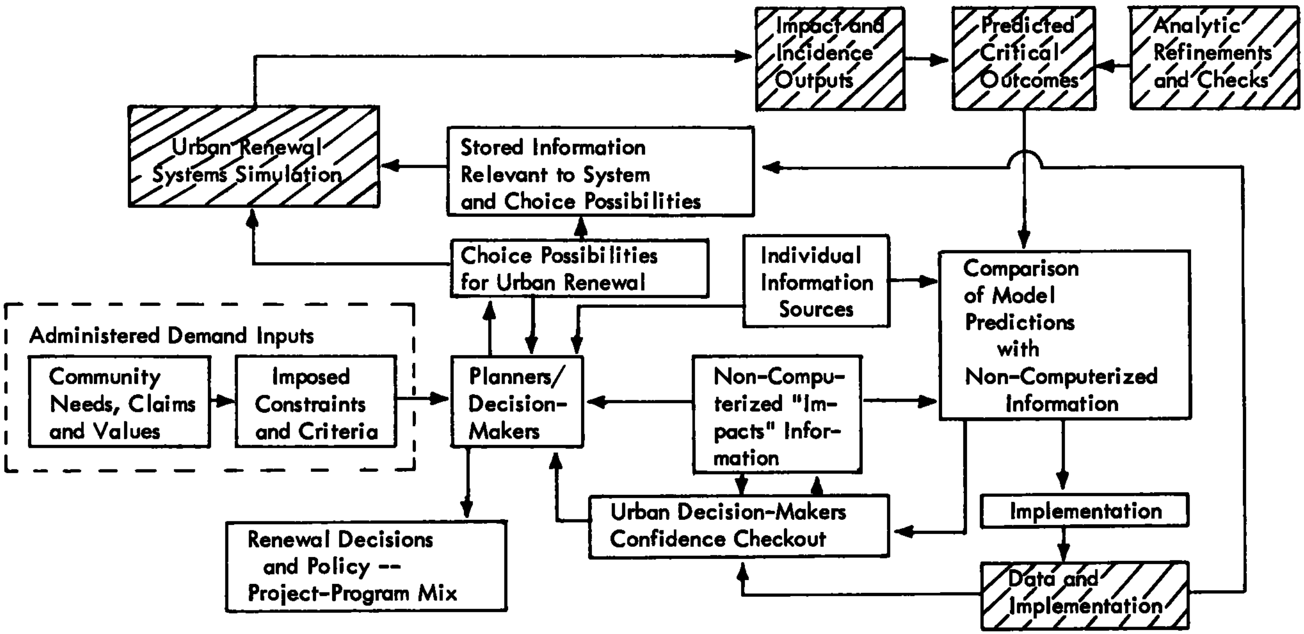
Impact and Incidence Outputs
Predicted Critical Outcomes
Analytic Refinements and Checks
Urban Renewal Systems Simulation
Stored Information Relevant to System and Choice Possibilities
Choice Possibilities for Urban Renewal
Individual Information Sources
Comparison of Model Predictions with Non-Computerized Information
Administered Demand Inputs
Community Needs, Claims and Values
Imposed Constraints and Criteria
Planners/ Decision-Makers
Non-Computerized "Impacts" Information
Implementation
Urban Decision-Makers Confidence Checkout
Renewal Decisions and Policy -- Project-Program Mix
Data and Implementation

Figure 2.

functional economic, social and political groups within the region. Implicit goals, however, must be set forth explicitly in the agency so as to develop a framework for programs of action that do represent the synthesis of collective need. These goals also provide a basis for identifying the leverage for alternative development patterns.

Many agencies conduct substantial analysis of data on socioeconomic variables and physical variables such as housing, land use, and transportation of all modes. From such informational bases, an attempt is made to identify to the extent possible the requirements suggested by the goals. Further, a general interpretation of the association between what is desired and the sort of control (or instrumental policy) variables to bring them about is often attempted. In addition to these formal and semiformal attempts, informal inquiries with key persons and groups have been helpful in identifying general development goals in the region. These regional goals may be specified over time and refer to various dimensions such as transportation, land use arrangements, and economic growth.

In the identification of goals, it may be conceptually satisfying to recognize two broad categories of goals performance goals and contextual goals. Performance goals and associated outputs are directly related to the performance of the system under review. In the case of a transportation system they refer to performance characteristics of the system. The contextual goals arise because of the way performance goals are realized. In the case of an urban area, visual beauty, pollution abatement, and noise reduction are examples of contextual goals that may be expressed in terms of threshold levels to be assured. It may be that a contextual goal of an earlier period, once recognized, may be incorporated into the performance goal structure at a later point in time of a region.[52]

Another point to recognize is that an urban system has multiple goals and the planner might want to specify an explicit utility (or trade-off) function that transforms all goals into a single compound goal. Different goals in the urban area are often hopelessly incommensurable in the sense that no general consensus exists as to the trade-off among them. In such a case, a spurious trade-off function suppresses information about alternative plans rather than simplifying the selection process.[53]

Sometimes, the global objectives of a large system such as an urban region, can be factored into a hierarchy of more manageable subobjectives[54] This is done through a means-end analysis that relates the desired end results to the means of accomplishing them. However, it must be clear that the goals generated in this manner at each level — regional, jurisdictional or subarea — are normally multidimensional, because.

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[52] Edwin Thomas and Joseph Schofer, *op. cit.*

[53] Hitch and McKean, *The Economics of Defense in a Nuclear Age* (Harvard University Press, Cambridge, 1960).

[54] March and Simon, *Organizations* (Wiley, New York, 1958).

- Compression of incommensurables reduces the information content;
- Multiple goals are often used as an approximation for a single "real" goal that cannot be measured in practice; and
- Multiple goals are often generated as a means of coping with interactions among different areas in the same level in the hierarchy.

A final point often made is that goal identification is not concerned with ultimate values, but with *proximate* values on which people who disagree on ultimate values can often agree.

In summary terms, the role of this process of scanning the region for issues and goals is not only to provide a point of entry into the planning continuum but also to provide a basis for testing the acceptability of proposed plans. It is designed to assure that issues are formulated and plan solutions developed with constant references to the totality of requirements, values, and constraints imposed by the regional and larger environment. Further, it is addressed to the requirement that land use and transportation prognoses over the planning period be formalized, made explicit, communicable, and hence subject to criticism and reappraisal. In this process, it may help identify goal conflicts and institutional constraints. At the end of this task, a set of goals relevant to the land use and transportation study and recognized on a functional basis will emerge. A set of tentative criteria reflecting the requirements imposed by the selected goal set may also be developed to be helpful in the evaluation phase.

Plan or Policy Design

This phase is concerned with the development of alternative plans or future end states and the policies that are suggested by the goal set chosen. The goal set may suggest a variety of desirable attributes which may conflict or be available at excessive costs (broadly conceived). Thus, as Harris points out, all locators in a metropolis cannot be given space, choice, and convenience — surely not at acceptable levels of cost and safety. Some balance is struck on the assumption that in principle one can manipulate the balance of these desired goals in alternative ways by postulating various levels of density of residential development and the location of employment.

Alternative sets of general policies and regional development patterns are prepared in conjunction with the goal statement. Such a review must be posed in a context that helps the sketch planning process, which may be defined as the preparation in a preliminary fashion of a number of alternative plans at an appropriate level of detail. The preparation of these alternatives permits the planning staff to explore the possibilities in the situation, set forth new ideas, and devise a basis for comparison among plans. Such imaginative views are often qualified by the awareness of the significant stability and conservatism inherent in current policies and development patterns. The ability to innovate is often thus in a narrow planning range. The recognition of this leverage for planned action is an essential preamble to the development of alternative plans.

In the light of the overall goals, a range of policies, form concepts, interaction concepts, and structural relationships that may be implied in the goal sets and the devised end-state spatial patterns are generated. It is easy to imagine that the resulting combinations of policies, form concepts and interaction arrangements can be a very large number. Care must be taken to assure that a few sets that include a wide range of possibilities which in terms of generic capability merit incorporation in plans be developed. A few preliminary analytical procedures must be employed to array and screen major combinations of policies, form concepts, etc. Such procedures related to performance aspects of physical environment may be relatively simple in concept but yet can be a useful adjunct to the combinational problem referred to above. It is in this manner that plan design and evaluations are highly interconnected.

The identification of each lever or control variable that can respond to public policy is therefore of strategic importance for goal achievement. This aspect of policy design can be illustrated in the context of a public investment program addressed to the economic development of an urban region.

In such a context, one must emphasize the importance of identifying all relevant control variables available to public influence, whether they be attached to the public or private sector of the economy. The first important analytical task is that of classifying public investment activities so as to identify all control variables that are relevant for achieving economic and social development goals, and of defining or classifying public investment activities in terms of these control variables. The significance of this type of classification scheme is that it relates existing public investment alternatives directly to their role in influencing the economy toward goal achievement in the same terms that may be employed in the analytic framework. In addition, it would suggest areas of public activity for which policies have been inadequately addressed.

A preliminary set of control variables into which public projects and programs may be classified include:

A. Indirect Controls (goal achievement through private sectors)

1. Primary resource development: (a) land orientation (including natural resources), (b) labor orientation (manpower development), (c) capital supply, and (d) entrepreneurship.

2. Social overhead capital (a) water supply, (b) power orientation (*i.e.,* electrification), (c) transportation, (d) education, and (e) communication

3. Amenity orientation: (a) park and recreational development, (b) residential investments, (c) cultural development, and (d) pollution reduction.

4. Urbanization and localization economies (market-orientation and growth pole effects). (a) sewage treatment and disposal, (b) health facilities, (c) industrial complex development (industrial state), and (d) mass transit.

B. Direct Control

1. Expenditure impacts (*i.e.*, government purchasing).
2. Employment in public works projects.
3. Employment in local, state, and Federal government.

The public policy instruments listed under Indirect Controls essentially affect performance variables, such as per capita income in a particular area in a specific time period, by upgrading internal and external locational advantages with respect to some specific industrial sector or population class for the purpose of effecting private capital or human investment in that region. On the other hand, direct controls affect performance variables with full control (*e.g.*, unemployment in an area is reduced through jobs created in a water resource development project). Both types of controls, however, further indirectly impact goals through various economic and social relationships.

The metropolitan plan incorporating many dimensions of physical, economic, and social development goals definitely offers a broader and more complex set of control variables than presented above. Thus, this list of control variables must be viewed as illustrative. However, it does represent many types of alternative opportunities that exist for the application of urban and regional public investments in attaining a variety of development goals.

Finally, the preparation of candidate plans that incorporate the results of all previous work is carried out. Such plans express in cartographic form land uses — their types, densities and disposition— transportation facilities, natural features and form concepts. These plans are the alternatives for testing through the models

In summary, the process of plan design consists of specifying various decision, or control variables (or policies) addressed to the planning objectives in the estimation phase and their expressions in plans. Independence obviously does not exist among all the variables and relationships that could be used to describe a plan. The choice of some variables as decision variables is somewhat arbitrary and depends to a considerable extent on the planner's view of the goal structure and ease of expression. In this judgment, the planner is considerably influenced by the outcome or impact measures to which we turn next, and the criteria used in the evaluation phase.

Estimation of Impacts of Alternate Control Variables

The impact estimation phase involves essentially the development of functional relationships between control or policy variables and the impact or effect variables identified as crucial to plan selection.

To identify the scope of this phase, one can begin by considering what information would be desired in an infinitely informed analytical climate. The fundamental dependent variable is, ideally, not only the magnitude of each type of effect but also the distribution of such overall magnitudes with respect to several important dimensions of incidence stratification: the time period, areal unit, and economic sector or population group which occasions any given effect. This broadly defined dependent variable is influenced by the fundamental characteristics of each hypothesized policy or project and the particular combination of such projects. The fundamental characteristics of any given project include its magnitude, project type, the time period of implementation, and its geographic location. The consequent effect depends upon the location characteristics of the respective areas in which each benefit type is occasioned. An ideal analysis of effect would trace the influences of such a complete characterization of projects and the local characteristics of the incident area(s), including interdependence effects between areal units and between projects.

For the sake of convenient exposition, it is helpful to cast this impacts problem into mathematical language. Assuming that all impacts of a set of public investment projects can be determined in reference to the project as a fundamental analytical unit, there are two distinct types of effects which must be considered. Some projects are mutually exclusive, while others entail joint effects. Accordingly, all relevant information about the effects accruing from any proposed set of projects, together with any hypothesized schedule for implementing any such projects over time, can be summarized by the following two descriptors:

$A^r_{g,s,j}{}^{(t_k)}$ = the magnitude of effort type r accruing during time period s incident upon population group j (or, alternatively, upon industrial sector i) in areal unit g, associated with the implementation of project k during time period t_k (for all g, j, r, s, and k)

$B^r_{g,s,j}{}^{(t_k,t_l)}$ = the incremental magnitude of effect type r occurring during time period s incident upon population group j (or industrial sector i) in areal unit g, associated with the joint implementation of both project k during time period t_k and project l during time period t_l (for all g, j, r, s, k and l)[55]

The parenthetical notation is employed to depict the three descriptors as a function of the choice variables t_k *and* t_l. Given such a complete description of each project's potential effects the general evaluation problem is to describe which specific projects should be implemented and how they should be staged over time. This problem is tantamount to choosing values for the t_k and t_l which are, in at least a crude sense, optimal or at least preferred over the range of projects considered.[56]

[55] Inherent to this conceptualization of the "joint" descriptor is the assumption that third-order effects (second-order interproject externalities) are negligible. This involves questions of project complementarity below

[56] We have already seen that much planning is of the "feasibility" or "satisficing," rather than the optimizing variety. J. W. Dyckman cites Herbert Simon's views as most descriptive of long-range social planning methods in "Planning and Decision Theory," *Journal of the American Institute of Planners*, XXVII (November, 1961), p. 339. Dyckman cites as reasons the difficulty of formulating objective functions, the difficulty of mathematically optimizing one, even if it exists, and the large cost (in time or money)—even if one *could* achieve a solution.

Given these descriptors of effects, it is further necessary to establish the cause-effect functional relationships by which the effects descriptors depend upon individual projects' characteristics, the combination of projects, and local characteristics.

$I^k_{h,\,t_k}$ = the magnitude of investment prescribed for project type k in areal unit h, implemented during time period t_k

$X^r_{g,\,s}$ = the magnitude of local characteristics type r in areal unit g at time period s.

Given these definitions, two types of functional relationships are of interest, expressed as f and g in the following mathematical statements:

$$A^r_{g\ s,\,l}{}^{(t_k)} = f(I^k_{h,\,t_k}, X^r_{g,\,s-l})$$
$$B^r_{g,\,s,\,l}{}^{(t_k,\,t_l)} = g\,(I^k_{h,\,t_k}, X^r_{g,\,s-l})$$

Note that, as the notation implies, effects may be defined as temporal increments or decrements in the local characteristics variable.

Utilizing the Impact Vectors· Transformation to Preference Vectors

The difficulties of transforming impact vectors to explicit preference vectors should not prevent the metropolitan planning agencies from attempting this task in one way or another. A decision must be made, and, while that decision is the responsibility of policy-makers, the planning effort must assist that decision-making process to the extent possible.

The first point to be realized in this context is that this sort of public investment decision has been made many times in the past. That is, various types of effects for which no obvious value exists in fact have had weights attached to them, although they are entirely subjective weights implicit to the thought processes of policy-makers.[57] Whether these decisions have been correct cannot be determined by any means; value judgments of policy-makers represent the final word. On the other hand, there may be legitimate cause to question whether those decisions have been made or even can be made by sounder methods. More to the point, the planning effort must address the question: given the communication of all relevant consequence information, how might the planner assist the policy-maker insofar as the latter's comprehension and comparison of these consequences are concerned?

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[57] This observation requires some qualification since practically all of the decision processes in which such "weights" have been attached have involved only a few effect variables, often times only two (efficiency and income distribution). On the other hand, it may be argued that, whether or not a policy-maker has dealt with only a few variables for which explicit information has been quoted, the question of what other (unmeasured) effects he *perceives* is purely speculative.

It is most convenient to approach this matter in reference to a general abstraction of the decision-making process, which is borrowed from Holt.[58]

> Any brief summary of the process by which the President, the Congress, and the electorate of the United States reach decisions on national economic policy is necessarily a crude caricature. Nevertheless, if we are to discuss some of the basic elements in the process, some such simplified picture as the following is needed: first, a problem is recognized which requires attention; second, alternative courses of action are formulated; third the outcome associated with each of the alternatives is predicted; fourth, the outcomes are evaluated to determine their relative desirabilities; fifth, a choice is made in the context of conflicting political and constituency interests. The actual process is, of course, a complicated successive approximation procedure: for example, one of the political choices may be to redefine the problem—thereby starting the whole process from the beginning again.

The concern here, of course, is with the last two elements of the decision process. Implicit to those elements is the formulation of a criterion function and the assignment of a weight to each outcome type, by each policy-maker individually in the first instance. The point to be realized here is that decisions on social investment, by the very fact that they are made, implicitly involve benefit calculations and therefore weights.

The discussion is of course extremely academic, but serves as a convenient point of departure as well, making the problem more explicit: how might the planner assist the policy-maker in assigning relative weights to effect variables? This is perhaps the most difficult aspect of the entire evaluation process, arousing considerable debate.

One finds many endorsements in the literature of both extremes of this debate, as well as the less staunch positions. A variety of intellectually appealing but mostly untried techniques for estimating relative weights for multiple-objective decision situations have been advanced, hypothesizing that the preference functions of policy-makers can be identified in objective terms through opportunistic interrogation.[59] Others argue that utility, by its very definition, cannot be measured, but that these methods attempt to do so. Still others suggest that, while utility-conversion factors are too nebulous to probe, it is sensible to pursue, where possible, the development of dollar conversion factors. The use of rating schemes for evaluating preferences has also been a rapidly developing technique, including the important consideration that indi-

[58] C. C. Holt, "Quantitative Decision Analysis and National Policy How Can We Bridge the Gap?" *Quantitative Planning of Economic Policy,* ed. B. G. Hickman (The Brookings Institution, Washington, D.C., 1965), p 253.

[59] Q. McNemar, "Opinion-Attitude Methodology," *Psychological Bulletin,* 43 (July 1946), pp. 289-374, J. Von Neumann, and O Morgenstern, *Theory of Games and Economic Behavior* (Princeton University Press, 1953); P. C. Fish-

vidual factors on which the items are being assessed interact in producing an overall result.[60]

From the bare fact that a decision is made by a policy-maker, it is incontestable that, through the intricate workings of his mind he is implicitly not only attaching weights to each outcome type or effect variable but also reducing these incommensurate variables to some common unit. Moreover, the nature of his criterion function is also incontestable: he is maximizing these units in a manner which is similar to the algebraic sum, over all effect variables including capital costs of the units which he attributes to each effect, be it positive or negative.

This criterion is not different from the maximization of a welfare function or, if referenced to the existing situation and thereby formulated in terms of temporal changes in effect variables rather than end-states *per se,* the maximization of consumer's surplus. Benefit-cost analysis, economic efficiency, and general equilibrium analysis, have been employed in evaluation efforts referring to tangible and valuable effects.[61] In reality, these techniques differ only in the types of effect variables they deal with. The policy-maker's criterion, even if an extremely implicit one, is no different in concept from these techniques. The weights are merely hypothetical prices, and the criterion represents a sum of individual price-quantity calculations.[62] This is true, also, for non-market effects, by reference to observed phenomenological trade-offs between such effects and some other effect for which a market exists.

It is hardly necessary to point out that, in view of the variety of effect variables defined as relevant, metropolitan planners cannot feasibly present to policy-makers one aggregate number for each system modification alternative. They would in all probability reject the concept, particularly if interaction between planners and decision-makers were concentrated toward the end of a study. It is far less easy, however, to dismiss entirely the idea of applying on a test basis one or more of the available scaling techniques to a subset of effect variables. As Holt argues, such a trial may be justified on the basis of sound

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burn, "Evaluation of Multiple-Criteria Alternatives Using Additive Utility Measures," Research Analysis Corporation, published as AD 633 595, U.S. Department of Commerce, National Bureau of Standards (Washington, March 1966); Marshall Freimer and Leonard S. Singer, "The Evaluation of Potential New Product Alternatives," *Management Science,* 13 (February 1967)

[60] Discriminant analysis and Bayesian theory have been applied here. See Freimer and Singer, *ibid,* also, Herbert Terry, "Comparative Evaluation of Performance Using Multiple Criteria," *Management Science,* 10 (April 1963); also Philip Kitler, "Competitive Strategies for New Product Marketing Over the Life Cycle," *Management Science,* 11 (December 1965).

[61] H. W. Bruck, S. H Putman, and W. A Steger, "Evaluation of Alternative Transportation Proposals. The Northeast Corridor," *op. cit*

[62] K. J. Arrow, "Criteria for Social Investment," *Water Resources Research,* Vol. I, (1965), p. 4.

forecasting.[63] To the extent that metropolitan plan evaluation involves the role of testing untried planning methodology which might lead to significant payoffs in the future, it should seriously consider testing such valuation techniques, at least on a group of planners and other professionals, if not on policy-makers themselves.

Holt's argument might be extended along still another dimension. One of the strongest sources of skepticism toward employing such techniques refers to the transitivity requirement common to all of these methods.[64] That is, the claim of some skeptics is that policy-makers may not exhibit transitivity when subject to such methods, particularly if many effect variables are included. Indeed, this may well be the case, even if only a few variables are included. The implication of such a result, of course, would be that perhaps many public policy decisons made in the past on a purely subjective basis have also been characterized by intransitivity. Were this the case, the immediate failure of a valuation technique in itself offers justification for continued use of such techniques to help improve future decisions, even if they remain subjective, merely by helping policy-makers to be aware of the transitivity problem.

In the final analysis, whether to try such techniques rests upon the extent to which policy-makers deem it worthwhile to participate in such a trial endeavor. If nothing else, the observations of the last few paragraphs emphasize the mutual benefits to be derived from relatively continuous interaction between planners and policy-makers.

There are several alternatives to such scaling techniques, none of which is claimed to come any closer to solving the evaluation problem *in toto* but all of which may be more practical. The most pessimistic approach, though not necessarily an unwise one, derives from the extreme point of view that so many effect variables must be dealt with in a real world decision that it is impossible to attach explicit weights to all of them Furthermore, the argument proceeds to conclude that, since only a few variables can be weighted in dollar terms and even these must be converted to some units of psychological value for a decision (subjective or objective) to be made, any effort to measure weights for any variables is ridiculous. This alternative, then, favors the stratgey of leaving everything up to the policy makers. Assistance could be offered, in a limited sense, by a cogent taxonomical design.

A more reasonable approach has been at least to attempt to clarify to policy-makers the phenomenological as opposed to the psychological trade-offs between selected effect variables. The modeling systems purport to be capable of representing the real world, within the limitations of available data. A limited but well-designed sensitivity analysis of this modeling system portrays at least, in a crude fashion, the substitution or complementarity relationships between

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[63] C. C. Holt, *op. cit.*, pp. 255-256

[64] By example, transitivity exists if a subject prefers A over C given that he has independently claimed to prefer A over B and B over C

selected effect variables without attempting to attach any sort of price to such variables.

Finally, some effort has been directed to examining in depth the trade-offs between selected non-market effect variables and one or more variables for which a market not only exists but indicates dollar value reliably. This approach derives from the point of view that, to the extent possible, all effects which can be expressed in dollar terms should be measured and summed as well as being identified separately. The valuation of travel time savings has been pursued along these lines with some success, and other variables might be amenable to analysis Such in-depth exploration of trade-offs are distinguished from the suggestion of the previous paragraph not only because a monetary valuation or price is involved, but more importantly because such research must concentrate on situations where only two variables — the non-market variable being priced and the market variable referred to as an indicator—vary significantly, so that all other variables are held constant or nearly so. In general, such explorations will at best reveal upper and lower bounds, but such information would be well worth any reasonably proportionate effort.

STATE-OF-THE-ART GAPS IN EVALUATION METHODOLOGY: DECISION-MAKING REQUIREMENTS AND THE ANALYTIC CAPABILITY TO MEET THESE REQUIREMENTS

We have attempted to describe a relatively complete spectrum of planning and decision-making requirements and to weigh against these the potential capabilities of analytic methods to meet these requirements.

Unfortunately, while substantial gaps appear to exist, it is difficult to estimate how important these are (or could be) to successful and improved decision-making. No one has yet developed adequate measures of the outputs of planning and decision-making. No substantial set of analytic, empirical case studies of cost effectiveness of planning and decision-making—with and without alternative planning and decision-making resources and operations—has been made Therefore, these evaluation gaps should be interpreted more as requirements than as an unambiguous preferred or optimal set.

The following factors, at least, are important in the evaluation of plans which are generated by the metropolitan planning process.

- Issue Space Under Review. Has a comprehensive range of issues been posed? Or is there just the traditional focus on spatial aspects of phenomena? Are the aspatial—normative and functional organizational—aspects of metropolitan issues under consideration?
- Scope of the Decision Process. To what extent are the goals and functions considered capable of incorporating the salient features of the metropolis and the decision-making process? To

what extent do the plan design and evaluation phases capture the essentials of the decision-processes of planning?

- Range of Alternatives. Is there an inclusive set of alternatives? Or is there really a basic alternative and a bunch of "straw men"? To what extent is alternative design influenced by the evaluation methodology?
- Impact Groups and Incidence Dimensions. Have the plans identified the social and economic groups to be impacted by them and the magnitude and dimensions of incidence to facilitate the evaluation process in terms of preset goals and benefit groups?
- Evaluation Framework. What is the framework of evaluation methodology? To what extent are the decision process, the concern for impact incidence, the preference structures of the populace, and other issues reflected in the methodology selected? How adequate is the informational base for the evaluation methodology selected? [65]

This list is quite clearly illustrative However, it is indicative of the set of criteria that could be used in evaluating the plans generated in metropolitan planning. In any case, these criteria have been used to structure the discussion of the gaps that follows next.

While both the planner and analytic technician talk of global assistance to decision-makers, their resource limitations, biases, and technology have caused them, by and large, to ignore much of the issues' space in urban and regional matters. When metropolitan planners seek to guide physical development, it is really the spatial organization of activities and use that is the focus of concern. Such a view ignores a whole range of aspatial issues relating to community values and functional organization that can be considered without regard for spatial arrangement. If the planners' issue space enlarges to include both the spatial and aspatial urban issues, he will be encouraged to take into account the ways in which the physical environment he recommends facilitates or impedes various activity systems that are accommodated by environment.[66]

Further, with few exceptions, the planners have left the two major issues of the preferred public role for urban functions, and the incidence (redistribution

[65] Some key factors in the evaluation of the planning process (not detailed here) are (a) the comprehensiveness or scope of the approach, (b) view of the planning process, (c) organizational structure of the process, (d) impact estimation techniques, and (e) relevance of evaluative criteria

[66] Donald L. Foley, "An Approach to Metropolitan Spatial Structure," in M. M. Webber, *et al.*, *Explorations into Urban Structure* (University of Pennsylvania Press, 1964).

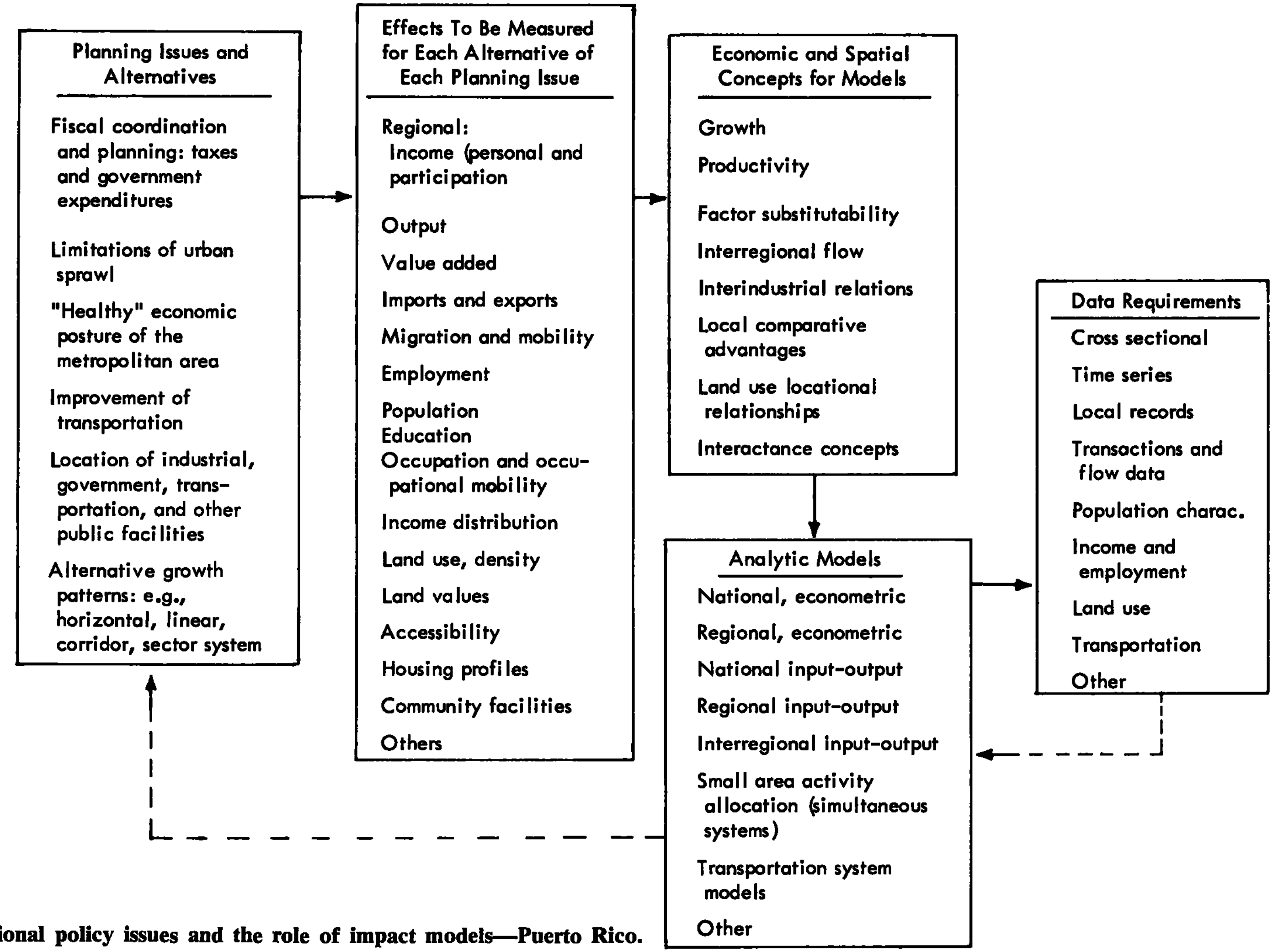

Figure 3. Regional policy issues and the role of impact models—Puerto Rico.

consequences) of alternatives, almost exclusively to more aggregate echelons and/or the political sector. This is unfortunate, because their role places them in an excellent position for defining urban and regional functions, for sensing (and thus measuring and communicating) externalities and scale economies. Furthermore, the technologies for attacking these problem areas are no less available than those for the issues with which we primarily do concern ourselves.

While this decade has been described as the golden age of decision-making studies,[67] there have been very few studies identifying the changing goal structures, the planning issues, the alternatives examined, the impact measures, and the evaluative methods.[68] One study has described the heuristics of budget decision-making in the cities of Detroit, Cleveland and Pittsburgh, and has utilized the results of the simulation for partially successful "forecasting" of these decisions.[69] Improved studies for systematically capturing the decision-making processes of planning are required, before normative models can be designed. Too much is being assumed today about the planner's information availability and processing requirements. Even acknowledging the likely changes analytic methods should make to and for the process, much of the current process will remain relatively undisturbed, and, thus, should be better understood. Operationally, this requires a more explicit understanding and explication of planning processes.

Impact Modeling Strategy

The overall strategy of impact modeling is arrived at—and should be, for each study by trade-offs between: the diversity of impact types to be estimated; the dimensions of impact incidence—areal, sectoral, population class, and temporal; the state of the art of analytical techniques; and the richness of the informational base Other papers in the Conference are addressed to an articulation of the difficult choices in this process. The scope of our discussion is limited to one aspect—the geographic hierarchy issue—of impact estimation. It illustrates an impact estimation strategy—the "top down" approach—found convenient in expressing location, comparative advantage and growth consequences of public policies at different geographical levels.

Figure 3 is an attempt to relate an illustrative set of policy issues to the process dimensions of which alternative planning programs are composed. Alternative planning issues of major importance are indicated on the left side of Figure 3; the effect types, which are the consequences of the alternative choices, and then, classes of relevant economic and spatial concepts are

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[67] Kent Mathewson, "Planning and Decision-Making in the Detroit Metropolitan Area," Highway Research Record, No 137, 1966, p. 14

[68] A. Altshuler, *The City Planning Process. A Political Analysis.* Cornell University Press, 1965, is an excellent case study of the planning process. Another is Frieden, *op. cit.*

[69] J. P. Crecine, doctoral dissertation, Carnegie Institute of Technology, 1966

shown, ranging from growth considerations to local comparative advantage concepts; next, various types of models are indicated; and, finally, the alternative data requirements for the concepts and the models are broadly indicated, with the feedback to models resulting from the feasibility and cost of the data-model system, combined.

The purpose underlying the general sequence of effect estimation in the illustrative case of Puerto Rico (Fig 3) is quite simple: to be able to estimate the consequences of impacts in terms of income, output, population and its characteristics, employment, land use of alternate policies addressed to the crucial planning issues at different geographical levels, nation, region, metropolitan area, and subareas in an urban area. As alternative policies are forged in response to planning issues and goals, mathematical models are used to make conditional forecasts, for example, if a particular land use growth policy or tax policy is envisaged, what growth or distribution consequences might occur?

The development of quantitative forecasting methods addressed to such sets of impact measures can be attempted through a theoretical framework embracing regional economic theory, comparative advantage, and location theory. No single analytical method, however, is likely to accomplish the forecasting requirements for evaluation of urban/regional public investments The various analytical models, furthermore, would have to rest heavily on empirical bases that attempt to capture most of the changing patterns of economic and social growth in response to public investments.

Comparison of alternative sets of procedures strongly indicates that impacts best can be arrived at by a series of successively finer geographical approximations. For example, first, what changes might occur at the level of the region which is most open to the outside world; then, the various subregional levels (metropolitan, urban, etc), and, finally, individual subareas within an urban area?

This type of framework of a multilevel impact estimation is envisaged in view of the different forces, in fine detail, that appear to operate at these different levels. Various modeling schemes may be devised so that the results of the immediately broader (geographically) scale model can constrain the solutions at the next level The multimodel "top down" approach can produce a maximum amount of valid information. It can serve as a very necessary and valuable link between the economic planning at the regional level and the physical planning at urban and subarea levels

The choice of modeling schema appropriate to this approach is a function of the potential benefits, tied to all the uses to which the modeling outputs would be put, and the total cost of producing these: the data, manpower requirements, computers, etc.

Needed Improvements for Evaluation

Aside from the obvious benefits for conditional forecasting methods, better understanding of underlying present and future preference patterns of individuals and client groups is also fundamental for evaluation. The methods of classifying and reducing effects categories, of choosing effects to forecast, and for weighting effects classes—these can no longer fall back on impractical schemes for measuring consumer surplus.[70] The translation of effects vectors into preference vectors strains the confines of traditional cost-benefit frameworks, or, for that matter, even the most sophisticated general equilibrium framework.[71]

More attention will have to be paid to other routes for assessing preference functions:

- to the historian, architect, ecologist and anthropologist, for what articulate human beings have said, and say, about the quality of their environment,
- to sociologists for the application of content analysis;
- to opinion pollsters for what people claim they want, directly;
- to the econometrician and statistician for measuring what has and is actually chosen by consumers;
- to the social scientist for descriptive and normative models of consumer behavior;
- to the social psychologist, for structural and constrained methods for conducting interviews,
- to system analysts, for structured experimental situations;
- to the political scientist and statistician, for intensive analysis of voting behavior, and for methods to simulate voting behavior; and,
- to public administrators, for improved ways to ascertain the trade-offs between effects measures desired by community leadership.

Operationally, within existing regional planning studies, this would call for intensive review and use of home interview techniques, and the enlarging of the view as to which resources might be helpful in ascertaining present and future preferences and future preference functions.

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[70] M Ahmed, "The Development of the Concept of Consumers' Surplus in Economic Theory and Policy," *Indian Economic Journal*, 13 (April-June 1966); P M. Gutmann, "Neoclassical Utility and Inter-temporal Consumer Decisions," *Economia Internazionale*, August 1966

[71] For a summary and comparison of these many methods used in evaluating transportation and land use systems, see Bruck, Putman and Steger, "Evaluation of Alternative Transportation Proposals The Northeast Corridor," *op cit*, pp. 330-333.

Operational measures of the output of urban areas and regions; *i.e.*, the contribution of the metropolitan environment to the public welfare are also, ultimately, required. Much can be said about the need to improve the social infrastructure so as to maximize human potential through increased access to opportunities of all varieties. But what actually do agglomerated environments add to social and economic productivity? Without a fuller description of the functions of agglomeration, and an appreciation of the preferences toward the products of these functions, we can never achieve these output measures. And without an agreed-upon set of output measures, we never really fully can achieve rational resource allocation to the policy issues of regional and urban public investments, let alone to planning for these Clearly, this is a high-order need, similar in importance to a rekindling of interest in land, *i e.*, spatial allocation as a factor of production, commensurate in importance to labor and capital.

Without dwelling at length on any of these topics, each of which itself would deserve its own paper, experience with developing planning models has convinced us that the following improvements are required.

- More emphasis on total system costing of projects and programs;
- More use of games and man-machine simulations, not just for pedagogical purposes, but for the development of alternatives for testing, and "goal-goal" trade-off functions;
- More intensive use of case studies of the effects of public investments, if the data collection schemes can be made appropriate to the detection of the system effects;
- More explicit attention paid to the communications and mutual education relationships between analyst and planner,[72]
- More advance attention paid to the relationship between analytic outputs and specific design needs of the planners;[73]
- Better definition and mutual acceptance of definitions of analytic validity, including specification of validation criteria;[74] and,
- More attention paid to the incidence of effects.

[72] W. A. Steger, "Review of Analytic Techniques for the CRP," *op cit.*, pp 170-171; N. Grundstein, "Urban Information Systems," *op cit.*

[73] The Bureau of Public Roads and the Department of Housing and Urban Development are both supporting research in this important area, currently.

[74] Charles F. Hermann defines several kinds of model-building validation including: internal validity, face validity; variable-parameter validity, event validity, and hypothesis validity. See "Validation Problems in Games and Simulations with Special Reference to Models of International Politics," *Behavioral Science,* 12 (May 1967), pp. 220-224

New technology users—and model-builders are no exception—frequently begin to construct their second generation models before they are prepared to analyze the value of their first generation efforts Given the availability of resources this may be desirable; the second generation work can serve as beneficial incentive feedbacks upon the first-generation work, given proper communications between them This work is proceeding, and should proceed, along several points:

- Improved capabilities to link models at different areal and functional hierarchies, to use and automatically revise control totals, so as to efficiently exhaust a total information space;[75]
- Better methods for utilizing comprehensive problem solving models for smaller problems, or for building on smaller problem solving models to fit better into a larger scheme (*i.e.*, the global versus piecemeal approaches);
- Better explicit strategic and tactical planning in the use of all systems research techniques, including the types of trade-offs between technique attributes and techniques;
- Improved measures of externalities and social costs as outputs of analytic methods,
- Explicit incorporation within urban and regional models of "states of the system," described through historical stages of growth,[76] or in terms of decision-making capabilities;[77] and,
- More explicit incorporation of the structure of behavior and decision-making, even if this requires new combinations of heuristic and normative submodels within a larger framework.

Concluding Remarks

We have attempted to describe public sector decision-making needs in such

[75] Some people refer to this as a "top-down versus bottoms-up" problem: can urban areas make choices so efficiently that macro-income and wealth totals should be formed by summing regional data rather than allocating macro totals to regions?

[76] Eric E Lampard, "American Historians and the Study of Urbanization," *American Historical Review,* 66 (October 1961), Ray Lubove, "The Urbanization Process· An Approach to Historical Research," *Journal of the American Institute of Planners,* XXXIII (January 1967), Sam Bass Warner, Jr., "If All the World Were Philadelphia: A Framework for Urban History, 1774-1930," Institute for Urban and Regional Studies, Washington University, Working Paper INS #1, 1967.

[77] Nathan D. Grundstein, "Some Conceptual Problems in the Simulation of Public Social Systems," *Selected Papers in Operational Gaming,* ed Allen G Feldt, pp. 51-53.

a way that gaps could be revealed between requirements and the capabilities of analysts to meet these needs. We have not attempted to quantify these gaps, or even to arrange them in some priority order

To some extent, the problem is similar to trying to arrange for priorities within basic research by linking this research to all potential uses. To a larger extent, however, it is more similar to managing resource allocation for applied research and science programs Here, the basic urban and regional issues of the future would be arrayed in some order of importance and the feasible contribution, at the margin, of decision-aiding techniques would be related to each of these issues and the informational needs represented by these issues.

Nobody, apparently, can yet do the long-term priority ordering which would be needed to accomplish this management task. Until that time, our resource allocations will be based on more pragmatic grounds—near-in supply aspects, more vocal demanders, and non-military budgets.

At the very least, a better record of what is happening in this field, as well as a more uniformly accepted set of definitions—and perhaps, criteria—is needed.

COMMENTS

LYLE C. FITCH, *President, Institute of Public Administration*

Not having obtained a copy of the paper before arriving, I am constrained to generalizations. First, I shall comment on problems of uncertainty in planning and in model building, and raise questions about accommodating models to uncertainty, particularly in this age where things are changing rather more rapidly than they have ever changed before, except in brief cataclysmic periods. We have become more accustomed to change than we have to stability So I would like to raise a question as to how change affects planning.

The concept of "planning" implies at least a reasonable degree of certainty If you propose to go on a trip you lay out your razor and your toothbrush, and you make "plans" with a conviction that a high percentage of the things you have "planned for" will happen. But is this really planning? I would argue that it is not. Laying out the razor and toothbrush is more properly described, not as planning, but mere preparation making. Planning really in this day and age is concerned with uncertainty, and the essence of planning is coping with, and inventing ways of handling, uncertainty.

There are many kinds of uncertainty, of course. One of the great uncertainties we all face is the uncertainty of data. In this connection I was struck by Alonso's paper (see Part III) which illustrates how data uncertainties cumulate. Thus, you may start with a sequence of 80 percent probabilities and find that the probability of the fourth event in the sequence is only about 40 percent.

Second, I am concerned about the license with which poor numbers, originally constructed or assumed for some specific purpose, are used and misused once they get into public domain. They may get bruited about, appearing in all kinds of policy decisions and other inappropriate contexts. Numbers being inherently mischievous, data uncertainties encountered in model building can perpetrate all kinds of new mischief. The danger is more serious in that so much of our social science model building requires contrived data, and surrogates of various kinds (*e.g.*, an index of violence, or poverty, or government output).

The above, now that I think about it, is no more than a restatement of the garbage-in ——► garbage-out principle. A more inherently serious challenge to social science model building is posed by the school which argues that the social order is inherently so complex as to defy systematic planning and which argues that the best one can do is to plan for very incremental change in a very partial kind of way, for short periods, and for unrelated kinds of decisions, in part because change itself is a process of "disjointed incrementalism." One trouble with this thesis, the Lindblom-Braybrooke thesis, is that the world is full of changes which are more than incremental. But the basic question is whether the world of affairs is in fact as disjointed and unsystematic as the thesis asserts, or whether some things are so systematically hooked together in systems as to make the use of models fruitful. Agreeing with Britton Harris that every policy-maker, even those who rely on divination or serendipity, has some kind of model, at least an implicit one, in his subconscious, I would argue for the systematic modeling approach. (I must admit to having been a bit shaken by Lowry's paper, however.)

I am also concerned about the vulnerability to uncertainty of models which seek to optimize or maximize something. Herbert Simon's concept of "satisficing" is one approach to coping with this kind of uncertainty. There are numerous other ways of handling uncertainty, which we have been exploring at the Institute of Public Administration. One means of reducing uncertainty is improving data. Another familiar technique is that of making projections which put reasonable limits on uncertain magnitudes. Thus one might place the average growth rate of the Gross National Product over the next 33 years between 3 percent and 4 percent, reject 2 percent as being unreasonably low and 5 percent as being unreasonably high, and take a range between 3 and 4. (Incidentally, that makes quite a difference. In 33 years there will be a difference of $9 trillion between a 3 percent and a 4 percent growth rate in Gross National Product.)

Another technique, of course, is to choose carefully among the alternatives for analysis. Choosing lines of action that preserve flexibility is a highly important means of reducing uncertainty. Consider the question of whether to take over certain unused New York piers for such other purposes as building apartment houses on the sites Certain unnamed planners have said we should have an econometric model of the regional development in this area in order to determine whether those piers someday will be needed—in which case it would be awkward if they had been converted into apartment houses. In this case, I assert that more analysis would have indicated ways of retaining flexibility. Piers are not that difficult to build, and there is no reason why they all must be located on either the east or west side of Manhattan. Again, one may reduce uncertainty by hedging and by grouping future events to take advantage of probabilities instead of staking everything on the outcome of a single venture, or single event. For example, it would be better for a municipality or a region with foreseeable land needs to acquire land for a number of future needs, as part of an integrated plan to minimize risk, than to consider and handle individual needs separately. In the latter, the decision-maker may risk his neck on too narrow an outcome—a kind of risk, incidentally, that politicians always shun.

Finally, we must consider the question of formulating social goals that can serve as broad policy guidelines and which, in so doing, themselves tend to reduce uncertainty, a topic of the Steger-Lakshmanan paper. Where do the model-builders' goals come from? Fundamentally, America still exhibits attitudes of a free enterprise society and American values are predominantly middle-class. The middle-class looks at the market to satisfy most of its wants, and it still does not recognize very clearly the legitimacy of the public process We do not usually think of public policy constructively, but rather as a means of removing irritations, like congestion and pollution It never occurs to most people to plan against any of these things until after they occur. And the reason is, of course, that as a society we are not accustomed to thinking in such a social idiom. This lack of instinct is fortified by the economists who tell us that a social decision usually is inferior to counterpart market decisions because a social decision leaves a number of people unsatisfied, with more or less of the social good than they would prefer.

But this line of reasoning, I submit, reflects one of the weaknesses of contemporary economic theory—the weakness of assuming that preference scales are stable and determinate. In fact, preference scales, particularly in the case of social decisions tend to be formed by interaction between the household and the individual on one hand, and the social process or society on the other. We have all had the experience of seeing people fight against community policies or improvements which, after adoption, they would not think of changing The substitute for the market process in the social sphere is the goal-making process. Goal formulation and the building of public consensus around goals is the most important role of political leadership. In the process, I still have faith that the emerging techniques of model-building can give greater force of rationality, however defined. Having alluded to the question of rationality, however, I hasten to leave the field to other discussants.

CHARLES GRAVES, *Department of Housing and Urban Development*

I would like to make a few comments on the gaps that Mr. Steger spoke about. One of the gaps is the issue space, and I think he is on the right track with the questions about who builds systems, who pays for them, and who gets special benefits. I think these are the kinds of questions asked by members of Councils of Governments or by advisors to metropolitan decision-makers. They do ask how much is this system going to cost and how many ordinary people are going to use it on the average day; and they also ask a lot of other questions—do I have to pay for it, or does somebody else pay for it? Is it going to hurt or help the tax base? I know that intellectually these are less than satisfying criteria, but in my short experience I have found that these questions are the ones that people ask. Decision-makers want to know what special benefits and social hurts would happen to particular groups inside the community. In the Department of Housing and Urban Development we are constantly asking how long people benefit from a particular set of recreation investments or transportation investments. Politicians want to know if it is going to cost votes at the next election. Model-builders are not responsible for the answers to most of these questions, and some of them are a little fictitious. But some of them are, I think, the subject for land use distribution models. I was a little disappointed that there were not some illustrations, even if incomplete ones, of how some of these issues might be incorporated into existing models, or some examples of what kind of data or approaches might be used to begin the modeling process

The second thing that struck me about the paper is a subject that Lyle Fitch touched on a good deal. I think he demolished one of the legs of the argument; that is, the incremental forward-looking kind of approach which I think Will Steger has. Lyle Fitch insists on considering the way decision-makers actually do go about making decisions and relates the kind of information planners ought to provide to the needs and limitations of these policy-makers. We in HUD have some sympathy with this approach because we have investments to make in the short run and we just assume that local politicians do too. It does seem that decision-makers are more interested in clearing up existing problems as they see them than working toward the technician's Utopia Their short terms of office almost dictate the short-term approach.

The unused capacity in many systems suggests to me that the change best can be brought about by analyzing existing problems in existing systems. Joe Stowers has said that this method is used in many transportation studies. After they crank up what purports to be a goal testing model, they turn it on the existing plus the committed system, and start zeroing in, as I have heard some engineers say, zeroing in on the final system. But this really is a kind of incremental approach. I do not think that so many planners would use this approach unless practical pressures required it.

However, perhaps I am making a straw argument, because even the goal-oriented people would insist that after analysis one comes back to the next investments that must be made. I would like to hear more comment about this because I do not observe planners doing it in a very explicit way, although good arguments are made in favor of Steger's approach.

There are a number of other gaps listed near the end of the paper. Steger speaks about a hierarchy of models, and I think that means a larger and smaller set of geographic spaces that the models operate on from the metropolitan to state, regional, and perhaps national level. It scares me a little bit because I do not think we have models operating very well at any of these levels and it is probably premature to talk about hierarchical networks.

Fitch's and Steger's discussions of public preferences open up an important subject. As Fitch has said, there are so many settled trade-offs that it is really politics. The whole political system is terribly complex and we have a whale of a long way to go. On the other hand I think we could all contribute by making objective measures of goals which can double as measures of performance output of the systems. Steger touches this subject in two places. It seems to me that better work can be done describing goals in ways that also will reveal if progress has been made towards the goals. For example, I suspect that crime rates, levels of education, and levels of transportation service are fairly easy to make explicit in a model. I do not know why someone does not say that people are moving around in the built-up portions of our region at 20 miles per hour on an average, and that our goal is to make it 30 miles per hour Then let them do a plan in terms of the minimum investment required to get speeds to 30 miles per hour. Then the planners could measure their achievement in terms of goals that the public understands; I think it would be helpful, too, to the allocators of funds in the Federal Government. If there were large gaps in some metropolitan areas between existing levels of services and what have been established as norms, I think we would be more willing to allocate investments in those areas rather than in others. Presently, the amorphous nature of goal statements discourages any kind of discussion along these lines.

I hope, in this discussion, that I have treated the most pertinent topics. I hope that we will have more discussion of the need to challenge a wide range of issues, to try to answer the questions that decision-makers ask, and of the problem of goals and the objective measurements of goals—perhaps the most important task before us.

ACTIVITY SYSTEMS AS A SOURCE OF INPUTS FOR LAND USE MODELS

F. STUART CHAPIN, JR. *

This is a time of transition to what may well be a whole new direction of emphasis in land use modeling (and possibly, too, in transportation modeling). While we are just in midstride in the course of achieving a capability in land use modeling, there are indications that increasingly research effort will be focusing on a new challenge—what might be thought of as the "behavioral antecedents" of location decisions. The discussion that follows centers around some work in these directions. It has to do with the analysis of daily routines of land users coupled with an analysis of policies (of firms or institutions) and preferences (of individuals or households) which govern location behavior that we seek to simulate in land use models.

There are several reasons for putting the spotlight on urban phenomena of this kind. A case can be built for this kind of emphasis in modeling efforts purely in terms of the need for developing more sensitive inputs for land use models. But there are other reasons which reinforce this purely technical need. It is becoming increasingly evident that there is a range of variables influencing the behavior of "users of land use" (and users of transportation systems) which in our kind of advanced society cannot be adequately represented in modeling systems by constants or by proxies. Not only has technology altered the chemistry of locational choices, but also coming into play in these decisions are new value emphases which need to be given explicit recognition.

In this paper the position is taken that the use of land in a metropolitan area at any particular point in the normal course of its growth is the sum total effect, aggregated over time, of man's accommodation to activity routines and to his felt needs concerning environmental qualities. This position holds that location behavior can no longer be disassociated from a larger behavioral system. This is not to disavow the role that the market place plays in the location decision of users of land use. Rather it is to introduce a different point of beginning, an additional and perhaps more fundamental stage to the study of location behavior. It is argued here that causes of location behavior are tied up complexly with daily routines of land users and associated value and policy bases concerning environmental qualities. The emphasis of such an approach goes into factors that location theorists normally treat as constants in their

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analysis of the location decision of a firm, a household, or other entities within the city. In emphasizing this pre-analysis stage to location behavior, this paper in effect stresses the importance of stratifying demand for space along lines sensitive to activity systems and preference patterns of space users. The position is taken that the tipping point in location choices, particularly in advanced societies, is more and more to be found in how well behavior patterns are accommodated and how appealing the environment is to the user of space. It is argued that if entirely satisfactory land use forecasts are to be achieved, we can no longer bury these considerations.

There is one other reason that makes it timely to consider such an emphasis. It seems quite clear that the evolution of the state of the arts and the remarkable growth in data handling technology have reached a stage which makes it possible for the first time to move in these directions. Consider the road we have come. Once, all we expected of a model was that "it works." Then as we began using these simple models, we soon discovered that to be really useful to decision-makers these models needed some values where policy changes could be injected. Whether we wanted to or not, we had to ask why it works if we were to be able to incorporate into the design a capability for taking account of differing policy assumptions. The why-question has led to more complex formulations, and fortuitously, computer technology has reached a state of development that makes it possible to execute them.

Yet even as we have begun to approach a capability of this kind through improved models and increased data-handling capabilities, we are experiencing pressures from decision-makers for some means of responding more directly to public preferences. These new pressures thus create an imperative for the application of the new technical capability of the kind we have developed in land use modeling to the more complex area of activity and value systems. Certainly support for this line of emphasis was implicit in the deliberations of the Second National Transportation Conference in 1965 at Williamsburg where much discussion centered around community reaction to highway location decisions and became explicit in discussions of community values at the 1967 Highway Research Board meetings. Taken together, these signs of interest and need lend support to the approach discussed in this paper.

While it is timely to move into a larger behavioral system approach, at the scale of research and development support now available, it is necessary to work with one subsystem at a time. For example, economists have been working for several years on a social accounts system for the metropolitan areas.[1] This work can be viewed as one system in the larger behavioral systems approach. Results from this kind of analysis can be expected to supply inputs for industrial and commercial land use models. In addition to defining the net-

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[1] For example, see Charles L. Leven, *Theory and Method of Income and Product Accounts for Metropolitan Areas, Including the Elgin-Dundee Area as a Case Study* (Pittsburgh: Center for Regional Economic Studies, University of Pittsburgh, 1963).

work of relationships among firms by analysis of "from-to" accounts in the flow of products or services within a metropolitan area and with the outside world, this kind of study might well investigate firm policies that affect expansion or contraction of these flows. Essentially this would be an investigation of an institutional set of values I will not go into this work and these possibilities. Rather, since my own experience with land use modeling has been concerned with residential land development I will endeavor to illustrate the possibilities of activity analysis by focusing on household activities as one system in a systems approach to metropolitan area activities.

While this paper reports on several years of work on household activity systems, it must be stressed that what is presented is still quite tentative in nature. At its present stage, this work is distinctly an off-line investigation. As it progresses and begins to clarify the nature of household behavior in the use of city space, we hope to be able to introduce one or more models for the simulation of household activities and preference patterns in forms compatible to a main-line land use modeling system.

Outlined first in what follows is a sketch of the household activity systems conceptual framework. Next, there is a description of some experimental studies made to identify activity routines and to determine the mix of accessibilities that go with households of various life styles. This is followed by a description of some efforts at identifying housing and environmental preferences and in defining the mix of living qualities that go with households of these life styles Finally, there is a brief listing illustrative of some of the problems faced in operationalizing the activity schema.

THE CONCEPTUAL BASIS OF HOUSEHOLD ACTIVITY SYSTEMS

The analysis of household activities (sometimes called time-budget studies) has a fascination for social scientists. For some it provides a snapshot of society, a means of describing it and noting cross-national differences between societies.[2] For others it provides a basis for studying social change in a particular society, for example, tracing out the possible consequences of automation for leisure time.[3] As intimated above, I come to the use of time-budget techniques with somewhat different purposes in mind. In this discussion, I want to use these techniques in ways which will demonstrate their applicability to urban development models.

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[2] For example, see Alexander Szalai, "The Multinational Comparative International Time-Budget Project," *The American Behavioral Scientist*, X (December 1966) See also Szalai's "Trends in Comparative Time-Budget Research," *The American Behavioral Scientist*, IX (May 1966).

[3] For example, see Sebastian de Grazia, *Of Time, Work and Leisure* (New York: The Twentieth Century Fund, 1962), and Marion Clawson, "How Much Leisure, Now and In the Future?" in *Leisure in America: Blessing or Curse?* J. C. Charlesworth, ed. (Philadelphia: The American Academy of Political and Social Science, April 1964).

The framework around which household activity systems are conceived utilizes choice theory to connect up the value system of a person and his activity system. It should be made clear that throughout this discussion activities refer to behavior patterns of persons or households and not the physical counterpart—housing or residential land use. Activities are viewed first in terms of descrete episodes which may be thought of as homogeneous intervals in the life of a person.[4] These episodes are generated by a motivational input drawn from a set of values and have an activity output produced by the choice mechanism. Choice of activity in each episode is thus seen to be governed by a set of values, but it is seen to be constrained by certain socioeconomic requisites—requisites which for purposes of activity analysis finally become grouped into specified life styles which then provide the basis in land use models for stratifying the demand side of the housing market. Stated another way, these life style characteristics become the basis for the analysis of household populations and for making the connection from activity behavior of household populations holding distinct values, to their locational propensities in the market place.

Activities can next be viewed in terms of "routines." A person's or household's routine is defined as a recurring sequence of episodes in a given unit of time.[5] When we examine the dynamics of routines, we are focusing on what may be called "activity systems." At the micro level of analysis, the activity system of the individual is viewed in terms of an evolutionary flow of activities, with reaction to each episode feeding back through the social system and producing changes in the value component, altering subsequent choices, and eventually modifying activity sequences. These rounds of activity, if followed over a period of sufficient time, appear to compose into routines or activity sequences at four time scales: the daily cycle, the weekly cycle, the seasonal cycle, and the life cycle. In the applications we make of these concepts, we are

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[4] An episode is the pure outcome of a choice, an activity is a classificatory concept that groups outcomes into classes. Thus one person might go to a concert in response to a highly developed musical knowledge and an interest in comparing the conductor's rendition to another conductor's techniques; whereas another may go for a great love of Mozart and the sheer delight of hearing a live performance of Mozart. Some may go for relaxation, some may go because they have season tickets and they have nothing else to do Still others may go because of a dinner party and as part of entertaining out-of-town business connections. Some may go for prestige purposes; still others may go for social purposes, *i e* , seeing friends at a concert For each person this is an "episode"; episodes become "activities" when they are grouped under "going to a concert "

[5] While we give special attention to routines in household activity analysis, it should be noted that the recurring aspect of routines is a relative phenomenon. There is variability in the sequence of episodes and this tends to increase with time.

particularly concerned with the system of episodes that fall into a week's routine and how these ultimately affect location behavior (which is an episode in the fourth time scale, the life cycle of a household).[6]

Since work has not progressed to the point where it is possible to give attention to the causal connections in time, only very tentative observations on this score are made. In short, the key cause and effect relationships hypothesized here, to borrow a concept from statistics and subverting it to our purposes, consists of a "within-time-system set of relationships" and a "between-time-system set of relationships." The within-time-system relationships involve sequenced relationships among activities within say, a week's routine which can be traced via the motivation ——→ choice——→ activity path. The between-time systems relationships of particular concern to us are the relationships between the weekly routine and the life cycle. In using this approach, we are aggregating time and assuming a cause and effect connection between dysfunctions experienced in weekly routines and the propensity of a household to move which evolves as an episode in the life cycle. The lag from the time dysfunctions are experienced in the weekly cycle until the time when corrective action is taken can thus be viewed as a segment in the life cycle. These dysfunctions arise as a difference between actual accessibility opportunities available to a household in following its weekly routine as compared to accessibility requirements defined from preference patterns and functional needs of the household at its particular stage in the life cycle.[7]

The "within" aspect of the weekly routine has been discussed elsewhere.[8] Very briefly, it utilizes as an organizing concept the motivation ——→ choice ——→ activity set of relationships following the Ackoff model land choice theory.[9] It will be recalled that choice theory calls for a statement of pertinent objectives, the determination of possible courses of action to achieve these objectives, and the specification of a context with respect to the environment and to the behavior of others involved and the choices they make—all relevant to a particular person or persons as the decision-maker(s).[10] In the present ap-

[6] For a fuller statement, see the author's "Activity Systems and Urban Structure: A Working Schema," *The Journal of the American Institute of Planners,* XXXIV (January 1968).

[7] As will become apparent below, we hypothesize that households enter the housing market under two kinds of motivations (a) dysfunctions between the weekly activity cycle and the life cycle, as brought out here, and (b) disutilities between values held about living qualities and the actual living environment, the second of which will be taken up presently.

[8] See author's article, *Journal of AIP, op. cit*

[9] Russell L. Ackoff, *Scientific Method: Optimizing Applied Research Decisions* (New York: John Wiley & Sons, Inc, 1962), Chapter 3.

[10] It may be argued that choice theory imputes a rationality to activity selection which is not fully borne out in the real world Indeed, it may be argued that many people fall into activities quite by default because they see nothing better to do, or they are functioning by whim and their activity patterns are random occurrences

plication of the model, *objectives* are defined in terms of motivations which are drawn from the value system of the individual. These motivations have been tentatively classified into (a) security bases of choice, (b) personal achievement orientations, (c) a sense of need for social status, and (d) a residual set of felt needs.[11] The *alternative courses of action* are the choices of activity perceived by the decision-maker(s), each to be examined in the choice process according to the satisfaction anticipated. The *context* is both the physical environment and the social system consisting of the myriad activities of others that the decision-maker(s) perceives to be relevant to his (their) choices. Applying this theoretical construct, the individual examines the activity alternatives available and consciously or unconsciously searches for an optimal combination of satisfactions based on the suboptimization of a particular set of basic motivations he possesses at a particular time, finally making his trade-offs based on the satisfaction levels anticipated from the particular set of motivations stressed in each combination. The output of this process is an activity choice, fitted into an activity routine.

What emerges from the "within" analysis which is of significance for location behavior is the definition of the activity locus for persons of different life styles. In making his choices of activities, the individual consciously or unconsciously considers the spatial configuration of his activity routine. He is constantly storing in his memory experience on the fit or misfit of his routine to a set of needs and preferences. If the spatial configuration is a serious misfit, a marked propensity to move develops. It is this aspect of the "within" analysis which has significance for land use models. Thus, from activity analysis we seek to define a set of accessibility opportunities—a spatial configuration of opportunities for engaging in activities which achieve some kind of optimum level in terms of satisfying needs and preferences of a household.

It should be noted that in the "between" aspect of the schema each household move made during the life cycle involves the application of choice theory to one other key area of study. This concerns motivations ——→ choice ——→ action with respect to livability opportunities. This is to posit that, given a certain cost limitation and needed dwelling space, the consumer also is searching for housing and environment of a certain quality. Essentially, the inputs for modeling consumer behavior in the housing market in a residential

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where no choice is exercised. On the other hand, it may be argued that these people may be drawing on recall of previous consciously made choices and are simply short-circuiting the formal choice-making process. In this connection, it might be observed that circumstances in making activity choices are quite different than those involved in making political decisions. Although some of the same reasons for questioning the synoptic rational model of decision-making apply in choice theory, the circumstances surrounding political decisions are quite different than those surrounding activity choices.

[11] See author's article, *Journal of AIP, op cit.*

model can draw on activity analysis to define the accessibility mix sought and can draw on environmental preference analysis to define the mix of living qualities sought; these two inputs form the key elements in modeling the demand for housing, within constraints of income, size of accommodation needed, and other relevant constraints.

These two focal areas of analysis thus supply inputs in the analysis of moving behavior, and this analysis, of course, provides estimates of one of the four sources of inputs for a residential land use model, the total number of households in the market consisting of (a) voluntary movers, (b) forced movers, (c) newly formed households, and (d) in-migrant households. While this paper does not dwell on this part of the linked system of models, it might be observed in passing that the modeling of moving behavior involves a Type 1 round in the application of choice theory revolving around a decision to move or not to move, and then a Type 2 round involving a try at finding a new place. The second round is a part of the household allocation model If the try at finding a new place is successful, not only is the household allocated to a new location, but its vacated place becomes available as part of the supply of housing on which the allocation model operates in the course of matching demand with supply in subsequent flows of the system.

With this capsule description of the conceptual framework, we can proceed to some of the experimental work in progress. In the section immediately following is a brief summary of work on activity analysis as a beginning step in defining accessibility opportunities, and following that is an even sketchier summary of work on preference analysis as an approach to defining livability opportunities.

SOME STEPS TOWARD MODELING HOUSEHOLD ACTIVITY SYSTEMS

"Activity analysis" is a rubric used for the study of urban living patterns. In this discussion it will have a somewhat narrower usage and will be concerned with aspects of these patterns which have particular relevance for land use models. It is too early to draw any conclusions from our experimental work in this area, and it is therefore not possible yet to evaluate fully the possibilities of achieving a capability for modeling the foregoing schema in simulating weekly routines of households Nevertheless, it may be useful to touch on two themes: (a) some first thoughts on the translation of the micro level schema we have been discussing to a macro level version, and (b) some initial efforts taken to record activities and measure them, including some very tentative steps in identifying activity preferences

A Macro Level View of Household Activities

A conversion from the micro level view of activity systems to a macro level perspective is essential if the foregoing schema is to be operationalized, and a macro approach calls for certain compromises if the schema is to be fitted to the real world. First of all, the changeover to a macro type approach involves an aggregative approach, and then it involves the development of a method of recording espisodic data on activities that is feasible and economical for an agency to undertake.

To operationalize the causal chain set forth in the micro level schema, we can aggregate in three ways. We can aggregate episodes; we can aggregate time; and we can aggregate persons or households. Instead of dealing with each episode in the routine as a discrete kind of activity, we can group episodes into some simplifying classification system. Likewise, in place of tracing routines from the daily cycle through the entire life cycle, as noted earlier, we can infer a causal connection from one time scale to another. Thus, we propose to infer a causal connection between the weekly routine and location behavior of households (the activity of searching for and selecting a place of residence at one or more times during the life cycle). Similarly, in place of dealing with each person or household, we can aggregate them into subpopulations, differentiated by characteristics or life styles.

As an aggregative concept, classification reduces the complexity of activity analysis. A shift from tracing episodes to tracing classes of activities enables the analyst to develop a set of building blocks for describing the content of urban life in a more synoptic version, as well as in a more manageable form. The classification system in use in our studies involves the following major classes of activity grouped along functional lines:

Income-Producing and Related Activities
Child-Raising and Family Activities
Education and Intellectual Development Activities
Church and Human Welfare Activities
Socializing Activities
Recreation and Relaxation Activities
Participation in Organizations and Their Activities
Participation in Public Affairs, Action or Service Activities
Activities Associated with Food, Shelter, Medical and Similar Needs

Within this coarse-grained classification system are nested subclassifications.

The second form of aggregation, time aggregation, offers some problems. As indicated earlier, we will need to carry our work somewhat further before we will have much to say about the aggregation of time in the "between-time-system." Within the weekly routine, the level of aggregation depends in part on the level of detail sought in the classification of activities and in part on practicalities of securing listings of activities in surveys. Since it is one of the key requisites of the study of routines to be able to identify the rhythmical characteristics of the routine, it is relevant to comment briefly on some thoughts we have for dealing with cyclical features of the weekly routine. Perhaps the simplest way to conceive of routines is to think of them as composed of obligatory and discretionary activities. Conceptually, the distinction is fairly simple. Obligatory activities in the routine include such things as sleep, work, attending school, or going to the doctor for emergency treatment; discretionary activities might include going to a movie or shopping, or going off for a weekend holiday. Upon reflection, however, one can find discretionary aspects for most obligatory activities, especially in generalized levels of the classification employed above. Thus, while work may be considered obligatory in the sense that in our society it is essential as a means of supporting the household, given a basic skill, the individual has some latitude as to where he works.

The concept of interest in making this differentiation is the interrelationship between obligatory and discretionary activities. To take an illustration, if work in the weekly routine involves a routinized set of work activities within the work portion of the routine, intuitively we suspect that there will be some causal connections between this obligatory portion of the routine and the discretionary portion, particularly in the choice of activities for recreation and relaxation. Clearly, obligatory activities occur more or less in cycles with almost the same regularity as time itself. Indeed, they are much more likely to be scheduled by the clock or the calendar than discretionary activities, and to a significant extent they serve as "a governor" and regulate choices and timing of discretionary activities. It is this kind of regularity to the routine that strongly suggests the possibilities that activity routines can be modeled with some success.

The third kind of aggregation is quite familiar to most who work with land use models. The aggregation of individuals into population classes for activity analysis can be approached in at least two ways. In one, we can use an *a priori* approach and sort households by conventional groupings based on income, occupation or some other characteristics or groups of characteristics, and then search the activity sequences of these classes of households to identify distinctive routines. The other is to aggregate according to patterns observed in activity sequences, with the range of patterns classified into a typology of life styles. We anticipate using a combination of the two approaches, where we make initial sorts on the basis of an occupational index of socioeconomic status, and then search the routines of these households for patterns. Household aggregates thus identified by life style provide control groups for the study of various dimensions of activity routines

Initial Investigations into Household Activities

From decisions of the kind discussed above, we have moved into what is an initial stage of activity analysis. At the macro level, we have been concentrating our efforts primarily on the output part of the choice process, namely on defining activities and developing measures which would be meaningful and feasible for model-building. However, exploratory work at the value end of the schema and the investigation of activity preferences using game techniques is under way as part of this effort A brief commentary on both areas of investigation follows.

Exploratory Work in Activity Analysis. Perhaps a chronological rundown would be the simplest way to introduce the experimentation we have been doing in the activity analysis aspect of our work. We began these studies as an "out-of-a-suitcase" kind of effort, experimenting with home interview techniques in a series of three successive studies in Durham, North Carolina.[12] Building on this experience, under a U. S. Public Health Service grant, a pretest of activity study techniques was undertaken in Minneapolis-St. Paul in 1966, and in the spring of 1968, under a continuation grant, the first full-scale study was mounted in Washington, D.C.[13]

The present emphasis of our investigations seeks to explore four dimensions of household activities. It aims to define *types* of activities, their *sequence,* their *timing,* and their *spatial distribution.* On the basis of activity listings obtained in home interview surveys, types of activities are grouped into classes compatible on the one hand with the analysis of preferences and on the other with their counterpart land uses. It is at this point that the technical distinction made earlier between an activity (which is studied in aggregates) and an episode (which is the pure and original form of an activity) is made. Under present procedures, the interview records all episodes which consume 15 minutes of time or more, with the assignment to a classification being made when results are coded. Should we ever enjoy the luxury of working with a micro level mode, undoubtedly we would be modeling episodes of an individual by the tick of a clock. As it is, we are struggling to reach a modeling capability working with populations of households who engage in certain classes of activity over aggregated intervals of time.

Sequence of activity is of interest to enable the investigator to search an activity routine for a pattern of choices. The simplest illustration chosen with a day's cycle is the sequence from meal preparation, to eating, to dish washing. A more useful illustration for modeling capability and an obvious one is the sequence in a week's cycle noted previously which moves from work to leisure-time pursuits. Obviously, the permutations and combinations in tracing out sequences of this kind are quite considerable. For example, it is reasonable to expect that when the man on the Ford assembly line moves into a leisure-time interval in his week's routine he might choose a different kind of recreation than the Ford executive who sits at a desk all day. Besides indicating how outcomes may vary with occupation and income, this illustration suggests the need for controlling the analysis of activity choices for the nature of a person's occupation and for his income level. Things get more complicated when other variables are taken into account, such as stage in the family cycle and sex,

[12] F. Stuart Chapin, Jr., and Henry C. Hightower, *Household Activity Systems —A Pilot Investigation* (Chapel Hill, N.C., Center for Urban and Regional Studies, May 1966).

[13] U.S. Public Health Service Research Grant CH 00116, "Household Activity Patterns and Community Health."

each of which we intuitively see affects choices. The key concern in the analysis of sequence is to establish what the relatively stable choice patterns are in the routine, to be able to sort people into classes with similar choice patterns (defined in terms of life styles), and to use this property of stability and recurrence as a basis for studying the predictability of activities in a routine for each defined life style.

The timing aspect of a routine is obviously related to the sequence, and the concern here is to fit the sequence to some reasonable and recallable interval of time. The basic significance of time cycles has already been noted, and earlier references to time-budgets suggest the operational significance of studying the duration of activities as well as their start and ending time. In this connection, clearly the decision on level of time aggregation must be made in relation to the type of activity and the aggregation levels used in the classification system. Turning to spatial measurements, it is to be noted that for these purposes only a portion of the activity routine is involved—the out-of-home pursuits. Even though for land use modeling purposes the concern is primarily with the locus of out-of-home activities, it must be evident nevertheless that these choices cannot be studied out of context from the content of the full routine. In this connection, in order to provide a capability for studying accessibility opportunities, it is necessary to code activities to a grid coordinate system compatible with the system used for land use files. This is no simple task.

These dimensions to household activities are probably not exhaustive, but they do represent the component elements we wish to use in the analysis of the composition of activity routines and in studying the dynamics of activity choices within the routine. Although it would be informative to extend activity studies to different members of a household and to different days of the week, presently economy and feasibility of data collection dictate some hard decisions in this respect. Since the present application of this analysis is to location behavior, attention is being concentrated in activity listing on the decision-making members of the household—the head of the household and the spouse. Obviously, by omitting various other members of the household, the survey schedules presently in use do not yield data on the full range of a household's living patterns. The decision on days of the week has been a particularly difficult one, since so much emphasis in this work is placed on the week's routine. We have experimented with week-long diaries, and even disregarding costs of follow-through, we find that even when respondents are paid to keep diaries for that length of time, returns are not fully satisfactory. Besides the problem of incomplete returns, among those completed there is a tendency for responses to be biased toward a particular socioeconomic level and a particular personality type challenged by the idea of keeping track of time. To work with the concept of a weekly routine it has been necessary to sample days logitudinally during a week, systematically sampling different weekdays and weekend days and constructing for different socioeconomic groups what might be though of as a homogenized week's routine for each such group.

Obviously there are many problems that must be checked out before this effort reaches the point where it is possible to simulate activity routines. Hemmens has suggested a model using a transitional probability approach and involving the use of a semi-Markov model in the simulation of choice and spatial distribution of activities.[11] Hightower has proposed an adaptation of the population potential model to get at choice of activity and its location.[12] These represent some first thoughts, and in the next year or so when data from the full scale study are available, some tests of these approaches perhaps can be made.

Investigations of Activity Preferences

The investigation of preferences is undertaken to put the spotlight on variables that affect our capability for forecasting activities. It is inherent in the activities schema outlined earlier that the cutting-in point in forecasting activity choices is an analysis of motivations connected with an activity and an analysis of the extent to which these motivations are fulfilled as determined subsequent to the activity. We can see that there are almost insurmountable problems of getting data on these pre-activity and post-activity phenomena To get some insight into the problem, we introduced into our survey a parlor-like game for simulating choices. At present the game is only a partial experiment. It simulates choices and records satisfaction levels from these choices, but it does not yet get at motivations for choices. To go this one further step will involve the development and use of attitudinal scales in conjunction with the choice-making step in the game.

The game focuses on the leisure-time portion of the week's routine, which is the part of the routine subject to the greatest variability in choice. To sustain the interest of the respondent, it borrows on the green stamp ritual that merchants use as a come-on to bring in the customers. The respondent receives a limited number of stamps corresponding to the number of hours presently available to him as free time during the week. He is given a game board (corresponding to the green stamp catalog of available goods) which indicates a range of choices from which he can shop He is told that his present time budget, his present income situation and his present family circumstances are the only constraints on his choices and that he should make choices of leisure-time activities that suit him best within these constraints. The game may be thought of as a primitive form of linear programming in which, under the given constraints, choices result in an optimal level of satisfaction based on the suboptimization of some unspecified motivations. As in the analysis of actual activity data, it is necessary to aggregate choices from the game into classes of

[11] George C. Hemmens, *The Structure of Urban Activity Linkages* (Chapel Hill, N.C., Center for Urban and Regional Studies, September 1966).

[12] Chapin and Hightower, *op cit*, pp 54-73

choices. We do this to simplify the analysis, but also to filter out fadism that goes with particular activities at a particular era of time. Obviously one can examine choice patterns, weight them by satisfactions reported, and examine for consistency of response for the life style group established from activity analysis.

Changes in the pattern of choices may come from changes in conditions under which choices are made To get some feel for this aspect of the problem, we have introduced a second stage to the game where we relax the constraints on amount of time. We inform the respondent that he is to imagine a shorter work week and that there is an extra eight hours to use for the game. Here we are still experimenting in the options open for the use of the time (extra day off, two afternoons off, or a 1½ hours additional each day). As in the initial phase of the game, again satisfactions are recorded. The notion here is to get at the class of choice which is presently marginal, but which would be a standby choice when constraints are lifted. If we are willing to forego the study of marginal choices and allow the respondent to reallocate all his stamps in the second stage of the game as presently conceived, we may find significant patterns to realignments in choice. Other constraints might be lifted, for example, the respondent might be told to imagine the situation where his children are ten years older in the process of making his choices. This form of experimentation would bring the analysis into a stage in which, by posing conditions and observing choices, it may be possible to infer motivations from our data, in which case we might not need to include extensive attitude questions as previously mentioned.

SOME EFFORTS IN IDENTIFYING ENVIRONMENTAL PREFERENCES

In the micro level model discussed earlier, for the typical household already established in a metropolitan area, moving behavior involves two rounds through the decision-making sequence. The first round focuses both on dysfunctions of accessibility in the weekly routine and on disutilities in the way in which housing accommodations and the environment match up with a household's felt needs. The first round thus leads to a decision to search for housing. In the second-round decision the moving household mingles in the market with other households involved in the search process. The other households include (a) forced-move households; (b) the newly formed ones, and (c) the new arrivals. The second-round decision, thus, is the subject of the classic market-type model and is well covered in other works. For purposes of this discussion, we will consider only the first decision, *i.e.*, the decision of the household whether or not to move.

In narrowing the focus to the Round 1 decision, the discussion will center on that part of the decision to move which develops from disutilities between current housing circumstances and felt needs and desires in this respect. While it is recognized that the two parts to the Round 1 decision must be treated as a joint set of considerations, for purposes of these investigations they are handled singly. Having covered the accessibility aspect of the decision in the study of activity routines and activity preferences, I turn now to the work we have been doing on housing and environmental preferences. Following the approach in the preceding discussion, this portion of the paper will briefly touch on some conceptual elements and then allude to directions of exploratory investigations. Since our work in this area is still quite exploratory and is not as far along as activity analysis, this part of the discussion necessarily will be short.

Some Conceptual Considerations

The outcome from applying choice theory to the Round 1 decision sequence (motivation ——► decision ——► search) is a choice either to proceed or not to proceed with Round 2—the housing search This means that the household's satisfactions with its particular circumstances in both accessibility and living conditions are subjected to a test to establish whether the household wants to move or stay put. Because this particular kind of application of choice theory involves no measured outputs but only a simple yes-no decision, the more complex part of the formulation is at the input end of the sequence. This becomes eminently clear when the nature of the phenomena involved in these inputs is considered. For obviously if we are to understand the origins of motivations, this takes us directly into the subject of value systems which is among the most elusive areas of study the researcher faces.

Initially it should be noted that to go behind the motivational inputs of the Round 1 decision, we must recognize that the value systems of the household decision-makers are not static, that they involve an evolutionary mix of values which in the first instance are culturally transmitted to the individuals via the particular subculture in which each was reared and which become modified by subsequent social mobility and the experience acquired through each household member's lifetime The problem is made more complicated, if the motivations concerning livability are to be disentangled from motivations concerning accessibility in the formulation of a Round 1 decision.[16] To be able to trace the dynamics of the decision to move or not to move at this microscale level of research, clearly requires the expertise of the social psychologist. In our work, we still have ahead of us this kind of interdisciplinary effort, and how far we go in this direction depends on progress in the present explor-

[16] Of course, at the micro level the problem is infinitely more complicated when one stops to consider how the decision process would be formulated considering all members of the household, the value system of each, their personalities and their roles in household decisions As in the previous analysis the study of livability centers around the attitudes of the presumed decision-makers of the household—the head and the spouse. For the conjugal household, we assume that there is a process in husband-wife decision-making which homogenizes the values and thus the attitudes of the two personalities involved. This assumption needs to be checked.

atory phase of the investigation. A great deal depends on the results obtained from the present primitive effort in dealing with environmental preferences at the macro level.

A macro type version of this decision process involves aggregation in ways comparable to what has been discussed under activity analysis. In this application of choice theory, we deal in aggregates of households possessing similar livability motivations. In effect, we are dealing with statistical means of behavior in which many of the variables operative in a micro level model are locked into the formulation and become treated as constants. The idea here, of course, is that the dominant factors influencing decisions will surface in statistical analyses of attitude data and can be isolated and treated as motivational inputs to a Round 1 model.

Before turning to our survey efforts at defining livability motivations, it will be helpful to spell out a little more clearly a few terms that crop up in these studies. In the usage here, livability in an urban setting refers to those qualities of an urban resident's surroundings which induce in him feelings of well-being and satisfaction. Values imply the existence of norms, and so when we refer to livability attitudes, we are assuming the existence of a set of initially undefined norms—a set of glasses, if you will, through which a person perceives his surroundings and makes evaluations. Although presently we are working only in terms of one snapshot in time, it is recognized that just as glasses must be changed to accommodate eye changes over time, a person's norms will change with his aspirations at different stages in the life cycle. Superimposed on these changes, there are others from the culture generally, which will serve to modify statistical means in this respect over time. To take account of this last source of change requires logitudinal studies; for the kind of exploratory effort involved in our work we must ignore this last source of variation.

Using "test borings" from a representative sample of households, the research strategy is to construct a crude picture of the hidden understructure of norms. Through attitudinal questions in which we get the respondent to indicate for a range of livability dimensions of his intensity of feeling on a series of "ought to be" statements, we seek to block out a continuum of qualities about housing and its environs associated with life style and stage in the family cycle. Analyzing a population first by life style, we anticipate finding a continuum extending at one end from norms described in terms of basic subsistence needs of food, clothing, and shelter, with gradations toward the other end involving shifts in emphasis toward social concerns (for example, prestige considerations), intellectual concerns (for example, opportunities for pursuing the arts), and physical concerns (for example, emphasis of the visual environment). Then controlling for life style and analyzing preferences by stage in the family cycle, we anticipate finding significant preference patterns concerning facilities and spatial arrangements of housing and surroundings for each stage in the family cycle. Of course, these investigations must be interpreted against the background of the respondent, the range of his experience with differing housing and environmental situations.

In addition to attitudinal questions to establish norms, we include in our survey work a whole line of questioning aimed at eliciting respondent satisfactions with features about their present accommodations and environment. Although some consideration is given to previous housing experience, we are inclined to discount the usefulness of retrospective reactions. From these two lines of inquiry, controlling for life style and stage in the family cycle, our strategy in this exploratory work is to identify a range of housing and environmental qualities and facilities where there is consensus in taste norms and within these areas examine for high, medium, and low-order livability satisfactions. From this kind of analysis, we look to the possibility of reducing the motivational basis of choice to a few key factors in which there are high intensity feelings of dissatisfaction concerning qualities available in present housing and surroundings as compared to norms held about needs and desires in this respect. Obviously, in a macro level analysis of this kind, we are dealing with the propensity to move of aggregates of population. We acknowledge that there are highly individual bases of reaching decisions on whether or not to search for housing which must be accommodated. So, in adapting these studies to a model of the Round 1 decision, we anticipate that outputs will take a probabilistic form as opposed to a deterministic one.

Exploratory Studies of Resident Tastes and Preferences

Investigation of residential tastes and preferences about their environment setting has a fascination for the researcher accustomed to dealing with inanimate forms of data on acres of land, square feet of floor area, or even with descriptions of families and their residences gleaned from housing surveys Somehow there is a feeling of homing in on the why part of the phenomena usually dealt with in the inanimate forms of bulk data, perhaps a sense of expectancy that comes in working with a new data form, or perhaps it is simply the amateur psychiatrist in us—the opportunity to get our subjects to come clean on all the things that long have puzzled us. Whatever the reason for being drawn to this source of information, it is no panacea for model inputs.

In all of this work, it was simple enough to record moving behavior and to register the facts contingent on the move, on the premise that this was some reflection of what the respondent wanted in the way of housing and environmental surroundings in making the move. Even discounting the serious problems of a retrospective approach of this kind, our own experience tells us that housing choices are made under a host of conditions, involving whim and expediency as well as rationality. Yet, if studies of actual behavior offer problems for the investigator, studies of what people say they want offer even more. A number of panel-type studies where respondents are revisited at intervals for a checkout on intentions against actual subsequent behavior indicate considerable variability in this respect. Although the conditions of variability in the intended-versus-actual behavior can be pinpointed fairly well, this complicates the use of such data. However, if these kinds of data offer difficulties, the study of respondent feelings about their surroundings in relation to subsequent moving behavior is much more difficult and the pinpointing of qualities about the housing and the environment that consistently are associated with moving behavior offer more problems.

Yet with all the difficulties, the schema outlined earlier surely indicates the importance we hold for this source of data. Our work on preferences draws on some past experimental interviewing under a range of situations and settings—boom-town conditions facing newcomer defense plant employees, the colorless gridiron environment slowly obsolescing in suburbia, Harlem, Radburn, Greenbelt, and so on. While much of this work was aimed at learning ways of asking questions in forms meaningful to respondents of differing value orientations and with differing levels of schooling, we began experimenting with ways of circumventing the problems noted above concerning recall and the costs inherent in checking out the variability of responses in this respect by using simple parlor-type gaming devices. One of the most promising of these prototype devices was Wilson's "game" for choosing a neighborhood and a lot, patterned around the TV give-away programs of that era.[17] Since then we have experimented with house-hunting "games" of various forms, all aimed at simulating real world conditions under which the respondent would make choices. A great deal of experimentation and testing is required to develop such instruments and test both their validity and reliability for getting at the variables needed in the analysis of conditions that trigger Round 1 decisions.

Recently we have been analyzing preference patterns of a national sample of households obtained under a National Cooperative Highway Research Program study. In this and other work, we are seeking to identify preference data which show some promise for predicting Round 1 decisions. This requires a line of questioning which will enable us to identify taste norms as well as preferences. Although others easily come to mind, two control variables for these analyses are life style and stage in the life cycle. As this work proceeds, it is quite probable we will seek to establish the degree of consensus in taste norms, controlling for these and other factors for a range of housing and environmental facilities and qualities, and then test for high, medium, and low-order preference against these norms. Although work presently in progress will not permit us to do this now, we look to the time when we can define for different life styles and stages in the life cycle, those housing and environmental factors where deviations of actual living conditions from norms were pivotal in the Round 1 decision to move. Thus, in a prospective kind of investigation

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[17] Robert L. Wilson, "Livability in the City: Attitudes and Urban Development," *Urban Growth Dynamics*, ed. Chapin and Weiss (John Wiley & Sons, Inc., 1962), Chapter 11.

we would hypothesize that individuals grouped today into life styles (identified from activity patterns) and then further grouped by stage in the life cycle, will show consensus on a number of norms and that extreme deviations from these norms registered for the present place of residence will be highly associated with subsequent moves We suspect that life style will affect preferences that are more concerned with the neighborhood environment, whereas stage in the life cycle will be more closely associated with housing facilities and arrangements and access to community facilities.

SOME PROBLEMS AND ISSUES

In the light of this progress report on our work on the behavioral antecedents of land use modeling, it seems appropriate to conclude with the recognition of a few of the problems and issues involved in this work.

One issue worthy of note centers around the aggregation problem. The identification of routines is directly affected by levels of aggregation in activity classification, in time, and in population selected by the analyst. Thus a routine may emerge or be wiped out as a measurable phenomenon simply by virtue of the level of aggregation chosen in each of these three ways of aggregating data. How broadly or how narrowly should activity classes be drawn? What rules should govern time aggregation or population aggregation? Are there *a priori* bases for making decisions on aggregation appropriate here?

Another even more elusive issue is the problem of operationalizing attitudinal investigations. Ostensibly the purpose of including an attitudinal dimension to the study is to enable us to evaluate activity patterns. We construct routines on the basis of actual recorded behavior, and we wish to know under what circumstances these routines might be expected to change in the future. Our micro level conceptual framework posits that not only do changes of income, changes in stage in the family cycle, and similar status variables generate changes in routines, but also certain security, achievement, social status, and other situational variables may modify routines. If attitudinal data are to be used in evaluating the parameters of behavioral variables used in activity forecast models, can the cause and effect relationships of these sources of variation in behavior be established and defined sharply enough to permit us to calibrate models? What decision rules can be introduced to govern adjustment of parameters?

A third issue that certainly should be acknowledged here concerns the implicit assumption in our work that value systems not only should, but can be taken into account in modeling systems. Considering the infinitely complex nature of value systems and granted that the above issues can be resolved, do surface responses of an attitudinal nature adequately represent value systems? Is it pure bravado to be seeking motivational inputs to behavior?

One last issue concerns a problem which lies ahead of us but which is not directly involved in the work reported here This relates to the uses in location models of analyses of activity systems and consumer preferences as described above. How are results from these analyses to be brought into unidimensional space? What forms of output from these behavioral systems are required to insure compatibility with land use modeling systems?

COMMENTS

FREDERICK T. ASCHMAN, *Barton-Aschman Associates, Inc.*

I should say at the outset that I do have a couple of outstanding but negative qualifications to be on this panel. I am completely ignorant in the area of mathematical technique and I have neither the potential nor the desire to overcome this. Secondly, my own experience in urban development has been in the city of Chicago, which is well known as one of the great centers of intuitive decision-making.

Many of us involved in necessarily pragmatic decision-making abhor the kind of planning that simply accommodates projections of past trends. The reasons for this, of course, are that many of us see very little point in continuing to build cities to patterns with which we are obviously dissatisfied. What is needed is a true attitudinal investigation, which will replace the use of superficial indicators with an effort to give us a much better understanding of the basic needs and aspirations of people. I think this topic clearly relates to the previous discussions because decision-makers, particularly in our very loosely organized and largely incapable metropolitan area structures, really have two great, immediate needs that must be met by planners.

The first is help in goal setting. Aid especially is needed in defining what you might call the boundary conditions, or the specifications as to what decisions ought to produce and what they ought to accomplish. Second, it seems to me that we need much more creative and workable types of possibilities that decision-makers, chiefly elected officials, can pose to the public and gain public support for through the exercise of political leadership. This must be done at two levels. We have potential capabilities for controlling at least the certain elements of metropolitan development, essentially elements involving the land use/transportation relationship. We also have a very strong need for creative policy proposals which go into the actual components of metropolitan plans. We all will agree that modeling techniques certainly offer great promise of meeting these needs, both in the identification of realistic goals and in the assessment of goal achievement potentials involving forms of action. The important thing to realize is that our urban conditions have got to be defined generically for models to meet these needs. Hopefully we have given up long-term master plans which are really wish lists, responding to the planners' quest for certainty, and in that event it becomes extremely important that the urban condition be defined generically, and that solutions be posed in some generic form. Otherwise there will be no utility whatsoever in policy-making.

As I see it, Stuart Chapin is attempting to give us a much sounder base for this kind of generic definition. However, I do have some concern with the semantics of the statement which deals with the term preferences, and in which he says that planners are experiencing pressures from decision-makers for some means of responding more directly to public preference. It seems to me that this can open up some legal misunderstandings. These pressures do exist, but it seems to me that progressive mayors and other officials are not really asking planners today to respond simply to what the public wants. Instead, they are asking us to bring about a creative expansion of the options; that is, the addition of options that presently are not known to the public. There is great danger, it seems to me, in oversimplifying this matter of preferences. Those of us who were in World War II remember that we were questioned as to how much we wanted to pay for an apartment when we got back, and we all said fifty dollars. So the government wasted two full years attempting to provide fifty dollar apartments. For this reason, I think it is very important to recognize that our public officials are not quite as concerned as they seem to be with the superficial problems of taking land off the tax roles and whether or not they can be elected two or four years hence. I think they really are calling very strongly for the expansion of available options. And here, it seems to me, is one of the most exciting uses for the techniques which modelers are developing.

I would also hope that along with the discussion of preferences we could consider the constraints on widening available options. For example, we may have to broaden options simply to accommodate some of the spatial requirements that we have. I think we should investigate such questions as: what we can do about higher density in terms of environmental design; the possibilities and problems of the new cities, and the possibility of accelerating growth in smaller cities. We must try to acquire options to meet the problems that cannot be handled on the basis of present public preference.

I would hope, also, that we might deal somewhat with the fluctuating restraints imposed by groups of people upon other groups of people. Quite obviously this refers specifically to racial prejudices, to kinds of institutional practices that impose constraints on the preferences and aspirations of some of our citizens. This relates to the zoning question, to the old question of restrictive practices and how these hinder achievement of national housing goals. Our tax system also poses a kind of constraint.

In conclusion, I wish to say that when we examine preferences we have to be conscious also of the parallel constraints. I see much potential in the work that Chapin has presented. His work attempts to meet the problem of simply accommodating projections. And this, in my view, is the proper approach to take.

DANIEL R. MANDELKER, *Professor of Law, Washington University, St. Louis*

I would like to start by telling you that I am a consumer of urban development models who has not the slightest idea of what goes into them. And I expect to preserve my ignorance. I think it gives me a useful perspective to look at what models of this kind can do for the urban development process.

I think I may be most helpful by indicating how I think the policy elements in the urban development proeess can be utilized in building development models that mobilize the legal system. I would like to suggest first of all that there is a good deal of confusion about how lawyers and decision-makers using legal tools attempt to reach decisions about different development patterns. I will illustrate this point with a few examples below, but I would like to suggest first of all that the legal system itself is a model. It is a very rough model, but it is also a fairly successful predictive model in which we begin with a series of inputs, apply a rough set of criteria, and come out with a decision. Given certain kinds of facts we are often able to predict how the decision-maker, whether a court or an administrative agency, will act in a particular case. Thus, it seems to me that it must be useful to consider building a separate model of the decision-making process which would be employed in the solution of legal problems suggested by urban development models. For example, you might produce for us a residential dynamic which indicates a preference for large areas of low-density residential development. You might then ask the decision-making legal model to make legal responses to this choice. You certainly can build different kinds of decision-making criteria into that decision-making model which will give you a wide spectrum of results.

However, speaking as an academic lawyer, I would say that you can assume that the legal system will build for you any kind of legal control you desire to have. Perhaps this is a radical position, but I think it is perfectly suitable. I can illustrate this point best, I think, by using as an example the location of shopping centers.

Let us assume a metropolitan area in which there are two existing regional shopping centers. Let us next assume that these centers are saturated; there is not enough parking, the stores are crowded, access is difficult, and more and more residential development is taking place outside their trading areas. So it is necessary to build a third regional shopping center in this metropolitan area. In building a model for the solution of this problem, planners may assume that we lawyers can give you a legal system which dictates a choice that is preemptive. Only one site will be selected for the third regional shopping center, and construction on other sites will be legally prohibited in one way or another.

But the legal system may not presently be able to dictate a preemptive choice. In this hypothetical region there may be a master plan or a comprehensive plan, and several sites may be indicated for the third shopping center There may be several applications from interested developers, and there may be political pressures from all directions. Perhaps, as a result, two shopping centers will be built instead of one. A partial explanation of this result is the fact that lawyers have difficulty constructing legal criteria that are sensitive to mutually exclusive choices but which do not involve us in other difficulties.

For example, in the context of the shopping center problem the courts have been reluctant to consider business competition as a factor in land use and zoning decisions. A model of how the physical environment responds to competitive business pressures would help convince the courts that competitive interactions are related to decisions about physical development

I suggest that it would be possible either to build policy factors influencing legal judgments into the model itself, or to leave them outside. Either method is feasible provided the choice is made explicit. If the decision-making process is exogenous to the model, the modeler should be very much aware of exactly how the decision-maker can respond to the contributions of the model.

A decision on the way in which we use the policy element depends upon the extent to which discretion is built into the decision-making process. This is another problem of which you perhaps may not be fully aware. Occasionally, we can construct legal rules of decision which have a small discretionary element. For example, we could enact a statute which forbids the location of an Interstate highway within one mile of an historic site, with the latter term very carefully defined in the statute. This legal rule could be incorporated into the model, I presume, in such a way that every time the models showed an Interstate highway within a mile of an historic site the model would reject that location point. This is one kind of legal problem with which modelers can work in order to derive quantifiable criteria which can be very useful.

The same point can be made about market models of the housing market. To some extent, the legal rules applicable to demolition of housing are circumscribed and quite precise. It is very common for municipalities to pass ordinances or for states to pass statutes which stipulate that when needed repairs exceed 50 percent of reproduction value, the house may be demolished by the municipal authority. Information you collect must be concrete enough to enable the model to identify those dwellings that qualify for demolition under this statute. An assumed rate of demolition can then be built into the model which should be able to take out of the housing stock in every year those units that qualify under this statute and which the municipal authority is willing to subtract.

I would like to move now to another example where the policy outcomes are not as clear, and where it seems to me that we get into some evaluative problems that are difficult to resolve. I am referring to an asumed developmental model of the urban region in metropolitan areas—a model with which the appellate courts have been working When I say that the appellate courts are working from a model, I mean that they are assuming a definitive norm of what an urban area ought to be like. From this assumption of what the urban area ought to look like comes a series of judgments in specific cases. If the court were informed about different patterns, it might render different judgments.

Here is an actual case in which a sensitive development model could help. The situation is that of a planned Interstate highway with the customary interchange areas. The comprehensive plan for this municipality indicated a large civic and commercial complex near this point. Now the approach road to this interchange passed very near a four-corner intersection at which there already had been constructed two gas stations on two of the corners. This corner was right at the center of the proposed complex. On a third corner a developer made application for a third filling station Ordinarily, in a case like this, the court would accept the third applicant and would permit the gas station to be built. The reason is that the courts are working with an assumed model under which the pattern of development is incremental change, heavily influenced by the existing, built-up development pattern. This pattern also happens to fit our notions of equal protection of law, and beyond that, planners' conceptions of what a metropolitan area ought to look like. The courts accept the idea that development occurs through incremental change, and I can cite case after case in which they have acted on that assumption. Most courts would refuse to block a development proposal in order to gain future time for the municipality to implement a more ambitious plan. In this case, however, the planners said, "Oh, no, you can't build your filling station " "Why?" "Because this plan shows an unbuilt civic and commercial center at this point, and it is our conclusion that to build a filling station here as a secondary local business would so disturb traffic and shopping patterns that it would interfere with the objectives of the comprehensive plan." In this instance the court is being asked to render a judgment about land use in accordance with a master plan which as yet has not been implemented This step is a very difficult one for the court to take, but in this case it took that step and denied the application.

There is one final point that I would like to make and it bears on the aggregation and disaggregation of data for purposes of model-building. For example, in the law of landlord and tenant no distinction is made between owners of substandard housing and owners of standard housing. Smart lawyers, however, come into court and say, "This man owns a slum or substandard unit and he should have a high degree of responsibility and different standards of care." These claims for the recognition and separate treatment of different classes of housing could lead to an effective categorization of housing that would have important legal significance This kind of distinction then would be useful to model builders

I could, if I had time, also go through a study we recently conducted in St. Louis of what happens to owners of slum housing when they relocate out of an urban renewal project area. The results are very tentative, but they suggest the existence of a class of entrepreneurs who knowingly invest in substandard housing I would also suggest that the racial factor ought to be important in studies like this, in which the planner aggregates and disaggregates data for purposes of understanding urban processes. There is a very simple reason: the Constitution demands equal protection of the law and, consequently, the law will respond in a legally significant way towards different racial groups. Therefore, I would suggest that in most of the models you build you should be very interested in the spatial implications of the treatment of different racial groups. Racial stratifications should become very important to anyone who deals with models of the urban system.

GEORGE T. LATHROP, *University of North Carolina at Chapel Hill*

I would like to speak about two points that grow primarily out of my experiences in New York with John Hamburg and our efforts to build a crude land use model for our work in transportation planning. Both pertain to the question of disaggregation. Stu Chapin's paper brings out the issue fairly clearly, and to me the paper illustrates a context in which I agree that disaggregation is useful. However, I would like to express some concern about it.

The first of these two points concerns the nature of the "search for understanding." The examination of the motives, preferences, and behavior of individual actors or family groups in the urban area certainly provides a strong basis for understanding and for returning to a more aggregative approach. I think this obviously is one of the strong intentions in Chapin's work This reaggregation may not take the form of mathematical modeling or "social physics," but it is aggregation based on a grouping with a purpose in mind. I would like to emphasize, although it should be obvious, that the purpose of the modeling effort must determine the level of aggregation or disaggregation. This implicitly assumes that modeling is the end sought, or that it is the vehicle which serves as a way-station in the "search for understanding."

That brings me to the second point which also is involved closely with this question of purpose—and that is a question of scale. We talk both of temporal and spatial dimensions and Chapin includes these dimensions in his discussion of activities. I think they are appropriate, too, to a panel of discussion of modeling. In transportation, to borrow an example from my own experience, we may plan for five or for twenty-five years, or even perhaps for forty or fifty years. Ignoring, for the present, other issues that are raised by that statement, we also plan for regional transportation facilities, and we plan for very localized transportation facilities. It almost goes without saying that the sort of information we need for these different scales is very different in terms of detail and in terms of aggregation. These changes in scale lead to different types and degrees of uncertainty, to different degrees of likelihood of fluctuation—in short, they present completely different contexts. They require different levels of aggregation and different kinds of modeling. Chapin explicitly makes a point of the difficulties of moving back toward aggregation for modeling and of the necessity for doing so. My point here is to emphasize the necessity for choosing an appropriate scale, and to express my concern about the number of variables that sometimes appear in disaggregative models and about the uncertainties of data handling, which compound the probabilities of error to which Alonso refers in his paper. Substituting four variables, which are difficult to predict, for a single variable which is very little more difficult seems self-defeating and laborious unless there is a substantial gain in understanding or a specific need in terms of scale.

As long as purpose and scale, both physical and temporal, are kept clearly in mind, I think the issue of aggregation will take care of itself

TOWARDS A THEORY OF THE CITY

CHARLES LEVEN *

By way of preface, let me engage in a little public self-therapy and recite three incidents that really lay behind some of the interests that I have developed

One of these occurred about three years ago when I was approached by a consultant for the Penn-Jersey Transportation Study. I was asked to say something about the question· if different transportation systems lead to different land use patterns, and given that we can appraise all the merits and demerits of the transportation system, but different land use patterns evolve, which would be the better land use pattern? And they were prepared to show me two land use maps, one estimated to result from one transportation plan and one from the other. I was to worry about which was the "better" land use pattern. Aside from this being a somewhat difficult question, I think what concerned me at that time was that most people who thought about this question (and I think to some extent this is only historical because lots of people no longer think of it this way) did so in terms of looking at the land use plan parcel by parcel, the game was to figure out what was the best thing to put in each parcel. Essentially, one would score plus, minus, or neutral for each parcel of land and add up all the thousands of parcels to determine which was the best pattern

What occurred to me at that time was that they really were not asking the right question. You could not look at a parcel of land and say that its use was good or not in any absolute sense; it was a question of its use relative to the use of all other parcels. A very simple notion came out of this—that one is not really concerned with the discrete description of some land use pattern, but rather with the emergence of a pattern of land use which would be more, rather than less, desirable in terms of some of its characteristics.

It is not surprising for an economist to think of this; although most of us have the concept of some kind of optimum allocation of resources, we know that that does not mean we can say how many tons of steel or how many blue shirts would appear in an optimum resource allocation. Even if we cannot really describe an optimum allocation of resources, we can say that whatever allocation of resources we observed was, in fact, optimum when certain conditions were satisfied. But, that is a very primitive kind of idea that leads one to no more than the notion that what one wants to look at is not so much a

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painting or a map or a replication of what actually exists in all of its full and rich detail, but measures of the relevant characteristics of any particular distribution in terms of its being better or worse in satisfying the conditions.

Another thing that happened to me was a remarkable conversation in Yugoslavia some months ago with a high official in the finance ministry for the Republic of Slovenia I was told about an idea they had for a new tax; a property tax. After expressing my surprise and the general unpopularity of the property tax in the United States, I found out that it not only was going to be a property tax, but that it was going to be a very strange kind of property tax. Specifically, while there would be certain classes of property with different rates, the tax would be levied on the square meters of space without respect to its value or its location, rather than on the value of the property. My reaction was to say something like, "Oh, you must want Ljubljana to be a very dense and compact city where you will encourage high-rise construction." The reply was something like, "Well, that is all in the hands of our Ministry of Town Planning. I would not know anything about that." Then I went to visit the Ministry of Town Planning, and they showed me a very nice map with superhighways and parks and residential areas. Of them I inquired, "When you made up this plan, was this under the assumption of the present fiscal arrangement, or were you assuming the new property tax would be put into effect?" They said, "What property tax?" It showed that they are just as far ahead in planning as we are.

And so another idea occurred to me, which is related somewhat to the first, namely that describing a desirable outcome is not a very useful exercise. Drawing a map of a plan of a city the way one would like it to be is not very useful for two reasons. One is fairly obvious—simply that the drawing of this picture is not going to make it happen. Most of us understand that as one of the weaknesses of master planning. But there is perhaps a still more important weakness. This is that quite obviously one can, at least in principle, draw a plan for a city which fulfills all of the characteristics which one would like the plan to fulfill. I am sure, at least to the extent that desirable characteristics can be specified, that such a master plan can be drawn. The problem is that hundreds, if not thousands, if not tens of thousands of master plans can be drawn, all of which would have these characteristics, and all of which would be in some sense equally desirable. And so, instead of describing outcomes that one would like to see occur, one might begin to think in terms of the characteristics of these outcomes which would lead one to think that they were optimal, and then worry about the kinds of institutional conditions that would be necessary for these characteristics to be satisfied instead of worrying about exactly where various specific facilities are to be located. This is the second idea underlying my current views, namely that we should think in terms of how we can regulate institutional processes so that the actors in the locational process will somehow or other produce a location that satisfies certain characteristics.

The third event to which I allude is my recent exploration of sociology and the Burgess zonal hypothesis. In its most basic form it proposes a law about cities. It observes that they grow outward in rings, like trees. As physical deterioration progresses in an inner zone, the people who have more money move out and poorer people take over. And then the poor people take over another ring and the middle class and well-to-do move further out and this keeps proceeding in expanding rings. This struck me as a very remarkable fact, if it were true. I gather there is considerable doubt about its truth—at least in so crude a form. But the interesting thing about the literature stemming from this idea is that while it describes what cities are like and how they change over time, in very sweeping if not grandiose terms, it does not seem to have very much to say about why this process is occurring, under what conditions it would occur differently; nor does it even have much to say about whether it is desirable or undesirable. It is simply a morphological description of a changing state over time.

While I find the notion of describing cities at this level of generalization very appealing, the description itself is not really satisfactory. I want to be able to say something about the kinds of institutional or environmental conditions which generate such a process. I want to have some idea of the conditions under which this process would accelerate, decelerate, or take a different direction. Finally, I want to know something about whether it is desirable or not. In other words, I am interested in the process in the spirit of a normative economic theorist. I would like to come to grips with the city as a kind of social organization in a generalized fashion, but in a way that would produce deductive hypotheses that were testable.

THEORY OF URBAN SPATIAL FORM

By city I mean something like the Census definition of urbanized area, some compact collection of people. Throughout the rest of the discussion I will use the word city in that sense. My use of the term spatial form refers to the collection, and more particularly, to the arrangement in space of geographically identifiable activities (not necessarily economic activities) and structures associated with them. An important point of my argument will be that this sort of concept of spatial form, as applied to an urban area, needs a much more rigorous definition and analytic specification than has been applied. But, let me leave that until a bit later and for now, let me use spatial form as a loosely defined reference for such arrangements By arrangement I mean to include the density and the spacing of things like houses, stores, factories, and transportation.

The spatial forms of the city have come to the fore as a focus of public attention in recent years. In part our concern over spatial disorder is just one of the many facets of the general perception of an urban crisis. Beyond this, however, there seem to be four more specific bases for concern. First, the spatial form itself seems to make a difference to a variety of people professionally involved with planning and administering the city. Things like open space, wide variety of choice in locational environment, the grouping together of different kinds of people in residential areas, compatibility of abutting land uses, and so forth are seen as ends in themselves.

The second concern with spatial form would be that frequently, form affecting policies are undertaken mainly for other social objectives which impinge on the actual spatial form. In short, broad social purposes frequently underly such instruments as clearance, renewal, zoning, and code enforcement, and these purposes are not directed at a particular arrangement of things in cities, even though they have a great impact on this arrangement. This is another reason why we may be concerned with form, for we want to know what these things are doing.

Third, I think spatial form may have an influence on the effectiveness of other social processes. Let me cite a few examples. For example, public and private costs of congestion which are imposed on city occupants and production processes do vary with the spatial form of the city. Internal transportation costs certainly vary with spatial forms, especially with changes in journey to work and industrial input-output access patterns. The question of whether given political jurisdictions are sufficiently large to serve as efficient service areas for public services and to provide tax equity among jurisdictions depends upon the pattern of settlement and the demands for public services by income class, quite as much as it depends on where political boundaries are drawn.

Some people think that social conflict may be a function of the settlement pattern of socioeconomic groups; like the notion that the degree of physical segregation between racial groups may have something to do with social tension. And so we might be interested in whether elements of the physical plan *per se* contributes to such segregation.

A fourth reason for being concerned with spatial form is that a greater ability to predict it, either historically, or as a function of public policy, probably will be very helpful to urban planning and administrative decision-making.

Thus it would seem that there is a need to develop an operating theory of the spatial form of the city in a manner which is empirically testable, to develop operational definitions for the variables in it, to collect relevant data, and to test hypotheses contained in the theory

The foregoing remarks imply that conceiving a theory of the city is a useful methodological position. What I mean by this is a theory of the city as a meaningful social aggregation in the same sense that we recognize a theory of the firm, the household, the family, or the individual consumer. To construct such a theory, a function or functions of the city as a city must be postulated, and hypotheses constructed with respect to how those forces which most affect the city's fulfilling of these functions influence the characteristics of the city and its evolution. Attempts must be made to validate these hypotheses and to evaluate the relative social desirability of outcomes.

It should be pointed out that a theory of the city is not meant to imply a set of propositions that will analyze and determine all those kinds of human behavior and their relationship to environment which are found in cities as opposed to non-cities. A general theory of social science in urban microcosm is not what is intended. Instead, I think I really am intending an examination of selected functions of a particular institution which I call the city, and the aspects of social behavior most closely connected with those functions. Not only is the city an institution which many people view as behaving very poorly, but also it is one which has not been studied in a systematic *a priori* theoretical way. I do not mean to say, of course, that no one has studied cities before. But I think there has been relatively little study of the city as a meaningful aggregation in an *a priori* deductive way which leads to some sort of testable hypotheses about it. Also let me note that I am not talking about urban economics. For example, we can talk about economics as a discipline which is concerned with the behavior of certain units that we call households and firms, and urban economics as the study of how these kinds of units function in an urban setting. Instead of an urban economics we might be talking about an eco-urbanomics as the study of an institution called the city. It is not about things in the city—it is about the city itself. And one could study eco-urbanomics or socio-urbanomics or politico-urbanomics. One would not have to study everything about the city at one time. One might concentrate on the economic or the political or the sociological aspects.

I would like to emphasize that the intention is an applied theoretical approach to the city *qua* city, as an institution. Much of what is done now under the heading of urban and regional studies deals with problems in the city, rather than of the city. Let me give a simple example. The problem of adequate employment opportunities is a function, in any particular city, of the product demand, the determinants of which may be largely external to the city, worker productivity, and the functioning of the labor market. These will determine the level and distribution of employment in a city. That regional differences exist, with the function of space affecting the solutions, certainly is the case, so that research on such problems in a regional or urban context is a very important contribution. But such research ordinarily focuses on particular institutions or groups within the urban area, like firms or industries, consumers, the labor force, or particular local governmental units. It ordinarily does not focus on the urban area itself as a meaningful analytic aggregate. This may be unfortunate for a number of reasons.

First, institutions and processes may be affected by the kind of city in which they are located. Second, the form of the city itself may be highly dependent on the working out of social, economic, and political processes within it. Third, there seems to be considerable sentiment to the effect that cities may be functioning poorly, aside from whether the institutions within them are functioning well or not. Even where particular institutions are functioning poorly, it seems useful to investigate the possibility that there is something in the functioning of the city itself which produces breakdown in these processes within it. The other side of the picture is the investigation of the extent to which the city takes its form from its environment and the particular process within it. It is this question, at least initially, which mainly concerns us here.

DETERMINANTS OF URBAN FORM

In regard to the theory of determinants of spatial form of the city, two problems arise at the start. First, the city, as I have defined it, probably is not a decision unit to any important extent. Second, the form of the city probably influences virtually every kind of human interaction. Insofar as the first question is concerned, it does not seem very serious. Industries, neighborhoods, occupations, and races are not decision units either, yet we still find that many processes can be analyzed usefully by interpreting such groups as if they were organic units; that is, as if they were engaged in some kind of purposeful behavior in a functionally identifiable way. As to the city influencing in some way every aspect of human behavior, the situation simply would have to be compromised. This is a familiar aspect of almost all social science methodology. A business enterprise is a very complex organization, affecting the lives of the people in it in myriad ways. Nonetheless, it still seems useful, for some purposes, to study businesses as if they were involved only in the transformation of resources into commodities.

With these limitations in mind it might seem reasonable to regard the city as the unit within which the following functions are performed. As noted above, we have to specify some functions which uniquely are those of the city:

1. The selection of enclosures for all of those activities which locate in the city—that is, which cluster around nodes, in continuous areas of markedly higher density than is found in the non-city. This would include residential, production, social, governmental, and cultural activities. It would involve understanding the emergence of particular classes of structural forms out of the much wider range of technically possible problems or solutions. Some sort of selection within these possibilities emerges; selections of tall versus short, dense versus sparse, durable versus nondurable, high versus low quality. These selections do not really emerge out of the real estate market—they emerge out of something which I think is substantially larger than the real estate market, and I find it useful to regard this whole complex of processes out of which they emerge as "*the city*."

2. The arrangement of these facilities and enclosures in a way that will facilitate those interactions between units (that is, firms, houses, enterprises, organizations) which are the basis for their being in the city as opposed to the non-city. This would include the arrangement of facilities designed to facilitate the interactions themselves, that is, transportation and communication.

3. To serve as the environment in which a number of services are consumed and paid for, or resources created in common or semi-common by the inhabitants and institutions as well as by individuals, or some identifiable

group of them. Obviously this would include government services as things consumed and paid for in common. But it also should include such things as higher education, medical and health services, cultural and recreational services, clean air, clean water, a many-skilled adaptable labor force; in short, a variety of things which are produced by an urban environment that cannot be said to be produced by the local government in any sense, or by firms or by households, but by the urban environment.

What we really want to develop is some kind of theoretical framework within which we identify factors which are determinants of city form and which, in turn, produce some spatial form in an analytically predictable way. Then we search for some method of evaluating the resultant spatial performance, which, in turn, probably would feed back upon the determinants of spatial form themselves.

The research needed for such a theory should be directed to the following three problems:

1. Elucidation of a deductive theory of the determinants of the spatial form of the city.
2. Specification (definition and measurement) of the spatial form of the city in a way that would make testing of the theoretical hypotheses possible.
3. Development of methods for evaluating the effect of the spatial form of the city on the performance of the city and the social processes within it.

The number of things that might affect the spatial form of the city certainly are quite large: there should be no attempt to maximize the number of testable hypotheses that can be formulated. Instead, hypotheses should be formulated only with respect to a limited number of *a priori* selected determinants. The selection of these determinants should be guided by three principles: (a) that there be a strong *a priori* basis for suspecting a strong influence on city form, (b) that they represent forces, or be importantly related to forces subject to public policy control, and (c) that they represent areas within the competence of the researchers.

Given these principles, the primary factors an economist might select as determinants of city form might be:

1. The intra-area transportation systems. This would include consideration of all modes and several characteristics of them, such as, speed, cost, pricing, and frequency.
2. The system for providing public goods by local government. This would include the system(s) of taxation employed, the kinds of public services provided and the effects of having separate small jurisdictions within which taxation and expenditure are carried out.

Other important factors which might be considered in the same framework, if we had the knowledge of them, are the following:

1. Limitations in construction technology or urban design possibilities.

2. Personal desires for "social distance," *i.e.,* the desire of individuals, *ceteris paribus* to live near people who are similar to them in socioeconomic characteristics.

3. The importance of living in proximity to others in the same occupation or employed by the same establishment.

One constraint imposed on this aspect of the research probably should be noted explicitly, namely, that if the attempt is to develop testable hypotheses, the asserted determinants of city form would have to be expressed in ways in which they could be observed and measured, at least in principle, and to a considerable extent in practice. For the most part, however, what is called for is quantitative characterization of the kinds of things which social scientists are used to dealing with in this manner. The most difficult item, perhaps, is the transportation system. But recent work suggests that this problem is manageable.

If the problems of definition, specification, and measurement are minor annoyances in expressing the determinants of city form, they represent a major research problem so far as specifying the spatial form of the city itself is concerned.

Part of the problem, of course, is the lack of consistent data on land use. But there seems to be involved a much more fundamental issue which arises out of viewing the form of the city as a functional element within an organized theory. In this context, spatial form does not mean a detailed description of every physical form and every spacing between forms and people. First, assembling and classifying such information would be a very formidable task. Second, spatial form probably could not be predicted in anything approaching this extreme degree of disaggregation. Third, even if it could be predicted at this scale it does not seem likely that we could discriminate between the relative desirability for the urban society as a whole of most of the different possible patterns at this scale of observation.

Therefore, it would seem that the description of spatial form must be condensed in detail, to be meaningful as well as manageable. But more than that, it must be written in an analytical form as a variable or set of variables which take on continuous or discrete values if ever relationships between people, institutions, and the emergent spatial form are to be tested.

In short, a land-use map is not a number and cannot be fitted into a quantitative model. That it is not a number is not really important—it could be described as a very large set of numbers. That it is a description of an outcome and not the properties or conditions of that outcome is the real problem.

This latter point perhaps can be understood more easily if the problem is viewed in a more familiar context, namely the problem in economics of determining optimum resource allocation. There we want not a description of the actual resource allocation (a detailed list of inputs and what was produced), but evidence that certain conditions have been satisfied (competitive pricing, production at minimum average cost, and so forth) which if satisfied, would cause us to conclude that the resultant allocation was in fact optimal. We resort to this kind of methodology for two reasons: (a) there is reason to believe that there are many discrete solutions which would be optimal, and hence desirable on economic grounds; (b) we want to engage in the analysis of public policy aimed at correcting non-optimal situations as well as simply evaluating specific outcomes *ex post facto,* and hence seek for theoretical explanations relating outcomes to controllable and uncontrollable elements in the environment. The idea here is that this same methodological view could be applied to the size and spatial form of the city. In this case too, a large number of specific outcomes probably would be satisfactory, even if a large number of considerations, non-economic as well as economic, were taken into account. What finally is being sought is the specification of a set of conditions, which if satisfied, would lead us to conclude that the resultant spatial form was optimal with respect to one or more processes of, or in, the city, depending on the degree of generality of the model.

CONCLUSION

The foregoing has provided two criteria for the specification of characteristics of spatial form: (a) that they be relevant to the effective performance of the city, and (b) that they be predictable (explainable) from the determinants of city form being considered. In the context of this proposal this means that we would be looking for those characteristics of spatial form which are influenced importantly by the transportation system, the local taxing and public expenditure institutions, and other factors considered, and which are relevant to the economic efficiency of the land use-transportation-public services pattern of the urban area.

Obviously, the measures initially selected would be subject to considerable revision as the theoretical effects progressed, and certainly after empirical testing. Some thought has gone into this question and the following can be given as illustrative of the kinds of measures which could be used, at least initially: population, area, density gradient, socioeconomic gradients, heterogeneity, average height, height variance and gradient, average spacing, spacing gradient, concentricity, sectorality, transport conformity, and political boundary conformity. Most of these measures are self-explanatory. Some that may not be are as follows.

> *Heterogeneity.* The average size (absolute and as a percent of urban area) of all single contiguous land-use areas under some standard land-use classification.
>
> *Concentricity.* The extent to which concentric rings (in distance or time, adjusted for topography) could be drawn about a central point such that they would tend to segregate people of various socioeconomic classes and different land uses. Analysis of variance techniques could be used to establish such measures.

Sectorality. Essentially the same concept as concentricity, but with respect to radial segments.

Transport conformity. The extent to which land use conforms to what would be predicted from a given transportation system and the assumption of transport cost minimization as the only factor affecting location.

Political boundary conformity. The extent to which political boundaries define patterns of settlement in terms of socioeconomic characteristics of land use. Perhaps this could be measured by the ratio of the average variance in heterogeneity with jurisdictions to the variance in heterogeneity between regions.

A major focus in this part of the research should be on the evaluation of spatial results, as opposed to their prediction. This is in contrast to most past and current work on analytical models of land use. The evaluation techniques to be developed should permit a more effective and general analysis of the interactions between costs of access, congestion, and construction. In addition they should permit an analysis of intra-urban variations in tax yields and public expenditure requirements on the basis of subareal units not necessarily coinciding with political boundaries. To meet these evaluation needs, however, the models will have to be transport cost intransitive with distance in order to represent real land use patterns in them. (They must allow for cost of movement from B to A to exceed the cost from C to A even where B is closer in miles to A than is C.) Topological problems enter when more than one chain of dominant paths exist (in the foregoing, suppose a location D, which is closer to A than B, but further than C).

In conclusion, I think it is possible to begin thinking of urban form in a generalized way. I hope that when interpreted correctly, I will be seen not as looking for a theory of a generalized concern with urban man, but rather for a generalized and generalizable way of looking at particular processes and particular concerns of (not in) the city

COMMENTS

STEVE PUTMAN, *CONSAD Research Corporation*

I have the feeling that we are not admitting that even before models existed, decision-makers were asking those who knew a little bit about computers and a little bit about statistics and a little bit about economics to help them decide what actions should be taken if they had the opportunity, in their city, to change things that were unpleasant or inefficient. And I think that this jack-of-all-trades probably discovered on investigation that the questions were almost impossible to answer. He then tried to throw the policy-maker off guard by asking him some new questions. After that he gathered together colleagues to answer these new questions which had been asked.

I think this sort of thing has been going on here; we tend to discuss criteria for evaluating the results of transportation plans and land use plans without making sure that we have valid ways of forecasting the things that we later plan to evaluate. What bothers me particularly is the nature of the constraints on goal formulation. For example, the first thing that I considered when I began modeling was that within a city we were constrained to consider only things within a politically defined city boundary, and further defined by aerial units which were also politically defined and by census tracts. Thus we were confined to working on a very specific level. We talked of why firms were moving from one place to another. We talked about households disliking other kinds of households, and how they would not locate in census tracts where these others lived.

After doing this for a couple of years, I found myself in the position of working with a huge region several hundred miles long, also politically defined, where data about firms locating in counties indicated that their behavior was very different from that of firms locating in census tracts. The study of household location in terms of prejudice became irrelevant.

This experience suggests the question. how do we tie together the previous discussion with some of the kinds of very general questions that Charlie Leven posed? If we stop to think about a city and certain ways of describing "city phenomena," where does this leave us with respect to the questions of movers? Similarly, if we talk about the questions of movers, I am concerned as to how this relates back to questions of city-wide phenomena. In this regard, I think that there have been studies in which we tried to go from looking at micro decision units, to seeing what the whole city would be like. I am not sure that it is relevant to discuss the method by which we move from individual behavior to a theory of the behavior of groups Nor am I sure that we should; but I think that what I would like to consider is whether there are, in fact, city-wide or region-wide phenomena, and whether these phenomena are caused by aggregations of movement? But these would be derived in the way that Hooke's law of pressure, volume and temperature of gasses was derived in the absence of information concerning Shroedinger's wave equation and other kinds of atomic and molecular physics. I think that we probably could consider descriptions of regional and city-wide phenomena, but in the same way that atomic and molecular physics have in some way contributed to understanding why Hooke's law works or ways in which it might not be relevant. We can look at individual decision units or firms in terms of how this might give us information about our urban or our city-wide and regional phenomena, without expecting information that we could directly aggregate.

DANIEL BRAND, *Peat, Marwick, Livingston & Company*

Charles Leven has presented a most stimulating paper. He has thoughtfully commented on and suggested directions to the efforts of many land use modelers around the country, including our own efforts in Boston over the last four years. I am almost surprised at how closely his approach to modeling spatial form resembles our own, since we approach the problem from quite different institutional bases. This closeness would indicate that either we must be close to cracking the problem (or we are all wrong) or that the organizers of this Conference have done a fine job of bringing together preachers of the same gospel to stroke one another.

My comments are in two parts. First are comments and thoughts on specific points raised in the paper. Second, is a description of our work in developing land use models in Boston. In many ways our experience with EMPIRIC represents a case study in the approach on which Mr. Leven and many of us seem to agree, and so a brief discussion of the results of this experience are appropriate here

There are certain almost definitional points on which I agree fully. We should not be concerned with land use, as in land areas, but in "the arrangement in space of geographically identifiable activities." We need to examine selected functions of the city "in an *a priori* deductive way which leads to some sort of testable hypotheses about it." We may find it useful to treat activities such as "industries, neighborhoods, occupations and races" as though they were decision units, even though they do not normally engage in some sort of "purposeful behavior" in the context of location (with the possible exception of the last named example).

Also we have some similarities in purpose. Leven is "interested in the (urban spatial) process in the spirit of someone interested in normative economic theory." I could not agree more. It can be frustrating to argue with colleagues who refuse to see that you have to be able to evaluate and then push the right kinds of programs or expenditures of public capital in transportation, relief of poverty, educational and social services, etc. Some people are only concerned with and get hung up in the process of change itself: the political scientist in problems of how to change political organizations, the sociologist in changing existing group structures, and the land use planner who says this part of the region will not grow (or decline) the way your model says it will, because these people do not want change. It is often very difficult to get across the idea that a comprehensive approach may first be needed in order to evaluate what programs and resultant changes may be good or bad, before struggling with the problem of change itself.

Leven also states that a major focus of our research efforts in land use modeling "should be on the evaluation of spatial results, as opposed to their prediction." The two purposes are, of course, complementary if we can formulate a model of urban change which uses and/or predicts measures "relevant to the effective performance of the city" and which predicts "from the determinants of city form being considered." An example of the complementarity of evaluation and prediction is our desire to use a model such as the Boston EMPIRIC Model, to predict certain activity distribution patterns which might be considered "optimum when certain conditions were satisfied." EMPIRIC is a linear model and so can be formulated as a linear program to do this. With such a procedure we do not have to draw pretty pictures of master plans, all of which are pretty, etc. This kind of complementarity leads us to the conclusion that we should model the urban spatial change process using variables and measures which allow us to consider optimality in terms of the kinds of decisions which we are called upon to recommend or make in the expenditures of public capital.

The second part of my comments relate to the EMPIRIC land use model work we have done in Boston over the last four years. The first purpose of developing the EMPIRIC model was to forecast and evaluate the future land uses which would occur in the Boston region given the proposed alternative transportation and other public facilities plans The second was to understand the urban mechanism. The client was most interested, of course, in the first use of the model. We were probably more interested in the second. You may notice that these are the first two of Charles Zwick's three purposes of land use models. Indeed, in Boston we also may be achieving the third purpose, that is, using the model as an educational and propaganda tool, whether we like it or not, in order to get the plan implemented.

The EMPIRIC model is an aggregative level model in Chapin's terms. I agree that as we go from the micro to the more aggregative level we will see the same basic market factors in effect, and we will see the same parameters descriptive of the aggregative process as of the micro process. Also, we will see different subpopulations exhibiting different behavior. In formulating EMPIRIC, I feel we stuck fairly well by Leven's guidelines with respect to (a) not maximizing the number of testable hypotheses, (b) including suspected *a priori* influences on city form, and (c) (particularly) that we select determinants within our competence. With respect to the latter, I feel we do know something about transportation.

The EMPIRIC model rests on the following hypothesis: The change in activity in a subregion over time is a function of the changes in other activities in the subregion; the levels of the activities in the subregion, the present and future accessibilities to other activities, singly or collectively; the land available in the subregion for development, and the present and future quality of such public services as water supply, sewage disposal, and schools. The particular model calibrated in Boston distributed four classes of population by income groupings, and five classes of employment. The form of the model lends itself also to stratifying population by race, educational level, or other characteristics. We picked these population and employment output variables after an analysis of the data for Boston, and especially according to the wishes of the client for output data. The model was to be used primarily for input to traffic forecasting techniques. Later, we discovered a wealth of output data that could be used for housing, solid waste disposal, open space studies, and other analyses.

Some interesting results on locational theories have come out of this work. A short description of some of the theories and hypotheses that were verified in this work may be in order. The estimated equations making up the model indicate that the accessibility variables are the most important of the policy variables for forecasting the locations of population and employment. However, the non-policy variables over which the planner has no direct control are generally stronger determinants of locational patterns than are the policy variables, in particular, growth in the various population income groups. The social distance measure which Leven has postulated enters here. Also, among the strongest variables in the employment equations are one or more of the other output variables. This provides evidence of the realism of using a simultaneous model such as EMPIRIC.

In all the equations one of the most important determinants of growth was the lagged variables, that is, the value of the output variable at the beginning of the forecasting interval. In every instance but one, the lagged variable carried a medium or large negative sign. This indicates the concern with space, the fact that people are tending, all else being equal, to locate at lower densities. The single exception is very important in that it is for the lowest-income population group In only that instance does the presence of the same activity at the beginning of the time interval induce increased growth in its own share of the activity. This is striking statistical evidence of the increasing growth of low-income ghettos, about which there is much discussion today.

Many of the other coefficients express relationships which are worthy of mention. In the low-income population equations, vehicle accessibility is such as to indicate that low-income families do not have the resources to take their full share of the advantages of improvements in the regional highway system. This is in line with Stowers' comment about shorter moves in the lower-income groups. However, the highest-income group exhibits the same behavior with respect to accessibility. This would indicate that they chose to pay increased transportation costs relative to the other groups to enjoy certain residential amenities and a concern for space. The middle-income groups, on the other hand, exhibit the concern for improved highways with which we are all familiar, indicating a desire to increase their accessibility to other activities.

In conclusion, there is a debate going on between the purists, and the applications or task-oriented people in planning (to be polemic). I think Leven states the process of model-building in a way with which I can entirely agree when he calls for producing hypotheses which are testable with respect to forces effecting urban change and effective measures of urban form. Empirical tests are required because the problem is so complex. Only through the use of both techniques, hypothesis building and empirical testing, will we be able to develop methods that will adequately forecast the distribution of large numbers of variables in order that follow-up steps in the planning process can proceed.

GENERAL DISCUSSION OF PART II

The discussion generated by these three prepared papers was centered on a group of questions on the role of models in the planning and decision-making process and on the appropriate structure of models. The initial concern stimulated by the first paper was whether or not a good match exists between the concerns of decision-makers and their information needs and the kind of information about urban areas which may be produced by the urban models now available or being developed. There were at least two dimensions to this. One was, are the policy issues, which the decision-maker is interested in and about which he must make choices, policy issues which can be addressed in the models? It was argued that the (political) decision-maker was concerned primarily with short-run and narrow, well-defined issues while current models were oriented toward long-run change and were very broad in terms of the issues and objectives encompassed.

The other dimension to the question of the match between the decision-maker and the model, and the one to which most attention was given in the discussion, dealt with the role of models in the planning process. Should the model be specifically designed to include evaluation of model outcomes? Two slightly different viewpoints emerged in the discussion, and these were more nearly differences in emphasis than in substance. On the one hand, it was argued that a model of some aspect of the urban development process is essentially a tool for analysis; that "maybe in some cases it has nothing at all to do with the planning process"; and therefore evaluation of the outcomes of models is a separate question and not an appropriate basis on which to evaluate the models themselves. The counter position was that since models of the urban development process are often developed for use in a planning process —for decision-making—they should either contain or be directly linked to an evaluation process. This position was partly based on the argument that in order for the model to be useful the appropriate measures on which the planner or decision-maker would evaluate the outcomes of the model necessarily have to be built into the model. If the evaluation process was not conceived when the model was designed, it was argued, the model, while producing useful analyses and predictions, might fail the test of usefulness to the decision-maker.

In subsequent discussion, it was suggested that difficulty in dealing with questions about the purpose of models in the planning process is largely due to a lack of specification of what existing land use models and modeling approaches are capable of producing in terms of projections of spatial distributions and conditional predictions of land development. There was general agreement with this viewpoint, but no apparent agreement on an answer to the question of whether models should be evaluated as to their adequacy and utility in terms of their descriptive, replicative and predictive capabilities, or their relevance to the bases on which decision-makers would actually make choices. One viewpoint was based on the argument that, given our current limited knowledge about urban phenomena, the critical concern must first be whether the models are able to describe and replicate those phenomena; and that the adequacy of the model for the decision-maker was irrelevant until it was clear that the phenomena under consideration could be reliably modeled, that is, that they were adequately understood. Once a satisfactory level of reliability of models was achieved, it was argued, evaluative features could be added to the models, and decision-makers would be more willing to consider the results of models in their deliberations. An alternative viewpoint presented was that economic evaluation—the costs and benefits related to public actions and other changes—are of prime interest to decision-makers, and that models which do not provide for economic evaluation would not be used by decision-makers even though satisfactory predictions were produced with the models. It was argued that such models would not be helpful to decision-makers because they do not give either the kind of answers or any answers to the questions decision-makers are interested in.

The discussion indicated not a polarity of the discussants between these two views, but a difference in emphasis and priority between concern for the technical, "scientific" soundness of models as devices for describing real world events and the requirements of models for use in policy making. All agreed that technical soundness and relevance to the choice confronting decision-makers are inseparable twin requirements of a successful model. The difference in viewpoint that emerged was between those who argued that a model could be technically sound, that is, capable of accurate predictions, but not relevant to the choices confronting decision-makers, particularly by not being couched in the framework and terms which the decision-maker used in evaluating the choices available; and those who argued that a sound model would be necessarily relevant and useful, if perhaps incomplete. The strategy of model design suggested by the first view is that the evaluation phase of the planning process in which the model is to be employed should serve as a guide to the output, and possibly the structure of the model, the relationships employed, the variables used, etc. The second view suggests a strategy of model design oriented more to the capability of the model to replicate real-world phenomena and where choice of relationships to be included and variables to be used would be based on their relevance to explanation of the phenomena being modeled.

Discussion on the appropriate structure of urban development models was generated by the second and third papers which presented somewhat contrasting approaches to the theoretical base of models and the level of detail at which the models operated. Chapin's presentation suggested a behavioral approach with analysis of individual decision-units (families, in this case) as the basic data. The aim of the analysis would be to develop theoretical constructs of the behavior of individual decision-units, and using these, a model of the urban development process. In contrast to this micro approach Leven argued the need for a macro level approach which utilized descriptions of the urban community as a unit and aimed at theoretical constructs explaining the structure and change of the urban unit Models operative at this macro level could then be developed.

Two separate but related issues emerged in this discussion. One issue was whether the micro level, behavioral approach or the macro level, structural approach offered a more suitable and more promising theoretical base for urban models. The other issue was the appropriate level of aggregation in urban models. There was no consensus on either issue; rather there was a range of views which generally did not extend to extreme positions but ranged across what might be called the broad center of each issue. On the issue of micro versus macro level explanations, it was recognized that both were necessary, and that, perhaps, the question of which was most appropriate depended on the use to which the model would be put. Similarly with respect to the question of aggregation of data in models (in size of spatial units, classes of population, etc.) it appeared that differences of view expressed were traceable to individual discussant's implicit conceptual base of and purpose for a model. An additional thread running through this discussion was a widespread concern by many of the participants for increasing the scope and applicability of urban models to include greater explicit consideration of social policy issues.

PART III

Design and Construction of Models

The fifth through the eighth sessions of the Conference were concerned with model-building. Ira Lowry's paper, which opens this section, is a review and analysis of seven prominent land use models which have been developed over the past decade. The models are analyzed in terms of a paradigm of the urban land market which forms the basis for classifying models according to whether they focus on land use patterns, location patterns, or other strategies of model design.

Morton Schneider offers a general framework for an integrated model of land development patterns and tripmaking based on aggregate observations and accessibility concepts. In the final paper, William Alonso examines the problems of data reliability and error propagation in models in terms of alternate strategies of model design. Because of data and error progagation problems he suggests that simple models should be used for applied work and that complex, sophisticated models aimed at scientific research should be employed in university or other research settings. The remainder of this section contains the comments of panelists and summaries of general discussion from two sessions on model-building. The discussion centers on the relative merits of design models and projection models, on the construction of nonresidential models, and on data requirements for models.

SEVEN MODELS OF URBAN DEVELOPMENT: A STRUCTURAL COMPARISON

IRA S. LOWRY *

Attempts to develop quantitative models of the spatial aspects of urban development for use as planning tools hardly antedate 1960. Since then, there have been innumerable prospectuses, many serious enterprises, and at least a few substantial accomplishments.

The model-builders—a group that overlaps but does not coincide with the planning profession—claim that their brain-children have present or potential value as planning aids. One of the frustrations of the planner as client is that he does not usually find it easy to judge these claims or to choose among the many alternatives now available for his consideration.

In this essay, I shall try to show how a number of these models relate to each other and to a generally accepted theory of the market for urban land. The undertaking involves some risk of misrepresentation, since only two of the specific models I shall discuss are adequately and finally documented. It also involves some risk of misunderstanding; my analysis by no means exhausts the grounds on which these models may be compared, but focuses on the significance of the variables included and the coherence of the model's formal structure.

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* The RAND Corporation. Since this Conference was convened to review the state of the art of modeling urban development, I have taken the liberty of commenting quite directly on a number of existing models Because documentation of these models is characteristically incomplete and fugitive and the models themselves are in a more or less continuous state of revision, it is quite possible that my information is neither complete nor up-to-date. I have indicated my documentary sources in each case and have tried to avoid reliance on information from other documents in my files which are marked "Not for Publication."

Although I am quite prepared to encounter dissent from my critique of these models, I will be grateful for clarifications or corrections on matters of fact. And no doubt the editor of these proceedings will welcome, as I will, written rebuttals from any who dissent from my interpretations Any views expressed in this paper are those of the author. They should not be interpreted as reflecting the views of The RAND Corporation or the official opinion or policy of any of its governmental or private research sponsors.

Briefly, I shall argue that an adequate system of interdependence is spelled out by the theory of the market for urban land, the formal structure of which is elaborate but easily grasped. Most model-builders leave out substantial portions of this system in order to reduce the number of variables and relationships to be manipulated. I do not imply that anyone is cheating. The art of model-building is above all the art of simplifying complicated problems. But in choosing a model for a particular purpose, the planner will do well to understand what is left out as well as what is left in.

The following section of this essay presents a theory of the urban land market in paradigm. A paradigm is itself a kind of model. I choose this mode of presentation because it is both adequate to my needs and more readily accessible to readers short on mathematical training. The paradigm provides me with heuristic definitions of a number of important variables and relationships among variables, and it is illustrated with two charts whose features are easily retained for later reference.

In the next section, seven specific models are reviewed in some detail. Each was chosen to illustrate a particular strategy of simplification. In no case is this a "pure" strategy; I speak more frequently of greater or less emphasis on a particular set of relationships than of omission or inclusion. And I must confess being troubled from time to time by a sort of optical illusion in which the foreground relationships of the model reverse values with the background relationships. On the whole, however, I am satisfied with my perspective and hope that I make it convincing to the reader.

In dealing with these models, my attention is confined to their formal structures; I am not concerned with the quality of the data assembled nor the integrity of calibration methods nor the adequacy of such tests as may have been made. My interest in specific variables ends with their conceptual definitions; for my purposes, one "accessibility" measure is as good as another.

Nor have I exhausted the possible dimensions of formal structure. Britton Harris recently drew up a list of six such dimensions,[1] describable either by categorical alternatives or by polar extremes: (a) descriptive versus analytic, (b) holistic versus partial, (c) macro versus micro, (d) static versus dynmic, (e) deterministic versus probabilistic, and (f) simultaneous versus sequential. Although most of these are represented in my selection of examples and are discussed insofar as they relate to my central purpose, my comparisons among models are not systematic on these six dimensions. I have a different axe to grind.

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[1] In a paper prepared for The Committee on Urban Economics of Resources for the Future, Inc., Conference on *Urban Economics Analytical and Policy Issues*, Washington, D.C. January 26-28, 1967. See also Ira S. Lowry, "A Short Course in Model Design," *Journal of the American Institute of Planners*, XXXI (May 1965) pp. 158-166.

THE MARKET FOR URBAN LAND

Urban spatial organization is the outcome of a process which allocates activities to sites. In our society, the process is mainly one of transactions between owners of real estate and those who wish to rent or purchase space for their homes and businesses. These transactions are freely entered contracts, neither party having a legal obligation to accept the other's offer. These elements suffice to define a "market" in the economist's dictionary.

To be sure, there are exceptions to the general rule of the market. Governments exercise the power of eminent domain, although an independent judiciary controls the terms of forced contracts with at least formal obeisance to the standards of the market place. Transactions which are internal to an organization—between agencies of government, divisions of a corporation, or members of a family—are sheltered from the market. Nearly all urban governments impose negative constraints on land use and also levy real estate taxes, both of which may influence a potential buyer's interest in a particular site but do not constrain his freedom of contract.

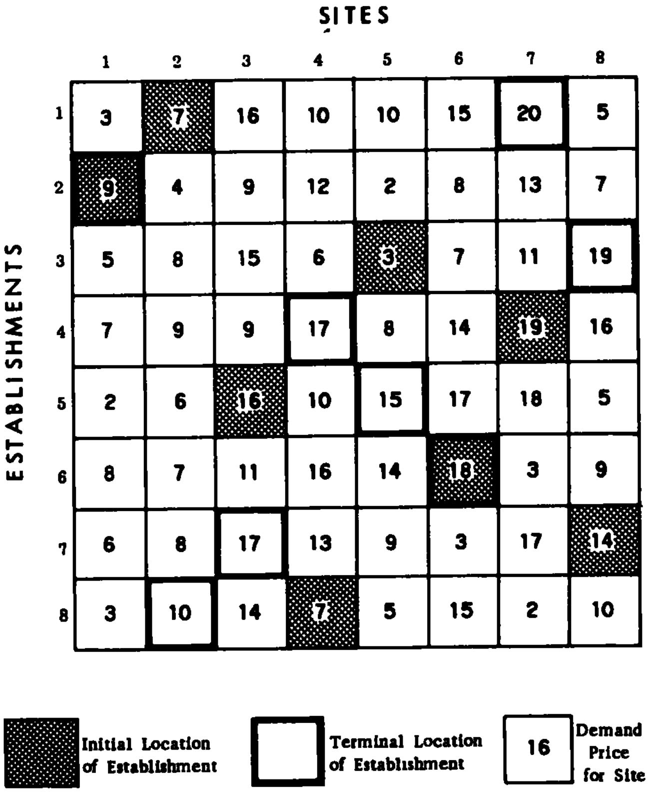
With exceptions as noted, the market process of transactions between willing buyers and willing sellers determines the spatial organization of urban activities in a very immediate sense. Since models of urban development must reflect the institutional arrangements of our society if they are to reproduce the results, a closer look at the market process will serve as point of departure for the analysis of alternative models The salient features of the process can be vividly shown by paradigm.

Consider a city whose territory is divided into many parcels of land, each of which I shall describe as a site. Most of these sites have structural improvements designed for some particular use. Each site has an owner who is free to sell or lease his property. His potential clients, whether households, business enterprises, quasi-public corporations, or governmental agencies, will be called establishments.

Since I wish to describe a market process over time, I will define a unit of time, the transaction period. At the beginning of each transaction period, every establishment in the city reappraises the advantages of its present site as compared to other sites. Indeed, each establishment explicitly considers the merits of every site in the city and decides what dollar price it would be willing to pay for each. At the designated prices, then, the establishment would be indifferent among locations.

This set of demand prices can be displayed in matrix form, as in Figure 1 The shaded cells in each row of the matrix indicate the initial location of each establishment; note that the establishment sets a price on that site as well as on all others.

Assume also that this matrix is published, available for inspection by the owner of each site. He scans the appropriate column of demand prices to identify the tenant who would be willing to pay the highest price for the use of



Establishments \ Sites	1	2	3	4	5	6	7	8
1	3	7	16	10	10	15	20	5
2	9	4	9	12	2	8	13	7
3	5	8	15	6	3	7	11	19
4	7	9	9	17	8	14	19	16
5	2	6	16	10	15	17	18	5
6	8	7	11	16	14	18	3	9
7	6	8	17	13	9	3	17	14
8	3	10	14	7	5	15	2	10

Figure 1. The urban land market: demand prices for sites and locations of establishments.

that property during the coming transaction period. Naturally he deals with the highest "bidder," who may be the present tenant, the owner himself, or some third party. Some sites change hands and some establishments move to new locations, thus modifying the distribution of establishments in space. In Figure 1, the location of each establishment at the end of the transaction period is indicated by a heavy border on the appropriate cell.

This paradigm, which could easily be elaborated to deal with unequal numbers of establishments and sites, illustrates in its essentials the economist's interpretation of the market for urban land. Competition among potential occupants determines the market price of land and each site goes to the highest bidder. Under the simplifying assumptions of the paradigm, there is an unequivocal market-clearing solution so long as no one establishment offers the highest prices for two or more sites. In the latter event, the solution depends on bilateral bargaining between the several site-owners and this particular establishment, with the next-highest demand price for each site providing a floor to each site-owner's bargaining position.

Of course, the paradigm assumes a higher level of calculation and communication than exists in real markets. Few establishments ever make a thorough investigation of the full range of alternative possibilities, and none does so frequently. Except for occasional auctions, real estate negotiations are conducted by offer and counter-offer; an establishment's "demand price" is always a closely guarded secret, and the floor to an owner's bargaining position is unstable unless he knows these prices. Real estate leases do not conveniently expire simultaneously; thus only a portion of all establishments and of all sites are on the market at any one time.

It requires at least a small act of faith to assert, despite these known market imperfections, that the actual allocation of urban sites to establishments is approximately that suggested by the market-clearing solution of the paradigm. But this theory offers a general and reasonably coherent account of the process by which urban land is allocated, and it has no serious intellectual competition—at least among analysts whose background is the discipline of economics.

The existence of a market-clearing solution does not depend on any particular assumption about the sources or pattern of demand prices except as noted above. Whatever method establishments use to decide on demand prices for individual sites, we need know only that they reach conclusions—*i.e.*, that we have definite demand prices to enter into the matrix. But we are not interested in the market process *per se;* we are interested in the spatial distribution of activities within the city, a distribution that changes over time. This interest leads us to ask why different establishments will offer different prices for a given site, and why the same establishment will offer different prices for different sites. We want to know what regularities can be found in the matrix of demand prices, and how these regularities reflect in the market-clearing solution.

The abundant evidence of spatial patterns in our cities suggests a certain consistency over time and space in the evaluation of sites by establishments of a given type. Demand prices are not random numbers In fact, we can with considerable confidence formalize the evaluation function by which they are determined:

$$P^{hi} = f\,(X^h{}_1, X^h{}_2, \ldots; Y^i{}_1, Y^i{}_2, \ldots; Z^{hi}, h = 1,2, \ldots, n)$$

Where h is a particular establishment and i is a particular site, the price P that establishment h will offer for site i depends on a number of characteristics of the establishment $(X^h{}_1, X^h{}_2, \ldots)$, on a number of characteristics of the site $(Y^i{}_1, Y^i{}_2, \ldots)$, and on the location of the site with respect to the locations of other establishments $(Z^{hi}, h = 1,2, \ldots, n)$.

The formal statement is easy, but it is far from easy to identify and measure the relevant X's, Y's, and Z's. If we are dealing with households, for example, both reflection and observation suggest that income, number and ages of household members, and ethnic background are among the relevant X's. As for site characteristics, one would expect the size and shape and topography of the lot, the nature of its structural improvements, and the availability of utilities to be among the important Y's; we might also include microclimate and view, noise pollution, and even historical values attached to the site or the neighborhood. Prominent among the relevant Z's will be the most recurrent travel-destinations of household members—places of work, schools, shopping facilities, and the homes of friends.

These examples suggest both the number of possibly relevant variables and some of the difficulties of classification and measurement. There still remain the difficulties of determining a concrete form for the function which relates these variables to P^{hi}, and of specifying the numerical parameters of the function. These problems are not peculiar to the theory of demand for urban land. Economists have had scant success in giving empirical content to consumer preference functions in any context.

One group of variables in the evaluation function represents the characteristics of the site under consideration. Not all these characteristics are fixed. Raw land may be graded, utilities may be laid on, buildings may be erected, remodeled, or demolished. These actions are taken by site-owners, sometimes to meet their own needs as occupants, often with a view to selling or leasing the site. Corresponding to the evaluation function by means of which establishments appraise sites, we can usefully postulate an investment function by means of which owners appraise the merits of site-improvements At any point in time, the characteristics of a site are given; the owner must decide what improvements, if any, would be likely to raise his revenue by more than his outlay. Such an investment function might be written as follows:

$$E^i_j = g(C^i_j, P_j)$$

In this notation, i is a specific site and j is a specific bundle of site characteristics, some combination of the Y's which we encountered in the evaluation function. E^i_j is the expected gain from converting site i to condition j. C^i_j is the expected cost of imposing the jth bundle of site characteristics on site i, a cost which may well vary with the present condition of the site. P_j is the current market price of sites in condition j. The owner will choose an investment program which maximizes E^i_j; to do so, he must compare P_j and C^i_j for each alternative j.

As in the case of the evaluation function, it is easier to formulate the investment function in such general terms than it is to give it empirical content. Though the number of conceivable combinations of site characteristics which might be imposed on a particular site is infinite, only a cursory knowledge of the market will enable the owner to narrow the alternatives to a manageable set. For a given alternative, costs are readily approximated. The going price for that alternative is easily ascertained if it is currently offered on the market at sites in the geographical vicinity of *i;* the pioneer developer faces greater uncertainty.

The dynamics of the land market thus extend beyond the transaction period of my paradigm. Each period's market-clearing solution is examined by landowners for clues to profitable investments in site-improvements. As improvements are installed on particular sites, establishments reevaluate these sites. The matrix of demand prices is thus altered, and a new market-clearing solution is in the making. The site-owner's expectations of profit from the site improvements he has made may or may not be realized. Typically, too many developers respond to favorable market signals in one period, glutting the market with a particular type of improvement in the next period. Competition among landlords drives prices for this type of site improvement downward in the market-clearing solution.

The passage of time also brings changes in the number and types of establishments seeking locations. Existing establishments also change in their characteristics. households change in size, manufacturers acquire new production methods, retailers shift product lines. So long as some establishments are moving, the pattern of accessibility and contiguity changes for other establishments. These various changes in the argument of the evaluation function would cumulate over time to cause significant shifts in the demand-price matrix even though site characteristics were fixed.

There are also forces which stabilize the market. All other things equal, the existing location of an establishment is usually preferred to alternatives; for in adapting its activities to the characteristics of the site and vice versa, an establishment makes an investment which is seldom recoverable on the market. The search for alternative sites is tedious, transaction costs are high, and a move itself can be expensive. Consequently, few establishments are likely to move during any short period of time.

CLASSIFYING MODELS OF URBAN DEVELOPMENT

From what I have said so far about the theory of the urban land market and the underlying evaluation and investment functions, it must be obvious that, while these provide a useful abstract framework for analysis, the theory could not readily be applied directly to a concrete case—the empirical problems would be overwhelming. Consequently, we resort to models of urban spatial organization. In this context, a model is the operational simplification of a theory which is necessary to fit our limited resources for empirical work. Not all models are explicitly derived from a more general theory; but if they work (and if the theory is correct), it should still be possible to interpret even an *ad hoc* model in terms of this theory.

One simplification which is characteristic of every model I have seen is aggregation. If one were to compile a matrix of the kind shown in Figure 1, it would have thousands of rows and thousands of columns. Since these are models of urban spatial organization, the reasonable horizontal aggregation is

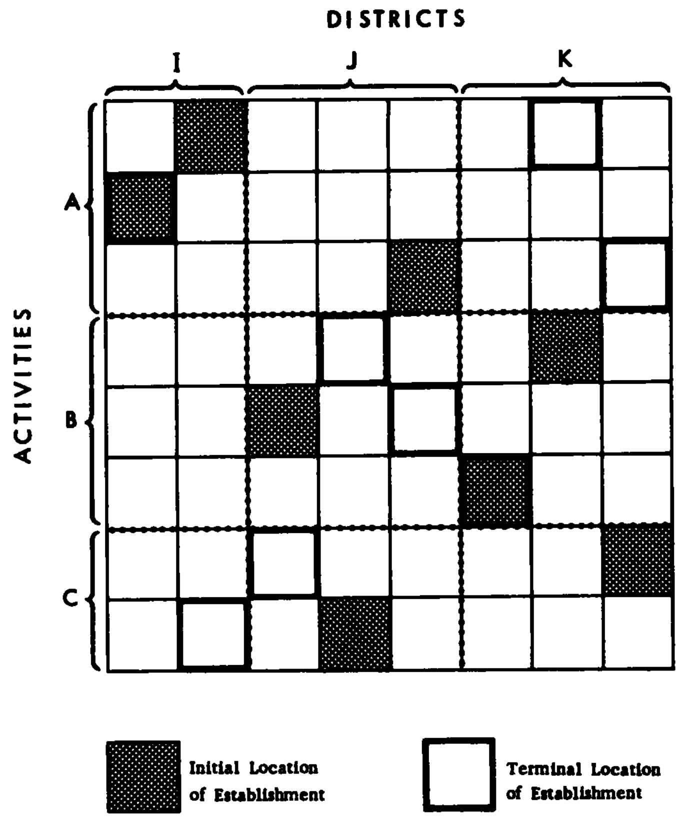


Figure 2. Changes in location and land use during a transaction period.

to group contiguous sites into larger areas which I shall call districts. The best way to group establishments is not so clear, but the usual practice distinguishes households, business enterprises, and government agencies, perhaps with subgroups among these broad categories of activities.[2] The sites and establishments of Figure 1 have been thus grouped to create Figure 2.

My illustration would have been better if I had used a larger matrix to begin with; but even the reduced 3 $\times$ 3 matrix of Figure 2 will allow me to make my principal points if the reader will tolerate a rather casual treatment

[2]When more than one characteristic of a site or establishment is relevant to analysis, grouping is a delicate art. If sites are grouped merely on the basis of contiguity, the district is likely to be heterogeneous in terms of other site-characteristics. If establishments are grouped in terms of one trait important to the planner-client (*e g*, trip-generation characteristics), the group may be heterogeneous in other important respects.

of discontinuities. Notice that I have not carried over the prices which were registered in the cells of Figure 1, but have retained the symbols which indicate both the old occupancy of each site and its new occupancy.

I want especially to direct the reader's attention to the significance of the rows and columns of the reduced matrix. Since each column represents a district, the initial distribution of land uses (*i.e.,* by type of user) in each district is indicated by the vertical pattern of shaded cells. Since each row represents an activity, the shaded cells of the row display the initial distribution of establishments belonging to this activity among the several districts. Vertically, the matrix displays land-use patterns; horizontally, it displays location patterns.

The heavily banded cells also form vertical and horizontal distributions, representing land use and location patterns, respectively, at the end of the transaction period. Moreover, we may compare initial and terminal distributions to derive additional patterns. vertically, these are patterns of land use succession; horizontally, they are patterns of migration.

The various patterns interlock, in the sense that each individual pattern implies others. Given an initial distribution of establishments among districts, a pattern of land use is implied. Given also a list of migratory movements, a new distribution of establishments among districts is implied, also a new pattern of land use and a certain pattern of land use succession. Whichever of these patterns we choose to manipulate, the others change by implication.

One clear difference among models of urban development, however, is just this choice. Some models focus on land use patterns, some on location patterns, a few on land use succession or on migration. The choice is important because it provides a focus for the ingenuity of the model-builder. He strives for coherence in one pattern and neglects or subordinates the coherence of others. By this means, he radically reduces the number of relationships which enter into the determination of a solution to the model. Depending on the use to which the model will be put, such an incomplete solution may be adequate; but it is nonetheless incomplete.

In the following pages, I will present concrete examples of these modeling strategies and explore their implications. I will also present three examples which do not fit any of the four classifications given above, one is a hybrid of two strategies, and two approach the complete system of market interdependence, but with significant variations in emphasis. For the reader's convenience, the seven examples are listed below.

1. Land Use: The CATS Model
2. Land Use Succession The UNC Model
3. Location: The EMPIRIC Model
4. Migration: The POLIMETRIC Model
5. Hybrid: The Pittsburgh Model
6. Market Demand The Penn Jersey Model
7. Market Supply: The San Francisco Model

Land Use: The CATS Model

The method used by the Chicago Area Transportation Study for forecasting 1980 land uses in that study area will serve as an example of a land use model. Of the models discussed in this essay, it is the earliest. It has a less formal structure than its successors, and *ad hoc* judgments are introduced at many points in the forecasting process. It is also unique among those to be discussed in that it was seriously used in conjuction with a transportation plan.[3]

The model is built around a strong system of land use accounting for small territorial subdivisions[4] of the study area. For each such district in turn, the future inventory of land uses is extrapolated from the initial inventory according to rules (modified by judgment) specific to the kind of use. Six land uses are recognized: residential, commercial, manufacturing, transportation, public buildings, public open space, and streets. Vacant land is classified as residential, commercial, or industrial, according to its status under local zoning ordinances. Unusable land is also accounted for.

The initial land use pattern of each district is modified in six steps.

1. Specific parcels of land in some districts are designated for conversion to public open space and transportation uses (*e.g.*, a new airport). The designations are based primarily on existing plans of public agencies for such development.

2. Commercially zoned vacant land in some districts is designated for shopping centers and heavy commercial uses. These designations are based on announced private plans and staff judgments

3. Residentially zoned vacant land is designated for residential use. The amount so designated in each district depends on the location of the district and its residential holding capacity at existing or slightly modified net densities. The percentage of a district's holding capacity to be filled by 1980 is defined as a function of distance from the Central Business District, with sectoral and local modifications based on staff judgments.

4. For residentially oriented uses, per capita norms are applied to the estimated 1980 population of each district as determined in the third step. Thus space for streets, local commercial facilities, public buildings, and recreation is set aside in each district.

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[3] My sources are John R Hamburg and Robert H. Sharkey, *Land Use Forecast*, Document No. 32, 610 (Chicago Area Transportation Study: Chicago, 1961); and Chicago Area Transportation Study, *Final Report*, Vol. II (Chicago, 1960), pp. 16-33.

[4] These are "traffic zones" in the original. I will call them "districts" to avoid confusion with "land-use zones" determined by municipal ordinances.

5. Industrially zoned vacant land is designated for manufacturing use. The amount so designated in each district depends on the location of the district and its manufacturing holding capacity. Trends in net employment density in manufacturing establishments, both over time and by distance from the CBD, serve as the basis for 1980 forecasts of such employment density for each district; this projected density, in conjunction with the amount of industrially zoned space, determines the district's holding capacity The percentage of this capacity to be filled by 1980 is defined as a function of distance from the CBD, with sector and local modifications based on staff judgments

6. Since net activity density and acreage in each use have been explicitly predicted for each district, the implied population and employment totals for the district can be calculated. These are summarized for the study area as a whole and compared to independent projections of the area's population and employment. The land use forecast (acreage occupied) is then systematically modified so as to reconcile the implied activity totals with the independent projections.

In terms of Figure 2, this is clearly a column model. The inventory of land uses is projected for each district separately; the forecast is based on that district's initial inventory, its zoning map, and its location. After each column has been filled out, the resulting tableau of land uses is indeed modified by scaling the entries along each row so that they add to a control total. But the model avoids systematic comparisons of districts with respect to their merits as locations for establishments belonging to a given activity group; such comparisons are either highly generalized (distance from CBD) or else embedded in undocumented staff judgments (locations of shopping centers).

In its dynamic as well as its static aspects, land use accounting is much more rigorous than establishment accounting. Thus, there is a fairly explicit account of land use succession within each district, but no account whatever of the origins of new tenants of each district or of the destinations of those who leave.

In summary, the CATS model suppresses most horizontal relationships even at the level of aggregation implied by the reduced matrix of Figure 2. Its implications for the full matrix of Figure 1 are unguessable We cannot say what structure of demand prices is consistent with the solution of the CATS model, nor can we infer much about the evaluation and investment functions which presumably motivate the establishments and land developers of Chicago. I do not offer these observations as objections to the CATS modeling strategy, merely as matters worthy of note. The reader would do well to withhold judgment until we have examined alternatives.

Land Use Succession: The UNC Model

The model of residential growth developed at the Center for Urban and Regional Studies, University of North Carolina, can best be described as a model of land use succession.[5] It is designed to predict the incidence of conversion of rural or vacant land to residential use as the population of the study area increases.

The study area is divided by a rectangular grid into cells of about 23 acres each. The cells in turn are divided into "ninths" of about 2.5 acres, the unit of land development. All previously developed ninths are removed from the inventory, and certain ninths are exogenously scheduled for nonresidential development during the forecasting interval. The remainder are available for conversion to residential use at densities which are determined from zoning laws or master plans.

The UNC program assigns to each cell an "attractiveness" score which is a linear combination of initial assessed value, accessibility to work areas, availability of public sewerage, accessibility to nearest major street, and accessibility to nearest elementary school. For each unit of undeveloped land within the cell, the probability of conversion to residential use during the ensuing forecasting period is proportional to that cell's attractiveness score, and discrete units of development are assigned to cells by random sampling (without replacement) from the resulting probability distribution. The sampling process continues until enough ninths have been developed to accommodate the given increment of urban population.

The manipulation of land uses within each cell is quite rigorously controlled in this model. Net residential densities of each ninth are predetermined, and there is no point in the assignment algorithm at which it is possible to "overdevelop" a cell or to carry inconsistent land use accounts for the cell. Moreover, land use succession is quite explicitly represented by conversion of specific ninths from rural (agricultural or vacant) to residential use.

Oddly, and despite some suggestive language in the text of the reports, the UNC group's extensive research into the behavior of land developers is not reflected in the formal structure of the model. The entrepreneur is certainly not explicitly represented, and one looks in vain for such phenomena as speculative overbuilding or withholding of choice land from the market. "Development" occurs only when households are assigned to a site. Land use succession is governed by demand, not by entrepreneurial decision.

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[5] The evolution of the model to date is described in a series of monographs by F. Stuart Chapin, Jr, Shirley F. Weiss, and Thomas G. Donnelly, under the imprint of the Institute for Research in Social Science, University of North Carolina, Chapel Hill. The principal titles are *Factors Influencing Land Development* (1962), *A Probabilistic Model for Residential Growth* (1964), and *Some Input Refinements for a Residential Model* (1965) See also F Stuart Chapin, Jr., "A Model for Simulating Residential Development," *Journal of the American Institute of Planners*, XXXI (May 1965), pp 120-125.

Although the entrepreneur is invisible, there is an explicit pool of households to be located, and each ninth of a cell is assigned an attractiveness score which is clearly intended to reflect its relative merits as a residential location. But it is not at all clear why the chances of development for each ninth are proportional to its attractiveness. If there are no constraining prices, one would expect the most attractive ninths to be developed first, and the least attractive ones to be developed last. If there are price constraints on residential choice, one would expect the prices to be collinear with attractiveness.

In fact, there is considerable resemblance between the UNC attractiveness scores and the demand prices of my market paradigm. On that interpretation, the UNC scoring procedure is equivalent to filling out a single row of demand prices on behalf of a homogeneous group of households. But the market solution would not be a proportional distribution; indeed, it could not be determined at all without comparing demand prices offered for each ninth by competing user-groups. Since nonresidential urban users have been preassigned to specific sites independently of the ensuing residential development, the only competing users left, presumably, are agricultural. The most likely alternative demand price is the site-owner's (speculative) reservation price.

Whatever the ambiguities of this process, the UNC model does use an explicit evaluation function. Since it applies to a single group of residential establishments, the function's argument does not include establishment characteristics (X's), only site and accessibility characteristics (Y's and Z's). The most recent extension of the model,[6] however, does distinguish nine classes of households on grounds which are not clearly stated; each group apparently uses the same evaluation function, but is permitted to locate within only a subset of the stock of available ninths. These subsets are characterized by particular ranges of zoned density and initial assessed values. In terms of my market paradigm, the revised program fills out nine rows of demand prices, but only one non-zero entry per column is permitted. The remainder of the program operates as described above. Thus, the nine household groups are prevented from confronting each other in the market place.

Like the CATS model, the UNC model abstains from direct comment on the origins or destinations of movers. The implication of the algorithm seems to be that no one moves within the study area, and no one leaves the study area: "The study presently concentrates on the growth areas and new residential development, leaving the handling of decrease areas and renewal processes. . . to be dealt with in later extensions of this research." [7]

Location: The EMPIRIC *Model*

An interesting example of a model with a strong emphasis on locational patterns to the exclusion of other perspectives in the EMPIRIC, devised for the

[6] *Some Input Refinements for a Residential Model,* pp. 14-20.

[7] *A Probabilistic Model for Residential Growth,* p 3.

Boston Regional Planning Project by Traffic Research Corporation.[8] The model is designed to reallocate population and employment among the region's territorial subdivisions as the regional totals change over time and as local changes occur in the quality of public services and transportation networks. The territorial subdivisions are irregular in size and shape and many times larger than the 23-acre cells of the UNC model.

In the reports cited, the model distinguishes two classes of population (blue collar, white collar) and three classes of employment (retail and wholesale, manufacturing, all other). The model is formulated as a set of simultaneous linear equations for each district, one equation for each population or employment variable. However, these equations do not directly estimate the number of households or employees to be assigned to each district at the target date. The dependent variable in each case is the change, during the forecasting interval, in the district's share of the regional total for that activity. After the model has been solved, these changes-in-shares are added into the shares held by each district at the beginning of the forecasting interval, and the revised shares determine the distribution of independently forecast totals for each activity group.

The determinants of each district's change-in-share of a given activity appear on the right-hand sides of the equations described above. They include concurrent change-in-share variables for each other activity and also variables which represent various site and accessibility characteristics of the district (existing activity distributions, quality of water service, quality of sewage disposal service, automobile and transit accessibilities). These forecasts are thus simultaneous in population and employment variables, each change-in-share influencing the others.[9]

Land use accounting plays a very minor role in this model. Apparently at some stage in the forecasting cycle, forecasts of activity-volumes are converted

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[8] My account is based on Donald M. Hill, "A Growth Allocation Model for the Boston Region," *Journal of the American Institute of Planners,* XXXI (May 1965), pp. 111-120; and Donald M. Hill, Daniel Brand, and Willard B. Hansen, "Prototype Development of a Statistical Land Use Prediction Model for the Greater Boston Region," *Highway Research Record* 114 (1965), pp. 51-70. There have been subsequent revisions of the model, not yet documented in quotable form. These pertain mostly to further disaggregation of both activities and territorial units; so far as I know, they do not affect the structural features to be discussed here.

[9] The method used for simultaneously estimating the parameters of all equations should yield regression coefficients that are true partial derivatives. However, the logic of these equations is puzzling. Since each district's population and employment variables are expressed as changes in shares, the fitted parameters fix relationships among these changes in *shares* without regard for the magnitude or even the sign of changes in the total regional volumes of the relevant activities. The fitted equations tell nothing about the relationships among changes in volumes for the activities within a district.

to forecasts of land use volumes, and measures of activity density and holding capacity have been included in various versions of the estimating equations. Since these variables appear in linear combination with others, they cannot absolutely constrain the solution of the equations so as to prevent "overdevelopment" of a district. Since the dependent variable of each equation is in any case a change-in-share of an unspecified regional total, the land-use implications of this model's forecast of activity distributions do not in any significant way constrain the forecasts. In terms of my paradigm, EMPIRIC is *par excellence* a row model: the columns are left to fend for themselves.

Although EMPIRIC's equations solve for changes in the spatial distribution of the elements of each activity group, only net changes are explicit. The model does not comment on the pattern of interdistrict flows necessary to produce these net changes. In view of the casual land use accounting, the model is also silent on the question of land use succession within each district.

There is a formal resemblance between the solution values of the EMPIRIC equations and the demand prices of my paradigm a "score" is calculated for each activity in each district by means of a formula which greatly resembles my concept of an evaluation function. Conceivably, these scores might be interpreted as *changes* in demand prices which are subsequently added into the initial demand prices (base-year shares). But in any case, scores for different activities in the same district are never compared. As with the UNC model, comparisons are horizontal rather than vertical, serving to allocate the establishments of a given activity among districts. I have already indicated the difficulty of finding a market interpretation for this method of allocation.

Migration: The POLIMETRIC *Model*

Studies of metropolitan development usually give some attention to the scant data on intrametropolitan shifts in the location of residential population and employment. They are rarely able, without special surveys, to identify the origins and destinations of actual movers. Because of the expense and technical difficulty of such surveys, the migration strategy for modeling metropolitan development has received relatively little attention.

The best example of such a model is POLIMETRIC, devised by Traffic Research Corporation for application to the Boston Region, but soon abandoned in favor of the EMPIRIC model described above. However, POLIMETRIC was simplified, calibrated, and used by the Delaware Valley Regional Planning Commission for projections of residential location (RESLOC) and manufacturing employment location (LINTA) within the Philadelphia Region as part of the Commission's transportation planning process.[10]

[10] My source of POLIMETRIC is a public but fugitive document: Richard S. Bolan, Willard B. Hansen, Neal A. Irwin, and Karl H. Dieter, "Planning Applications of a Simulation Model," a paper prepared for the New England Section, Regional Science Association, Fall Meeting (Boston College, October 1963). The name POLIMETRIC is not used therein, but the model is so known to the trade.

POLIMETRIC is formulated as a simultaneous set of nonlinear differential equations, one for each activity in each district. In each such equation, the dependent variable is the rate of change over time in the level or volume of the specified activity. This rate of change consists of a growth component, an inmigration component, and an outmigration component. An activity is assumed to grow at the same rate in all districts, the rate being determined by independent forecasts for the region as a whole; redistribution occurs only through interdistrict migration The inmigration component is the sum of all movement from other districts of the region. The outmigration component is the sum of all movement to other districts of the region [11]

The heart of the model, then, would seem to be the estimation, for each activity, of a square matrix of migratory movements between each pair of districts. In fact, this matrix is suppressed. The operational form of the model expresses the dependent variable of each equation (*i.e.*, the rate of change in activity-volume in a specific district) as a function of the regional growth rate for the activity, the current volume of the activity in each district, the effective area of each district, the difference in desirability of the subject district and each other district, and the general mobility of the activity.[12] These are the relationships actually to be calibrated; the migration variable is simply a theoretical convenience from which the model-builder derives an appropriate functional form for the operational equations.

Land use accounting is suppressed in this model. The only land use variable which enters the system of equations is effective area, which may vary by district but would be fixed over time. Development densities are unspecified. However, the authors do suggest a supplementary monitoring routine which "has at its disposal a table of [district] holding capacities" for each activity, and uses these entries to forestall overdevelopment of any district.

The formal structure of the model has an elegant symmetry and simultaneity which is partially eroded by its confrontation with normally intractable

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For the Philadelphia application, see David R Seidman, "A Decision-Oriented Model of Urban Growth," paper presented to the Fourth Annual Conference of the International Federation of Operations Research Societies (Boston, 29 August —2 September 1966), and "A Linear Interaction Model for Manufacturing Location," mimeographed document (Delaware Valley Regional Planning Commission, January 1964).

[11] This definitional relationship is repeatedly presented in my sources as a mixed differential-difference equation; the rate of growth of the subject activity is written *(dR/dt)*, while its components are defined as magnitudes per unit period of time —in effect, first differences of activity-variables As it turns out, this curious identity is not used in the calculations

[12] "Effective area" is undefined in my source, but it seems to mean all usable space, whether or not occupied "Desirability" is defined as a weighted sum of the intensity (gross density) of each activity in the district plus a measure of the district's accessibility to other districts The "mobility" term is not a variable, but a constant fitted for each activity.

data in the Philadelphia application. Like EMPIRIC, this is emphatically a row model, but it deals at least implicitly with interdistrict movements of the elements of each activity, while EMPIRIC is concerned with net shifts only. These interdistrict movements are premised on direct comparisons of the "desirability" of alternative locations for each activity. Although the desirability scores have a substantive resemblance to both the attractiveness scores of the UNC model and the demand prices of my paradigm, the authors deny any motivational hypotheses [13]

The net effect of the algorithm is to shift establishments from districts of below-average desirability to districts of above-average desirability; each activity has its own standards of desirability, and scores for different activities within a given district are never compared. If there is a market interpretation of this model, it is (as the authors cheerfully concede) buried in the parameters rather than in the formal structure.

A Hybrid: The Pittsburgh Model

My own contribution to the inventory of urban models was developed in the course of a study of the Pittsburgh region, and is calibrated to data drawn from that study.[14] Although it could be described without great injustice as a location model, it has a stronger system of land use accounts than the preceding two examples, and the land use implications of each activity-distribution serve as constraints on the distribution itself.

The model allocates three classes of retail employment and one of residential population among mile-square tracts of the urban region. The resulting pattern is claimed to be uniquely consistent with a given spatial distribution of basic employment. It is thus an equilibrium model with no time dimension.[15]

The model is formulated as a series of distributional algorithms, one for each activity In the algorithm for residential distribution, each tract is assigned a score which reflects its accessibility to places of employment. A pool of households (whose number is consistent with total employment in the study area) is distributed among tracts in proportion to these scores. A maximum-density constraint, derived from the land use accounting system, limits the number of households which can be assigned to a specific tract, given the residential space available.

[13] "There are no assertions with respect to maximization of profit, seeking of low-cost locations, or other motivational hypotheses The model is quite analogous to traditional population analysis which asks not why births and deaths occur but simply observes that they do and seeks to determine if there are any statistical regularities to form a basis for prediction" (*Ibid.*, p 17.)

[14] Ira S Lowry, *A Model of Metropolis*, RM-4035-RC, The RAND Corporation, Santa Monica, 1964

[15] A time-phased version of the model was developed by CONSAD Research Corporation. See John P Crecine, "A Time-Oriented Metropolitan Model for Spatial Location," CRP Technical Bulletin No. 6, Department of City Planning: Pittsburgh, 1964.

Retail employment is grouped into three activities, the number of employees in each being determined by productivity norms and the size of the regional market (number of households). The three groups correspond roughly with conventional hierarchical clusters—neighborhood, local, and metropolitan—which are functionally distinguished by the increasing territorial "range" of their markets.

For each retail activity, in turn, tracts are individually scored for their accessibility to consumer markets, *i.e.*, to residential population and employment centers. The appropriate total of retail employment is then distributed among the tracts in proportion to these accessibility scores, with the proviso that the number of employees assigned to any one tract must be either zero or greater than a specified minimum.

The novel feature of the algorithm is an iterative process for achieving consistency between the spatial distributions of retail employment and residential population, each distribution entering (along with the distribution of basic employment) into the accessibility calculation for the others. The atemporal structure of the model naturally suppresses all questions of land use succession or internal migration of establishments.

Throughout the iterative sequence, the model carries a running account of land uses in each tract, beginning with fixed amounts assigned to exogenously located basic employment and fixed amounts of unusable land. Retail uses have next priority; each class of retail trade absorbs land at a fixed rate per employee so long as additional space is available; thereafter, retail densities automatically rise to accommodate the assigned number of employees.

For most tracts, however, the assigned complement of retail trade absorbs only a small fraction of the available land. The remainder is then classified as residential. In effect, households are the residual claimants of space in each tract. Residential density is a free variable which reflects rather than controls the household assignment up to the point at which the maximum-density constraint is violated.

The text of the report goes to some trouble to develop a market interpretation of the distributional algorithms without explicitly invoking land prices. In the case of retail trade, however, the effect of the algorithm is really to deny the relevance of land prices to retail location. Assuming that the accessibility scores indicate the relative volumes of business that can be done in each tract, the assignment of retail employment to tracts simply equalizes the volume of business per employee for all tracts; the assignment of retail land equalizes the volume of business per unit of space except in those few tracts where the assigned employment could not be accommodated at standard densities.

The case for a market interpretation of the method of residential distribution is somewhat better. Residential densities are not predetermined in the Pittsburgh model as they are in the CATS and UNC models The accessibility score of a tract determines the number of households to be assigned there, and the average size of a residential parcel in the tract is jointly determined by this assignment and by the amount of residential space available after higher-priority uses have been accommodated. Residential density thus varies directly with the accessibility of a tract to places of employment; among tracts with equal accessibility scores, residential density varies inversely with the amount of space available.

These two results are generated by the model, not imposed upon it. The first result is clearly consistent with a market allocation of land given the assumption that accessible space commands a premium to which households adapt by living at higher densities. The second result is ambiguous; it would be clearly consistent with a market allocation only if accessibility fields did not overlap.

A striking feature of this model is its concentration on spatial relationships among different activities, to the exclusion of most other variables which seem pertinent to the market process. Households have no dimension except number; retail activities are only slightly more differentiated. Available space is described only by quantity and location; its historical development, as reflected in lot size or existing structures, is ignored. Virtually the entire machinery of the model is given over to the calculation of accessibility measures. The solution of the model is explicitly a locational equilibrium, constrained only by the availability of space.

Market Demand: The Penn Jersey Model

The builders of the models so far discussed were of course aware of the existence of a market for urban land, but their stratagems are designed to avoid its explicit representation. We now turn to a model which undertakes this representation, although only for the market in residential land. I have characterized it as a demand model because it limits the functions of landowners to choosing among prospective tenants, entrepreneurial behavior is suppressed.

The Penn Jersey model was originally formulated as a forecasting device for the Penn Jersey Transportation Study. Although the model was eventually abandoned by that Study in favor of other approaches, its development resumed at the Institute for Environmental Studies, University of Pennsylvania, under the guidance of its steward at Penn Jersey.[16]

In its first incarnation, the model was intended to link with other models dealing with non-residential land and activities The operations of the various

[16] My direct sources are John Herbert and Benjamin J. Stevens, "A Model for the Distribution of Residential Activities in Urban Areas," *Journal of Regional Science*, II (Fall 1960), pp 21-36; Britton Harris, *Linear Programming and the Projection of Land Uses*, P J Paper #20 (Pennsylvania Department of Highways: Harrisburg, no date), Britton Harris, Josef Nathanson, and Louis Rosenberg, *Research on an Equilibrium Model of Metropolitan Housing and Locational Change*, and Britton Harris, *Basic Assumptions for a Simulation of the Urban Residential Housing and Land Market* (Institute for Environmental Studies, University of Pennsylvania: Philadelphia, both dated 1966).

models were to be sequenced so as to provide comprehensive forecasts of activity distributions and land uses within the region under study, distributions which were sensitive not only to changes in regional aggregates but also to changes in the transportation network. In the model's current development, its transportation features have been retained, but distributions of non-residential activities are treated as independent parameters of residential distribution. The solution of the model is an atemporal equilibrium allocation of households to residential sites.

The data requirements of this model far exceed those of any of the models so far discussed. It calls for an inventory of households cross-classified by incomes, patterns of consumption preferences, and patterns of daily movement; and an inventory of all residential sites in the region, grouped into districts such that sites within a given district are homogeneous with respect to size of lot, type and quality of structure, and neighborhood amenities. For each district, accessibility to alternative destination-sets (the sets reflecting alternative patterns of daily movement) must be calculated.

These data are entered as arguments of an evaluation function similar in form to that previously presented in this essay. Although the grouping of households and sites implies some repetition of entries, in principle the Penn Jersey model calculates the complete matrix of demand prices suggested by my paradigm (Fig. 1). The model then seeks the market-clearing solution which is interpreted as the "equilibrium" assignment of households to residential sites.

The solution is found by a linear program which assigns households to sites so as to maximize aggregate "rent-paying ability" of the region's population. This quantity was originally defined for an individual household as the household's budget allocation for jointly consumed housing and transportation minus the cost of obtaining these items in a given district if sites were free; in other words, it is the budget residual available for land rent. For a given pattern of daily travel, it is assumed that travel costs will vary with residential location. The cost of a dwelling unit which meets the household's standards would vary with the character of existing structures in a given area. Obviously this cost would be least when the appropriate housing is already in place, but, in principle, an existing structure could be remodeled or replaced. Thus the investment calculation attributed in my paradigm to land-owners is here represented explicitly, but attributed to households evaluating sites.

In the current version of the model, this investment calculation has been suppressed. "Rent-paying ability" is replaced by "bid rent," a budget residual covering the entire residential package of site and structure (but not the cost of transportation), and households are not permitted to tamper with the given inventory of dwelling units. This modification was in part a response to certain mechanical difficulties in the linear program which threatened the integrity of the solution. Linear programming, an algorithm designed for continuous variables, does not readily cope with an assignment problem involving groups of households and groups of residential sites.[17]

An assignment of households to residential sites which maximizes bid rents is mathematically equivalent to the process by which the market-clearing solution was found in my paradigm; the reader can readily test this equivalence in the example offered by Fig. 1. Discussions of the Penn Jersey model have been much plagued by interpretations of this algorithm as an "optimizing" procedure. Depending on the reader's taste in welfare theory, the market-clearing solution may be endowed with social values, but surely these values do not derive from the algebra by which the solution is identified.

Designing a linear program appropriate to this assignment problem has proved difficult Only recently have the architects of the model come to grips with an even more intractable problem, that of formulating and calibrating an evaluation function. This function is necessary to generate the matrix of demand prices; the linear program comes into play only after the matrix is available.

For the linear program, grouping households and sites is a means of reducing the assignment problem to dimensions manageable by present-day computer storage. For calibrating the evaluation function, grouping is essential to the statistical identification of preference structures, while selection of appropriate grouping criteria presupposes considerable *a priori* knowledge of these structures. It is not easy to break into this circle. The statistical identification of preference structures is the focus of current research on the Penn Jersey model.

With respect to that portion of the urban land market involving households and residential space, the Penn Jersey model closely approximates my land-market paradigm. (Indeed, that paradigm's construction was considerably aided by Herbert and Stevens' conceptualization of the assignment problem.) Within these limits, both row and column controls govern the allocation of a given pool of households to a given stock of sites. Because the solution is an atemporal equilibrium, it cannot comment on either the patterns of population movement or the incidence of land-use succession en route to equilibrium.

Market Supply The San Francisco Model

My final example is the model developed for the San Francisco Community Renewal Program by Arthur D. Little, Inc.[18] It is intended as a tool for ana-

[17] The issues are too complex for exposition here, but compare Herbert and Stevens, *op. cit*, with Harris, "Basic Assumptions ," especially on the use of "subsidies" as a variable in the original model

[18] My sources are Arthur D Little, Inc, *Model of the San Francisco Housing Market,* San Francisco Community Renewal Program, Technical Paper No. 8 (January 1966); and Ira M Robinson, Harry B. Wolfe, and Robert L Barringer, "A Simulation Model for Renewal Programming," *Journal of the American Institute of Planners,* XXXI (May 1965), pp 126-134.

lyzing the impacts of various public programs—zoning projects, public housing, rent subsidies, mortgage guarantees, etc —on the housing stock of the city and its utilization. Given a time-phased program of public actions, the model provides biennial forecasts of construction and demolition, of changes in the physical condition of the standing stock, and of rent-levels and occupancy rates for its various components.

These components are numerous Dwelling units are cross-classified by type of structure, tenure, number of rooms, physical condition, and type of neighborhood—more than 1100 combinatorial possibilities, although not all are actually represented in the inventory at a given time. The characterization of the resident population is equally elaborate. Households are cross-classified by size, stage in family cycle, color, and income, for a total of 114 types. An independent population forecast is required to provide this detailed inventory to the model at two-year intervals

At the beginning of each biennial forecasting cycle, the model is instructed to match this population with the stock of housing inherited from the preceding period. Normally, the attempt will be unsuccessful, in the sense that not all households can be assigned to suitable housing and not all housing units will find tenants. These discrepancies are noted as market signals which cause landlords to alter the physical condition of their properties, raise or lower rents, build new units, or demolish old ones. These events reflect as changes in the housing inventory reported for the end of the forecasting period.

For each household group, the model-builders provide a list of 50 housing types in order of preference by that group. It is not altogether clear what "preference" means in this context, but the list reflects, in a complicated way, the relative frequency with which each housing type was occupied in 1960 by the specified group.[19] From similar empirical sources, a range of rent-budgets is calculated for each household group, representing the maximum and minimum (!) prices that members of that group would be willing to pay for housing of any kind.

[19] Robinson, *et al*, say, "The preference list is in order of priority so that the first space type (including location) represents the first choice of living space for a household type The space types listed will in general be those for which the people in a particular kind of household would normally search and make their needs felt through real estate agents " ("A Simulation Model . ," p. 130). Construction of the preference list from 1960 Census data is explained in Technical Report No 8, pp. 28-29, but the account is garbled, I think, by misplacement of two paragraphs on p. 28

Both sources imply that the household's budget and the market price of each type of housing, as well as the physical qualities of the housing unit and its neighborhood, enter directly into the preference ordering. If so, the list is improperly used in the model, for it is there treated as though it reflected "pure" preferences for housing qualities, unconstrained by budgets or prices.

SUPPLY PRICES FOR HOUSING

HOUSEHOLD RENT BUDGETS

	$15	10	18	17	11	4	5	12
$20	**A**	H	C	D	B	G	F	E
18	C	E	F	H	**A**	D	B	G
17	F	C	A	**B**	E	G	H	D
14	H	**A**	G	D	F	B	C	E
10	E	B	D	A	G	H	**C**	F
6	G	H	B	E	A	**D**	F	C
5	A	E	F	B	G	H	D	C
4	E	F	B	H	G	A	D	C

A — Most satisfactory House; H — Least satisfactory House; (heavy box) — Chosen House

Figure 3. A model of the housing market: household budgets, housing preferences, and supply prices.

The assignment process, somewhat simplified, can be illustrated in a way that clarifies its relationship to my paradigm of the land market. In Fig. 3, each column of the matrix represents a single dwelling unit, and each row a single household. The numbers across the top margin are the prices at which the owners of each dwelling offer their property on the market. The numbers down the left margin are the amounts budgeted by each household for rent. Note that the households are arranged in descending order of prosperity, as indicated by the sizes of their rent budgets.

Households differ in their opinions of the available alternatives. The preferences of each are shown by letters of the alphabet, with A as the most satisfactory alternative, and H as the least satisfactory. In this model, the household selects the dwelling, rather than the landlord selecting the tenant. The most prosperous household has first choice; among those dwellings that are within its budget, it chooses the one which ranks highest on its preference list. With that alternative eliminated, the second household makes its choice, and so on. The results of these choices are indicated by heavy outlines on the appropriate cells of the matrix.

This procedure does not ordinarily result in a market-clearing solution. In the illustrated case, the $18 house and the $12 house found no takers, while the $5 family and the $4 family found no homes within their budgets. In the San Francisco model, these discrepancies set off a chain of events which move landlords and home-seekers toward a market-clearing solution. After examining the market to see what changes could be made either in their properties or in their asking-prices to gain tenants, the owners of the $18 and $12 houses calculate which of several alternatives would be most profitable.

The model-builders have provided a number of rules for landlord responses in particular situations. In general, these rules reflect the sort of calculation suggested by the investment function previously proposed. Structural modifications and rent-changes are recorded in the housing inventory along with physical deterioration due to the passage of time. The "solution" of the model is the state of the inventory and the pattern of rents after these events have been recorded.

Of course, the actual simulation proceeds at a somewhat higher level of aggregation than the illustration suggests; the rows are household groups, and the columns are housing categories. Within each housing category, the unit of account is the "fract," a two-acre parcel [20] containing the appropriate number of units for housing of a given type, and located in a particular district of the city. Households, however, do not choose locations in the geographical sense; they choose a housing category, and the particular fract to which they are assigned is a matter of chance.

Indeed, a notable feature of this model is its neglect of accessibility, a variable which is prominent in every other model we have reviewed. Neighborhood accessibility could easily be added to the characterization of the housing types, and this was apparently contemplated at one stage of model development. But it would seriously complicate the already ambiguous scheme for ranking housing preferences, and, in the compact city for which the model was developed, accessibility differentials are not large.

Within their limited scope, the model's land-use accounts are rigorous. The amount of space available for residential uses and the initial details of these uses are given; the remainder of the city's land is apparently excluded from the accounting system Within the residential sector, land-use changes are faithfully recorded for each two-acre fract in each district, so that both its current status and history of change are available to the user of the model.

Establishment accounting is more casual. The number and types of households in the market during each forecasting cycle are externally specified, without identifying previous place of residence. Not all households need to be

[20] The fract is merely a unit of account Its location within a district about the size of a Census Tract is unspecified, and the dwelling units it contains need not be contiguous in space

located by the model and the disposition of those who fail to find a suitable home within their budget is left vague. Their function is fulfilled when they have registered their unsatisfied preferences; landlords may or may not respond to accommodate them, depending on the profitability of doing so.

CONCLUSIONS

The foregoing section of this essay at least establishes that a variety of modeling strategies are available to anyone seeking to represent or forecast the process of urban development. But surely there are more profound lessons to be learned from these comparisons.

I have deliberately avoided the question probably of most immediate interest to my readers: How well does each model work? I have avoided this question because I don't know the answers in each case and have little hope of finding them. The authors of the San Francisco model say bluntly, "The accuracy of the Model ['s forecasts] cannot be determined with presently available data." This statement would apply with little qualification to the other six models reviewed.[21]

In lieu of this question, I offer another which might help to evaluate a particular model: How well should it work considering those aspects of the market process which are ignored or subordinated in the model's structure? Suppose the model were provided with accurate data and the parameters were fitted by exemplary statistical procedures: Does it capture enough of the structure of the market to reproduce market results? Do the relationships which form the structure of the model appear to be consistent with market theory, even if crude in detail? If some pertinent factors are not explicitly present as variables, can we believe that they are implicitly represented by fitted parameters which are fixed over time? Is the accounting system sufficiently rigorous to guarantee internal consistency of the model's solution? If these questions cannot be answered affirmatively, we have grounds for skepticism as to the soundness of the modeling strategy.

The reader is of course entitled to object that the theory of the market, as presented, is itself open to question. I would agree in principle, although I would ask for a bill of particulars. At the same time, I would point out that the authors of every model in my collection pay at least casual obeisance to this theory. Their strategic simplifications seem to derive not from the conviction that the theory is wrong, but from the more reasonable premise that its literal translation into a tool for forecasting or program analysis requires data which are not practically obtainable.

The force of this point is illustrated by the two models which can be fairly said to try this translation. Seven years after its engagement, the Penn Jersey model is still not married to data. The San Francisco model is on its honey-

[21] See Lowry, "A Short Course . . ," pp. 164-165, for an account of the inherent difficulties in testing these models

moon, and I wish it *bon voyage*. In idle moments I have tried to imagine the expression on the face of the staff demographer when he was asked to contribute, for each biennium of an 18-year forecasting interval, a prediction of the numbers of households in each of 114 socio-economic categories

One's evaluation of a modeling strategy cannot, however, be dissociated from the purpose for which the model is built. If land-use forecasting at a level of detail adequate for transportation planning is the sole objective, and if the transportation plan does not contemplate any radical change in either the general ease of movement within the urban area or the relative ease of movement in its various parts, one could do much worse than use the CATS model. But this model does little to enlarge understanding of the spatial organization of the city, nor does it help us evaluate alternatives of land use which might be achieved through public policy.

At the other end of the spectrum stands the San Francisco model—of dubious value for literal forecasting, but immensely educational in other ways, especially as a means of experimenting with public policies whose consequences cannot easily be imagined outside some detailed context of implementation. In contrast to the CATS model, the San Francisco model has the potentiality of enriching the user's understanding of his problems with every repeated run under slightly changed assumptions.

The sequence in which the seven examples are presented is not strictly linear in transition between these polar extremes, but the general drift is clear. As the ease with which a model can be used for forecasting diminishes, its educational potential increases. This judgment must be qualified by an assessment in each case of the care with which the data are handled. Such an assessment is not provided in this essay because it is not particularly relevant to the usefulness of a model outside the hands of its present custodians.

COMMENTS

BRIAN BARBER, *Metropolitan Area Planning Council, Boston*

I would like to say that I welcome Jack Lowry's type of paper because we in public agencies are interested in seeing to what extent the work we are doing conforms to theory. It is not a principal concern; we consider it more of a restraint. I know that in the EMPIRIC model, with which we have been working, there are economic and social principles which guided development and calibration of the model. For example, we think that we can see something like social climbing in the patterns of population distribution by income groups; and I would like to compare a sociologist's simplified theoretical construct and the findings of our model.

Public agencies have a production-oriented point of view; deadlines are very important to us For this reason, conformance to theory is a secondary consideration University groups have another point of view. I think each should be encouraged provided that each group is aware of, and sensitive to, the requirements and work of the other. I think that the development of many models in various public agencies (even *ad hoc* temporary ones) is a very healthy circumstance. I would like to see this trend continue until something like an authoritative approach and technique emerges.

In the short run, most agencies will probably be limited to only one model. In this case there will be a tendency to choose the kind of model that will permit the agency the most options. While they will be interested in questions of theory and reliability, agencies will be more interested in the kinds of different jobs the model can do. Agencies are interested in using models to predict, to simulate, to conduct *ceteris paribus* tests, and they want to introduce as many realistic types of constraints in their tests as possible. Therefore, I would predict a tendency for agencies to choose a model which employs many variables in spite of the serious data measurement errors and their consequences which Bill Alonso covered in his paper. This problem would be a secondary consideration, in terms of the questions that agencies are expected to answer. Even if you have low reliability in your models, you might take the chance that you could come up with the right answer.

There are various kinds of payoffs for public agencies in modeling that I think one can measure, at least in a qualitative way. One of these is propaganda value. I foresee a situation in which a model would serve as a staff-unifying device. Land use forecasts are basic to many of the studies that planning agencies do. A common set of forecasts prepared with a model all parties had agreed to, would be one way of unifying staff work. I do think that the dominance (in a technical sense) within an agency of a particular type of model might be a disadvantage. I particularly see this happening if we tend toward design models. Basically, the problem is that simplification is required for modeling, while all factors have to be considered for planning studies and proposals. We have found that the model we are presently using influenced greatly the kind of planning work that we are able to do. We have acquired quite a bit of information about the policy variables that we are able to manipulate and to test systematically. We have been accused by our lay policy groups of dealing with too narrow a scope of problems, but because of time and money constraints, we have to gear everything to the capabilities of this model.

It is also possible with a land use model to do plan evaluation work on the question of ordinal ranking of plan alternatives. If wide enough forecast differences in the alternatives can be found, and the plan alternatives can be ranked ordinally by plan performance measures, perhaps a greater range of errors can be accommodated. Plan evaluation criteria and their use in developing and using land use models should be mentioned. This is an issue which has been raised in almost every session. I think that the development of urban systems modeling has proceeded much faster than the whole field of goal formulation and quantification, selection of objectives, and plan evaluation measures. This has been rather unfortunate because this question of goals introduces additional criteria which can be of use in designing a model. Perhaps the area of modeling urban systems is more interesting than the problem of establishing planning goals. I do not quite see why, but I would strongly urge that the problem of goals be explored intensely and that it receive at least equal priority in the short term with such other research areas as design models, applied models, and so forth.

On the other hand, urban systems models can contribute to the plan evaluation process. We have done this to some extent with the EMPIRIC model, We think we are able to judge some features of the plan alternatives objectively. I think the decision-makers are more confident about these outputs than the staff is. When the decision-makers see results such as property loss or employment loss, they translate the results into terms of benefits and costs from their own internal calculations. Staff people seem to feel that they need to have some more formal procedures to do this.

More specifically, I would like to comment on Lowry's remark about density being a free variable in what he calls row models. I am curious about what the term "free" might imply. In the EMPIRIC model (a row model) we have kept these column totals in mind, although as he points out it is done via monitoring routines. The densities we used are not completely free in the sense that we just let them fall where they may. We use preconceived, planned densities or forecast densities that are derived either from a plan or from existing patterns. I am very much in favor of using planned densities that are external to the model. I think they provide a real bridge between the traditional urban land use designers and the model builders. We use the planned densities, and after we have done our accounting we find that we do not have to adjust density significantly in order to keep zones from filling up or from losing too much.

Finally, I would like to comment on what was said about the idea of using market clearing procedures in a land use model. Having a model not directly developed from and dependent on market clearing theory makes it more amenable to the kinds of possible adjustments and manipulations required by non-market clearing public actions, *e.g.*, urban renewal. We had to do this very extensively because there is a large urban renewal program under way in Boston. It was very useful to be able to put these predetermined renewal decisions directly into the whole forecasting procedure without upsetting the basic logic and elegance of the model.

One further note. We are in the position now of having had some operational experience with the EMPIRIC model. It has gotten on the critical path in the transportation study, and we have used it to do some production forecasting. This puts us in the position of being able to make some good, management-type estimates of future use of the model. For example, I have just been working out a work program for a future study employing the model. It is a 15-month work program in which I have been able to make some reasonable estimates of time and manpower requirements for use of the model. A

PERT schedule to which I think we may be able to hold has been developed. We are by no means at the point of being able to look at land use forecasting as a routine job, but it is likely that in a few years it will be routine.

ALAN BLACK, *Tri-State Transportation Commission*

First of all, I am going to address myself to Jack Lowry's theory of the urban land market. He asked for specific objections to it, and I am going to state the ones that I have. Some of the difficulties, although not all of them, perhaps come from the particular numbers that he put in the illustration that he gives in his paper. I would argue that in such a matrix many of the cells would have either zeroes or negative values. There would be many cases in which an establishment would not move to a new site, even if it were given that site free. There is a considerable moving cost involved which generally tends to encourage the firm to stay where it is, and Lowry does acknowledge this at the end of his discussion. I would say that for each of the alternative sites the moving cost should be subtracted from the demand price.

I question some of the demand price argument of this paradigm. I do not think that a firm wants to pay demand price. The firm wants to pay as little as it possibly can for a site, and if it decides that it wants a particular site, it will offer only slightly more than its competition in bidding. For example, establishment No. 3 has a demand price of 19 for site 8, but this establishment would not actually pay 19 for this site. I say it would pay 17, because the next highest bid is 16. The demand price essentially indicates a break-even point for each establishment—the point at which it makes no profit or the profit is at some fixed level.

I would argue that each firm wants to maximize its own profits, and thus will try to attain the lowest possible site price. Each firm would select that site which maximizes the difference between its demand price and the price it actually has to pay for the site. Just how this would work out in a matrix, I cannot really say, but it would be more complicated than what is given here. In general, the matrix demand price is only indirectly related to the way in which sites are allocated. Perhaps all the models are based on this urban land theory, but I do not think it is a very good representation of how the land market works.

I guess I am an anti-taxonomist, because my reaction to this paper was that I did not see a great deal of value to this classification of models. The particular model Lowry describes with which I am most familiar is the CATS model. From his description I had a little trouble recognizing it. He says that this is clearly a column model in which there is a calibration of row totals. My own particular interpretation of it is that it is a row model in which there is a careful accounting of the column totals. I am not sure who is right, but this kind of argument is not very productive.

The one classification that would interest me would be the old "plan versus prediction" dichotomy, because in my current work I am interested in developing a land use plan rather than a projection. Lowry really did not go into this, and I could not tell which one of these models would be useful in making up a plan in which you could plug in some kind of planning decisions, although the San Francisco model does have building codes and zoning requirements in it.

DAVID R. SEIDMAN, *Delaware Valley Regional Planning Commission*

I have one point of information concerning Lowry's paper. We have constructed the RESLOC model which is a transformation of POLIMETRIC which takes the original simultaneous differential equations apart. It makes an exponential function into a piecewise linear function which represents migration from less desirable to more desirable districts, but not vice versa; the desirabilities are a linear combination of variables weighted by parameters. Thus we have had some experience with that kind of migration model.

Now I would like to state the several conclusions I have reached in constructing an operational forecasting model. These are stated as rules proposed as part of a set of standard operating procedures for anyone setting about the construction of an operational land use model. These were distilled out of five years of effort in the construction of the Activities Allocation Model at the Delaware Valley Regional Planning Commission. The rules are stated succinctly for the sake of brevity; because of this they may imply a greater conviction than is intended for them. Several of these statements are in fact still controversial, such as those in items 12, 13, 15, and 16. One purpose for asserting these as well as the less controversial items is to generate greater discussion. There has been an unfortunate tendency to ignore such tactics in favor of discussing the grander strategies of modeling theory—unfortunate because these tiresome tactical details can lose in the field the battle won in the war room.

As employed in the following paragraphs, a research model is one whose prime purpose is to provide a better understanding of the urban system and the process of location and land use; an operational model is one whose prime purpose is to provide conditional predictions for planning purposes.

Administrative Strategy

1. Research models should be "off line" completely. The time has come to call research *research*. In the earlier days of model-building, the only possible way to obtain funds for such modeling efforts was in the name of a planning process. Now, however, more funds are being made available for research and these should be used instead.

2. The operational models being developed should have reliable back-up procedures available for them if there is any doubt about their being fully operational in the required time. Furthermore, the management must be willing to go to these back-up procedures as soon as the schedule is threatened. Mod-

els have gained a very bad reputation with decision-makers in the planning field because they have deflected the agencies from their main purpose, which is not to build models but to provide plans and implement programs.

Data Reduction and Data Manipulation

3. Since approximately 80 percent of the work on the Activities Allocation Model was concerned with the data, it is crucial that an agency have a good data manipulation system available before it starts a similar modeling effort. There are several alternative types of systems to choose from for this capability. Large agencies might want to use an elaborate and highly integrated system such as the one developed by the System Development Corporation. The small or medium-sized agencies might not want such an elaborate system but might instead prefer a modular approach like that used at DVRPC. This modular approach provides a series of subroutines which can be used independently or linked together. In either case, the time has gone when we can afford to spend much time writing individual small programs to specify each of the routine data manipulations required in such abundance in modeling efforts.

4. Any data manipulation system must have available to it a set of standardized data files on which it can operate. These data files will generally be in a matrix format, in which the rows stand for areal units, such as census tracts, and the columns stand for variables, such as population by age, race, and sex. Such standardized files will generally be constructed for areal systems at a higher level of aggregation than that at which the data were collected.

5. The *basic* data files, constructed on the individual areal systems originally used for each file, cannot generally be placed into the standardized data file format; there are usually some peculiarities in each data collection and reduction which require a unique format for each basic file. A separate set of so-called extractor programs is therefore required to produce standardized data format tapes from these basic data files.

6. A set of flow charts should be drawn to indicate how each of the variables required in the models is to be constructed from the variables in the existing basic and standardized data files. These flow charts can then be used to construct a PERT diagram with which to plan and schedule this major block of work.

Areal and Classification Systems

7. An early decision must be made about the areal systems to be used in the calibration of models and in projections into the future. This is necessary before the input tapes to these processes can be prepared. As few areal systems as possible should be involved, but more than one system may be required, as will be shown later. In any case, it is important that the areal systems be compatible with one another, with major secondary data sources, and

with areal systems used in other models or in analyses dependent upon the model's output.

8. In addition to being compatible, the areal systems used in calibration and projection should cover approximately the same area. It is statistically unsound, for example, to calibrate on the urbanized area of a region and then, using these calibration parameters, project on an area twice as large.

9. Areal units in calibration should be chosen small enough so that the parameters will be stable; in a projection they should be chosen large enough so that the output does not have large spurious variations between contiguous districts. These joint criteria can conflict seriously if regression methods are employed. Different areal systems might be used without serious difficulty. However, the parameters might not be sufficiently constant over different levels of areal aggregation. If this is the case the projection output should be aggregated to a higher areal level, and then disaggregated according to some proportioning scheme.

10. Spurious effects of the areal systems on the modeling outputs should be avoided by means including the following: All variables should be either intensive or extensive. An extensive variable is a number, like population; an intensive variable is generally a ratio of two extensive variables, like population density. Cutting a homogeneous district in half will cut an extensive variable in half and leave an intensive variable unchanged. For this reason they should not be mixed in a model unless they are suitably transformed by the model itself.

Suitable weighting factors should be used in regression analyses to assure that large districts do not have a disproportionate influence. To observe this hazard, consider two districts having equal proportionate errors in a residential location model, with one district holding twice the population of the other. Then in the regression analysis, the first district will get four times the weight of the second district because the residual errors are squared.

11. As with areal systems, care must be taken that classification systems used to define the model's variables are compatible with one another, with the classification systems of data sources, and with the systems of other models and analyses dependent on the model's output.

Model Structure

12. If regression models are used for projection, a strenuous effort should be made to solve for their required parameters individually rather than simultaneously. Outside data should be used wherever possible as a means to obtain parameters through nonregression means. For example, in constructing a model of retail location one might solve for the parameter specifying the attenuation of influence with distance by using trip data, rather than by solving for this parameter using only the values of the dependent and independent variables within the model. Additionally, wherever possible, more than one time period should be used in determining the regression parameters.

13. Partly because of the above considerations, a good case can be made that sequential models are preferable to simultaneous models; that is, it is preferable to construct a model which determines the location of the activities sequentially rather than to construct a model which locates all activities in one simultaneous equation solution. The argument again is that too many parameters have to be solved for at once in the simultaneous equation model, thus causing greater parameter instability. Furthermore, sequential models allow greater flexibility in tailoring the structure of the model to fit the behavior of the activities and the availability of data. This runs counter to William Alonso's argument in his paper presented to this Conference against constructing a long sequence of models. He has demonstrated that such a structure can have an explosive effect on prediction errors. Nevertheless, considerations of parameter stability and specification error must be balanced against the errors caused by such chainings of models.

Form of the Model Variables

14. In agreement with Alonso's considerations, independent variables should be chosen for which there are good data, and which can be forecasted accurately themselves, either by exogenous means or by derivation from the dependent variables of the previous recursive step. (Here we are assuming that a recursive projection process is involved in which a series of projection steps are used to get to the target year, such as the five-year increments we use to project 1985 from 1960; this is generally accepted now as the preferable way to project most locational behavior.) An accurately measured proxy variable is generally better than a badly measured "basic" variable. Similarly, basing the projection of a dependent variable upon an independent variable which is itself difficult to project is, of course, to be avoided. For example, basing the projection of the incidence of blight on the vacancy rate is a poor idea because the vacancy rate is harder to predict than blight.

15. For the reasons stated above "state" variables are generally preferable to "change" variables as independent variables. In this context, a state variable is one which describes the state of existence at a point in time, and a change variable is one which describes the amount of change occurring between two points in time. Since state variables tend to be much more stable than change variables, they have less tendency to promote explosive feedbacks in recursive projections.

16. Although the independent variables should be as uncorrelated as possible in a regression analysis, component analysis does not appear to be a very useful means of providing uncorrelated variables to the regression analysis. (Component analysis is a special case of factor analysis; in either, one obtains a linear combination of independent variables which are uncorrelated with one another.) The trouble with component analysis is that the projection phase requires translating the parameters obtained for the components back to the original independent variables. In this process a great deal of the parameter

variance is generally reintroduced, unless the number of components is so small as to provide little predictive power.

17. In operational models the dependent variables should be aggregated across categories as much as possible. A key difference between research and operational models is this preferability of aggregation. Dependent variables should generally be disaggregated only for the following reasons: (a) because it is necessary to provide the output required for evaluation or by other models; (b) because the mix of categories within a dependent variable is going to change drastically in the future and the behavior of the different portions of this mix is sufficiently different to require being taken into account; and (c) because the model calibrates better disaggregated than aggregated. With regard to (c), we can easily test whether in a given model heterogeneity sufficiently outweighs statistical randomness to justify disaggregation on the grounds of goodness of fit.

Supervisory Program

18. Because of the large number of operations involved in a recursive projection process, it will generally prove necessary to construct a supervisory program which executes the submodels and transforms the outputs of each submodel into the inputs to subsequent models.

19. A series of feasibility checks and corrections should be incorporated into this supervisory program. Included in these checks might be maximum growth and decline rates and checks for negative population, employment and land. Since regression models are especially apt to produce some extreme values, they should not generally be allowed to project unchecked. The feasibility checks should, however, influence only a minority of the values projected; otherwise, they will become in essence a significant model themselves.

DISCUSSION

DONALD HILL

Jack Lowry as usual has been painfully honest, and I have enjoyed it. I think this type of appraisal is very much in place. I think the more honest we can be about the kind of work we are doing, and the objectives we hope to achieve the better. I am very sympathetic with the numerous comments made about the particular developments we have contributed to the field, but there are two points I would like to clarify in regards to the development of the EMPIRIC model.

The first is that the original purpose of the model was to produce an unconstrained forecast as part of a total plan evaluation package. The only real constraint was that the sum of activities projected for the region should equal some overall control; so the sum across all sites or districts should equal some regional total. But within this general context it was our intention, and continues to be our intention, to have some sort of iterative adjustment procedure for achieving this so-called vertical or site balance. This is somewhat analogous to negative feedback where on the first round of forecasts the intention would be to reassign the overloads or overflows and thereby alter some of the original specifications of the sites, for example, their control densities. Now, to the best of my knowledge, this iterative feedback process has only been used very slightly, although perhaps in the later evaluation work it will be used more extensively. It is more or less a trial-and-error process; but I think it gives the opportunity to the planner to perhaps become better educated in the model, to learn how to use it. So this vertical control . . the vertical land use accounting can be taken into account, and probably will be.

The second point I would like to make, and it is a further comment to Dave Seidman, is that we do have an example where there was a dual model development—the POLIMETRIC. We had high ideals and expectations for POLIMETRIC. If it had not been for a number of reasons, I think it would be a truly operational model today. I do hope that sometime in the future we will be able to encourage sponsors to come forward and continue this type of research.

At the same time, there was a backup model developed. This was the EMPIRIC model. And as time went on and our data requirements became painfully obvious, and as budget restraints and timetables also became painfully obvious, it was necessary to fall back on the backup procedures, and still come up with a technique which the planning agency could use. But at the same time we feel that we did not sacrifice our ideals or objectives; we still had this research done on POLIMETRIC, and we did try to encourage other agencies to make use of it. We were very pleased that Penn-Jersey did pick it up. However, we do feel that they did oversimplify it. They very neatly destroyed the differential equation construction of the model, and they dropped the simultaneous interaction between the activities. This was done for a very good reason—data limitations, but I think Dave Seidman would agree that this is a property he would like to keep in that model, but because of necessary constraints, it was necessary to go the other way. Now, what this implied, both the data limitation and the differential equation construct, was very great computational expense to reformat and expand the data base in order to fit the general theory of the model. It became, again, very painfully obvious that it could not be made an operational tool within the constraints of the data at hand.

IRA ROBINSON

I want to make a few comments about the San Francisco model to clarify Jack Lowry's paper. Before I do this I should say that his allusion to the honeymoon is a very good one. It has been about two years since the honeymoon started, and as far as I know, the honeymoon is continuing. The marriage has not become very mature, and it seems to me that this is very unfortunate; what would be very good, perhaps, is a completely new marriage. What I am really saying is that from what I understand from a distance, and I have been away from this for almost two years, no one is really doing any serious work in refinement along the lines that Lowry himself implied, or on some of the refinements that we would like to have seen done. And this is one of those sad things. The model just may die, or become something of only historical interest.

The first point of clarification has to do with Lowry's reference to the establishment accounting being most casual. The fact is that the number and distribution of households are obtained in a computer printout after each period. However, we do not follow out the movements of the household, and for the purpose of model, the only reason we were concerned about the distribution was to compute space pressures and rent pressures. But in fact, we can obtain, and do obtain, and can keep track of if we wish to, the number and distribution of households.

Another point is the illusion to the rent budgets and maximum/minimum prices. What we did was for each household type we computed a rent paying distribution, and generally this conformed to a normal distribution. In other words, based on rents paid in 1960 we had a range of both a maximum and a minimum.

Finally, it is correct, as Lowry mentioned, that unlike the Herbert-Stevens model we do not use accessibility as an explicit variable. However, location is a factor. Remember all neighborhoods are grouped into fourteen location categories; location is based on topography, predominant dwelling type, and median rents; and households are bidding for not only a housing type but also for a particular location within the city. But accessibility clearly was not a variable for the reasons that Lowry points out. We decided early in the game, and I am sure that everybody would agree, that in San Francisco it really is not an important consideration.

JACK LOWRY

To respond to those three points, the first one had to do with the rigor of establishment accounting, and my point there was that not all households need to be located by the model and the disposition of those who fail to find a suitable home within their budget is left vague. You may have a printout, but it does not necessarily explain what to do with all the people you started with. Presumably they must have left the city or something.

The second point was on minimum prices. I recognize that what you did was find a distribution of actual rents paid, but when you connect that with an interpretation, *i.e.*, that this range represents the prices that members of the particular group in question would be willing to pay for housing of any kind, I think it is appropriate to raise a question.

The third point was on location classes. Perhaps this is simply a difference in vocabulary, but I do not think of location as meaning topography, or class, or type of structure, or things like that. I think of it as referring to points in space, and as we agree, points in space are not part of the definition of your housing types.

JOHN HAMBURG

Over the past ten years there has been a curious kind of switch. I can remember talking about the work we did in Chicago, and telling the people that while it was not a model it seemed to be a very useful and instructive way of organizing a tremendous amount of data in a way that you could handle and learn something from. Jack Lowry now tells me that, in fact, we did have a model, but you cannot learn anything from it. In the sense that it is not an experimental design which you can run again and again and learn from, I would agree. Moreover, the very thought of going through that process again for any purpose, I think would drive me to a mad-house. But I am not going to admit that we did not learn something from such a macroscopic view of the city. I still recommend many of the points in it.

Regarding this question of a horizontal versus a vertical model—and which is which—I am not sure I agree that this is a column model. But knowing the source from which you drew these conclusions, if there is ambiguity, I provided it to you in giving you the original document. So I cannot complain except to say that the things which had been described as staff judgment were, indeed, staff judgment just as were the gradient extrapolations into the future and the densities. A great deal of judgment went into the model. I would insist that a good many of these staff judgments were based on a fairly careful analysis of data and a variety of statistical formats, as well as just looking at maps and geographic distributions of data. I cannot argue that they were objective. In fact, I am flattered to think that this whole series of calculations has been characterized as a model. But I do think it is more than either simply a vertical or horizontal approach.

DANIEL BRAND

My comments will be addressed mostly to the research strategy which Dave Seidman enumerated. I think that Seidman has done a great service and set an example for a lot of us in that he has enumerated a set of procedures which he feels, on the basis of his own experience, should be followed in developing models of the sort that we are talking about. However, I think he has essentially recoiled from some of his own bad experiences to state perhaps too firmly that we should be avoiding certain procedures in the future. There are certain parallels which we have had to his experience, and there are areas where our experiences rather radically diverge. And so, let me discuss two or three of the elements in his research strategy, and then perhaps add another one of our own.

First of all, he feels that *ad hoc* programming should be out. This is a sore point with many, but I should disagree with this based on our experience in Boston We had large amounts of data, and we also have a very elaborate data system. However, we find that there are constantly new demands for data and for new types of analysis. We find that intelligent programmers want to get these data, not using a set of canned programs, but by adapting the canned programs, or when they feel that they can get at it a lot quicker and produce summaries a lot better by constantly changing programs and writing new programs. Frankly, I do not think you are going to keep good programmers if you do not allow them this flexibility.

The second point I would like to dispute is really one of his major points: he is in favor of sequential models rather than simultaneous models. I think there are a lot of advantages to simultaneous models. I think one of the reasons why he is in favor of sequential models is because of problems with stability of parameters, and my feeling is that we just have to do a lot of work with the data, making sure that the data are in very good shape. Then we will not have problems with stability of parameters, particularly if we make efforts to reduce the collinearity of the variables On this point I would suggest that we do run factor analysis, but only use it as a guide to get variables which represent different classes of variables, but not use the factors themselves. In other words, do everything possible to extract variables which represent classes of activities but which do not have collinearity problems.

Finally, I would add one additional element to this strategy. Seidman mentioned that in least squares analysis, you should have zones of similar size. I would also say that you should be forecasting in your model the variables to be used in the final analysis—the variables to be used in plan evaluation, or as input to further models or for steps in the planning process.

DAVE SEIDMAN

On the programming question I did not mean to suggest that specific analyses which come up should not have any programming done for them. I do believe strongly that an extractive program, as we call it, ought to be constructed for every basic data file and a set of extractor programs for the standardized data file, so that you do not have to do *ad hoc* programming to get the basic data you want. Now as far as holding good programmers, I do not think you should have all good programmers. I think you should have one or two, and the rest of them should be the kind of programmers who put together the parameter cards for an extractor program. You get into a similar argument for doing research in agencies—being able to keep their staff—and I am not sure that it is worth it either.

On the sequential problem—and this is partly in response to Don Hill's comment—if your recursive period is fairly small, say five years, I do not think you have to worry nearly as much about interdependence between variables. I acknowledge that calibrating on a ten-year period makes me uncomfortable. I would rather calibrate on a five-year period, or two five-year periods. This question of interdependency can be solved entirely adequately by keeping a moderate period of time for each recursive step without necessitating the relative inflexibility caused by the sequential process. I did not say, by the way, that I am in favor of similar size of zones. I am in favor of taking out the effect of dissimilar sizes of zones by carefully chosen weighting factors. When you get to the question of similar sizes of zones, you get to the question of similar sizes according to what . . . area or population . . . and I regard this as sufficiently intractible that I would not argue for it strongly.

TERRY LATHROP

I think basically what bothers me is an easy sort of establishment of absolutes, and Seidman has, very much in accordance with the way I feel, replied to what Brand said. His assurances that he was not outlawing all *ad hoc* programming or advocating complete divorcement from manipulation of data after the first day of the study, and so on. I think the thing that perhaps bothers me most is something that came up in comments on Chapin's paper where we are facing the question of aggregation or disaggregation on the question of *ad hoc* programming or the question of data manipulation . . . it is very difficult for me to arrive at general principles about these things without a context to the problem. I think that is clearly reflected in everybody's comments after Seidman made his first statement, but I would not want it to go unsaid.

BEN STEVENS

I am not going to comment right away on the so-called Penn-Jersey model to which I thought Lowry gave very fair treatment. He suggests that taxonomy and seeing the labels on the shelf may give him some ideas. There is no question in my mind that this kind of operation tends to make you concentrate on what the problem is in designing land use models in general. And as a matter of fact, carries you a step further, towards a statement (which I do not think exists in the literature) of what the kind of minimum requirements are of a model that is going to the kind of things that we want to do if we can define those things.

We should at least be able to describe the urban area in a way that allows us to make certain kinds of predictions or plans and to evaluate alternative public policies, and be able to simulate the way the urban area behaves in a way that will respond intelligently to alternative plans and policies. I think this kind of presentation of what the elements are that should be in a basic model is extremely useful. I do not think that Lowry pretends that he necessarily has all the elements that need to be there, but he does concentrate on a very important feature—the market solution encompassing the relationship between the activities and their desires to be at various locations and the profits they can make or the satisfactions which they can achieve, and the point of view of the sites and the site-owners and their interest in getting the maximum possible out of the land.

I would like to reiterate what Harris said that from the scientific point of view, the development of a great many models without an underlying theory of how metropolitan areas work is a little bit disturbing. There is some very good theory available. Alonso has written a book about it. There are not in the literature very great extensions of what Bill was saying to take into consideration some of the things that come up in his book. One of these is the question of multiple centers of interest—employment, shopping, and so forth—which have a very significant substantial effect. There are other bits and pieces of theory of the urban area that need to be inserted. But this building of models without really understanding what is going on, I think, has worked to the detriment of some of the model-building activities which end up perhaps solving the immediate problems of the agencies involved, but do not necessarily add to the state of the art. The real difficulty is, of course, that the decision-makers need something that answers their particular problems, and theory building is something that is done on the side. I agree that the theory has to be done to some extent on the side, but the theoretical development has not been good enough to give the people who have to answer the questions of the decision-makers enough to go on. So things are perhaps more *ad hoc* than they really need to be.

I might add that the opportunity to take advantage of the kind of information that has assembled in transportation studies and really develop some generalizations about metropolitan areas as a whole has been very badly underplayed so far. There is now a vast amount of information out of which I am sure with more intensive research we would find that there is a lot more you can generalize about how metropolitan areas work than has so far been either found out or put in the literature. The ability to use the information resulting from existing transportation studies to improve both the projections and the attempts at model-building for future transportation studies is very badly overlooked. I think the kind of thing Lowry is talking about and the way he has organized the material in some of the existing models leads me to the same conclusion. This is a whole area of research on its own which perhaps the transportation studies themselves should not have to support, but which is well worthy supporting

RONALD GRAYBEAL

I would like to comment on three topics. The first is an observation of three out of seven of the modelers whose work is discussed in Jack Lowry's paper reacted in an attempt to clarify what their model attempted to do. Inasmuch as three out of seven of them have had to do this with Jack's paper indicates to me a sufficient reason for much more clarity and communication of our work. Second, whether we are going to use simultaneous equation models or recursive models tends to be a matter of specification; that is, how do we view the world operating and how we view the world operating frequently has to be modified by the kinds of data that are available. These kinds of considerations cause me to take the position that a firm rule here may be inapplicable unless it is qualified by the characteristics of the situation. My third point concerns the applicability of the market model. Alan Black made the statement that it is not a very good representation of the land market, and I hope that he will suggest what is a more appropriate representation of the land use market.

ALAN BLACK

I am not an economist and this is just an intuitive reaction to the theory that Jack Lowry presented. I do not think that he has shown a profit maximization principle. It seems to be perhaps based more on the assumption that a firm wishes to make a certain threshold of profit, but . . . and it is going to be pay-off suffice which will match that exactly. This paradigm seemed to me to take up the viewpoint of the site-owner rather than the establishment. It seems to assume that the site-owner had a lot of information, but that the establishments do not, which I do not think is true. Usually, of course, the site-owner does not have any idea what demand prices are. All he knows is what has been bid for his site, which may be much lower than what a demand price would be. Of course, each establishment could know its own demand price for every site in the region, if you wanted to bother to calculate it. I have a feeling it would be possible to work out a matrix in which each firm would seek to maximize its profits for the choice of the site and the external income and costs that are associated with that site, but I do not know.

JACK LOWRY

Alan Black raised four points about my matrix. First, he was upset not to find any negative numbers in it. It works quite well with negative numbers, just so you have some positive ones, or at least one positive one in each column; and if you have not got positive ones there, I would say you did not have a city. On the question of moving costs, I concede some ambiguity. As a matter of fact, an earlier draft of the paper specifically made a point that the demand prices as entered in that matrix were meant to take into account for each establishment its costs of moving.

Alan Black's third point was that he would expect to find establishments looking for lower priced sites than the ones they currently occupied, and the fourth point has to do with his inability to see profit maximizing behavior in the site assignment process that I have described. I think that these both derive from some confusion on Alan's part about what the demand prices are; and I do not think this confusion arises because I was obscure. In the paper I say, "At the designated prices, then, the establishment would be indifferent among locations." In other words, I am suggesting that we fill out the matrix with prices such that the relative advantages of each location are reflected in the price that the establishment would be willing to pay for it. In this case the establishments are indifferent between locations provided they can get them at the prices listed. And also, the prices listed reflect the profit anticipations of doing business at any one of those locations So that the demand prices are, if you like, profit equalization prices for establishments whose businesses are making a profit, prices which equalize the profit producing potential, in some sense, of each of the alternative sites. Clearly, there is some profit maximizing in the picture because we have at least the site owners picking tenants so as to maximize the return to their land.

I think John Hamburg replied adequately to Alan's comment on my interpretation of the CATS model If it is a row model as Alan claims, this is not reflected in the published documents. I might just add as a footnote to John Hamburg's point that when I say something is a staff judgment, I am not saying that it is bad. I am just saying that it is very difficult to document so that people can reproduce your results.

BILL ALONSO

I want to call attention to one thing that I find personally intriguing and which I think may in the long run be a problem that comes back to haunt us at first, and later on may be productive. This is the distinction between continuous space and regionalized space. Jack Lowry's model, to some extent, deals with regionalized space. In doing this there are some effects that happen. The reason for doing this, in general, I think, is that both because of the way we think and because of computers, we use matrix operations. The matrix is particularly suited to the naming of districts. However, when you have ordered the districts on, say, the top, you use the information because you have a one dimensional ordering system as opposed to two dimensional spatial system, and so you come back to accessibility measures and things like that to try to bring that back in.

There is a second effect which is that by districting you introduce grain into the territory which may not be there from theory. That is, I think that feedback from theory, which probably goes back to central place theory, and the size of districts has not received enough attention When I was working on rent theory I ran into this problem. I did not know the size of the site until I knew the locator. Therefore, I could not identify it The solution that I proposed was to iterate the solution to fix boundaries. What I did was a topological transformation, and this is why the emphasis on the single center, that ordered not just normally, but ordered the users sequentially the users, and therefore named the sites, and then defined the sites by sequentially defining the users and getting the size, and therefore defining the next one. When you shift to the industry scale, be it sectors of the population or occupations, the grain of the decision is more permissive because if you are dealing with large districts and large groups you can cut them and spill a little over into the next one, or you can fill if you have some unused space with some other user.

This is why the shift from the establishment to the industry is an important one when you go to the matrix and not a trivial one.

There still seems to me to be an important distinction in the types of land uses. There are some land uses which may be said to be distributed. I think households are that. That is, you spread them as you spread marmalade or something like that. The thicknesses may vary but they are more or less all over the place. Certain types of shopping and schools are similar. But other uses—industry is very often an instance—are distinct events rather than density functions, and these are much harder and much less tractable by this technique. I would only like to point out again the fundamental importance of the scale implicit in matrix formulations, not just for the capacity of the computer and the aggregation used in the sense that it is spoken of here, but from the point of view of fundamental theory of urban form. If areas are sufficiently big and defined by population rather than space, so that their grain is larger than the grain of certain phenomena, these phenomena disappear as interesting phenomena to be studied. For instance, if the areas are larger than school districts, I disregard school districts because they fall within the areas. Shopping centers may be treated similarly. If I have fine areas I need to worry where the shopping centers are going to go. As the areas get bigger, I do not. There is a lot of thinking to be done. There is a great deal of theory available; and what seem to be difficulties and irritations are, I believe, very often clues as to the sources of insight in the future.

ACCESS AND LAND DEVELOPMENT

Morton Schneider*

The starting point of this paper is a modest mathematical observation concerning the relation between the number of trips emanating from any elementary area and the geography in which the area is embedded. It has been possible, or has seemed so, to trace out from that beginning a line of thought —intercalating an assumption here, forcing an argument there—leading to a more or less coherent view of how people move about and where they build their works.

The framework of ideas given here is complete in the sense that one can think of fleshing it out into a working, computerized model for calculating expected patterns of floor area accrual and traffic on facilities of all modes, as indeed one has thought of doing. But it is by no means perfectly clear that these ideas are really tenable. There is still a certain amount of computational sneaking up on a full scale model to be done, and it is the purpose of this paper to lay a basic, if diffident, case rather than to report on a methodology or to stumble around in a clutter of possible complications. The treatment here will stick mostly to main features and long, untroubled perspectives on the grounds that, for the time being, enough is enough.

ACCESS AND TRIP GENERATION

It is quite usual, in analyzing travel, to suppose that every piece of the earth's surface has some stipulated supply of trip ends per day, and to assert that the number of trips between an origin place and a destination place is proportional to the number of origin trip ends, to the number of destination trip ends, and to a function of the separation between origin and destination. A slight generalization of this is

$$V_{ij} = \frac{V_i F_{ij} R_j}{I_i} \qquad (1)$$

Where V is number of trips, F is the function of separation, and I_i is $\Sigma F_{ij} R_j$ (or, more neatly, $I = \int F dR$). R is an undefined quantity measuring that which attracts people to a place; it will not become defined until much later on in the paper, if then. If V_j, or something proportional to it, were substituted for R_j, Eq. 1 would represent virtually every trip interchange formula ever used. However, the distinction is not as trivial as it looks.

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Viewed as a destination place, any small area receiving trips from the rest of the world according to Eq. 1 will receive some very definite number of trips, and this must be essentially the same over the course of a period such as an average day (neglecting migration effects) as the number of trips it sends out. It appears, then, that if Eq. 1 has any validity—and it is so general it almost has to—the generation of trip origins or destinations cannot really be prescribed by arbitrary manipulation, but is subject to some kind of natural equilibrium. The obvious next step is to add up all of the trips received by an area in order to see how many must originate there; but it is a great deal less obvious just how to go about this in any meaningful way. As it happens, though, the problem yields with astonishing ease to a little simple-mindedness.

One condition, reasonably well supported by both intuition and data, which logically guarantees the equality everywhere of origins and destinations is that trip movements between any two points be symmetrical; that is, that V_{ij} always equals V_{ji}. If this is taken to be true, then, working Eq. 1:

$$\frac{V_i F_{ij} R_j}{I_i} = \frac{V_j F_{ji} R_i}{I_j} \qquad (2)$$

If it is further assumed that F is symmetrical, that $F_{ij} = F_{ji}$. The F's cancel out and this can be restated as:

$$\frac{V_i}{R_i I_i} = \frac{V_j}{R_j I_j} \qquad (3)$$

But this cannot hold for all pairs of points unless each side of the equation is separately equal to the same constant, a circumstance that gives rise to the general and possibly important result

$$\frac{V}{R} = cI \qquad (4a)$$

or, passing to notation more comfortable for dealing with indefinite but relatively fine partitioning,

$$\frac{dV}{dR} = cI \qquad (4b)$$

So with hardly any trouble at all, it develops that trip density at a point in terms of origins (or destinations) per unit of R, whatever R may be, is proportional to something that can very naturally be called the access integral around the point. By integrating Eq. 4b, the constant of proportionality can be seen to be a special kind of average density:

$$c = \frac{V_T}{\int I dR} \qquad (5)$$

where V_T is total trips in the system. This constant will be evaluated in a somewhat different, but equivalent, form later on from other considerations.

Another way of stating Eqs. 4*a* and 4*b*, in words, is that the number of trips at a point is proportional to the accessibility of the point and to its attractiveness to people; trip ends appear at a place because people can and want to get there. This is a small shift from the customary point of view in which trips are thought of as occurring to satisfy the craving for fulfillment of trip ends. The usual proposition that travel is formed by trip ends groping for each other has never seemed to have much explanatory feel to it; as it turns out, it does not seem to have much mathematical feel to it, either. If R is replaced by V, reverting to the standard formulation, everything breaks down; the sent-received balance described by Eq. 2 can then obtain only in a world so uniform that every access integral has the same value An attempt to introduce correction factors—to use quantities proportional to the V's rather than the V's themselves—works well enough as far as Eq. 2 is concerned; it is just that the required correction factors are precisely those which convert the V's back into R's, according to Eq. 4. (It can also be shown that permitting F to be nonsymmetrical does not help this state of affairs.) In other words, whether or not one likes the shadowy stuff called R, one is stuck with it.

The function F, which distributes trips from an origin place among all destination places, is amenable to a simple argument. It has been said above that R measures that which attracts people to a place. Taking that at its word, the easiest supposition about where people are going when they leave some origin area is that they are going everywhere in proportion to the R-values found there. But this would result in an infinite average trip length, or as nearly infinite as the circumference of the earth will tolerate. There is one most conspicuous constraint operating: trip lengths cannot get out of hand: It is not too hard, however, to compound this constraint into the first supposition by means of a little rephrasing. If the R-value of an area, now, is taken to measure the *a priori* probability (*i.e.*, without regard to travel time or cost) that a trip will go there, then that easy first supposition can become the easy second supposition: trips leaving an origin area tend to distribute themselves among destination areas in the most probable way, subject to the condition that their average length must remain finite. A perfectly definite function can be derived from this statement.[1] If travel occurs in the dimensions of time and cost, this function is

$$F = e^{-(k_1 t + k_2 u)} \tag{6}$$

where t is travel time and u is travel cost; the k's are constants governing average length. And, to recapitulate, the access integral becomes

$$I = \int e^{-(k_1 t + k_2 u)}\, dR \tag{7}$$

where the integration, of course, is over the whole surface of the earth or some other large region.

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[1] See the section on the Distribution Function in Morton Schneider, "Direct Estimation of Traffic Volume at a Point," Highway Research Record 165, 1967.

An interesting aside is the relation of all this to the method of calculating traffic described in the reference cited above. The arguments there, with one exception, can be carried out exactly as before merely by replacing integration over trip ends with integration over R The exception is a crucial one, however: it is no longer permissible to arbitrarily place a single trip destination in the vicinity of the traffic stream. It is necessary, instead, to place an arbitrary amount of R there and let it generate its own proper number of destinations (or, the same thing, the correct amount of R to generate one destination). When this is done, the formulation is altered in such a way that its one apparently fundamental flaw miraculously vanishes. In its original form, the formula calculates systematically different (but not greatly different) traffic volumes at different points along a bridge; altered, it produces exactly the same volume at every point. Another, perhaps more generally interesting, connection is that the revised traffic equation contains the constant c of Eqs. 4 and 5, but no other explicit dependence on trip ends. In principle, c could be numerically evaluated as a kind of activity constant from a study of traffic flows, and travel could then be calculated without once mentioning trips.

It is not very usual, in analyzing travel, to speculate on the exact meaning of the word trip, but it really cannot be avoided forever. Trips here are used to some extent as concepts of convenience, neither very interesting nor very observable in themselves, having whatever properties the mathematical treatment generates and being roughly similar to, though far more inclusive than, those things reported in an origin-destination survey. There is more to it than that, however. One property a trip must have, if only to give meaning to the terms travel time and travel cost, is that of defining travel: knowledge of an origin and destination must imply knowledge of the travel path between them. This suggests, as does common understanding, that the end points of trips are set apart from all the other points along the way and that perhaps these other points are there only to be traversed as easily as possible. Which is to say that trips follow minimum paths because it is very hard to think of any other rule that allows the trip concept to be useful. So trips can be defined strictly, if unsentimentally, as segments of a person's total travel trajectory that lie entirely on minimum paths, and those points at which departures from minimum paths occur are necessarily trip ends. The travel times and costs in the trip distribution function (Eq. 6) are to be measured along minimum paths, since if the trips take any other paths, they are not trips.

Now that the question, "what is a trip?" has been settled, it becomes possible to move on to the next issue. What is a minimum path?

MODE OF TRAVEL

For the purposes of this paper, it appears inescapable to speak simply of minimum paths in order to speak of parameters such as time and cost separating points in geography. But just what is it that a minimum path, in the trip defining sense, minimizes? If travel time alone, everyone would charter helicopters; if travel cost, everyone would walk. More likely, the quantity to be minimized is some combination of time and cost. But the distribution function (Eq. 6) has already stated that trip making is sensitive to a linear combination of time and cost, so what better bet than that this is the path discriminating measure? The minimum path between any two points can now be selected from among all possible paths: it is the one for which the exponent in Eq. 6, $k_1t + k_2u$, has the least value

Incidentally, travel time and cost are considered throughout this paper to be the only generally significant distances, as seems to be the case empirically. Everything could, however, be extended to include other dimensions.

Minimum paths are now clearly defined and only one difficulty remains. In the real world, trips between two points do not by any means always choose the same path, nor can this always be explained by dispersion of indeterminacy of travel times and costs. However, the quantity $k_1t + k_2u$ suggests that the path selected as a minimum depends on the values of k_1 and k_2, and this leads to the conjecture that there are different trip groups which respond to different values of the k's, weighing time and money and the trade-off between them differently. Running through spectra of values for the two k's, it appears that between any two places there might very well be more than one path that could function as a minimum during some intervals of k-values, but not all conceivable paths could so function. The test is this: if a path is *both* slower and more expensive than some other path, no values of the k's can ever make a minimum of it and, presumably, no trip will ever use it. Paths which pass this test, which can hope to be used, can be ranked in order of increasing travel time and then in order of decreasing travel cost, and will have the same rank in both cases. Proceeding down such an ordered list of paths—call them path *a*, path *b*, etc.—it is easy to see that path *a*, which is the fastest and most expensive path (involving, perhaps, an airplane), will be the minimum path as long as

$$0 \leq k_2 < k_1 \frac{(t_b - t_a)}{(u_a - u_b)} \tag{8a}$$

path *b* will become the minimum in the range

$$k_1 \frac{(t_b - t_a)}{(u_a - u_b)} < k_2 < k_1 \frac{(t_c - t_b)}{(u_b - u_c)} \tag{8b}$$

and so on down to the slowest, cheapest path (*e.g.*, walking)

$$k_1 \frac{(t_n - t_m)}{(u_m - u_n)} < k_2 \leq \infty \tag{8c}$$

In general the breakpoints—the k-values at which one path stops being a minimum and the next takes over—occur when

$$k_2 = \frac{\Delta_{nm}t}{\Delta_{mn}u} k_1 \tag{8d}$$

Paths of this sort seem to deserve to be called modes, though the term takes on a slightly exotic meaning. A mode, in this sense, will not necessarily retain its identity from one pair of points to another, and it will not necessarily correspond to ordinary usage; an expressway route and an arterial route between two points, for example, might very well function as competing modes.

If the distribution of trips with respect to values of k_1 and k_2—the probability of a trip falling within an interval $dk_1\, dk_2$—could be established, all of this would begin to form an intelligible picture. The problem can be attacked in much the same way as that of the distribution function in the preceding section, although it fights back a little harder. Essentially the same constraint operates here as in that case: however trips may be distributed among k-values, it must be in such a way that over all average trip length stays within reason. If the distributions with respect to k_1 and k_2 are assumed to be independent of each other (not a strictly necessary condition), it should be possible to develop each distribution separately, as though the other were not there. Adopting this attitude of ignoring one dimension when dealing with the other, the crucial parameter directly controlling average trip length for any particular value of k is $1/k$, and it is plausible to think of applying the constraint in the form

$$\sum V_k \cdot \frac{1}{k} = \text{finite constant}$$

At the same time it is plausible to think of $1/k$, which has the dimension of length, as constituting a one-dimensional space within which trips are equally likely, *a priori,* to distribute themselves everywhere. And the plausible result, finally, is

$$dV = \frac{1}{k^2} e^{-a/k}\, dk \tag{9a}$$

or, adding the other dimension,

$$dV = \frac{1}{k_1{}^2} e^{-a/k_1} \frac{1}{k_2{}^2} e^{-b/k_2}\, dk_1\, dk_2 \tag{9b}$$

where a and b are constants of the distribution.

With a little semantic exertion, all of this can be carried out at the same time as the derivation of Eq. 6, and the distribution function becomes

$$F = \frac{1}{k_1{}^2} e^{-(k_1 t + a/k_1)} \frac{1}{k_2{}^2} e^{-(k_2 u + b/k_2)} \tag{10}$$

Other variations on this theme are entertainable, but it appears at the moment that they would not and should not give strikingly different results. This one follows the principle of least complication without good reason for more. Good reason might, of course, turn up at any time.

The complete distribution function as it operates between two points, referring to relations (Eq. 8), is

$$G = \int_0^\infty \left(\int_0^{Z_{ba}} F dk_2 + \int_{Z_{ba}}^{Z_{cb}} F dk_2 + \ldots + \int_{Z_{nm}}^\infty F dk_2 \right) dk_1 \tag{11}$$

where the F is, of course, that of (Eq. 10) and the Z's are the mode breakpoints of Eq. 8*d*, $Z_{nm} = \frac{\Delta_{nm}t}{\Delta_{nm}u} k_1$.

The integrals are broken into pieces as the travel paths shift from one to another, causing the times and costs to change. If the transportation network is symmetric, if the same paths exist in one direction as the other (as has been tacitly assumed all along), then the mode points will be the same in both directions and G will be symmetric, allowing the trip generation argument to go on as before. The only difference is that the I of Eqs. 4 and 7 must be replaced with

$$I = \int G\, dR \tag{12}$$

If a transportation system consists of distinct, noninterconnecting uniform networks, each network will constitute a mode in both the special and the ordinary sense, and trip generation at any point by each mode will be proportional to that mode's respective piece of Eq. 11 integrated out over the world of R. Examining this closely reveals an interesting and fortunate character: if a new mode is added to the system, it will attract trips from its neighboring modes but it will also increase the total trips generated However, the closer it is in speed and cost to some other mode, the less the increment of trip generation. Thus as more and more modes are added, crowding in on each other, they will more and more be merely competing for each other's trips rather than generating new ones of their own. Also, it goes almost without saying that the highest trip generation for a mode occurs at those places especially well served by the mode.

The case in which the above transportation system has only one mode is of special interest for purposes of trial calculating, getting the feel of the thing, and even practical approximating. In this case, the function (Eq. 11) simplifies to:

$$G = \int_0^\infty \int_0^\infty F dk_2\, dk_1 \tag{13}$$

and this, if the author's rheumatic mathematical agility has not betrayed him, is integrable, giving

$$G = 4\sqrt{\frac{tu}{ab}} K_1\left(2\sqrt{at}\right) K_1\left(2\sqrt{bu}\right) \tag{14}$$

K_1 is conventional notation for the modified bessel function of the second kind, order one.

The argument that trips vary in their sensitivity to time and cost has led to a distribution function substantially different than the simple exponential of Eq. 6, quite aside from any question of mode. Even if only one dimension of distance were used (implying only one mode), the distribution function would still have the form of Eq. 14, but without terms in the other dimension. The general behavior of this function is to descend more rapidly than an exponential at short distances and more slowly at long.

Thus, the large problems of travel activity—the generation of trips by mode and their distribution through a transportation system, also by mode—have been solved, or at least laid to fitful rest. Now, if only someone knew what R was.

LAND DEVELOPMENT

As far as this section of the paper is concerned, what has gone before is prologue. Its purpose has been to establish the role of the stuff called R in human activity, to define a relation between trip generation and access, and to give an exact, computable meaning to the term access. The brave purpose of this section is to introduce capital improvement of land and to tie everything together.

The first step is to ponder the nature of R. From Eq. 4, it can be said that the amount of R at a place is proportional to the trips arising there divided by the access of the place (access refers to the all-mode access of Eq. 12, not to that of Eq. 7, and so will the symbol I when it appears). This brings up the possibility of calculating R at various places where data exist to see if it can be identified with anything visible. If that were fairly easy to do, it would probably be worth trying, but it would actually be a very formidable piece of work for several technical reasons, not the least of which is the fact that the access integrals themselves depend on R. Besides, any relationship that is not fairly well anticipated is most unlikely to be found in that sort of a campaign.

Speculating on the identity of R, two immediate possibilities come to mind. One is that R is just proportional to land area, modified perhaps by the intrinsic desirability of the land for human purposes (oceans, swamps, glaciers, etc., would certainly have low rates of R per square foot) but basically a kind of geometric concept referring to the surface of the earth, to the space in which people locate. But if this were the case, the only thing that could account for the very high rate of trip generation of, for example, Manhattan, would be, according to Eq. 4, a very large access integral. While Manhattan is at the center of a dense, extensive, and many-moded transportation system, it does not seem conceivable that this alone could supply the leverage for that kind of differentiation. How different can access integrals be when land area is the only thing to be accessed?

The other first glance possibility is that R is proportional to floor area, which seems intuitively to be something that attracts people. Again, Eq. 4 doubts it, because trips per square foot of floor area would then be proportional to the access integral. Places of high accessibility would show higher trip generation rates than places of low accessibility, and a place like Manhattan would have an enormous number of trips per square foot of floor area since the access integration this time would be over a highly differentiated surface. But evidence from origin-destination and land use surveys apparently denies this. There seems to be no systematic variation in person trip generation rates per unit of floor space from place to place, and even Manhattan is about average in this measure. Of course, the trips in Eq. 4 include many events which would never be reported in an O-D survey and do not correspond exactly to survey definitions anyway. Even so, the generation due to the longer distance part of the integration in Eq. 4 ought to be at least roughly the same as survey trip generation, and although this part of the integral may not vary as much as the whole thing, it would still vary a great deal in a floor area surface.

Rather than reject land area and floor area out of hand—they are almost the only sensible candidates—it is reasonable to wonder if R might be some combination of the two. It cannot be a multiplicative combination, since that would imply that land without structures on it could never attract trips, and the world could never have gotten started moving. The simplest acceptable combination is a linear one. With this in mind, a line of reasoning begins to emerge.

In what follows, a piece of land is regarded as a kind of abstract element of spatial location, attractive to people in much the same way that an element of volume in a box is attractive to gas molecules. Floor area is used as a convenient, meaningful, and measurable (as well as measured) surrogate for capital improvement of all kinds. Possible differences in attractiveness from one piece of land to another and from one unit of floor space to another are not ruled out, but they are not stressed, either. Various costs, congestion effects, and other odds and ends that no doubt complicate the real world are considered to be largely beside the point of this paper.

Imagine a piece of vacant, but accessible, land lying fallow. If there are people in the vicinity, they will inevitably find some reason to go there and to do something on that land. This implies, by Eq. 4, that the land has some value of R. As people use the land, there will be a tendency for improvements to appear to accommodate them, to serve and augment their inscrutable purposes. But these improvements (which are in the form of floor area) will in turn tend to attract still more people. This implies that the floor area, too, has some value of R, which is easiest to think of as an additive increment. So R in general can perhaps be defined as

$$R = R_a + R_f \tag{15}$$

where R_a is proportional to land area and R_f is proportional to floor area, though the proportion need not be the same for both R's

The increment of people attracted by the increment of floor area will in their turn foster yet another increment of floor area, and so on, although this does not have to go on forever.

Although there is no pretension that the simple and occasionally labored considerations of the first two sections can really account for all the fine structure of human activity, they do seem to apply in their crude way to relatively microscopic movements; the trip generation of Eq. 4 might be construed as a close measure of activity or average occupancy of small areas—activity which determines the amount of floor space required for its accommodation. Even on the macroscopic scale of the O-D survey, as was mentioned earlier, trips are more or less proportional to floor space. Trip generation per square foot of floor area is scattered, but it seems always to be scattered around the same mean.

If it is assumed that, in the way the world works, there is some proper amount of floor space per trip, then the growth of floor space described above moves to an equilibrium, an equilibrium strictly governed by the access of the site. From Eqs. 4 and 15,

$$V = cIR = cIR_a + cIR_f \tag{16a}$$

but also, now

$$V = sR_f \tag{16b}$$

Putting these together gives

$$R_f = \frac{cIR_a}{s - cI} \tag{17}$$

From Eqs. 16*a* and 16*b*, it can be seen that

$$c = \frac{sR_F}{J} \tag{18}$$

the promised counterpart of Eq. 5; R_F is proportional to total floor area in the region and J is a notational convenience,

$$J = \int IdR \tag{19}$$

Substituting in Eq. 17 produces the final expression for equilibrium floor area at a site:

$$R_f = R_F \cdot \frac{R_a I}{J - R_F I} \tag{20}$$

This is a rather subtle expression, and it may be well to elucidate some of its elementary properties. When the access, I, is small compared to the average, the floor area will be essentially proportional to the access. As I grows large, however, the denominator in Eq. 20 becomes small, exerting a powerful leverage on floor area, powerful enough, probably, to explain a phenomenon such as Manhattan. If the world has completely uniform access everywhere, J becomes

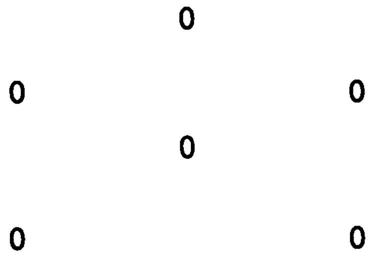
$$\int I\,dR = \int I\,dR_a + \int I\,dR_f = IR_A + IR_F \tag{21}$$

and Eq. 20 reduces to

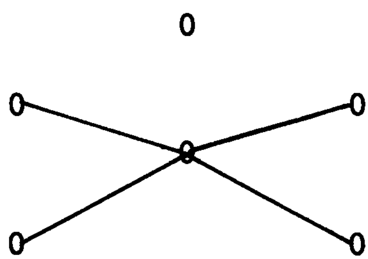
$$R_f = R_F \cdot \frac{R_a}{R_A} \tag{22}$$

The floor space on any site is just its share of total floor space based on its share of total land area.

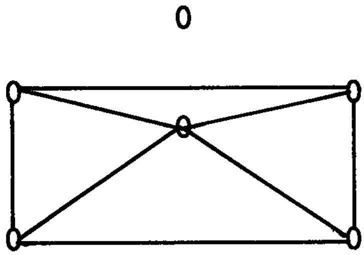
It is difficult to compute realistic cases, even highly simplified ones, from Eq. 20 without moderately elaborate computer techniques because of the interdependencies of the floor area equilibria throughout the region. One extremely simple example that can be worked out by hand and that reveals some of the behavior of the scheme is this. Imagine six villages of equal floor area scattered about a wilderness so:



These villages are virtually isolated, the transportation being just rudimentary, slow trails. Now let someone come in and build a transportation system an order of magnitude faster than the old trails, thus



If the floor area is portable, but the total amount cannot change, Eq. 20 prescribes a new equilibrium (after a suitable time) in which the center village will have become the largest while the outer villages will have decreased. The poor village at the top, left out of things, will have declined most of all. If, now the transportation network is extended,



the center village will shrink, though it will remain larger than any other, while the outer connected villages will grow. The neglected, and by now probably unfriendly, village at the top will decline still more than it already has.

It is possible to carry this further, and in a vague, qualitative way, trace the evolution of cities. A city getting started in the days before powered locomotion would most likely nucleate, according to Eq. 20, on or near a waterway—almost the only thing that could give it an access advantage. It would tend to grow in a dense fashion, because the only sites with unusually large access integrals would be those very close to already developed sites With the appearance of the railroad, operating an order of magnitude faster than anything else, places along the rail line would suddenly have very large access integrals, and new floor area would gravitate to the rail territory. If the railroads centered on the original city, and if the secular growth of floor area were great enough, the central city might also experience a growth of relative access. But now throw ubiquitous roads and automobiles into the picture, and everything changes. Access integrals everywhere increase greatly, a growth so extensive that the relative access of the center and of the rail territories almost certainly must decline. Moreover, the automobile inserts itself into the mode integral (Eq. 11), cutting off a large part of the railroads range of influence there and decreasing its absolute contribution to accessibility. New floor area, following Eq. 20, migrates to the vacant land, now much more accessible than it used to be, even though the older areas are still the most accessible. The very extensive increase in access integrals causes J in Eq. 18 to increase faster than total floor area, and the constant c grows smaller, implying a decrease in traffic between any two places whose growth in floor area is less than average. This effect expresses the redirecting of travel patterns, and tends to cause traffic on railroads, whose territories are mostly slower growing, to decline, entirely apart from mode competition.

Cities that have done most of their growing during the automobile age—Detroit and Los Angeles are excellent examples—look quite different from older cities. Presumably, this is due to persistence of history. If Eq. 20 were to start with nothing but the transportation system in the New York area and build the city from scratch, it would be most unlikely to create the central city as it now is. The processes leading to the equilibrium of Eq. 20 are slow, and to a great extent a city is what it used to be. As a matter of practical application, this does not seem too troublesome. It is easy enough, in forecasting development, to require existing floor area to stay where it is and to expect new floor area to occur in an equilibrium condition. Or, perhaps better, existing floor area can be allowed to disappear at the rate of 1 or 2 percent a year (or even at a rate appropriate to its actual age), and the amount that disappears can be treated as new space, free to seek out a new equilibrium in a new place.

In fact, this can easily enough be generalized in a working model, if one is ever produced, to allow any kind of constraints—planning, legal, physical—of a form that limits or requires development in particular locations. One output might then be a measure of the utilization that might be expected in these constrained places.

The model, in its perfected form, would produce, then, expected floor area by, say, square mile, and traffic on facilities of all modes; because of constraints, trip generation by square mile would probably also be desirable. Inputs would be existing floor area, the expected transportation system, and constraints. The floor area estimates would be generalized things, intended to let the planner understand the bounds within which to work; it would still be up to him to figure out what it would actually look like.

A most interesting possibility is that of working out some system of accounts which would set up a criterion to distinguish a better region from a worse. The model, which predicts what will happen under a given set of conditions, could then be turned around to help find those conditions that would yield a better region, in other words to plan. Also, there is no evident reason why the model cannot be applied on a national scale to worry about things like airline traffic, high speed ground traffic, and the growth of cities—the latter probably implying something about migration.

It might be mentioned that several parameters in this theory, if it may so be called, depend on large social states. The constants in the distribution function, a and b (Eq. 10), might be termed value of time and money, respectively. As a society grows wealthier, it can be presumed that b will grow smaller; as the world grows more interesting and enjoyable, and as people become less willing to spend their time in the kind of travel which, by the definition of a trip given a long way back, is in itself just a nuisance, a may very well grow larger. Also, the coefficient s of Eq. 16*b* *et seq.*, which converts floor space (or capital improvement) to trips, is perhaps not greatly different than the inverse of wealth per capita.

In summary, a few very simple ideas have been put, sometimes hammered, together in a way that seems qualitatively to explain a great many things, from the decline of commuter railroads to the opening of the West. The equations here can all be turned into real calculations, some easy, some very hard to perform (the reader is invited to guess which is which). It will take quite a few of these calculations to find out whether or not any of them are worth doing.

THE QUALITY OF DATA AND THE CHOICE AND DESIGN OF PREDICTIVE MODELS

WILLIAM ALONSO*

Long chains of argument are the delight of theorists and the source of their mistrust by practical men. There is some merit in this mistrust. Imagine that we argue that if A then B, if B then C, etc. If we are 80 percent certain of each step in the chain, from the joint probability of the steps it follows that we are less than 50 percent certain of where we stand after four steps.[1] Thus the brilliant deductive chains of Sherlock Holmes or the young Ellery Queen, while dazzling, leave us with the feeling that they will not secure a conviction. In this paper I will raise the issue of the effect of errors and their propagation in models for prediction, and suggest some strategies for the selection and construction of models which are intended for applied work. The gist of my argument is that the use of sophisticated models is not always best in applied work, and that the design of the model must take into account the accuracy of the data on which it will be run. There exists the possibility, which should be explored, that some of our most intellectually satisfying models should be pursued as fundamental scientific research, but that simpler and more robust models should be used in practice.

Let us distinguish two types of error: error of measurement and error of specification. Error of specification arises from a misunderstanding or purposeful simplification in the model of the phenomenon we are trying to represent. A simple instance is the representation of a nonlinear relation by a linear expression; another is the omission from the model of variables which have only a small effect or the aggregation of variables. Measurement errors are those that arise from inaccuracy in assessing a magnitude. If I say that a man is six foot tall, or a nation has a population of 200 million, I really mean that he is six foot give or take an inch, or that the population is 200 million give or take 10 million. Thus, in scientific work it is customary to indicate measurement, M, as having an error, e, attached, and we may write the height of a man, the population of a nation, or the density of a population as $M \pm e$. It

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[1] I first met this argument in C I Barnard, *The Functions of the Executive* (Cambridge. Harvard University Press, 1958). A similar argument appears somewhere in A. Marshall's work.

is customary to use either the standard deviation or the probable error as the measure of error.[2]

A quantitative model puts together various numbers obtained by measurement, and combines them through algebraic operations. Normally we consider only the measurements and forget the error terms, and give the result of our calculations as a number without indicating its error. Too often we seem to hope that the errors in the inputs somehow cancel out as they go through the model, but in fact they do not. There exists a well-known formula for estimating the error in the output which results from the propagation of errors in the inputs. If we have

$$z = f(x_1, \ldots, x_n)$$

$$e^2_z = \sum_i f^2_{x_i} e^2_{x_i} + \sum_i \sum_j f_{x_i} f_{x_j} e_{x_i} e_{x_j} r_{ij}$$

where e_z is the error of z; f_{x_i} is the partial derivative of f with respect to x_i; e_{x_i} is the measurement error in x_i; and r_{ij} is the correlation between x_i and x_j.[3]

This formula is exact when the function is linear, but an approximation when it is not. However, recent work has shown it to be a much better approximation than had been previously thought.[4] Thus, by applying it to a model, we may estimate the probable error in the result that arises from errors of measurement in the input variables.

Examination of the formula gives several simple rules of thumb for the construction of models or the selection of models, and these may be useful when, as is often the case, the investigator has several choices in the formulation of the model.

The first rule is to avoid intercorrelated variables whenever possible. The second term on the right-hand side shows that the error in the dependent variable can increase very rapidly from this source.

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[2] The probable error is a distance from the mean such that one-half of the probability distribution lies within the mean plus or minus the probable error; in other words, there is a fifty-fifty chance that the true magnitude lies within $M \pm e$. The probable error is approximately 0 675 the standard deviation I will not deal in this discussion with the question of an asymmetric error distribution.

[3] See E. B. Wilson, *An Introduction to Scientific Research* (New York: McGraw-Hill, 1952), pp. 272-274; L. G. Parratt, *Probability and Experimental Errors in Science* (New York: J. Wiley and Sons, 1961), pp. 110-118; A. deF. Palmer, *The Theory of Measurements* (New York. McGraw-Hill, 1930). H. Theil uses a different approach in *Applied Economic Forecasting* (Amsterdam: North-Holland Publishing Co., 1966), pp. 262 ff He formulates the problem in terms of information theory and considers the prediction of sets of numbers

[4] J. W. Tukey, "The Propagation of Errors, Fluctuations and Tolerances: Basic Generalized Formulas," Tech. Report No 10, Statistical Techniques Research Group, Department of Mathematics, Princeton University. This paper and its companions Tech. Reports Nos. 11 and 12 were not published, and they are now unobtainable.

Let us now examine the most basic algebraic operations to derive some other general rules. For simplicity, let us have $z = f(x,y)$, where $x = 10 \pm 1$ and $y = 8 \pm 1$. We will assume that x and y are mutually independent.

Addition:

$$z = x + y$$
$$18 = 10 + 8$$
$$e^2_z = e^2_x + e^2_y = 1 + 1 = 2$$
$$e_z = 1.4$$

We see therefore that, in the case of addition, the absolute magnitude of the error in the dependent variable is greater than in the independent variables. On the other hand, the percentage error is smaller (8 percent) than in the independent variables (10 and 12.5 percent). It may be said, then, that the operation of addition is relatively benign with respect to the cumulation of error. With one exception,[5] it is the only operation which reduces relative error. It must be noted, however, that the size of the absolute error increases.

Subtraction:

$$z = x - y$$
$$2 = 10 - 8$$
$$e^2_z = e^2_x + e^2_y = 1 + 1 = 2$$
$$e_z = 1 4$$

The deceptively simple operation of subtraction is explosive with respect to relative error, especially when the difference is small relative to the independent variables. In this case the relative error is 70 percent.

Multiplication and Division.

$$z = xy$$
$$80 = 10(8)$$
$$e^2_z = y^2 e^2_x + x^2 e^2_y = 64(1) + 100(1) = 164$$
$$e_z = 13.3$$

It can be seen that multiplication not only raises the absolute error, but also the relative error (in this case to 17 percent). Division behaves exactly like multiplication.

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[5] The exception is when an independent variable is raised to a power with an absolute value smaller than one, in which case both the absolute and the relative error are reduced.

Raising to a Power:

$$z = x^2$$
$$100 = 10^2$$
$$e^2_z = (2x)^2 e^2_x = 400(1) = 400$$
$$e_z = 20$$

Raising to a power is another explosive operation. In this case the relative error has climbed to 20 percent. It may be thought of as multiplication of perfectly correlated variables, and thus, from the second term in the basic equation, we may expect the error to be substantially higher. However, if the variable is raised to a power between 1 and -1, both the absolute and the relative error decrease.

From these simple exercises, we can generalize a few rules of thumb for building or choosing models if choices are available:

1. *Avoid intercorrelated variables.*
2. *Add where possible.*
3. *If you cannot add, multiply or divide.*
4. *Avoid as far as possible taking differences or raising variables to powers.*

I will illustrate these rules by a "simple" model of the type we all use every day without thinking twice about it. We want to predict population in 1980, P_{80}, from the populations of 1950, P_{50}, and 1960, P_{60}. These populations were enumerated by excellent censuses, with very small errors in the order of 1 percent. To take arbitrary but typical numbers, let us say that $P_{50} = 100 \pm 1$ and $P_{60} = 105 \pm 1$. We will extrapolate the 1950 to 1960 rate of growth to 1980:

$$P_{80} = P_{60}\left(\frac{P_{60}}{P_{50}}\right)^2 = \frac{P_{60}^3}{P_{50}^2}$$

Of course, we are squaring the rate of growth because we are predicting for two decades. Simple application of the formula, without taking into account any correlation between the 1950 and 1960 populations, gives $P_{80} = 115.76 \pm 4.03$. The relative error in the prediction has risen to 3.5 from 1 percent in the data. But if we ask the accuracy with which we are predicting the *change* in population, we obtain 10.76 ± 4.03, which represents a 38 percent error. This error is due entirely to measurement errors and assumes that the specification of the model is perfect. That is to say, that if we know the exact rate of growth from 1950 to 1960, we would be able to predict the 1980 population exactly.

If we consider that such an extrapolation is a crude model and we say, for instance, that the use of the rate of growth has a 20 percent specification error (that is to say, that the rate of growth per decade will be 5 ± 1 percent from the effect of variables not considered) and that the variations from decade to decade are independent, we would have $P_{80} = 115.76 \pm 1.56$, and the change in population will be 10.76 ± 1.56. In other words, there would be a 14.5 percent specification error if the data were perfect. The joint effect of measurement and specification errors will be 40.2 percent on the population change.[6]

Before continuing the discussion of the strategy of model construction it may be useful to point out the usefulness of this type of analysis for determining strategies of improvement of data to minimize the compounding of measurement errors. By taking the partial derivative of the error in the dependent variable with respect to the error in an independent variable, we can get the rate of improvement to be gained from better measurement of that variable. The expression, if we disregard the correlation term, is quite simple:

$$\frac{\partial e_z}{\partial e_i} = \frac{f^2_{x_i} e_i}{e_z}$$

That is to say, the marginal rate of improvement in predictive error is equal to the square of the partial of the variable times the measurement error divided by the error in the dependent variable. By use of these marginal rates of improvement divided into the cost of improving the data (*e.g.*, by denser sampling), one can determine the best distribution of budget in data collection. Examination of the expression gives two general rules: (a) concentrate on important variables (*i.e.*, those which affect the dependent variable significantly, as shown by a large f_{x_i}), and (b) concentrate on those with large errors.

Let us illustrate this point by an example. Let us assume the following information:

$$z = xy + w$$

$$x = 100 \pm 10 \qquad y = 50 \pm 5 \qquad w = 200 \pm 50$$

Marginal cost of improving x (to 100 ± 9):	\$ 5.00
Marginal cost of improving y (to 50 ± 4):	\$ 6.00
Marginal cost of improving w (to 200 ± 49):	\$ 0.02

Using our formula we obtain

$$\frac{\partial e_z}{\partial e_x} = 35.2 \qquad \frac{\partial e_z}{\partial e_y} = 70.5 \qquad \frac{\partial e_z}{\partial e_w} = 0.0705$$

These are the marginal improvements on e_z that derive from a marginal improvement in each of the variables. To find the cost of marginal improvement in e_z, we divide these rates into the cost of marginal improvement in each of the variables, and we obtain.

marginal cost of improvements in e_z	from improvements in x:	\$ 0.142
	from improvements in y:	\$ 0.085
	from improvements in w:	\$ 0.284

[6] Out of concern for the sensibilities of those who make projections, I am not questioning the exactitude of the period of two decades, but, of course, the length of time is also a variable. When we say 1980, we really mean sometime around 1980, and thus the exponent of the rate of growth might be 2±0.1 decades. The consequences of this upon the error are spectacular.

Consequently, it would pay us to improve y *if* marginal reductions in e_z are worth 8.5 cents. It should be noted that improvement of any one variable is subject to diminishing returns, even if the cost of improvement does not rise (which it will normally do). Therefore the analysis should be repeated at small intervals. As might be expected from economic theory, the most efficient situation is that where the marginal cost of improvement in the predicted variable is the same for all variables.

Let us return now to considerations of model construction. Imagine a situation in which we have a choice of some very naive model, which we shall not describe, which has historically given us 30 percent error, largely because of poor specification. We have a perfect specification model to predict the same phenomenon of the form $z = x_1 \, x_2 \, x_3 \, x_4 \, x_5$. If each of these variables has a 10 percent error, the estimate of z will have an error of 22.2 percent resulting entirely from measurement errors. We then will choose the second model.

Consider now the same situation in a developing country, where the data are poorer The naive model performs worse because its data inputs are worse, although its specification error will be the same. Let us say that the error of the naive model is 40 percent. We can use the perfect specification model, but now each of the variables has a 20 percent measurement error. The second model, then, will have an error of 44.5 percent due entirely to the compounding of measurement error. In this case we would be better off with the naive model.

The point being made is that the choice of model depends in part upon the quality of the data. The more complex the model, in the sense of having more operations of the same kind or more "explosive" operations such as raising to powers, the more the measurement errors cumulate as the data churn through their arithmetic. The gains in correctness of specification in a more complex model may be offset by the compounding of measurement errors. Although I lack the competence to demonstrate it, I am suggesting that if we tried to predict celestial phenomena by Einstein's General Theory of Relativity using data of the quality which were available to Copernicus, the predictions might be worse than if we used the Copernican theory.

To use a homier example, suppose that we had the wit to design the structure of a skyscraper, but our construction material were timber and our joints were secured with nails. The give in the joints and the members are like weakness in the data: we sometimes can design beyond the capacity of our materials. With timber one should build relatively low and wide, with steel one can build tall and narrow. We shall return to this analogy.

The proposition may be represented in a diagram (Fig. 1). On the horizontal axis we measure the complexity of the model. I know of no good definition of complexity. The suggested definition, that one model is more complex than another if it has more operations of the same kind or if it has operations which are more explosive with regard to the compounding of errors (such as subtraction of nearly equal numbers or exponential functions) is somewhat

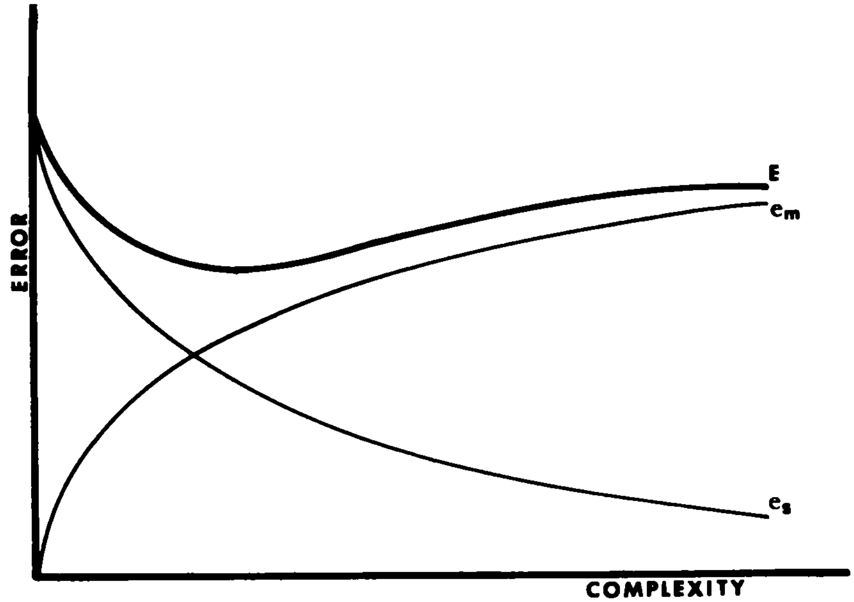

Figure 1.

circular, but it will have to do. If we are good model-builders, we will only complicate a model to gain advantages of specification. Thus, if our data were perfect, we could imagine a curve of specification error, e_s, which slopes downward asymptotically to the horizontal axis.[7]

On the same diagram we can draw a curve, e_m, for the prediction errors that result solely from measurement errors in our input variables. As the complexity of the model increases, the compounding of measurement error increases. Measurement error increases rapidly at first, but under most conditions, it will increase more slowly with further complications. Total predictive error, E, is the combination of these two types of error in a multiplicative relation, so that $E = (e^2_s + e^2_m)^{1/2}$. The best point for prediction is the bottom of the total error curve.

In Figure 2 we consider two cases subject to the same specification, but the data in one case are worse than in the other. The curve for the case with poor data, e^*_m, is therefore higher than the curve e_m of the case with good data. The

[7] I am speaking of situations in which models are improved by progressive refinements, rather than by radical reformulation which may give better predictive accuracy with a simpler model. Such a radical reformulation, which may be called a Copernican advance, would result in a new e_s curve substantially below the original one. This would be the case of a radical scientific advance, and these cannot be called upon at will. I am speaking here of the marginal improvements in the formulation of models.

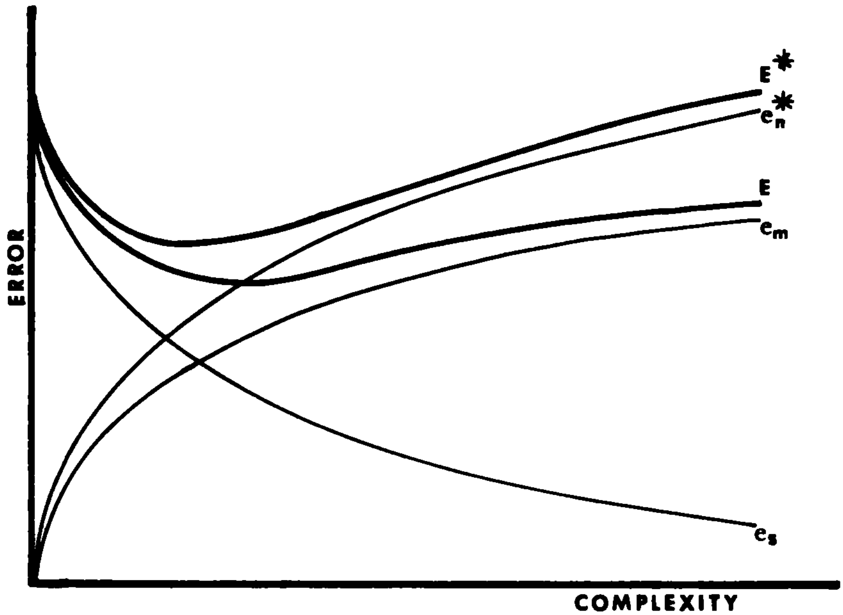

Figure 2.

curve E^* of total error in the poor data case is quite naturally higher than the curve E of the good data case. But the important point is that E^* bottoms out at a lower degree of complexity than E. In other words, when accurate data are available, complex models are possible. When the data are poor, simpler models are advisable.[8]

In this view, it is perfectly conceivable that we can devise predictive models which are beyond the capacity of the data, in the sense that, although they are more "accurate" in their specification, the quality of the data results in a deterioration of prediction. I raise the question of whether in the field of land use and traffic models we have not gone beyond the best predictors. I must stress that I do not know whether we have or have not; but we must try to find out.

Let me outline a fairly typical form of one of today's models for predicting needed changes in highway capacity. (1) We predict a change in the absolute numbers of basic employment defined by some reference to a theory of export multipliers. (2) Based on an estimated participation rate, we predict "basic" population. (3) We predict a basic-service employment ratio. (4) We predict service employment. (5) We predict "service" population. We now pass on to (6) a prediction of the location of basic employment. Based on this, (7) we predict the location of "basic" population. (8) We distribute service employ-

[8] Note that under these assumptions, as the effects of cumulation of errors and of better specification both flatten out, the curve of total error approximates the curve of measurement error and becomes relatively flat.

ment according to basic population. (9) We distribute "service" population.[9] We now have a predicted distribution of jobs and people. Based on this we predict (10) travel patterns or desire lines. (11) We subtract existing capacity from projected demand to obtain (12) needed changes in highway capacity.

Data for earlier periods are fitted, most commonly by multiple regressions, to each of the postulated relationships, and the ordinary tests of significance are applied to the relations one by one. But when the predictive phase is reached, these relations are strung together in a chain. The values of some variables such as basic employment are estimated outside of the model and plugged in. The predicted values of these variables are measurements, and their errors in estimate are measurement errors. The parameters which were calculated in the first stage of the model now become themselves variables to which we can often attach concrete significance such as land requirements per worker or propensity to travel. It should be noted that standard regression techniques give us estimates of error for the parameters. The estimates of the final variables will thus have five sources of error: (1) specification error in the period for which we have calibrated; (2) further specification error if conditions in the future differ structurally to some degree from conditions in the calibration period, so that a perfect specification of past relations does not specify perfectly for the future; (3) measurement (or predictive) errors in the exogenous variables; (4) measurement errors in the parameters (now variables) in the calibration period; and (5) measurement (or predictive) errors resulting from using past values in place of future values for these parameters/variables.[10] Predictive errors from each of these sources will compound through the operations of the model, as the dependent variables of one step in the chain become the "exogenous" inputs into the next step.

The effects of such a chain can lead to rapid deterioration of prediction. Imagine a three-step chain of regression equations, each validated with an $R = 0.9$. Assume further that the last four types of error are nil, so that we are dealing only with specification errors in the original relations. The result of the three-step chain will have a 34 percent standard error of estimate from this source alone.

The general point has now been made, and gives rise to a fifth rule of model construction:

5. Avoid as far as possible models which proceed by chains.

This general rule, in its positive aspect, says that we should proceed by models which do not build step upon step. This rule increases in importance with weaker data.

[9] I omit here some possible iterative steps to adjust services to total population.

[10] Sometimes these parameters are adjusted for the predictive equations, based on some other information; this may reduce this source of error, but, of course, will not eliminate it.

But certainly, if we have information on many variables, we want to put it to use, on the general principle that any further information will assist our prediction, and that simple models which use few variables neglect some of the information available. My suggested strategy, which I cannot illustrate by concrete example, is to build several simple models which among them use all of the data, and to make some sort of average of them. To paraphrase a scientist in a field that faces similar problems,[11] the strategy is not to build one master model of the real world, but rather a set of weak models as alternative models for the same set of phenomena. Their intersection will produce "robust theorems." As complementary models, they shed light on different aspects of the same problem. In other words, an average of simple models will give predictors which are far stronger than the individual models. For instance, if we have eight variables with 10 percent measurement errors, and we can construct four simple models of products of different pairs of the variables, each of these simple models having 40 percent specification error, the total error in their average will be 23 percent. If we had a single multiplicative model using all eight variables which were perfect with regard to specification, the expected error would be 28 percent.

This strategy of netting out weak and complementary models may be called a technique of mulling over, in contrast to the deductive chains of our present models and the classic detectives of fiction. It is what most of us do in real life when faced with a difficult problem. We consider first one aspect and then another; when we have considered every aspect we can think of, we start all over again, and eventually we come to a decision.

I want to stress that I am by no means certain that our urban and regional models have reached the level of mathematical complexity where the compounding of experimental or predictive error offsets the gains in specification accuracy. I am only raising the question of whether they have. If this is the case, I am suggesting a strategy of many short, stubby models to be averaged as opposed to the present strategy of long, thin models. In terms of my earlier analogy, I am questioning whether we have arrived at the design of skyscrapers but we have only lumber for construction material. If we do, we had better build low to the ground while we improve upon our materials.

This argument has a complementary conclusion. If the data are very good, it is wasteful to use too simple models. This raises some interesting issues concerning the applicability of models generated in developed countries to situations in developing countries, where the data are invariably poorer. The use of the same model implies that its specification is acceptable in both cases. But if the specification is properly matched to the quality of data in the developed country, the poorer data in the developing country assure us that we shall be well past the low point of the total error curve for that country, as illustrated in Figure 2. On the other hand, if the model is well suited to the quality of

[11] R. Levine, "The Strategy of Model Building in Population Biology," *American Scientist*, 54 (December 5, 1966).

the data in the developing country, it is wasteful of the power of the data in the developed country. The use of the same model for reasons other than those of expediency in both situations will be justified only if we cannot think of alternative model designs.

In conclusion, I want to touch lightly upon three general points which have to do with the uses of models rather than with their design. The first point is that, whether or not we have exceeded the capacity of our data in the design of models, we are surely operating in broad areas of uncertainty, and that we find errors of 50 or even 100 percent acceptable because alternative means give even larger errors.[12] Yet the institutional context in which most of our most advanced models are constructed results in relatively short tenures by the key investigators, in the order of one to five years. In that conditions of high uncertainty place an extraordinary premium on feedback, it seems to me that the love-them-and-leave-them nature of most of our significant modeling efforts is extremely wasteful. At a time when urban planners are rebelling against the master plan and calling for continuing planning (that is, continuously revised plans), our most advanced quantitative planning is reverting to the master plan, not out of the logic of its instruments, but out of the sociology and the institutional matrix of the investigations. It is obvious that these models should be designed and placed in their institutional context in such a way that continuing revisions and improvements can be incorporated easily and, more important, the consequences and importance of such revisions be understood by the decision-makers who are the consumers of the model.

This matter must be stressed. A decade ago, these models were viewed primarily as predictors of the future. Somewhat later, stress was placed in their use as conditional predictors of the consequences of alternative policies, and efforts were made to incorporate into them policy variables which would permit such experimentation. Most recently, as experience has been gained, the practitioners of this craft have tended to play down the ability of the models to predict, and to stress their value as educational instruments which serve to

[12] General literature on the actual size of errors for various types of data and forecasts is relatively rare and often polemic. See O. Morgenstern, *On the Accuracy of Economic Observations* (Princeton: Princeton University Press, 1963), for a sobering discussion of the magnitudes of error in national economic statistics. Urban data may be expected to have errors of at least this magnitude For a discussion of the actual errors in the prediction of national macro-economic variables, see Victor Zarnowitz, *An Appraisal of Short-Term Economic Forecasts*, Occasional Paper 104, National Bureau of Economic Research, 1967. The Bureau of the Census and other agencies frequently produce studies on the reliability of their data One that has received considerable recent attention is *Measuring the Quality of Housing: An Appraisal of Census Statistics and Methods*, Working Paper No. 25, Bureau of the Census. Interesting points on the interpretation of error and reliability of standard statistical procedures are found in W. H. White, "The Trustworthiness of 'Reliable' Econometric Evidence," *Zeitschrift fur Nationalökonomie*, XXVII:1-2, 1967.

bring to the consciousness of those who make decisions the complex interrelations among the variables, including those which can be manipulated for normative purposes. Thus, the downgrading of the importance of the numbers which emerge from the model accords with the viewpoint being advanced here. The large model may serve as a context or evolving background for a collection of more partial and overlapping quantitative models and for that vast reservoir of knowledge about the urban system which inhabits the heads of experienced men and which has yet to find its way into formal models.

In justice, it must be noted that some of this takes place now during the relative privacy of the period in which the model is calibrated.[13] Commonly, in the early runs the model will produce some outrageous results, and the modelers will use their necromantic powers to have the black boxes give reasonable results. Although these false starts are little advertised, the corrections constitute a combining or averaging of models. For how would we know what is outrageous or what is reasonable except by appeal to other models of the future, even if some of these are implicit or intuitive? Rather than treating this process as an embarrassing occurrence during the model's infancy, it should be treated as a continuing source of strength and enrichment to be carried into adulthood.[14]

A second general point has to do with models as instruments for decision. Our models give point estimates for the variables which we are predicting. In

[13] This is the term commonly applied by traffic and land-use technicians to the obtaining of parameters to fit data for earlier periods

[14] At the presentation of this paper, Britton Harris raised the question of whether the problem of cumulation of error would apply with equal force to models which possessed negative feedback. This is an intriguing suggestion, although it is hard to determine what constitutes negative feedback. In many cases the underlying theory may have this feature, but the computational model does not. In other cases, the feedback is no more than a series of dampening mechanisms to foster conservative predictions. Among these mechanisms are the use of rigid constraints which will not yield, or soft ones which yield grudgingly. Of course, the mathematical form of some models, based on systems of equations, provides for a particular form of negative feedback Recent models have frequently been based on algorithms for numerical estimation of the hill-climbing type, in which the investigator uses feedback from each successive estimation to proceed to the next. Yet this feedback, used to find the solution of the model, must not be confused with feedback within the model itself, but rather results from our inability to solve the model analytically. If we could solve it analytically, the arguments presented in the body of this paper would apply. When we use a technique of numerical approximation, we add to the errors of specification and compounded errors of measurement a further error resulting from the remaining inaccuracy of our last numerical approximation to the analytic solution.

Of course, a form of feedback is involved when consistency checks are used, often by the use of alternative models. This reflects the position argued in this paper. Lastly, unambiguous feedback occurs when models are kept a long time and incorporate corrections as new information becomes available.

this paper I have suggested that these estimates should include estimates of predictive error. The crude techniques I have employed have dealt entirely with probable error or standard deviation.

But the purpose of the study of error is not to burnish our scientific conscience, but to assist in the making of decisions. If either the penalties of error or the probabilities of error are asymmetric about the most probable estimate, in all likelihood our best action will not be addressed to the most probable estimate. This may be illustrated concretely. Suppose that our estimate of traffic on a new roadway is a central value with a symmetric probability distribution about it. If we guess too high, the cost is the waste of a bit more land bought and a bit more surfacing laid. If we guess too low, the costs of widening the road later are far higher, for we are forced to buy out development by the side of the road which the road itself has induced, to widen bridges, rebuild cloverleafs, etc Where the costs of error are asymmetrical, the best action will be off the most probable value in the direction in which the error has higher cost. Similarly, skewness in the error distribution about our central estimate should lead us to base our actions on quantities other than the point prediction.[15] Thus far, builders of models of urban traffic and land use have been content to predict a single value or, at most, a set of high-medium-low values without attached probabilities. The challenge is to pass from this to more reasoned recommendations for action. This is undoubtedly very difficult to do, but it needs doing.

The third point is one of which I am statistically less certain, although the institutional sociology of it is clear. For instance, the most important studies in the field of transportation and land use projection have cost several millions of dollars The techniques they have employed are generally pioneering. But they have found themselves in a difficult position. As pioneering studies, they

[15] While most workers in the field seem to view the point prediction as a central value of a normal distribution (as evidenced in part by the occasional use of high-medium-low estimates), it is hard to know the precise statistical meaning of this value In many models the probability distribution of the output variable will be non-normal and skewed. In such cases the point estimate will not be any particular statistic such as the mean, the mode, or the median (although it will tend to be closer to the median), and therefore its interpretation and consequences for action remain ambiguous, even when the distribution of costs of being wrong are known. The presentation in these pages has followed a hybrid version of classical statistics, but readers interested in these issues may refer to the growing literature on Bayesian approaches See, for instance, J. W. Pratt, H. Raiffa, and R. Schlaifer, *Introduction to Statistical Decision Theory* (A Preliminary Edition) (New York. McGraw-Hill, 1965), and in particular "Appendix 3: Classical Methods," which compares the two approaches. The approach followed in this article has been chosen because it permits simple and intuitively accessible development of the arguments, and because the existing formulae make it easier to apply to chains of operations than the more demanding Bayesian approaches.

went into the unknown, where there is a high possibility of failure. As professional agents, they were in fact charged with using an existing and generalized body of knowledge upon a concrete situation. After having spent some millions of dollars, they could not afford to say that the experiment did not work. I submit that, considering the vast national investment in such studies, the reportage on what we have found out has been minimal. A few journal articles and a few handfuls of agency reports which are generally unclear is all we have. Seldom do we find clear and self-examining evaluations of the work.[16]

It seems that the vast expense required for these studies places them beyond what the sources of funds are currently disposed to spend for basic research; these are labeled planning costs for applied work, where a handful of millions are acceptable in the face of investments in infrastructure in the order of magnitude of one billion. Yet, to those with an interest in this subject, the promise of one after another of these multi-million-dollar studies has not been fulfilled. It is not that strong statistical findings have been lacking; it is my impression that there is a wealth of regularities What is lacking is a dispassionate report on findings and failures from which scholars in this field, including those in the project, can test and evolve new understanding of the phenomena with which we are dealing and techniques to deal with them. Researchers are being put in the very difficult position of being both practitioners and innovators. As practitioners, they are called upon to use techniques that have a high probability of success; in effect, to apply known and proven methods. But in this field most of our methods are still in their infancy, still in the process of discovery. Innovative or scientific work is by definition an exploration beyond what is presently known, and any one probe will have low probability of success. The societal logic of support for scientific work is that the rare successes tend to have very high pay-offs. The institutional context of these studies blurs this distinction under the pressing need to decide how to spend vast quantities of money in urban infrastructure, and thus hampers the openness of method, the candidness of reportage, and the freedom of discussion of these important studies. This represents a dreadful waste, as errors are repeated and successes are not followed up. Although there have been significant advances, they have not matched the possibilities.

In conclusion, I would like to advance, with considerable hesitation, a statistical argument for a distinction between models for fundamental research and models for applied work. Consider a case in which we use the same model design for both purposes. In the research model we are asking what are the relations among the measured variables, and whether they conform to what we would expect from various theories and prior empirical work. We may regard the parameters we obtain not as variables in their own right, but

[16] The most significant exception of which I am aware is Ira Lowry's, *A Model of Metropolis* (Santa Monica, Calif.: The RAND Corporation, 1964).

as relations among the variables we have measured.[17] But, as we have discussed, if we are using the model for prediction, all of our numbers become variables. Further, as variables they have a larger error when they are predicted for a future state of the system, and the model itself, as mentioned, may have a larger specification error with regard to a future state. From these considerations, it would seem that a model that seeks to increase our understanding by asking how certain variables relate to each other is in a sense less subject to some of the sources of error than the identical model design used to predict the future.

This point may be arguable both in statistical terms and in terms of the philosophy of science, in which it is often held that the purpose of all scientific work is prediction. This may be countered by pointing to much of the good scientific work which classifies, describes efficiently, generalizes, merely checks that things are as we expect them to be, and in other ways improves our comprehension of nature. Such work will often result in better prediction, not by its direct use, but by shedding light on some facets of the structure we are considering, while the prediction itself proceeds in the fashion which I have called mulling over. But if there is merit to the statistical argument, it follows that, for a given quality of data, the scientific model is more tolerant of complexity of formulation than an applied model. If this is true—and the alert reader will note that this is a deductive chain—it follows that we should have research groups in universities and other centers working on complex models, while operational agencies would be working with simpler and safer models.

[17] This, of course, is relative, for we often "measure" a variable as a relation among variables which have been measured directly. The question of what is direct measurement is a difficult one.

CONSTRUCTION OF MODELS

The fifth and eighth sessions of the Conference were given to discussion of issues in model-building. No formal papers were presented at these sessions. At the fifth session panelists Kenneth Schlager, Britton Harris, T R. Lakshmanan, and Boris Pushkarev opened the discussion. At the eighth session Britton Harris, as session chairman, opened and moderated the discussion

Discussion touched on many concerns that ran through the conference These ranged from concerns with the data base for modeling, particularly the appropriateness for model-building of existing approaches to stratification and and classification of data, and concerns about aggregation of data in models, to questions of the relative importance in terms of resource allocation that should be assigned to different modeling strategies. The discussion from both sessions is summarized here. Where possible, selected direct comments of the discussants are used to present the major topics and viewpoints.

KENNETH SCHLAGER, *Southeastern Wisconsin Regional Planning Commission*

The topic of this session is model-building. Discussion will be general, taking its start from optimizing and design models as related both to decision-making and to the functioning of the urban environment. I think at least a good part of this discussion should be devoted to the subject of design models, which I would define as models that are used to determine design objectives and criteria, costs and various constraints—providing a search procedure for coming up with a recommended spatial plan. We will be interested, I think, in considering the question: What are the applications of such models in the planning process? What is the present state of the art? What are some of the research needs?

What is the present allocation of resources to design models, or normative models as opposed to predictive models? I feel strongly that the allocation is very distorted. How many of these problems are really design or normative problems?

Two extremes of conditions might exist: one in which many well thought out, intensely designed plans would be ready for implementation, but could not be implemented; in which case there would be very little need for design models. The other extreme would be the case in which implementation was possible, but no good recommendations existed. Here the emphasis would definitely call for design models. Of course, we are somewhere in between, but I do believe there is a certain amount of misallocation of resources in this area. I agree with the idea that a theory of the city is a good thing, but in terms of the immediate problems of designing plans and implementing plans, it might be well for us to look at the role of design models.

To begin, I would like to present some of the needs that we have seen in our work in design models in Southeastern Wisconsin. One is in the area of cost data. Almost any design model involves measuring the cost of alternatives, and the work that has been done in the area of detailed costing has been very slight. We have done much, I think, in a short time, but it is not adequate for the long haul. Another important need is an ability to translate subjective goals into design criteria. A third area is the model as such which does not try to copy a process in real life, but is rather an efficient search procedure for evaluating many alternatives. A fourth area which we found to be quite important in terms of the user is the man/machine relationship. What is the relationship between the person who runs the model and uses the model, and the model itself? We are beginning to feel that the planner, rather than a systems analyst or programmer or data processing expert, should be able to work directly with the model. In other words, the design model is more like a laboratory experiment than it is a data-processing exercise.

Another area of discussion should be the urban design process itself. Our previous discussions have been on the urban development process. We have tried to understand how and why cities develop in certain ways and how they may develop in the future, but there has been little discussion of the design process, of how our plans develop, and of how models might influence this process.

We might also discuss the design qualifications of people now in the model-building field. Perhaps one reason for the slight emphasis in this area is that the background of people working in urban model development has oriented them towards models that describe and predict the world rather than towards design interests. I think it is difficult to conceive a design model if the model-builder has never been involved with design.

In summary, I would like to make some comments about our own design work in southeastern Wisconsin. In July 1966, we received a grant from the Department of Housing and Urban Development for the development of a land use plan design model. The objective was to have a three-phased program in which the first phase would be to build the model and make it run. The second phase, which we are just starting now, would be to apply this model at community and regional levels in order to come up with an actual plan that we could compare with the plan that we had developed with a variety of quantitative aids, but mostly intuitively, in the region before. In the third stage, we would use our experience to write manuals and training aids so that people hopefully could use this in other areas.

A couple of years ago, one of the articles in Britton Harris' series in the *Journal of the American Institute of Planners* described an approach using linear programming, which for several reasons, we found to be very inadequate as a means of handling a plan design. One reason was the discrete nature of design planning. A design modeler is interested in the locations of hospitals, schools, residential areas, shopping centers. A linear programming model used to deal with quantities did not seem a very appropriate way to handle the problem. Another problem was that many of the important costs were not just the location costs, but linkages that had to be developed. An area developed on very nice land might require highway, sewer, and water facilities that had to be built new or had to be extended. Consequently, we worked out a modification not of the program's objective, but of the method. We changed the linear programming model from using variables that represented areas of land to an approach in which we could define certain basic modules such as schools, shopping centers, and residential areas, knowing full well that some of the initial definitions of the modules were arbitrary. These modules could then be the elements of the design model.

Our orientation was at the community and regional levels rather than at the neighborhood level, and so we defined a set of 70 or 80 modules. The purpose of the model was to locate these modules in spaces which we defined as cells These cells were just geometrically irregular areas of land.

We also had to incorporate the cost of development into the model. We developed this as much as possible from the elemental cost data of digging trenches, putting in pipe, and building roads. These costs were an important input to the model because in going through alternative solutions, the model would evaluate what the cost would be of putting a module on a particular type of topographic area, and also the cost of linking it to other areas that would be in different cells in the planning area.

We also put into the model various types of design constraints geared to prevent certain undesirable plans from being implemented. The best background help that we had in the conceptual area was the work that is going on in electronic packaging design. We found the idea of dividing sets and hill climbing very applicable, because it enabled us to deal with these discrete things through a partitioning process.

Up to the present we have made a preliminary application of the model to Germantown, Wisconsin, for which we took our forecast for 1970 and 1980, translated this into a number of modules of various types, and went through an exercise of running it We did not make any attempt to make this realistic in the sense that our goals or constraints resemble those of this town, because we were only interested in exercising the model and testing it out to see what problems we had. In the second phase, however, we are actually going to use our goals, our design standards, and constraints in southeastern Wisconsin; we are going to use the resource inventory that we have, which is, of course, very critical in terms of soil and topography, and we plan to apply it to regional development planning in this area. This is an example of a design model and I described it to provide a little background as to what a design model does, so that we are not just talking about vague ideas.

BRITTON HARRIS, *Department of City and Regional Planning, University of Pennsylvania*

I think we are dealing at this point with a very interesting and somewhat difficult question, and the ideas which I have are rather tentative. I would like to refer, however, to two things which were said previously. John Hamburg said with some passion that a model-builder must be a good deal more than a model-builder. I am not always sure exactly what that remark means, but I think that in this case he was referring to a somewhat larger context than the one in which model-makers are operating, which is planning and problem solving

I think that the distinction between descriptive models, predictive models, and design models is a useful way to approach this problem of the differences between planning and problem solving on the one hand and building projective or predictive models on the other. This is a problem which has been subterranean. Throughout the conference it has come up to the surface and if we do not recognize it explicitly, I think it will create a good many problems.

I also would like to refer to Leven's talk which brought to the conference an economic and optimizing approach which, in my opinion, is extremely useful. However, I would like to discuss an aspect of this approach which has not yet been mentioned In urban development, as we describe it in predictive models or attempt to deal with it in design models, there exists an important feature which we call externality which does not exist in the same way in national economic planning. Externalities take the form that certain types of land uses, for example, are either mutually supporting or mutually repelling. These externalities lead to economies of scale and economies of agglomeration, and they have extremely important consequences for analysis and for model-building What they say essentially is that there is not any single optimum. Externalities indicate a situation in which there are local optima in any particular setup of policy; one may achieve a local optimum, but that may not be at a very good optimum. Let me give you a concrete example, based on Leven's discussion of the size of the city and on his discussion of the way in which cities are formed and grow.

If we assume that metropolitan growth is largely determined by individual locators' decisions and if some locators require to be located in moderate to large-sized subcenters, then an interesting situation may develop. If a growing city has only one large center, we may get urban sprawl and large subcenters may never develop. If, on the other hand, through some accident large-scale subcenters exist, they may continue to grow. Optimizing behavior might thus lead to different outcomes and the desirability or optimality of these outcomes might also differ.

This problem might be resolved in the future by a conscious policy of developing large scale subcenters. After all, Nassau and Suffolk counties in New York are now as large at least as the Twin Cities standard metropolitan statistical area, and they could support as much symphony music, as many art galleries, as many public recreational facilities as the Twin Cities, were it not for the powerful pull of Manhattan. I am raising these problems to emphasize the fact that optimum seeking methods will not necessarily create a large metropolitan subcenter in Nassau County. This becomes, then, a problem of planning and of design in the larger sense. I think that as model-builders, whatever our predilection, we must be very conscious of this particular problem and of the technical differences between prediction and design. I would like to treat this problem, and the problems associated with it, in terms partly of some of the work which we are doing at the University of Pennsylvania on the development of the Herbert-Stevens model which is based on the Alonso theory of urban land rent, and by extension, of housing rent. I think the application which we are attempting to make illustrates very clearly some of the overlaps and differences between design and prediction, and some of the problems of setting up a design model.

The model which we are working on is certainly an optimizing model, but in the behavioral rather than the design sense. I have spoken briefly about our difficulties and tentative conclusions in developing preference functions, and our capability of estimating what various groups in the population will be willing to spend for rent for facilities of different types in different locations. We found that there is a marked difference between population groups and the way in which they view the housing market. These differences depend on family size and income (factors which Herbert and Stevens take for granted), and they must be subjected to study if we are serious about putting in new features and new technologies in the economy and in the urban arrangement.

Now, assuming that these preference functions exist and have been identified, our model takes as inputs a designed location of employment, except possibly for retail trade employment, and a designed transportation system, which together enable us to establish levels of accessibility. Zoning restrictions and design standards can also be incorporated into the model. The model, then, locates population by a linear programming algorithm either in the existing housing stock or in new construction which is necessary to accommodate the additional households. This may be done for the population as a whole, or it may be done for increments of population, making it into a more dynamic type of model. Cost information is very important; design standards are very important, and we expect them to influence the functioning of the model.

There are two or three major observations that I would like to make about the way in which this model relates to prediction and to design. In the first place, in spite of the fact that it is an optimizing model, it is not a normative model unless you choose to interpret it that way. It achieves a Pareto optimum in location and can be interpreted as assuming that people behave in an optimizing way when they locate in a particular place. Insofar as people do not behave in an optimizing way, it can be said that this illustrates the achievable optimum in location, given the inputs and provided that people had perfect information and were free to move and to relocate. Interpreted in this way it sets the highest level of satisfaction which might be achieved. This knowledge is important because we are dealing with utilities and preferences, and we are able, in some degree, to measure consumer satisfaction. This measurement, however, will always be the same for a given run of the model, that is, for given inputs, so that the design aspects are outside of the model. This is why I said that the model itself is not normative.

The design aspects take two different forms. Constraints such as zoning can be imposed on the model which will force people to locate in prescribed patterns, regardless of the satisfactions which they would achieve. Through an interpretation of the dual variables of the model or through iterating the model in a special way, it is possible to estimate the value to the user of the housing which is attained under these different sets of constraints. One can play with the large scale inputs such as the location of employment or the location of transportation routes and one could play equally well in regard to housing technology, with the cost of providing housing of different types. Thus, for different planned arrangements, one could achieve measures of utility for locating population, and in this sense the model can be considered evaluative.

In general, I think that there are many desirable features connected with models which have the design characteristics which Schlager has talked about and which, to a certain extent, I have talked about. Even within the large-scale design of transportation routes and employment location, our model can be considered a design model, in the sense that it designs the densities, the subdivision regulations, or the zoning regulations which will apply over the metropolitan area if you wish to achieve optimum location. In the future, the optimum locations may be quite different from present ones and in this sense the model is exercising a design power, if the implementing agencies are prepared to enforce a kind of zoning which would be desired at a future date. The model, for example, could indicate that in a growing metropolitan area the densities which would be predicted for 20 years from now would be higher than the ones that would be predicted for the next year. In this case there is a design decision to be made which is outside of the general predictive framework. A choice must be made as to whether, in this case, we propose to accommodate next year's locators at the densities that they would like, or to force them to locate at densities which the people, 10, 20 or 30 years from now would desire. This raises a whole host of planning problems, but permits us to examine them concretely and explicitly.

Finally, I think that two or three features of optimizing models need to be examined carefully. Optimizing models are efficient for answering many economic questions which people have urged us to consider. And I think it is quite possible that models which have strong equilibrium implications may tend to control errors of projection, virtually by way of negative feedback. If things get out of line in a projection, the equilibrium aspects tend to kick them back into line.

However, there are two dangers that I would like to emphasize. One is that if we use backward seeking models, we have to be very careful about the objective functions which we use and their social implications. Now, I think there may be a danger in Schlager's work in that he emphasizes the minimization of construction costs without adequate attention to user costs and satisfaction.

The question is, does this type of design model represent a complete cost benefit analysis, and if it does not, how do we get one? Another aspect of the same problem is that the objective functions which the economists put into their models frequently do not deal with social costs which must be considered if we wish to optimize in the social sense. Let me give you a simple example. Location at very low densities may cause undesirable results. In England, for instance, low-density location might use up the landscape which is highly desired. In the United States we have a little bit more landscape to go around, but it might raise facility costs very substantially, and these social costs may not be accounted for in the cost figures for the individual household. We could deal with this discrepancy either by putting the actual costs into the model or by postulating restraints and not allowing densities to fall below a certain level. Since the ultimate purpose of planning is to improve conditions, optimizing models fill an obvious purpose. In spite of the many difficulties which I have identified, I agree with Schlager that much more emphasis must continue to be placed on backward-seeking optimizing design models.

T. R. LAKSHMANAN, *CONSAD Research Corporation*

I believe that the objective of this Conference is to identify promising lines of inquiry and a broad outline of a "plan for innovation" in the area of urban development models. I shall attempt accordingly to structure my brief comments by these objectives. Essentially, my comments pertain to three areas: the range of public policy issues relevant to urban models, the approaches to model design, and strategies of innovation.

Discussions on model design appropriately begin with questions of scope of the models. What processes are to be described by the models? What range of public policies should these models be concerned with? The greater part of this group, I daresay, has been concerned with the description of urban growth processes as seen from the perspective of land use and transportation planning. This has meant traditionally a focus on physical planning policies pertaining to land development densities, transportation utilities and the like.

There has developed recently, as evidenced in the earlier sessions of this Conference, a clamor for enlarging the scope of the models to include a variety of social issues such as manpower training, poverty programs and other related social issues. This demand for scope extension of the urban development models from new model clients expresses a recognition of the interrelatedness of physical and social planning policies and a desire to build on the only major effort in modeling of small area processes and changes. Predictably, model-builders in the land use and transportation studies, keenly aware of the complexity and the resistance to easy abstractions of the metropolitan phenomena, remain skeptical of these "psychedelic" approaches to model scope definition.

However, it seems to me that urban development models should be cognizant of these new clients and focus on physical and social planning processes and relevant policies. Our recommendations for future urban model development strategy should reflect this broadening scope.

Another question concerns the nature of modeling strategies themselves. Discussion of this subject should begin with a partial definition of models. I view models as ways of portraying functional relationships between a set of control or policy variables and effect or consequence variables. The choice of control (or policy) variables depends upon the scope of the issues under consideration. As the issue space enlarges, so do the control variables.

What, then, are the relevant effects or consequences associated with these control variables? These effects or consequences of interest should be described by their magnitude and several dimensions of incidence of such consequences. Thus as we are concerned with transportation, land use, integration and other social policies, our models should measure the magnitude effects of the relevant policies in the first instance In addition, the models should describe these impacts in terms of incidence. In other words, who receives the effects? Which population group? Which economic sector? Which geographical area? What points in time? What do these requirements imply for model-design strategy? The design of a model is often a trade-off among such factors as the diversity of control variables to be considered, the diversity of the impacts, the state of the art, and the information base available.

The models designed and built by such trade-offs are judged by both the model-builders themselves and the public at large. Peer-group (modelers) judgments are based on such criteria as the relevance of the model to the problem under attack, validity, and experimental utility Judgments by model clients may be based on the comprehensibility of model processes and results, or on policy coverage, or the degree to which the model reflects public concerns—the quality of its treatment of policy variables and the quality of those variables themselves. The urban development models do not do well by these criteria.

Those of us who have worked on urban development models know that such criteria as parsimony and accuracy in model construction are hard to meet currently; perhaps a more realistic criterion of the model "goodness" is the insight gained into the development process.

Another aspect in model design discussions pertains to questions of design versus impact models. In impact modeling, one estimates consequences; but design models go beyond impact models in specifying a criterion function by which to select among the consequences of alternative plans. This criterion is basically a social-welfare function, in which the weights attached to various impact vectors represent some sort of a price/quantity relationship.

To develop such a criterion function in a complex analytical area requires assumptions that are (a) of heroic proportions and (b) based on knowledge of behavior which we do not now possess.

For the future, of course, the implication is clear. If design models are to be successful, there must be greatly increased analysis of impacts, their incidence, choice criteria, and the trade-offs acceptable to various groups of the population. For example, in a retail market potential model the criterion problem is relatively simple and tractable. One can think of criteria such as sales per square foot, or a minimum size center, or a minimum level of service, and there is a fortunate convergence of these criteria in solution space. But, in a multi-dimensional situation like residential location, the problem is not so simple. The criteria multiply with no clear relationship among them. I believe that backward-seeking models that trace an optimum path from a prespecified end state are unrealistic except in very simple modeling situations.

Further, may I comment on a related aspect of a popular model design style? Many of us have tried to follow the examples of those successful physical scientists, the physicists who use a few key variables to describe a process. This method, however, is not applicable to a social system composed of a multiplicity of interrelated variables. Such a desire for simplicity, despite its intellectual attractiveness, demands a high price, in terms of present and future error and, perhaps, even future loss of confidence. "The pathways of knowledge," says Professor Kendall, "are littered with the wreckage of premature generalizations."

I began by saying that the way in which we plan for innovation very much depends upon the philosophical view of the problem we adopt.

The problem of developing a plan for innovation in a field that is itself expanding is cause for some alarm, but it is encouraging to note that such fields as space research, oceanography, and atomic energy have achieved varying degrees of planned and directed innovation. There are four major schools of thought on structuring such innovation. The first would allow innovation to develop opportunistically, depending upon the autonomous workings of science. More popular in Europe than in this country, this viewpoint is associated with the name of Michael Polanyi. A second approach is that taken by Dr. Weinburg, who views basic research as a technical overhead that should be borne as part of mission-oriented activities. The Bureau of Public Roads and the Department of Housing and Urban Development have reflected this viewpoint in funding, in connection with ongoing metropolitan studies, most of our research on urban models. A third school of thought treats innovation as a social overhead investment. It looks upon science from the viewpoint of the entire society which is to benefit from the research, rather than from that of an individual operation which may or may not directly be aided by particular research. This approach may have come from recognition that, as Daniel Bell put it, knowledge is really the matrix of innovation. The fourth point of view, expressed in a recent issue of *Minerva,* views science as a consumer good, a luxury upon which society may spend its extra product. In such a view, science is an open-ended and cumulative investment.

These viewpoints have been implicit in much of our discussion, but they are not as contradictory as they may seem. Rather, they are to a large extent complementary, reflecting emphasis on different aspects of science—basic versus applied research or exact versus inexact sciences. Polanyi, for example, is concerned with the pure research spectrum of research while Weinburg focuses on applied technology.

A basic step, then, is to synthesize from these viewpoints an approach to the planning of innovation in urban development modeling.

If we limit our scope to such current concerns as land use and transportation and the strategy of model design, research might be considered a technical role suitable for handling by universities, nonprofit organizations, or line agencies or their consultants. Our concern, then, would be to improve the state of the art as we develop better models. Others who use our models on their own problems would do so at their own risk. If, on the other hand, we address ourselves to the larger areas of concern—socioeconomic and/or physical—what we do must be viewed as part of a larger view of urban management. We should view these urban models as aids in the twin objectives of the management of urban development: management of urban uses and the coordination of public investments in urban space. The strategy of innovation to be recommended by us should reflect this management view.

Boris Pushkarev, *Regional Plan Association*

I would like to begin with the question of what are the real issues, the substantive issues in the modeling effort? And I would like to answer this with another question, namely, how did the whole modeling process arise in the first place? It began because engineers needed traffic estimates to design highways. Now, I think the issue is how to design metropolitan areas, and this is what models are needed for, and this is what I think they should be geared to. Skeptics may argue that while engineers are, in fact, decision-makers, nobody is kidding themselves that publicly elected officials locate highways. One might say that economists do not really design economic systems, and that no planner has yet planned a metropolitan area. Let me offer two counter arguments. One is that the share of public capital investments in our metropolitan areas is rising. In New York City the share of public versus private investment is now close to 50 percent, but this investment does not present an integrated design. Thus there are increasing possibilities for influencing the shape of the metropolitan area. The other argument is that even if the model of an ideal region is never implemented, it is nevertheless extremely useful and interesting to compare it with the performance of reality, partly to see what is wrong with the model and partly to see what is wrong with reality. So the issue is, I repeat, how to design the region.

The regional plan is what we have been worrying about for the last three years or so. As a result, we have expressed wishes for models in four areas of land use: nonresidential land use, transportation, residential land use, deliberate over space. I think the sequence reflects the relative importance of these four categories of land use for urban performance. In regard to the second category, transportation, there has been tremendous progress in this area over the past twenty years culminating in the Einsteinesque elegance of Morton Schneider's work. In residential location, we totally rely on Britton Harris and take off our hats in deference. However, the first category, the location of nonresidential land use, which is most important in shaping urban structure, has received little attention, except for retail location models. It follows, then, that we would like to focus on nonresidential land use.

I will briefly discuss how we approach the problem without having any really rigorous models for dealing with it. To begin with, we find that the standard SIC categories in which economic activity is inventoried are locationally not homogeneous. In fact, they are frequently irrelevant to location, so that nonresidential activities or nonresidential land use has to be disaggregated into some other categories which have locational relevance and which are hopefully relatively few in number, so that they are manageable. We have chosen about five categories which, in turn, are subdivided into three classes. The categories are: office employment, production-oriented goods handling employment and warehousing, retail employment, institutional employment, and other. The "other" includes locationally indeterminant activities such as construction, employment in construction, and transportation. Now, these five categories, in turn, are broken down into three classes according to the degree to which they are distributed or are not distributed in the same way as population. Class 1 is population independent, class 2 is population semidependent, and class 3 is totally population dependent Class 3 accounts for such things as local grocery stores and school teachers and elementary schools. In class 1, which is supposedly population independent, are office headquarters, central institutions such as the Metropolitan Museum of Art, and also most of the manufacturing. This sort of classification is really our only conceptual innovation in this field and we would hope eventually to develop a rationale and rigorous method of allocating these activities. Presently, all we have been trying to construct are some density gradients which represent the distribution of these things within the region. The problem is to construct density surfaces which have several peaks, and to try to play around with these future density surfaces.

There have been two problems here. One pertains to linking these three employment classes in a useful way. For example, the first could be considered as basic employment, the second as relating to basic employment, and the third as relating to both of the former categories. It would seem plausible to relate them through some sort of accessibility measure, but this has proven to be fairly difficult. By definition, the first category is population unrelated, so there is very little correlation between its location and the location of other activities. Thus one of the snags has been the accessibility measures in relating these three mountains to each other. The other snag, of course, is the arbitrariness of locating the basic employment in the first place. You can guess that a certain amount of it would locate in Manhattan, but locating the remainder becomes a mere design exercise with no criteria for trying to distribute it in the future in a normative way. We do have a projection for these phenomena. But I think our strongest wish is to have some rigorous way of locating future office jobs; we place particular stress on this because the projections indicate that office jobs in office buildings will rise from about 21 percent of all jobs now to about 32 percent of the total by the year 2000. This has tremendous implications for the concentration of future work trips, and also for the possible renewal of old cities and other central places. In fact, the main purpose of our recent book is to emphasize the impending growth of office jobs versus the stability in manufacturing jobs over the remainder of the decade.

The other unsolved problem is the evaluation of alternate future distributions. For the future we have a glimmer of hope that Harris' system will come up with some answers on the relative performance of these alternative distributions.

In the meantime, we have been trying to play around with the transportation implications of alternate employment distributions. Here a salient point is the issue of scale. Are we talking about concentrations at the level of, for example 200 square miles or at the level of 2000 square miles? It seems that at the level of about 200 square miles it does not make any difference how the jobs are arranged in space given an even distribution of the population over the surface. We have gone through a few exercises that are similar to the ones Aaron Fleischer has done at M.I.T. and we find, for example, if one-third of the jobs are grouped in one central square mile rather than dispersed evenly or grouped in several centers, the difference in person-miles of travel is only on the order of 4 or 5 percent However, if, for example, Manhattan were eliminated by dispersing the population through the region the saving in person-miles of travel would be on the order of 20 percent or more. Now, this, of course, does not suggest that we do intend to recommend disbanding Manhattan. In fact, when we were presenting some of these things at a meeting with the Tri-State Transportation Commission, the remark was made that to cut person-miles of travel by 20 percent, it is not necessary to disband Manhattan The reduction of incomes below $5,000 would achieve the same goal, more or less, because 40 percent of the men who make over $10,000 work in Manhattan while only 25 percent of all workers do. This brings us to the issue of the cost and benefit of agglomeration in economies. Apparently the high cost, long journeys to work, performed mostly by men who make over $10,000 a year, are voluntary trips, and apparently these people get something for their effort. Thus, it is possible that added transportation cost is outweighed by the benefits of agglomeration in Manhattan. The issue of determining these benefits is somewhat problematical. In evaluating these we will attempt to test one at a time changes in the transportation system or changes in land use to see how these things reflect on each other.

Our approach, in exploring future transportation systems, is quite different from the generalized approach that was published in a description of the work of the Office of High Speed Ground Transportation. We would like to take a specific piece of hardware that might be feasible in the future and test that to see what it would produce. I am talking specifically about the pneumatic-tube system that Lockheed has been thinking about, which definitely has implications for much higher concentration of density near stations, and probably quite revolutionary implications for the entire eastern seaboard chain.

The final wish is for a model that would establish criteria for open space design within the framework of accessibility. I think that things like site quality can be translated into accessibility measures. That is, if one is on the same site as the grass and the trees, this particular kind of amenity is very accessible. If one lives in Harlem, a mile away, this kind of amenity entails certain accessibility cost. I believe that a park location procedure can be developed on this basis, given the specific propensities of children between 2 and 5 years of age.

However, I am afraid that manipulating the urban form on a micro basis within realistic limits, and without abolishing agglomeration economies, has very little effect on the overall performance of the metropolitan area. Possibly the real difference in livability and environmental attractiveness is made by architectural design at the scale of a quarter of a mile, or less. Consequently, we are trying to determine people's perception of space and density. We are trying to create a design model that will handle psychological data, but I am not very enthusiastic about it at the present time.

DISCUSSION

Kenneth Schlager opened the discussion with a call for comment on design models—the relative resource allocation which should go into their development versus development of predictive models, and the appropriateness of hill-climbing or other search techniques of design models. The subsequent discussion focused on the determination of appropriate objectives of models, translating these objectives into operational terms for use in design models, the difficulties of selecting appropriate criteria and evaluation of model output, appropriateness of hill-climbing techniques, and the use of models of subsystems rather than the total system.

Britton Harris began with a comment on possible objections to design models. "I would like to anticipate the main problem and objection I think that people will have to design models. The greatest danger would be to have a very simple objective function, throw in a few constraints that are easy to manage, and then come up with a design that would violate important constraints that were not expressed. I recognize this, but I make two comments on it. One is that I do not think it is wise to hold up the development of design models until we understand everything about all the possible criteria. Second, I think design models should be run like an experiment. And I think if planners start to use design models in a way that permits them to be close to them, and even see visual displays of their operation, there is going to be a learning process, because if you come up with a plan from a design model that violates something that you do know but cannot express, feedback will develop when you see that you did violate something, and then you will be forced to try to express it."

In response to Harris' comments, discussion centered on the selection of proper objective functions for design models and the possibility of suboptimization resulting from use of design models because of inadequate objectives and the limitations of hill-climbing techniques. Marvin Manheim suggested, "If you ask a decision-maker for a statement of goals that you can put into a design model, by and large you are going to draw a blank. So really we need to be concerned with how we can present small numbers of alternative objective functions. Because you have a very complex space of alternatives in which there are real dangers of suboptimization, the optimum that you end up at is a local optimum and depends upon the starting point. I think it is a very real danger, but it is also a virtue in a sense. When you generate a starting point for the hill climb (or other search process) you are generating a basic theme. You still have to worry about looking at large numbers of different starting points. If you happen to have a hill-climbing procedure which ends up at a local optimum, this is a local optimum for a particular objective function and has its value."

Charles Leven responded, "I think there are two problems. One is how to discriminate among starting points with respect to a hill-climbing experiment. The other is how to design hill-climbing experiments in order to achieve an optimal position with respect to that starting point. I think the notion that search models are just trying out different sets of objectives as if this were kind of a casual experiment is kind of bizarre. I suspect selecting objectives is much more difficult than hill-climbing problems. The sad fact is that we do not have an apparatus for discriminating between different starting points. What is needed in order to discriminate among starting points is a theory of the city which would relate to city planning the way that economics relates to business administration or the way that physics relates to engineering. In the absence of this body of theory we tend to become mesmerized with hill-climbing operations"

Taking off from the slightly different positions stated by Manheim and Leven, the discussion centered on the question of adequate definition, or specification of objectives for use in operational models. It was generally agreed that two major problems exist. The first is the difficulty of identifying all of the relevant objectives to be considered The second is the inability at present to evaluate adequately the outcomes of models because of the difficulties in identifying and measuring externalities, and the lack of simple criteria. Harris summed up, "Choosing between starting points and hill climbing both have a common problem. How do you evaluate the objective function. Whether you want to formalize it and call it an objective function is not important, but if you call it criteria of choice, or whatever name you want to put on it, you still have to evaluate. People start talking about evaluating land use plans, and say we are going to evaluate the transportation efficiency and then they stop. Now I do not know whether this comes from our background in transportation planning or from the fact that we are dealing with a lot of intangible values, but I think that we ought to be talking about how we can measure the quality of life in very realistic ways."

Michael Tietz switched the topic to the design of subsystems pointing out the tendency of designers to break problems into smaller sections which have internal coherence. He noted that work was proceeding on subsystem components of the city such as hospitals and libraries and raised the question of whether it was possible to incorporate institutional subsystem components directly into the design process given the complexities of the subsystem components and the limitations of the design models. Schlager replied based on his experience with water and waste treatment subsystems that this would depend on the ability to incorporate the linkages of the subsystems components with the total system into the design model. The specification of the value of these linkages might then be handled in the overall design and considerable freedom of detailed subsystem design would be retained. Stevens then suggested that emphasis on subsystem analysis presented a danger to progress on analysis of the total system, and that, in many cases, very little information about a subsystem was actually needed to incorporate it into the total system analysis. He proposed that some form of general systems analysis which would take into consideration the amount of information needed at that level about each system would be most appropriate given the likelihood of using gross aggregative models.

Alonso raised the point that often the discussion of objective functions indicated that these were cost minimizing functions. This is due, in his opinion, partly to the strong association of land use models with the transportation modeling experience, and partly reflects the traditional work in planning which concentrated on defining problems and then finding ways to alleviate or minimize them. He suggested the need for developing positive goals and objectives rather than the negative objectives of cost reduction.

Stevens objected saying that he felt current model-building efforts went far beyond simply minimizing costs and pointed to the Herbert-Stevens model as an example of a model that "was specifically for the purpose of avoiding simply minimizing cost . . . for looking at a whole package of values which people get out of urban locations." Stevens suggested "that perhaps we have not gone far enough in trying to do the much more difficult job of evaluating what kinds of satisfactions people get out of living in urban areas and what kinds of values they have." Responses in agreement with Stevens' position came from Schlager, Harris, and Garrison. Schlager suggested that direct cost functions tended to become relatively less important and the constraints more important as the model-builder's understanding of the problem increased. Harris pointed out that the current version of the Herbert-Stevens model maximizes consumer surplus subject to market clearing constraints and consumer preference, and does not minimize transportation costs or rents. Garrison commented on the duality of minimization and maximization and argued that dealing with optimization problems "forces us into looking both positively and negatively at the same time."

Switching the topic, Leven suggested that several dangerous ideas seemed to pervade the discussion. One is the idea that "a plan for a city must be concerned with every aspect of human existence which goes on in the city." He argued that the task of planning should be "to use physical arrangement and connective tissue (transportation and communication) to make transactions efficient." Turning to the proper basis for planning he argued, "We are not looking for the science of man, we are looking for the science of an urban region which describes the functioning of urban concentration independent of a lot of other functioning of human beings." Leven cited as a second danger "the notion that in order to make large decisions one must be able to forecast the future." He suggested rather that more reliance should be placed on simulation models to be used "for analyzing consequences of actions in a situation where you have no behavioral model." Garrison suggested as another danger in the discussion the idea "that there is such a thing as a general model that exists apart from the society in which we find ourselves," partly in response to Leven's second point. He argued for the need to make sure that theory development was oriented to specific, present problems. Harris, reacting to Leven's first point, argued that emphasis on transactions was misleading—that a city provided both transactions and site, and that "even if we are only talking about location problems the essence of the problem is the trade-offs for businesses and households between space requirements and interaction requirements." He argued further the need to look at space related activities, including enjoyment of the environment, recreation, work, etc., since "these things added together are the qualities of life in which the consumer of space is interested, and since they influence the operational aspects of the city in which the developer is interested.

Manheim suggested the need for distinguishing "between theories which explain how the urban system works and theories which prescribe what a desirable urban system should be like." He argued the desirability of using optimum-seeking design models to explore alternate urban patterns, and the need for a balance between "heuristic design techniques for inventin^ basically different kinds of solutions and operational analytical techniques." Leven agreed but suggested that model outcomes for the total system need not be detailed. Schneider added, "What we really want to do is find ways of breaking the total system into subsystems such that we can make general policy decisions about subsystems and delegate detailed decision-making about these subsystems to groups. But we want to do this in such a way that the overall structure is in some way consistent." The discussion ended on this note.

In summary, the discussion demonstrated that while there was general consensus among the participants on the desirability of pursuing both design (or backward-seeking) models and projection (or forward-seeking) models, at both the general, total urban system scale and in terms of urban subsystems, dealing with broad objectives of human welfare and with limited objectives of operational efficiency, there was little agreement on the relative importance and priority for work on one or the other aspect of any of these three dimensions of modeling effort.

* * *

The framework for discussion in the eighth session was set by Britton Harris as chairman. Two main topics dominated—the construction of nonresidential land use models and data requirements for models with particular emphasis on problems classification and aggregation of data. The discussion has been summarized by selecting comments of the participants.

NONRESIDENTIAL LAND USE MODELS

JACK LOWRY

I want to talk to the issue of modeling manufacturing location, open space location, and nonresidential land uses. These have proved particularly intractable in the sense of devising some system of guessing where these things are going to be. I think it was reasonable to try this for a while, but it seems to me that we have probably tried about enough. It is not clear to me that we can guess where these things are going to be, with or without the aid of the model. It seems to me fairly reasonable that we take a quite different tack and say, "give me not the job of guessing where these things are going to be but the job of devising some institutions which will force them to go where you want them to, *i.e.*, designing zoning regulations, tax policies, industrial park promotion policies, schemes for municipal designation of open space, and so forth." I do not see much utility in trying to predict whether a firm is going to put a plant on the west side of town or on the east side of town. With a choice like that, you are going to be wrong in a big way if you make a guess. It does not seem to me reasonable to hold the model-builder responsible for being able to predict this kind of thing.

BORIS PUSHKAREV

I would like to briefly respond to Lowry's point. For manufacturing location, the point was brought out previously that it is the scale of the areal unit that one is dealing with that is important. If one deals on a parcel basis, Lowry is completely right. But if one deals, let us say, on the basis of 100 square miles or at least 50 square miles, the problem of prediction becomes less intractable. On open space, I think it is not so much the size of the open space as the criterion of how much of it is good, because I do not agree with current open space standards. They just say that one ought to have so much open space, without any regard for use of this space, location of any particular population, density, and so forth It seems that based on the use of open space in areas where it is readily accessible one can develop much more substantial criteria than ones used up to now.

RONALD GRAYBEAL

I think Lowry's point is most applicable for those large manufacturing firms for which you do care where they locate, and thus you could use his suggestion that if you care enough where they locate, then devise some policies to guide their location. But how many of the manufacturing firms fall into that class? It may be that there are some—maybe most—that do not fall into that class, so you still have the problem of locating them.

Let me describe very briefly a method that I use in the Honolulu industrial submodel. I had 10 manufacturing industries I simply ranked them by their ability to pay for their site as evidenced by where they are presently located assuming that their present location is an equilibrium, that is, they are satisfied with their present location. I estimated what I called preference functions containing various accessibility and land value variables for each of these ten. I estimated these preference functions on cross-sectional data, recognizing that this is a hazardous thing to do for time series forecasting purposes; but in the absence of alternative data, I did it anyway. I allocated my manufacturing industries by simply taking that one which would pay the highest price for land, and using the preference function found those areas that, according to this preference function, were most appealing to this type of industry.

Let me conclude by saying that I think modeling is an art; and it is the ability to combine limited data, the purpose of the model, and limited research resources in some kind of an optimal fashion.

DAVID SEIDMAN

I want to try to tie together some thoughts I have had on the significant factor in locational modeling which is perfectly applicable to nonresidential land use. To me a critical consideration is the size of the decision-making unit, and one reason I think we can construct traffic models more easily than locational models is that in the traffic model the individual trip maker is the decision unit, whereas very often in location it is not. The individual household may not be the decision-making unit; perhaps the developer is. In large manufacturing plants the decision-maker is not each employee, it is the board of directors or the president, and the smaller the number of decision-makers, the less the law of large numbers helps you in cancelling prediction errors. It is for this reason that I suspect that it may well prove easier to control this phenomenon than to predict it. There is another process which I think makes it difficult to predict location and which may apply equally to residential and nonresidential location. To me certain locational phenomena begin with a random sort of selection, and then are followed by a quite nonrandom process. For example, the introduction of a Negro family into a suburb is an essentially random phenomenon. But once one Negro family is located, the likelihood is that other Negro families will locate by a nonrandom process. This is naturally a very difficult phenomenon to predict, since you have a large number of locations dependent essentially on one randomly chosen event. This is simply an argument for the difficulty of modeling this process, and especially modeling certain kinds of nonresidential locations.

STEVEN PUTMAN

I have an objection, not so much to Lowry's saying that we are guessing about an industrial or nonresidential location, because I think in a large sense we are, but I object to his throwing up his hands so quickly. I agree that there are not any really good statements about urban economics that allow you to say where nonresidential location is likely to occur. But, rather, there is probably in every urban area a reasonably well-established, traditional land brokerage operation going on where there are people in the city who sell land for new facilities coming into the city or who provide locations for firms moving around in the city. If we could in some way investigate the means by which these people make their recommendations to people looking for property, we might then have a good description of where things are likely to locate. This was basically the kind of thing that I tried to develop in the intra-urban industrial location model that I did in Pittsburgh. I think that in some senses it did locate things where it seemed eminently likely that they would locate, but I think maybe even more importantly it did provide some good guesses as inputs to the residential location aspect of the overall model.

BRITTON HARRIS

I think we are to a certain extent addressing different problems. Lowry was talking about very large plants. Steve Putman and Ron Graybeal are more concerned with small plants.

BENJAMIN STEVENS

There are clearly parts of manufacturing which are easier to predict than other parts—the activities that are very dependent on agglomeration economies, the small firm activities that locate downtown and spread themselves around certain centers of activities downtown. Certain parts of retail activity also behave in a regular way. It is the large units—the shopping center is perhaps more like the location of a large manufacturing enterprise than like the rest of retail location—that are difficult. I think you have to talk about these things as a group, depending upon how many there are, how large the units are, and how discrete they are. I think that the investigation of location patterns of industries in metropolitan areas and the way these patterns are changing can suggest that there is a bit of logic to the pattern that would certainly allow you to assign a much higher probability that certain kinds of sites would be used. It may be guesswork, but it is guesswork with a probability distribution attached to it.

T. R. LAKSHMANAN

I have a comment on the question that Boris Pushkarev raised on recreation land use. I want to briefly report on a study we did on recreation planning in Connecticut. Very early in the game they accepted the point that Pushkarev raised, namely that existing standards were extraordinarily insensitive to the changes taking place in the area of recreation usage. So they posed the question, could we in any way explore the problem of how we would evaluate alternative plans of outdoor recreation. What we tried to do was look at the problem in terms of the activity participation rates for people for different kinds of activities. The basic ideas behind this model are that a person or household, given a certain amount of time, trades off different kinds of activities in the sense that they have to come out of the same time budget; and the participation rate in any particular activity is a function of the total amount of recreation activities participated in. It is also a function of the income level of the family group. The data for implementing this model were collected by a special telephone survey. We were able to estimate total requirement for land assuming that there was some sort of equilibrium between the total amount of participation days in the state today and the total amount of land that is available making allowances for travel in and out of the state. Alternatives were then developed and the potential concept was employed in a recreation trip model to evaluate usage of recreation sites.

DANIEL BRAND

I have some items of information as to the regularity of employment location. Let me cite some examples of some factor analysis output that we ran in Boston. On the city and town level—152 cities and towns—for 1950 and 1963 by 2-digit SIC manufacturing employment classes, as I recall, all but 3 of these 2-digit SIC categories for 1950 fell into one factor and all but 2 fell into the 1963 factor—the same factor. The point that I want to make is that there is a great deal of regularity operating here. We also ran factor analysis at the 626 zone level for 2-digit SIC employment. We were quite pleased that the divisional aggregations seemed to be falling in the same factor, exhibiting similarity of locational behavior. Where certain 2-digit SIC categories within a division did not fall in that divisional factor, it was very interesting to try to rationalize why they did not and there was a lot of insight gained as to why they did not. So I do feel there may well be some hope for applying statistical techniques to locating firms.

WILLIAM GOLDNER

I would like to mention the efforts we are doing in this same direction. We are using the size distribution of firms by individual industries as the basic source of information to generate a firm life-cycle concept in which firms find it necessary to relocate after they reach a certain maximum size threshold, die when they decline below a certain threshold, and move within this range on the basis of a Markovian process. This has already been formulated and is in the process of being programmed.

CLASSIFICATION AND STRATIFICATION OF DATA FOR MODELS

MORTON SCHNEIDER

Everyone talks as though there is some very clear distinction, some property of activities, that makes one activity utterly different from the other, and that this continues on through the whole SIC code. I do not quite know why we are talking about these distinctions. Is there something about these differences that makes it useful to consider them? I know there are differences in quality and differences in perception. You can look at things and say that this is more or less one or the other. But so what? Does it mean that you are able to, for example, predict how they will behave differently. I am addressing myself really to the whole question of stratification. Why form a stratum unless you can do more with the stratum than you can without it?

MICHAEL TIETZ

I would like to point out that there are some kinds of things which are located as a public decision, that is, as a result of a decision to spend some part of the public budget rather than some kind of a market process. And that these things have to be located with respect to some kind of rationale which perhaps is not explainable in the same way, partly because you are operating in effect inside budget constraints. This I think would be one reason for making distinctions. This is simply a convenience distinction—convenient for thinking about things.

BENJAMIN STEVENS

If you say that residential and nonresidential is an arbitrary classification that does not tell you very much, I would argue that some sort of classification of locators is probably useful and that the locational characteristics are different.

But the important distinction may be the importance of access in the location decision of the household and the location decision of the firm. Perhaps relative access is much more important to certain kinds of activities. I would define nonresidential activities as those things for which access is more important relative to other site characteristics than it is for residential activities. In other words, accessibility itself and the values that go with accessibility for some activities are quite different from the importance of accessibility to the individual household.

MORTON SCHNEIDER

I quite accept that distinction, but then I would ask, if you can make such a distinction why not use it instead of residential or nonresidential class? Why not measure the importance of accessibility and attach a number to an object you are talking about, saying that it falls into a particular accessibility level?

BENJAMIN STEVENS

I agree with you, and it is because I think you actually can attach such a number that I think Lowry is wrong and that in fact you can predict much better the location of these so-called nonresidential activities than he indicates.

BRITTON HARRIS

I happen to disagree with what Schneider and Stevens just agreed on, for a number of reasons. Residential space is an important locus of family life which is a basic social unit and has certain specific social qualities which are not unique to it but which differ from many of the social qualities of other located activities. Therefore, from the whole point of view of policy-making and legislation, and exposure of the population to many aspects of our current life, it has to be considered separately. This is perhaps a planning rather than an analysis question. I also think that there are differences in the decision unit. If we take a decision view of the processes which go on in metropolitan space, then I think that we have to distinguish institutional decisions, decisions by profit-making units, decisions by households, and so on. And I think there are many other dimensions to this problem Some of them are connected with planning. Some of them are connected with legislation. Some are connected with locational decision-making. Some are connected with the kinds of phenomena that Schneider and Stevens were agreeing are directly important. And I agree too, but I do not agree with their conclusion.

JOHN HAMBURG

It seems to me that if there is some reason for making a distinction in these activities, that you can make certain kinds of distinctions if you think they are important distinctions for the particular purposes that you are working at.

JACK LOWRY

I think it is quite reasonable to ask if there is some other way of stratifying which would be more useful for, or as useful, for modeling purposes. But I might make the point that you at least have the option of subdividing what we have here called residential into internally homogeneous groups by whatever the property is that you are interested in, and the classification of residential, I think, may have some obvious uses as an output. In other words you want to be able to reaggregate your forecast in terms of the possibly nonfunctional classification. So it seems to me that the point is not to forget the classification residential, but to ask if it might be a good idea to divide it somewhat.

* * *

Discussion shifted from general concepts of approaches to classification discussed by Schneider, Stevens, and Harris to the specifics of the existing Standard Land Use Classification System used by the Department of Housing and Urban Development and the Bureau of Public Roads. From this initial focus discussion shifted to the desired characteristics of land use or activity classification schemes. There was general agreement in the discussion that the coding of attributes of the objects being surveyed was the preferable form of recording data so that maximum utility could be gained from it. The Standard Land Use Classification System was criticized on the grounds that although it is a code it is based on names of objects rather than on a structure of attributes or variables (Tietz). Another aspect of the question of land use classification raised in the discussion was the relation of the classification system to data collection. It was suggested that a general coding scheme is an unsatisfactory guide to data collection because "only those attributes are collected (by agencies) that are necessary to sort data into a pre-established list of classes" (Harris).

A general question (Harris) underlying the discussion of data collection and classification systems on which there was no consensus in the discussion was the utility of developing large scale "data banks" containing a description of urban areas potentially useful for many purposes versus collection of data primarily in terms of pre-specified uses for it in models and other analyses designed to treat particular problems. In terms of model design, it was suggested that an economic analysis "evaluating the cost of additional information and the way the additional information will contribute in the context of the model" was necessary (Goldner). There appeared to be general agreement in the discussion that the specification of a "minimum data set", suitable at least for transportation and land use modeling, could be developed if some additional research effort were directed to this question. There was also apparent agreement that time-series data on metropolitan areas was essential for further development of models, but that this kind of information need be developed in detail for only a limited number of metropolitan areas and the knowledge gained could be transferred to other areas

The discussion on the general problem of sequencing the specifying of an adequate data set for modeling and developing an adequate modeling system which in turn defines the data requirements was summed up (Seidman) as being necessarily a cyclical process in which data improvements lead to refinement of models and these to further specification of data requirements.

PART IV

Use of Models

This final part contains reports on the use of urban development models. Hemmens reports on a survey of current planning agency experience with models and data processing. He finds that mission-oriented planning agencies have encountered considerable difficulty in developing and operationalizing models and in making effective use of data processing capabilities. The survey also indicates little communication among agencies on these problems and little cumulative work building on the experience of others. Creighton, Hamburg and Scott explore the requirements for using land use models for evaluation of alternative forms. They stress the need for evaluation in terms of achievement of prespecified goals and identify existing gaps between the capabilities of current models and the measurement of social impacts of land development patterns. Boyce surveys the formal communication among model-builders as evidenced by the published literature and finds, similarly, that there is inadequate reporting and sharing of modeling experience.

SURVEY OF PLANNING AGENCY EXPERIENCE WITH URBAN DEVELOPMENT MODELS, DATA PROCESSING, AND COMPUTERS

GEORGE C. HEMMENS *

This paper is a report on a small survey of planning agencies on the subject of the use of urban development models and data processing in their operations. Questionnaires were sent to 34 planning agencies. The agencies were selected to include the metropolitan area land use and transportation planning agencies in the 25 largest SMSA's and selected city planning agencies of the central cities within these SMSA's. Where more than one metropolitan planning agency exists in a single SMSA, the questionnaire was generally sent to only one agency. In these instances the agency selected was the one having responsibility for comprehensive transportation planning. Similarly, no claim is made that the survey is representative of the use of models and data processing in urban or metropolitan planning agencies in general. Rather, the survey results should be viewed as representative only of the agencies interviewed.

The survey was designed to provide the following kinds of information on the use of models and data processing: description of models used including source of model, input requirements, output from model, computer usage, and agency use of model; evaluation of use of models including appropriate purpose of models, responsibility for model development, responsibility for model operation, problems in using models, and benefits from using models; experience with data processing including agency operations using EDP, EDP equipment and usage, and maintenance of data systems (or data banks); and evaluation of agency experience including agency problems and benefits, and plans for expansion of EDP operations.

Replies were received from 26 of the 34 agencies surveyed. All 26 agencies indicated either current or planned use of data processing and computers in their agency's operations Twenty of these agencies are currently involved in the use of data processing. The other six agencies are planning or developing data processing capability. Sixteen reported on either current usage or active development of models, and 3 other agencies reported definite plans for the use of models in their programs.

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The 26 agencies include 16 metropolitan or regional planning agencies, 6 city planning agencies, 2 state agencies, 1 federal agency, and 1 consulting firm. The agencies are listed in Table 1.

In the discussion of survey results that follows, an attempt is made to summarize the individual agency replies and to interpret agency comments where possible. At this point a caveat is necessary. It is very difficult to summarize or generalize the individual agency responses. The survey results clearly show that each agency's operation is in some sense unique and that its answers to the questions posed in the survey are conditioned by the experience within that agency. Since the survey results themselves do not provide detailed information of the history and circumstances of each agency, the summarization which has been done is based on fragmentary, incomplete knowledge and is a perilous exercise. In addition, the agencies are varied in the scope and nature of their planning responsibilities Also the agencies are of varied staff size and budget, and thus have unequal resources for data processing operations.

TABLE 1 PLANNING AGENCIES RESPONDING TO SURVEY

1	Baltimore Regional Planning Council
2.	Bay Area Transportation Study Commission
3	Chicago Area Transportation Study
4	Cleveland-Seven County Land Use and Transportation Study
5.	Colorado Department of Highways (Denver Area Transportation Study)
6	Delaware Valley Regional Planning Commission
7	Denver City Planning Commission
8	Detroit Regional Transportation and Land Use Study
9	Eastern Massachusetts Regional Planning Project
10	East-West Gateway Coordinating Council (St Louis)
11	Houston City Planning Department
12	Los Angeles City Planning Department
13	Metropolitan Washington Council of Governments
14	Milwaukee Department of City Development
15	New Orleans City Planning Commission
16.	New York State Department of Public Works (Subdivision of Transportation Planning and Programming)
17	Ohio-Kentucky-Indiana Regional Transportation Study (Cincinnati)
18	Northeast Corridor Transportation Project
19	Puget Sound Regional Transportation Study
20.	Regional Plan Association (New York)
21	San Diego City Planning Department
22	Southeastern Wisconsin Regional Planning Commission
23.	Southwestern Pennsylvania Regional Planning Commission
24.	Tri-State Transportation Commission (New York)
25	Twin-Cities Metropolitan Area Planning Commission (Minneapolis-St Paul)
26.	Alan M Voorhees and Associates

The agencies are also at differing stages in their work program. Some are relatively new; others are continuing programs which have been through a peak analysis effort; and still others are in midstream. All of these cautionary remarks are inserted here as a warning to the reader that this is not a definitive survey, and that the results should not be generalized to a larger universe of planning agencies. A further purpose of these remarks is to request the reader's indulgence for errors of interpretation and assistance in setting the record right.

USE OF URBAN DEVELOPMENT MODELS

Nineteen agencies reported on urban development models in their past, present, or future. For 3 agencies the models are sufficiently far in the future that precise descriptions are not possible. The other 16 agencies have provided descriptions of their models. Some of these are operational, some are under development, and some are in the planning stage. Since existing urban development models are being very adequately summarized and analyzed in other papers for this Conference, no attempt will be made to summarize these models here. However, the agencies' description of their models, where provided in response to specific questions in the survey, are given in Appendix A.

Seven agencies indicated that they do not now use and do not have definite plans for using urban development models in their work. Five of these are city agencies (of the 6 city agencies responding to the survey). The other 2 are a state agency and a metropolitan/regional agency.

The 14 agencies responding to a question on the appropriate purposes for the use of models in planning split about two to one in giving the use of models for analysis and evaluation of policy alternatives as the major purpose. The minority view gives forecasting and analysis as the major purpose of using models in planning. A few of the agency comments serve to illustrate the majority view

> Models should be used "to simulate the consequences of selecting actions, and to dimension a general plan and make it internally consistent."

> Models should be used "to predict the effects of varying policy sets on certain factions of the urban system considered to be significant and predictable . . . ."

> Models should be used "to forecast the effect of alternative courses of action on land development, and the effectiveness of urban systems such as water and sewer."

> Models should be used "when and where they can sharpen up or illustrate consequences of following certain development policies more rapidly and/or more objectively than other procedures."

The minority view stresses the analytic capabilities of modeling. This view is also best expressed by the comment of one of the agencies.

> Models can and should be used for any number of purposes in urban planning; since they are simply constructed for simplifying and systematizing the tremendous variation in the phenomena of reality such that it can be understood, controlled or resynthesized.

Regardless of whether stress is placed on the use of models for evaluation of policy or on the use of models to improve analysis and forecast of urban systems, all respondents are essentially concerned with using models to improve the rationality of planning decisions.

The agencies responding to the survey are virtually unanimous in stating that the planning agency responsible for plan proposals should be in charge of the use of models regardless of the origin of these models. In stating this position, the agencies indicate by their comments a concern that unless planning agency personnel are sufficiently well acquainted with the mechanics of the model to operate it, they will not be able to evaluate the output of model runs.

In response to a question on who should be responsible for the development of models the agencies split two to one in preferring that models be developed within the planning agency which will use them, rather than being developed either entirely outside the agency, or through a combination of agency staff and outside expertise. The basis for this view is best expressed by agency comments.

> The agency's own research and planning staff should be responsible for the development of all models used because of the uniqueness of each area and requirements of each study. If previously developed or canned programs are used, care should be taken that appropriate features are tailored to the special demands of the study in question.

And, in the words of another agency, "Responsibility for development of models should be fixed as close to the decision-making body (implementing agencies) as is practical, because the model should be designed to solve their problems."

In taking the view that the individual planning agency should be responsible for model development, the agencies appear to be making a distinction between model design (specification of output information, areal detail, decision criteria, model parameters, etc.) and model construction (programming, debugging, testing, etc.). Many of the agencies expressing a preference for in-house model development suggest that the use of outside experts for model construction may be both desirable and necessary depending on agency staff and budget limitations. In suggesting this however, the agencies often disclosed another major reason for preferring in-house model development. They are concerned that communications between the staff and its expert consultants will not be sufficiently good to permit full understanding of the model by the agency and consequently full utilization of the model by the agency. In the words of one agency:

> The agency should be responsible for developing [the model]; however, the actual work may be done by consultants if agency staff are intimately involved with model development. The agency should be able to use, modify, and explain the model after the consultant has gone. Perhaps all that is required is adequate documentation, something that is seldom done. For some purposes canned models would suffice if local staffs could understand them.

In summary, it appears that agencies who have had experience with urban models tend to prefer in-house development of models because of the need for the local agency to define the purpose and operational character of the model so that it will satisfy local needs, because of the uniqueness of each urban area, and because of the difficulty of generating adequate staff understanding of models produced outside the agency. This preference, however, is tempered by the realization that for many agencies in-house development of models is not feasible. In evaluating these responses, it should be realized that many of the agencies expressing the majority view are rather large, well-staffed agencies.

The difficulty most often mentioned by agencies in commenting on problems of integrating the use of models with other planning operations is the inability to schedule agency work well because of the uncertainty of completing developmental work on models. This problem is expressed in a variety of ways. The primary cause of the problem appears to be that many of the agencies have been engaged in original, or developmental work with models. It has been difficult for them to maintain time schedules established for other agency operations because of unexpected delays in making the models operational. Several agencies note that the "model" is on the critical path of the agency's operations so that any delays in model development cause chain reactions throughout the work program.

The second most frequently mentioned problem is communication between the model-builders and other staff personnel. As discussed above, this problem is part of the basis for agency preference for in-house model development. In addition several agencies reported in-house problems of misunderstanding between planner and programmer of the role and purpose of models in the agency's program.

These two problems, scheduling and communications, account for two-thirds of the responses to the question on agency problems. The remaining comments include such concerns as the large amounts of data required by the models, the staff time required to interpret the results of model runs, distortion of work program emphasis due to models, and the comment of two agencies that they had experienced no problems.

In discussing the benefits to their agency of the development and use of models, the clearly dominant benefit experienced was education of the staff. Beyond this, and mentioned much less often were more accurate forecasts and other analyses, and the ability to analyze a number of policy choices. The education benefits expressed are of three types. One is better staff knowledge of the nature of models and of the role of models in planning. A second type is better knowledge about urban areas and about the interaction of components of urban areas. The third education benefit is better understanding of planning through clarification of planning concepts and analysis of planning assumptions in the process of model development.

Several other benefits were mentioned by the agencies. In general these can be grouped under the heading of technical proficiency as they are concerned in one way or another with increased speed and efficiency of planning analysis and forecasting. Several agencies which are working with models have not yet proceeded far enough to evaluate their experience.

It is difficult to generalize the responses of the agencies because there is considerable variety in the shading and nuance of their comments. The flavor of their replies can be gotten from the examples below.

> The major benefits appear to have been the educational process concerning good and bad approaches to the model building effort, and the assistance this knowledge will give to later model-building attempts. The model itself appears to have somewhat limited utility.

> The major benefit of model usage is the ability to make decisions based on an objective, replicable process instead of a subjective process. Secondary benefits accrue from the professional growth of staff members which normally accompanies their involvement in model development and usage.

> The major benefits ought to be the sophisticated manipulation and analysis of large quantities of data, and calculations with rapidity and facility. I am not completely convinced that this is always the case, particularly when total programming time is figured in the efficiency calculation for the total process.

All of the agencies presently using models indicate that they intend to continue using them, and generally plan to modify and refine model techniques over time. Two-thirds of these agencies indicate that they intend to expand their use of models into other areas of planning analysis or forecast.

DATA PROCESSING AND COMPUTER USE IN AGENCY OPERATIONS

The survey results show that most agencies which use computers for models also use them for other agency operations. The extent of such usage appears to be somewhat dependent on whether or not a computer facility is on-site or readily accessible through another public agency. To a larger degree this probably reflects the concomitance of computer-based preparation and analysis of data with the use of models. The existence of a data processing operation within the agency then leads to further use of data processing for other operations.

Most agencies reporting the use of models thus also use data processing for preparation of data (cleaning, sorting, etc.); for maintenance of such basic files as land use inventories, travel data, and population; for tabular reports and statistical analyses of these files; and for preparation of model inputs. Other uses of data processing mentioned by several agencies include: administration (cost accounting, inventory, personnel), work planning (PERT, CPM), and prefield and field control operations for local surveys (sampling, addressing survey forms, data editing and checking).

There is one exception to this general pattern of the use of computer based models coupled with more extensive use of data processing in agency operations. Several of the city planning agencies report the use of data processing for planning operations, principally data file handling and tabular and statistical reports on these files, but no use of models. In these cases, the planning agency has access to a city-operated computer facility. Considerable variation exists among the agencies in the amount of data processing work done by agency staff and the amount contracted to consultants, and in the division of work between in-shop and service bureau computer facilities.

Most of the agencies which reported their computer usage utilize more than one computer system (Table 2). Typically, they use a small computer which is operated by the agency itself or by another public agency, and they rent time on a large computer from a service bureau or other vendor. Twelve of the sixteen agencies reporting equipment usage employ either an agency-operated, or city or state-operated computer facility. Three of the remaining four use service bureaus exclusively, and the fourth uses computer services provided by consultants.

The average usage of computers varies widely among agencies. This variation appears to reflect the stage of the planning process the agency is in at the present time as well as the size of the planning operation. Some agencies report that they anticipate a substantial increase in computer usage in the near future as their programs progress. Others report that current usage is below previous experience.

No agency reported the existence of a fully developed data bank system consisting of both regular data updating procedures and existing programming systems for manipulation and retrieval. However, half of the agencies reported operating systems somewhat short of this ideal. About one-fourth of the agen-

TABLE 2. COMPUTER FACILITIES USED BY PLANNING AGENCIES

AGENCY	COMPUTER	SOURCE	ESTIMATED CURRENT AVERAGE USAGE (*hr/week*)
Baltimore Regional Planning Council	IBM 1460 & 1620 IBM 7090 & 360/40, UNIVAC 1005	State operated Service bureau	4
Bay Area Transportation Study Commission	Honeywell 120 IBM 7094 CDC 3800	Agency Service bureau Service bureau	50 2-10 1-5
Chicago Area Transportation Study	IBM 1401	Agency	30
Cleveland-Seven County Land Use—Transportation Study	CDC 3200 CDC 360	Agency Service bureau	90 —
Delaware Valley Regional Planning Commission	IBM 360/30 IBM 7094	Agency Service bureau	25 3
Denver Planning Office	IBM 360/30	City operated	less than 1
Eastern Massachusetts Regional Planning Project	IBM 7094 IBM 1401	Service bureau Service bureau	1.2 3 8
Los Angeles City Planning Department	IBM 360/30;/40 IBM 7044; 7094	City operated Service bureau	10
Metropolitan Washington Council of Governments	CDC 3600, GE 235	Service bureau	½-2
New Orleans City Planning Commission	IBM 1401	City operated	4
New York State Departments of Public Works—Subdivision of Transportation Planning and Programming	Burroughs B-5500	State operated	60
Puget Sound Regional Transportation Planning Program	IBM 1401 IBM 7094	Service bureau Service bureau	½
Regional Plan Association of New York	IBM 7094 CDC 3600	Consultant Consultant	— —

TABLE 2. *(Continued)*

AGENCY	COMPUTER	AGENCY	ESTIMATED CURRENT AVERAGE USAGE (*hr/week*)
Southwestern Pennsylvania Regional Planning Commission	Honeywell 200	Agency	90-100
Southeastern Wisconsin Regional Planning Commission	IBM 360/30	Agency	25
Tri-State Transportation Commission	IBM 1460	Agency	75
	IBM 7094, IBM 360/65	Service bureau	—

cies maintain extensive machine-readable data files of such information as land use, population characteristics, travel behavior, and transportation networks In addition they maintain software packages used for manipulation and retrieval of these files. Only two of these agencies indicated extensive use of general purpose computer program packages for this purpose. By inference, it appears that the others rely primarily on original programming designed for their use The systems operated by the other fourth of the agencies appear to consist primarily of machine-readable data files which can be readily accessed for special purposes but lack a general purpose manipulation and retrieval capability.

The major problem in data processing reported by the agencies is finding and keeping qualified programmers and other data processing personnel. Almost every agency reported this to be a problem. The staffing problem apparently takes many forms including inadequate salaries for programming staff resulting in high personnel turnover; difficulty of training programmers on-site; management of EDP operations, especially program quality control; and, more basic, finding suitable personnel to fill available positions.

The second most often mentioned problem is the difficulty of communications between the planning staff and the programmers and other EDP personnel. One agency summarized the problem as establishing meaningful communications "between the staff who have a knowledge of machine capabilities and the staff who wish to make use of these machine capabilities." This problem is, of course, related to the programmer personnel problem. The concern for program quality control and dissatisfaction with available programming staff appears, from the statements of several agencies, to result in part from communications difficulty. The program prepared by the programmer often does not produce the output desired by the planning analyst. Agencies' comments suggest that this is due equally to inability of the planning analyst to describe precisely to the programmer what he wants, and to the inability of the programmer to understand how the substance of the planning analyst's problem may be affected by the choice of data manipulation and computer operations.

It is encouraging to note that in only one instance the planning agency ascribed the planner-programmer communication problem to a negative attitude of the planning staff toward data processing In general the concern expressed is in terms of an honest misunderstanding between programmer and planner. Few agencies hazarded an opinion on how to deal with this problem other than a general suggestion of improved education on the other's point-of-view for all parties involved. The few who expressed an opinion on a particular strategy for this education agreed that the most promising and efficient approach is to stress education of the planning analyst in the mysteries of computers and programming rather than the reverse. One agency summarized their experience and suggestion this way: "It is easier to train someone familiar with the (planning) application in data processing than it is to train someone familiar with data processing in the application."

A number of other problems were mentioned by the agencies in addition to the major problems of maintaining data processing staff and programmer-planner communication. To a large extent these problems are related to the major problems. For example, concern was expressed for the large amount of time required to get data processing projects operational; for the time involved in debugging programs; for the difficulties of adapting data sources to computer files; for the difficulties of merging data files into a common, consistent framework; and for the general inefficiency of data processing operations. These problems reflect both the personnel limitations and the communications difficulties experienced by the agencies.

This summary of the problems experienced with data processing should clearly be interpreted in light of the current operating experience of these agencies. As discussed above, many of these agencies are actively using computers for a variety of agency operations.

All of the agencies responding to the survey report substantial benefits from their data processing operations. For many of the agencies the discussion of benefits starts from the premise that data processing and the use of computers are essential to their operation. This is true for all agencies involved in the use of models, and particularly true for those agencies responsible for planning and testing transportation systems.

Three kinds of benefits are reported by the agencies. First, and most frequently mentioned, is rapid access to large amounts of data. This includes time saving in data handling, and the benefit of more detailed and more accurate data. Second, several agencies count the ability to solve otherwise intractable problems and do "more sophisticated" work as a major benefit. As one agency put it, we can "develop answers which no one else can." Third, several agencies attribute both greater planning staff productivity and greater efficiency in using planning staff to the availability of data processing operations.

About half of the agencies reported specific plans for expansion of data processing activities. Mainly these plans entail an expansion of data processing operations to include more data files, and to move toward an integrated information system or data bank. In addition, two agencies intend to add data plotters or other graphic display devices to their computer systems. Several agencies are now in the process of or are contemplating a change in their basic computer equipment. One agency plans a major effort in improving computer utilization.

SUMMARY

We noted at the outset the difficulty and danger of attempting to compare and summarize the reports of agency experience with use of urban development models and data processing Having ignored reasonable caution already, we will now, with temerity, attempt a brief summary across these two general topics.

The planning agencies appear to be caught between two problems. adequate personnel for computer operations—especially programming—and inadequate communication between planner and programmer. These seem to be disequilibrating problems. The desire of agencies to have model development and use as an in-house operation to alleviate the communications problem runs head-on into the personnel problem. Solving the personnel problem by use of outside expertise appears to aggravate the communications problem, particularly for continuing use of models.

Despite these problems, it is clear from agency experience and future plans that the use of models and data processing has been highly beneficial and often essential. Although the problems are difficult they are being overcome.

Some other characteristics of agency experience seem quite important to future development in this area. It appears that there is relatively little communication between agencies on either models or data processing systems. As was noted earlier the real or apparent uniqueness of each urban area and each planning program leads to some sentiment for particularized models. However, as indicated in Appendix A, there is some current use of the same model in several agencies. Similarly, there seems to be a heavy dependence on original programming for data manipulation and retrieval, file maintenance, data analysis, etc. There is little evidence of communication between agencies on software systems for these purposes, and little evidence of the use of existing, general purpose software systems. Again the uniqueness of the planning programs, the data sources, the coding systems, etc., explain, at least in part, why this is so.

In view of these problems and in view of planning agency determination to continue and expand these activities, it appears that two "services" to the planning agencies would be highly beneficial at this point. One, obviously, would be extensive documentation of existing models, a careful evaluation of these models, and an effort to generalize them for easy use by many agencies. Second, and equally obvious, is the desirability of a serious effort to evaluate, develop, and make generally available programming systems specifically designed for planning analysis and manipulation of the kind of data files used by planning agencies.

Neither the documentation of these problems, nor these suggestions are original. The survey results simply reinforce the concerns already expressed by people active in this area. The arguments against these suggestions—the rapidly changing needs and possibilities in the field, the need for additional research to validate model assumptions, and the primitive state of exploration of modeling techniques in planning—are well known. But, it is equally clear that considerable resources will be committed to model development and use of data processing in the future; and it appears that considerable economies, improved efficiency, and higher quality could be achieved through some stock-taking and greater coordination.

EVALUATION OF LAND USE PATTERNS

JOHN R. HAMBURG, ROGER L. CREIGHTON, AND ROBERT S. SCOTT *

If the development and redevelopment of urban land in the world is to be anything more than an evolutionary process of incremental growth, we must have at least a means of evaluating alternative developments. While many planners are rightly concerned about implementation, this paper will attempt to examine some of the problems involved in evaluation and suggest the broad areas of research which might be undertaken to strengthen evaluation techniques.

WHAT IS MEANT BY SHAPE OR PATTERN OF THE LAND USE PILE

The term land use has gradually given way to terms such as space use and activity structure. Human society exists in three dimensions and an industrial or post-industrial society must be concerned with space, not just land. The pattern of urban land use may be viewed in a three dimensional form. There have been a rich variety of such forms.

The shape of these patterns has most often been represented by an outline of the developed land in a region. Such shapes have given rise to terms such as stellate, linear city, strip development, and urban sprawl. There has been some recognition of the vertical dimension of cities with analyses of density patterns and three dimensional renditions of city form.

These dimensions, the height of the pile and the shape of the base of the pile are certainly useful in describing urban settlement. But when we make even the most casual appraisal of cities in the United States, we find a variety of shapes and heights. How can we say that any given shape is better than some alternative shape?

Differences in shape have often been attributed to particular aspects of technologies characterizing the period of a city's growth. Thus high-rise or dense industrial cities in the United States tend to be older and associated with mass transit, mechanical transmission of power, and assembly of raw materials at a break in water and rail transport. Low-density dispersed settlement has accompanied the development of the automobile, the ubiquitous highway, electrical power and improved communication systems.

To the extent that city shape is a response to evolving technologies, the question might become not so much one of evaluating alternative shapes, but one of anticipating changing technologies of transportation, building, power transmission, energy sources, and so on.

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COMPOSITION OF THE PILE

Another important consideration is the composition of the urban activity pile. That is, what kind of activities characterize a particular cross section or plug of the pile. How are residential activities distributed throughout the pile? How are manufacturing and service activities distributed throughout the pile and with respect to each other and residential activities? Are different mixtures found even within piles of the same general shape? Do different mixtures result in greater efficiency within the pile? That is, is the composition of activities within the pile a response to transport facilities or can the composition be manipulated independently? Are there significant factors associated with varying composition that suggest a better or best mix?

A critical factor in examining the pile is how closely we examine it. Should one deal with individuals, families, neighborhoods, or groups of neighborhoods? Our ability to make meaningful observations and measurements will hinge on the selection of the appropriate unit. Aggregations that are too coarse will mask significant patterns and relationships while units that are too fine may exhibit seemingly random behavior.

IMPACT OF SHAPE AND COMPOSITION ON SOCIETY

While we can see differences in shape and composition among cities, are these differences responsible for variations in the quality of urban life? Proponents of the dense, compact city are so certain of the superiority of this form that they would take any action which would foster a denser development. Yet the low-density "spread" city obviously has able promoters.

In the absence of rigorous definitions and measurements of the impact that shape and composition have, discussions of the best, or even a better city form, become mere exercises in rhetoric. Is it safer to live in dense cities? Do low-density cities have less air pollution? Does a green belt make people happier? Are the costs of governing a sprawling metropolis higher than the costs of a compact city with the same population?

These are the kinds of questions we must be able to answer. They suggest that we must begin our process with an examination of the goals.

GOALS FOR URBAN LIVING

We have listed ten goals from which one might expect to find some agreement among city dwellers. There are undoubtedly many more.

1. Reduce transportation, utilities, and communication costs. These would include costs of construction, operation, and maintenance.
2. Reduce pollution, including dirt, noise, air and water pollution.
3. Reduce danger.
4. Reduce hunger, lack of shelter, and poor clothing. This concern may be felt strongly in other countries.

5. Reduce the costs of government.
6. Increase personal wealth, that is, increase productivity and assume an equitable distribution.
7. Increase the opportunity for personal development, including opportunities for education, for physical development, and for recreation.
8. Increase freedom. Mobility is a kind of freedom and there are people who are relatively immobilized in some present settlement patterns.
9. Increase the energy power available to people.
10. Decrease social unrest.

More could be listed, although the majority of additions would probably be more exact specifications from the above first ten. Granting that the discussion of goals tends to be a never ending debate, we would still insist that an evaluation of land use patterns must begin with a tentative list of goals and an investigation of the goal achievement levels associated with alternative patterns of land use.

This is not easily accomplished. The relationship between land use patterns and transportation facilities, so clearly seen in a historical perspective, has yet to be harnessed productively in city planning. There have been speculations that particular modes of travel will induce particular city forms. That this is so has not really been demonstrated. Nor would a valid demonstration have real planning relevance without a parallel demonstration of relative goal achievement associated with alternate forms of development

POSSIBLE STRATEGIES FOR DEVELOPMENT OF EVALUATION TECHNIQUES.

We live in a continuing experiment. There are a variety of existing city forms all around us. One time honored approach is simply to make observations within alternative forms and compare the results. This is probably an excellent beginning point. Measures of the quality of life, however, are not easy to come by. The profile of crime in a city is not easily perceived using reported statistics and especially, existing indexes. The quality of education, medical care, and utility provision all tend to be somewhat vaguely portrayed by currently available data and indexes.

Recent years, however, have seen the development of great interest in social goals and indicators. Out of the interest and enthusiasm generated by the social scientists in this movement, we may expect to see a greatly expanded data base. With improved statistics on the quality of urban life, we may be able to design some comparative studies of urban form as it relates to urban living.

A major difficulty with such "real-life" experiments is the problem of control. With so many factors varying simultaneously, it is difficult to observe, much less measure, the operation of a single factor. Even with an understanding of the basic relationships, the complexity—the sheer bulk of numbers—places analysis and manipulation well beyond the reach of the pencil and yellow pad. The electronic computer has given us the potential to simulate urban life and conduct experiments wherein we may "pre-live" alternative environments.

Efforts to improve transportation planning have resulted in the development of several simulation models which permit the measurement of the consequences of alternative transportation decisions. Many of these models have been integrated with an evaluation process which measures the transportation costs (accident, operating, personal time, construction and maintenance, and investment costs) associated with a particular proposed plan. These methodologies do not absolutely guarantee the optimum or least cost plan. They do enable one to select the best of all the given alternatives. This is no small achievement. While there is always the possibility that there is a superior plan lurking somewhere behind the scenes, the planner has the comfort of knowing that he has chosen the best from among the available or competing candidates.

Of course, what he cannot measure with existing methodology are the non-transport consequences of the alternative transportation plans. Will the region, in fact, develop as anticipated by the planning process and thus fit the selected transportation plan? Is there an alternate form of development which would be better served by a different transportation system? While we have seen attempts to deal with these questions, no satisfactory model currently exists.

DEVELOPMENT OF THE SUPER MODEL

One approach to the problems posed by increasing the scope of the goals and the dimensions of urban life to be represented is to build a bigger model (bigger computers are on their way). A first effort to develop such a model or series of models is illustrated in the following two diagrams.

The basic components of the planning process as it has evolved is shown in Figure 1. The first step is to have an agreed upon set of goals. These goals must be measurable, singular, relevant and represent system performance standards. Alternative proposals are required as an input to the simulation model. The origin of these proposals runs the gamut from political favorites to planning staff design. Their origin is not as significant as the range of possible actions which they should represent. If the range is too limited, one runs the risk of missing a really significant improvement. Too rich an assortment drastically increases the cost of the planning process. In preparation of the transportation system plan, the testing phase involves the actual simulation of vehicular traffic under the conditions of a particular transportation plan and urban development at some specific point in time. Parenthetically, one should note that simulation requires not only ingenious mathematical and programming skills, it requires knowledge of the phenomenon being simulated. The computer gives us the ability to manipulate enormous volumes of data at incredible speed; it gives us no knowledge of human behavior. The evaluation process consists of comparing the system performance with respect to stated

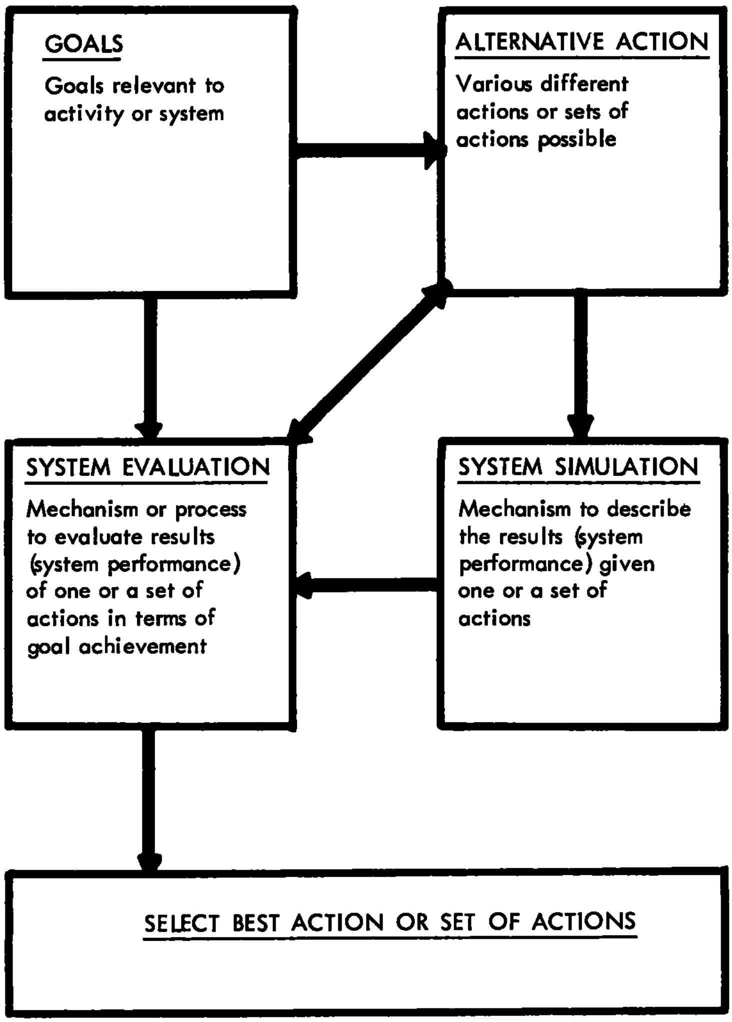

Figure 1. The single system planning process.

goals of the several proposals. The proposal with the best goal achievement is the winner. The two-directional arrow between proposals and evaluation indicates both the cut and try nature of the process and the potential learning that can take place during the process. That is, results of a given series of tests may suggest new proposals with potentially higher goal performance.

The difficulties of goal definition and measurement are manifold. Without a common metric, trade-off decisions are both difficult and subjective. One tech-

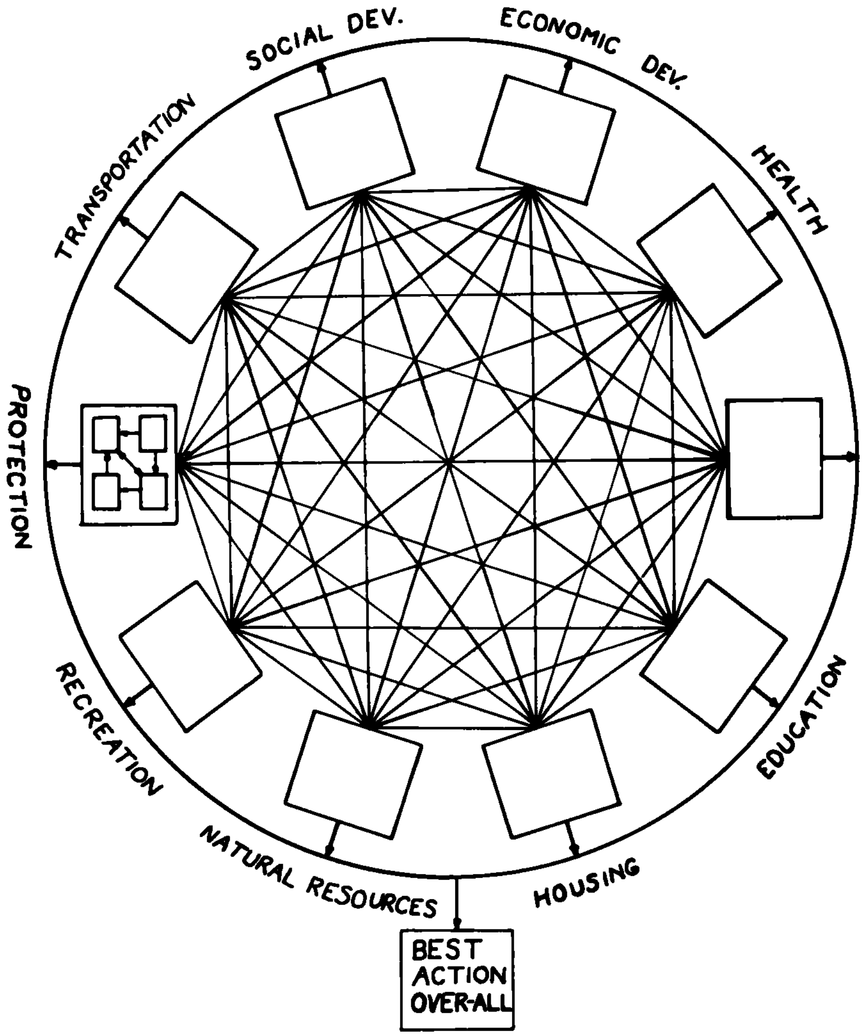

Figure 2. Planning process—multiple systems.

nique which might be used more frequently is the use of constrained simulation. That is, where the measurement of the value of a particular goal achievement is difficult or impossible to measure, we may still be able to assess the cost of achievement. For instance, a minimum level of public transportation service may be recommended as a goal to provide greater access to employment, educational, and cultural facilities. While we might not be able to evaluate at this time the benefits associated with these minimum standards of service, we could constrain our plan to meet these levels. The difference in measured goal achievement between the plan with the minimum levels of service and the plan without such service represents the cost of providing such minimum levels of service.

However, the single system approach has been deservedly criticized for its failure to consider impacts in other systems. In short, the problem of suboptimization. Figure 2 is a sketch of how the extension of the single system approach might be expanded. The basic phases of goal selection, plan proposals, simulation, and evaluation are carried on in each system. However, the lines connecting the individual systems represent the impact that a proposal in one system would have on the operation on all other systems. For example, the line connecting transportation and housing represents the impact that a proposed housing plan would have on the transportation system and, coming the other way, the impact that a proposed transportation facility would have on the housing system.

There is an arbitrariness to the selection of the 10 systems represented. We are not certain that each of them truly qualifies as a system. Moreover, we are certain that reality might be represented with fewer than 10 subsystems or with an almost infinite number.

The diagram does, however, represent a logical methodology towards which we should be moving. Unless one has simulation capability with one of these systems, one can scarcely hope to be able to simulate impact on other systems. Therefore, this direction carries two levels of concentration. The first, and the one most susceptible to attack by existing institutions, is the investigation of single systems. The second requires a far broader focus. This level may only be feasible by state and federal agencies. An investigation of the interrelationships between systems would hopefully pinpoint those systems which require joint planning and those which seem relatively independent of other systems.

At this writing, one would speculate that computer capability to perform such a task exceeds our present understanding of intersystem relationships.

EVOLUTIONARY-INCREMENTAL NATURES OF CITY FORM

In our desire to "pre-live" a rich variety of regional environments through simulation techniques, we should not ignore the way in which cities have grown and continue to grow. They are not ejected whole from a vast cosmic machine. They grow through a process of developing vacant land at the periphery and redeveloping land within the region. This process goes on during times of changing power, building and transportation technologies. Therefore, there might be greater potential savings by a complete and integrated design for a whole city than might ever be realized in the usual piecemeal approach of planning for change in existing cities. For example, if we were to design a city of 1,000,000 people in which the automobile were to be the dominant form of transportation, we would never get a city resembling those we see today in which the automobile is dominant. There would be no parking on streets. There would be no intersections at which cars would stop to wait for crossing vehicles. There would be no opposing streams of traffic. Pedestrians would not risk their lives by cutting across the traffic stream. People would not walk several blocks from their parked vehicle to get where they were going. A transportation system with this capability is easy to conceive, but impossible to build block by block as we have been building cities in the past.

Such a system must be designed into the land use system (activity structure) at the design stage and then carried forward throughout the building of the city. Unless the city or region is viewed as a complete entity, and designed and built as such, the potential savings of integrated systems will not be reachable.

CONCLUSION

Evaluating alternative land use patterns must be based on the impact that differences in city form and composition have on the goal structure of society. To attack the problem of evaluation therefore requires (a) a definition and a means of measuring land use patterns (form and composition), (b) a compilation and measurement of relevant goals, and (c) the identification and measurement of the impact of differences in land use patterns on societal goals.

The expanding interest of social scientists in the area of social goals and indicators holds promise for the development of a better data base. This in turn could stimulate comparative studies of form and composition of existing cities as related to the quality of urban life.

The rapid growth in computer technology, coupled with systems and simulation capability in single systems areas such as transportation, housing and water resources, gives some promise of a super-model, which would integrate these and several other systems into an overall model.

Finally, it should be remembered that the incremental nature of urban growth in itself may preclude the potential benefits of multi-system integration which would be possible if a city were designed and built as a whole.

COMMUNICATION IN THE FIELD OF URBAN DEVELOPMENT MODELS

DAVID E. BOYCE *

The publication of two articles on land use and traffic models by Hanson (1959) and Hamburg and Creighton (1959) in a special issue of the *Journal of the American Institute of Planners* marks the formal beginnings of the field of urban development or urban land use models. Since that time the number of researchers and studies engaged in the formulation, calibration, testing and application of urban development models has expanded rapidly. These Proceedings, published nearly ten years after the original contributions to the literature of urban development models, mark a major milestone in this young but vigorous field. However, the advances reported here and elsewhere in the literature do not fully reflect the aggregate increase in information and ability for predicting the development of urban land. Much of what has been learned has yet to be reported in the literature, with the result that further advances may be retarded and the entry of new researchers in the field may be delayed.

The purpose of this paper is to examine the status of communication among researchers in this field, as a part of the larger examination of the status of the field of urban development models. Also developed here are new methods and recommendations for expanding and encouraging communication among researchers in the field and between researchers and users of urban models.

Unlike some other fields of inquiry, communication in the field of urban development models is not experiencing an information explosion, at least in the published literature. Moreover, there does not appear to be a communications problem with regard to keeping up with a rapidly expanding published literature, nor as is the case in some fields, is there a need to develop more rapid and informal methods of information exchange than the published literature provides. Rather, the problem in this field is perhaps the lack of an information explosion. The thesis examined here is that in the field of urban development models, there is needed a scientific information explosion—scientific in the sense of generating publications that are detailed, rigorous, well-documented and referenced reports on research findings that collectively form a basis for new work, and information explosion in the sense of providing for full publication of the results of model development research on a continuing basis. In the course of examining this thesis, a framework for

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communication methods in science is described, followed by a review of recent communications in the urban development model field. Next, the journals presently available to this field are reviewed in terms of orientation and potential for expansion. Finally, proposed new methods of communication are examined, and recommendations for communications in this field are discussed.

COMMUNICATION METHODS IN SCIENCE

Questions concerned with communication in science are a topic of active interest to scientists in general. During the past two years, no less than five full-length articles and eight editorials, letters and reports appeared in *Science,* the weekly journal of the American Association for the Advancement of Science. Perhaps the most important of these for the purpose here is "The Future of Scientific Journals," by Brown, Pierce, and Traub (1967). For examples of general articles, also see Abelson (1966), Carter (1966), Garvey and Griffith (1967) and Margolis (1967).

Brown, Pierce and Traub develop the concept that scientific journals form a method of communication among scientists that is formal, public and orderly. Formal is defined to mean that papers appearing in journals can be cited and retrieved unambiguously. Public means that journals are available to anyone in libraries or by subscription, and that anyone can submit a paper. Orderly means that the inputs are accepted or rejected by the scientific community itself on the basis of merit. This framework for classification of communication in scientific research can be summarized by defining open communication as that communication which meets the above standards, and defining all other exchange as closed communication.

COMMUNICATION IN THE FIELD OF URBAN DEVELOPMENT MODELS

The framework described above provides a basis for classifying channels of communication in the field of urban development models. Books, monographs, and journals constitute formal, public, and orderly communication for both researchers and users in the field. Conferences and preprints of papers distributed at conferences, such as the Annual Meeting of the Highway Research Board, provide for public and semi-orderly, but not formal communication. On the other hand, the reports of local, state, and federal agencies provide for semi-public, but neither formal nor orderly communication in the field. Finally, invisible colleges, that is, informal exchange of papers among small groups of research workers, or the somewhat more formalized information exchange groups (to be described below) are neither public nor formal nor orderly. It is noted by Brown, Pierce, and Traub that in some fields these last informal means of communication among groups of researchers are tending to disrupt well-established journal publication practices; in less developed and less organized fields such as urban development models, such practices may actually be stunting normal growth.

To determine the level of communication in the field of urban development models, the years 1964 through 1967 were selected as a sample period for the nearly ten-year period of growth and expansion. For this representative period, the status of communications has been examined by compiling a list of book, monographs and journal articles published (see Bibliography). This list, while not necessarily complete, is representative of the contributions to the literature during the period. In compiling the list, rather narrow criteria were employed for an article to be admitted, that the article reported on specific details of an urban development or land use model usually in conjunction with tests and evaluation for a particular metropolitan area. General articles on techniques and theory were thus excluded from this list. Furthermore, in order for a book, monograph, or journal article to be included, it had to meet the criteria of formal, public, and orderly communication; thus, many many reports of government agencies were excluded.

Books and Monographs

Three research groups produced four monographs during the 1964 to 1967 period. There were no books on urban development models published during this time. Two of these four monographs were issued by university research agencies, and two were publications of the RAND Corporation. The four monographs constitute communications among researchers, as contrasted with communications between researchers and users.

Journal Articles

Fourteen researchers or research groups produced 23 journal articles during the 1964 to 1967 period. Three university groups contributed 5 articles, four government agencies contributed 8 articles, and six consultants and private research institutes contributed 10 articles. The articles were distributed by type of model as follows· (a) residential location models, 13; (b) population and employment location models, 5; (c) retail location models, 4; and (d) industrial location models, 1.

Six journals were included in the survey for articles on urban development models. The journals, with the number of articles appearing in the 1964 to 1967 period, are as follows: (a) *Journal of the American Institute of Planners,* 8 (all in the May 1965, Special Issue); (b) *Highway Research Record,* 10; (c) *Traffic Quarterly,* 2; (d) *Land Economics,* 2; (e) *Papers, Regional Science Association,* 1; and (f) *Journal of Regional Science,* 0.

Journals in other fields, particularly geography and statistics were excluded from the survey because of the limited time available. Of the above articles, about half were communications among researchers in the field, and the remainder were communications between researchers and users.

Closed Communication

Although no attempt was made to survey the huge volume of closed communication during the 1964 to 1967 period, the following comments are suggestive of its quality and quantity. The Annual Meeting of the Highway Research Board and to a lesser extent the Annual Meeting of the Regional Science Association provided for important conference-type communication. In most cases, preprints of papers given at these meetings were available either at the time of the meeting or, upon request, from the author after the meeting. In addition to these public conferences, a number of private conferences were held including the annual meetings of the Land Use Evaluation Committee of the Highway Research Board at which important model development issues were discussed, and the Seminar on Models of Metropolitan Land Use Development held at the University of Pennsylvania in October 1964. Both the public and private conferences held in this field have provided important channels of communication among researchers; discussions of models at such meetings often appeared later in published form.

A huge volume of local, state and federal government reports, including reports by consultants, were produced during the survey period in the form of official reports, working manuals, and staff papers. While a large percentage of these reports has been available to a select number of researchers working in the field, their distribution to a somewhat larger group of interested researchers and potential contributors was extremely irregular. In addition, the quality of these reports tends to be uneven in that many were not intended to be distributed beyond the agency for which they were prepared; also, in many cases, reports on model research are mixed in with substantive issues and problems relating to a particular planning area, reducing their value as communications with other researchers.

A limited number of reports were published by the Federal Government through the U.S. Government Printing Office and the U.S. Department of Commerce during the survey period. In addition, the Clearinghouse for Federal Scientific and Technical Information was established during the period to reproduce and distribute reports submitted by a variety of government agencies and government contractors In particular, the unclassified reports of all defense research agencies and contractors are deposited in the Clearinghouse. At present, the feasibility of depositing metropolitan planning reports prepared by local governmental agencies and their consultants in the Clearinghouse is being examined in a demonstration project being conducted by the American Institute of Planners. Such a development would make available a large volume of reports on a selective basis. However, the problem of the quality of the reports and their orderly review remains to be resolved.

Finally, invisible colleges, or informal exchange of papers among individual researchers, have undoubtedly also been a rather important means of communication in the urban development models field for many researchers during the survey period. In addition, several indexes and information services have come into being during the past four years. Chief among these are the Highway Research Information Service and the Science Citation Index prepared by the Institute for Scientific Information (1965). Such services have an important contribution in the more mature areas of transportation and urban research; however, in this field the literature is so small that the benefits of such information services will probably be negligible for some time to come.

STATUS AND POTENTIAL OF VARIOUS MODES OF COMMUNICATION IN THE URBAN DEVELOPMENT MODELS FIELD

One possible explanation of the relatively small number of articles published during the past four years is the lack of available journal capacity. Although it may be widely believed that this is not the case, it is nevertheless useful to review the status of the several journals available to the field of urban development models to determine any potential problems of this sort. This review is divided into two sections, the first dealing with communication among researchers, and the second concerned with communications between researchers and users of the research. Each journal is examined for the quality of its refereeing system, its publication lag from submission of manuscripts to their publication, and the available capacity for expansion of the number of articles on urban development models.

COMMUNICATION AMONG RESEARCHERS

At present, there are two established journals available for publication of results of model research. One of these, the *Highway Research Record,* is clearly at present the leading journal for researchers in the field. It has, in conjunction with the Annual Meeting of the Highway Research Board, an excellent refereeing system, and considering the delay from the Annual Meeting itself, an acceptable publication lag; in this regard, a delay of 12 months is typical. As the number of papers in the field submitted each year to the Highway Research Board increases, there is a reasonable expectation that the *Record* can be expanded to accommodate the increased volume.

The second established journal available to this field, the *Journal of Regional Science,* has had no articles on urban development models during the past four years, but has published several important articles in the allied field of urban travel models. This journal mainly emphasizes theory and models of urban and regional location and development, and is a somewhat more academically oriented journal than the *Highway Research Record.* The journal has an active refereeing system, and at present has a good publication lag, on the order of 10 to 12 months. The management of the *Journal* recently has announced an expansion from two to three numbers per year. The *Journal of Regional Science* has the potential of becoming one of the major journals for this field, particularly for the more technical publications.

Several other established journals should be mentioned under this category considering their past contributions to publications in this field, and their future potential for publishing one or two articles per year. Included in this group are *Land Economics, Economic Geography,* the *Annals of the American Association of Geographers,* and the *Papers of the Regional Science Association.*

During the past year, four new journals were inaugurated in the general field of urban activities and transportation research, each of which has excellent potential for contribution to communication among researchers in the urban development model field. These journals are *Socio-Economic Planning Sciences, Transportation Research, Journal of Transportation Economics and Policy,* and *Transportation Science.* Certainly with the addition of these journals, as well as the two established journals discussed above, there can be no question about the availability of journal capacity in this field.

Communication Between Researchers and Users

There are at present three journals serving the function of communication between researchers and users in addition to the *Highway Research Record* which clearly fulfills this function as well as the role already discussed. Perhaps the major journal for communication between researchers and users is the *Journal of the American Institute of Planners.* In particular, special issues of the *Journal* in 1959 and 1965 have had a significant impact on the general field of planning. This journal has a highly developed refereeing system, and is generally regarded as having an adequate to good publication lag. The *Journal* probably has only limited growth potential for this field inasmuch as its main orientation is towards a large and varied membership. However, it can be expected to publish a few quality articles written mainly for the purpose of communication with users of urban development models.

A second journal also well established in the urban transportation planning field is *Traffic Quarterly.* This journal is well known for its rapid publication of manuscripts, although the quality of the articles published tends to be somewhat uneven. The journal probably has somewhat limited growth potential for this field, although there is clearly an opportunity for a continuing flow of well-written articles. A third publication, the *Journal of the Urban Planning and Development Division of the American Society of Civil Engineers* publishes general articles of minor interest to this field at present, but has a good growth potential for contributing to communications in the field. It is somewhat hampered by a limited distribution, mainly to civil engineers, but it could provide a useful service, particularly for urban and state engineering departments.

Journal capacity for communication between researchers and users is evidently quite adequate at this time, and will continue to improve and to expand through the submission of high quality manuscripts. There is, therefore, no apparent need for new journals to serve this function at the present time. However, in the next three to five years, there may be an opportunity for a monthly journal of a technical nature similar to the weekly *Science* for reports, review articles, abstracts and news and comment in the field of urban and transportation planning research. The recently announced Design Methods Group *Newsletter*, founded "to fill the communications gap in the dissemination of information on the methodology for solving large scale design problems as they occur in the context of urban systems" may serve this need. Such a journal could make a large contribution to communication in the urban development models field.

STATUS OF NEW METHODS OF COMMUNICATION IN SCIENTIFIC RESEARCH

Coincident with the expansion of information and the number of journal articles and books being published in several fields of science, there has been expanding interest in possible new methods of communication. The relevance of several proposed new methods of communication for the field of urban development models is now reviewed.

Information Exchange Groups

A possible means for increasing communication among researchers is the establishment of an information exchange group (IEG) that would institutionalize the existing informal exchange of papers in manuscript form. In such a program, an agency such as the Highway Research Board would reproduce in preprint form and distribute to a select group any paper submitted by a member of the group.

The establishment of such a group would permit rapid communication (with delays of perhaps two months) among researchers in this field. Communications would include brief reports, technical memos, as well as papers prepared for publication. Membership in the group would be subject to careful selection because of the cost of the endeavor and the requirement of active participation.

There is considerable experience to draw on for evaluating the effectiveness of an IEG for urban development models, and it is useful to review it briefly here. Seven information exchange groups were formed in an experimental program recently concluded by the National Institutes of Health. The program was initiated in 1961 with one group consisting of 56 members that circulated ten preprints. Six more IEG's were added in 1964 and 1965. In 1966, the seven groups included 3,625 members, and 1.5 million copies of preprints were circulated. A continuation of this growth trend for the program for another two years would have resulted in a membership in the established IEG's of as many as 14,000 with a distribution of perhaps 30 million copies of preprints; see Abelson (1966). Recalling that the program was only experimental, the National Institutes of Health discontinued the program in early 1967.

An interesting and spontaneous evaluation of the program is recorded in the *Science* Letters Section, in late 1966; for further information, see:

"IEG's. Some Evaluations," *Science* Letters (1966a); "Information Exchange Groups to be Discontinued," *Science* Letters (1966); "International Statement on Information Exchange Groups, *Science* Letters (1967). Several authors wrote that the information exchange group was a useful procedure particularly in the early stages of its existence, but that a decrease in quality of papers accompanied the expansion of the groups. It was also noted that the exchange stimulated local seminars to discuss the papers circulated.

However, the arguments against the program were considerably more pronounced and convincing First, there was a tendency towards shoddy, unrefereed manuscripts. Second, after the expansion of a group, publication time through the IEG was equal to or greater than the normal journal publication time for a first rate short article; therefore, the preprints and the journal articles begin arriving at the same time. Third, it was suggested that the long delays in journal publications are often due to manuscripts of doubtful scientific value and to poorly written articles and not to any inherent problems with the journal publication system itself. Finally, there were a few comments on why the great rush in communication anyway, as if publication four to six months sooner would change the course of scientific research.

The experience of other fields with information exchange groups suggests that if the field of urban development models desires to become more rigorous and thorough in its communication, the formation of an IEG could be detrimental to this objective.

Individual Publication of Articles

As an alternative to the information exchange group, a new journal distribution system has been proposed by Brown, et al (1967) in "The Future of Scientific Journals." The authors propose that journals stop binding papers into issues and instead, distribute to each subscriber a stream of papers, abstracts and titles specifically selected to meet his personal and perhaps frequently changing desires." The authors develop a careful analysis of the present journal system including concepts of relevance and coverage of the stream of articles that an individual receives. A detailed proposal for a computer-based indexing and distribution system is also presented.

An information system and primary publisher of scientific reports, Communications in Behavioral Biology, initiated a computerized journal similar in concept to the above proposal in January, 1968; see *Science* Letters (1968). The journal consists of two primary sections—abstracts and indices of articles, and original articles. All articles are published as singles, prepunched for insertion in binders. Articles are preindexed using a hierarchical index, processed and printed, and are immediately available as preprints. The abstract and index section of the journal allows readers to select articles of interest, or readers may request that all articles in selected index categories or by selected authors be sent to them, either as preprints, or a month later in final form. The abstract section publishes abstracts of accepted articles in over twelve leading U.S. and foreign biological journals.

A journal distribution system such as the one described has considerable appeal. Not only does it improve one's ability to keep up to date with the highly relevant literature, but it also provides the journal article in a form that is convenient for use in research, as well as for filing and retrieval. The publication of journal articles in this form would certainly encourage the use of published articles in day to day research.

Communication Via Computers

The third area of new methods of communication is the use of computer terminals for communication among researchers. EDUCOM, the Interuniversity Communications Council, is currently encouraging technological progress in communications, and evaluating effectiveness and costs of academic communication; see Miller (1966). The kinds of advances being advocated by EDUCOM and similar organizations include the use of computer terminals to exchange computer programs and data and eventually to publish reports and articles. The potentially rapid development of this field merits the full participation and monitoring of individuals and organizations concerned with urban development models.

RECOMMENDATIONS AND CONCLUSIONS

The major thesis of this paper has been that the field of urban development models requires a rapid but careful expansion of its open literature in order to successfully continue advances in urban development models and related techniques. The status of communications during a typical period has been examined, together with the capacity of journal communication in the field. In addition, new means of communication have been reviewed. Based on these analyses and reviews, and drawing from the experience of other fields of science, it is urged that researchers in the urban development model field accept and espouse the basic communication system of science, that is, a formal, public, and orderly system of journal communication, that, in turn, generates a more permanent literature in the form of books. How can such a recommendation be implemented?

First, a major responsibility lies with the universities, particularly as the research efforts of planning agencies and consultants during the past ten years are more and more assumed by university research personnel. University researchers must by their own example lead the way to this proposed scientific communications system both through complete and rigorous reporting of their own research and through the synthesis and detailed review of the past ten years' advances. Furthermore, the universities must accomplish this goal by teaching the coming generations of scientists to accept responsibility toward information and communication, not grudgingly and with half heart, but fully and constructively.

Second, planning agencies, consultants, and research institutions must report full and rigorously on the application of methods and models, development of new techniques, and their current problems and requirements for new methods. These reports must be made in the open literature or through documents available in the Clearinghouse for Federal Scientific and Technical Information or similar means.

Third, funding agencies such as the Department of Transportation and the Department of Housing and Urban Development should adopt scientific criteria in the organization of research programs, award of contracts, administration of research, and the form of research products. In this regard, public reports through the regular literature should be one form of contract reports on research studies, instead of confidential reports to the agencies. This procedure would increase the quality of research through regular refereeing procedures already established, as well as making research readily accessible. In this regard, the grant and contract awarding procedures developed by the National Institutes of Health and the National Science Foundation certainly deserve serious study as models for funding research projects.

Finally, professional and academic organizations including the Highway Research Board, American Institute of Planners, Regional Science Association, and the American Society of Civil Engineers need to set a new level of standards to promote fuller reporting of research and methods development, and to consider more carefully their own vital publication roles.

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Appendices

APPENDIX A

AGENCY DESCRIPTIONS OF URBAN DEVELOPMENT MODELS

The descriptions of models used by their agency and comments on their usage by the fifteen agencies who replied in some detail to the specific questions posed in the survey of the use of models and data processing are reproduced below. The variations in agency experience will be apparent to the reader. Some agencies are reporting on operational models used regularly in their work. Others are reporting on models currently being developed and have not yet had operational experience. There is also considerable variation in the use of consultants versus agency staff for model development and operation.

The agency replies reproduced below are in response to these specific questions.

1 Model Name and Description Give a brief description of the purpose and scope of the model.

2. Source of Model. Was the model developed in-house, supplied by another agency, by a consultant, or from some other source?

3. Use of Model in the Planning Process How was the model used—for analysis, projection, plan evaluation, etc? How often has it been used?

4. Inputs to Model. Were the data required for the model readily available within the agency, or was special data collection required? If so, what kind?

5. Computer Usage. What computer was used for the model, where was the computer facility located; and were agency or other personnel responsible for computer operations?

Agency: **Baltimore Regional Planning Council**

Model Name and Description· Baltimore Land Use Model (BALTLAND) distributes population and employment throughout the planning region and computes related land utilization. The program operates in sequential iterative periods, allocating predetermined regional increments to small areas. Seven categories of land use, vacant land, and employment are accommodated.

Source of Model: Consultant with significant in-house support

Use of Model in the Planning Process Used in plan design. Different development policies were tested using constant region-wide population and employment forecasts. Three discrete plan alternatives resulted and were presented to policy makers. This procedure has been followed once.

Inputs to Model Land use data were readily available within the agency for two-thirds of the region. Aerial photos were reviewed in the office for the remaining area. Employment data by location were obtained from secondary sources and required considerable staff time.

Computer Usage: Control data 3600. IBM 7094. Consultant and commercial service bureaus responsible for computer operations. Agency handled most key punching of data.

Model Name and Description Industrial Projections Model 1. To project total regional industrial activity by employment. Industrial Projections Model 11. To translate regional employment projections to estimates of number of firms by behavior category. Industrial Projections Model 111 To allocate firms to transportation district by matching behavioral groups with policy characteristics of the locations.

Source of Model Model 1—presently supplied by another agency, expected to be developed in-house during coming work program Model 11—in-house. Model 111 —majority of work in process by consultant—will soon be taken over by this agency.

Use of Model in the Planning Process Model 1—primarily projection will be used for plan evaluation. Model 11——projection analysis and plan evaluation. Model 111—primarily plan evaluation (all three models currently being used for the first time).

Inputs to Model Data: Model 1—secondary sources used by the agency that developed model. Special data manipulation but not special collection Model 11—secondary sources used, considerable data manipulation required. Model 111—data available in agency.

Computer Usage· IBM 1460/IBM 7094/Control Data 3600. Primary output produced by consultants. Graphic display developed with agency personnel.

Model Name and Description Retail Market Potential The model is designed to estimate retail market potential in terms of estimated annual sales volumes, of large-scale retail centers. It does so by evaluating a region-wide retail system against a given highway network, population, and disposable income distribution.

Source of Model This was adapted from the Bureau of Public Roads Gravity Model by a consultant Techniques for evaluating model output were jointly developed by the consultant and the agency.

Use of Model in the Planning Process The model has been used to *design* the commercial element of one land use plan and subsequently used to *evaluate* the commercial element of another.

Inputs to Model. Data inputs required are demand (a function of population and median income), supply (retail floor space) and the linkages between the two (driving times over the highway net). Population and income data were developed within the agency from secondary sources Travel times were available from a transportation study. Retail floor space required a special field survey.

Computer Usage The computer utilized was the IBM 7090/7094. Consultants were responsible for its operation.

Model Name and Description· Metropolitan Sewer System Model. To be used in the design of portions of a sewer system, given land use data and constraints of the natural land features This model is now being designed.

Source of Model Consultants are designing the model in accordance with an in-house proposal

Use of Model in the Planning Process It will be used for evaluating the effect of alternate land use patterns on utility requirements Determining the implications of alternate sewer systems on land use also is an anticipated use.

Inputs to Model: Data will be readily available within the agency or from member agencies. Considerable work may be required to put data in a usable format.

Computer Usage: Not decided.

Model Name and Description: (a) Design-day participation is specific outdoor recreation activities (DDPRA). This model is composed of several submodels, one for each selected recreation activity It produces planning data for small areas of the region. Used as input to (b). (b) Recreation trip distribution model (RTDM) applies a form of gravity model in estimating the destinations of recreation trips by predominant activity. Analysis from model results provides information on intensity of activity by location. Model produces target date supply requirements for locations.

Source of Model. Conceptual development—in-house. Regression analysis and gravity model application—consultant

Use of Model in the Planning Process: Plan design: Basis for interagency discussions regarding physical plan elements, particularly with specialists in recreation and park activities Used to aid specialists outside agency in making land acquisitions decisions. Several runs have been made during past year's planning effort.

Inputs to Model Recreation data available from secondary sources, most of which in other government agencies. Supplemental verification checks from aerial photos, in-house. Population and socioeconomic projections produced, in-house.

Computer Usage. IBM 7094, consultant

Model Name and Description: The Baltimore Model—1962. This model or series of related submodels was given no name It was a significant step however, in the development of projection techniques for transportation studies See Baltimore Regional Planning Council, *A Projection of Planning Factors for Land Use and Transportation,* by Alan M. Voorhees & Associates, Inc., and Wilbur Smith & Associates, March, 1963. Given 1962 traffic generation and attraction factors (land use, population, and employment for small areas) the model generated similar characteristics for 1980. It was an accounting type model which operated within overall regional forecasts

Source of Model. Consultant

Use of Model in the Planning Process: Used for projection of data by small area for transportation system analysis

Inputs to Model: Economic data from secondary sources. Land use data compiled from maps in member jurisdictions School enrollment from secondary sources.

Computer Usage: None—a hand allocation process was used—consultants responsible

Agency: **Bay Area Transportation Study Commission**

Model Name and Description: PLUM (Projective Land Use Model): A BASS I, Lowry type model designed to locate residential population, population serving employment, housing units, and acreages associated with these activities; will operate incrementally and time recursively. SPILLOVER. A model to project county level two-digit SIC industries. BALFLO (Industry location model—P. J. Study). MHS

(Modified Herbert Stevens Model). Two versions—equilibrium and growth. Residential activity location model.

Source of Model: PLUM. BATSC modification of BASS I model (Lowry type model). SPILLOVER: BATSC design and development. BALFLO: MHS (University of Pennsylvania, Prof. Britton Harris).

Use of Model in the Planning Process. Models are in developmental stage. Nothing can yet be said about use experience

Inputs to Model: With few exceptions the data collection program supports the model input demands. Special data required were usually of the construction costs type.

Computer Usage: All models are to operate on a 65K CDC 3800 computer located at a service center approximately 45 miles from staff offices. BATSC staff will specify model runs.

Agency: **Chicago Area Transportation Study**

Model Name and Description The CATS Density-Saturation Gradient Model for Land Use Forecasting. The purpose of this model was to forecast land use by major categories (*i.e.*, residential, commercial, manufacturing, public open space, public buildings, transportation, communications, and public utilities and streets) for the Chicago Metropolitan Area by square mile traffic analysis zones.

Source of Model. This model was developed at CATS by its research and planning staff and is completely documented in a technical report, *Land Use Forecast,* prepared by John R. Hamburg and Robert H Sharkey.

Use of Model in the Planning Process The model was used to forecast land uses, from which trip generation activities could be derived and ultimately converted to future traffic behavior via the opportunity model

Inputs to Model This model necessitated a complete land use survey and population inventory in 1956 in order to provide these inputs to the development of the forecast

Computer Usage This model was not programmed for computer, and necessitated only data processing on EAM type machines.

Agency: **Cleveland-Seven County Transportation-Land Use Study**

Model Name and Description Direct Trip Allocation Model (see description under entry for New York State Department of Public Works).

Source of Model The model was developed by the Bureau of Planning, Subdivision of Transportation Planning and Programming of the New York State Department of Public Works, and is being utilized with only minor alterations.

Use of Model in the Planning Process: It is anticipated that the model will be used extensively in the near future to allocate projected urban activities. It will provide inputs for a trip distribution model and a "traditional" urban planning program. It will serve as a vehicle for evaluating certain aspects of both transportation and land use proposals Only preliminary allocations have been attempted thus far.

Inputs to Model Input requirements were satisfied by study transportation planning data files.

Computer Usage· A CDC 3200 in-house installation has been used for testing purposes and output processing. A CDC 3600 at an out of town data center has been used for full scale model operations. A local transmission system is utilized for access to the 3600, so that the operation is very similar to an in-house one

Agency: **Detroit Regional Transportation and Land Use Study**

Model Name and Description.

Regional Allocation Models

a. The Employment Distribution Model will allocate employment to approximately 100 sub-areas in the region The zonal variables that are contemplated as being relevant are· Labor force accessibility, customer accessibility, accessibility to external trade, public service levels, land value, and industry mix. Of particular importance is the attempt to make employment location sensitive to the characteristics of the resident labor force through the accessibility measure

b. The Population Distribution Model will allocate the regional increment of population over a time period to the 1400 zones in the region and will produce by zone the characteristics of the population by life cycle group, income and possibly educational attainment and occupation. The generation of such characteristics for the region as a whole (through the regional forecast models) will be relevant here. Sub-models for generating income distribution and automobile availability within the zone will be developed. The final models for both the resident population and employment distribution will be merged into a singular allocation model which will be sensitive to policy variables implied in the plan alternatives. The models will be run in five year increments and, hence, incremental area policies can be introduced in a temporal sequence.

Facilities Model

The Facilities Model is essentially an impact analysis model. It will measure the effect of new land use and activity distribution on the sewer and water systems through a measure of system capacity by area, peak design capacity needed by area Generation factors for land use type will be developed and applied to zonal distributions and the effect on the existing system and new systems measured. Unit cost contours for development will be produced for the given system assuming certain operating characteristics. The facilities model will also generate a level-of-service index by zone as an input to the regional allocation model.

Environmental Impact Model

The regional plan that we hope to develop will be sensitive to environmental design quality To accomplish this, we are developing a typology of environmental units which analytically describes the component characteristics of an area. Such typology will completely describe the entire region and assign through intuitive and objective measurements a quality rating to the environmental unit. Development of alternative plans will be influenced by the desire for change towards alternative environmental unit types, and the development of the future plan will be measured against criteria for such change The method used here is sufficiently analytical and capable of reproduction to be termed a model. The value of this is in the ability to foretell the characteristics of an environmental unit implied in a plan alternative. Suboptimization Models for regional subsystems in the areas of industry, commerce, housing, and recreation will be developed to refine a chosen plan alternative. The development of such models will occur in the later stages of the planning program.

Agency **Delaware Valley Regional Planning Commission**

Model Name and Description: The Activities Allocation Model is a deterministic computer simulation of future urban development that is sensitive to changes in transportation policies Variations in new freeway and transit networks, tolls, fares and parking charges, may be input to obtain variations in projections of future development. The model is recursive, proceeding in steps from the base year to a target year. It consists of seven major submodels, each determining the location of a given type of activity—residential, industrial, or commerical—or the amount of land that an activity uses The submodels are generally nonlinear regressions calibrated individually on 1950 and 1960 data.

Source of Model· The model was constructed within the agency with additional help on a consulting basis from Britton Harris of the University of Pennsylvania; and the Consad Research Corporation between July 1964 and October 1965

Use of Model in the Planning Process. The model was used to project intra-regional location and land use in 5-year increments in 1985 for three alternative transportation plans. To date it has only been used to provide projections for these three plans. These projections provide the inputs to the traffic simulation models.

Inputs to Model. No special data collection was required for the model. It used 1950 and 1960 population census data, 1960 employment data from the Bureaus of Economic Security of the two states, 1950 manufacturing employment data from a special data reduction done for other purposes, and land use data collected by the agency.

Computer Usage: The primary computer used was an IBM 7094. An in-house IBM 1401 was used for input-output to the 7094 and for manipulations of basic data files. All programming was done by the agency's programming staff

Agency **Eastern Massachusetts Regional Planning Project**

Model Name and Description Empiric Land Use Distribution Model. Purpose. To forecast the consequences of selected policy actions The consequences are output in terms of population and employment. The selected policy actions are improvements to highway and transit systems and reservations of land for any purposes and sewer and water service levels.

Source of Model Model developed by Traffic Research Corporation (now Peat, Marwick, Livingston) under contract Close technical policy direction was supplied in-house. There was also key in-house participation in the critical area of calibration of the production version

Use of Model in the Planning Process Projection: 10 production runs. Analysis (as design tool). 5 production runs. Model outputs are used as inputs for another independent plan evaluation technique.

Inputs to Model (1) Population—total & families by income; (2) employment—five 1 digit SIC categories; (3) highway and transit skim trees, (4) land areas for five categories; (5) sewer and water service level codes.

Computer Usage. IBM 7090-94 Mod. II. Consultants responsible for computer operations.

Agency: **Los Angeles City Planning Department**

Model Name and Description· (a) Population Projection Model—projects population by age, sex and color It then apportions the populations to subregions. (b) Residential Location Model—Allocates projected households by type to subregions.

Source of Model (a) Population Projection Model—Al Chevan of the Penn Jersey Transportation Study. (b) Britton Harris, University of Pennsylvania—an adaptation of the Herbert/Stevens model.

Use of Model in the Planning Process (a) Used to obtain overall estimates (projections) and will be used to test various plan alternatives. It is being run about once every two weeks (b) Still under development.

Inputs to Model: (a) Data were readily available but because of quantity much formatting work was required. (b) Basically census and land use data are used. Exogenous projections required are quite difficult to prepare.

Computer Usage: (a) IBM 360 model 30—as a 1401 emulator (in-house). (b) IBM 7094 and 7040—rented computer time from different organizations.

Agency **New York State Department of Public Works**—Subdivision of Transportation Planning and Programming

Model Name and Description: A Direct Trip Allocation Model. The purpose of this model is to allocate future urban development over a region taking into account such factors as accessibility, present vacant and developed land, exogenously supplied asumptions pertaining to future land use development and operational policies defining the availability of land for development The model includes a provision for output which is directly compatible with the input requirements of the traffic simulation and assignment programs.

Source of Model: This model was developed by the staff of the Bureau of Planning in the Department of Public Works

Use of Model in the Planning Process The model is used for projecting future development and determining travel demand. It has been used as a research tool and in planning and evaluating transportation systems

Inputs to Model: The model requires the following input data· (a) Future population by the appropriate temporal increments (2, 5, and 10-year periods); (b) future residential trips by the same temporal units; (c) future nonresidential trips by the same temporal units; (d) base year land use by traffic analysis zone; (e) base year population by traffic analysis zone, (f) base year travel data by traffic analysis zone; (g) new residential density of future developed land by traffic analysis zone (optional), (h) new residential trip end density by traffic analysis zone (optional); (i) minimum time path trees from transporation network assumed to be extent during period of growth Data required for the model had previously been collected by the Department or were readily available elsewhere.

Computer Usage: The model was programmed originally for the IBM 7094. It is now available for use on the Burroughs B-5500. Since it is written in FORTRAN, it can be readily reprogrammed for other computers, such as the IBM 360. Subdivision personnel are responsible for preparing program input files and parameter cards The computer, a Burroughs B-5500, is operated by the Department's Bureau of Electronic Data Processing. If run on service bureau hardware, the same arrangements would apply.

Agency: **Puget Sound Regional Transportation Planning Program**

Model Name and Description: (a) Multiple regression model to distribute population gain to analysis areas in the region (single family dwelling units and multifamily structures with less than 20 units). (b) Multiple regression model to estimate population loss in analysis area in the region (single family dwelling units and multi-family structures with less than 20 units.) Special analyses were made to estimate the distribution of population in structures with more than 20 units: hotels, motels, etc. (c) Cross-section multiple regression models to estimate changes in the "repair services," "construction," and "medical, religious and institutional" employment categories Special analyses were made to estimate the distribution of other employment categories.

Source of Model: All models were developed in-house.

Use of Model in the Planning Process. The models were used primarily for forecasting. Two alternative urban development patterns were delineated

Inputs to Model· Data from a land use survey and a home interview origin and destination survey were utilized supplemented by data from the U S. Census and local planning agencies

Computer Usage An IBM 7090 was used to the multiple regression analyses Personnel responsible for computer operations were employed by the Transportation Study.

Agency: **Regional Plan Association** (New York)

Model Name and Description· We do not have any one model, rather, the work proceeds in two stages *first,* a semi-handicraft density gradient method (which we may computerize using Bruce Newling's parabolic density gradient) is used to develop an interim allocation of future employment and population, then, the straight BPR Gravity Model and a land-use sensitive Modal Split model are used to evaluate the transportation implications of several variants of this interim allocation; *second,* Britton Harris's adaptation of the Herbert-Stevens model is used to develop a more refined distribution of the population by income, household size, etc., given certain assumptions of future employment and transportation, we may also try to adopt Harris's Retail Location model to distribute certain types of population-related employment.

Source of Model Source of Gravity Model—BPR, our only innovation is to have calibrated it on 1960 Census Journey-to-Work data, and to stratify by income group (3 incomes). Source of Modal Split model—In-house with consultants (Traffic Research Group of Peat, Marwick & Livingston); takes account of employment density at place of employment, net residential density at place of residence, trip time difference, trip cost difference, service factor, as well as income (if used with income-stratified trips). Source of density gradient allocation—in-house.

Use of Model in the Planning Process: The two transportation models were used for analysis, projection, and evaluation. The Britton Harris model is still in the analytic stage. The density gradient method is useful for analysis and projection.

Inputs to Model. Population and journey-to-work data were taken directly off Census tapes. Employment data by small area were laboriously constructed to match published data by county, etc. Land use data (specifically, net residential land) were partly constructed from aerial photography, maps, etc. Time-distance data were constructed from various sources

Computer Usage: Gravity model—IBM 7094. Consultants responsible for all computer work.

Agency: **Southeastern Wisconsin Regional Planning Commission**

Model Name and Description: (a) Regional Economic Simulation Model—conditional forecasts of economic activity. (b) Land Use Simulation Model—design of public policies to guide land development. (c) Land Use Plan Design Model—design of land use plans.

Source of Model: In-house—Systems Engineering Division

Use of Model in the Planning Process: First two models were used in land use-transportation study. Design model is still experimental.

Inputs to Model: Partially available; partially special. Special data were primarily cost data.

Computer Usage: IBM 1620 at University of Wisconsin-Milwaukee. Agency personnel.

Agency: **Southwestern Pennsylvania Regional Planning Commission**

Model Name and Description: Opportunity Accessibility Model (see description under entry for New York State Department of Public Works).

Source of Model: Model supplied by New York State Department of Public Works; however, basic logic of model has been reprogrammed by our staff for our own computer.

Use of Model in the Planning Process Model has not been used yet.

Inputs to Model: Coarse data are available in our agency. Initial runs will be made with these data. As soon as new land use data are available from our new series of inventories, they will be used

Computer Usage: Honeywell 200 computer is used. Located at our offices. Agency personnel are responsible for computer operation.

Agency· **Twin Cities Metropolitan Planning Commission** (Minneapolis-St. Paul)

Model Name and Description: Land Use Model—Made intrametropolitan allocations of predetermined housing, population and employment (8 different groups) totals. Used to test alternative sets of assumptions and their role in shaping future physical development of metropolitan area and to derive statistical and geographical pictures of final plan land use and selected supporting facilities. Actually a program to link a series of linear regression equations.

Source of Model. Supplied by consultant after Commission staff had developed basic regression equations.

Use of Model in the Planning Process Used to derive alternative distribution patterns based on different sets of assumed policies, *i.e.*, to show the physical development results of policies planning—run for each of four alternatives and for final plan for total of five different patterns.

Inputs to Model: 1962 housing units, land quality, population per housing unit; medium income; eight categories of employment; sewer, and open space assumptions and highway-transit networks—land use data collected by field and air photo survey; employment obtained from outside agency, rest of information worked up by staff from published sources.

Computer Usage: IBM (7094)—Arlington, Virginia—Consultant responsible for computer phase.

Agency: **Alan M. Voorhees & Associates, Inc.**

Model Name and Description Employment and Population Distribution Models (a) multiple regression; (b) differential shift—simultaneous equation. Market Potential Models: Gravity model formulation used to evaluate: (1) retail structure —metropolitan level; (2) recreation activities—metropolitan and state-side level.

Source of Model: All of above developed in-house under contract by a variety of public and private organizations.

Use of Model in the Planning Process. Land Use Models—projection—different versions; used 10-15 times. Market Potential Models—plan evaluation; used 4-5 times.

Inputs to Model: Data not normally available. Required inputs are: change in population, change in employment, land availability, sewer, highway service. Most data obtained as part of Transportation Study.

Computer Usage: Normally 7090/94. Switching to IBM 360/40. In-house operation.

APPENDIX B

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Under the terms of its Congressional charter, the Academy is also called upon to act as an official—yet independent—adviser to the Federal Government in any matter of science and technology. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental agency and its activities are not limited to those on behalf of the Government.

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Supported by private and public contributions, grants, and contracts, and voluntary contributions of time and effort by several thousand of the nation's leading scientists and engineers, the Academies and their Research Council thus work to serve the national interest, to foster the sound development of science and engineering, and to promote their effective application for the benefit of society.

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