Science and Human Affairs

Research Activities

The major goals of the Science and Human Affairs Program are to develop more effective research methods for comprehensively studying complex societal problems and to communicate those methods so they are available for wider use by public and private institutions facing problems needing study. One of the major projects sponsored in this Program, the Urban Systems project, is under way at Battelle-Frankfurt.

URBAN SYSTEMS STUDIES

The Urban Systems project, described here by Messrs. Bauer, Meise, and Wegener, is directed toward improving decision making in urban planning. The approach being studied incorporates elements of systems-analysis methods as well as those of social sciences by combining an urban simulation model (POLIS) with a formal evaluation procedure (MAUT).

The Need for Research

Today, most large cities all over the world are experiencing serious problems: increasing size and complexity of the urban agglomeration, irrational use of urban land, noisy and overcrowded city centers, urban sprawl, choked traffic arteries, insufficient public transport, polluted air and water, and inefficient public services. All of these problems are side effects that stem from the pursuit of goals too narrowly oriented toward economic growth and technological progress. With the rapid decrease in the social and physical quality of urban life and with the growing dissatisfaction of citizens with their urban environments, conflicts between different social and ethnic groups arise; these conflicts are further aggravated by rapid changes in attitudes and values.

The inability to cope with these problems indicates that we are badly equipped to understand, to plan, and to control complex social systems such as large cities. There is a need for a new capability for comprehensive planning that encompasses the urban environment as a whole, that strives toward an integrative view of the various dimensions and aspects that make up urban life, and that considers the broad range of consequences that follow from actions, both planned and unplanned, for the different groups and for the society at large.

The overall goal of the Urban Systems project is to provide an approach for improving decisions in urban planning. Specifically, the following objectives have been adopted:

- Understanding the complex mechanism of the urban system and the multifaceted consequences arising from public planning actions
- Laying open the process of urban planning, the actors involved, their influence and capacity to effect decisions
- Exposing the structure of goals and expectations of people and the conflicts arising between different groups of interest
- Developing formalized instruments for urban planning
- Disseminating information on results and experiences.

The research project relies as much on the analytic methods of systems analysis as on the value-oriented methods of the social sciences. Systems analysis offers an approach to handle complex sets of interrelationships as they exist in an "urban system" in a theoretically founded and flexible manner. It supplies the instrument for organizing and understanding and directing changes in the behavior of the urban system. Social-science methods provide a means to expose attitudes and value structures of people. These methods aid in developing procedures for identifying goals of urban life, for exposing conflicts, and for evaluating strategies to move into a desirable urban future.

The Approach

The methodology explored in the research project is based on the following concept: A digital *simulation model* of urban development is combined with a formal *evaluation procedure* to initiate an iterative *learning process.*

The *simulation model* of urban development describes the behavior of the city system as it responds to various stimuli (planning decisions and unplanned "market" developments) accruing over time. Representing the complex, dynamic spatial system of a city by means of a mathematical model allows the experimental study of the behavior of the city within a laboratory setting; alternative planning actions and assumptions about unplanned changes can be tested and their probable consequences described without requiring real-world experimentation.

The consequences of these alternatives as they are predicted by the model are the inputs to an *evaluation procedure,* a guideline for assessing the relative merit of a plan. It is based on the Multiattributive Utility Theory (MAUT), a decision-aiding technique relying on multidimensional scaling of utility[1]. MAUT proceeds by decomposing a complex object of evaluation (a plan) into its independent dimensions (attributes) by way of a goal hierarchy. A composite "value index" that expresses the plan's overall utility is arrived at by individually evaluating the attributes by means of utility functions, by weighting the importance of the attributes with respect to the higher level goals, and by aggregating them by a formal additive composition model.

The results of the evaluation may suggest that the plan or the goal structure underlying the evaluation be modified. Also, it may become apparent that certain

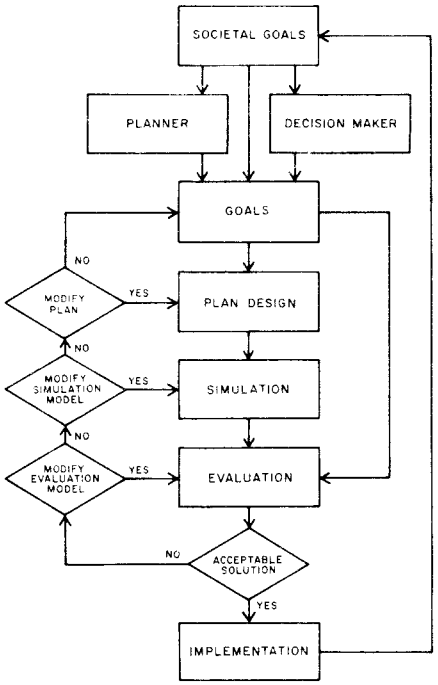

FIGURE 1. Simulation and Evaluation.

aspects of the simulation model need to be changed. Thus, a new sequence of simulation and evaluation will begin, in the course of which the participants will learn by gaining better information about the planning problems involved, their many implications, and the possible conflicts arising from them. This learning process – the iterative application of the simulation model in combination with a formal evaluation procedure – can be characterized as follows (Figure 1):

Step 1. Participants of the planning process define goals to be achieved by urban development planning.

Step 2. The "planner" is guided by these goals in formulating the "plan" in the process of design.

Step 3. The consequences of the plan are predicted by the simulation model.

Step 4. The consequences are "learned" by checking them against the predetermined criteria (goals in the formal evaluation process).

Step 5. The plan is adopted if the criteria are satisfied. If not, the process is repeated.

Progress of Work

The Simulation Model

Large, computerized simulation models for urban planning have a long, not always undisputed, history. From the transportation studies of the late fifties to Forrester's "urban dynamics", much effort was spent on the attempt to simulate urban processes with the help of digital computers. The results, for many reasons, were disappointing, and many ambitious projects were abandoned when they did not yield immediate success(2). Moreover, with the advent of the concept of participative planning, urban modeling became for a long time associated with being narrow-minded, conservative, and technocratic. Only recently has a new interest in comprehensive urban models arisen.

Since 1969, Battelle-Frankfurt has been developing its own urban simulation model, named POLIS. It is aimed at being a balanced representation of the major aspects of spatial urban development. It contains many traditional elements of earlier models; the urban area is spatially disaggregated into geographical subunits (zones) for which status variables representing stocks or activities are collected. The zones are connected to each other and to the surrounding region by transportation networks (public transit, highway), which are coded by links. The model contains a transportation section, a developers' market section, and a demographic section, as do many other models. However, it also contains some features which have not been present in most earlier models:

- The model contains an extensive policy section that allows the user to introduce various kinds of time-sequenced and spatially disaggregated action programs (e.g., zoning, housing construction, industrial development, educational, social, recreational, and transport infrastructure).
- The model also incorporates and exhibits side effects of major physical changes (e.g., noise, pollution, safety, distribution of costs and benefits between social groups).
- The model has been designed for use in an interactive computer environment.

The POLIS model has been applied for the long-range planning of the cities of Vienna and Cologne under research contracts from the City of Vienna and the Housing Ministry of the Federal Republic of Germany.

For use in the present project, the latest version of the model produces a continuous "historical" record of all successive states of all zones. This record is placed on a special file which constitutes the interface between the simulation model and the subsequent evaluation procedure.

The Evaluation Method

The application of the proposed evaluation procedure, MAUT, requires the goal space to be completely specified by all of its elements in the form of a hierarchy.

There are two ways to define goal structures: the synthetic and the analytic strategy. The synthetic strategy relies on methods of correlation and attempts to construct a hierarchy from the bottom up. The analytic strategy, with the aid of dual semantic relationships, constructs a hierarchy from the top down.

The project team adopted the analytic strategy because of its predominance in

literature and its economy in application. The data base was derived from group experiments in which two different procedures for defining goal structures, the associative goal-defining process and the analytic goal-defining process, were used. In the first procedure, associations related to the personal experience of the experimental subject provide the basis for exhibiting goals and criteria of urban life. In the analytic goal-defining process, the goal hierarchy must be derived by the experimental subjects themselves by logical deduction. Also, relevant literature was searched for useful hierarchies.

To demonstrate how the proposed evaluation method worked and to determine its role in the overall learning process, the method was subsequently applied in a number of experiments. Alternative plans and their consequences were assumed, and panels were asked to evaluate them according to a hierarchy indicated by the POLIS model. The different panels weighted the attributes of the hierarchy according to their specific goals; they assigned utility functions; and composed the individual elements of evaluation into an overall judgment about the plans. Thus, the specific goals and expectations of the different groups with respect to urban life, as well as the quality of the plans with respect to these goals, became tangible.

This evaluation is the basis of the learning process, viz., by evaluating and learning about a plan, the interests and conflicts, goals and plans may be adapted to one another in an iterative process that will lead finally to more rational decisions.

As suggested by the analysis, values should not be attached to elements of the hierarchy in its construction. Rather, the hierarchy as used for MAUT should be seen as a descriptive model of the city. Consequently, conflicts are not implied in a hierarchy but become tangible only when goals are established, i.e., when group-specific weights and utility functions are assigned to the elements of the hierarchy. That is to say, in the development of a hierarchy the function of different groups is to contribute to the description of the urban system; in the evaluation of the system, their function is to point out specific goals of the groups.

When this point of view is adopted, indicators of three basic aspects of conflict can be developed from

(1) Differences between the weights given by different groups to the elements of the hierarchy,

(2) Differences between the utility functions assigned by different groups to the elements of the hierarchy, and

(3) Differences between the public and the planning authority.

The Learning Process

The most recent phase of the research project focused on the critical task of integrating the simulation model and the evaluation procedure to form an operational framework for the intended learning process. This resulted in the development of a computer program that allows submission of the results of simulation runs as taken from the interface file to the evaluated goal structures of one or more evaluation groups. The program computes utility values for all levels of the goal hierarchy, for all zones or any aggregates of them, and for each evaluation group. The utility values are edited and presented in computer tables, maps, and graphs. In addition, comparisons between different plans, or between their evaluation by different groups (i.e., potential conflicts), can be tabulated or mapped.

For the thorough testing of this new planning tool, a special "experimental" city of manageable size had to be found. The City of Darmstadt (population 150,000) was selected because of its closeness to Frankfurt and the availability of data. The Darmstadt data, having been assembled and coded in the way required by the POLIS model, will form the experimental setting for a workshop held at Battelle-Frankfurt in September, at which research staff from other Battelle laboratories together with outside guests will participate in a series of simulation-evaluation exercises.

Outlook

It is planned to conduct similar experi-

Volker Bauer (center) a psychologist, joined Battelle-Frankfurt in 1972. He is interested mostly in formal models in psychology. His main working area within the Urban Systems Studies project is the elaboration and testing of evaluation procedures and decision-aiding techniques. He received his degree of Diplom-Psychologe from the University of Hamburg in 1971. Besides his involvement with Battelle, Mr. Bauer is currently lecturing in environmental psychology at the University of Hamburg.

Jörg Meise (left) since joining Battelle-Frankfurt in 1970, has worked mainly with the urban-planning group on the POLIS model and the Urban Systems Studies project. His primary areas of interest are quantitative methods for urban and regional analysis. He received his degree of Diplom-Ingenieur in architecture from the Institute of Technology of Vienna, and his M.C.P. in city and regional planning and M.S. in transportation engineering from the University of California, Berkeley.

Michael Wegener's interests are directed toward the application of simulation and other modeling techniques to the field of urban planning. He came to Battelle-Frankfurt in 1969, and has since been working with the POLIS group. His prior experience includes work in architectural offices, 3 years of teaching at the Technical University of Berlin, and other teaching assignments. He received his degree of Diplom-Ingenieur in architecture from the Technical University of Berlin in 1966.

ments with more panels of various backgrounds, including practitioners from municipal planning administrations.

Also, the theoretical foundations of the learning process will have to be studied further. Problems encountered in the construction of the goal hierarchy will lead to an improved way of constructing hierarchies or, more likely, to the search for an alternative type of goal structure that more realistically represents the dynamic, ever-changing network of human attitudes and values.

Finally, there are strong hopes that the learning process can be made truly conversational by running simulation and evaluation simultaneously during a simulation session. With this operational mode, the planner will be able to evaluate his plan at any point, while it is being simulated; he may proceed from there with a modified plan or with a modified evaluation, or he may return to an earlier year of the simulation and start again with changed parameters until eventually he arrives at a satisfactory solution to his problem. It is hoped that this powerful tool will greatly enhance the creative capability of man to design an urban environment as a place for people.

REFERENCES

(1) See, among others, H. Raiffa, "Preferences for Multiattributed Alternatives", Memorandum RM-5868-DOT/RC, RAND Corporation, Santa Monica, Calif. (April 1969).

(2) For a more complete discussion, see Douglas B. Lee, Jr., "Requiem for Large-Scale Models", *AIP Journal* (May 1973).

Conferences

Dr. John N. Warfield, Senior Advisor at Battelle-Columbus, chaired a Panel on Urban Systems at the Joint Automatic Control Conference, Columbus, Ohio, in June, and served on a Panel on Model Validation at the Summer Joint Computer Conference, Montreal, Canada, in July.

Lectures

Mr. E. A. Eschbach, Staff Scientist at Battelle-Northwest, presented a lecture on Battelle's research on interactive computer systems at the Computer Simulation Conference, Montreal, Canada, on August 17.

Dr. Ahmed El-Mokadem, Associate Fellow, Community and Economic Development Group, Battelle-Columbus, presented lectures on

- "Structural Modeling and the Solution of Large and Complex Econometric Models", Conference on Systems Application and Forecasting, Lancaster University, England, in June.
- "The Systems Approach to Complex Societal Problems", Oxford University, England, in August.

New Appointments

Professor Uri Ra'anan, Professor of International Politics, the Fletcher School of Law and Diplomacy at Tufts and also an Associate of Harvard's Russian Research Center and of the Center for International Studies at M.I.T., began a 6 months' Visiting Fellow appointment at the Seattle Research Center on August 1. He will pursue research concerning conflict resolution in multi-ethnic societies, working interaction with interested members of the BSRC cluster in behavioral and social sciences and with study circles on these topics at the University of Washington.

Publications

Cassidy, Harold G., "Our Infinite World", *The Society of the Sigma Xi Newsletter*, VIII, No. 2 (Summer 1973).

Duncan, Gordon W., Hilton, Elizabeth J., Kreager, Philip, and Lumsdaine, Arthur A., *Fertility Control Methods: Strategies for Introduction*, Academic Press, New York and London (1973).

Figueiredo, J. Burle de, and Gabus, A., "Planners Confront Events: A Short Account of Battelle's New Development Planning Model EXPLOR-SIM", Battelle-Geneva for Institute de Desarrollo Economico (IDE), Madrid, Spain (Summer 1973).

Gastil, Raymond D., "Social Humanities", *Policy Sciences*, 4 (1973).

Hood, David, "In-Migration as a Component of Hawaii Population Growth: Its Legal Implications", Hawaii Legislative Reference Bureau (March 1973).

Kleinman, David S., "Fertility Variation and Resources in Rural India (1961)", *Economic Development and Cultural Change*, 21, (4), Part I (July 1973).