# Simulation, Evaluation, and Conflict Analysis in Urban Planning

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*Abstract*—Recent developments in urban simulation try to avoid failures of earlier models by being more open to changing problems, more aware of the social context of problems, and by paying more attention to user involvement. In this paper, a pragmatic approach is presented which combines dynamic simulation, multiattributive evaluation, and group participation. The approach consists of a combination of a multiperiod, multiregion, dynamic, digital simulation model of urban development with an evaluation model based on the multiattributive utility theory (MAUT). Iterative application of simulation and evaluation to planning alternatives by one or more planners, decision makers or interest groups leads to a learning process about the impacts of plans and the potential conflicts arising from them. The approach has been tested in a number of experimental workshops. It seems possible that the tools and procedures described in this paper form the nucleus of a *municipal simulation laboratory*. Work of the laboratory might follow two strategies: One would emphasize citizen involvement in group experiments, the other would attempt to simulate urban preference structures in a dynamic simulation model.

## INTRODUCTION

THE FIRST decennium of large-scale urban modeling has shown the typical characteristics of an emerging discipline: discovery, euphoria, overambitious plans, first failures, disappointment, total disillusion, and reorientation. Encouraged by the obvious success of transportation modeling in the fifties, urban researchers looked for ways to also represent the spatial distribution of housing and employment in mathematical models. Lowry's model of spatial equilibrium [1] became the predecessor for a generation of spatially oriented allocation models. Forrester's aspatial model [2] stimulated a second wave of time-oriented modeling efforts, the discussion of which spread far beyond the circle of professional urbanists.[1] However, many ambitious projects were abandoned when they did not yield immediate success. Moreover, with the advent of the concept of participative planning, urban modeling became associated with being narrow-minded, conservative, and technocratic. Lee in [4] stated the reasons for the failure of large modeling projects since Lowry.

However, Lee failed to notice that the reorientation in urban modeling which he propagated has been silently under way for quite a while. Together with new interest in complex urban simulation models a new generation of models is emerging which try to avoid the failures of their predecessors:

by being more open to changing problems, employing flexible, modularized rather than rigid bulk model structures;
by being more aware of the social context of problems being more value oriented, less technocratic; and
by paying more attention to user involvement utilizing advanced interactive techniques to incorporate human judgement and creativeness into the simulation process.

The integration of spontaneous human input into the simulation is to be seen as a reaction of the model builders to the experience that simulation models have almost never played a role in the down-to-earth municipal planning practice. While most of the objections raised by Lee against models could be put aside relatively easily as initial difficulties of a rapidly developing discipline, this experience pointed to a basic weakness of the whole model concept which could only be encountered by a basic reorientation. Today even a voluminous simulation model of the "third" generation as the River Basin Model [5] contains an extensive gaming sector in which spontaneous decisions of yet fictitious decision makers can be processed. Attempts to incorporate a simulation model in the local decision making process have been reported from Grand Rapids, Mich., [6], and from San Jose, Calif., [7].

In the following, a pragmatic model approach is presented which, in one integrated computerized planning instrument, combines

1) dynamic simulation of spatial urban development;
2) multiattributive evaluation methodology; and
3) group participation in a gaming environment.

The approach is based on the following concept: A digital simulation model of urban development is combined with a formal evaluation procedure to initiate an iterative solution finding process. The simulation model represents the behavior of the urban system as it responds to planning decisions and unplanned "market" developments; alternative planning actions and assumptions about unplanned changes can be tested and their probable consequences observed without requiring real-world experimentation. The results of the urban simulation may at any point in time be submitted to a formalized evaluation procedure containing not only one, but several goal or preference structures representing the interests of various social groups of the community. The procedure not only allows evaluation of straightforward indicators of system performance like housing quality, availability of services, or accessibility, but also the relating of these indicators to more general concepts of utility, such as quality of life. By using more than one preference structure potential conflicts likely to be caused by alternative plans may be exposed. The proposed participatory planning process consists of the iterative application of simulation and evaluation to planning alternatives by planners together with decision makers or interest groups. It is hoped, that by collectively learning about the impacts of plans and the potential conflicts arising from them it will be possible to arrive at solutions that best serve the interests of the community.

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[1] One example is [3].

## The POLIS Simulation Model

Since 1969, Battelle-Frankfurt has been developing an urban simulation model named POLIS. The POLIS model is the first comprehensive simulation model specifically designed for urban development planning in large cities of the Federal Republic of Germany. It is also the first such model practically tested with data of three cities (Cologne, Vienna, Darmstadt). POLIS is a dynamic simulation model of major aspects of spatial urban development. The urban area is divided into subunits (zones) the structure of which is represented by state variables. The zones are connected to each other and to the surrounding region by public transit and highway networks. Starting from the state of the city in the base year, the model simulates the development of the spatial distribution of population, employment, buildings and land use, as well as of transportation, as it responds to planning interventions by the city or other public agencies over a number of time intervals (periods), until a planning horizon is reached. Fig. 1 is a schematic representation of the aspects of urban development contained in the model and their most important interrelationships.

The POLIS model uses elements of earlier models developed mainly in the United States and adapts them to West Germany conditions. The transportation submodel, e.g., follows the classical scheme of trip generation, trip distribution, modal split and trip assignment. It, however, takes into account specific traffic conditions in German cities by an extensive public transit sector. In the developers' market submodel, the typical Lowry approach [1] which distributes housing as a function of the location of basic employment has been replaced by a sequence of incremental allocation algorithms controlled by multidimensional attractivity measures. Although the model is not a Forrester model [2], it recognizes the basic dynamic feedback structure introduced into urban modeling by *Urban Dynamics*.

In addition, the model contains some features which were not present in most earlier models:

POLIS allows control of spatial development by zoning and land use regulations;
POLIS contains an extensive policy section that allows the user to introduce various kinds of action programs;
POLIS also incorporates and exhibits side effects of major physical changes;
POLIS has been designed for use in an interactive computer environment.

Fig. 2 is a process diagram of the model showing major submodels, permanent files, and standard line printer output.

The simulation of a period begins with the analysis, description, and documentation of the state of the urban system (STATUS). The analysis starts with the simulation of traffic flows of the base year. Travel times computed in the traffic model are used to calculate accessibility indices of all zones which are a measure of locational advantage with respect to various activities and infrastructure facilities of the urban area and the transportation system available. From accessibilities and other zonal attributes for each zone attractivity indices are computed which serve to express the market demand for land by various urban activities.

Next, the allocation part of the model begins (ALLOK). First public action programs are executed. The model allows the introduction of time-sequenced and localized programs in the fields of housing construction, industrial development, educational, social, recreational, and transport infrastructure. Simultaneously with all construction programs, necessary local roads and parking facilities, with housing programs also service facilities like kindergartens, elementary schools, neighborhood shopping and recreation areas are provided. The remaining construction activity is distributed over the urban area following the market pattern of supply and demand by private developers within the restrictions indicated by the zoning plan. The likely distribution of private construction for each type of activity is estimated as a function of the attractivity and the available land of each zone. Displacement of one activity by more prof-

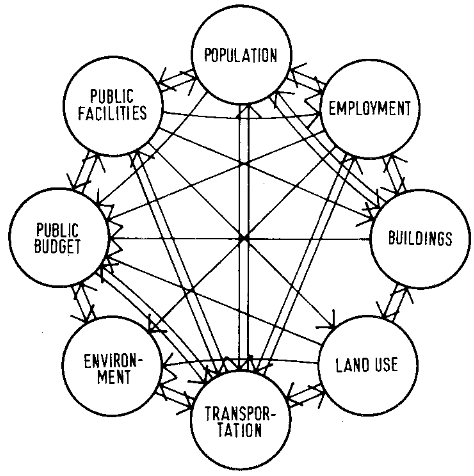


Fig. 1. Aspects of urban development.

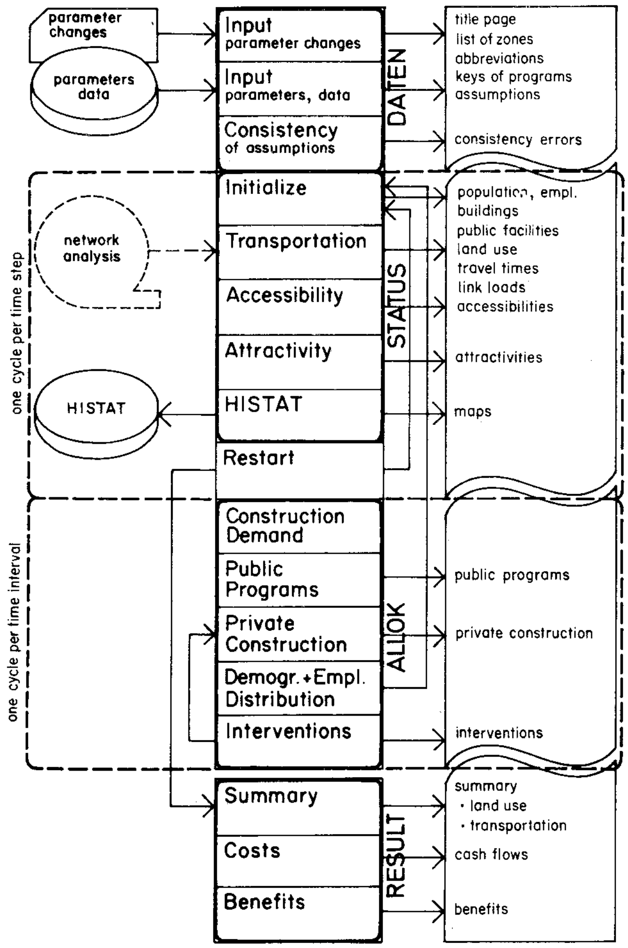


Fig. 2. The POLIS model (process diagram).

itable ones is effected in the model by demolition or by change of use of buildings. After simulation of private construction, population and employment projections are distributed across the available housing, commercial and industrial building stock, including the updating of the respective demographic, social, and employment distribution. Finally, the availability of local service facilities is checked against relevant standards. Where service is severely substandard, the city administration intervenes with a crash program.

This closes the simulation of the period. The state variables of the model have received new values. The model starts, with changed parameters and new assumptions, the simulation of the next period. This cycle is reiterated until the planning horizon has been reached, i.e., the last period has been simulated. For each simulated alternative the model gives detailed information about the development of population, employment, physical structure, transportation, and environmental quality of each urban zone. In addition, the costs of each alternative are accumulated and exhibited as cash flows between various groups of the city.[2]

## The POLIS Evaluation Model

Simulation models, powerful as they may be to represent complex systems, obviously have one basic weakness: they do not generate optimal solutions, they only describe the consequences of given solution alternatives. At first thought this seems to be a grave deficiency, especially when one considers the solution of a planning problem to consist of the selection of a strategy which is optimal by predetermined criteria, i.e., in an optimization problem. With simulation models, however, evaluation and selection of an appropriate alternative remain outside of the model. In the following paragraphs it will be demonstrated that this apparent deficiency actually constitutes one of the essential advantages of simulation techniques.

In fact, all planning models eventually serve to "optimize" the planned system. However, two strategies may be followed to approach this objective: optimization and simulation. Optimization models contain an explicit optimization algorithm which calculates an optimal solution with respect to predetermined criteria. Simulation models do not contain such algorithm; here the solution of the planning problem is approached experimentally by an iterative process of learning about the behavior of the system modeled under different conditions.

There have been several attempts to apply mathematical optimization to urban problems. However, they have, in general, not been very successful. There may be two reasons for this. First, available optimization techniques pose severe restrictions with respect to the number of equations and type of variables and functions. Second, and this is more relevant to the point, optimization requires as a first step the formulation of a goal function. Such a formulation, however, is much more difficult in socioeconomic or political problem areas than in the predominantly technoeconomic projects, for which one single or a few operational objectives usually suffice. Socioeconomic planning must deal with a superposition of many group-specific goal structures which are not independent of each other, and which change over time. Moreover, the knowledge about such goal structures is especially low at the beginning of a solution finding task.

The experimental character of the simulation, however, corresponds specificly with the iterative decision process of socioeconomic planning projects. Experiments with simulation models may be started without much prior knowledge about the planning problem itself, the constellation of goals or their potential conflicts. Evaluation and selection of alternatives remain outside of the simulation model. Instead, work with the model initiates a learning process about the interdependencies of the modeled system, about the consequences and interactions of planning interventions, which allows an iterative approach to successively "better" solutions.

This, of course, does not solve the problem of evaluation, but puts it more into focus. The results of a simulation are, notwithstanding the many value judgements implied in them, value free in a formal sense. It is only by evaluation that the results which really matter to the participants, their understanding of the problem and their configuration of interests are extracted from the large volume of information produced. Because the criteria of that selection are not known beforehand, the large volume of output is indispensable. This makes the processing of the results of a complex simulation model with respect to one or more multidimensional goal structures a problem itself; a problem of complex information processing that can be accomplished only by an efficient operationalized procedure. In the latest version of the POLIS model, the simulation model has been augmented by such a process. To this purpose, a formalized evaluation model based on the multiattributive utility theory (MAUT) has been developed.[3] In this model a complex object of evaluation (a plan) is decomposed into its independent dimensions (attributes) by means of a goal hierarchy. The attributes are individually evaluated by means of utility functions, weighted, and aggregated by a formal additive composition model. On each level of the hierarchy the utility of the plan with respect to specific aspects, on its top level the total utility becomes apparent. Thus it is possible not only to evaluate straightforward indicators of system performance like housing quality, availability of services, or accessibility, but also to view them within a larger framework, i.e. to relate them to attributes of other problem areas as well as to higher level more general goals or concepts of utility, such as quality of life.

Differences between the value structures of different groups involved in the planning process are expressed in the model by the same hierarchy used with different weights and utility functions. If not only one, but several goal or preference structures are used, it is possible not only to compare different plans but also to show differences in the evaluation of the plans by different groups. Thus, potential conflicts that may arise from a plan may become apparent [10], [11]. For use with the POLIS simulation model a goal hierarchy has been adopted the elements of which are implied by the aspects of urban development contained in the POLIS model (Fig. 3). The top level goal of the hierarchy is "the city" as it changes during a simulation. The elements on the lowest level of the hierarchy are attributes, i.e., quantitative properties or indicators for intangible properties of the evaluation object; in this case they are data about the state of the planning object "city" and its zones as provided by the simulation.

The evaluation model receives these data from the simulation model and evaluates them by using one or more goal structures. The goal or value structures represent attitudes or interests of

[2]The general nature of this paper does not allow a more detailed description of the POLIS model. The model is fully documented in [8].

[3]The multiattributive utility theory (MAUT) was developed by Edwards and Raiffa (see, among others [19]).

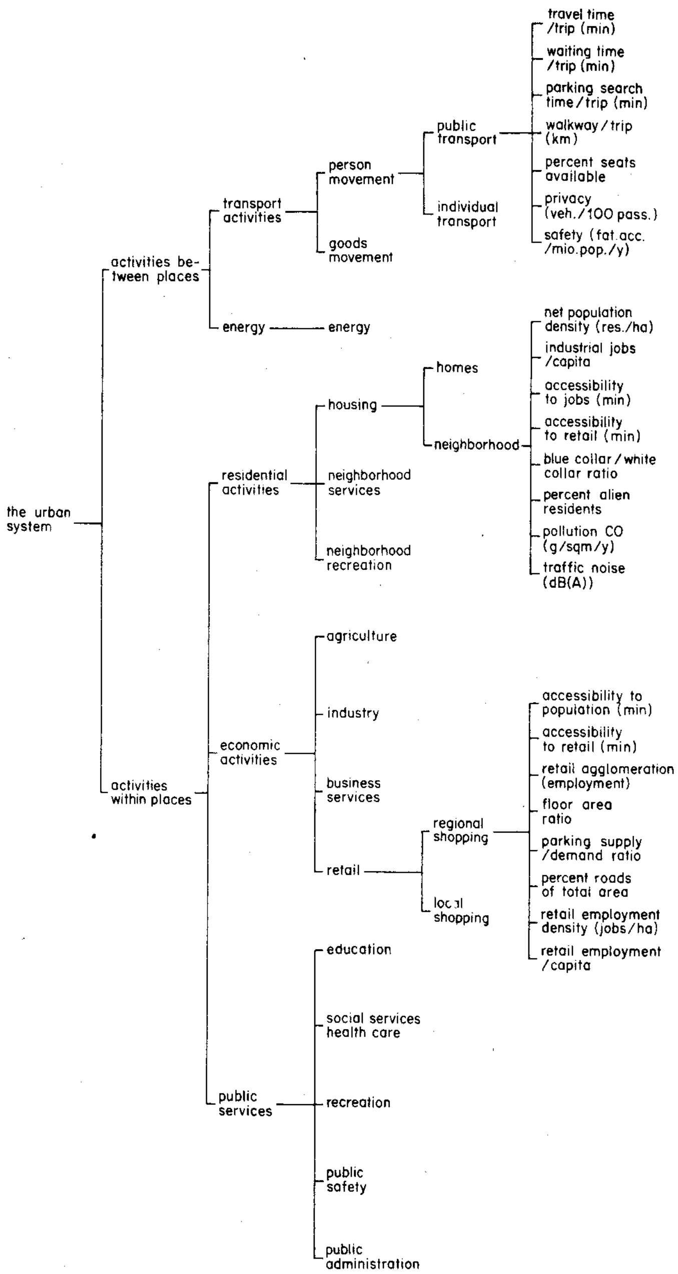


Fig. 3. The POLIS hierarchy (excerpt).

groups of the community and differ in weights and utility functions. For each group the model exhibits utility values for all levels of the hierarchy and for all zones or any aggregates of them. Also, differences between the evaluations by the groups, i.e., potential conflicts are shown.

## Integration of Simulation and Evaluation

There are five basic modes of operating the model. In the following discussion they will be looked at from the viewpoint of, say, an urban transportation planner.

*1) Simulation:* In its simplest application the transportation planner may use the simulation model to check the consequences of network design alternatives. For instance, he may introduce different highway configurations, changes of service levels in the public transit system, new public transit lines, or entirely new modes of transit. He may experiment with timing, sequence, or financing of transportation programs. The model will give him information about the likely development of the following:

construction, maintenance, operating, and user costs;
network utilization, including link loads, frequency distributions of travel times, walking, waiting, congestion times, number of trips, mileages by mode or link type;
comfort, e.g., car occupancy, percent seated;
safety, like number of fatal accidents, injuries, or property damages;
environmental effects, as air pollution by CO and $NO_x$, or traffic noise;
aesthetic effects, e.g., space requirements for new right-of-ways, or intrusion by traffic arteries.

In addition, he may observe the likely consequences of his design alternative on the urban system at large. He may find out how, following network or service improvements, accessibilities locally change, but also how pollution and noise levels go up concurrently. He may look into the effects these changes have on the development of land prices and land demand, and the resulting shifts in the spatial distribution of construction activity. He may observe how displacement processes slowly change the land use, social, and age structure of certain areas. He may be interested to know if minority groups are affected by these changes, and whether their concerns are adequately accounted for.

*2) Interagency Simulation:* In another form of application, the transportation planner would join with planners of other planning departments or agencies, e.g., the land use planner, the school planner, the recreational planner, etc., to discuss design alternatives. Now each participant contributes the opinions, ideas, and constraints of his agency or discipline. In this way it is possible to combine different transportation schemes with various concepts of land use, housing, industrial development, social, educational, or recreational planning. The model would show where discrepancies between the concepts exist, where badly served areas or major diseconomies would result. This information may then be used to jointly search for more compatible plans, and eventually may lead to improved interagency coordination.

*3) Simulation and Evaluation:* In this and the following kinds of application, the evaluation model would also be applied. In its simplest form the combined process is a spatially disaggregated evaluation procedure. Only one goal system is used, e.g., urban development goals as formulated by the municipal legislature. In this case, any future state of any plan alternative may be checked against that goal structure. If only one such state is evaluated, the model shows spatial disparities in the distribution of public services and other indicators of quality of life. Also, several successive states of a plan may be evaluated to analyze the temporal development of such indicators. If more than one plan is evaluated, comparisons between plans on each desired level of spatial, temporal or sectoral disaggregation may be made.

*4) Simulation and Conflict Analysis:* The process is augmented by another dimension, if not one, but several different goal systems of various groups are assumed. This allows not only comparison between plans, but also comparison between attitudes of different groups towards one single plan in any desired spatial, temporal or sectoral detail. In addition, it is possible to analyze the differences between group attitudes

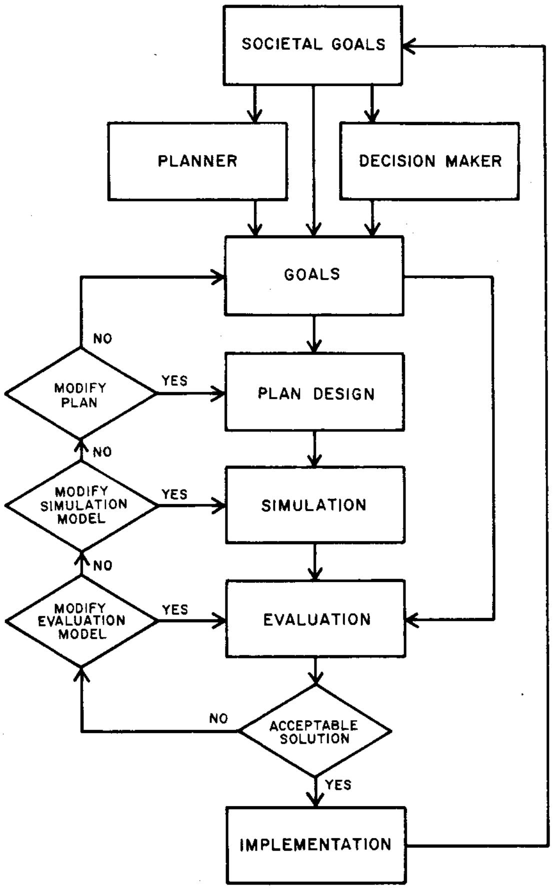


Fig. 4. Simulation and evaluation and the planning process.

and thus identify potential conflict zones or problem areas. By listing of attributes below "critical values," conflicts may be traced back to the disparities which caused them.

*5) The Iterative Planning Process:* In its most complex application the combination of simulation and evaluation model is one step in the iterative solution finding process of urban development planning. In this case, and as a first step, a preliminary plan, or a set of alternative plans, is evaluated. The results of the evaluation suggest how the process may be continued. If all criteria are satisfied for all participants by a plan, it can be selected for implementation. More frequently, however, the plans will not be acceptable for one or more of the participating individuals or groups. In this situation the process may be continued in three different ways.

a) The planner proposes a changed plan which either contains new elements or modifies existing elements in the direction of a compromise.

b) The participants agree to change their assumptions about future developments, i.e., they modify the simulation model.

c) At least one of the participating groups agrees to change the weights of its goals or its satisfaction standards, i.e., it modifies the evaluation model.

If these three possible responses are seen within the framework of the planning process, the following five steps may be identified (Fig. 4):

i) participants of the planning process define goals to be achieved by planning;
ii) the planner is guided by these goals in formulating one or more plans in the process of design;
iii) the consequences of the plans are predicted by the simulation model;
iv) the consequences of the plans are checked against the predetermined goals in the evaluation model;
v) a plan is adopted, if the goals of all groups are satisfied; if no such plan is found, the process is continued with one of the steps a), b), or c), until an acceptable plan is found.

The motivation for these modifications comes from the growing information about the planning problem, the solution alternatives and their consequences, and about the potential conflicts arising from them. This makes the solution finding process an individual or collective learning process, in which through iterative application of simulation and evaluation a plan that is acceptable to all participants is approached.

In this type of planning process, the decision situation has been changed. Earlier decision aiding techniques tended to take the decision away from the decision maker after the formula: Select the alternative with the highest utility value. In this technique the decision maker is confronted with the question in whose interest he decides and what conflicts he is willing to risk. In other words, the decision maker becomes aware of his partisanship. The partisanship has not been produced by the evaluation technique; rather, the evaluation technique is only so good as its ability to reveal the partisanships that govern the political process, and thus recognizes societal conflicts as the propelling force of societal (or urban) change. Evaluation techniques that fail to do so, and, instead, assume one generally accepted goal structure, bemuddle rather than control the real conditions of society.

## First Applications

The combination of simulation and evaluation has, in different stages of implementation, been applied to land use and transportation planning problems of the cities of Cologne, Vienna, and Darmstadt. In Cologne and Vienna, only the simulation model has been used. For the purpose of testing of both models together, Darmstadt was selected as an "experimental" city because of its manageable size and the availability of data. The Darmstadt data, having been assembled and coded in the way required by the POLIS model, have served as the input for a series of experimental workshops with groups of different size and professional background.

The duration of the workshops was between three and five days. At the beginning the participants were asked to evaluate a set of basic alternatives of urban development simulated in advance. To ensure different initial evaluations, the participants were divided into groups and asked to evaluate according to their group specific interests. To facilitate group identification three typical representatives of social groups (high, medium, low income) were sketched out in the form of written selfportraits. Also in the workshop material, suggestions were made for the selection of weights and utility functions by each group in a first cycle of evaluation.

As may be expected, in all workshops the first evaluation showed considerable differences between the attitudes of the groups towards different plans and between the groups' satisfaction levels. After the first cycle the results were discussed within the groups. In a gaming discussion with all groups the conflicts that had become apparent were verbalized, and the conflicting positions were stated; also first possibilities for a compromise were indicated. Next, a "planning commission" sat down to develop a compromise plan, while simultaneously the groups did their second evaluation. In the evening the compromise plan was simulated and evaluated with the modified goal systems of the groups.

The result of each cycle of simulation and evaluation showed in all workshops significantly reduced conflicts between the groups and a convergence of satisfaction levels. Other remarkable results were: Dissatisfaction of all groups tended to increase regardless of the simulated plan. This tendency was most obvious for the "low-income" group. With each cycle conflicts between the "low-income" and the "high-income" groups lessened; while the "low income" group more and more adopted the values and standards of medium and high income people, its dissatisfaction with the conditions of its life increased.

## The Municipal Simulation Laboratory

The favorable experiences made in a limited experimental setting strongly suggest that the planning tool be tested more thoroughly in a real-world city.

Large cities all over the world are experiencing similar problems: increasing size and complexity of the urban agglomeration, urban sprawl, noisy and overcrowded city centers, choked traffic arteries, insufficient public transport, polluted air and water, and inefficient public services. The rapid decrease in the social and physical quality of urban life is one cause for the growing dissatisfaction of citizens with their urban environment and for conflicts between interests of different social groups. The inability of city administrations to cope with these problems coincides with a growing sensibility of the population for local planning issues.

In many West European countries, one can observe numerous efforts to improve the organization, mode, and methodology of urban planning. The most important of these approaches are as follows.

1) Cities install new administrative units to provide for better interagency coordination for long-range comprehensive urban development planning.

2) Cities support various public, semipublic, and private activities and organizations to stimulate, encourage, or sometimes channel citizen participation in urban planning.

3) Cities begin to enjoy the benefits of improved planning data, as computer-based planning information systems on state- and local-level approach first, if modest levels of operationality.

However, it can be expected that none of these three approaches alone will help much to improve the quality of urban planning decisions. What is clearly lacking is a link that unifies them to a comprehensive concept of *coordinated, participatory, informed urban development planning.* It seems possible that the planning tool described in this paper, if implemented in a real-world framework, may serve as such link. It would form the nucleus of a *municipal simulation laboratory.*

1) The municipal simulation laboratory would be a public institution for interdisciplinary, interagency, and participatory solution of planning problems.

2) The mode of operation of the municipal simulation laboratory would consist of experimental testing of future alternatives with respect to technical and economic interdependencies, general development trends and group-specific goal systems.

3) The methodology of the municipal simulation laboratory would combine group-dynamic techniques such as gaming,

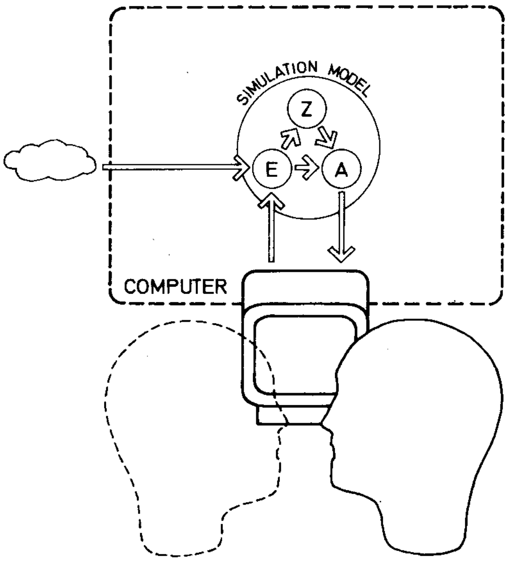


Fig. 5. Interactive simulation (man-machine dialog).

with advanced information technology, dynamic systems simulation and multidimensional evaluation.

With these objectives the municipal simulation laboratory would constitute:

a) an *observatory* for observation and investigation of present and future development lines;
b) a *forum* for structuring and discussion of goal systems;
c) a *workshop* for designing action alternatives;
d) a *test-ground* to examine alternative futures;
e) a *checkpoint* for comparative evaluation and conflict analysis;
f) a *training-center* for rehearsing conflict resolution.

In the following sections, the institutional and methodological implications of such an approach are discussed.

## The Integrated Interactive Model

The core of the municipal simulation laboratory would be a set of interactive computer programs the most prominent of which are the simulation and evaluation models.[4]

Fig. 5 shows the interaction of one or more users with a simulation model in a highly abstract, symbolic representation. The model basically consists of a system boundary and three kinds of state variables. The system boundary separates the modeled system from the rest of the world. The three types of variables are input variables $E$, intermediate variables $Z$, and output variables $A$. Input variables receive signals from outside of the system boundary and transmit them into the system modeled. Intermediate variables are generated inside of the model and transmit signals within the system (endogenous variables). A selection of these are output variables which deliver information about the state of the system to the outer world. The arrows in the figure indicate the direction of interdependencies in the model.

The model is set into motion in two ways: First by information about developments which influence the interaction within the model, but are themselves not affected by them (exogenous influences). They are here indicated by a "cloud"

[4]Other programs are programs for file creation, maintenance and manipulation, a query system with program modules for tables, diagrams, and maps, as well as programs for data analysis. These supporting programs will not be discussed in this paper.

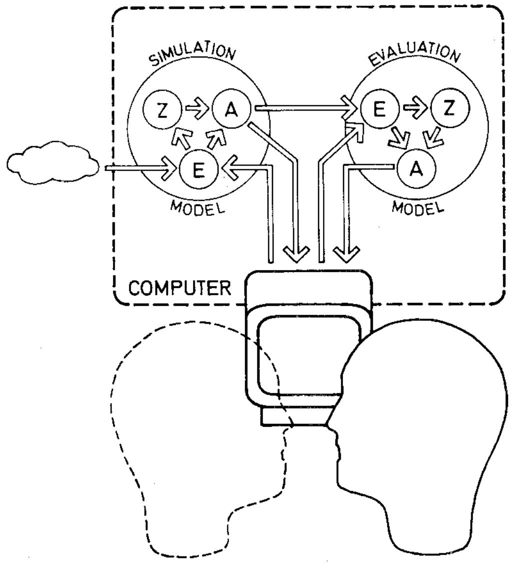


Fig. 6. Interactive integration of simulation and evaluation model.

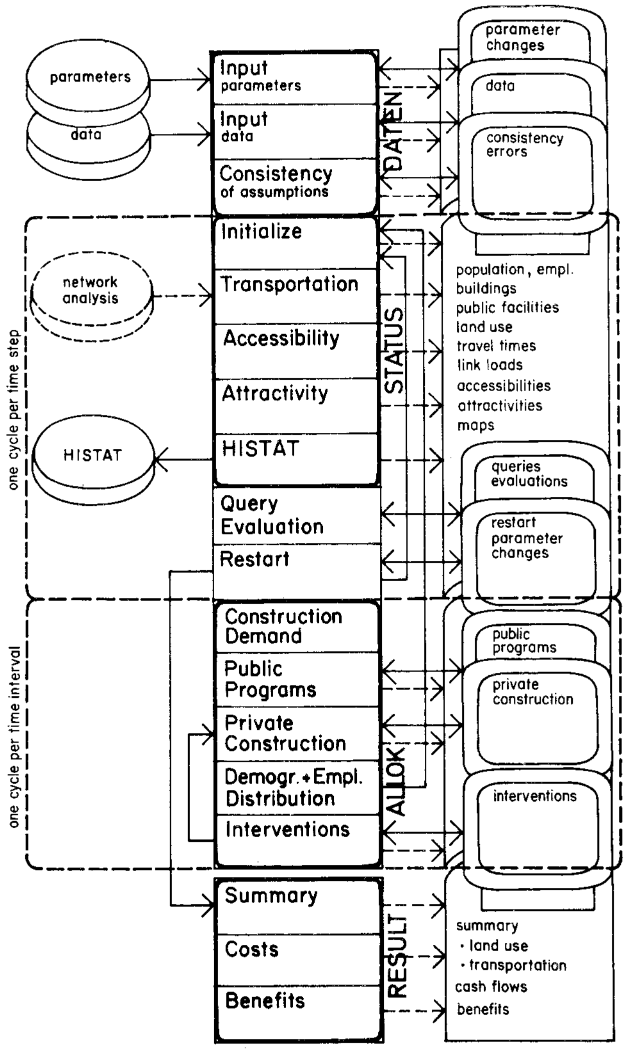


Fig. 7. The integrated interactive model (process diagram).

symbol. Second by human intervention, in this case in the form of user inputs through an interactive terminal. The results of the simulation, too, appear on the display and may cause the user to again intervene with more corrections, be it through new planning actions, or be it by re-simulating periods with changed parameters.

The situation gets more complex, if the user communicates with two different models. Fig. 6 contains the interactive integration of the simulation and evaluation model using the same symbolic representation. Now the simulation model transmits information about the state of the simulated system not only to the user's display, but also to the evaluation model. The user may choose to receive the simulation results either directly from the simulation model, or after having been evaluated by prespecified criteria from the evaluation model. Fig. 7 shows the integrated interactive simulation and evaluation model in more detail.

## Group Experiments

Several users, rather than only *one*, might communicate with the model, for example other planners and planning experts, decision makers and group representatives, or groups affected by planning decisions themselves. The additional participants have, in principle, all the functions and privileges of a single user: They participate in selection and formulation of the alternatives to be simulated, and in the control of the simulation itself. They may request intermediate results and may modify the course of the simulation accordingly. They may contribute their own specific value system in the form of criteria, weights, and utility functions, and have the simulation results evaluated by them.

The least difficulties are to be expected when a relatively small number of planners or experts interacts with the planning instrument, and when the dialog with the computer is conconducted by way of a single input-output terminal. The background of the participants is relatively homogeneous, and differences in the view of the problem and the selection of the policies to be investigated can be settled by discussion, so that an agreement about what to input may be relatively easy. More difficulties will arise, when the participants are locally separated, e.g., in different agencies, and conduct a joint planning session from separate terminals. In this case special program functions must ascertain that the participants do not obstruct each other, but cooperate towards a common solution. As data communication networks become available also in the public administration, such application deserves attention.[5]

Another type of difficulties arises when the participants have no specific training in planning matters, e.g., representatives of civil action groups. Participation of nonexperts is essential, because there is no other way to prevent that planning instruments like this one are misused by the expert administration as unrefutable "evidence" of the wisdom of its decisions. In other words, the more complex a planning instrument is, the more it must be available to all participants of the urban development process, and its mechanism and implied assumptions must be comprehended and verified also by nonexperts. This is an enormous challenge as to the simplicity of use and clearness of output of such instruments. It may be expected that the technical and didactic problems associated with this task can in the near future only be approached, i.e., for the dialog between model and nonexpert user, interpretation by an expert will be required.

The third and most extreme kind of difficulties will be encountered when not only representatives of groups, but

[5] Interuniversity and internation simulations have been conducted with the POLIS network [12] of the University of California, Santa Barbara (the name identity is coincidental).

the groups themselves participate in the planning discussion. In this case the additional task consists in the communication of complex information matter to a large number of persons the experience and insight of which individually differ. This communication must enable all participants, no matter how different their capability to articulate themselves, to effectively present their point of view and their interests. The necessity to solve this communication problem cannot be denied, if one seriously thinks of incorporating people into the solution finding process of urban planning. To say that such planning models or procedures are too complex to be communicated to the "man in the street" is not very helpful; the complexity is with the problems and cannot be removed by simplifications. However, the didactic, organizational and political problems connected with such a participation are presently difficult to assess. Initial and incomplete experiences indicate that the didactic efforts to overcome the communication barrier between experts and nonexperts, between planners and planned upon will be quite formidable. This suggests a rather cautious assessment; for the next years the importance of simulation models is likely to lie in the field of expert planning; for participatory planning such models may at best play a role as didactic tools, but hardly as a means for the actual opinion formation of nonexperts.

## Dynamic Simulation of Goal Systems

In view of the difficulties in obtaining representative value judgements for the planning process by participatory discussion with affected groups, another direction of development seems to be at least equally promising. It is based on the notion that goal structures themselves have systematic character which makes them accessible to treatment in a simulation model. However, it soon becomes apparent that the structure of such a model is only insufficiently reproduced by a tree-like goal hierarchy as it is used in the MAUT. The difficulties usually observed with the formulation of goal structures suggest that a model of urban goal systems must not be less complex than the model used for simulation of the actual urban development; that in such a model positive and negative cyclic relations between goals must be feasible, and that it must allow for dynamic development over time. These requirements lead to a dynamic simulation model of urban value structures which moves through time simultaneously with the simulation model of the actual city.

In Fig. 8, the two models and the interrelationships between them are shown in the symbolic representation introduced in the preceding. The left part of the figure is the technosocioeconomic model of the actual city. This model will be called the "external" model. On the right part the "internal" model is shown which represents the value or goal structures of one or more individuals or groups and their temporal development. In other words, the external model represents the city as it *is*, the internal as it *is perceived*. The head-shaped line around the internal model is to indicate that here a part of the individual or collective perception and its changes are modeled.

The external model is stimulated by exogenous influences ("cloud" symbol) or by human interventions, which here are symbolized as "oral" instructions of those participating in the process. The results of the simulation of the external model are "perceived" by the participants and evaluated with the help of the internal model. The resulting value judgement—disaggregated dissatisfaction—is the cause of more corrective interventions. This cycle corresponds to the iterative solution

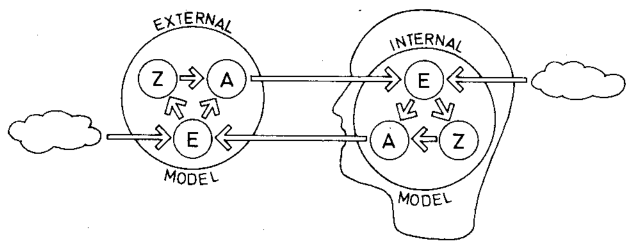


Fig. 8. The external and the internal model.

finding or learning process: Each loop effects a change of behavior motivated by improved insight into the system. The learning process is discontinued, once all participants are satisfied, or when further improvements cannot be achieved.

The internal model is not an identical copy of the external model. Relations which are made explicit in the external model need not to appear in a similar fashion in the internal model. The modeling technique for the internal model combines elements of the MAUT with elements of dynamic systems simulation. State variables of the internal model are the elements of the urban system, or rather their utility values. Some of these variables are identical with specific output attributes or indicators of the external model; they are exogenous for the perceptive model. Others are more general goals of higher abstraction; they are generated endogenously within the model. Also in this model are exogenous influences which represent the social background, class, or education of the evaluating individual or group. The relations between the state variables are represented by utility and weighting functions.

Consequently, for changes of the state variables of the internal model, i.e., for changes of the perceptive copy of the external model, there are four possibilities.

1) The state variables of the internal model change their utility values, when information about changes of attribute values is communicated from the external model. This corresponds to a straightforward utility evaluation with one goal structure and might be called the equilibrium model.

2) Changes of utility values of the internal model are caused by purely time-dependent changes in the parameters of weighting and utility functions. This takes into account that value structures change in time, but leaves the causes of these changes outside of the model.

3) The parameters of the weighting and utility functions of the internal model may change as a function of attribute values of the external model. In this way the impacts of technical, economic, or social changes of the real world on the perception of it are introduced into the model.

4) Finally, the parameters of several goal systems may be interdependent. In this case also sociocultural influences, i.e., adaptive processes between goal structures of different social groups are to be modeled.

The advantages of such dynamic simulation of goal structures are obvious:

a) one single unified modeling technique is used for the modeling of the actual system as well as of its perceptive copy;
b) by connecting both models, feedbacks between simulation and evaluation can be effected;
c) the essential quality of the actual system, the dynamic and cyclic structure of its interrelations, may be represented also in the perceptive model;

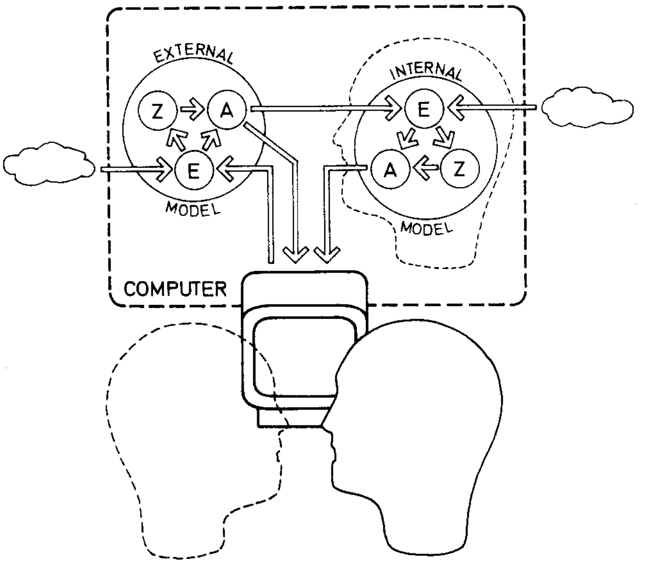


Fig. 9. Implementation of the external and the internal model.

d) by adding a temporal dimension to the evaluation model, time-dependent changes of value structures may be anticipated;
e) by simultaneously considering several value structures, conflicts between interest groups may be anticipated and their solution be simulated.

On the other hand, it will not be easy to overcome the theoretical, methodological, and political problems raised by this approach. The relations between the actual world, its copy in the simulation model and the copy of its copy in the human mind are still more or less uninvestigated. It cannot be said how an adequate "algebra" for the formulation of the perceptive model would have to look in detail. It is equally impossible to say whether the "logistical tyranny"[6] of the evaluation of large interaction matrices may put a pragmatic limit to all advances into a complex treatment of the evaluation problem. Completely unresolved are the problems of calibration or validation of the model.

Presently work is under way to approach some of these problems. Fig. 9 shows a possible first implementation of the interaction between user, external, and internal model. For formulating the perceptive model experiments are being made with logical matrices and their derivations, whereby through a time-oriented treatment of interrelations cyclic interactions are made possible in the model. In a second phase the logical relations are quantified by linear equations, which is equivalent to the additive model of the MAUT. In principle, it is possible to introduce in a third phase also nonlinear relations.

Although the feasibility of such a model approach still seems to be extremely uncertain, the practical and political problems associated with its application deserve careful investigation. It is necessary to realize which functions such an advanced instrument might have for the planning practice and in the political decision process. It is necessary to ask who would benefit from the information lead associated with it, whether it might be an instrument for rational conflict resolution and avoidance, or a manipulative tool in the hands of a small minority, under the influence of which the rules and procedures of municipal self-government might degenerate to a mere formality. The answers to such questions may turn out to touch upon fundamental issues of democratic government in the age of communication.

[6] This is a term borrowed from Warfield [13].

## References

[1] I. S. Lowry, "A model of metropolis," Rand Corp., Santa Monica, Calif., Memo. RM-4035-RC, 1964.
[2] J. W. Forrester, *Urban Dynamics.* Cambridge, Mass.: M.I.T. Press, 1969.
[3] "Urban dynamics: Extensions and reflections," *IEEE Trans. Syst., Man, Cybern.*, special issue, vol. SMC-2, pp. 121–237, 1972.
[4] D. B. Lee, Jr., "Requiem for large-scale models," *J. Amer. Inst. Planners*, vol. 39, no. 3, pp. 163–178, May 1973.
[5] P. W. House and P. D. Patterson, Eds., *An Environmental Laboratory for the Social Sciences.* Washington, D.C.: U.S. Environmental Protection Agency, 1972.
[6] K. Anundsen and N. Lindgren, "Can you put a simulation model to work in a real community?" *Innovation*, no. 29, pp. 43–56, 1972.
[7] E. J. Cristiani, R. J. Evey, R. E. Goldman, and P. E. Mantey, "An interactive system for aiding evaluation of local government policies," *IEEE Trans. Syst., Man, Cybern.*, vol. SMC-3, pp. 141–146, 1973.
[8] "Simulationsmodell POLIS," User Manual (Preliminary ed., Aug. 1972), Bundesministerium für Raumordnung, Bauwesen und Städtebau, Bonn, Germany, Res. Rep. 03.012, 1973.
[9] H. Raiffa, "Preferences for multiattributed alternatives," Rand Corp., Santa Monica, Calif., Memo. RM-5868-DOT/RC, 1969.
[10] V. Bauer, J. Meise, and M. Wegener, "Urban systems studies, Part One, Evaluation in urban planning: Approach and project plan," Battelle-Frankfurt, Frankfurt, Germany, 1972.
[11] V. Bauer, A. Gebert, and J. Meise, "Urban systems studies, Part One, Evaluation in urban planning: Report," Battelle-Frankfurt, Frankfurt, Germany, 1973.
[12] J. McLeod, "POLIS and network simulation," *Simulation in the Service of Society*, vol. 3, no. 1, pp. 1–4, 1973.
[13] J. N. Warfield, *Structuring Complex Systems.* Columbus, Ohio: Battelle Memorial Institute, 1974.