15 A Community Information Feedback System with Multiattribute Utilities[1]

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All over the world, the task of planning and controlling the development of large conurbations seems beyond the problem-solving capacity of even highly developed social systems. In spite of immense capital investment and use of sophisticated technology, industrialized countries have failed to improve or even maintain living conditions in large cities. Urban sprawl, traffic chaos, collapsing public services, noise, and air and water pollution are indicators of the decline of the quality of urban life and have become the focus of growing citizen dissatisfaction with the urban environment and of conflicts between various interests.

The causes of the inability of large cities to cope with their most vital problems are various. They include the concentration of economic and political power in the hands of few relatively small segments of urban society, as well as the *de jure* and *de facto* limitations on the planning authority of communities and the inadequacy of municipal budgets in relation to the growing responsibilities of municipal administrations. They also include outdated land use legislation that makes rational allocation of land uses nearly impossible. They include, as well, the growing size, complexity, and vulnerability of the technical infrastructure; the growing interdependency and complexity of the economic and social environment; and the foreseeable depletion of natural resources like land, water, air, and energy. However, they also include the ever-growing expectations with which the population perceives and measures the results of urban planning.

The growing sensitivity of the population to local planning issues is expressed by increased demand for public services, by more frequent and more articulate statements of group interests, and by stronger claims for citizen participation in the local decision-making process. This tendency seems to be irreversible. With

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growing complexity the sociotechnoeconomic system becomes increasingly vulnerable to disturbances like sabotage, terrorism, or strike originating from small groups of outsiders or key insiders. It is this vulnerability, more than anything else, that forces government at all levels to base its authority on broad consent and cooperation rather than on coercion and technocratic control.

This perspective focuses attention on the participation of "plain" people, i.e., of nonexperts, in the local decision process. The difficulty lies in the fact that the management of a city is a highly specialized activity and is normally performed by experts – planners, economists, and administrators. How can these experts communicate with people not trained in matters like planning, economy, or administration, whose assent and cooperation, however, they have to win? The same system complexity that makes nonexpert participation necessary makes it nearly impossible for nonexperts to understand the decision alternatives or to introduce their preferences into the decision process.

One of the core problems of urban decision making, therefore, is the establishment of effective information feedback between experts and nonexperts about planning alternatives, consequences, and preferences. In this paper, an approach is presented that attacks this problem in two ways:

- By using dynamic systems simulation techniques to provide and process structured information on planning alternatives and their outcomes
- By using decision analysis techniques to provide and process structured information on the perception of the outcomes by experts and nonexperts

While both parts of the approach are of equal importance, the emphasis of the paper is on decision analysis. From a decision-analytic point of view, the urban decision situation is extremely complex:

Multiple objectives. Urban decision making deals with a large sector of societal life encompassing many closely interrelated subsectors. Each of these sectors contributes in some way to the overall success of planning.

Long time frame. Although urban change seems to proceed incrementally, many decisions in urban planning are indivisible, are irreversible, and have long-lasting effects.

Multiple interest groups. In no other field of decision making is the distinction between decision subjects and decision objects so elusive. The decision makers usually are part of the groups affected by the decisions.

Uncertainty. Only a part of the urban system can be influenced directly by public planning decisions. Decision outcomes depend to a large degree on the behavior of private actors.

Section 15.1 is an attempt to explicate more fully the urban decision situation and its problems. In section 15.2 the methodology designed to address some of these problems is introduced. Section 15.3 is a detailed account of the evaluation component of the proposed methodology. In section 15.4 the first experimental applications of the methodology are reported. Section 15.5 is a critical appraisal of the methodology and a report on the outlook for further development.

15.1 THE URBAN DECISION PROBLEM

The ultimate goal of urban planning is to maintain and improve the conditions of life of the urban population at large. The failure of most large cities to achieve that goal suggests that a close look at the urban decision-making process is in order.

The urban decision-making process differs in many respects from decision-making processes in other fields, such as industrial or military planning. The first basic difference lies in the size and complexity of the decision object, the urban system. Urban planning deals with a complex sector of societal life that comprises nearly all aspects of human activity, such as living, working, travel, education, and leisure. For planning purposes, the system must be considered as a whole, as changes in one part of it affect elements in all other parts. Accordingly, the goal system that is to guide urban planning decisions must be comprehensive indeed if it is to cover all relevant aspects of urban life. This comprehensiveness is indispensable, as trade-offs are made between objectives from different aspects of urban life.

The second characteristic of urban planning is its relation to time. On the one hand, the physical plant, the social and economic structure of a city, changes only in small, marginal increments. This requires that the action set, as well as the goal system, be very specific and detailed. On the other hand, there are many decisions in urban planning that are basic, indivisible, and irreversible and that have long-lasting effects.

The third essential characteristic of the urban decision-making process lies in the relation between decision subjects and decision objects. Inasmuch as the objects of decisions are people who themselves might participate in the decision making, the distinction between decision subjects and decision objects tends to become irrelevant. The implications for the decision process are fundamental: even if the decision makers try to anticipate the assumed preferences of their clients, the single goal structure guiding the decision analysis has to be replaced by a multitude of goal structures representing the different perceptions of the "conditions of life" by various groups.

The fourth important difference in the urban decision-making process is that only a relatively small part of the urban system is in fact controlled by the planning authority. A far larger part is subject to individual decisions made by a large number of private individuals, groups, or organizations. The instruments that the public authority can use to influence the development of that larger "market" part are limited, even though the "conditions of life" depend greatly on the functioning of the market sector. Therefore, the eventual consequences of decision alternatives are not easy to predict; as their prediction implies the consideration of the behavioral response of a large number of other actors, it is bound to contain a measure of uncertainty and error.

In summary, the urban decision-making process can be characterized by the following properties. It deals with a large sector of society that is at once decision subject and decision object. Because the object system is large and indivisible, the goal system has to be comprehensive and contain a large number of objectives. Because changes in the system occur on a micro scale, the alternatives and objectives have to be specified in great detail, yet there are some decisions that are long-term and irreversible. Because various groups of the city are affected by planning decisions, not one but many preference or goal systems have to be considered in the analysis. Because control of the urban system by the planning authority is only partial, prediction of decision consequences is particularly difficult.

If this is a valid description of the urban decision-making process, the next question is: How well does it work? The unsatisfactory state of large cities suggests that it does not work well. Of course, there is the convincing argument that even if it did work well, the troubles of cities would not be relieved, as their causes lie outside the jurisdiction of city governments. But it still seems likely that improvements in the urban decision-making process might at least help to improve the situation.

Therefore, a step-by-step inspection of the traditional practice in urban decision-making seems necessary if we are to find out why it does not work well. It soon becomes apparent why the traditional practice is in no way prepared to tackle the difficulties characteristic of urban planning. In the first place, the planner has only the vaguest idea of the goals and objectives that the plans, programs, or actions he designs are supposed to serve. Moreover, he has no analytic tools to predict any but the most trivial first-order effects of his action alternatives; he cannot forecast with any degree of reliability what the second-order and third-order effects of his plans might be throughout the urban system: how private actors – e.g., developers, homeowners, commuters – might respond. But even if he could, he would not be able to communicate these consequences in a comprehensible way to the decision makers and the people affected by his plans, because there are no tools to convey such complex technical material to people not trained in planning. By the same token, because the people affected by planning decisions do not comprehend what the consequences will be, they have no way of developing an informed opinion about the issues and of expressing their attitudes and interests in the matter, which, again, leaves the planner without badly needed information about the public acceptance of his projects and about the needs and aspirations of his clients.

Hence, insufficient information feedback may be identified as one of the major causes of malfunction of urban planning practice. Underlying this difficulty is the fact that the information-processing capacity of planners, decision makers, and the individuals or groups affected by planning is unequal to the complexity of the problems. This complexity cannot be reduced without losing sight of the substance of the problems themselves, nor can the necessity of feedback between experts and nonexperts be dismissed without losing sight of the overall purpose of planning – improving the condition of people.

From this it follows that new tools are needed to support the dialogue between planning experts and nonexpert citizens:

By providing relevant and detailed information about direct and indirect consequences of planning decisions

By providing relevant and detailed information about the preferences of different groups in the population affected by planning

By relating the above two kinds of information and displaying them in a transparent format comprehensible to both planning experts and nonexpert citizens

In the following section a methodology designed to meet these requirements will be presented.

15.2 SIMULATION AND EVALUATION

The methodology presented in this paper consists of a combination of systems simulation and decision analysis techniques. In this section, the components of the proposed process – a multiperiod, multiregion, dynamic, digital simulation model of urban development and an evaluation procedure based on the multiattribute utility theory – will be described separately. Then it will be shown how these components are combined into an integrated process in which, by iteratively applying simulation and evaluation to planning alternatives, one or more planners, decision makers, or citizen groups may learn about the impacts of plans and the potential conflicts arising from them.

15.2.1 THE SIMULATION MODEL

Simulation is a scientific experiment on a model of the object of investigation, rather than on the object itself. If a mathematical model of the relevant characteristics of the investigated system is available, action alternatives to influence the development of the system may be tested with little risk and effort.

Mathematical simulation models for urban planning were first developed in the United States in the 1950s. In Western Europe, urban simulation models have been developed, mainly in Great Britain and Switzerland. In the Federal Republic of Germany, two major research projects on urban simulation have been conducted under research contracts with the federal government (Battelle-Institute, 1973; Popp *et al.*, 1974). The product of one of these projects is the urban simulation model POLIS, developed by Battelle–Frankfurt. The POLIS model simulates the development of the spatial distribution of population, employment, buildings, and land use, as well as of transportation, in response to planning interventions by the city or other public agencies over a number of time intervals (periods) until a planning horizon is reached. The urban area is divided into subunits (zones) whose structure is represented by state variables. The zones are connected to each other and to the surrounding region by public transit and highway networks.

The simulation of a period begins with the analysis, description, and documentation of the state of the urban system. 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; these indices are a measure of locational advantage, afforded by the available transportation system, with respect to various activities and infrastructure facilities of the urban area. From accessibilities and other zonal attributes for each zone, attractivity indices are computed that express the market demand for land by various urban activities.

Next, the allocation part of the model begins. First, public action programs are executed. The model allows the introduction of time-sequenced and localized programs in housing construction; industrial development; and educational, social, recreational, and transport infrastructure. All construction programs are accompanied by necessary local roads and parking facilities, and all housing programs provide foı service facilities like schools and neighborhood shopping and recreation areas. The remaining (private) construction activity is distributed over the urban area according to the market pattern of supply and demand within the restrictions of a zoning plan. The likely distribution of private construction for each type of building use is estimated as a function of the attractivity and capacity of each zone for that particular use. Displacement of one type of building use by more profitable types is considered in the model by demolition or explicit change in building-use type. After the simulation of private construction, projected population and employment are distributed over the available housing and commercial and industrial buildings, and demographic, social, and employment distributions are updated. Finally, the availability of local service facilities is checked against relevant standards. Where service is severely substandard, the city administration is assumed to intervene with an appropriate program.

This closes the simulation of the first 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 last period has been simulated. For each simulated planning alternative, the model gives detailed information about the development of population, employment, physical structure, transportation, and environmental quality of each zone. In addition, the costs of each alternative are accumulated and exhibited as cash flows between various groups in the city.

The results of the simulation are documented in various forms of printed output – tables, diagrams, and maps. In addition, the levels of some 240 state variables for each zone, representing the demographic, employment, and building and land use structure of the zone and its service, transportation, and environmental characteristics, are stored for each time step of the simulation in a "historical" file. The historical file thus contains a point-to-point account of the likely consequences of all simulated alternatives in great spatial and temporal detail. After the simulation, the historical file is kept available for further analysis.

15.2.2 THE EVALUATION MODEL

Simulation models do not generate "optimal" solutions; they only describe the consequences of given solution alternatives. This "deficiency" turns out to be one of the essential advantages of simulation techniques. The experimental character of the simulation corresponds specifically with the iterative decision process of socioeconomic planning. Experiments with simulation models may be started without much prior knowledge about the planning problem itself, the constellation of goals, or their potential conflicts. The work with the model initiates a learning process about the interdependencies of the modeled system and about the consequences and interactions of planning interventions that allows an iterative approach to successively "better" solutions.

Simulation models thus, in a formal sense, are value-free. Judgments about the desirability of the outcomes have to be made outside the simulation model; without such judgments the outcomes would be meaningless. Hence, evaluation is an indispensable part of the simulation approach. It is only by evaluation that the simulation results that really matter are extracted from the large volume of information produced. Processing the results of a complex simulation model can be accomplished only by an efficient operationalized procedure.

For processing the results of the POLIS simulation model a formalized evaluation procedure for assessing the relative merit of plans for one or more goal structures was developed and operationalized in the form of a computer program. It is based on multidimensional scaling of utility as implied in the multiattribute utility theory (MAUT) (Raiffa, 1969; Bauer *et al.*, 1972; Humphreys, in press). MAUT proceeds by decomposing a complex object of evaluation (a plan) into its independent dimensions (attributes) through the use of a goal hierarchy. The attributes are individually evaluated by means of utility functions, weighted, and aggregated by a formal additive composition model. At each level of the hierarchy, the utility of the plan with respect to specific aspects is found, and at the top level the total utility becomes apparent.

Differences in the value structures of different groups involved in the planning process are expressed in the model by the same hierarchy but with different weights and utility functions. The program thus simultaneously evaluates the results of the simulation for goal structures representing the interests of different individuals or groups in the city. For use with the POLIS simulation model a goal hierarchy has been adopted whose elements are implied by the aspects of urban development contained in the model. The interface between the simulation and evaluation models is the historical file mentioned above. Following the instructions of the user, the evaluation program reads from this file for each zone the data required for the evaluation, translates them into utility-relevant attributes, and maps these attributes by means of utility functions on a standardized utility scale. After these two kinds of transformations, the simulation results enter the lowest level of the goal hierarchy, whence, subject to the underlying weighting scheme, they are successively aggregated to higher-level, more general utility measures. Thus it is possible not only to evaluate straightforward indicators of system performance like housing quality, availability of services, and accessibility, but also to relate them to attributes of other problem areas as well as to more general utility aggregates, such as quality of life. The program calculates for all goal structures utility values for all levels of the hierarchy and for all zones or for any aggregates of zones. In addition, differences between the evaluations by different evaluators – i.e., potential conflicts – are shown.

15.2.3 THE LEARNING PROCESS

The combination of simulation and evaluation can be applied to the solution of planning problems in three ways:

- 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 principle, any past, present, or future state of the city may be checked against that goal system. 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. If more than one plan is evaluated, comparisons between plans on each desired level of spatial, temporal, or sectoral disaggregation may be made.
- If different goal systems of various groups are assumed, the augmented procedure allows not only a comparison between plans but also a comparison between attitudes of different groups toward a single plan in any desired spatial, temporal, or sectoral detail. In addition, it is possible to analyze the differences between group attitudes and thus identify potential conflict zones or problem areas.
- In its most complex application the combination of simulation and evaluation is integrated as a part of the iterative solution-finding process of urban development planning. The following five steps may be identified:

1. Participants of the planning process define goals to be achieved by planning.
2. The planner is guided by these goals in formulating one or more plans in the process of design.
3. The consequences of the plans are predicted by the simulation model.
4. The consequences of the plans are measured against the predetermined goals in the evaluation model.
5. A plan that satisfies the goals of all groups is adopted; if no such plan is found, the process is continued in one of three ways:

a. The planner proposes a new plan that either contains new elements or modifies existing elements so that a compromise can be reached.

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.

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

15.3 THE EVALUATION TECHNIQUE

Evaluation is the measurement, as objectively as possible, of the contribution of certain actions or programs to the achievement of individual or public objectives or goals. The dimension that is measured is utility, a function of three basic elements: the evaluator, the entity being evaluated, and the purpose for which the evaluation is being made (Edwards, 1971).

In the urban planning context the object of evaluation seems to follow from the obvious purpose of evaluation – to make choices among possible programs. It seems, at first, obvious that the competing programs should be evaluated, but because of their instrumental character, it is not the programs but their consequences for the urban system that have to be evaluated. More precisely, it is the different states of the urban system resulting from the programs that constitute the object of evaluation.

The question of who does the evaluation will make things even more problematic. It has been argued earlier that urban planning represents one of the most difficult decision situations, one in which a large, complex sector of society is, at the same time, the subject and the object of decisions. Since urban society is not monolithic but consists of groups with usually divergent interests, all groups likely to be affected by the programs under debate should, ideally, participate in the evaluation. The methodology reported in this paper is typically applied, therefore, in the situation where the evaluation subjects are groups that represent different sections of the urban population whose interests in the problem at issue conflict. It may be noted that, with Arrow's theorem in mind (Arrow, 1963), no formal technique is provided either to aggregate evaluation judgments over groups or to aggregate group evaluations from individual judgments. Both aggregation steps are deliberately left to the informal process of group discussion and consensus finding. In fact, the group dynamics involved in the process of establishing consensus within and among the participating groups are considered to be an essential component of the learning process.[1]

[1] That is, groups are, irrespective of their size, expected to end up with one single evaluation result, which formally looks exactly like an evaluation prepared by a single evaluator. Hence, the single evaluator can be considered a special case of the group evaluator. This makes the methodology also applicable to situations in which not groups, but one or more individuals, are to be the evaluators.

With the above definition of the evaluation object and subject, the definition of the purpose of the evaluation can be reformulated. While the effectuation of decisions remains the ultimate rationale of the evaluation, the informal intermediate steps of the process become more and more important, the steps of incrementally approaching consensus within and between the evaluating groups. Only if evaluation techniques can be successfully integrated into the process of social learning are they likely to play any part in urban decision making.

15.3.1 THE MAUT PROCEDURE

The principal concept of multiattribute utility theory is simple: The evaluation object, here the "city," is decomposed by means of a hierarchical, descriptive model into its relevant dimensions. The dimensions at the lowest hierarchical level are operational: i.e., they are measurable attributes or indicators for intangible attributes of the evaluation object. The individuals or groups participating in the evaluation assign relative importance weights to each element of the hierarchy. In addition, the evaluators attach to each of the attributes of the lowest level of the hierarchy a transformation or utility function that determines a utility value for each plausible value of the attribute. In a final step, for each element of the hierarchy, a utility value can be calculated as a weighted average of all lower-level elements that are associated with that element by using the additive model of MAUT[1]:

$$u_i = \frac{\sum_j w_j u_j}{\sum_j w_j},$$

where u_i = utility of element i; u_j = utility of lower-level elements j associated with i; and w_j = importance weights of lower-level elements j.

In this particular application the values of the lowest-level attributes of the hierarchy are provided by the urban simulation model. Utility functions are weighted and designed by each participating individual or group separately. For each of them and for each plan one utility value is generated for each element of the hierarchy, including a total utility value for the top-level element.

15.3.2 GOAL HIERARCHIES

The term "goal hierarchy," used traditionally in multiattribute studies, is misleading. The hierarchy does not involve any normative aspects; it is simply understood as a set of rules to represent a complex object: a descriptive model. The descriptive model is value-free insofar as it is complete.

[1] The conditions for the validity of the additive model are discussed in Bauer *et al.* (1972, pp. 36–39). It may be noted that this formulation of the model is wholly deterministic, leaving the problem of uncertainty to a later discussion.

The generative rules of the hierarchical model originated in the tradition of medieval logic:

1. A hierarchy is a configuration of interrelated elements arranged in levels.
2. Each element of the hierarchy is completely represented by the associated elements on the next lower level.
3. The elements of the hierarchy are independent dimensions of the associated element on the next higher level.

Various techniques for the construction of hierarchies have been reported (Bauer *et al.*, 1973, pp. 17–40). If the conditions of the hierarchy are strictly observed, the result will be a complete description of the evaluation object in the form of a tree. Each level is in itself a complete description of the evaluation object, with generality or abstraction decreasing from the top to the bottom. The lowest-level attributes must be directly measurable if the hierarchy is to be operational. This requirement determines the number of levels and elements of the hierarchy.

The hierarchical model of utility is favored because the acceptance of its restrictive conditions allows the application of the simplest conceivable mathematical model of utility aggregation: addition. Besides this, there is one more reason for the retention of the hierarchy: as indicated above, there is usually more than one plan evaluated and more than one individual or group participating in the evaluation. This means that the numbers that matter are not so much the calculated utilities in absolute terms – which may be impaired by interdependencies between the elements – but differences between utilities, which may be considerably less affected by those interdependencies.

Given the above considerations, it seems advisable to use the hierarchical model, the additive form of MAUT. Furthermore, it seems permissible, for pragmatic reasons, to relax its exhaustiveness and independence assumptions:

1. The hierarchy need contain only those attributes that the simulation model is able to generate, provided the areas not covered by the model are carefully pointed out to the evaluators.
2. The attributes of the hierarchy need not be completely independent of each other, as long as care is taken to work with relative rather than absolute utilities.

These two assumptions, dictated by pragmatic considerations, will seem debatable to many.[1] But one can hardly see any alternative way to decompose an object of

[1] In a 1974 meeting at Battelle (Frankfurt), H. Raiffa linked the concept of independence to the question of trade-offs between attributes: two attributes are independent of a third attribute if trade-offs between them do not depend upon the level of the third attribute. But this is "preferential" or "utility" independence, as opposed to probabilistic-technical or "environmental" independence, e.g., correlation of real-world phenomena. Raiffa argued that environmental interdependence is irrelevant as long as preferential independence is preserved to justify the additive model. At the same meeting, W. Edwards pointed to the robustness of additive models in the presence of input error, but he was concerned about the danger of double-counting associated with environmental correlation.

evaluation of such immense complexity as a city, if simplistic and intuitive judgments are to be avoided. Perhaps the hierarchy should be considered no more nor less than a syntactical skeleton displaying certain semantic conventions. The user of the hierarchy, different from its designer, does not really care whether this semantic relation holds in the real world or whether the elements are independent. From this perspective, the hierarchy functions in the communication process: it guarantees that evaluating groups with different educational backgrounds understand each other. If they talk about, say, public transit, then at least the semantic components of the term are unambiguously determined by its context in the hierarchy. Only by using this common linguistic base can differences between groups be recognized.

15.3.3 WEIGHTS

The descriptive hierarchy obtains normative character, i.e., it becomes a goal hierarchy, by weights and utility functions. This statement is based on the assumption that human judgment may be modeled (a) by determining for each element of reality a number that represents its importance relative to other elements and (b) by determining for each such element a function that represents the relation between the actual value of the element and the satisfaction of the evaluator.

In earlier tests the weighting technique of paired comparison was selected and demonstrated with a small attribute set (Bauer *et al.*, 1973, pp. 44–48). It soon became obvious that this technique becomes impractical if it is transferred to a goal hierarchy with a large number of attributes. Therefore, the weighting technique was modifed in the following manner:

- The weighting is done separately for each cluster of the hierarchy. "Cluster" is used to denote any hierarchy element plus its subordinate element set on the next lower level of the hierarchy. In each cluster the sum of weights is defined to be one hundred. In addition, care is taken that no cluster contains more than eight or nine subordinate elements, in order to reduce the number of concepts to be handled simultaneously by the evaluators.
- Instead of paired comparison, a method of direct scaling was adopted for weighting the cluster elements. The evaluators are asked to decide upon the relative weight of each of the subordinate elements of each cluster – i.e., its relative importance for the utility of the associated element on the next higher level of the hierarchy.
- To further facilitate the weighting process, alternative sample weightings are provided by the project team, so that the evaluators may simply select one of the suggested alternatives. Figure 15.1 (right) contains examples of such weighting suggestions for a series of clusters on successively lower hierarchical levels.
- If the evaluators are groups, each one is requested to agree upon a single weighting scheme. They are encouraged to settle intragroup disagreement or

		1	2	3
Super Goal and First Level				
0011 city				
1012	activities between places	50	70	30
1011	activities within places	50	30	70
First and Second Level		1	2	3
1012 activities between places				
2022	transport activities	60	70	90
2021	energy	40	30	10
Second and Third Level		1	2	3
2022 transport activities				
3052	person movement	50	60	90
3051	goods movement	50	40	10
Third and Fourth Level		1	2	3
3052 person movement				
4152	public transport	30	40	80
4151	individual transport	70	60	20
Fourth and Fifth Level		1	2	3
4152 public transport				
5277g	travel time per trip (min)	15	20	30
5276g	waiting time per trip (min)	15	10	20
5275	parking search time per trip (min)	20	10	0
5274g	walkway per trip (km)	10	20	20
5273g	percent seats available	10	20	20
5272g	privacy (vehicles per 100 passengers)	20	5	5
5271	safety (fatal accidents per 10^6 pop./year)	10	15	5

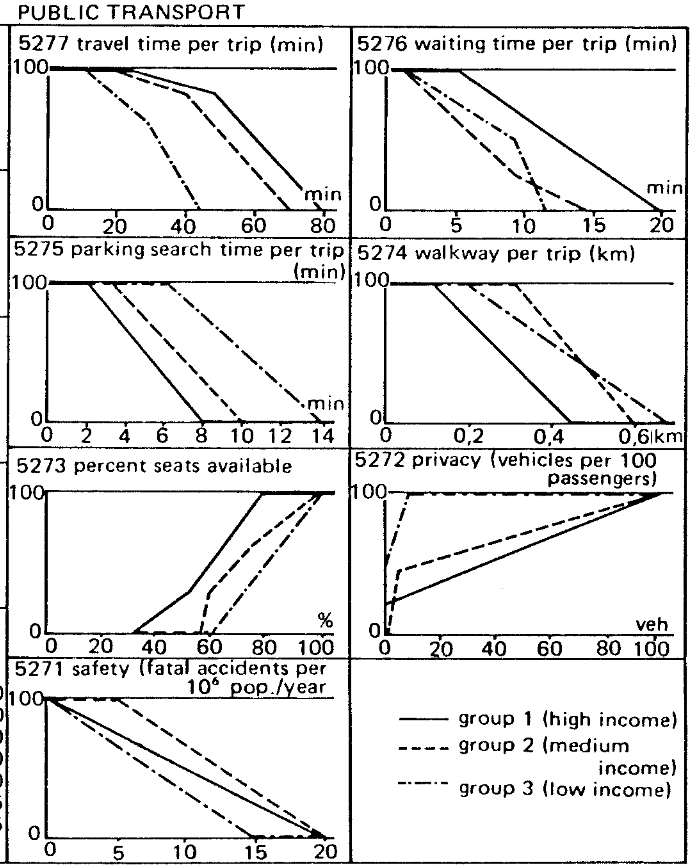

FIGURE 15.1 Excerpts from the POLIS hierarchy, with initial weights (left) and utility functions (right).

conflict by discussion rather than by formal rules like majority vote or averaging of individual weights.

- If an evaluator or a group of evaluators does not explicitly specify weights for any one cluster, a "default" weighting scheme taken from the sample weightings is automatically assigned. The project team specifies which of the sample weightings should serve as default for each group.

It may be argued that by handing out suggested weighting alternatives the project team is likely to influence the results. This clearly did not happen in the experiments, since in all cases the evaluators soon started to override the suggested weights by their own ratings. Rather, they used the suggestions as a kind of orientation to structure their discussion about the issues. The provision of "default" weights relieves the evaluators from the burden of working through every detail and, instead, frees them to concentrate on the issues that they feel to be most central.

The direct scaling technique itself may also be questioned. And, indeed, it may be a questionable practice to ask whether "housing" is more important than "education" without knowing the range or domain in which these aspects of urban life may vary.[1] However, this argument must be viewed in conjunction with the technique of cluster weighting and with the conventions used for the design of the utility functions, which will be discussed below. The cluster-weighting technique guarantees that the elements whose importance is to be compared are at least roughly comparable, since, by definition, they belong to the same aspect of the evaluation object and since they are likely to include no totally irrelevant items. The convention of designing utility functions, on the other hand, provides a semantic norming of the domains of the attributes, regardless of the actual numerical levels they may acquire later. These two circumstances help to convey to the participants a fairly clear understanding of what the weights really mean.

15.3.4 UTILITY FUNCTIONS

While the hierarchy and the weights establish the relation between a goal and all other goals of the goal system, the goal itself – its meaning, direction, and domain – is established by a utility function. The utility function represents the aspirations of the evaluator with respect to a certain goal, or, in other words, his ideas about the level of achievement that is desirable with respect to that goal. The utility function specifies for each goal whether it has been served badly or satisfactorily or well.

This leads to a distinction between two types of goals that have different types of utility functions. For the goals on all but the lowest level of the hierarchy the

[1] In Raiffa's argumentation (expressed at the 1974 Battelle meeting), importance weights have meaning only relative to the scaling of the attributes: if the domain of an attribute changes, its weight should change, too. In Edwards' more pragmatic view, the implicit specification of the domains of the attributes given by the context often must suffice, since frequently the actual range of the action alternatives is not known at the time the weighting has to be done.

type of function is already known: these goals are well served if their subordinate goals on the next lower level are served well. More precisely, the degree of achievement of such goals, or their utility value, is simply the weighted average of the utility values of the subordinate goals, with the weights provided by the weighting procedure. This is the weighting function underlying the additive model of MAUT.

The goals on the lowest level of the hierarchy are not amenable to such treatment because they do not have subordinate goals. Instead, they are defined to be independent dimensions or attributes of the evaluation object. While the goal hierarchy and the weighting scheme are concerned with general properties of all possible evaluation objects, it is at this point that the actual levels of the properties of a particular evaluation object enter the evaluation procedure. The second type of utility function serves to make that entrance possible. As the first type of utility function coincides with the additive weighting function of MAUT, the term "utility function" will be used exclusively for the second type.

The goals or attributes on the lowest level of the hierarchy may be any relevant aspect of the evaluation object, provided that they are operational or measurable on some nonarbitrary scale. Of course, one must expect that they come in many different dimensions – technical, physical, monetary, and so on. The utility function translates these differently scaled dimensions into the dimension that the evaluation model is intended to measure: utility. That means that one utility value has to be assigned to each plausible value of the attribute, no matter what scale it is measured on. It thus becomes apparent in which direction and by how much the attribute has to be changed to increase its utility by a certain margin.

If the attributes are not operational and measurable, evaluation still would be possible, but only on an *ad hoc* basis, by subjectively assessing the utility of a specific attribute level in a specific option environment. Hence, each option alternative would have to be evaluated directly by human evaluators. In most cases, however, this is neither desirable nor possible. Instead, the utility function provides a general transition rule by which even alternatives unknown to the evaluators may be evaluated. Thus, the operationality of the attributes is indispensable; it allows *a priori* evaluations that can be applied to a whole category of action alternatives. On the other hand, the postulate of operationality certainly does restrict the selection of more qualitative attributes of the evaluation object for which appropriate indicators cannot be found.

Another problem of utility functions has to do with the independence assumption underlying the additive model of MAUT. Especially in the case of complex evaluation objects containing a large number of attributes, the independence assumption, whether it is "environmental" or "preferential" independence, is almost certain to be violated. At best, the attributes can be expected to be fairly independent of each other if they are allowed to vary only within a very narrow margin – that is, if the domains of the utility functions are very small. One way of securing additivity, therefore, would be to reduce the domains of the attributes as much as possible. However, this would prevent the evaluation of innovative action alternatives with still unknown levels of attributes that may fall outside the restrictive domains, and assessing innovative designs is one of the very purposes of evaluation in planning.

The technique selected for designing utility functions reflects the above considerations. The most straightforward of all techniques, "curve drawing," was used and modified by analogy to the weighting technique applied:

1. The utility function of an attribute is defined to be a real-numbered function of the attribute value (AV), or level, or outcome, of that attribute. The value of the utility function, or the utility value (UV), of the attribute, is defined to be bounded between zero and one hundred, with the following semantic implications:

Utility Value (UV)	Attribute Value (AV)
0	A totally unacceptable outcome
100	The outcome that can be achieved by reasonable, good practice of planning

There are no restrictions on the character of the utility function within the above domain; in other words, it need not be monotonic, continuous, or convex, nor need it have a unique minimum or maximum.

2. For each lowest-level attribute one utility function has to be designed by each evaluator or group of evaluators. First, the utility function is discussed with the help of graphic representation. Then, the resulting curve is entered into the computation as a set of up to ten pairs (AV, UV). Thus, there is no need to define the function in terms of a mathematical expression. The sections of the curve between the points entered are approximated linearly by the procedure.

3. To further facilitate the process of designing utility functions, alternative sample utility functions are provided by the project team, so that evaluators may simply select one of the suggested alternatives, or define new ones. Figure 15.1 contains some examples of suggested utility functions.

4. If the evaluators are groups, each group is requested to agree on the selection of utility functions. As with the weighting, the groups are encouraged to settle intragroup disagreement by discussion instead of through a formal voting procedure.

5. If an evaluator or a group of evaluators does not explicitly specify a utility function for any one attribute, a "default" utility function taken from the sample utility functions is automatically assigned. The project team specifies which of the sample utility functions should serve as default for each group.

This technique has proven to have many advantages. In the experiments, the evaluators quickly grasped how to read and interpret utility functions with the help of the sample utility functions handed out to them. They used the sample utility functions to focus their own discussion and usually settled on one of them without difficulty. As with the weights, the provision of "default" utility functions was extremely valuable in reducing the amount of evaluation work to be performed by the evaluators. In fact, only in this way is it possible to make such a large number of individual judgments within a reasonable length of time without losing sight of the important issues and of the larger context in which they must be seen.

15.3.5 CONFLICT MEASUREMENT

Two kinds of conflict may occur in the context of multiattribute evaluation:

- Conflict between goals (intrapersonal conflict): Two goals are said to be in conflict if the achievement of one of them reduces the probability of achieving the other. Almost everyone's goal system contains many such conflicts.
- Conflict between people (interpersonal conflict): Two evaluators or groups of evaluators may have different opinions on the importance of goals and on goal achievement – i.e., they have different interests or preferences. Consequently, their evaluations may result in the selection of different alternatives.

While the weighting technique of MAUT takes into account the first kind of conflict, no formal procedure is provided for the second kind. Disagreement between or within groups is to be settled by informal discussion. However, this discussion may be supported by supplying information about the degree and constitution of the disagreement. Therefore, an attempt has been made to measure interpersonal conflict, or differences between evaluation judgments.

Mack and Snyder (1957) postulate three conditions for the existence of conflict between two groups:

Satisfaction of interests of both groups is impossible. Winning by one group implies loss for the other.

One group is more powerful than the other and is interested in keeping its power.

Both groups are aware of the difference between their interests and of the inequality in their power.

Obviously, only the first condition of conflict is addressed here, as no information about the distribution of power between the groups or their perception of it is available. Hence, the concept of conflict measured here is a rather narrow one: it is merely the divergence of preferences, expressed by different weights and utility functions; it may be termed latent conflict. However, detailed and concrete information is available about this kind of conflict.

There may be various ways of measuring differences between weights and utility functions of two evaluators or groups of evaluators. In this case, linear correlation was used. The Bravais–Pearson product–moment correlation coefficient was considered to be a good measure of similarity of judgment, a coefficient of +1 indicating complete agreement and a coefficient of −1 indicating complete antagonism between the groups. Three types of conflict measures were computed:

Correlation between the weights assigned to the goals by each group: a measure of agreement on priorities

Correlation between the utility values calculated for each plan using the utility functions of each group: a measure of agreement on satisfaction levels

Correlation between the weighted utilities of each plan for each group: a measure of agreement on achieved satisfaction

The latter two types of conflict measures can be calculated for each zone of the city, using zonal utility values. Thus, conflicts may be localized and traced back to their origins – lack of public services, unsatisfactory housing, or insufficient transportation, for example. Such localized conflict measures, however, are meaningful only when both groups live or work in that zone.

Since not only existing but also projected states of the city may be the object of evaluation, it is, in principle, possible to predict the occurrence of local conflicts. However, this facility must be used with caution. First, one must consider that the future states are evaluated on the basis of present knowledge and goal systems; potential changes of values and attitudes are, at least in the present form of the analysis, not taken into account. Second, the limited concept of latent conflict disregards the dynamics of genuine, or open, conflicts, which usually originate from causes that are beyond the scope of local planning. Nevertheless, it can be assumed that planning alternatives that reduce the amount of latent conflict may at least help to reduce the overall conflict potential in urban society.

15.3.6 COMMUNICATION OF RESULTS

It is essential to the success of a dialogue that the participants understand each other. Therefore, the communication of the results of simulation and evaluation to the evaluators is a critical step in the procedure and a prerequisite to the intended learning process.

At present, the standard printed output of the simulation and the evaluation model each consists of some 100 pages of tables, diagrams, and maps. In spite of careful design, much of it usually turns out to be irrelevant, while other information is required by the participants in the experiments that might have easily been provided from the computations performed. This indicates that the problem of communication of results is still largely unsolved. Much of the difficulty encountered may be attributed to the fact that interactive computer access was not available at the time of the experiments, but even with interactive computing, the output options have to be carefully tailored to the information needs of the users. This is even more important when the users are not trained in the processing of large amounts of numerical information. In such cases, appropriate nonnumerical (i.e., graphic or textual) transformations of numerical information become important elements of the procedure.

A few guidelines for effective communication of the evaluation results to the evaluators can be derived from the experiments that have been conducted. Much depends on the ability of the person explaining the results to divide the information into digestible portions in order to avoid information overload. It is equally important always to relate the results to the interests and problems of the particular group addressed.

The communication of results usually starts with the most general information and moves from there to the concrete and specific. First, for each plan the total utility as seen by different groups is discussed. Next, this total utility is disaggregated into its components. They reveal in which sector of the goal hierarchy the different groups are well or badly served by each plan. The same type of analysis can be repeated for each goal cluster on each level of the hierarchy as desired.

In the next step, the analysis is augmented by the local dimension. On the most general level, the utility values of the zones as seen by any two groups may be plotted against each other. Zonal utility values of any goal for any group may be displayed in a map showing local disparities in the satisfaction of that goal.

From there, one or more zones may be selected for further analysis, zones in which the participating groups have a specific interest because they live or work there. For the selected zones, all previous steps of the analysis may be repeated. In addition, on the zonal level, utilities may be traced down to the attributes that caused them. By a listing of attributes with "critical values" it is possible to identify attributes whose improvement appears to be most urgent.

With all this information, the participants are prepared to understand the conflict measures. The most general measures of conflict apply to the whole city. Zonal conflicts may be displayed in conflict maps that show where there is a discrepancy between the satisfaction levels or the achieved satisfaction as perceived by any two groups. The information contained in the conflict measures has a twofold function in the process: it helps the participants to find out where and how other groups are better or worse served by a plan, and it makes them realize where the achievement of their own satisfaction interferes with that of others. In addition, changes in the conflict measures over repeated applications provide a measure of successful adaptation of interests during the learning process.

Sample evaluation results are presented in section 15.4.

15.3.7 ITERATION

After a first cycle of simulation and evaluation, all input is reviewed, and the whole process is repeated. The iteration constitutes a learning process as the participants act with improved insight into the behavior of the system that is to be planned.

From the first simulation and evaluation results each evaluator or group of evaluators has a fairly good perception of where the present plans are satisfactory and where or how they should be changed. The ideas of different groups on these changes will differ. As, obviously, only one plan can be executed, the divergent ideas must be consolidated.

The appropriate format of such consolidation is public bargaining. In the hypothetical environment of experimentation, this means some sort of organized gaming. It should be noted that even in reality such bargaining will remain in a sense fictitious, since in most countries there is no room for actual local planning decision outside the institutional bodies of the local legislature. The gaming session will result in guidelines for plan revision. In the experiments, a "planning commission" composed of members of all participating groups was constituted to design a compromise plan from these guidelines.

In addition, the evaluators are free to revise their goal systems. In most cases, they will start with changing the importance weights. From the preceding evaluation the evaluators know which attributes or sectors of the hierarchy are served less well than others. It may be assumed that most evaluators will shift additional weight to those attributes that seem to deserve more attention because of failure to achieve them. If this happens at the same time that the plan is revised, the overall rating of the plan may become worse, even though the plan has, in fact, improved.

Only after they have altered their importance weights are the evaluators likely to change their utility functions. People will decrease their aspirations or standards with respect to a goal only if they understand that these standards are completely unrealistic. On the other hand, an increase in aspiration levels seems plausible only if no other attributes have grave, deficits, something that is hardly ever achieved.

15.3.8 ON UNCERTAINTY

A brief final comment should be made on the treatment of uncertainty in the proposed procedure. There can be no doubt that the outcomes of planning measures in urban planning over a long time frame are far from certain, as has been emphasized earlier. Nevertheless, as will have been noticed, the mathematical model of utility used in the procedure described here contains no term for the consideration of uncertainty. The rationale for this lies in the fact that a highly sophisticated prediction instrument, the simulation model, is used to predict the outcomes to be evaluated. If the consequences of the planning actions were predicted intuitively (which hardly seems possible), a subjectively estimated probability could, and should, have been assigned to each of them. This is not possible with the simulation results, as there has been no attempt so far to trace probabilities from model input to model output, and it seems very unlikely that such an attempt should ever be successful. Hence, from the point of view of the evaluators, all model output has equal certainty, or equal uncertainty, which relieves the decision model of the necessity of distinguishing between different levels of probability.

Of course, this means that the reliability of the evaluation results can be no better than that of the simulation output. Still, it is assumed that this reliability is higher than that of a decision analysis based on intuitive prediction of outcomes.

15.4 WORKSHOP EXPERIMENTS

Although the simulation model alone has been applied to land use and transportation planning problems in Cologne and Vienna, the combination of simulation and evaluation has been tested in a series of experimental applications. For these tests, 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 as required by the simulation model, served as the input for three experimental workshops with groups of different size and professional background.[1] Selected results of these workshops are presented below.

15.4.1 WORKSHOP ORGANIZATION

As a common basis for all three workshops three basically different alternatives for land use and transportation planning in Darmstadt were formulated with the help of staff members of the Darmstadt city planning department (Figure 15.2):

10/A New concentration of population and employment in the northern part of the urban area, combined with maximum investment for highway construction; no improvement of public transportation

20/B Incremental housing development added to old village cores; balanced transportation concept with moderate improvement of highway system and transit service

30/C "Antisprawl" concept with high-density corridor across the central city district; environment-conscious transport scheme with cutbacks on highway construction; new linear (individual-cabin-type) transportation system along inner city corridor

A fourth alternative is the hypothetical "zero" or do-nothing alternative (NV, for the German *Nullvariante*), which assumes no public planning actions whatsoever

[1] These workshops were held in 1973 and 1974. Participating in the first workshop were 26 researchers from various Battelle laboratories; the second workshop was held with 25 junior planning officials of the State of Hessen; the third workshop was conducted at the University of Karlsruhe with 22 postgraduate students of regional sciences.

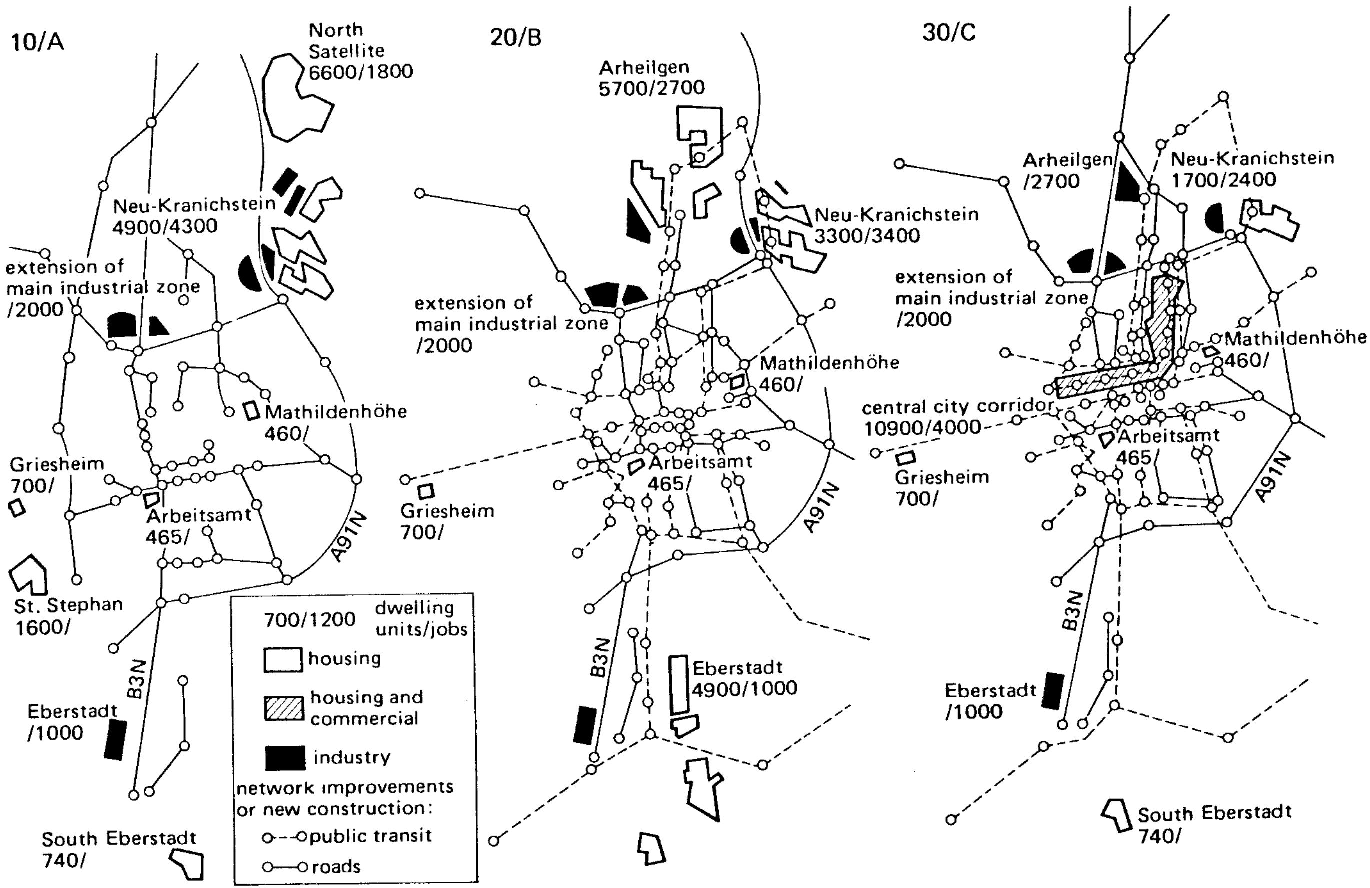

FIGURE 15.2 Darmstadt planning alternatives.

and represents pure market behavior. These four planning alternatives were prepared for input into the simulation model and simulated in advance for workshop use.

Because of lack of space it is not possible to illustrate the results of the simulations in this paper. It must suffice to say that the four alternatives differed widely with respect to land requirements, depletion of natural resources, traffic conditions, environmental quality, and costs for the public budget and for the society at large.

The workshops lasted from 3 to 5 days. At the beginning of each workshop the participants were divided into three groups representing socioeconomic groups (high, medium, and low income). To facilitate group identification, typical representatives of each socioeconomic group were described in written self-portraits included in the workshop material. The groups were asked to anticipate as well as they could the needs and interests of the socioeconomic group they were to represent and to make evaluations from that perspective. In workshops 2 and 3 the results of the preceding workshops were explained to the participants in an attempt to build upon the earlier experiences and thus make all three workshops a continuous learning process.

After the participants were briefed on the procedure and on general planning problems of Darmstadt, the workshops followed the sequence of steps shown below:

1. The results of the advance simulation of the four initial plans were presented to the participants. In workshops 2 and 3 the results of the preceding workshops were communicated as well.
2. The groups made their first evaluations.
3. The initial plans were evaluated with these initial goal systems. In workshops 2 and 3 plans generated during the preceding workshops were also evaluated.
4. In a gaming session the new results were discussed by the groups.
5. A "planning commission" consisting of two delegates from each group designed a "compromise" plan.
6. The groups revised their goal systems.
7. The compromise plan was simulated and evaluated with the initial and the new goal systems.

Because of lack of time only in workshop 3 was it possible to reiterate and reenter the procedure with step 4, a new gaming session.

15.4.2 INITIAL RESULTS

In all workshops the first evaluation showed considerable differences in the attitudes of the groups toward the different plans and in the groups' satisfaction levels. The most interesting result was that, at the higher aggregation levels of utility, the group representing the medium-income sector of the population arrived at the highest utility values for all planning alternatives. All plans seemed to meet the needs of the middle class, which may partly be explained by the fact that most planners are middle-class people. The lowest utility values were computed for the group representing low-income people, which may be considered self-evident.

Of the plans, least favored was the "do-nothing" alternative (NV), which seems plausible, as by definition this alternative does not attempt to solve any problem at all. However, the groups did not agree on the rank order of the remaining alternatives. The low-income and medium-income groups expressed a clear preference for the antisprawl concept 30/C, the plan that implies the most radical change of urban structure. These two groups might have agreed on this alternative, even though the middle class would derive more benefits from it. The high-income group, however, preferred the incremental-growth alternative (20/B), an alternative that implies only minor changes compared with the "do-nothing" alternative. Table 15.1 shows the total utility of the four initial plans as seen by each group after the initial evaluation of the first workshop. All utilities shown are computed for the simulated system state 25 years after the base year, i.e., for the year 1995.

The numerical differences between the utilities of the plans may seem to be relatively small. This raises the question of the sensitivity of the evaluation procedure to input changes. Formally, utilities may vary, by definition, between 0 and 100. For utilities aggregated from a number of attributes, however, both extremes are equally unlikely as they imply that all subordinate attributes with nonzero weights have utility 0 or 100. For a given set of subordinate attributes the aggregate utility may vary only between the lowest and the highest utility value occuring in the attribute set. These extremes are still very unlikely as they imply that all less extreme attributes have zero weights. In summary, the "averaging of averages" implied in the additive model of MAUT causes, on the higher levels of a goal hierarchy, a strong tendency toward utilities in the medium range of the utility scale.

The conclusion from this is that the interpretation of aggregate utilities must consider relatively small differences. In addition, it suggests that the analysis should proceed from aggregate utilities to partial or disaggregate utilities whose domains tend to increase with disaggregation. An example of such disaggregated analysis is shown in Figure 15.3. The global utility values of alternatives NV and 30/C from the second workshop are disaggregated into their five components on the second

TABLE 15.1 Total Utility of Four Initial Plans, by Group (Workshop 1)

Income Group	Plan			
	NV	10/A	20/B	30/C
High (1)	47.2	49.3	50.7	49.4
Medium (2)	54.8	58.6	52.4	59.2
Low (3)	39.8	43.8	41.2	44.2

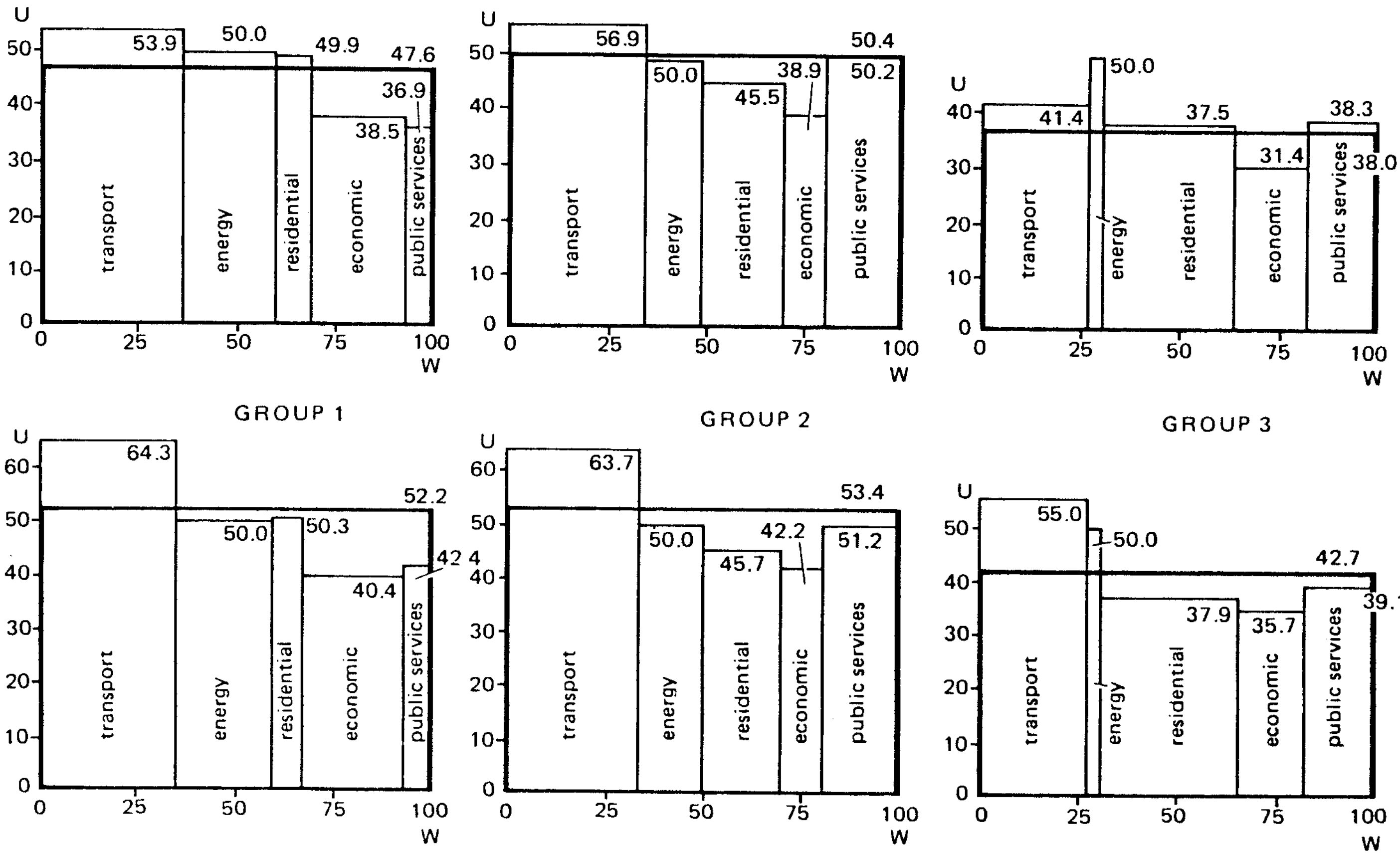

FIGURE 15.3 Sample of evaluation results: decomposition of total utility of plans NV and 30/C, from the second workshop. Group 1, high income; group 2, medium income; group 3, low income.

hierarchical level. Each of these components is depicted as a rectangle whose width represents its relative weight and whose height represents its utility value. It is readily seen that the improvement of plan 30/C over the do-nothing alternative is effected mainly by the improvement of transport services. One general observation can be made: the profile of the weighted utility values is largely determined by the weights. This can be explained by the fact that the standard deviation relative to the mean is much higher for the weights than for the utilities, and this difference tends to increase on the higher levels of the hierarchy.

Figure 15.4 shows results that are disaggregated locally as well as hierarchically. A zone was selected for each of the three groups; each zone is populated predominantly by members of the socioeconomic segment represented by the group. In this case the selected utility aggregates are not taken from the same hierarchical level, so their weights do not add up to 100. The most interesting result of this kind of analysis is that at the level of zonal utilities the differences between the groups are much more distinct than if they are aggregated for the whole city. For instance, the zonal utilities of group 3 are, with one exception, much lower than the global utilities averaged over all zones for the same group. For comparison, the respective global utilities are shown by broken lines. The conclusion from this is that, obviously, low-income people live in those areas of the city that they themselves consider to be less desirable. The reader may note that a similar analysis for the two other groups leads to quite different conclusions. (These findings suggest a modification in aggregating utilities over zones. Instead of averaging utilities weighted by total zonal population, only the population of the socioeconomic group for which the evaluation is made might be used as weights. It is likely that this would increase the differences of utility between groups.)

The above results help in the interpretation of intergroup conflicts as they are revealed by the evaluation technique. Conflicts between the high-income and low-income groups tended to be most severe, the major areas of conflict being the most favored, attractive, and expensive housing areas in the southeast part of the city, and the northern part of the city, where a new satellite is currently being constructed. The conflict intensity between the high-income and the medium-income groups and between the medium-income and the low-income groups, appeared to be generally lower, which again seems plausible.

15.4.3 ITERATION RESULTS

If it is supposed that repeated application of simulation and evaluation initiates a learning process for the participants, the changes of results after iteration are of specific interest. Two questions may be asked: (a) How do the utilities of plans change? and (b) Can the conflicts between groups be reduced? It will be shown that these questions are closely related.

To answer the first question, the total utilities of the compromise plans as designed by the "planning commissions" of the second and third workshops are

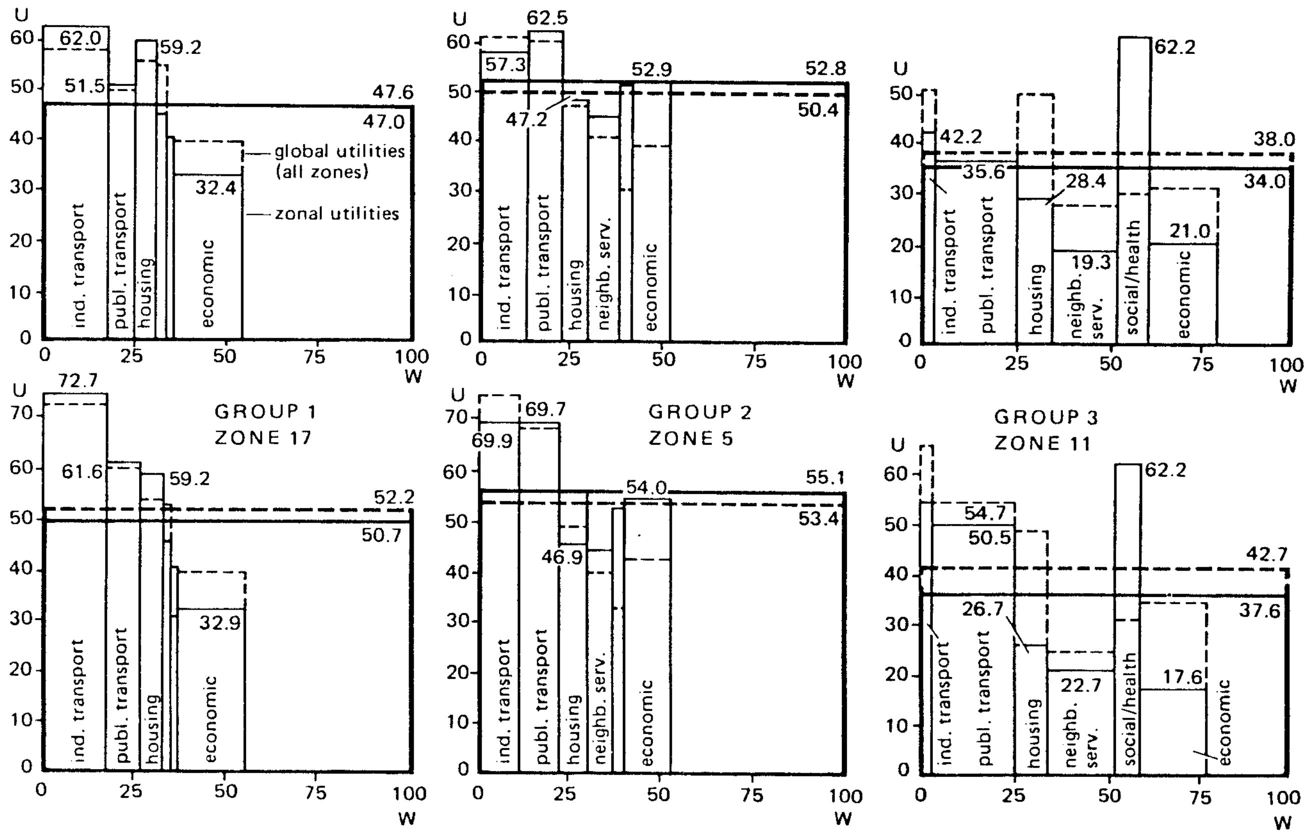

FIGURE 15.4 Sample of evaluation results: decomposition of zonal utilities (solid lines) of plans NV and 30/C. Broken lines are global utilities (see Figure 15.3).

TABLE 15.2 Total Utility of Compromise Plans, Compared with Utility of Best Plans of Preceding Workshop, by Group

	Workshop 2		Workshop 3	
Income Group	30/C	31/E	31/E	32/F
High (1)	52.2	50.5	49.9	49.9
Medium (2)	53.4	51.8	48.0	48.4
Low (3)	42.7	41.6	41.6	42.5

TABLE 15.3 Total Utility of Plan 30/C in All Three Workshops, by Group

	Workshop		
Income Group	1	2	3
High (1)	49.4	52.2	49.2
Medium (2)	59.2	53.4	46.6
Low (3)	44.2	42.7	41.8

compared in Table 15.2 with those of the best plans of the preceding workshops, evaluated with the same goal systems. It can be seen that in the second workshop the compromise plan means a reduction of utility for all groups. Only the planning commission of the third workshop succeeded in improving the utility of the city. Even there, the gains in utility seem small compared to the amount of effort that went into the design of the plan.

There may be several reasons for this. First, the planning commissions worked under limitations of time and resources; only one iteration was performed. Second, the small degree of improvement may be an indication of the difficulty of influencing the conditions of life with the limited instruments of urban planning. The third reason may be the most important: "improving" the existing plans was not the only purpose of the planning commission; it also had the task of consolidating diverging opinions into a plan that was acceptable to all groups. One of the characteristics of compromise is that a gain in consensus may have to be paid for with a loss of satisfaction for all.

This leads to the second question, which concerns the reduction of normative differences between the groups. This process can be analyzed by looking at how the same plan was evaluated by groups with changing goal systems over time. Table 15.3 shows how planning alternative 30/C was evaluated in all three workshops. Obviously, the perceived utility of plan 30/C decreased from workshop to workshop. As the plan was always the same, this decrease must be attributed to changes in the value systems applied in the evaluation. In fact, a look at the distribution of weights on the second level of the hierarchy reveals significant shifts in emphasis (Table 15.4). The general tendency of these shifts was away from the technical aspects of urban life, such as transportation and energy, and toward more socially oriented aspects, such as housing and public services. But, as pointed out earlier,

TABLE 15.4 Perceived Utility of Plan 30/C, at Second Level of Hierarchy, by Group and Workshop

Income Group	Transport	Energy	Residential	Economic	Public Services	Total
High (1)						
Workshop 1	30	20	10	30	10	100
Workshop 2	36	24	8	24	8	100
Workshop 3	28	28	9	27	9	100
Medium (2)						
Workshop 1	49	21	9	12	9	100
Workshop 2	35	15	20	10	20	100
Workshop 3	12	18	28	21	21	100
Low (3)						
Workshop 1	27	3	35	7	28	100
Workshop 2	27	3	35	18	18	100
Workshop 3	20	0	48	8	24	100

good transportation was the greatest asset of plan 30/C. Therefore, a shift of emphasis to less-well-served areas of the hierarchy must necessarily lead to a decrease in the plan's overall utility. These findings seem to underline the assumption that evaluators are likely to shift weight to attributes that rated low in previous evaluations.

It remains to be seen if these losses in perceived utility were compensated for by a gain in achieved consensus. Table 15.5 shows the development of the three kinds of correlation coefficients computed as conflict measures of plan 30/C. The numbers clearly convey the degree of similarity in the goal systems of the three groups. With respect to the weights (i.e., the relative importance of goals), there is

TABLE 15.5 Correlation Coefficients of Weights, Utilities, and Weighted Utilities as Conflict Measures

	Correlation Coefficient		
	Group 1–2	Group 1–3	Group 2–3
Weights			
Workshop 1	0.83	0.00	0.31
Workshop 2	0.87	0.07	0.20
Workshop 3	0.74	−0.22	0.13
Utilities			
Workshop 1	0.77	0.43	0.71
Workshop 2	0.63	0.71	0.72
Workshop 3	0.80	0.78	0.92
Weighted utilities			
Workshop 1	0.90	0.34	0.61
Workshop 2	0.91	0.20	0.38
Workshop 3	0.55	−0.21	0.27

TABLE 15.6 Correlation Coefficients of Weighted Utilities, Workshops 2 and 3

Income Groups Correlated	Workshop 2		Workshop 3	
	30/C	31/E	31/E	32/F
1–2	0.90	0.91	0.84	0.71
1–3	0.20	0.19	0.09	−0.16
2–3	0.38	0.38	0.29	0.27

fairly high consensus (correlation) between groups 1 and 2, less consensus between groups 2 and 3, and practically no consensus between groups 1 and 3. Clearly, the consensus decreased from workshop to workshop; this must be attributed to the shifts in weights discussed above. If one correlates unweighted utilities, the correlations are, in general, much higher. Here, the tendency is reversed. With each workshop, the agreement between the groups about the perceived state of the urban system increased. The conflict measures using weighted utilities show the combined effects of those two tendencies: consensus between the groups on their achieved satisfaction decreased from one workshop to the next.

A final inspection may show whether this tendency can also be observed in the development of consensus between the groups during the workshops. Table 15.6 shows conflict measures based on weighted utilities of the compromise plans designed in workshops 2 and 3 and of the respective previous plans. Clearly, disagreement between the groups on the satisfaction achieved by the plans again remained constant or increased.

These results are far from satisfying. They imply that in no case did the groups succeed in finding a substantially better plan or in reaching consensus on a compromise. For a decision aid designed to improve urban decision making, this looks like a poor performance. Could it be that increased dissatisfaction and disagreement are necessary first steps in the learning process, before real progress can be made? The experiments conducted so far have been too limited, both in number and in duration, to answer that question.

15.5 APPRAISAL AND OUTLOOK

In spite of the limited number of experiments conducted, a preliminary assessment of the applicability of the proposed procedure seems to be possible.

On the procedural–technical level, the following observations can be made:

- The procedure is accepted by the participants as a meaningful decision aid that supplies relevant information.
- The procedure is transparent and straightforward enough to be understood and operated by the participants.
- The procedure is flexible enough to respond to spontaneous input by the participants.

- The procedure provides the participants with insights into interdependencies of the urban system that they might otherwise have been unable to recognize.
- The procedure makes the participants realize that satisfaction of their own interests may interfere with that of others'.
- The procedure motivates the participants to cooperate in resolving conflict by compromise.

On the other hand, two problems still need to be solved if the procedure is to be successful:

- The output of the simulation and evaluation programs should respond more flexibly to the information needs of the participants.
- Feedback between the computer models and the participants should be made quicker, easier, and more economical in order to allow more iterations in less time.

Interactive computing and more sophisticated output media – multiscreen graphic displays, for example – seem to offer reasonable solutions to these two problems. It is expected that the application of such technology, in conjunction with more refined group-dynamic techniques, would help to make the group discussions more realistic and effective, so that, eventually, the distant goal of inviting "real" people to the sessions could be approached.

On the theoretical level, an unanswered question is how appropriate the assumptions underlying the evaluation procedure are with respect to the decision situation of urban planning. A preliminary answer will be given in two parts.

First, the restrictions under which the multiattribute model is considered valid are inspected for their applicability to the urban decision situation. It has been demonstrated in this paper that they are applicable only in a very crude, approximate manner. In particular, it has been shown that because of the immense complexity of the evaluation object, the conditions of data exhaustiveness, precision, and independence can hardly be satisfied: as the decision outcomes cannot be predicted intuitively, only attributes implied in the simulation model (which is far from complete) can be processed. But, as the number of attributes is still very large, only the crudest techniques for determining weights and utility functions (e.g., direct scaling and "curve drawing") can be applied. And again, because of the large number of attributes, the time required to test the independence of each one would be prohibitive. Moreover, it cannot even be expected that the attributes will be independent, either preferentially or environmentally. In summary, it must be concluded that, with respect to very large goal systems, the restrictions of the multiattribute model are far too great; they must be relaxed drastically if the model is to become practical.

Second, the multiattribute model itself – that is, its ability to portray human judgment in the context of urban decision making – is examined. The discussion will touch only briefly upon three important problems. The first of these is the additive model itself. The theory does not explain which part of human judgment is represented by utility or satisfaction as expressed by weights and utility functions. What does it really mean to multiply weights and utilities? In this paper, the assumption has been made that evaluators tend to shift weight to badly served attributes. If this is true, weights would, in a sense, be measures of dissatisfaction. Utility, in the additive model, would then be the sum of the products of dissatisfaction and satisfaction. Does this make sense? At least it makes the interpretation of weighted utility values extremely difficult. They can no longer be seen as an expression of pure utility; they might instead express the interest of the evaluator in changing the appropriate domain of reality. To put it simply, the "utility" of an important attribute with a low satisfaction level is *not* the same as that of an unimportant attribute with a high satisfaction level, although MAUT would suggest that it is.

The second problem is the static nature of the multiattribute model as it is presently applied. This problem becomes critical when the simulation and evaluation models are combined: the evaluators are to evaluate future states of the city with current values. Obviously, goal systems change with time, either in response to changes in technology and life-style or in adapting to changes in the goal systems of others, or because the limited perceptional capacity of man prevents the evaluators from perceiving more than a small portion of their total goal system at any one point, which forces them to periodically update their awareness of their own preferences. Only this last type of short-term adjustments of goal systems is dealt with adequately by the intended learning process. The treatment of long-term changes of goal systems would require the design of a dynamic simulation model of urban value structures that would be no less complex than the simulation model of the real city. As such a model would have to contain feedback cycles, it is very unlikely that the model structure of a dynamic MAUT would still be the additive, hierarchical model. [Some thoughts on dynamic simulation of goal systems are contained in Bauer and Wegener (1975, pp. 412–413).]

The third problem is the limited concept of rationality implicit in the multiattribute model, as it is in most decision analytic approaches. Following this concept of rationality, a rational decision consists of the selection of the action alternative with the highest utility with respect to a given set of goals. The goal system is taken as fixed, its validity depending only on its being as errorless as possible – that is, on its representing the goal system of the decision maker as truly as possible. With multiple-group decision making, conflict analysis, and the possibility of feedback, this concept of rationality becomes obsolete. Now the goals, too, become dependent variables and are subject to change. The situation of the decision makers has changed: they have to decide which interests their decisions are going to serve; they are becoming aware of their partisanships. Rational decision making now implies the awareness of partisanship, and the validity of a decision analysis depends on the extent to which it reveals this partisanship. Decisions must finally be made. This means that at some point the learning process has to be stopped, but when? When all participants are satisfied, or when no more improvement of plans is possible?

It has been the purpose of the last three paragraphs to show that the multi-attribute model of MAUT, in its present form, is by far too restrictive in scope, too insensitive to change, and too limited in its concept of reality to encompass human conflict resolution behavior in complex decision-making environments like urban planning.

There are no easy solutions to these problems. A few pragmatic attempts to deal with some of them have been discussed in this paper. While all of the problems will offer opportunity for research for some time to come, further work in two directions seems particularly important. One line of development would try to improve the feedback mechanism by integrating simulation and evaluation models in one interactive model. With this tool, more realistic gaming techniques and guidelines for conflict resolution could be devised. The other line of development would attempt to simulate urban preference structures in a dynamic MAUT model.

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