GUIDANCE FOR DECISION

B. Schwarz
K. C. Bowen
Istvàn Kiss
Edward S. Quade

April 1980
WP-80-63

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

April 27, 1980

FOREWORD

The International Institute for Applied Systems Analysis is preparing a *Handbook of Systems Analysis*, which will appear in three volumes:

- *Volume 1: Overview* is aimed at a widely varied audience of producers and users of systems analysis
- *Volume 2: Methods* is aimed at systems analysts who need basic knowledge of methods in which they are not expert; the volume contains introductory overviews of such methods
- *Volume 3: Cases* contains descriptions of actual systems analyses that illustrate the methods and diversity of systems analysis

Volume 1 will have ten chapters:

1. The context, nature, and use of systems analysis
2. Applied systems analysis: a genetic approach
3. Examples of systems analysis
4. The method of applied systems analysis: finding a solution
5. Formulating problems for systems analysis

6. Generating alternatives for systems analysis

7. Estimating and predicting consequences

8. Guidance for decision

9. Implementation

10. Principles of good practice

To these ten chapters will be added a glossary of systems analysis terms and a bibliography of basic books in the field.

Drafts of this material are being widely circulated for comments and suggestions for improvement. In addition to responding to such interventions, the task of detailed coordination of the chapters—prepared separately by several authors—has yet to be carried out. Correspondence about this material should be addressed to the undersigned.

This Working Paper is the current draft of Chapter 8.

A word about the format of this Working Paper. In order to make the text of each chapter easily amended, it has been entered into the IIASA computer, from which the current version can be reproduced in a few minute's time whenever needed. This Working Paper was produced from the version current on the date shown on each page.

Hugh J. Miser
Survey Project

April 27, 1980

CONTENTS

GUIDANCE FOR DECISION

B. Schwarz, K. C. Bowen, Istvan Kiss, and Edward S. Quade

1. INTRODUCTION

Previous chapters have presented a summary description of the classical methodology of systems analysis and then treated in more detail problem formulation, the identification, design, and improvement of alternatives, and, finally, model building and the use of models to predict the consequences that follow each choice of alternative. This chapter is concerned with the guidance an analyst can provide, based on the information he has produced regarding the advantages and disadvantages of the various alternatives, to those responsible for selecting an action. This selection can sometimes be uncomplicated, but more often, when there are competing objectives, multiple decisionmakers, or great uncertainty about future conditions, it becomes a complex social process in which conflicts are resolved by bargaining and political judgment overpowers research findings. Objectives and constraints may be changed and new questions posed, forcing further analysis.

An analyst can never, based on his analysis alone, say with confidence: "This alternative should be selected." His mathematical model may designate an optimum action but this action is an optimum only in the domain of the model, for even the most perfect of models corresponds only imperfectly to the real world. Optimization is a technical concept, inapplicable in situations where differing values, uncertainty, ambiguity, multidimensionality, and qualitative judgment are present and possibly dominant. Even with perfect information, the most that can be done is to find the alternative that best satisfies a certain criterion under a given set of assumptions. This is far from full optimization; this would require the simultaneous consideration of the complete set of consequences for every choice of alternative, taking into account the full range of future events and their associated probabilities. For multiple decisionmakers, there can, in fact, be no optimality; any such concept depends on a particular decisionmaker's values, purpose, ability, and need. Consequently, as Boothroyd (1978) puts it "...would-be-scientific intervention is at best a way of getting things righter, not of getting them right." Earlier, for other causes, Charles Hitch (1960) had laid the ghost of optimization to rest in his retiring address as president of ORSA: "...Most of our relations are so unpredictable that we do well to get the right sign and order of magnitude of first differentials. In most of our attempted optimizations we are kidding our customers or ourselves or both. If we can show our customer how to make a better decision than he would otherwise have made, we are doing well, and all that can reasonably be expected of us."

Thus, in systems analysis, whenever the terms optimum, optimal, and optimization are found, they must be interpreted with great caution, for they refer to something that is, at best, a suboptimization.

In systems analysis as presented in Chapter 4, the decisionmaker was assumed to be a goal-oriented individual who makes his decision rationally by taking into consideration the probable consequences of each of his available courses of action, selecting the best by balancing the extent to which these actions achieve his objective against their costs. This model (called the "rational actor model" or Model I in Allison, 1971) suffices to produce good results for many operational and some policy or strategic decisions. It is not, however, an adequate formulation for decisionmaking in the public sector or for policy and strategy formulation where large complex systems are concerned. These latter decisions cannot be separated from the managerial, organizational and/or political situation in which they are made (Mintzberg and Shakun, 1978) and the classical model must be supplemented or modified by bringing in organizational and political considerations (Allison 1971, Lynn 1978, Rein and White 1977). Nevertheless, "For solving problems, a Model I-style analysis provides the best first cut. Indeed, for analyzing alternatives and distinguishing the preferred proposal, there is no clear alternative to this basic framework" (Allison 1971, p. 268). As remarked earlier, the degree to which systems analysis can define good policy depends to a large extent on two key elements--agreement regarding objectives and the strength of the underlying scientific understanding of the problem (Nelson 1977). About the latter, we can say nothing in this Handbook. But, before reviewing various schemes for presenting the results of analysis in ways to better facilitate decision by the responsible authorities, we can say somewhat more than has been said previously about objectives and the related concepts of constraints and values.

2. OBJECTIVES, CONSTRAINTS, AND VALUES

Ideally, problems with objectives and constraints are settled early in the study. In practice, however, systems analysis is an iterative process and objectives change and constraints are introduced or removed as we, and our sponsors, learn from the study. Also, as time for a decision nears, the decisionmaker who sponsored the study is strongly influenced by interested parties and other decisionmakers whose domain may be affected by whatever action should be taken.

To help a decisionmaker, it is, of course, crucial to know what he wants to achieve. He may have more than one objective. If so, then these objectives compete in the sense that, for given resources, if he is to strive for more of one, he must usually expect less of another.

Ideally for the analyst, there are clear, well thought through, and precisely spelled out objectives when the study is commissioned. In complex problems, however, this is hardly ever the case. Objectives must be fixed with a fair degree of certainty early in the problem-formulation phase of a study, for they determine what alternative actions are to be considered. When the consequences of these alternatives have been worked out, it is important in the light of the information gained to reexamine the original objectives and perhaps introduce modifications and design new alternatives.

Even when objectives are well defined by the client at the outset, they can seldom be adopted uncritically by the analyst. Means are sometimes taken for ends; a decisionmaker may say that his problem is where to place a new comprehensive health center in his district, but his real objective may be to improve health services in his community. In that case, better ways to do the latter may be to provide several neighborhood health centers or services through other mechanisms (hospital outpatient clinics or group practice). Perhaps programs focusing on maternal and child health services, or the screening of apparently well people to turn up heart conditions, should be considered. Unless the broader objective is adopted, these latter alternatives will not appear.

For certain issues, the question of *whose* objectives are relevant may need to be considered. For public issues, it is some subset of the citizens of today or of future generations; the decisionmaker is merely the person or organization charged with the responsibility for changing the system and the analyst may have to find some discrete way to make this clear.

It is important to distinguish between objectives on different levels. A lower-level objective is a means to achieve a higher-level objective. To build a new health center can thus be considered a lower-level objective and to improve health services a higher-level objective. Clear definitions of lower-level objectives are usually more easily provided and are technically easier to use for ranking decision alternatives. However, misleading results will occur if the lower-level objectives are not, under all circumstances, an appropriate means to achieve the higher-level objectives. The relationship need not be direct; for example, to relocate fire stations, the objective of lowering average travel time serves well as a substitute for better protection of lives and property (Walker et al. 1979).

High-level objectives usually express general intentions and are valid over a longer time period. A frequent problem is that such objectives are difficult to formulate clearly enough for direct use in analytical studies.

Constraints often have a function similar to objectives from an evaluation point of view. Herbert Simon (1964, p. 20) writes: "It is doubtful whether decisions are generally directed towards a goal. It is easier and clearer to view decisions as being concerned with discovering courses of action that satisfy a whole set of constraints. It is this set, and not any one of its members, that is most accurately viewed as the goal of the action. If we select any of the constraints for special attention, it is (a) because of its relation to the motivations of the decisionmaker, or (b) because of its relation to the search process that is generating or designing particular courses of action. Those constraints that motivate the decisionmaker and those that guide his search for actions are sometimes regarded as more "goal-like" than those that limit the actions he may consider, or those that are used to test whether a potential course of action he has designed is satisfactory. Whether we treat all the constraints symmetrically or refer to some asymmetrically, as goals, is largely a matter of linguistic or analytic convenience."

When a distinction between objectives and constraints is made, it is usually based on the idea of a constraint as an absolute restriction. G. Majone (1978) suggests, and we concur, that when there are several objectives they can always be traded off at the margin if this leads to an improvement in the total utility. That is, it is reasonable to sacrifice a particular objective if the situation on the whole is thereby improved. A constraint on the other hand, cannot be so exchanged against other constraints, for its logical force resides wholly in its inviolability. However, the translations of a decisionmaker's desires into a problem formulation, including the definitions of limit values (constraints), must be done with a lot of care. For example, once a constraint, a limit value, is established by, or in concurrence with, the decisionmaker, it will be held to during analysis. Majone (1978) remarks: "The opportunity cost of a proposed policy constraint must be carefully considered before the constraint becomes firmly embedded in the analytic structure. As Hitch and McKean (1960, p. 196) write, 'casually selected or arbitrary constraints can easily increase system cost or degrade system performance manifold, and lead to solutions that would be unacceptable to the person who set the constraints in the first place.' They cite the example of a weapon-systems study, where a constraint on acceptable casualities lead to solutions in which 100 million dollars was being spent, at the margin, to save a single life. Many more lives could have been saved with the same resources. Had the policymakers realized the opportunity cost of their safety requirements, they would probably have set them at a lower level. Or, like good utilitarians, they may have chosen to treat the risk factor as a subgoal, to be optimized compatibly with other system's requirements and the available resources."

A number of different approaches can be used to expedite the process of reducing the number of objectives when there are multiple objectives (and constraints). The following list gives some examples. All of these require discussion among those decisionmakers holding competing objectives and a certain amount of compromise and concession.

• Objectives which are only means to achieve other objectives can be eliminated.

• If all the objectives can be interpreted as means to achieve some higher-level objective and a relevant measure of effectiveness or good proxy that corresponds to this objective can be defined and measured, than this higher-level objective may serve as the single objective.

• A preference ordering of objectives can sometimes be set up and "optimizing" done in sequence.

• All objectives except (the most important) one can be converted into constraints, by agreement on the minimum acceptable level of attainment.

• Tradeoffs among the objectives can be sought and used to construct a composite index of worth, a value or utility function (decision analysis).

• No effort can be made to "optimize" with respect to any specific objective. Instead, all objectives can be converted into constraints and with the agreement that any solution satisfying all constraints—called a *satisficing* solution—will be "good enough."

It is, of course, not always possible to reach the agreement necessary to implement any of the above, although the use of special techniques to increase the *value sensitivity* of decisionmakers (Dror 1975, p.250) may make them more amenable to compromise. We will treat value sensitivity in a section under that title after discussing satisficing and the more common schemes for presenting results: cost-effectiveness and cost-benefit analysis, decision analysis, and the so-called "scorecards."

First, however, it should be mentioned that quantitative evaluation schemes often cannot be based directly on estimates of the extent to which various objectives are achieved. The problem is that many objectives are difficult or impossible to quantify directly in any useful fashion. It is therefore necessary to use a surrogate or proxy, a substitute scale that can measure at least approximately the extent to which the real objective is attained. The problem is to get a good approximation. Thus to measure the quality of medical care in a community, one might use the infant mortality rate as a proxy.

One technique for finding quantifiable measures of effectiveness is to try several successive modifications of tentatively postulated possibilities for stating an objective to see whether any appropriate measures of effectiveness appear. Sometimes it can be easier to try several measures of effectiveness. These can be examined to see whether, if they were satisfied, the desired end would be achieved.

The mark of a good measure of effectiveness is that it closely reflects the objective. Unfortunately, there are a number of inadequate ways to go about obtaining such a measure.

One is to use input to measure output; to compare the quality of primary school education in various districts in terms of expenditures per pupil. A second is to use workload measures or efficiency measures to compare quality of output, say, to compare the quality of education on the basis of teacher-pupil ratios.

Consider a single unambiguous objective, say, to improve garbage collection. To facilitate comparisons, it is useful to have a scale on which to measure the effectiveness of the various possibilities. But there is no obvious scale to measure better garbage collection, so we need a proxy—a measure such as the percentage of blocks remaining without health hazards, or the reduction in the number of fires involving uncollected solid waste, or rodent bites, or valid citizen complaints. All of these unfortunately treat just an aspect, not the full value of better garbage collection. In practice, people often use even less satisfactory scales, for instance, an input measure—expenditure per household—or an efficiency measure—number of tons collected per man-hour—or a workload measure—tons of waste collected—that indicate nothing about the quality of the work.

When several attributes need to be considered, some system of weighting is sometimes used, resulting in an ordinal or cardinal utility function. The failing here is that the function is to a large extent the product of the analyst's judgment and not that of the responsible decisionmakers. The decisionmakers, if they were willing to spend the time, could work out their own set of weights (with guidance from the analyst) but even here the analyst's influence is powerful. H. Hatry (1970) comments:

> There is no doubt that the job of decisionmaker would be easier if a single effectiveness measure could approximately be used. However, I contend that such procedures place the analyst in the position of making a considerable number of value judgments that rightfully should be made in the political decisionmaking process, and not by the analyst. Such value judgments are buried in the procedures used by the analysts and are seldom revealed to, or understood by, the decisionmakers.
>
> Such hocus pocus in the long run tends to discredit analysis and distract significantly from what should be its principal role: to present to decisionmakers alternative ways of achieving objectives, and to estimate and display all the major tradeoffs of cost and effectiveness that exist among these alternatives.

3. SATISFICING

Since optimization is impossible, satisficing is an attempt to move closer to the world as it actually is. The reasons as summarized by H. Simon (1969, p. 64) are: "In the real world we usually do not have a choice between satisfactory and optimal solutions, for we only rarely have a method of finding the optimum. ...We cannot, within practicable computational limits, generate all the admissible alternatives and compare their relative merits. Nor can we recognize the best alternative, even if we are fortunate enough to generate it early, until we have seen all of them. We satisfice by looking for alternatives in such a way that we can generally find an acceptable one after only moderate search."

To satisfice, lower bounds are set for the various goals that, if attained, are "good enough." An alternative is sought that will at least exceed those bounds. A unique solution is not sought and conflicts between goals do not have to be resolved. The satisficer does have to worry that the performance standards are not set too high, for then it may be impossible to satisfy the constraints. An alternative is usually considered to be good enough if it promises to do better than has been done previously.

4. COST-BENEFIT ANALYSIS AND THE COST-BENEFIT CRITERION

Decisionmaking is often described as a weighing of benefits against costs if the benefits and costs are interpreted in the broad sense of referring to *all* kinds of advantages and disadvantages of different decision alternatives. Sometimes risk is considered as a cost, sometimes as a separate dimension. Comparisons of various alternatives in terms of benefit-cost-risk can therefore be considered a general framework of analysis (Dror 1975). Nevertheless, when the term cost-benefit analysis is used, it usually refers to a somewhat simplified type of analysis, well known to economists, and having its origin in welfare economics.

In economic cost-benefit analysis the analyst identifies the different types of consequences of each alternative, usually a governmental project (e.g., the location of an airport or a power station). The consequences are estimated quantitatively and the quantities converted to monetary units. Monetary benefits and costs are then summed separately with proper attention to probability and time of occurrence. The *cost-benefit criterion* means a ranking of the alternatives in decreasing order of the excess of benefits over costs. It should be borne in mind that not all costs and benefits, even though expressed in the same monetary units, can necessarily be added in a straightforward way, without additional scaling: costs like benefits have to be treated initially as a multidimensional variable.

Cost-benefit analysis has several attractive characteristics. The cost-benefit criterion seems very relevant for decisionmaking and defines a unequivocal method for ranking alternatives. Also, theoretically, it can be used to guide choice between such diverse alternatives as allocating funds for a water project (with irrigation, electric power, flood control, and recreation as goals) or for a health program to reduce infant mortality. If the projects are roughly of the same scale, one prefers the project with the greater excess of benefits over costs; if the projected benefits are less than the costs, then the project should not be undertaken.

Ideally, in an application, all consequences associated with implementation of an alternative, for all future time, should be identified, and then probability of their occurrence and their benefit or cost to society determined. The expected loss or gain to society is calculated by multiplying the amount by the probability of occurrences. A discount rate is then assumed and the time streams of costs and benefits are discounted and summed to obtain their present values. The translation of consequences of implementation into monetary terms includes estimates by the analyst of the prices that would have been attached to various goods and services if a perfectly competitive market had existed. In principle, cost-benefit analysis can thus associate with each possible choice all the inputs and outputs, all the positive and negative effects, including spillovers, with their probabilities and times of occurrence, condensing everything into a single number. However, a number of complications often arise in connection with practical applications.

In practice, the quantification of all types of effects and their translation into monetary terms may be very difficult and any method used will be open to question. For instance, pollution effects can often not be considered as quite equivalent to some sum of money. Different decisionmakers may also have different time preferences and these may not be very conveniently expressed through the discount rate. Further, a general assumption behind the cost-benefit approach is that undesirable distributional effects can be corrected by transfer payments; costs and benefits, however, often accrue to different categories of people and satisfactory compensation to those who lose can often not be found.

As a consequence of the complications mentioned above there are various objections to the use of a cost-benefit criterion. One is that it is easily subject to abuse since so many critical assumptions tend to be buried in the computation. The choice of a discount rate is particularly tricky. For instance, to promote a project with high installation costs but with the benefits deferred in time, advocates would argue for a low discount rate (two percent has been used for some water projects where the benefits were marginal and a long time in the future). Perhaps the most common objection to the cost-benefit criterion is that it requires the analyst to make judgments (for instance in connection with distributional effects) which in fact are value judgments of the sort that should be left to the responsible decisionmaking body.

Again, in theory, a considerable advantage of the cost-benefit criterion is that it permits comparisons of very different projects. But experience of applications indicates that it is more likely to be used successfully when the decision alternatives are rather similar, i.e., with consequences similar in type and involving the same scale of effort.

To give an illustration of the possibilities and limitations of cost-benefit analysis, we will here use a hypothetical application. Assume that an additional airport is considered to be required in a city area because of increasing air traffic. As the existing one cannot be extended, the problem is to find a suitable location for a second airport. To simplify, we will assume further that there are several suitable and uninhabited land areas and that air traffic does not cause any negative side-effects, i.e., there are no noise or air pollution problems. To calculate the costs and benefits of the different locations the analyst will have to estimate the impact on future air and surface travel, the monetary worth of savings in travel time, etc. These estimates may involve considerable uncertainties but rough approximations are likely to be obtainable. Because of the uncertainties it may not be possible to arrive at a definite ranking order. Nevertheless, very bad alternatives can probably be revealed as such and the analysis can help the decisionmakers to focus their further attention on a subset of the original alternatives, a subset which is likely to contain only reasonably good alternatives.

To make our hypothesized airport example somewhat more realistic, let us now assume that the alternative airport locations will, to a varying extent, bring noise disturbances into residential areas and also require that some residents, factories, etc. be displaced. This means that there will be a group of people who probably cannot be compensated in a way they find quite satisfactory. Surely this information is important to the decisionmakers and should be brought to their attention; the cost-benefit criterion alone, in this case, is not the most suitable basis for ranking the alternatives and needs to be supplemented in some way, say by a "scorecard" presentation as described later.

The term "cost-benefit analysis" is also used to describe studies whose results are not quite as condensed as a strict cost-benefit criterion requires. In such cost-benefit analysis, it is usually recommended that benefits and costs that cannot be expressed in monetary units in a satisfactory way be displayed separately. When there are such effects more complex information has thus to be communicated from the analyst to the decisionmakers. For the analyst to choose when and how to do this, the information exchange between the analyst and the decisionmakers is of considerable importance. The analyst needs information about the decisionmaking situation and about what the decisionmakers consider important and he has to structure the communication of his results in a way to fit the prevailing decision situation and in the language of the decisionmaker.

In the evaluation of risky projects with highly adverse but rare consequences and negligible costs, a risk-benefit rather than a cost-benefit analysis is frequently used (Jennergren and Keeney 1979, Fischhoff 1977). The fundamental idea is to appraise whether or not the benefits outweigh the risks. It is used, for example, in deciding whether various food additives and drugs should be barred from the public.

5. COST-EFFECTIVENESS ANALYSIS

If we now turn back to our simplified airport example, it may happen that the study is being carried out at a time when the decision to build a second airport has already been taken. Perhaps several feasible and quite attractive alternative locations have been found and general estimates or judgments have indicated that the benefits of a second airport will exceed the costs. In this case it may be an unnecessary complication to try to estimate the benefits in monetary terms for some *measure of effectiveness* (e.g., some kind of air-travel capacity measure) may be of more interest. More generally, a project is usually undertaken to achieve some objective; the measure of effectiveness should indicate the extent to which the objective is achieved. This leads us to a type of criterion of choice which can be termed cost-effectiveness. In this, alternatives are ranked either in terms of decreasing effectiveness for equal cost or in terms of increasing cost for equal effectiveness. Sometimes the maximum of the ratio of effectiveness to cost is used to indicate the preferred choice but this is open to all the objections that apply to the use of ratios for criteria (Hitch and McKean 1960) and will require additional information to fix the scale of the effort, as seen by the tangent in Fig. 1. Here, typical cost-effectiveness behavior is illustrated for two programs. Whether 1 is preferred to 2 depends on the scale of the effort; if, for instance, the effectiveness must be at least E_2, then 2 must be preferred (Attaway, 1968). If, however, the cost cannot exceed C_1, 1 is preferred.

Cost-effectiveness is probably the most commonly used criterion for the ranking of alternatives. The reason is clear; it provides a comparison in terms of two factors of crucial importance to every decisionmaker—how much he will need to spend,

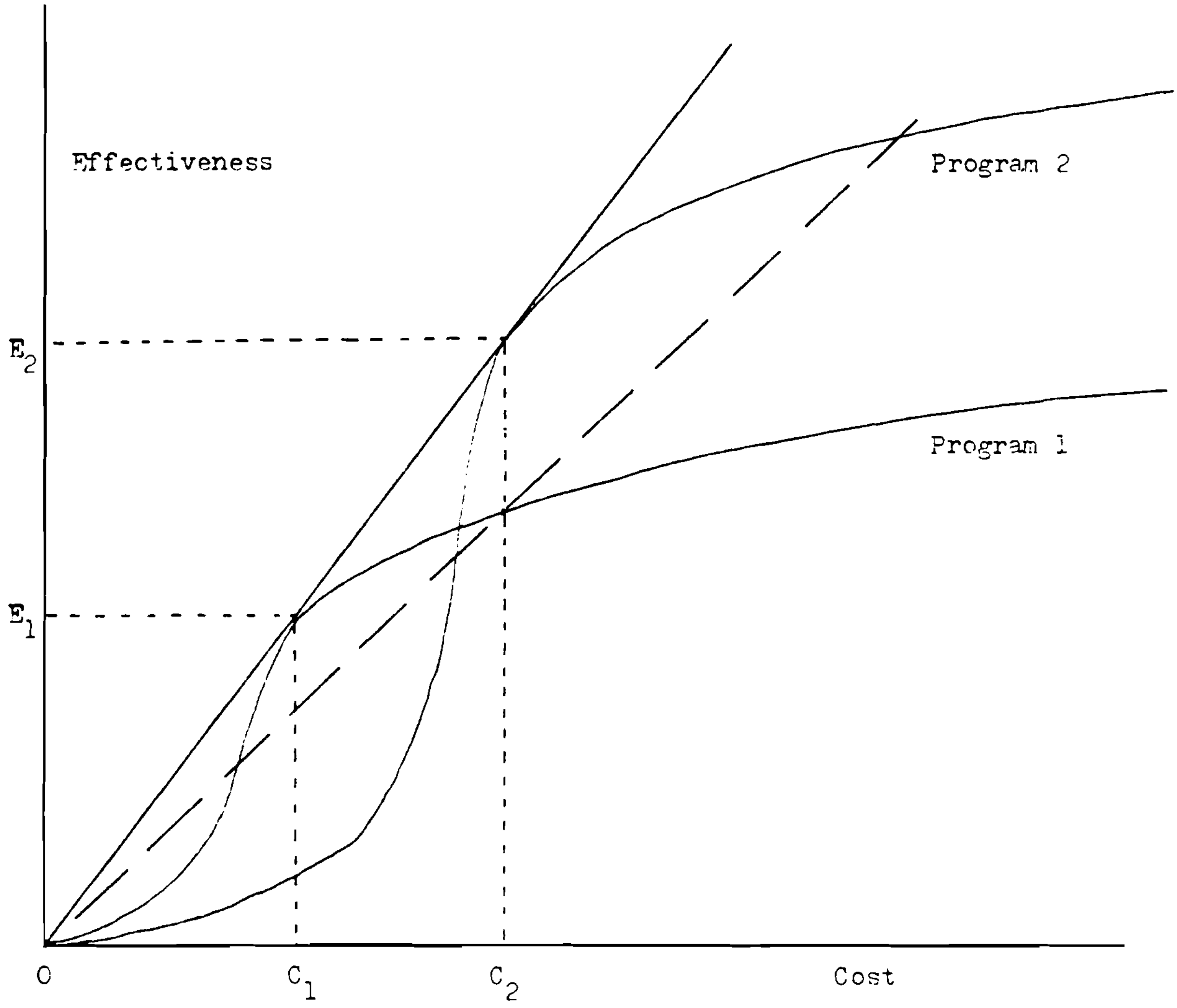

Figure 1. Typical cost-effectiveness curves.

and to what extent the action he takes will get him what he wants. It may be a sufficient basis for choice only in those rare instances when "other considerations" are not significant, but the information it provides is always helpful.

The cost-effectiveness criterion is open to a number of objections. One is that cost as used in cost-effectiveness reflects only the costs that are inputs—the money, resources, time, and manpower required to implement and maintain an alternative. The penalties or losses that may accompany an implemented alternative—it may, for instance, interfere with something else that is wanted or bring undesirable consequences to other people—are costs that are not taken into account.

Ordinarily, effectiveness does not measure value but is merely a proxy for some aspect of it. A different choice of how we measure effectiveness can lead to a different preference among alternatives. For example, if the objective is to increase traffic safety and we choose as our measure of effectiveness the decrease in fatalities, we may then give high priority to reducing accidents where two cars collide at high speed, for these are very serious. But if our measure is the decrease in the economic cost of accidents, then priority may go to the avoidance of low-speed collisions in rush-hour traffic, for these are very numerous.

Another defect is that the people who must pay the costs of a decision and those who stand to gain may not be the same. Unless the alternatives are so similar that this aspect can be neglected, a decision based on a cost-effectiveness criterion may mean trouble for the decisionmaker. Again, there is a likely clash of values.

Finally, even if cost and effectiveness were fully and properly determined, the decisionmaker would still be faced with the problem of what to choose. He needs some way to set the scale of effort—either the cost he must not exceed or the effectiveness level he needs to achieve. Sometimes this can be provided by setting the maximum cost so that it corresponds to the "knee" of the cost-effectiveness curve (Fig. 1), since very little additional effectiveness is gained by further investment.

It is clear that the type of cost-effectiveness criterion we have discussed here is often inadequate for decisionmaking problems for which multiple objectives, spillover effects, or the distributional aspects are important characteristics.

6. DECISION ANALYSIS

Cost-benefit analysis, as presented above, can be considered as a means of reconciling competing objectives through converting the various consequences into monetary units. The analysis is merely done for a higher-level objective—to find the course of action that brings the greatest excess of benefits over costs. As the benefits and costs associated with any proposal are quantified in monetary units, a system of weighting the various consequences of courses of action is, in effect, being used.

Numerous other schemes for using a weighted combination of the consequences to provide a preference ranking of the alternatives have been tried. Some of these work satisfactorily when the decisions involved are of a repetitive type. Under the name of decision analysis a considerable body of knowledge has been developed which, in principle, is applicable both for the one-time decision as well as for the repetitive decision.

In the decision analysis approach, the analyst attempts to model the value system or preference structure of the decisionmakers in such a way as to be able to predict with the model what the decisions would be, were the decisionmakers to be presented with the full set of alternatives and their consequences. To do this, an attempt is made to construct a function of the form

$$V = f(x_1, x_2, \ldots, x_n)$$

representing the decisionmaker's value or utility rating of each alternative. Here the x_i's, $i = 1,2,\ldots,n$, are measures (on appropriate scales) of the consequences, properties, aspects or anything else associated with an alternative that the decisionmaker would take into account in estimating the value of the alternative.[1] Thus, if competing designs for communication satellites were being ranked, x_1 might be the initial investment cost, x_2 the expected mean time to failure, x_3 the number of channels, and so on. The total number of factors that the decisionmaker considers is n.

Any aggregate approach of this type, like the cost-benefit approach, has two serious disadvantages. One is that a great deal of information is lost by aggregation; the fact that alternative A has environmental problems whereas alternative B has political implementation problems is suppressed. The second is that any single measure of value depends on the relative weights assigned by the analyst and the assumptions he used to get them into commensurable units.

To produce anything resembling a valid value function is clearly difficult and may be impossible in many situations. There are problems both with getting the preference information from the decisionmakers and with putting it together in a usable expression.[2] The first can require a substantial effort on the part of the decisionmakers.

Many analysts believe that, while such value functions are clearly useful for preliminary screening of alternatives, the final designation of a preferred alternative must be made by other means. Particularly when the decision concerns the public sector, and the preferences depend on basic values, the decision thus being essentially a political decision, more disaggregated information needs to be communicated to the decisionmakers. Nevertheless, the analyst may, in the process of developing and using value functions, for his own initial inquiry, find that his understanding of the compleity of the problem, and consequently the advice that he finally offers, has been enhanced.

7. SCORECARDS

If someone is to help me decide whether something I think I would like to have is worth what I would have to give up to get it, the most informative way for him to do so is to present me with a full and honest description of what I would be getting, and getting into, including all negative aspects and side effects. I would judge this preferable to being told that, because of previous decisions or statements, if I am to be consistent, I should do so and so. Many decisionmakers, ranging from individuals to the body politic, have this same feeling.

The usual way of presenting the required information is by means of a matrix called a *scorecard* (Goeller 1972). On a scorecard, the consequences that ensue from a possible decision to select each of the alternatives—the costs, benefits, spillovers, risks, segments of society affected, and in fact, anything about an alternative that the analyst thinks the decisionmaker might want to consider in his decision, including its characteristics and origins if that seems pertinent—are displayed (in terms of the natural units commonly used to characterize them) in a matrix, or tabular array. In such an array, the entries in each column represent the consequences associated with a particular alternative and the entries in a row show how a particular consequence or other characteristic varies from alternative to alternative. [For examples, see the chapter on cost in Volume 2 and Goeller 1977.] Improvement by Goeller over the usual presentation lies in the careful selection of units for characterizing impacts, in grouping similar impacts into categories, and in the use of underlining, shading, or colors to show a crude ranking of alternatives (based on the analyst's interpretation of the decisionmaker's values of course). The aim is to provide the decisionmaker with an effective "gestalt" of the relative advantages and disadvantages of particular alternatives.

Consider noise impacts as an example. These have usually been reported in terms of land area exposed to a noise level above some specified threshold. But the decisionmaker is more interested in how noise affects people and in how many people. A scorecard can report the number of people exposed to various noise levels on a noise-annoyance scale.

To illustrate the detail with which impacts can be presented, consider the group of "community impacts" reported in a transportation study (Goeller 1972). These report changes in the activity patterns, tax base, and environment that would occur to the various communities in the region as the result of construction and operation of various alternative transportation systems. Specific examples include the number of households annoyed by excessive noise, the amount of air pollution, the savings in petroleum consumption, the households displaced by system construction, the amount of land taken, the resulting tax losses to the community, and even such an intangible as the loss of a community landmark.

For oral presentation, color, in the form of transparent colored rectangles placed over the numerical values, can be used to give a quick indication of each alternative's ranking on a particular impact. Goeller used green to show the best value and red to show the worst, with two colors for intermediate values, blue for next best and orange for the next to worst. The numerical values themselves were visible through the colors. Sensitivities to changes in parameters or to different forecasts for the environment were shown by further transparent overlays and the use of multi-colored rectangles.

The scorecard seems to be such a simple and obvious device that no argument for its use is needed. It is extremely flexible. A decisionmaker can see where an alternative he favors is deficient; he can ask what modifications would eliminate the unfavorable impacts from an otherwise promising alternative and whether that action might turn some presently acceptabe impact into an unacceptable one. He can call for further analysis to show how changes in the assumptions originally made by the analyst will affect the results. Since the decisionmaker assigns his own weights to the different impacts, the scorecard can help him understand the tradeoffs implied by the decision he is to make. If he chooses A over B he may be trading off substantial increases in noise and future costs for savings in air pollution and initial investment costs. Such tradeoffs are implicit in every decision, but the decisionmaker who views an aggregate index may not see them for they have been obscured by the process that combined the different impacts into a single measure, even though he may have played a part in agreeing to that process. The scorecard explicitly confronts the decisionmaker with the tradeoffs he must make. To decide, he must weight them subjectively, bringing to bear not only factual knowledge but his feeling for societal values.

A scorecard presentation can also be understood, and used, by the public. Different groups can, in the same way as the ultimate decisionmakers, ask "what if" questions, apply their own weights, and confront the decisionmakers with their views based on much more information than if they had merely an index to go on.

The advantages of the scorecard over an aggregated index for providing guidance to decisionmakers may be summarized as follows:

The scorecard

- seeks convergence to a decision—not agreement on value judgments from the decisionmaker or decisionmakers;
- is understandable and usable by decisionmakers and other groups involved, including the public at large;
- enables impacts and alternatives to be evaluated with minimal interposition of the analysts' biases and values;
- gives attention to qualitative as well as quantitative impacts;
- retains multidimensionality, showing tradeoffs explicitly;
- uses natural physical and thus understandable units.

A disadvantage, if there is one, is that it may present too much information for a decisionmaker to absorb. But this can be handled by careful selection of what to present, holding other information for later presentation when requested, bearing in mind that this process must be kept as free from the analyst's values as possible.[5]

8. VALUE ANALYSIS AND POLITICAL FEASIBILITY

Values and beliefs held by individuals and organizations affect analysis at all stages from problem formulation to decision and implementation. Differences in values can lead decisionmakers to advocate different actions on the basis of the same study, and, after a choice is made, can lead the implementing bureaucracy to take actions the decisionmaker did not intend.

In ranking the alternatives in preparation for a decision, or in helping the decisionmaker in ranking the alternatives, the analyst needs to discover a great deal about the decisionmaker's values. This is not easily done; "we can always ask people about their values, but in the end, we can only infer what values they appear to hold by analyzing their behavior, including their statements, in a number of situation" (Bowen 1979). Other approaches are possible. Bowen (1979) suggests such topics as the following merit more attention than they have been given: analysis of options, hypergame theory, structural mapping, personal construct theory, fuzzy sets, and a number of ideas stemming from conflict research and research gaming.

It is sometimes argued that decision problems that are "political" or value sensitive cannot be subjected to analysis. According to another view, values and facts are distinguishable and analysts (or experts, scientists, etc.) should contribute only facts to the decisionmaking process. There are also arguments for a direct involvement of analysts in "value analysis" which includes improving the value judgment of "legitimate value judges" without usurping that function. To quote Dror (1975): "...this is achieved through methodologies designed to structure the judgment field and to explicate value dimensions in a way that permits more conscious, comprehensive and explicit judgment by the legitimate value judges. These processes help them to make more 'responsible' value judgments on the basis of clarification of the fullest meanings of the involved values. Primary methods of value analysis include testing of value sensitivity, examination of value consistency, checking the completeness of the value set, explication of tacit value dimensions (e.g., time preferences and lottery preferences), value mapping, consideration of value futures, design of value and goal taxonomies, and more."

The feasibility of implementation is an important aspect when decision alternatives are compared. Depending on the decisionmaking process some alternatives may not be implementable if there are certain groups who object to them. The analysis of such aspects is sometimes called "political feasibility" testing (Dror 1968). It involves investigating the probability that a proposed action will be acceptable to various secondary decisionmakers—the special interest groups, the public, and the bureaucracy who must translate it into action. If the probability is too low, compromises can be made to increase acceptability. Analysis can help find the preferable compromises—those that increase acceptability without a proportionate loss in attainment of policy goals.

Cost-benefit and similar analyses, designed to produce an economically efficient solution, may encounter political opposition. For an alternative to be politically feasible, it may not only have to approximate the largest total benefit available to the affected parties as a whole, but, in addition, allocate the aggregate benefits and costs among the various interest groups in a way that reflects their political strengths. Thus, the alternative selected must be acceptable to the most influencial interest groups and not too strongly opposed by the others. When a group is asked to accept an alternative in a situation where a competing alternative would bring them greater benefit, then, if the losses can be estimated, the chosen alternative frequently can be made acceptable (and thus politically feasible), by arranging a payoff to the objecting group, say, by tax exemptions or deductions designed to benefit them specifically (Olson 1971, Starling 1979).

9. UNCERTAINTIES

In previous sections we have mentioned the existence of uncertainties but not sufficiently emphasized their dominant role, and their pervasiveness in systems analysis and decisionmaking. To evaluate decision alternatives we must estimate the future consequences of various courses of action, and the future is always uncertain. The effects of some uncertainties, say those in economic, technical, and operational parameters that can be identified, measured, or at least estimated, and treated statistically, can often be taken account of in the analysis proper by actual calculation of the probabilities, or by Monte Carlo methods, or, less precisely, by using means or expected values. Sensitivity testing and *a fortiori* analysis can also be done and presented to the decisionmaker. Other uncertainties, about future environments and contingencies and about certain activities that depend on the actions of people (now as well as in the future), are more intractable.

The decisionmaker is always confronted with a certain amount of uncertainty when presented with the results of a systems analysis. When the issue has long-term implications or involves a rapidly changing situation or one being manipulated by other decisionmakers, a number of different forecasts of the state of the world or scenarios may have to be considered. In this case, the results of the analysis as carried out for each contingency or forecast may not indicate the same order of preference among the alternatives. What then can the analyst suggest to the decisionmaker if, under one contingency with high probability of occurrence, alternative A is clearly superior, but, under another contingency of low probability but with catastrophic implications, alternative B is better?

Faced with such uncertainty the decisionmaker can, depending on the circumstances, take one or more of the following actions:

1) Delay: that is, defer his action until better information is available. Delay, of course, is not always an option and, when it is, it may be costly, particularly when competition or conflict is involved.

2) Buy information: attempt to alleviate uncertainty by supporting further research and data collection. This also involves delay and cost and may or may not improve the situation.

3) Hedge: adopt duplicate alternatives or modify an alternative to introduce greater flexibility—at a higher cost, of course.

4) Compromise: select an alternative that while it may not be best for the contingency judged to be most likely, does not rank too low on the less likely ones.

5) Be conservative: attempt to choose the alternative that gives the best result if the environment is maximally unkind. This is the "maximin" approach, in which one resolves uncertainties by making the blanket assumption that the worst will happen.

6) Use decision theory: argue that the probabilities of the various states of nature are not completely unknown and beyond human judgment, subjectively assign probabilities to them, and then use an approach that would be appropriate for the case in which the probabilities are known.

The U.S. military (which may have had as long an experience with systems analysis under conditions of uncertainty as any other institution) has something like the following philosophy. Any attempt to determine a unique best solution to a problem involving a large number of uncertain factors, some of which may be under the influence of other decisionmakers, is doomed to failure. The aim instead should be to search out or design alternatives that perform well or even close to the best for what appear to be the most likely set of contingencies and from such alternatives, whenever it can be done, select the one that gives some sort of reasonably satisfactory performance under the more unlikely and even pessimistic circumstances.

10. RISK EVALUATION

Side effects, or negative impacts that are not direct costs to be borne by the decisionmaker,[4] may sometimes need special attention both when designing and when comparing the alternatives. Side effects are sometimes treated by imposing constraints. However, the elimination, or the reduction in the probability, of the occurrence of serious negative side effects must often be made an objective. Reductions that are below some low probability limit usually have a value.

The term risk is often used in connection with uncertain negative side-effects.[5] More specifically, risk is often associated with highly negative consequences, occurring rarely. The exact meaning of risk varies somewhat. Sometimes it means the probability of a negative consequence. In other cases it may mean the negative consequences themselves. In yet other cases, it may refer to the statistical expectation of the negative consequences. Most commonly, however, risk refers to the entire spectrum of negative consequences with their associated probabilities (see Jennergren and Keeney 1979).

Risk assessment is often thought of as consisting of two parts: risk estimation and risk evaluation. In risk estimation, one is concerned with identifying the various serious negative consequences of a project or activity, and assigning probabilities (or rates of occurrence) to those consequences. In risk evaluation, one appraises the acceptability of the risk to society.

A risk evaluation sometimes includes comparisons with other risks that exist in society. This does not mean that such comparisons necessarily lead to definite conclusions. The acceptability of a risk depends on whether it is considered as a voluntary or an involuntary one, and also on the magnitude of the associated benefits. Also, the character of the risk is of importance. When two projects have risks with the same expected value (and the same benefits) people are not necessarily indifferent to them. If the worst that can happen is less serious in project A than in project B many people will prefer A. Consequently, risk evaluation may depend on value preferences, in which case the analyst must leave the final evaluation to "the legitimate value judges."

11. DECISION PROCESSES, PLANNING, AND POLICIES

In the previous parts of this chapter, we have assumed that the guidance to be given to the decisionmakers concerns the choice between a number of alternatives that have been evaluated in the analysis. Actually, the decisionmakers may make other types of decision. If the alternatives studied have been different designs of a public project, the first decision to be taken may not be a final decision in favor of one of the alternatives but may, for instance, be a decision:

- to study some of the designs in more detail, perhaps with new constraints;
- to accept a part of a design and keep the option open to choose later on between several alternatives;
- to include one design, perhaps vaguely described, in a plan which is to be reconsidered or reviewed later on. Certain options are thus left open regarding the final version of the project;
- to do further study.

The decision processes which follow a systems analysis may take many different forms and the form to be chosen may be difficult to predict. However, some information about the likely decisionmaking process is usually available to the analyst(s) and this type of information can be important to take into account both in the design and the evaluation phases of a study. Much research has also been devoted to decision processes (Allison 1971, Simon 1957, Keen 1977, Cyert and March 1963, Lindblom 1959). Results from such descriptive-explanatory research is, of course, of considerable importance to the applied systems analyst.

It should be stressed that a systems study does not always focus on the choice between a number of alternatives. Sometimes the start of the study is a vaguely defined problem area and the output of the study consists of some tentatively defined decision alternatives or some guidelines for developing such alternatives. In the U.S., many systems studies in the form of "program evaluations" have been performed. Here the study starts after the decision to launch a new program has been taken and the program has been tried for some time. The problem defined at the outset may be "Has it worked as expected?" The result of the study is usually that it has not, but, more importantly, the study may suggest where to look for possible improvements (Hatry 1979). Analysis should not stop with implementation. Models are imperfect and circumstances change. As part of the analytic effort, it should be determined as soon as possible whether the results are as anticipated, and if not, how to modify the process accordingly discovered. This monitoring and evaluating function could, and perhaps should, be undertaken by someone other than the original analyst or policymaker (Walker 1978).

12. GUIDANCE FOR DECISION

The effectiveness of these various schemes for presenting the results of analysis, and for carrying out the analysis itself, depends to an extent on the decision-making situation. It is best when the situation approximates the rational actor model. Other models—the process-oriented view (Simon 1949), the organization-process view (Cyert and March 1963, Allison, 1971), the political paradigm (Lindblom 1959, Allison 1971), and the apprehensive man (Keen 1977)—are useful, not so much in finding a "best" solution, but in finding one that can be accepted or adopted and implemented by the relevant organizations. Adoption of a proposal is, in fact, usually easier than implementation. At the decision stage, participants do not feel it necessary to resolve uncertainties, for they can be taken care of during implementation. All that is needed may be enough support to tip the decisionmaking body in favor of the proposal. This support can be verbal; implementation demands the organization contribute real resources.

The type of guidance for decision that can be given as a result of a systems analysis may be in the form of clearly specified recommendations, e.g., in favor of a given decision alternative. Whether this is satisfactory depends on many issues, for example,

- Have the criteria for the recommendations been thoroughly explored and agreed?
- Are these criteria expressible in a quantifiable manner?
- Has this quantification been based on value judgments which have been agreed?
- Are the models used fully satisfactory and agreed?
- Are the situations tested by the models, and the alternative options explored in these situations, reasonably complete and unquestionable?
- Are there agreed ways of weighing multiple criteria and multiple objectives?

Apprehension is sometimes said to dominate analysis (Keen 1977). Decisionmakers learn through apprehension rather than comprehension and rely on experience rather than on understanding and analytic methods.

It is often possible for decisionmakers to agree on the action to be taken, even though they disagree on objectives. A policymaker may concur in the decision to accept a study recommendation for reasons far different from those the analyst had in mind. He may do so, for instance, because by so doing he may forestall stronger action or because he may see how to divert money that will be appropriated to implement the recommendation to other purposes.

It is not surprising then that, in general, it is safer and more satisfactory merely to provide pros and cons of many options in many situations. In dialogue with the decisionmakers, there is a wide-ranging exploration and attempt to make less vague both the nature of the problem itself and the values that the various possible options for decision have for the decisionmaker. Most systems analysts have ways of doing this, although there seems to be no general methodology: there are different approaches depending on the values held by analysts and decisionmakers and the way in which they interact.

The aim of systems analysis, while it is to improve decisionmaking, is also to make the decisionmaker more satisfied that the basis for his decision is adequate and informed. The study done must provide new insights into the problem area under discussion, and it must be structured and presented in a way that facilitates his use of the information it contains. The analysis must be seen to be relevant and its communication must be readily understood. The mode of communication, continuous or at intervals, orally or in writing, diagrammatic or in words, technical or nontechnical, mathematical or nonmathematical, will vary with circumstances, but it must be in terms familiar to the decisionmaker. Special communication aids include interactive computer modeling, scenario writing, games and game-theoretic processes, films, and even forms of counselling.

The important issue is how decisionmakers interpret the data put before them, because only some of this will be seen by them as information relevant to their decisions.[6] Their previous experience, their general world view, their reaction to variables and constraints that the analyst has or has not been able to take fully into account, and particularly their attitude towards analysis and their prior beliefs, will all affect how they use what they are offered. Analysts should strive always to understand the total environment of decisionmaking so as to provide the maximum of information and the minimum of redundant data, although initial redundancies have a habit of being useful if the decisionmaker chooses to delay his decision in one way or another.

The fact, mentioned above, that no general methodology exists for the final stage of analysis and decision, leaves one important thing still to be said. Any analyst who can make explicit, for a stated systems analysis, how the communication process used was conceived and what its successes and failures were, will have added something of value to the literature on the subject. The trouble is that, because the process depends so much on personal values and understanding of values, it is difficult to write anything down in a way that can be interpreted and used by others. It is, nevertheless, worth trying.

Notes

1. For a more detailed description of the paradigms of decision analysis see chapter 1 in Keeney and Raiffa (1976).

2. For examination of the basic assumptions behind decision analysis and the consequential problems in applications, see Tribe 1972 and White and Bowen 1975.

3. Scorecards can be considered as a well-linked transition from nearly-quantitative methods to lexicographic ones. For a theoretical basis of the latter see Roy 1977.

4. Such negative impacts are costs to the decisionmaker in the sense that they prevent successful implementation or otherwise frustrate his decision.

5. In economic and decision-theoretic literature, risk is sometimes used with a different meaning, denoting a nondeterministic situation where the probabilities of various events are known (see Jennergren and Keeney 1979.)

6. For some of the pitfalls, see Lynn 1980.

References

1. Allison, Graham T., *Essence of Decision,* Boston: Little, Brown, and Company, 1971, p. 10.

2. Attaway, L.D., "Criteria and the Measurement of Effectiveness," in *Systems Analysis and Policy Planning,* E.S. Quade and W.I. Boucher (Eds.) New York: American Elsevier, 1968.

3. Boothroyd, Hylton, *Articulate Intervention,* London: Taylor and Francis, 1978, p. 73.

4. Bowen, K.C., "Personal and Organizational Value Systems: how should we treat these in OR studies," *Omega,* 7 (1979).

5. Cyert, R.M. and J.G. March, *A Behavioral Theory of the Firm,* Englewood Cliffs, N.J.: Prentice Hall, 1963.

6. Dror, Y., *Public Policymaking Reexamined,* Scranton, Pennsylvania: Chandler, 1968.

7. Dror, Y., "Some Features of a Meta-Model for Policy Studies," *Policy Studies Journal, 3* (1975) 3, pp. 247-255.

8. Fischhoff, B., "Cost-Benefit Analysis and the Art of Motorcycle Maintenance," *Policy Sciences,* Vol. 8, p. 177-202.

9. Goeller, B.F., "The STAR Study: Impacts of Alternative Intercity Transportation Systems on the California Corridor in *Policy Analysis and the Problems of the 1970's,* Kamakura, Japan: Nomura Research Institute, 1972.

10. Goeller, B.F., A.F. Abrahamse, J.H. Bigelow, J.G. Bolten, D.M. de Ferranti, J.C. De Haven, T.F. Kirkwood, and R.L. Petruschell. *Protecting an estuary from floods—a policy analysis of the* Oosterschelde. Santa Monica, California: The

Rand Corporation. R-2121/1-NETH, 1977.

11. Hatry, Harry P., "Measuring to Effectiveness of Nondefense Public Programs," *Operations Research*, 18 (1970) 5, P. 774.

12. Hatry, H., "Program Evaluation," 1980, to be published.

13. Hitch, Charles J., "Uncertainties in Operations Research," *Operations Research*, Vol 8, July-August 1960, pp. 443-444.

14. Hitch, C.H., and R. McKean, *The Economics of Defense in the Nuclear Age*, Cambridge, Mass.: Harvard University Press, 1960.

15. Jennergren, L.P., and R.L. Keeney, "Risk Assessment." In *Handbook of Systems Analysis*, Volume 2. To be published.

16. Keen P.G.W., "The Evolving Concept of Optimality," in M.K. Starr and M. Zeleny (eds.), *Multi-Criteria Decisionmaking*, pp. 31-57, TIMS Studies in Management Science, Vol. 6, 1977.

17. Keeney, R.L. and H. Raiffa, *Decisions with Multiple Objectives: Preference and Value Tradeoffs*, New York: John Wiley and Sons, 1976.

18. Lindblom, C.W., "The Science of Muddling Through," *Public Admnistration Review*, Vol. 19, No. 2, pp. 79-88, Spring 1959.

19. Lynn, L.E. Jr., "The Question of Relevance," in L.E. Lynn, Jr. (ed) *Knowledge and Policy: The Uncertain Connection*, Washington, D.C.: National Research Council, 1978.

20. Lynn, E.J., Jr., "The User's Perspective," in *Pitfalls of Analysis*, G. Majone and E. Quade (eds.), Chichester: John Wiley and Sons, Ltd., 1980.

21. Majone, G., "The ABC's of Constraint Analysis," January 1978.

22. Mintzberg H., and Shakun, M.F., "Strategy Formulation," *Management Science, 24* (1978), 9, pp. 920-972.

23. Nelson, R.R., *The Moon and the Ghetto*, New York: W.W. Norton and Company, 1977.

24. Olson, M.L., *The Logic of Collective Actions*, Harvard University Press, Cambridge, Mass., 1971.

25. Ozernoi, V.M. and M.G. Gaft, "Multicriterion Decision Problems," in D.E. Bell, R.L. Keeney, and H. Raiffa, *Conflicting Objectives in Decisions*, Chichester: John Wiley and Sons, Ltd., 1977, pp. 17-37, 1977.

26. Rein, Martin and Sheldon H. White, "Policy Research: Belief and Doubt," *Policy Analysis* 3(1977)2.

27. Roy, B., "Partial Preference Analysis and Decision-Aid: The Fuzzy Outranking Relation Concept," in D.E. Bell, R.L. Keeney, and H. Raiffa, *Conflicting Objectives in Decisions*, Chichester: John Wiley and Sons, Ltd., 1977, pp. 40-75.

28. Simon, H.A., *Administrative Behavior*, New York: McMillan Co., 1945.

29. Simon, H.A., "A Behavioral Model of Rational Choice," in H.A. Simon, *Models of Man*, New York: Wiley, 1957, pp. 241-260.

30. Simon, H., "On the Concept of Organizational Goal," *Administrative Science Quarterly*, Vol. 9, No. 1, 1964.

31. Simon, H.A., *The Science of the Artificial*, Cambridge, Mass.: MIT Press, 1969.

32. Starling, G., *The Politics of Economics and Public Policy*, Dorsey, Homewood, Ill., 1979.

33. Tribe, L.H., "Policy Sciences: Analysis or Teleology?", *Philosophy of Public Affairs*, (1972) 2.

34. Walker, Warren E., *Public Policy Analysis: A Partnership Between Analysts and Policymakers*, Santa Monica, California, The Rand Corporation, P-6074, January 1978.

35. Walker, Warren E., Jan M. Chaiken, and Edward J. Ignall, *Fire Department Deployment Analysis: A Public Policy Analysis Case Study*, New York:

North Holland, 1979.

36. White, D.J. and Bowen, K.C., *The Role and Effectiveness of Theories of Decision in Practice*, London: Hodder and Stoughton, 1975.