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Chapter 2 describes four methods useful to project planners for assessing quantitative factors and for transforming qualitative attributes into quantitive measures. Two are scaling measures (Rating Scales and Multiple Criteria Utility Assessment). A rating scale is used to quantify factors which may be subjective or qualitative in nature and measures the degree to which an entity possesses or exhibits a specified property, either as an absolute or relative judgment. Multiple Criteria Utility Assessment is a systematic process for providing a common scale for combining judgments of more than one dimension and for assessing the worth of complex alternatives. The other techniques are broadly based assessment procedures having a variety of uses (Surveys and Organization Climate Analysis). Sample surveys are used to gather information from a fraction of a subject population in order to identify and measure the attributes of the whole population. Organizational Climate Analysis aids in identifying the organizational climate needed to achieve desired behavior from a target group within the organization. It is also useful in comparing the climate or internal environment of similar organizations, e.g., secondary schools within a country.

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II

Assessing Qualitative Factors

Rating Scales
Multiple Criteria Utility Assessment
Surveys
Organizational Climate Analysis

There is a danger in project design and systems modeling of overlooking a factor because it is not in quantitative form. Techniques for assessing qualitative factors are essential to a systems approach, and four such techniques are described. Two are scaling procedures (Rating Scales and Multiple Criteria Utility Assessment). The other techniques are broadly based assessment procedures (Surveys and Organizational Climate Analysis). All four provide a means of transforming qualitative attributes into quantitative measures, though clearly the latter two have a variety of uses.

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Foreword

This is a *toolbook*.

It can be used either as a text or a reference by people studying or doing such things as project analysis.

In principle, analysis is the mother of rationality. The word *analysis* labels a large array of orderly efforts to transform the imponderable into the manageable. People try through analysis to identify the key properties of problematical situations, to contrive promising solutions, and to frame these solutions in convincing ways.

Three things affect the success of such efforts—*the nature of the "reality" being examined, the power of the analysis tools that are used, and the decisional arrangements to which analysis contributes.* What is out there and our interest in it set the basic requirements of analysis. The tools and their use determine what we see and influence what we then try to do. This volume focuses upon tools and their uses. It indicates how they can be applied to study various kinds of realities, or to imposing a sense of order upon real-world concerns. It does not address the third factor which affects the success of analysis efforts—the decision-making settings in which the tools are applied.

The trend of our times is to demand more and better analysis tools in order to try to solve increasingly complicated problems through planned, managed action. The solutions often breed new problems. The expanding pressure to diagnose and resolve outruns our ability to respond. One American sociologist speculates that the ultimate outcome of this dynamic imbalance might be the collapse of societies in "the stupidity death," as the needs to interpret and manage fatally exceed the capacity to do so.

No single book will solve that problem. This one may make some incremental contributions to the intelligent use of analysis in sensible problem-definition and informed solution-seeking. For example, it presents a wide range of analytical tools—about forty—and it classifies them into nine functional categories, from methods of generating ideas to techniques for controlling and evaluating results. There is an important implication here: *there are many kinds of analysis which can be used for a variety of purposes.*

Why does this matter? Partly because the formal analysis strategies of social and economic change organizations are usually quite selective. They are usually skewed in favor of certain kinds of issues and techniques. The pattern of this book at least shows that there are significant categories of analysis beyond the economic and financial, and beyond determinate systems techniques for planning implementation. This is important because some of the best-established, most conventional techniques of analysis, used undiscerningly, make it possible to design unworkable programs and projects.

This book reflects another important idea: *analysis* is not solely the province of insulated experts with little responsibility for entrepreneurship or implementation. Some of the techniques presented here are as useful to "operators" as to "analysts." All of them can profitably be understood by people primarily concerned with promoting and executing projects.

In practice, the interplay of analysis and action is quite complicated. How it works depends chiefly upon the third factor mentioned at the beginning of this brief essay: the decisional arrangements to which analysis contributes.

In most organizations which rely upon analysis as an important input into decisions about programs and projects, systematic analysis and decisional action tend to be rather loosely linked.

A good part of this looseness is necessary and desirable. Studying things and doing things are frequently very different kinds of activity engaged in by different kinds of people. Even so, decision makers and people with discretionary responsibility for executing decisions had better understand the nature—and the limitations—of the analytic techniques upon which their decisions and their mandates may be based; just as analysis specialists will be wise to perceive the practical usefulness of their products and the limits thereof.

Various kinds of analyses produce knowledge for use in designing, reviewing, deciding, and executing programs and projects. Such analysis, coupled with criteria about goals and standards, helps produce decisional frameworks and programmatic targets. It also helps produce decisions about particular plans or proposals: Do they fit within the frameworks? Are they likely to achieve acceptable targets? By helping answer these questions, the analysis may reduce the uncertainty of efforts to shape the future and lessen the need to rely upon hope and intuition. Even when uncertainty defies dissipation, the authoritative use of systematic analysis techniques imposes a degree of *order* and focus upon decision making.

Order is a much valued quality in circumstances where uncertainty abounds. It is also a limited, potentially perverse quality. The quest for order sometimes buries real uncertainties beneath exhaustive analyses. These analyses tools apply techniques which look like formulas or recipes for calculating, deciding, and planning. They are often treated as if they are formulas or recipes. But they are not

decisional recipes. Analysis techniques only produce *ingredients* for cooking in decision-making pots, and for envisioning the future. With sufficient skill and judgment these ingredients—the products of analysis—can be used in cooking up programs and projects. But they are readily misused too.

The tendency toward misuse is encouraged by the lopsided, unbalanced quality of our aggregation of tools. The more *intrinsically determinate* the tools, the more attractive they are. Economic analyses and financial analyses, and schemes for "mapping" formalized plans of action (which are actually techniques for hopefully idealizing what is intended), are attractive. Quantitative analyses of costs and benefits, of cash flows, of sensitivities, and so forth, produce determinate answers, even if important data must often be stipulated. Projected maps of future sequences of events have the appeal of apparent certitude, even if they do not tell us *how* these sequences are going to be caused and controlled, or how plausible they are.

To say these things is not to reject the merit of quantitative analyses and precise-looking maps of future courses of action. Both can be valuable, just as both are dangerous in the hands of those who take the products as "true." Unfortunately, these intrinsically determinate techniques are not matched and balanced by methods for analyzing *how best to organize* the activity, *how to determine managerial resource needs* and ways to meet them, *how to specify the incentives* which will increase the probability of success, and *how to measure the full range of effects.* Our tools for doing these latter things are at best rather messy and imprecise. So decisions tend to turn more upon the findings and projections of the neater techniques; and endless effort goes into refining and applying them.

This general observation is reflected in the contents of this book. It does present heuristic techniques for addressing some of the troublesome problems of design—generating ideas, pinning down objectives, and trying to map complex relationships, for example. But, understandably, much of its bulk presents relatively determinate computational tools. Because these are the tools we have.

A longer essay on the interplay of analysis and action would address other important aspects of the subject, such as the use of analysis to manipulate consent and acceptance and the manipulation of analysis to secure acceptance for for proposals. The function of analysis in the decisional processes of development agencies is not limited to the uncontaminated generation of unassailable objective premises, nor can it ever be so limited.

But the ultimate justification of analysis as a kind of activity is its contribution to better knowledge, better understanding, better decisions—to the reduction of error and the enlargement of human capacities for auspicious action. It is to these aims that this toolbook is dedicated.

The book itself is the eventual product of a question put to two young industrial engineers at the University of Wisconsin a few years ago: "What sorts of tools and techniques do you people use in defining problems and shaping solutions which might be transferrable to the field of economic and social development?" Here are the answers provided by Professors Delp and Thesen and their associates.

These answers are neither exhaustive nor definitive; there is little limit to the full array of tools that might be cited. Many of the individual tools offered here are themselves subjects of more than one book. But this work is a valuable introduction and overview. Each tool is presented in a way which facilitates intelligent judgment about its use. The tool descriptions are buttressed by citations which enable the reader to pursue topics of special interest.

If this book should somehow cause one consequential error to be avoided, in the design or implementation of a single project significantly affecting the lives and well-being of some people, the enterprise which has produced it will stand justified. Given the limits of our ability to analyze certain kinds of cause-effect relations we shall never know.

William J. Siffin
Director
IDI/PASITAM
June 1977

Preface

The word "tool," in its strictest sense, refers to an implement, a means for effecting some purpose. When we started the project which led to this volume, we used techniques, methodologies, and tools synonymously to describe various means for planning. On reflection, perhaps the stricter definition is also inappropriate, for this collection represents a set of implements—*tools for implementing a systems approach to planning.*

Systems, system models, and the systems approach tend to blur together into a conceptual mass whose tangible aspects are represented as tools. We've called them "system tools," not because they are necessarily derived from systems concepts or systems engineering, but because they are tools which facilitate a systems approach to planning. A systems analyst uses techniques which shape plans from a systems perspective. The wholistic, future-oriented, inter-relatedness of systems thinking models the situation facing development planners—situations filled with myriad interdependencies, uncertain futures, an ill-defined present, and a data-deficient past. The alternatives to a systems approach tend to produce fragmented, incrementally effective (if not counter-productive) development efforts.

Action-oriented development activities are implemented as policies, programs, or projects. We have used the project concept to represent both programs and policies in the sense that one or more projects are specific activities in order to implement a program or policy of action. The distinction between a project and a system is not always clear.

Often the system tools describe techniques for planning a project or a system. For example, cost-effectiveness analysis is used to evaluate 1) alternative components of a system, 2) alternative systems, or 3) alternative projects (which may involve many interacting systems). In many cases, techniques for project design and techniques for system design are indistinguishable.

Planning, as we have used the term, encompasses the entire range of activities associated with achieving development ends. Planning a project requires that all aspects of the project be designed or specified. This includes identifying objectives, sub-objectives, and criteria for evaluating the achievement of objectives. It includes specifying the essentials of implementation—those messy details of getting from an idea to a project. A systems approach to planning requires that the requisites of management be incorporated into the design and that the essentials of evaluation be considered *in the planning process.* Short-term feedback systems to provide management information are designed to complement long-term feedback of project impact in order to inform development planners. This broad view of planning and its intimate connection to implementation has guided our selection of techniques and their descriptions.

One aspect of the description which needs elaborating is our distinction between decision makers and analysts. Certain techniques require special skills for successful implementation (e.g., Surveys, Cost-Benefit Analysis). An analyst, possessing these needed skills, may also be the decision maker. In some techniques the two roles are distinct (Delphi, Program Planning Method), while in others the separation of roles is not important. A decision maker has discretionary control over resources including those required for analysis. Therefore, he views the problems of project planning from a different perspective from the analyst and usually a different degree of accountability. This reflects not only the way techniques are employed, but the decision to employ a particular tool. The classic case is an analyst who needs information recommending a sample survey, and the decision maker reconsidering this approach because of political sensitivities. We have included this distinction where relative to the application of the technique.

While we have sought to be comprehensive in our coverage of systems tools for planning, we recognize the omission of a great body of planning techniques developed in such fields as econometrics, business, and operations research. Linear programming, input-output models, or matrix algebra are useful planning tools, but they represent a level of sophistication, a rigidity of models, and a dependency on accurate data and computer implementation which seem inappropriate for the intended audience of this volume.

This collection of techniques and methodologies is intended for practitioners in the many diverse fields in which development touches both the peoples' lives and livelihood. Our examples are drawn from agriculture, education, health, family planning, employment, and resource management to underscore our belief in the universal utility of these tools in planning. We have focussed on project design and implementation as the action interface of planned development.

Peter Delp
Nairobi, 1977

Acknowledgments

Producing a volume of this scope is a long and difficult process. The support, constructive criticism, and encouragement of many have helped us in this endeavor.

We must begin by thanking the many authors who developed the techniques described in this volume. We have tried to give appropriate credit in the last sections of each tool description, citing the originators of the techniques where appropriate.

We are particularly indebted to our colleagues at the University of Wisconsin, Professors Andre Delbecq, Dave Gustafson, Howard Harrison, and Gerald Nadler. Their names will be found throughout the bibliographies for the techniques. We gratefully acknowledge their contributions, while excusing them for all responsibility for any errors or misinterpretations in our renditions.

Valuable criticism and support were provided by Dr. Richard Blue and Dan Creedon, United States Agency for International Development; Richard Hook and John Thomas, Harvard Institute for International Development; William Siffin, Russell Stout, and Paul Cunningham, Indiana University. Dr. Siffin's promotion, support, and professional guidance of this project from conception to final product was highly valued by the authors.

We are indebted to the Program for Advanced Studies in Institution Building and Technical Assistance (PASITAM) for providing the support necessary for redrafting materials used in this volume.

Final editing and production has been the responsibility of Marianne Platt who deserves major credit for transforming the writing of system engineers into useful communication. Ms. Platt worked closely with Peter Delp over the course of a year, editing and revising the work of four authors into a coherent volume. Other members of the PASITAM production staff deserve much credit for professional work, especially Clancey Maloney who inked the many diagrams appearing in the volume.

We need also to thank Pat Hochmuth who edited the first working draft, and Suzanne Machett and Doreen Marquardt who cheerfully endured our endless demands in order to produce a first draft.

A final tribute is due our families and friends, especially Sandra Kalscheur, without whose support, encouragement, and (often) direct assistance, completion of this work would not have been possible.

The Authors

Abbreviations

BCR	Benefit-Cost Ratio
BSG	Brainstorming
CBA	Cost-Benefit Analysis
CEA	Cost-Effectiveness Analysis
CFA	Cash Flow Analysis
CGA	Contingency Analysis
CPM	Critical Path Method
CSM	Computer Simulation Models
DIS	Discounting
DLP	Delphi
DTB	Decision Tables
DTR	Decision Trees
EXF	Exponential Smoothing Forecasts
FEX	Function Expansion
FLW	Flowcharts
GAM	Gaming
GNT	Gantt Charts
HIS	Histograms
IDL	IDEALS Strategy
IMD	Interaction Matrix Diagramming
INS	Intent Structures
IPX	Impact-Incidence Matrix
IRR	Internal Rate of Return
IVW	Interviews
LGF	Logical Framework
MCU	Multiple Criteria Utility Assessment
MPA	Morphological Analysis
NGT	Nominal Group Technique
NPW	Net Present Worth
OBT	Objective Trees
OCA	Organizational Climate Analysis
OVD	Oval Diagramming
PPB	Planning, Programming, and Budgeting
PPM	Program Planning Method
QTN	Questionnaires
RGF	Regression Forecasting
RTS	Rating Scales
SCN	Scenarios
SDM	System Definition Matrix
SPA	Subjective Probability Assessment
SVY	Surveys
SYN	Synectics
TRD	Tree Diagrams

Introduction

Designing development projects requires some form of "systems" approach. If any plan is to succeed, the factors that will probably determine the outcome must be identified, and their relationships must be established. There will always be surprises as implementation proceeds, for our ability to predict and control the future is limited. The object of planning and design is to keep these surprises at a minimum. A systems approach, properly used, can serve this aim.

There is another justification for a systematic approach to project planning and design: Even the simplest interventions have secondary effects—consequences which are easily overlooked because they are incidental or even irrelevant to the project itself. An irrigation project, designed to raise farmer income through increased productivity, may threaten established social and economic relationships. It may introduce water-borne disease vectors. It may have other unintended consequences which, in some cases, are more important than the direct impact of the project.

In the West, the word "systems" has acquired, for some people, a certain magical quality. The term is used promiscuously, vaguely, and enthusiastically. The problem lies not in the meaning of that term, but in the way in which it is applied.

Conceptually, a *system* is simply a set of interactive elements. In conventional usage, the term refers to a set of factors which are known (or assumed) to be necessary and sufficient to some purpose or effect. Systems thinkers often work backward, beginning with a desired objective and then determining what factors are needed to accomplish that objective and how those factors must be related. The success of this approach to design depends not on the use of the term "system," but on the ability of the designers to truly know what is necessary to the desired effect.

There are many areas where such knowledge exists, for example, in designing an electric motor, an automobile, an airplane, a computerized data processing program, or a water control system. In these and similar examples, the system can be thought of, for all practical purposes, as "closed." It is a tidy system. There is relatively perfect knowledge of its parts, and of their relation to a desired effect. And the essential relationships between the system and its environment can be known and controlled.

Problems arise when this alluring idea of "system" is transferred from the fields of determinate design into the messy world of "open systems." These are loose and not necessarily stable arrangements in which the environment of an action system, such as a government program, an enterprise, or a farming venture, is always affecting the working of that system.

In the language of systems, the "environment" consists of the factors which affect the system's working but which are not subject to full control from within the system. The weather is an important environmental factor in agricultural systems. "Politics" constantly affects the behavior and potential of a bureaucratic program system. In short, open systems are not nearly so determinate or so capable

of precise specification as the more closed systems of insulated engineering. There are two potential dangers in applying the idea of a system to designing development projects.

The first is the danger of failing to identify essential elements of an open system, or to effectively judge their probable working. A systems perspective cannot guarantee against this danger. It cannot tell you ahead of time what the factors are or how they will work. It can, however, make you aware that they exist and that you had better try to find and assess them.

The second danger might be labeled "undue narrowness," the danger that "incidental" effects may be ignored or undervalued. This can result from systems analyses which, as noted above, start with some desired aim or goal and then work backward to identify the necessary and sufficient factors for meeting the goal without also considering the *other* effects which those factors will have.

It is possible to examine and analyze the larger array of effects produced by any system. Some systems approaches fail to address this vital matter, but *only* a broad systems perspective can consider these effects in a reasonably orderly way. Therefore, the systems approaches reflected in this collection of tools and techniques are *comprehensive*. The aim is to help people search systematically for the broad implications of planned change. The approaches supported by these techniques are *future-oriented*. They offer help in trying to forecast immediate and longer-term effects in open systems designs. The approaches supported by the following tools are essentially *pragmatic*. They address the realities of the socio-political environment of any of the kinds of systems likely to concern us.

In these approaches, the systems analyst attempts to deal with unbounded complexity by identifying a set of salient variables which describe the problem. The organizing concept is the notion of a system, defined not as a static but as a dynamic entity. The values of descriptive variables and the status of relationships are projected into the future in order to look at the consequences of planned interventions. The systems designer recognizes both the limitations of deterministic analysis and the realities of power as it invariably affects the best laid plans. Consequently, a hallmark of a systems approach is pre-planned adaptability. Adaptive systems are better equipped to deal with uncertain futures, the vagaries of power, and the realities of complex political, social, and technical interactions.

Engineers have long straddled both hard and soft approaches to problems. In true engineering fashion, he/she uses whatever technique fits the task or promises insights into solutions. For the non-technical aspects of problems, the systems engineer must turn to other disciplines.

APPLYING A SYSTEMS APPROACH

Tackling complex problems requires a variety of techniques. Flowcharts (FLW, page 107), a diagramming technique which flourishes in the computer sciences, show the logic and sequence of complex computer programs. Not much imagination is required to adapt the technique to the complex decision processes confronting development planners. The aim for design remains the same: using the technique to understand the determinants of decision and action.

This adaptation of systems technology (software) to the complex realm of human behavior is a two-way street. Behavioral scientists have developed systems oriented techniques which have been readily adopted by project designers. Brainstorming (BSG, page 3) and Nominal Group Technique (NGT, page 14) emerged from a marriage of small group theory and empirical creative process analysis. System designers utilize the techniques because of their demonstrated power in generating ideas and innovative solutions.

Criteria used for selecting (or excluding) techniques from the volume were based on the needs of the intended audience. Many sophisticated techniques utilizing optimization theory and computer technology fill the systems literature and seem inappropriate for meeting the needs of a project planner in the field. Consequently, linear programming techniques, queuing and game theory, input-output models, and cross-impact matrices have not been included. By and large nothing more sophisticated than a pocket calculator is required for any of the tools. The exception is Computer Simulation Models (CSM, page 120), which was judged sufficiently important that a summary description was included. Complex mathematical formulations have been avoided, except where a step-by-step procedure can be described (see Regression Forecasting, RGF, page 160, and Discounting, DIS, page 184).

TOOL DESCRIPTIONS

Each tool describes what the project planner needs to know in order to 1) select a tool, 2) utilize the tool, and 3) understand its implications and underlying theory.

To aid selection, each tool begins with a brief statement of purpose and a summary of uses. A short description follows (supplemented by key definitions) and is augmented by a listing of advantages and limitations. The decision maker is thus given a brief overview of the tool to help him decide if the technique is a candidate for addressing a problem. To this end, a section on required resources (effort, skills, time) concludes the first part of each tool description.

In order to use a tool, a detailed description is needed, beginning with required inputs, expected outputs, and im-

portant assumptions. Moving from inputs to outputs involves a procedure, which is described for the tools at differing levels of detail. An example illustrates the procedure.

Finally, a brief section on the underlying theory and a bibliography conclude the tool description. Together with the listing of assumptions and limitations, these attempt to give each tool a theoretical base, while leading the reader to additional sources.

Ideally, each tool description should be self-sufficient, but in order to save space and provide essential continuity, the prerequisites of each tool precede the description. For example, the description of cost-benefit analysis (CBA, page 212) takes the form of a summary linking prerequisite tool descriptions comprehensively. In some cases, a common example is carried through several tools.

The examples draw on a broad range of problems and situations confronting project planners in the development fields, ranging from education and health to agriculture and economic policy. Most of the examples refer to the developing country of Temasek which (for convenience) has a widely varying climate and diverse ecological zones. The population is mostly agrarian. The examples are drawn from first-hand experiences, hypothetical situations, or the literature.

USING THE SYSTEM TOOLS HANDBOOK

The tools included in this volume fall into a number of categories: generating ideas; assessing qualitative factors; defining objectives; describing complex relationships; analyzing complex processes; accounting for alternative outcomes; forecast and prediction; analyzing projects; and planning, controlling, and evaluating projects. Clearly, many techniques could be included in more than one category. For example, computer simulation models (CSM, page 120) could be used for the last six purposes listed. It is presented in analyzing complex processes because that is the most basic use of computer simulation.

Each tool is designed to stand alone as a source of information for a decision maker, as an aid to the analyst, and as a catalyst for multidisciplinary design teams. The tool description (together with any prerequisite tools) provides a basis for action and/or the evaluation of actions by others (e.g., permitting a decision maker to interpret the models used by analysts).

DEVELOPING SYSTEM MODELS

Three tools are paramount to the description of any system: Tree Diagrams (TRD, page 74), Oval Diagramming (OVD, page 81), and Interaction Matrix Diagramming (IMD, page 92). Each describes the complex relationships of a system and defines a system as distinct from its environment.

One possible sequence for using the tools is given in figure 1a. The analyst uses a tree diagram (more specifically, an influence tree) to develop the relationships which prescribe system behavior. This leads to a specification of system variables and environmental factors which influence variables within the system. At some point, the tree diagram is redrawn as an oval diagram to show the feedback relationships and multiple interactions of system variables. If the oval diagram becomes too unwieldy, the analyst may turn to a matrix description. This has the distinct advantage of systematically pinpointing every possible interaction among system and environmental variables, while refining the oval diagram.

The analyst may wish to begin with an interaction matrix diagram rather than a tree diagram (see figure 1b). This approach appeals to those who are more comfortable separating the identification of variables from the specification of relationships. A tree diagram or an oval diagram is then used to interpret the interaction matrix in a form which permits tracing the sequence of cause and effect. An interaction matrix diagram is particularly useful in breaking down information-gathering and analysis tasks into distinct groups, thus facilitating task assignments.

The oval diagram constitutes a first attempt at a causal model of the system; it presents an explicit statement about key variables as well as hypotheses about cause and

FIGURE 1a

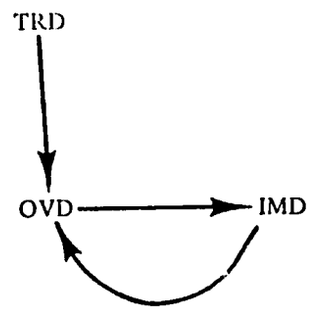
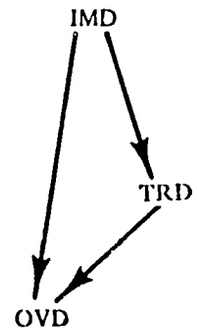
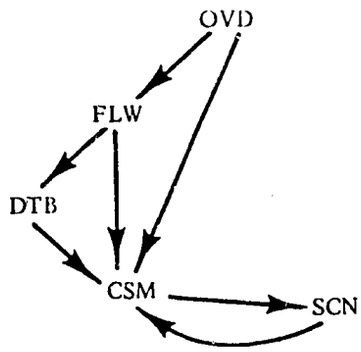


FIGURE 1b



effect relationships. These hypotheses may be tested by regression analysis (see RGF, page 160) and then quantitatively modeled. The oval diagram is then used in various ways to gain greater understanding of system behavior (see figure 2). For example, a computer simulation model (CSM, page 120) can be constructed in order to predict the consequence of changes in the system. A scenario (SCN, page 164) may be developed using the oval diagram as a basis for describing the base state and the kinds of changes expected in the future.

FIGURE 2



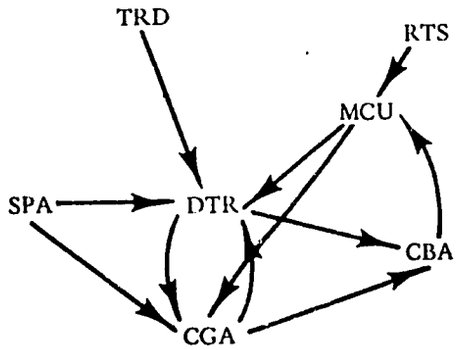
GENERATING AND ANALYZING ALTERNATIVE PLANS OF ACTION

Tree diagrams in the form of ends-means diagrams (see TRD, page 74) are useful for breaking a system into components or an objective into alternative means. This begins a sequence using several techniques to analyze alternative plans (see figure 3). The central tool in this process is the Decision Tree (DTR, page 141). Branches of a decision tree map alternative actions and probabilistic outcomes. The alternatives may be identified by the tree diagram branching process or the matrix format of morphological analysis (MPA, page 10). The probabilities of various outcomes are often subjectively assessed (SPA, page 137). Closely related to the decision tree, contingency analysis (CGA, page 147) tabulates alternative plans against the various possible states of nature which affect their outcomes.

Outcomes for both techniques are expressed either as monetary units (costs and benefits) or as utilities, using a concept which translates preferences for an outcome into a dimension on an interval scale (see RTS, page 29). Utilities assessed for various criteria are combined in Multiple Criteria Utility Assessment (MCU, page 32).

In short, these possible sequences of tools (figure 3) describe a process of analysis which begins with generating alternatives and results in an evaluation of alternative outcomes. The end use may be employed for a cost-benefit analysis or for the selection of plan elements.

FIGURE 3



CO-OPTING CLIENTS, RESOURCE CONTROLLERS, AND EXPERTS INTO THE PLANNING PROCESS

There is a set of techniques which claim their greatest strength in their ability to generate cooperation among various actors on the planning stage. The central tool is the Program Planning Method (PPM, page 227). Supporting this tool are a number of techniques, each of which is powerful when used alone and potentially more so when incorporated into a strategy (see figure 4). The Nominal Group Technique (NGT, page 14) permits maximum efficiency in generating ideas. It is particularly effective when used by diversely composed groups.

A companion technique is the Delphi process (DLP, page 168) to which experts and decision makers contribute without face-to-face confrontation. This anonymity is often necessary if the pursuit of ideas and constructive problem exploration is not to be hindered by social and bureaucratic sanctions. The Delphi utilizes repeated rounds of questionnaires (QTN, page 19).

The Program Planning Method combines these techniques to produce plans which co-opt clients, resource controllers, and experts in a carefully orchestrated planning process.

A NORMATIVE APPROACH TO PLANNING

One planning strategy begins with a normative concept of the ideal system, rather than analyzing what could be

FIGURE 4

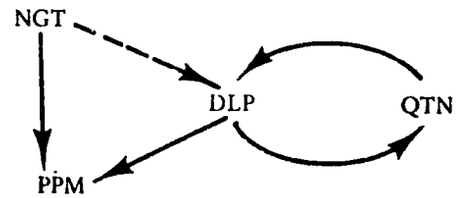
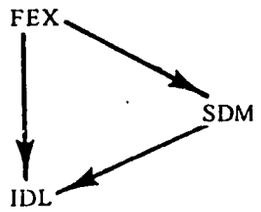


FIGURE 5



wrong with the existing one. This strategy is embodied in the IDEALS Strategy (IDL, page 231). Two other techniques support this approach (see figure 5).

Function expansion (FEX, page 45) forces the system designer to think in terms of the purpose of the system desired—what the system should be doing. This leads to a specification of the "ideal system target" which becomes the basis for designing a feasible system, using essentially the system design strategy. The form of the specification is the system definition matrix (SDM, page 67), which is the output of the IDEALS process.

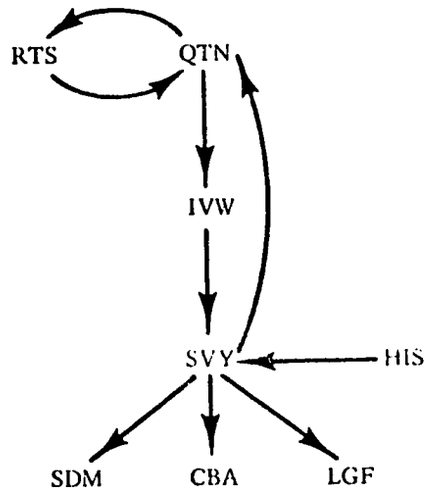
Focusing on function rather than on problems gets people involved in a constructive assessment of what should be, rather than what's wrong and who's to blame. There are sound arguments for both approaches. The IDEALS Strategy often comes under attack because its emphasis on normative specification may possibly ignore experiences gained from problems with the existing system. If the ideal system target proposes a radical change, where only incremental changes are acceptable, normative prescriptions may be counterproductive. Still, there is an intuitive appeal to any process that encourages minds to explore an unlimited problem-solution space, unbounded by existing system descriptions.

USING SAMPLE SURVEYS TO GATHER INFORMATION

A sequence of techniques is particularly useful for gathering information across a broad spectrum. The principal technique is the sample survey (SVY, page 36), which begins the design of the survey questionnaire (see figure 6). Where subjective assessments are to be quantified and aggregated, the questionnaire may incorporate rating scales (see RTS, page 29).

The questionnaire (QTN, page 19) must be pretested and refined so that the objectives of the survey may be realized. The means for obtaining the desired information may vary greatly, but one useful technique is the direct interview (see IVW, page 23). This is usually the preferred approach in pretesting the survey because it requires less time and gives more design information than mailed questionnaires. The latter technique, however, is widely used

FIGURE 6



when a large sample is to be covered by the survey, even though a high return is seldom possible.

The survey results are quantified and aggregated, often in the form of histograms from which statistics may be computed (HIS, page 131). These results are then used to formulate policies, to specify system design (see System Definition Matrix, SDM, page 67), to quantify costs and benefits (CBA, page 212), and to evaluate programs (see Logical Framework, LGF, page 260).

PROJECT FINANCIAL ANALYSIS

The financial analysis of projects is a sequential process which begins by identifying costs and benefit time streams (Cash Flow Analysis, CFA, page 177) and culminates in the presentation of recommendations (and assumptions) to decision makers (see figure 7). Many techniques support this analysis at each stage. A survey may be necessary to gather financial and production data. The various impacts of a project may be tabulated across directly and indirectly affected groups in an impact-incidence matrix (IPX, page 207). This technique attempts not only to quantify all impacts of a project, but nonmonetary impacts of a project using rating scales (RTS, page 29).

The time streams of costs and benefits are discounted to give their present value in order to compare project alternatives (see Discounting, DIS, page 184). The criterion for comparison may be net present worth (NPW, page 188), benefit-cost ratio (BCR, page 194), internal rate of return (IRR, page 200), or a combination of these.

The cash flow analysis, the evaluation criteria, and the impact-incidence analysis are brought together in cost-benefit analysis (CBA, page 212). The end result may take the form of a single go-no go decision on any one project, or a ranking of alternative projects for funding.

FIGURE 7

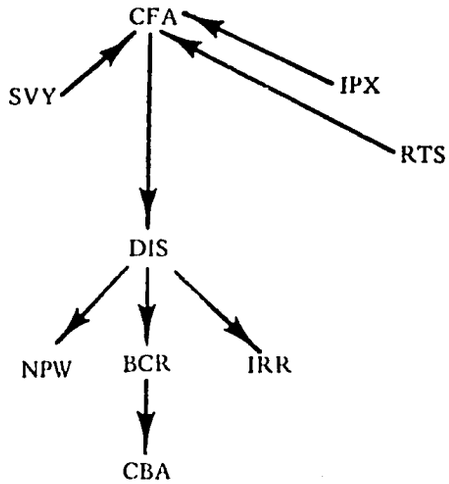
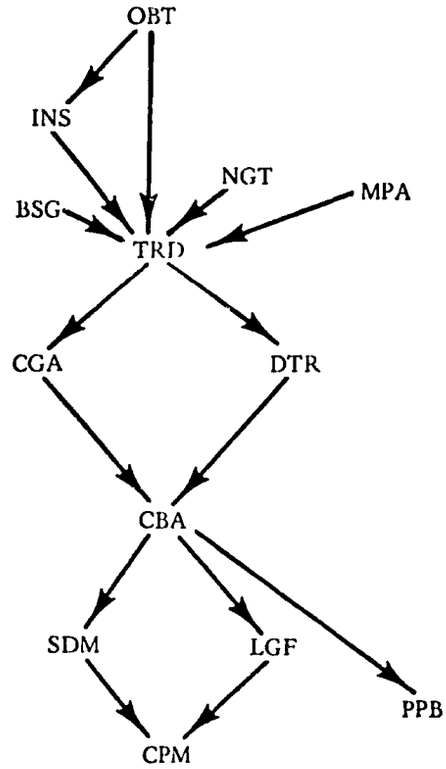


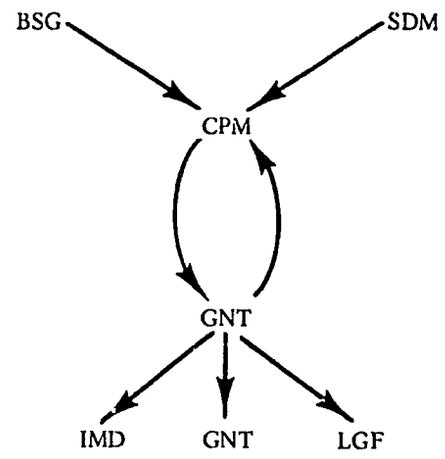
FIGURE 8



THE "CONVENTIONAL" SYSTEMS APPROACH

Systems analysis begins with identifying objectives, specifying alternative means, specifying the criteria for selecting among the alternatives, and then synthesizing a system or plan from the choices. A sequence of techniques for applying the systems analysis strategy begins with Objective Trees (OBT, page 49) and/or Intent Structures (INS, page 55) (see figure 8). Brainstorming, Nominal Group Technique, or morphological analysis may be used to specify alternative means (see also Tree Diagrams, TRD, page 74). The alternatives are analyzed using either decision trees or contingency analysis to develop the project plan. Cost-effective analysis, multiple criteria utility assessment, or both are used as criteria for evaluating alternatives. The plan may be specified as a System Definition Matrix, Logical Framework, or as an operating Planning, Programming, and Budgeting system (PPB, page 236). This strategy is not altogether different from the IDEALS approach; however, the starting point of the latter is the function of the system rather than objectives for a project.

FIGURE 9



PLANNING PROJECT ACTIVITIES FOR IMPLEMENTATION AND CONTROL

Two complementary techniques which specifically address the scheduling of project activities are the Critical Path Method (CPM, page 241) and Gantt Charts (GNT, page 252). The techniques may be incorporated into a strategy which plans and facilitates the implementation of a project.

Critical path techniques begin with a list of project activities essential to the achievement of project goals (see figure 9). The list may be generated using techniques such as brainstorming or, more formally, from a system specification (see System Definition Matrix). From the critical path network, a Gantt (bar) Chart may be prepared, enabling a planner or manager to schedule activities and resources. He may wish to present the activities and officers responsible in an interaction matrix (IMD, page 92) in order to emphasize both the interrelatedness of tasks and the multiple staff responsibilities. A Logical

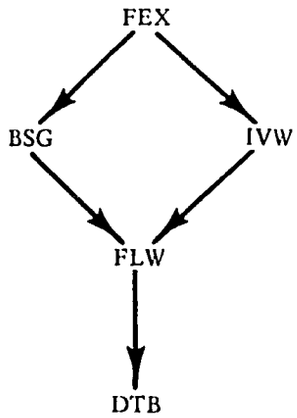
Framework may also be used to sharpen the identification of objectively identifiable indicators of progress. These milestones are shown as vertical lines on specific dates of the Gantt Chart and written on the Critical Path Method network at the appropriate nodes.

Altogether, the techniques serve to ease the manager's job by breaking down a complex project into finite tasks with planned start and end dates. Progress monitoring permits effective use of staff which is essential to successful project implementation.

ANALYSIS AND PROGRAMMING OF DECISION PROCESSES

A decision-making system exists for a specific purpose. The first step in any analysis is a function expansion to specify that purpose (FEX, page 45) (see figure 10). The aim is to specify the key decision points and the conditions which lead to particular actions, i.e., the decision-making policies. Two processes may be used to obtain this information. If the system exists, decision makers may be interviewed (IVW, page 23). If the task is to design a system, then idea generating techniques (e.g., Brainstorming, BSG, page 3) are used.

FIGURE 10

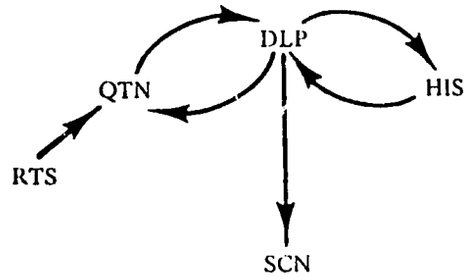


The results of this analysis are presented in the form of flowcharts (FLW, page 107) or decision tables (DTB, page 113). The flowchart uses different symbols to display and analyze complex processes. The decision table presents the decision as a preprogrammed process by specifying the conditions which precede—and the action which follows—a decision. Both techniques are usefully employed in management training as well as in diagnosis of potential problems in implementation.

QUALITATIVE FORECASTING

A scenario draws on a variety of expertise to produce a map of the future states of a system (SCN, page 164). It is the result of a strategy which incorporates intuition and judgments into a coherent framework (see figure 11).

FIGURE 11

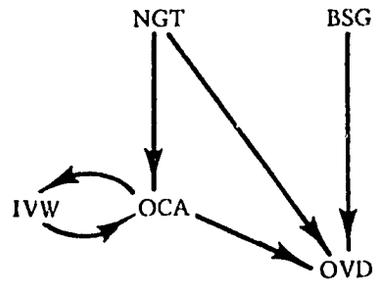


The Delphi technique (DLP, page 168) begins by directing questionnaires to a selected group of prognosticators. The results of each round are summarized for the Delphi group, often in the form of a histogram which aggregates the individual judgments. Rating scales attempt to quantify priorities and opinions. The Delphi rounds are then used to produce the successive state descriptions of the scenario. The desired result is a clearer understanding of the forces and constraints which are involved in planned change.

PROBLEM ANALYSIS STRATEGIES

Problems in systems (whether ongoing organizations or newly designed projects) may be analyzed by using a number of techniques, none of which guarantees a solution. Rather, they promise a greater understanding of the dimensions of the problem. Two techniques are central to the analysis of problematic behavior: Oval Diagramming (OVD, page 81) and Organizational Climate Analysis (OCA, page 40) (see figure 12).

FIGURE 12



Problems are first identified using a technique such as Intent Structures (INS, page 55) to specify conflicting objectives and competing interest groups. The Nominal Group Technique (NGT, page 14) or brainstorming (BSG, page 3) may also be used. The problems lists may be employed to guide the information-gathering, the interview-

ing necessary for an analysis of organizational climate, or the tackling of identified problems by a Synectic problem-solving team (SYN, page 6). The very least to be expected from a Synectics group is a better definition of the problem and a creative attempt at a solution.

One highly recommended technique for combining all these analyses is an oval diagram which describes the system or organization. Most problematic behavior stems from poorly designed feedback of information within a system, and poor understanding of the far-reaching effects of actions.

The analyst may ultimately wish to test the problem analysis by using management games (see Gaming, GAM, page 124) which are carefully designed to identify problems which arise from simulated interaction among system and organizational components.

CONCLUSIONS

This volume is a collection of techniques drawn from a variety of disciplines and presented in a standard format in order to bring together various means to a common end—better development project design. The organizing theme is a systems approach to project planning. The techniques are means to develop project designs which are comprehensive, future-oriented, and pragmatically shaped by the realities of power and uncertainty. While no single technique is the systems engineer's unique contribution, all should contribute to better project design.

Rating Scales

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

A rating scale measures the degree to which an entity possesses or exhibits a specified property, as either an absolute or a relative judgment.

USES

Rating scales are used to quantify factors which may be highly subjective or qualitative in nature. Once the judgment is scaled, the quantitative measure may be incorporated into analyses such as:

1) Rating the individual utilities of various criteria using Multiple Criteria Utility Assessment (MCU, page 32).

2) Evaluating alternative decision sequences in a decision tree (DTR, page 141).

3) Evaluating alternative plans, given various contingencies which may be expected to occur (Contingency Analysis, CGA, page 147).

4) Ranking alternatives as in Nominal Group Technique (NGT, page 14) and Delphi (DLP, page 168).

KEY DEFINITIONS

There are four primary types of rating scales (see figure 1):

1) *Nominal scales* simply categorize different factors, e.g., hot/cold, dark/light, and black/gray/white represent nominal scales for heat, illumination, and color.

2) *Ordinal scales* are used to rank-order a set of similar objects along a criterion dimension which reflects a basis for comparison, but not the degree of difference, e.g., warm, warmer, hot, hotter, hottest are ordinal rankings of heat sensation.

3) *Interval scales* reflect not only the rank of one factor over another, but the degree to which one exceeds the other. The difference between them corresponds to a length of scale interval. The zero point is arbitrary.

4) A *ratio scale* is an interval scale for which the dimension of comparison has a natural zero point, e.g., the centigrade temperature scale.

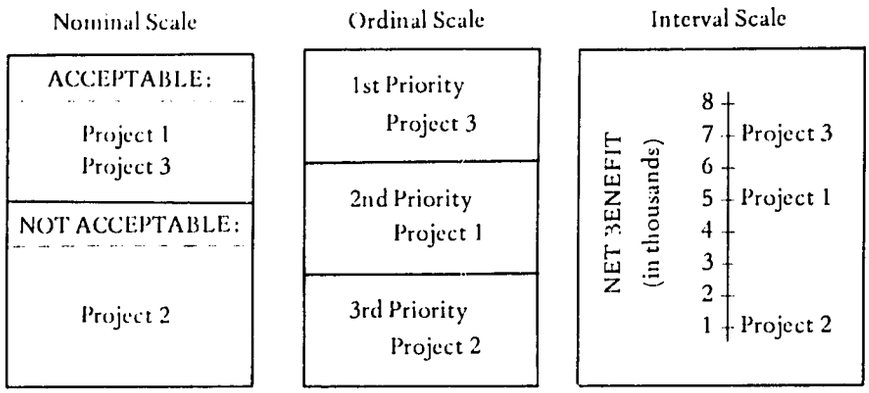
SHORT DESCRIPTION

Rating scales are described by their uses:

1) To rank the preferences for a set of factors: *ordinal* and *interval* scales.

2) To classify or categorize a dissimilar set of factors: *nominal* scales.

FIGURE 1
Examples of Rating Scales Applied to Discrimination Among Three Projects



3) To indicate the degree one factor exceeds another on a specified basis of comparison: *interval* and *ratio* scales.

The scale selected determines how discriminating the rater can be.

ADVANTAGES

Rating scales allow a quantitative comparison. If the comparison involves several factors, the discrimination between factors is enhanced by relating it to a physical dimension (the position or interval on ratio scales).

Factors quantified on rating scales may be combined to reflect a quantitative assessment of cumulative effect, e.g., the pooled judgments of a group of raters.

LIMITATIONS

Rating scales are constructed by subjective judgments in the assignment of rank or interval on the scale. This fact is sometimes lost when the rating is transferred to other tasks or used as information in other tasks.

REQUIRED RESOURCES

LEVEL OF EFFORT

The major task is to assign the rating for each factor. This may be an involved or a straightforward process, depending on the ultimate use of the rating. For example, rating may be used directly as part of cost-benefit analysis (CBA, page 212) or as an aggregated form to reflect multiple dimensions of discrimination (MCU, page 32). The aggregation process tends to minimize the contribution of any one rating.

SKILL LEVEL

Expertise is required in selecting the appropriate kind of rating scale and its parameters. The rating process is subjective and may combine the individual judgments of experts or project clients (see Delphi, DLP, page 168).

TIME REQUIRED

Nominal scales usually require little time since only classification is involved. Ordinal scales can be constructed quickly, particularly if only a few factors are to be ranked. Interval and ratio scales may require more time to construct and establish ratings because more judgment is involved.

DESCRIPTION OF TOOL

REQUIRED INPUTS

The inputs required are simply the scale selected for the ratings (nominal, ordinal, etc.) and the set of factors to be rated. If the rating is to be conducted by someone other than the person who constructed the scale, a sample rating is useful to illustrate the process. The dimension on which the comparisons and contrasts are to be made must be clearly identified and understood.

TOOL OUTPUT

The output is a rating scale which quantifies the subjective assessment of the factors.

IMPORTANT ASSUMPTIONS

The construction and application of rating scales rest on the assumption that humans can discriminate along the

rating dimension. There are two limiting factors involved: comparative and absolute judgment. The first suggests that humans are limited in their ability to discriminate between two adjacent factors along dimensions such as color, tone, volume, smell, size, length, etc. The second suggests that the number of discrete intervals which may be recognized along any one dimension is limited. For example, we recognize only four different tastes: sweet, sour, salt, and bitter. Discrimination is based on a combination of taste, texture, smell, and appearance. The implication is that it would be unproductive (and misleading) to ask the rater to distinguish more intervals than he is psycho-physiologically able to (Garner, 1960).

METHOD OF USE

GENERAL PROCEDURE

1. Determine the attributes or factors to be rated.
2. Determine the best scale for rating the factor.
   2.1 Consider the degree of subjective judgment that is feasible.
   2.3 Determine the time available and the discrimination desired.
3. Construct the rating scale.
4. Rate the attributes or factors.
5. Verify the consistency of the ratings.

EXAMPLES

Nominal Scale

Any classification system represents a nominal scaling of variables. For example, the tools in this handbook are categorized nominally by their major purpose. In general, the nominal classification of items is possible only if the categories are mutually exclusive and exhaustive. The latter requirement is usually met by a catch-all category, e.g., "none of the above."

Ordinal Scale

There are several examples of the construction and application of ordinal scales in this handbook, e.g., the *rank-ordering* method described in Nominal Group Techniques (see NGT, page 14).

Interval and Ratio Scales

Interval scales are used in assessing utility functions (see Multiple-Criteria Utility Assessment, MCU, page 32). Subjective Probability Assessment (SPA, page 137) requires an interval scale to rate the likelihood of events occurring. Krueckeberg (1974) describes the use of rating scales in urban planning.

THEORY

Rating scales are based on the theory of psycho-physical measurement (Garner, 1960). The literature of psychology, sociology, and decision making abounds with empirical studies on the subject.

Two works are of particular interest: Kaufman (1976) describes rating scales in a treatment of a systems approach to identifying and solving problems. Knepprethe, et al. (1972) catalog a number of different worth assessment techniques. Other studies (Huber, et al., 1969) deal with the issues of the aggregating group judgments. The results are significant, particularly where priorities are to be ranked in such a way that second and third choices are included.

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Multiple Criteria Utility Assessment

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

Multiple criteria utility assessment is a systematic procedure for assessing the worth of complex alternatives.

USES

Utility assessment provides a common scale for combining judgments on more than one dimension. The technique is used to:

1) Evaluate alternatives using more than one criterion.

2) Combine effectiveness measures into a single aggregated utility, e.g., as in cost-effectiveness analysis (CEA, page 219).

3) Determine a common criterion for valuing the possible outcomes in a decision under risk (see Decision Trees, DTR, page 141).

4) Provide a common measure for comparing the performance of alternative plans (e.g., Contingency Analysis, CGA, page 147).

KEY DEFINITIONS

1) *Utility* is a quantitative expression of the worth or satisfaction associated with an outcome.

2) A *utility function* associates the possible levels a criterion may take with the utilities for those levels.

3) A *utility matrix* presents the elements of a decision under certainty: alternatives, criteria for evaluating the alternatives, weights indicating the relative importance of the criteria, and the assessed utilities (see figure 1).

FIGURE 1
Utility Matrix for Evaluating Alternatives

		ALTERNATIVES	
CRITERIA	WEIGHT	A	B
x_1	w_1	U_{A1}	U_{B1}
x_2	w_2	U_{A2}	U_{B2}
x_3	w_3	U_{A3}	U_{B3}
Total Weighted Utility		U_A	U_B

SHORT DESCRIPTION

In order to compare and evaluate various alternatives (A, B, . . .), several criteria (x_1, x_2, . . .) are first specified (see figure 1). The decision maker considers each criterion separately, assessing the relative *utility* for different criterion levels. The criteria are weighted to represent their relative importance to the decision maker. The aggregate utility for each alternative is determined by computing the weighted sum of the individual utilities for each criterion. Alternatives are compared on the basis of overall utilities.

ADVANTAGES

Valuing alternatives using measures like expected payoff or costs ignores the preferences the decision maker may have for incremental benefits or costs. Utility assessments transform these preferences into quantitative scales which can be combined to determine aggregate utility.

Where a complex alternative must be evaluated, this technique requires the decision maker to consider only one criterion at a time. This simplifies the assessment task and increases the consistency of subjective judgments.

LIMITATIONS

Not all qualitative criteria can be assessed quantitatively, e.g., political acceptability. Multiple criteria utility assessment makes no allowance for preferences which change over time.

REQUIRED RESOURCES

LEVEL OF EFFORT

Multiple criteria utility assessment requires the cooperation of the analyst and the decision maker. The analyst frames the decision situation by identifying alternatives and working with the decision maker to specify criteria for evaluating the alternatives. The decision maker quantifies his preferences in the form of a utility function for each criterion. Aggregating utilities is then a straightforward analytical task.

SKILL LEVEL

Effective communication between analyst and decision maker is essential for eliciting utility functions and weighting criteria. The analyst must be able to evaluate the degree to which each alternative meets the criterion in question, a process which can involve subjective judgment.

TIME REQUIRED

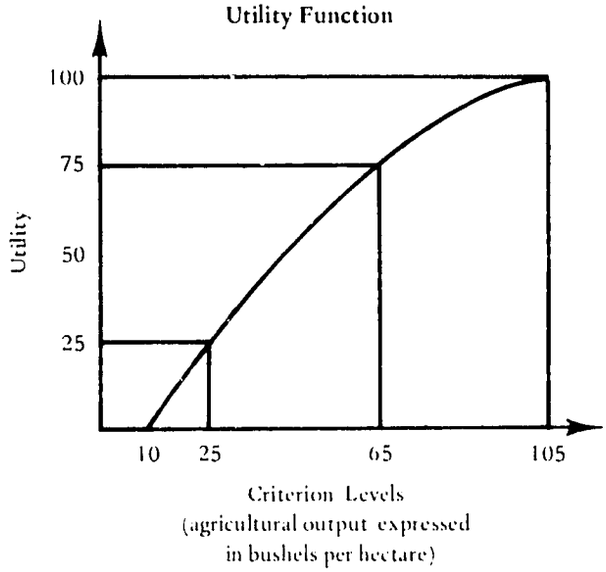
Determining utility functions and checking for consistency can take half a day. Otherwise, the computations and evaluations are not time-consuming, provided necessary information is available.

DESCRIPTION OF TOOL

REQUIRED INPUTS

The criteria by which the alternatives are judged must be specified. The criteria may be derived from an analysis of objectives (Objective Trees, OBT, page 49) or from the nature of the decision situation. The alternatives must be sufficiently detailed so that the decision maker can judge the extent to which each meets the criteria.

FIGURE 2
Utility Function



TOOL OUTPUT

The first products of the multiple criteria utility assessment technique are the utility functions corresponding to each criterion (see figure 2). These transfer the criterion levels to utilities (e.g., the utility of 65 bushels per hectare is 75*). Utility functions can be analyzed to indicate the underlying preferences of the decision makers, e.g., a preference to avoid risk (see Bierman, et al., 1973).

In a decision situation, the ultimate result is a quantitative ranking of the alternatives by decreasing aggregate utility. This measure can be used in other techniques where alternatives are evaluated using multiple criteria (e.g., Cost-Effectiveness Analysis, CEA, page 219).

IMPORTANT ASSUMPTIONS

Utility is a measure of satisfaction with an outcome and has the property of additivity. Utilities assessed for more than one criterion may be added to indicate a preference based on complex multi-dimensional judgments (see Rating Scales, RTS, page 29).

The criteria applicable to a decision are fixed dimensions for assessing the degree to which an alternative possesses each of the attributes, e.g., the dimensions do not vary from alternative to alternative in the decision situation although the criterion level for each alternative varies. That is, subjective preferences are consistently applied to all alternatives in the decision situation.

*Utilities are dimensionless, but may be thought of as percentage relative to complete satisfaction (100%) with a criterion level.

METHOD OF USE

GENERAL PROCEDURE

1. **Identify the decision criteria used to assess each alternative.**
   1.1 Determine nominal scale categories for the qualitative criteria (see Rating Scales, RTS, page 29).
   1.2 Determine the practical limits for quantifiable criteria, e.g., yield per hectare may range from 10 to 105 bushels.

2. Construct a utility function for each qualitative criterion.
   2.1 Identify a most preferred and a least preferred level.
   2.2 Assign utilities of 100% and 0% satisfaction.
   2.3 Assess the utilities for intermediate levels of the criterion.

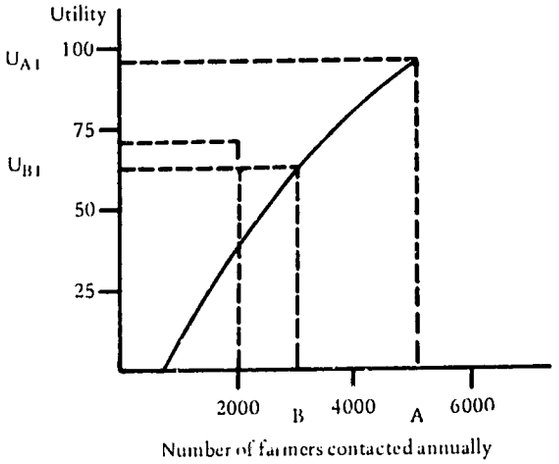
3. Construct utility functions for each quantitative criterion.
   3.1 Assign 100% utility to the quantitative criterion level, just beyond the practical limit which is most preferred.
   3.2 Assign 0% utility to the criterion level at the other extreme of the practical range of values.
   3.3 Assess the utility value which indicates the percentage satisfaction with intermediate criterion levels, e.g., "if your satisfaction with a harvest of 105 bushels is 100%, then what is your satisfaction with 60 bushels per hectare?"
   3.4 Connect a curved line through the intermediate utility values (see figure 2).

4. Test the internal consistency of the utility assessments.
   4.1 Pose questions like: "You have said that you would be 25% satisfied with 35 bushels and 75% satisfied with 60 bushels. Are 60 bushels actually preferred three times as much as 35 bushels?"
   4.2 If the answer is no, then adjust one or both utility assessments.

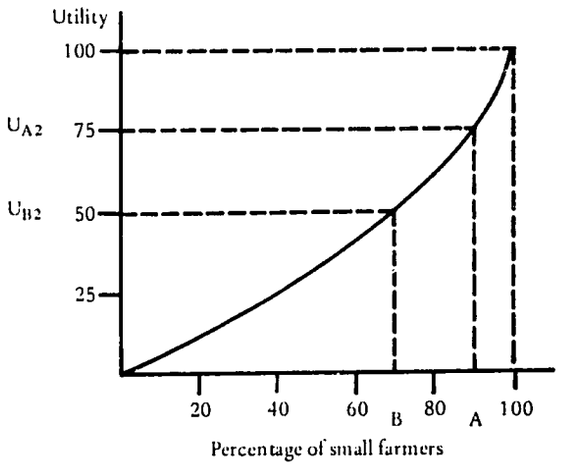
5. **Considering one criterion at a time, determine the utility for each alternative.**
   5.1 Construct the utility matrix (figure 1).
   5.2 Using the utility function for the respective criterion, evaluate the utilities for the various alternatives by assessing the criterion level achieved by each and then using the utility function to read off the corresponding utility.
   5.3 Enter these percentages in the rows corresponding to that criterion of the utility matrix.

FIGURE 3
Utility Functions for Evaluating Farmer Contact Strategies

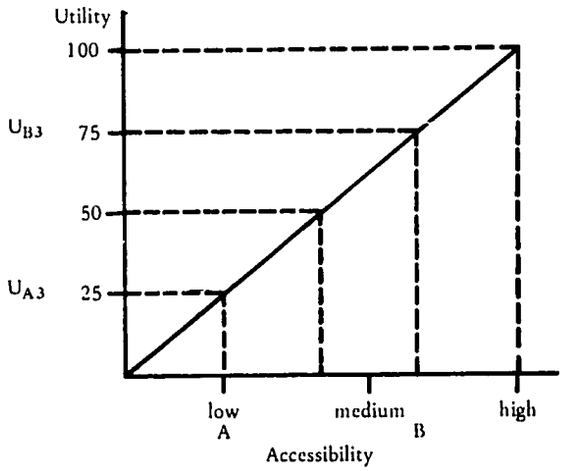
Criterion 1: Number of farmers contacted per year



Criterion 2: Percentage of farmers contacted who own less than 10 hectares



Criterion 3: Accessibility by farmers



6. **Weight the criteria.**
   6.1 Ask the decision maker to order the criteria by increasing importance to the decision.
   6.2 Assign a weight of 1.0 to the most important criteria.
   6.3 Ask the decision maker to indicate the fraction corresponding to each remaining criteria, e.g., "is this criterion one-half or one-third as important as the most important criterion?"

7. **Compute the aggregated utilities.**
   7.1 Multiply each utility by the weight assigned to the respective criterion for that row of the matrix.
   7.2 Compute the aggregated utility for an alternative by summing the weighted utilities across all criteria. Referring to figure 1, for alternative A:

   $$\text{Aggregate utility of A} = w_1 U_{A1} + \ldots + w_n U_{An}$$

   where

   U_{An} = utility of alternative A for criterion n

   w_n = weight of nth criterion (a positive fraction less than 1)

   7.3 Rank-order the alternatives by descending values of their aggregated utility. The alternative giving the greatest satisfaction is the one having the greatest aggregated utility.

EXAMPLE

The Temasek Ministry of Agriculture was considering two alternatives for disseminating innovations to small farmers: A) establishing farmer training centers at strategic locations in the region, or B) strengthening and expanding the agricultural extension service. The effectiveness of the alternatives were evaluated using three criteria: 1) the number of farmers contacted per year; 2) the percentage of farmers contacted having holdings of 10 hectares or less; and 3) the accessibility of the approach. Criterion (3) was formulated as a qualitative assessment of the ease with which farmers could use the system.

Utility functions were derived for the three criteria (see figure 3). The Ministry of Agriculture decision makers placed a high utility on reaching a significant percentage of small farmers. Also, no utility was associated with reaching less than 500 farmers as this was the present level of contact for the existing extension program. The practical limit for criterion (1) was the total number of farmers in the region, estimated at 10,000.

A utility matrix was constructed, and the utilities of the alternatives were evaluated (see figure 4). Considering criterion (2), the mobile extension workers could be more selective in contacting farmers, while only the larger farmers would tend to use the training center services.

FIGURE 4
Utility Matrix for Ministry of Agriculture Farmer Contact Strategy

Criteria W	Weights	Alternatives: A) Training Centers	Alternatives: B) Strengthened Extension
1. Total farmers contacted	1.0	90	60
2. Percentage small farmers	0.5	75	50
3. Accessibility	0.5	25	75
Weighted total		140	122.5 = 123

The importance of each criterion was evaluated and weights were assigned (see figure 4). The total number of farmers reached was judged to be twice as important as the other decision criteria. The weighted aggregate utility for each utility was computed. For example:

$$\text{Aggregate utility for alternative A} = (1.0)(90) + (0.5)(75) = (0.5)(25) = 140$$

The weighted aggregate utility for alternative B was computed at 123. Consequently, the farmer training center strategy was preferred. The aggregated utilities were then compared to projected costs (see Cost-Effectiveness Analysis, CEA, page 219).

THEORY

Huber (1974) identifies two methods by which multiple criteria utility assessment is carried out. The method shown here has been the client-explicated model, since the client (decision maker) indicates his utility for various levels of each criterion. In the observer-derived model, the client is asked to make a global judgment of the overall utility associated with a set of criterion levels. The client estimates the utility for several such sets; regression analysis (see Regression Forecasting, RGF, page 160) is used to estimate the utilities associated with each criterion.

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Surveys

PREREQUISITE TOOLS

Questionnaires, QTN, page 19.

USAGE

PURPOSE

A sample survey is used to gather information from a fraction of a subject population in order to identify and measure its attributes.

USES

A sample survey can be used to:

1) Explore the issues, opinions, and attitudes of inhabitants of a region or a selected target population.

2) Test fundamental hypotheses and assumptions which have been developed by a pilot study or other experiment.

3) Provide feedback on the progress of a project by measuring the delivery of services.

4) Form the basis for a post facto evaluation of the overall effectiveness of a project by measuring its impact on recipients and non-recipients.

5) Quantify statistical data used in the cost-benefit analysis (CBA, page 212) and cost-effectiveness analysis (CEA, page 219) of proposed projects.

KEY DEFINITIONS

1) A *subject population* is the set of all events or entities which possess certain specified characteristics, e.g., all married couples in a region of the country of Temasek.

2) A *sample* is a subset selected from a subject population, the attributes of which are assumed to hold true for the total population.

3) A *measuring instrument* is a technique for eliciting and measuring responses from a subject.

4) A *census* is a survey of all members of a subject population.

5) *Participant observation* is the gathering of information about and impressions of a selected group by direct interaction over an extended period of time, e.g., a social scientist living in a village to interact and observe behavior patterns, social relationships, and economic structures.

SHORT DESCRIPTION

A sample survey is a means of gathering maximum information at minimum cost. A *sample* of the *subject population* is selected based on the purpose of the survey and time and cost limitations. Two common *measuring instruments* are used to gather information: interviews (IVW, page 23) and questionnaires (QTN, page 19). They may be used together and administered by trained personnel.

Survey results are tabulated and analyzed in order to assess characteristics of the subject population. Surveys

are used in evaluation research for the "assessment of the process and/or consequences of deliberate and planned interventions" (Warwick and Lininger, 1975, page 51). Using rating scales (RTS, page 29) and statistics (see Histograms, HIS, page 131), the analyst makes inferences about the need for, the progress of, and the impact of development projects. These inferences are tested using the sample survey results.

ADVANTAGES

1) Information about a population may be gathered from a fraction of the population. This minimizes expensive data gathering costs.

2) A great deal of information can be gathered by making a careful selection of a representative sample.

3) In contrast to *participant observation*, a carefully designed survey permits generalization about the characteristics of the population as a whole.

4) Because fewer interviewers are required than for a *census*, the training and control over them is usually better.

LIMITATIONS

Even a small survey may be prohibitively expensive, particularly if accessibility to the subject population and training personnel are factors.

Biases in the information gathered and the sampling procedure may lead to erroneous inferences.

The return for mailed questionnaires is typically very low and may jeopardize the validity of the results. However, personal interviews introduce an additional source of bias (see Interviews, IVW, page 23).

A sample survey is less useful than participant observation when the analyst knows little about the society under study.

REQUIRED RESOURCES

LEVEL OF EFFORT

Surveys are normally major undertakings. The decision maker will have to weight the costs against the benefits (see Cost-Benefit Analysis, CBA, page 212) before undertaking the survey. The analyst will expend the major effort in designing the survey and analyzing the responses. If interviewing is desirable, the selection, training, and supervision of interviewers is crucial.

SKILL LEVEL

Survey design requires a good deal of research knowledge and statistical sophistication. Skills in selecting representative samples, constructing questionnaires, and analyzing data are essential.

TIME REQUIRED

A sample survey can be a very time-consuming process, not only in actually conducting the survey but in the planning and analysis stages. A critical path schedule is presented as an example in Gantt Charts (GNT, page 252) for a 33-day task.

SPECIAL REQUIREMENTS

A variety of statistical packages are available on computer programs. However, to use them to analyze sample survey results, the data must be coded in compatible formats (see Questionnaires, QTN, page 19). Though not strictly necessary, computerized techniques have the great advantage of shortening the time required to analyze results and permitting complex statistical measures to be derived from the data.

DESCRIPTION OF TOOL

SUPPLEMENTAL DEFINITIONS

1) A *simple random sample* is made so that every member of the target population has an equal probability of selection.

2) A *stratified sample* selects a proportional sample at random from each of the groups in a stratification of the total population, e.g., the sample includes an equal number of randomly selected individuals from low, middle, and high income strata.

3) *Cluster sampling* is the process of randomly selecting several clusters of subgroups from the total population and surveying all members of the selected subgroups, e.g., only three villages are selected in the region of the subject population, but every inhabitant of the village is interviewed.

4) *Multi-stage sampling* draws random samples in stages. The first stage selects random groups within the target population. A second stage randomly selects subgroups (or individuals) from within the groups, and so on.

REQUIRED INPUTS

The problem definition, the desired subject population, the measuring instruments, and the sample size are

necessary inputs for a survey. The decision maker has to interact with the analyst to determine the sample size. The size will affect costs as well as reliability. A choice between potential measuring instruments is made depending on the type of problem being faced, the costs of using the instrument, and the expected time lag before arriving at a final analysis.

TOOL OUTPUT

The tabulation of the responses is of primary interest to the decision maker. The simplest type of output would be marginal tabulations, indicating how the population is distributed across a list of categories. For example:

Religion	Percentage of Population
Protestant	15%
Catholic	5%
Muslim	30%
Buddhist	40%
Other	10%
TOTAL	100%

Hence, Muslims would form 30% of the subject population (see Histograms, HIS, page 131).

Another output is "correlation analysis." This analysis shows how variables are related to each other. For example:

	Response on Birth Control		
	Opposed	Indifferent	Agree
Protestant	5%	5%	90%
Catholic	60%	30%	10%
Muslim	55%	10%	35%
Buddhist	10%	10%	80%
Other	2%	15%	83%

This output would indicate that Catholics and Muslims generally oppose birth control. Hence, the decision maker may have to consider strategies to establish linkages with Catholic and Muslim priests if birth control is to be implemented (see Regression Forecasting, RGF, page 160).

A final type of output is due to "longitudinal research," where the attributes of a population are measured at two or more points in time. The results are used to indicate changes in measured attributes which are caused by planned interventions. For example, the effectiveness of a birth control education program would be assessed by repeating the survey of attitudes at several intervals after the program had started.

IMPORTANT ASSUMPTIONS

A sample population can be randomly selected to be representative of the subject population. Measuring instruments are unbiased. The inferences from the sample results to the target population are statistically valid.

METHOD OF USE

GENERAL PROCEDURE

Since sample surveys vary greatly in purpose, design, and execution, below is a broad sketch of the steps involved (for a more detailed description, see, for example, Warwick and Lininger, 1975).

1. Specify the purpose of the survey and its uses.

2. **Identify the subject population.**
   - 2.1 Consider the kinds of inferences which are to be made.
   - 2.2 Consider the accessibility and cooperativeness of the subject population (they may have already been saturated by surveys or experiments).

3. **Select a sample method:**
   - a) Simple random sampling,
   - b) Stratified sampling,
   - c) Cluster sampling, or
   - d) Multi-stage sampling.

4. **Determine the best sampling size.**
   - 4.1 Consider the desired accuracy and reliability of the survey results: the larger the sample, the more reliable the inferences about the target population.*
   - 4.2 Consider the cost of gathering data: the larger the sample, the more time or personnel required.
   - 4.3 Consider the cost of processing the data: unless the results are processed automatically, the smaller the sample, the less the cost in both time and effort.
   - 4.4 Consider the desired discrimination** in target population: the more homogeneous the target population, the smaller the sample may be.

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*Statistical reliability is proportional to the absolute sample size, not the fraction of the target population.

**This is related to the sampling method selected and the consideration in 4.1. Statistical reliability of quantitative attributes can be determined analytically (see Warwick and Lininger, 1975).

5. **Specify the measuring instrument and train personnel.**
   5.1 If a questionnaire is used, determine how it will be administered (see Questionnaires, QTN, page 19).
   5.2 If direct interviews are used, select and train the interviewers, taking into account cultural compatibility with the target population.

6. **Design the survey questionnaire and pretest (see Questionnaires, QTN, page 19).**
   6.1 Determine if both open-ended and close-ended questions are necessary. The former will require more training and interpretive analysis of results.
   6.2 Correct any deficiencies in design by pretesting on a small sample of the target population. If this is not desirable, then pretest on a group which matches communication characteristics of the target population, e.g., literacy level, candor, cooperativeness.

7. **Conduct the survey.**
   7.1 Arrange necessary transportation.
   7.2 Monitor interviewers by spot-checking survey results.
   7.3 Start analyzing results immediately in case adjustments to the questionnaire or the interviewing procedure are necessary.

8. **Tabulate and analyze results.**
   8.1 Prepare histograms for quantitative measures and compute descriptive statistics (see Histograms, HIS, page 131).
   8.2 Interpret and summarize open-ended responses (see Delphi, DLP, page 168).
   8.3 Analyze results to test statistical inferences.

9. **Report conclusions.**
   9.1 Include questionnaire and sampling procedure as appendices.
   9.2 In addition to presenting data and summary statistics, reflect on implications of the results.

EXAMPLES

The examples of sample surveys cross many fields and address a variety of purposes. Glock (1967) provides examples of how surveys have been used in sociology, economics, social work, and education.

The Survey Research Unit (Illo and Lynch, 1975) has been extensively involved in data gathering for the Bicol River Integrated Development Program in the Phillipines. The issues addressed range from social indicators such as "The Quality of Life" to yield data on rice production.

Mann (1974) describes a comprehensive survey conducted in Africa to identify the problems of small farmers.

THEORY

Survey research has developed into a theoretical area in its own right (Festinger and Katz, 1953, and Warwick and Lininger, 1975). Effective use of measuring instruments are described in Young (1956) and Cicourel (1964).

The underlying theory upon which sample surveys are based is the process of statistical inference and hypotheses testing. Meyers and Grossen (1974) describe basic statistical methods, and Smith (1975) gives a useful treatment of these methods in relation to sample surveys designed to gather quantitative project data. Kearl (1976) presents a collection of experiences, rules-of-thumb, and common sense in the design and execution of sample surveys.

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Organizational Climate Analysis

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

Organizational Climate Analysis determines the *organizational climate* required to achieve desired behavior from a *target group* within an organization.

USES

Climate analysis may be used to:

1) Identify *organizational attributes* (climate) which affect behavior.

2) Compare the climates of similar organizations, e.g., secondary schools within a country, or divisions within an army.

KEY DEFINITIONS

1) *Organizational climate* is the relatively enduring quality of the internal environment of an organization that (a) is experienced by its members, (b) influences their behavior, and (c) can be described in terms of the values of a particular set of characteristics (or attributes) (Tagiuri, 1968).

2) A *target group* is a number of individuals with some common roles or characteristics. Examples are students in a school and employees in a government agency.

3) *Organizational attributes* include the elements or components of an organizational system and the interrelationships among them.

4) *Measuring instruments* are techniques for eliciting and measuring responses from a subject. Examples are questionnaires (QTN, page 19) and interviews (IVW, page 23).

SHORT DESCRIPTION

A set of measurable organizational attributes which can be used as criteria for describing an organization's climate is determined. *Measuring instruments,* which engage people within the organization, are then utilized to determine the desired values of these attributes and thus the desired organizational climate. The present organizational climate is then determined through observing and objectively measuring the behavior or performance of the target group. Analysis of the climate and behavior then leads to a proposed organizational climate which can encourage desired behavior.

ADVANTAGES

Quantitative measures of organizational attributes are identified which help to determine the achievement of the desired organizational climate.

LIMITATIONS

1) If the people within an organization are unable to express their perceptions about the organizational attributes, then adequate measurements cannot be obtained.

2) The analysis requires an external consultant whose services may be expensive.

3) If the cooperation of the target group is not forthcoming, the results of the climate analysis may be invalid or unacceptable to the target group.

REQUIRED RESOURCES

LEVEL OF EFFORT

The analyst will expend considerable effort helping the decision maker to identify the desired types of behavior and the organizational attributes of the climate: to provide measures for these attributes, to construct measuring instruments (and possibly administering them), and to analyze the results obtained.

SKILL LEVEL

The analyst should have a strong background in organizational theory and its related aspects in psychology and sociology.

TIME REQUIRED

The climate analysis is a major effort which takes at least a month. The time required varies with the size of the target group, the number of organizations, and the accuracy desired.

DESCRIPTION OF TOOL

REQUIRED INPUTS

Perceptions about the organizational climate are solicited not only from the target group, but from other individuals within the organization.

Behavior may be judged by several criteria, including routine job performance, creativity, and scholastic ability. These are operationalized into measurable criteria, such as number of cars assembled per hour, number of ideas generated, and grade point average, respectively. Objective Trees (OBT, page 49) may be a useful technique for determining these criteria.

Sells (1968) identifies eight criteria to be considered in climate assessment (see figure 1).

FIGURE 1
Dimensions to Be Considered in Climate Assessment

1. Objective and Goals
   a. Remoteness of goals
   b. Formal vs. informal mode of designation
   c. Unitary vs. multiple goals
2. Philosophy and Value Systems
   a. Dominant economic values with respect to issues of property, profit, taxation, etc.
   b. Status and value accorded the individual, minorities, dependent individuals, and groups
3. Personnel Composition
   a. Intellectual potential
   b. Physical traits
   c. Position in status hierarchy
4. Organization
   a. Size
   b. Differentiation
   c. Autonomy
5. Technology
   a. Products and services involved
   b. Types and degree of technological complexity
6. Physical Environment
   a. Social isolation
   b. Types of furnishings
7. Social-Cultural Environment
   a. Language
   b. Living standards and routines
   c. Recreation
8. Temporal Characteristics
   a. Duration of individual participation
   b. Extent of daily participation

TOOL OUTPUT

The analyst will tell the organizational decision maker(s) which organizational attributes are aiding and which are hindering achievement of the desired behavior. Discussion between the analyst and the decision maker will then determine the changes to be made in the organizational climate.

METHOD OF USE

GENERAL PROCEDURE

This procedure may be followed in a climate analysis. Note that these steps are meant to provide only a general understanding.

1. Determine the basis for a climate analysis.
   1.1 Identify the target group (in consultation with the decision maker).
   1.2 Define desired behavior from the target group.
   1.3 If comparison of organizations is to be done, determine the number to be included in the study.

2. Obtain operational definitions of climate and behavior.
   2.1 Identify one or more measurable attributes for the organizational climate. The attributes may be comprehensive or they may be selectively perceived.
   2.2 Define objective criteria for measuring behavior.

3. Measure climate and behavior.
   3.1 Identify individuals in the target groups.
   3.2 Construct a measuring instrument for discovering individual perceptions (see Rating Scales, RTS, page 29, and Questionnaires, QTN, page 19).
   3.3 Administer the measuring instrument (see Interviews, IVW, page 23).
   3.4 Obtain objective measures of individual behavior by observation and from past records.

4. Analyze results.
   4.1 Analyze the responses to determine the perceptions of the organizational climate.
   4.2 Aggregate the responses for each organization to provide a measure of climate for the organization.
   4.3 Compare the measured attributes with the measures of behavior to determine which attributes significantly affect behavior (see Regression Forecasting, RGF, page 160).

5. Propose the desired organizational climate.
   5.1 Identify those attributes which seem to significantly affect the desired behavior.
   5.2 Propose an organizational climate which may achieve the desired behavior.

EXAMPLES

Shukla (1974) interviewed 25 people (faculty, students, staff) in a university department to assess the organizational climate. This climate analysis was intended to serve as a basis for: 1) changing policies in the department by the top management, 2) identifying teaching needs of the faculty, and 3) changing organizational attributes and practices. Some of the organizational attributes identified were decentralized decision making, interpersonal relationships, cohesiveness, rewards from teaching, faculty workload distribution (research, teaching, and advising), flexibility in choice of courses for students, student and faculty perceptions of independent study, departmental goals, and admission requirements.

Pace (1968) synthesized the results of several climate analyses related to the measurement of college environments. Dimensions of the college climate were scholarship (e.g., intellectual orientation of students), awareness (e.g., self-expression), practicality (e.g., vocational student culture), bureaucracy (e.g., faculty affiliation), and propriety (e.g., social conformity). These dimensions and their attributes were then related to some measure of behavior, e.g., high productivity of scholars, research work.

THEORY

The analysis of organizations encompasses a variety of disciplines including political science, social psychology, sociology, public administration, micro-economics, business and management science, and industrial engineering. The analytical bias depends largely upon the function of the organization.

Organizational Climate Analysis focuses on identifying the attributes which will enable a diagnosis of problems in the organizational environment, and assessing qualitative factors with which to measure improvement. The focus is largely on interpersonal factors and the orientation is social-psychological.

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List of Cross-References

Benefit-Cost Ratio
CBA, CFA, DIS, IPX, IRR, NPW, SVY
Brainstorming
CBA, DTR, NGT
Cash Flow Analysis
BCR, CBA, CEA, DIS, IPX, IRR, NPW, SVY
Computer Simulation Models
DTB, FLW, GAM, IMD, OVD, QTN, SVY
Contingency Analysis
CBA, CEA, DTR, IDL, MCU, PPM, SCN, SPA
Cost-Benefit Analysis
BCR, CEA, CFA, DIS, IMD, IPX, IRR, MPA, NPW, OBT, OVD, PPB, RTS, SDM, SVY
Cost-Effectiveness Analysis
BCR, CBA, CFA, CGA, CSM, DIS, DLP, IRR, OBT, RTS
Critical Path Method
CGA, GNT, SVY
Decision Tables
CSM, FLW, IRR
Decision Trees
CGA, MCU, SPA, SVY, TRD
Delphi
HIS, NGT, QTN
Discounting
BCR, CFA, IRR, NPW
Exponential Smoothing Forecasts
RGF
Flowcharts
DTB, IMD, SCN, SDM
Function Expansion
BSG, IDL, NGT, SDM
Gaming
CGA, CSM, IMD, OVD, SCN, TRD
Gantt Charts
CPM, SVY
Histograms
DLP, RTS, SPA, SVY
IDEALS Strategy
BSG, CBA, FEX, NGT, SDM
Impact-Incidence Matrix
BCR, FEX, INS, MCU, OVD, SVY
Intent Structures
BSG, DLP, FEX, IMD, NGT, OBT, TRD
Interaction Matrix Diagramming
BSG, DLP, NGT, OVD, RTS, TRD
Internal Rate of Return
BCR, CBA, CFA, DIS, DTB, IPX, NPW
Interviews
BSG, HIS, NGT, QTN, SVY
Logical Framework
IMD, OBT, OBD, SDM
Morphological Analysis
CGA, DLP, IMD, NGT, SCN, SDM, TRD
Multiple Criteria Utility Assessment
CEA, CGA, DTR, OBT, RGF, RTS
Net Present Worth
CBA, CFA, DIS, IRR
Nominal Group Technique
BSG, DLP, RTS
Objective Trees
IMD, INS, IVW, LGF, NGT, PPB, RTS, SVY, TRD
Organizational Climate Analysis
IVW, OBT, QTN, RGF, RTS
Oval Diagramming
CSM, FEX, IMD, LGF, SCN, SDM, TRD
Planning, Programming, and Budgeting
BCR, CBA, CEA, DIS, DLP, FEX, INS, LGF, MPA, OBT
Program Planning Method
NGT
Questionnaires
CBA, DLP, HIS, IVW, SVY
Rating Scales
CBA, CGA, DLP, DTR, MCU, NGT, SPA
Regression Forecasting
OVD, SVY
Scenarios
DLP, GAM, OVD
Subjective Probability Assessment
DLP, DTR, IVW, RTS
Surveys
CBA, CEA, DLP, GNT, HIS, IVW, QTN, RGF, RTS
Synectics
NGT, RTS
System Definition Matrix
BSG, CBA, CSM, FEX, GAM, IDL, LGF, NGT, SCN
Tree Diagrams
DTR, IMD, OBT, OVD

Glossary

ACTION STUB. That portion of a decision table which lists the actions or decisions to be taken if a particular combination of circumstances occurs (DTB).

ACTION-EVENT PATH. The sequence of alternative actions and relevant events represented by the branches in a decision tree (DTR).

ACTIVITY. An operation with a well-defined beginning and end and a specific purpose (CPM).

AND LOGIC ELEMENT. Links sub-objectives to objectives where all sub-objectives must be achieved in order to attain the higher level objective(s) (INS).

ANNUAL CASH FLOW. The net incremental benefits for each year of a project and the difference between the incremental benefits and costs (CFA).

ASSESSOR. A person who estimates the probability distribution of a set of events (SPA).

ATTRIBUTE. The elements or components of the system and the interrelationships among them (MPA, SCN).

AXIOLOGICAL MEASUREMENT. Involves value judgments, where the data necessary to determine accomplishment of an objective are gathered via subjective methods (OBT).

BASE SYSTEM STATE. The set of current conditions which describes the essential characteristics of the scenario (SCN).

BINARY-EVENT OBJECTIVE. An objective that either clearly occurs or does not occur (OBT).

BRANCHING RULE. A rule that governs the construction of relationships in a tree diagram (TRD).

CAUSAL CHAIN. A sequence of cause and effect relationships between variables (OVD).

CAUSAL LOOP. A causal chain which is connected so that a change in any variable eventually feeds back through the chain to affect this variable (OVD).

CENSUS. A survey of all members of a subject population (SVY).

CENTRAL TENDENCY. The most likely, or average value of the variable (HIS).

CHECKLIST. Used in design or analysis where items are marked or otherwise noted item by item (SDM).

CLASS INTERVAL. A uniform division of the variable range (HIS).

CLOSED QUESTIONS. Questions which require the respondent to limit responses to prespecified categories (QTN).

CLUSTER SAMPLE. The process of randomly selecting several clusters of subgroups from the total population and surveying all members of the selected subgroups (SVY).

CLUSTERED DATA. Used to aggregate the data into fewer points for analysis and plotting (HIS).

COMPONENTS. An entity in a system which may be elemental, or it may be a subsystem having distinct components (SDM, TRD).

CONDITION ENTRIES. The conditions of each factor (or question) listed in the condition stub (DTB).

CONDITION STUB. That portion of a decision table which lists the factors to be considered when making decisions in a given situation. Each factor is written in the form of a question (DTB).

CONTINGENCY. A particular combination of factors that describes a future environment (CGA).

CONTINUOUS MODEL. A model which treats variables that change continuously over time (CSM).

CONTINUOUS VARIABLE. Takes on an infinite number of values over some range of possible values (HIS).

CONTROL DIMENSION. Evaluates and regulates any element's specification. This dimension measures each element as the system operates, compares the measure to what is designed or desired, and takes action if the difference is greater than desired (SDM).

CORRELATION. An observed relationship between two or more variables in which the changes in one variable may be associated with predictable changes in another; the relationship, however, is not necessarily cause-effect (OVD).

CORRELATIVE BEHAVIOR. An assumed relationship between two or more variables in which the changes in one variable may be associated with predictable changes in the others (RGF).

CRITICAL ACTIVITY. An activity which, if not completed on time, will delay the entire project (CPM).

CRITICAL PATH. The sequence of critical activities from project start to project finish that determine the shortest project duration (CPM).

CROSS-INTERACTION MATRIX. A representation of relationships between dissimilar sets of variables (IMD).

DECISION RULES. The action entries of a decision table which link a particular combination of condition entries to specified actions (DTB).

DECISION SYMBOL. Represents a step in a process where there is a choice among two or more alternative actions (FLW).

DEPENDENT VARIABLE. The variable being forecast (RGF).

DESCRIPTIVE MODEL. A representation or imaginary entity containing information in a predefined form, intended to be interpreted by its user rules (SDM).

DETERMINISTIC MEASUREMENT. Where the realization of the objective is unequivocally determined from numerical data (OBT).

DIMENSION. Collections of attributes of the system, where each collection represents a major aspect of the system (SCN).

DIRECT ANALOGY. Compares the problem being faced to a parallel situation in another field, technology, or discipline (SCN).

DIRECT ANALOGY METHOD. Used in Synectics sessions when members compare the problem being faced to a parallel situation in another field, technology, or discipline (SYN).

DIRECT EFFECT. An interaction between two variables so that a change in one results in a similar change in the other (OVD).

DIRECT MARKET VALUES. Measures of project costs or benefits which are assessed from equivalent market prices (IPX).

DIRECTED LINE. Links two symbols together with an arrowhead indicating the sequence (FLW).

DIRECTED RELATIONSHIP. Specifies that the existence of the relationship is dependent on the order in which the two elements are considered (IMD).

DISCOUNT FACTOR. A fraction between 0 and 1 which gives the present worth of one monetary unit spent or received (DIS).

DISCOUNT RATE. A percentage rate (usually annual) which equates the present and the future worth of a payment (DIS).

DISCOUNTED CASH FLOW. A single value which represents the present worth of the net incremental benefits estimated for each project year (NPW).

DISCRETE STOCHASTIC MODEL. A model which describes the changes in variables at definite points in time (CSM).

DISCRETE VARIABLE. A variable with only a finite number of values which are multiples of a basic unit (HIS).

DRIVING FORCE. An attribute of a system which causes changes in the system state over time (SCN).

DUNNING. The process for recontacting participants who have failed to return their questionnaires (DLP).

DURATION. The estimated time needed to perform the activity (CPM).

DYNAMIC BEHAVIOR. A consequence of delayed interactions among system variables. The dynamic state of a system depends on the prior values of state variables (OBT, RTS).

EARLIEST FINISH (EF). The sum of an activity's earliest start time and its duration (CPM).

EARLIEST START (ES). The earliest time (measured from the start of the project) when an activity may begin, assuming all immediate predecessors are completed (CPM).

ECONOMIC ANALYSIS. Analysis from the viewpoint of the national government and the economy (CFA).

EFFECTIVENESS. The degree to which the project or system design objectives are achieved (CEA).

ELEMENT. Part of a problem situation which can be described by all its elements (MPA).

ELSE RULE. A column in a decision table which applies when no other decision rules may be added to cover the case or where no combination of conditions applies (DTB).

ENVIRONMENT. The set of all factors which are salient to the understanding of systems relationships, but which are outside the influence of the system variables (OBT, SDM).

EVENT. A future outcome, the occurrence of which is uncertain (SPA).

EXTERNAL CONTEXT. Represents the constraints on the base system (SCN).

FANTASY ANALOGY. The participant's wishful thinking that the problem may solve itself or cease to exist (SYN).

FEEDBACK STRUCTURE. The set of relationships describing a system that involves one or more interlocking causal loops (OVD).

FINANCIAL ANALYSIS. Analysis from the viewpoint of the individual, group, or business which will directly gain or lose because of the project (CFA).

FREQUENCY DISTRIBUTION. Plots the frequency of different categories of response (QTN).

FUNCTION. The primary concern of the system. It is the fundamental dimension of purpose (FEX, IDL, SDM).

FUNCTION HIERARCHY. An ordering of system functions from the most specific to the broadest (FEX).

FUNDAMENTAL DIMENSION. The basic characteristic of the eight system elements (SDM).

GOAL. A value judgment which satisfies one or more needs (FEX, LGF, SCN).

GOVERNING RULES. Describe the relationships between decisions made by the participants in a game and the resulting changes in the simulated environment (GAM).

HIERARCHY. An ordered structure illustrating which factors are subordinate to others (TRD).

HUMAN AGENTS. The personnel who may be necessary for the system to achieve its function, yet are not themselves inputs or outputs of the system (SDM).

IDEAL SYSTEM. A system that achieves the function in the best possible manner as judged by the criteria for evaluating the system. Such systems typically require the least possible cost, the least amount of human resources, and the least time while providing maximum benefits (IDL).

IMMEDIATE PREDECESSOR. Any activity which immediately precedes an activity and which must be completed before the activity can start (CPM).

IMMEDIATE SUCCESSOR. Any activity which immediately follows an activity and which may not start until completion of the activity (CPM).

IMPORTANT ASSUMPTIONS. The factors which affect the success of a project and which are beyond the influence of the decision maker (LGF).

INCREMENTAL COSTS AND BENEFITS. Computed by subtracting the "without project" values from the "with project" values (CFA).

INDEPENDENT VARIABLE. The non-random variable which is used for forecasting other variables using regression (RGF).

INFLUENCE RELATIONSHIP. When one variable's change in value influences change in another variable (TRD).

INFLUENCE TREE. A tree that diagrams the variables which influence other variables which are higher in the tree (TRD).

INFORMATION CATALYSTS. The communication (written or verbal) and the knowledge which enable the system process to occur, yet which are not inputs or outputs of the system (SDM).

INPUTS. The people, information, and/or physical items which enter the system to be transformed by a sequence into outputs of the system (LGF, SDM).

INTERACTING GROUP. A process that permits discussion among participants (NGT).

INTERFACE DIMENSION. The relation to other systems or elements—a linking entry to related system definition matrices (SDM).

INTERMEDIATE IMAGE. An intermediate image describes the state of the system after a time interval *n* (SCN).

INTERNAL ECONOMIC RETURN. The rate of return derived from an economic analysis of the benefits and costs to the society or economy of the country (IRR).

INTERNAL FINANCIAL RETURN. The rate of return derived from a financial analysis of the project cash flow (IRR).

INTERVAL SCALES. Scales that reflect not only the rank of one factor over another, but the degree to which one exceeds the other. The difference between them corresponds to a length of scale interval (RTS).

INTERVIEW SCHEDULE. The plan for conducting an interview. It includes the questions to be asked (IVW).

INVERTED EFFECT. An interaction between two variables so that a change in one results in an opposite change in the other (OVD).

IRREVERSIBLE VARIABLE INTERACTION. When the variable only increases or only decreases (OVD).

LATEST FINISH (LF). The latest time (measured from the start of the project) when an activity may be completed without delaying any immediate successor(s), thereby delaying completion of the project (CPM).

LATEST START (LS). An activity's latest finish time minus its duration (CPM).

LIMITED ENTRY. A type of decision table which permits only a limited set of condition and action entries in the decision rule columns (DTB).

LINEARLY LINKED MATRICES. Matrices with a common set of rows or columns (IMD).

LOGIC ELEMENT. A symbol indicating the nature of the relationship between two or more objectives at adjacent levels in a hierarchy (INS).

LOGICAL INCONSISTENCIES. When hypothesized relationships among variables are inconsistent (OVD).

LOGICAL MEASUREMENT. Determines whether a binary-event objective has or has not occurred (OBT).

MATRIX. A mathematical and graphical representation in two dimensions (IMD).

MATRIX ENTRY. The symbol used to indicate the existence or absence of a relationship between the element in the row and the element in the column (which together define the entry) (IMD).

MEAN. The average value or central tendency of the data (HIS).

MEANS OF VERIFICATION. The specific mechanisms by which quantitative indications of the accomplishment of a project may be observed (LGF).

MEANS-ENDS ANALYSIS. The identification of alternative actions to achieve specified ends (OBT, TRD).

MEASURING INSTRUMENT. A technique for eliciting and measuring responses from a subject (OCA, SVY).

MEDIAN. The value corresponding to the midpoint of the data points (HIS).

MILESTONE. A point in time (specific date) which marks the completion of a sequence of activities or the beginning date for subsequent activities (CPM).

MIXED ENTRY. A type of decision table which permits extended entries such as a range of values for a question in the condition stub (DTB).

MODE. The value or class interval which occurs most frequently (HIS).

MODEL. A representation of an imaginary entity that contains information in a certain predefined form and has specified rules for interpretation (TRD).

MULTIPLIER EFFECT. Occurs when a project impact on one aspect of an economic system generates a stimulating effect on other aspects (IPX).

MULTI-STAGE SAMPLING. Draws random samples in stages (SVY).

MUTUALLY-CAUSAL VARIABLES. Variables that occur when a change in one variable causes a change in another which is fed back to affect the first (OVD).

MUTUALLY-EXCLUSIVE PROJECTS. Incompatible alternatives where implementing one precludes implementing the others (NPW).

NOMINAL GROUP. A group process in which the members work independently but in each other's presence (NGT).

NOMINAL SCALES. Scales that categorize different factors (RTS).

OBJECTIVE. A specific statement of purpose expressing a desired end (INS, OBT).

OBJECTIVELY VERIFIABLE INDICATORS. Indicators that demonstrate that certain desired results are being accomplished (LGF).

OPEN QUESTIONS. Questions which permit the respondent to answer as he or she chooses (QTN).

OPPORTUNITY COST. The cost of committing resources to a particular use as measured by the highest return that could have been obtained by committing the same resources to an alternative use (DIS).

OR LOGIC ELEMENT. Links objectives where the attainment of any one or a combination of sub-objectives will achieve the higher level objective (INS).

ORDINAL SCALES. Scales used to rank-order a set of similar objects along a criterion dimension which reflects a basis for comparison, but not the degree of difference (RTS).

ORGANIZATIONAL ATTRIBUTES. The elements or components of an organizational system and the interrelationships among them (OCA).

ORGANIZATIONAL CLIMATE. The relatively enduring quality of the internal environment of an organization that (a) is experienced by its members, (b) influences their behavior, and (c) can be described in terms of the values of a particular set of characteristics (OCA).

ORTHOGONALLY LINKED MATRICES. Matrices with the same set of elements in the rows of one matrix and the columns of the other matrix (IMD).

OUTPUT. The desired and the undesired results of the transformation process of a system (FEX, LGF, SDM).

OWNER. An organization or person who possesses intent for, or has a vested interest in, a project (INS).

PARAMETER. A quantity with only one value over the entire range of the system behavior being simulated (CSM).

PARTICIPANT OBSERVATION. The gathering of information about and impressions of a selected group by direct interaction over an extended period of time (SVY).

PAYOFF VALUES. Represent the gain resulting from the occurrence of a particular action-event path (DTR).

PERIOD. The time interval between successive observations of the underlying process (EXF).

PERSONAL ANALOGY METHOD. Used in Synectics sessions where a group member identifies with an element of the problem and looks at it as though he were that element (SYN).

PHYSICAL CATALYSTS. The equipment, facilities, etc. which are necessary for the inputs to be transformed into outputs, but which are not themselves inputs or outputs of the system (SDM).

POLICY. Long-range decisions which influence a large number of diversified groups with different values. Policy made at one level of an institution forms the guiding criteria for shorter-range decisions at a lower level (INS).

PREDECESSOR ACTIVITY. An activity that must be completed before another activity can start (CPM).

PRESENT WORTH. The value today of a future payment (DIS).

PROBABILISTIC MEASUREMENT. Occurs when the attainment of the objective may not be determined with certainty (OBT).

PROBABILITY DENSITY FUNCTION. Represents the probability distribution of a set of continuous events (SPA).

PROBABILITY DISTRIBUTION. Associates each event in the set with its probability of occurrence (SPA).

PROBLEM ENVIRONMENT. The set of variables and relationships which are germaine to the decision process under study (GAM).

PROCESS SYMBOL. Represents an action which takes place over time (FLW).

PRODUCER-PRODUCT RELATIONSHIP. When one variable is a product of the other (TRD).

PROGRAM CATEGORY. A system category under which specific projects, or program subcategories, are developed (PPB).

PROGRAM ELEMENTS. The resources or inputs needed to carry on a project (PPB).

PROGRAM SUB-CATEGORY. Refers to the specific projects considered under a program category (PPB).

PROJECT EFFICIENCY. The ratio of project outputs to inputs (BCR, CEA).

PURPOSE. A project's primary intention or aim (LGF).

QUALITATIVE OBJECTIVE. Objectives that are judged subjectively to determine if they have been accomplished (OBT).

QUANTITATIVE OBJECTIVE. An objective that represents a quantifiably verifiable end or result (OBT).

RANK-ORDERING. The process of weighing one item against others and then ordering the items by weight on a scale such as importance or priority (BCR, NGT, NPW, PPM).

RATE DIMENSION. The performance measure for a system element (SDM).

RATIO METHOD. Estimates probabilities for a set of events by first obtaining the relative chance of pairs of events for all possible pairs (SPA).

RATIO SCALE. An interval scale for which the dimension of comparison has a natural zero point (RTS).

REDUCED MATRIX. A matrix formed by omitting one or more rows or columns from the original matrix (IMD).

REFLEXIVE RELATIONSHIP. Occurs when the variable interacts with itself (IMD).

REGRESSED VARIABLE. A variable is regressed on another when the former is dependent on the latter (RGF).

REGRESSION COEFFICIENT. The coefficient of the independent variable in a regression equation (RGF).

REGULARITY. The most frequent or dominant (and occasionally the most important) condition of concern to the project design (IDL, FEX).

RELATIVE CHANCE. Reflects whether one event will occur rather than another (SPA).

RELEVANCE TREE. A tree that diagrams the relationships among different sets of factors at each level of a hierarchy (TRD).

ROUND-ROBIN. A process for serially recording ideas where each participant provides an idea in turn. No discussion occurs, although the leader may ask for a show of hands on how many participants had a similar idea. Those responding then eliminate that idea from their respective lists. The process may continue in a circular fashion until all participants' lists are exhausted (NGT).

SAMPLE. A subset selected from a subject population, the attributes of which are assumed to hold true for the total population (SVY).

SAMPLE STATISTIC. A quantitative parameter which characterizes some aspect of the population from which a set of data are drawn (HIS).

SCORING. Used in games as feedback to the participants to reflect the effectiveness of their decisions (GAM).

SECTOR. The larger system of which a project is part (LGF).

SELF-INTERACTION MATRIX. A representation of relationships within a single set of variables (IMD).

SEQUENCE. The process by which the inputs are worked on, transformed, or processed into outputs, usually with the aid of catalysts (SDM).

SET. A collection of elements having some common property (IMD).

SET OF CONTINUOUS EVENTS. Consists of an infinite number of events (SPA).

SET OF DISCRETE EVENTS. Consists of a finite number of mutually-exclusive events (SPA).

SHADOW PRICES. Adjusted market prices which reflect the true benefit or cost to the economy (CFA).

SIMPLE RANDOM SAMPLE. A sample made so that every member of the target population has an equal probability of selection (SVY).

SLACK. The amount of leeway allowed in either starting or completing an activity (CPM).

SMOOTHED VALUE. An estimate of the average value of the variable being forecast (EXF).

SMOOTHING CONSTANT. A fraction between 0 and 1 that indicates the degree of confidence placed on the most recent datum (EXF).

SOLUTION COMPONENT. The part of a program that is proposed as the solution (PPM).

STANDARD DEVIATION. The measure of the dispersion of the data values about the mean (HIS).

STATE DIMENSION. A specification of anticipated changes and plans in specific time horizons for each of the four dimensions (SDM).

STATE SCENARIO. Describes conditions and events (the state of the system and the external context) at a single future point in time (SCN).

STATE SYMBOL. Represents a tangible product, requirement, or specific condition associated with a process sequence (FLW).

STOPPING RULE. A rule that determines when any branch of the tree diagram should end (TRD).

STRATEFIED SAMPLE. A sample that selects a proportional sample at random from each of the groups in a stratification of the total population (SVY).

SUBJECT POPULATION. The set of all events or entities which possesses certain specified characteristics (SVY).

SUBJECTIVE PROBABILITY. A quantified judgment of the chance of an event occurring (SPA).

SYMBOLIC ANALOGY METHOD. Describes the problem by objective and impersonal titles. These titles are used to identify other problems which may be described by the same title. They are generally expressed in two words, usually describing two conflicting attributes of the problem (SYN).

SYMMETRICAL RELATIONSHIP. Occurs when the relationship between two elements is non-directed (IMD).

SYSTEM. A collection of components which interact to achieve a common function (CEA, CSM, FEX, IDL, SCN, SDM, TRD).

TARGET GROUP. A set of persons with certain common characteristics (DLP, OCA).

THRESHOLD EFFECT. When one variable does not change until the other variable changes significantly (OVD).

TIME PREFERENCE. The general preference of individuals for present over future receipts and for future over present expenditures (DIS).

TOTAL CASH FLOW. The sum of all annual cash flows for the life of the project; an undiscounted measure of the aggregate change expected from implementing a project (CFA).

TRANSIENT SCENARIO. Forecasts changes in and the alternative actions on a system at various stages in the evolution of the system (SCN).

TRANSITIVE RELATIONSHIP. Requires that a directed relationship among three or more elements be consistent (IMD).

TREE GRAPH. A set of linked elements where only one exists between any two factors (OBT, TRD).

TUNING. The process of making changes in the parameters and initial values for variables in order to minimize the errors between expected and actual simulation output or between observed or simulated data (CSM).

UTILITY. A quantitative expression of the worth or satisfaction associated with an outcome (DTR, MCU).

UTILITY FUNCTION. Associates the possible levels a criterion may take with the utilities for those levels (MCU).

UTILITY MATRIX. Presents the elements of a decision under certainty (MCU).

VALIDATION. Testing whether a computer simulation program simulates the observed system behavior. It is a process of simulating the past and checking the simulated data against actual data (CSM).

VARIABLE. A factor used to describe a system which may change value as a function of time (CSM, OVD).

VERIFICATION. Testing a computer simulation program to see that the program functions as intended. It is a process of eliminating logical errors in the program (CSM).

XOR LOGIC ELEMENT. Links mutually exclusive sub-objectives to the higher level objective(s). The achievement of one sub-objective alone achieves the higher level objective (INS).

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