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Chapter 5 focuses on four project planning techniques for the dynamic analysis of complex relationships and processes in systems over a period of time. One such technique uses the electronic computer (Computer Simulation Models) to simulate system processes in order to analyze complex interactions and to forecast future behavior of the system. Two methods enable the planner to diagram sequences of decisions or processes performed in a system (Flowcharts and Decision Tables). A Flowchart consists of various symbols used to show the sequence or flow of processes or decision situations as a connected sequence of decisions and actions. It breaks down a complex procedure into its identifiable and connected processes. Decision Tables document the decision making process by describing actions to be followed under different conditions. A Decision Table is a tabular presentation of a decision process where a number of factors affect the choice of action. Gaming consists of a controlled situation where persons or teams compete against each other or against a simulated problem environment to attain predetermined objectives. This technique provides decision makers with experience in a simulated problem environment in order to analyze complex processes.

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V
Analyzing Complex Processes

Flowcharts
Decision Tables
Computer Simulation Models
Gaming

Project planning demands analysis of the complex processes of development. Static descriptions are useful for characterizing complex relationships, but dynamic analysis takes the description into the time dimension. A powerful technique for dynamic analysis utilizes the versatility of electronic computers (Computer Simulation Models) to examine the processes which bring about changes in systems. The computer is not an absolute requirement, as other means of simulation can be used to explore complex processes. Two analysis techniques (Flowcharts and Decision Tables) focus directly on the sequences of decision and action which characterize systems performance.

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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 t chniques 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

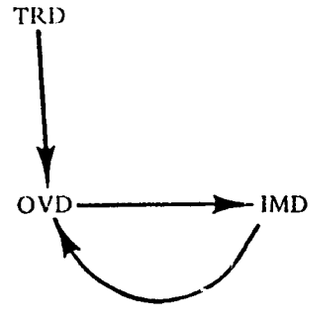
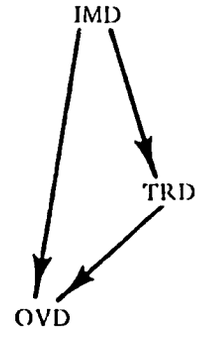
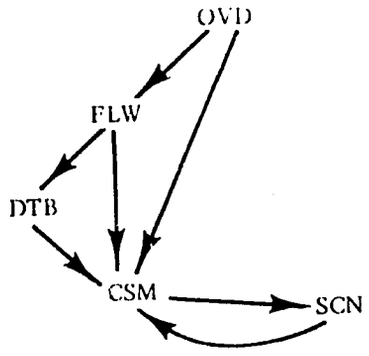


FIGURE 1b



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



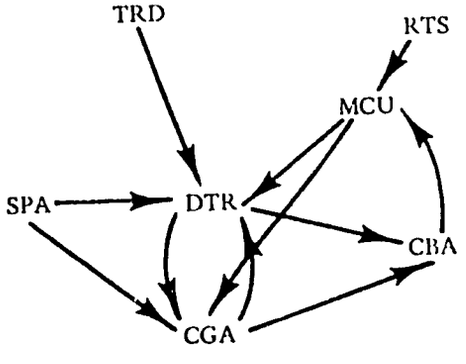
GENERATING AND ANALYZING ALTERNATIVE PLANS OF ACTION

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

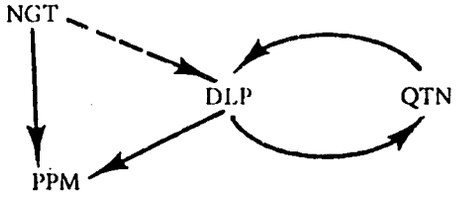
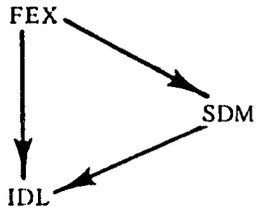


FIGURE 5



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.

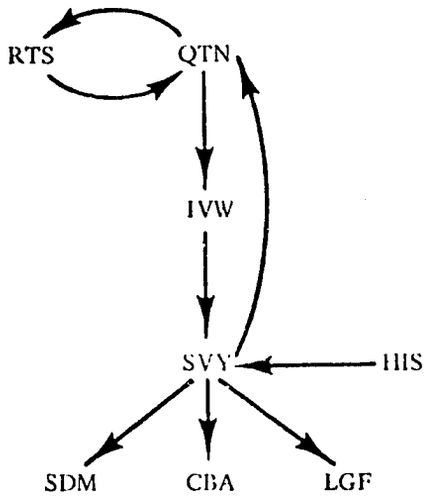
Focusing on function rather than on problems gets people involved in a constructive assessment of what should be, rather than what's wrong and who's to blame. There are sound arguments for both approaches. The IDEALS Strategy often comes under attack because its emphasis on normative specification may 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

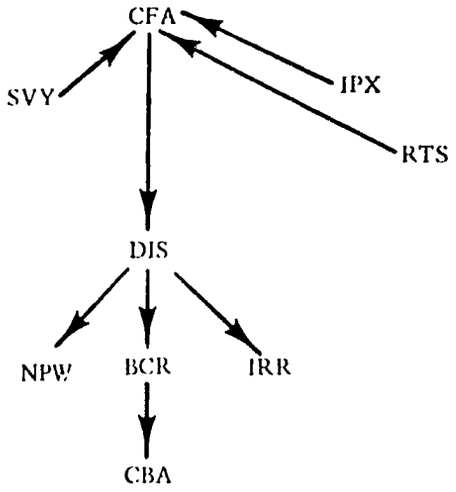
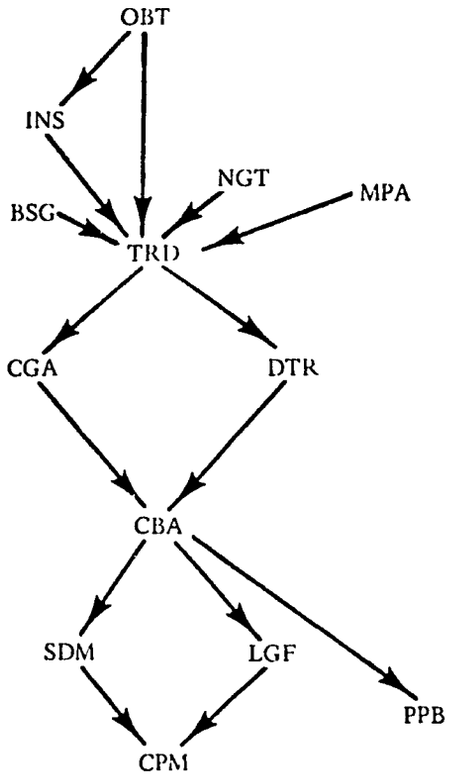


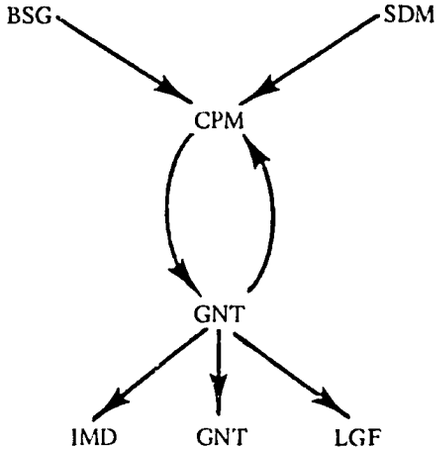
FIGURE 8



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

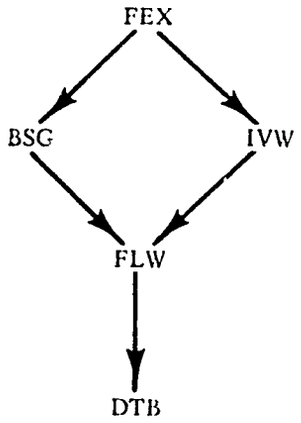
Framework may also be used to sharpen the identification of objectively identifiable indicators of progress. These milestones are shown as vertical lines on specific dates of the Gantt Chart and written on the Critical Path Method network at the appropriate nodes.

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

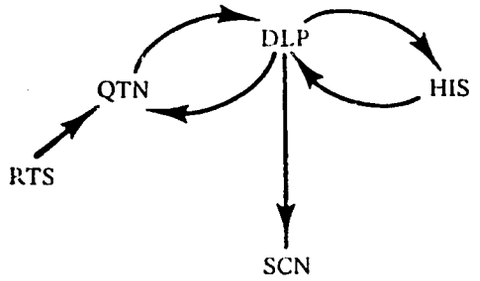


The results of this analysis are presented in the form of flowcharts (FLW, page 107) or decision tables (DTB, page 113). The flowchart uses different symbols to display and analyze complex processes. The decision table presents the decision as a preprogrammed process by specifying the conditions which 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

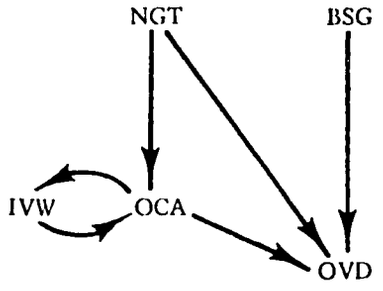


The Delphi technique (DLP, page 168) begins by directing questionnaires to a selected group of prognosticators. The results of each round are summarized for the Delphi group, often in the form of a histogram which aggregates the individual judgments. Rating scales attempt to quantify priorities and opinions. 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 developing 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.

Flowcharts

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

A flowchart represents complex processes as a connected sequence of decisions and alternative actions.

USES

A flowchart is used to:

1) Present the analysis of a complex decision situation or procedure which can be broken down into identifiable processes.

2) Depict a complex sequential process such as the steps in planning and implementing a project.

3) Indicate how a repetitive activity is to be carried out, e.g., the routine tasks in controlling project disbursements.

4) Design, analyze, and debug computer programs.

KEY DEFINITIONS

1) A *process symbol* represents an action which takes place over time (see figure 1).

2) A *decision symbol* represents a step in a process where there is a choice among two or more alternative actions (see figure 1).

3) A *state symbol* represents a tangible product, requirement, or specific condition associated with a process sequence (see figure 1).

4) A *directed line* links two symbols together with an arrowhead indicating the sequence (see figure 1).

SHORT DESCRIPTION

A flowchart consists of process, state, and decision symbols which are combined to show the sequence or flow of a complex process. The process may be the steps necessary to achieve a task, a series of decisions where choices are dependent on earlier choices, or the routing of information and materials in a system (see System Definition Matrix, SDM, page 67).

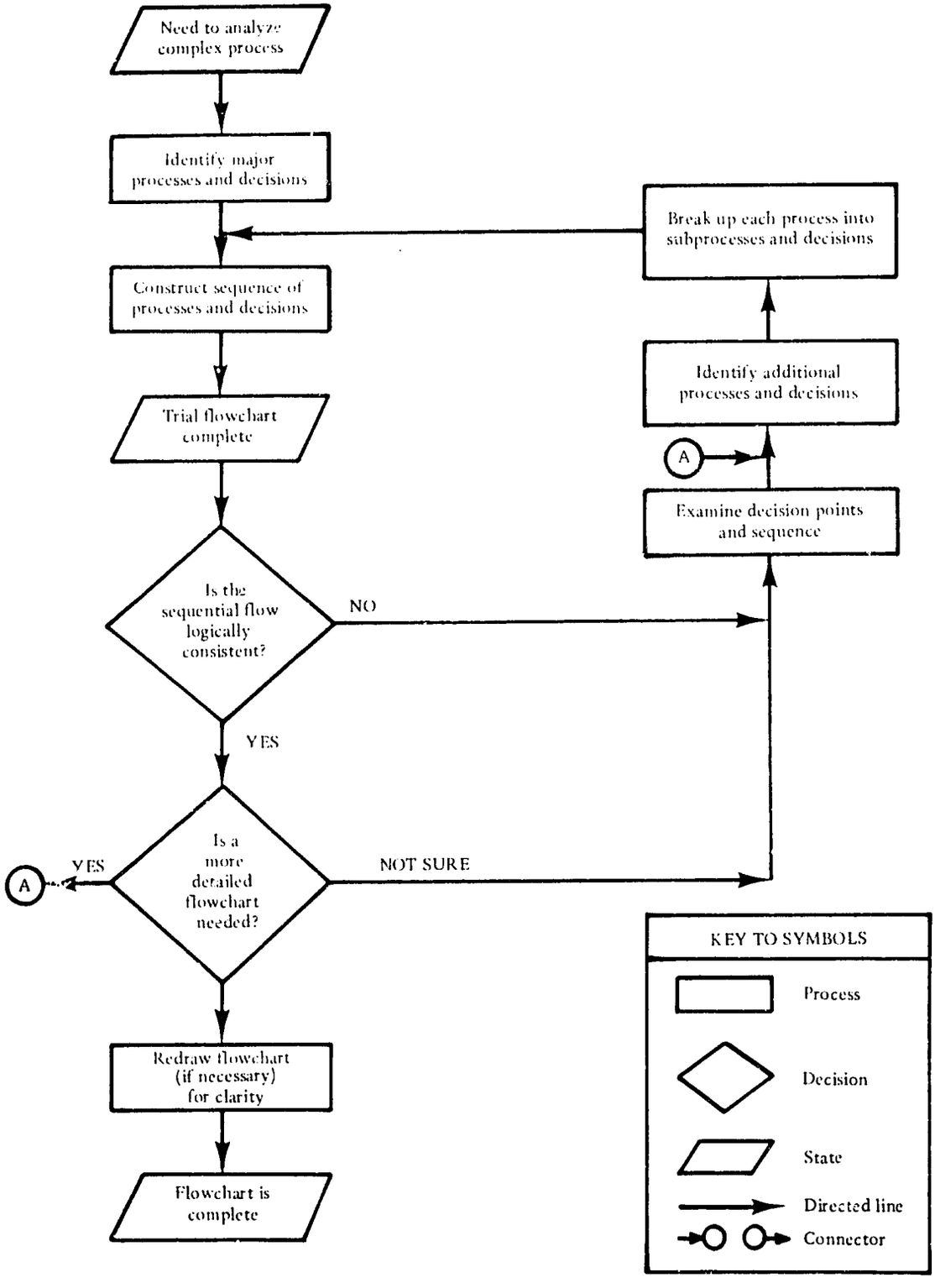
The symbols are linked by directed lines to indicate the order of occurrence (see figure 1). If a decision has an alternative which requires the repetition of a process or decision, then the flowchart depicts the feedback loop.

ADVANTAGES

1) Flowcharts are relatively simple to use and have wide applicability.

2) The graphic description of a complex process makes it easier to communicate with others.

FIGURE 1
A Flowchart for the Task of Constructing a Flowchart



3) Alternative courses of action are related to successive steps by their location on the flowchart.

4) The position of an activity in the overall task is clearer than in prose descriptions.

5) Logical inconsistencies in decision sequences can be identified, e.g., a portion of a computer program that cannot be executed because no action sequence leads to it.

LIMITATIONS

1) Constructing a flowchart may be somewhat more difficult than a simple prose account or the construction of a decision table (DTB, page 113). It is easier to overlook processes and decisions.

2) Modifying to include new processes or decision choices may require redrawing the flowchart.

3) A flowchart is less effective as an analysis tool where a large number of options are associated with a decision.

REQUIRED RESOURCES

LEVEL OF EFFORT

Effort is expended in identifying possible decisions, determining the processes required to carry out the activity, and constructing a flowchart which links these decisions and processes.

SKILL LEVEL

Flowcharting requires the ability to anticipate the scope of the project and to break down the project into a sequence of activities. Flowcharting becomes easier with practice.

TIME REQUIRED

The time required depends on the number of activities and the complexity of the sequence. A flowchart describing a sequence of 100 steps may take approximately a day to construct and refine for clarity.

DESCRIPTION OF TOOL

REQUIRED INPUTS

Flowcharts are combinations of symbols:

The *process symbol* describes an action or step in the overall process. The level of detail necessary to describe a process depends on how the chart is to be used (greater detail could lead to cluttering the diagram). Consequently, flowcharting requires identification of distinct actions within the complex process or system.

The *decision symbol* is another building block for flowcharts. It always contains a question like:

1) Did a particular event occur?
2) Has a specified criterion been met?
3) Is a prior process complete?

Question 1 is answered by a simple binary choice – yes or no. These answers are associated with the arrows emitting from the decision symbol and leading to subsequent symbols in the chart.

Question 2 may be answered by yes or no, or the specific criteria may be shown as branches emitting from the flowchart decision symbol (see figure 2).

Question 3 is a specific case of question 1 (the event is the completion of the prior step) and illustrates a common occurrence in the flowchart. The branch labeled NO will likely loop back to the prior symbol if the process cannot continue until that step is completed (see figure 2).

The *state symbol* is an optional, though useful, component of flowcharts. It is used to identify the resources needed (inputs) or the result of a process (outputs). The state symbol can also indicate the state of the activity at a specified point in time, e.g., the conditions necessary before disbursement of loan payments to a host country.

A pair of connector symbols, often used in flowcharts to promote clarity, permits breaking the line linking two symbols to avoid crossing lines or to connect portions of a flowchart on separate pages (see figure 1). The same letter or number should be used in each circle.

Any number of other symbols can be used in flowcharting as long as a suitable explanation of the significance of the shape is given. Otherwise, the different symbols may fail to communicate a complex decision process.

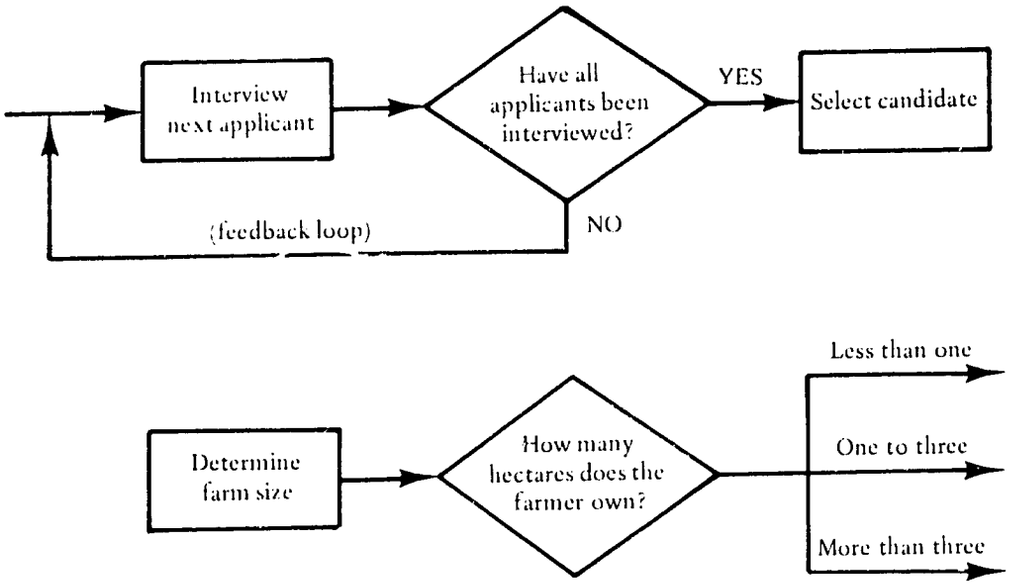
The Delta chart (described by Warfield and Hill, 1971) is a flowchart designed specifically as a planning and control tool. It provides more symbols (e.g., logic elements) and incorporates a larger amount of data (e.g., the person or organization responsible for a process and the time involved in carrying out a process).

TOOL OUTPUT

The flowchart is a planning tool that indicates how an activity can be carried out in the future. The planner may find the flowchart useful as a control tool if he identifies who is responsible for what process and if he specifies the timing of the processes.

The flowchart provides a description not only for design and analysis purposes, but for repeated use in the operational phases of a project. The operator follows the

FIGURE 2
Examples of Decision Points for Flowcharting



sequence of processes described and branches at each decision point according to the current conditions affecting the decision. In this regard, the decision table may be more useful than a flowchart (see DTB, page 113).

IMPORTANT ASSUMPTIONS

Flowcharts belong to a set of techniques which, even though allowing for various contingencies, assume that a fundamental determinacy underlies the diagrammed process. There is an underlying logic or basic rationality which must hold for the process. Otherwise the combination of decisions, actions, and states is meaningless.

This feature of flowcharts suggests their use in testing the logic and coherence of a prose description of a complex process. If the charted sequence does not "flow" logically, then perhaps the process being described is incoherent or inconsistent.

METHOD OF USE

GENERAL PROCEDURE

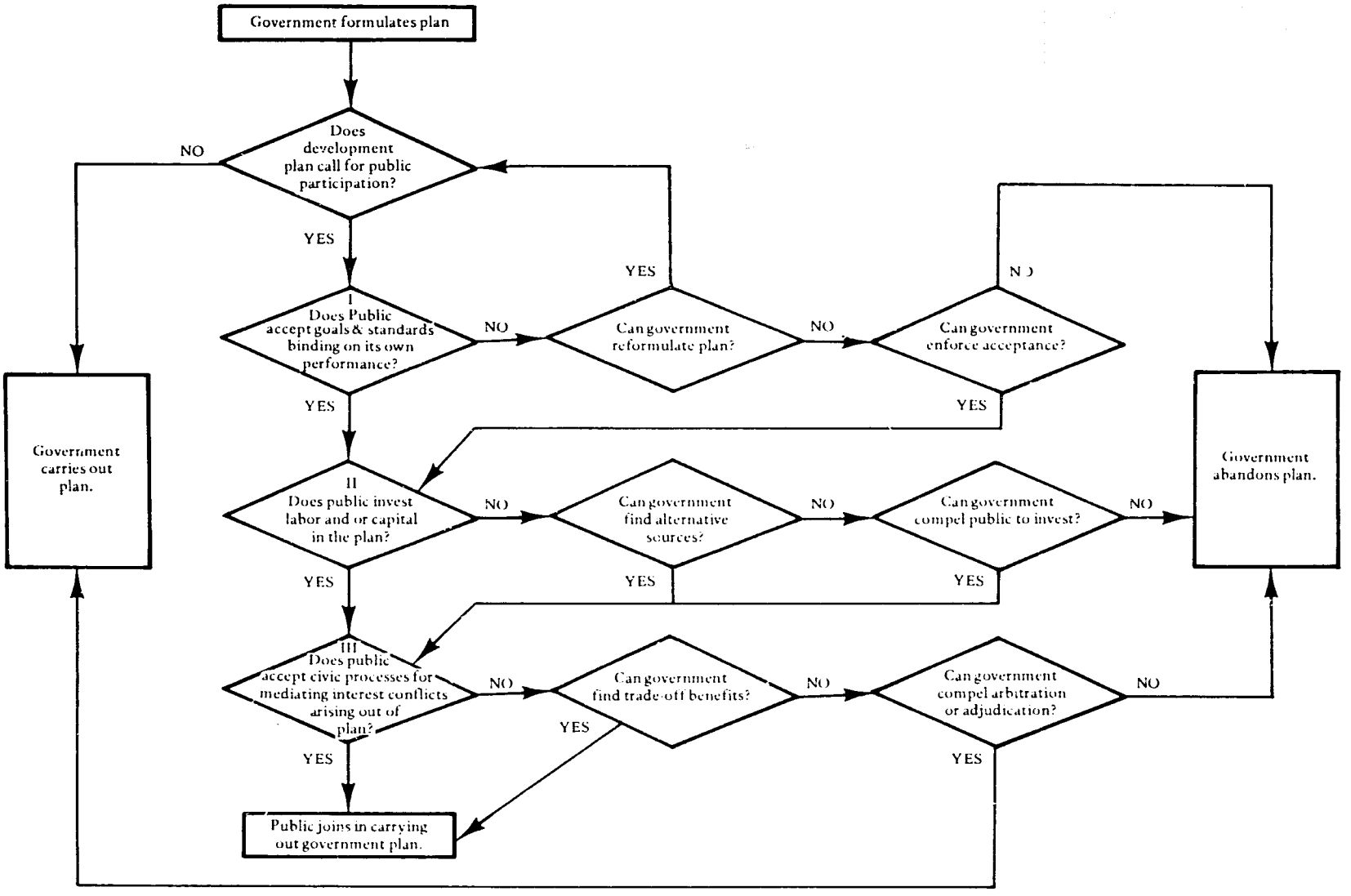
Constructing a flowchart is primarily a heuristic task: only general guidelines can be given. Be careful not to get bogged down in details; rather, start with a high level of abstraction to capture the basic processes and major decision points. The first chart should give a broad representation of the overall process. More detail may be added in successive versions.

The following steps are useful guidelines for describing a complex process which follows a more or less logical sequence from start to finish.

1. Identify major processes and decisions.
2. Single out those processes (and decisions) which represent the basic activity accomplished.
3. Order these in a sequence of successive symbols and sketch the basic flow by showing only the connections which represent the most likely choice at each decision point.
4. Identify the conditions which must be met before each decision can be made and connect them by arrows entering the flow before the decision point.
5. Identify the alternatives at each decision point and show these as labeled branches emitting from the decision symbol.
6. Rather than show a symbol for a process which must be repeated, loop back to the symbol representing the first occurrence of that process.
7. Examine the chart for consistency.
8. If further detail is desired, break the processes into subprocesses and insert additional decision points as required.

If the complex process is primarily a series of decisions, then the ordering in step 3 should reflect the logic of the questions asked, e.g., from general to specific, or in a selection process, those decisions which lead to an early acceptance or rejection, e.g., minimum qualifications which must be met for job applicants.

FIGURE 3
Behavioral Model of Development Administration



NOTE: Reprinted from *Technology and Civic Life* by John D. Montgomery by permission of the MIT Press, Cambridge, Massachusetts. Copyright (c) 1974 by the MIT Press.

EXAMPLE

The degree to which the public reacts to a plan which calls for public participation significantly affects the planning process and the ultimate course of action. Montgomery (1974) poses a series of questions which lead to three actions: 1) the government carries out the plan without public participation except as compelled by arbitration or adjudication; 2) the public participates in carrying out the plan; or 3) the plan is abandoned. Figure 3 presents a flowchart of the questions for determining which alternative is likely to occur.

Other examples may be found in the descriptions of Interaction Matrix Diagrams (IMD, page 92) and Scenarios (SCN, page 164).

THEORY

Flowcharts belong to a set of approaches for pictorially describing complex processes. Nadler (1970) describes many of these variations, all of which depend on the analyst's ability to abstract complex decisions and operations. This is a particularly useful skill for computer programmers where the logical flow of calculations and data manipulation may be traced.

The same idea may be used to describe any system or deterministic task. Signal flow graphs and networks are flowcharts with different symbols for representing the elements (Whitehouse, 1973). Basic laws have been developed for simplifying these representations, though their application to flowcharts is more difficult.

Decision tables have a one-to-one correspondence to flowcharts (see DTB, page 113). This format for analyzing a complex process lends itself to certain principles of simplification (see Lewis, 1970).

BIBLIOGRAPHY

Lewis, Brian N. *Decision Logic Tables for Algorithms and Logical Trees.* London: Her Majesty's Stationery Office, 1970.

Montgomery, John D. *Technology and Civic Life: Making and Implementing Development Decisions.* Cambridge, Mass.: MIT Press, 1974.

Nadler, Gerald. *Work Design: A Systems Concept.* Homewood, Ill.: Richard D. Irwin, 1970, pp. 258-62.

Warfield, John N., and Hill, J. D. "The Delta Chart: A Method for R & D Project Portrayal." *IEEE Transactions on Engineering Management* EM-18, 4 (November 1971): 132-38.

Whitehouse, Gary. *Systems Analysis and Design Using Network Techniques.* Englewood Cliffs, N.J.: Prentice-Hall, 1973.

Decision Tables

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

A decision table documents a decision-making process by describing *actions* to be followed under different *conditions* in a given environment.

USES

Decision tables are used to:

1) Analyze complex decision situations.

2) Provide a documented procedure for handling decisions which may re-occur under different conditions.

3) Record and communicate procedural rules and regulations within organizations.

4) Provide the basis for writing computer programs for use in tools such as Computer Simulation Models (CSM, page 120).

KEY DEFINITIONS

1) The *condition stub* is 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, e.g., "Are loan funds available?"

2) The *condition entries* are the conditions of each factor (or question) listed in the condition stub, e.g., "YES–loan funds are available."

3) The *action stub* is that portion of a decision table which lists the actions or decisions to be taken if a particular combination of circumstances occurs, e.g., "submit fund transfer request."

4) The *decision rules* are the action entries of a decision table which link a particular combination of condition entries to specified actions.

SHORT DESCRIPTION

A decision table is a tabular representation of a complex decision process where a number of factors affect the choice of action(s). The table has four parts: the *condition stub*, the *condition entries* or contingencies, the *action stub*, and the action entries or *decision rules* (see figure 1). The table is used by first determining the conditions which apply (e.g., loan funds are available, but the government has not deposited its contribution), and then by matching the condition entries to this contingency to determine the decision rule column (e.g., column 2). The actions to be taken (or the decision choices) are indicated by X's in the column. The "X" may be interpreted thusly: If these conditions occur, then these actions are specified.

Decision tables may be interconnected to present complex sequential decision processes.

FIGURE 1

Decision Table Used by Donor Agency for Depositing Loan Funds into Special Program Account

	CONDITIONS	DECISION RULES				
		1	2	3	4	
CONDITION STUB	Are loan funds available?	NO	YES	YES	YES	CONDITION ENTRIES
	Has government contribution been deposited?	–	NO	YES	YES	
	Has release of funds been authorized by government?	–	–	NO	YES	
ACTION STUB	ACTIONS					ACTION ENTRIES
	Submit fund transfer request.	X				
	Resolve constraints with Ministry.		X	X		
	Deposit funds in SSPA.*			X	X	
	Authorize release of funds from SSPA.				X	

*Special Segregated Program Account for disbursement of funds to programs.

ADVANTAGES

1) Decision tables are a concise method of describing situations.

2) Standard techniques are available to ascertain that there are no omissions or inconsistencies in the table.

3) Decision tables aid in understanding and communicating complex situations.

4) The decision table is easily adapted for computer programming.

5) A complex decision involving several factors (each of which may assume multiple values) typically requires a specification of a different action for each combination of factor values. This process is more easily represented on a decision table than by a prose description or a flowchart (see FLW, page 107).

LIMITATIONS

1) A flowchart has greater visual clarity for understanding the different courses of action in a complex procedure.

2) Decision tables are relatively little used and may deter the uninitiated until the mechanics are mastered.

REQUIRED RESOURCES

LEVEL OF EFFORT

Effort is required to identify the different conditions in a situation and the actions to be taken when specific conditions occur. Developing the table requires little additional effort.

SKILL LEVEL

The ability to logically break down a decision into relevant factors and decision rules for action is fundamental to constructing decision tables. Their use requires little skill once the format is understood.

TIME REQUIRED

The time required to develop a decision table depends on the complexity of the decision situation. Less than an hour is required to develop a decision table with 5-8 conditions, 8-10 actions, and 10-15 rules. Additional time is required if several interconnected tables are needed to describe the situation.

DESCRIPTION OF TOOL

SUPPLEMENTAL DEFINITIONS

1) A *limited entry* decision table permits only a limited set of condition and action entries in the decision rule columns, e.g., YES or NO (see figure 1).

2) A *mixed entry* decision table permits extended entries such as a range of values for a question, "What is the size of the land holding?" in the condition stub.

3) The *ELSE rule* is a column in the decision table which applies when no other decision rules may be added to cover the case or where no combination of conditions applies.

REQUIRED INPUTS

Construction of a decision table requires a breakdown of the factors relevant to the decision and the possible action choices. The analyst must consult with the decision maker on policy and conditions affecting the policy if the table is to be used as a guide for action.

TOOL OUTPUT

The decision table technique results in an analysis of the conditions and actions which compose a particular decision. The process may be valuable in itself to point out inconsistencies in procedure or areas where further specification of action is in order.

IMPORTANT ASSUMPTIONS

The decision table technique assumes that the decision process can be rationalized, and thus actions are prespecified. All relevant conditions must be identified a priori, i.e., all the actions which follow from a given set of conditions can be specified. The implication of a preprogrammed automatic response is somewhat counteracted by including an ELSE rule in the set of decision rules. This permits an escape clause if none of the relevant conditions hold, or if the analyst chooses not to specify every possible combination of circumstances. The action for the ELSE rule is almost always to call it to the attention of a supervisor or higher level decision-making authority.

METHOD OF USE

GENERAL PROCEDURE

Constructing a Limited Entry Table

1. **Fill in the condition stub of the table (upper left quadrant).**
   - 1.1 Determine the conditions which are relevant to the decision.
   - 1.2 Write each condition in the form of a yes/no question.
   - 1.3 List the conditions in the condition stub.

2. **Fill in the action stub of the table (lower left quadrant).**
   - 2.1 Determine the action options which correspond to each possible combination of conditions.
   - 2.2 List the actions in the action stub.

3. **Specify all possible contingencies (upper right quadrant).**
   - 3.1 Enter a YES or NO to the first condition (or simply Y or N) in the table at the first rule column (see figure 1).
   - 3.2 If the other conditions are relevant, enter a YES or NO for each remaining condition in that column; if not, enter a " ".
   - 3.3 Repeat this for the remaining columns until all possible combinations of conditions are marked. Each combination represents a contingency and occupies a single column in the table.
   - 3.4 Confirm that if there are n questions in the condition stub, then there are 2^n contingencies (unless some combinations are not feasible).

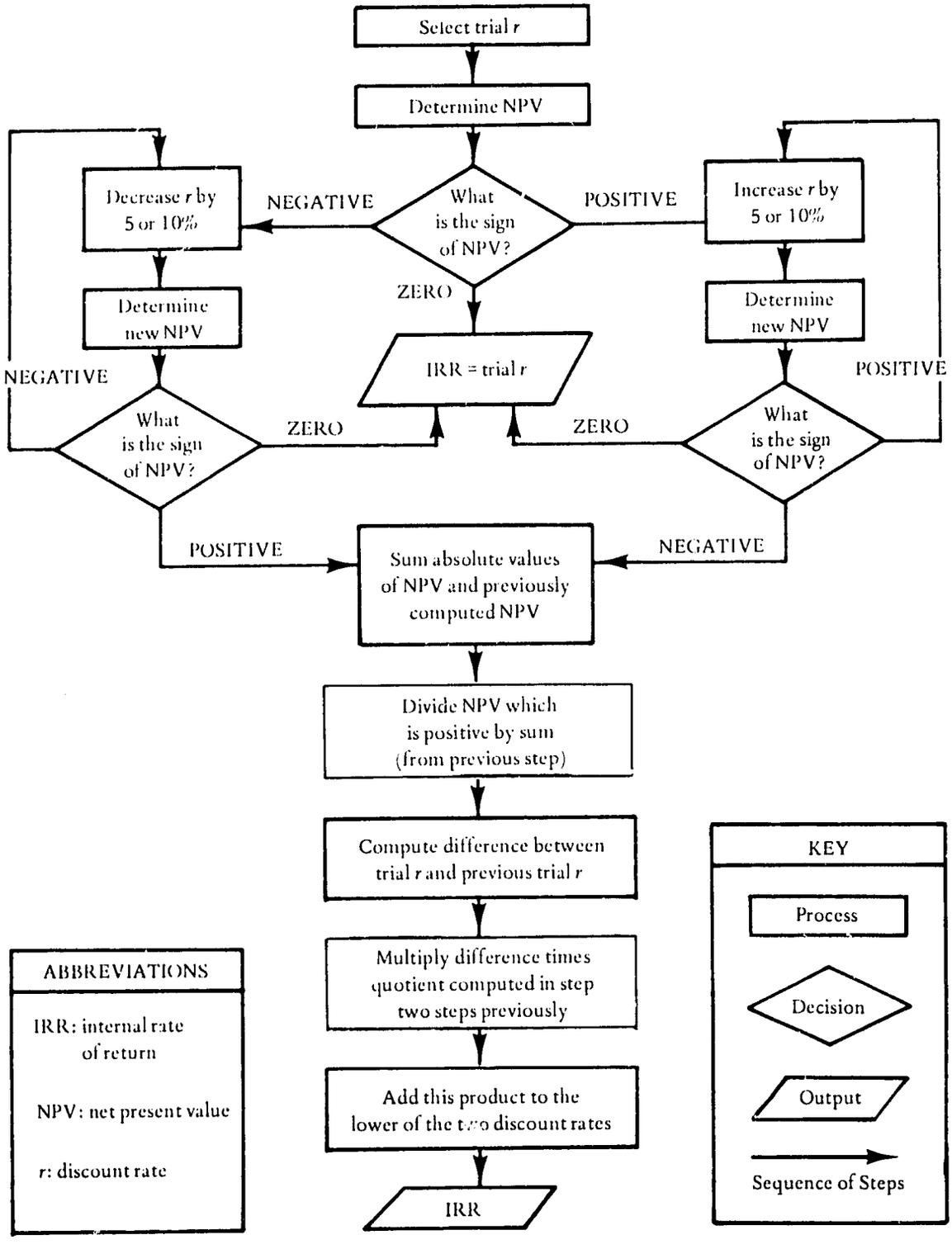
4. **Enter the decision rules (lower right quadrant).**
   - 4.1 Start with the first contingency (column 1) and indicate the appropriate action with an X at the intersection of the column with the corresponding action row.
   - 4.2 Repeat this process for each contingency until all columns have at least one entry in the bottom portion of the table.

5. **Simplify the table if possible.**
   - 5.1 Order the decision rules from left to right so that the rule which is indifferent to the most number of conditions is the first decision rule column.
   - 5.2 Order the condition questions so that the decision rules are applied first to the contingency where the least number of questions must be asked. Steps 5.1 and 5.2 should result in the condition entries occupying the upper right triangle with an increasing number of indifferent entries ( ) in the lower left portion (see figure 1).
   - 5.3 Combine any two decision rule columns which differ only by the answer to one condition question and mark the entry as indifferent, since the choice of action will not be affected.

Constructing an Extended Entry or Mixed Entry Table

Extended entries permit more flexibility in the formulation of conditions and decision rules. Otherwise, the procedure is the same. For example, step 1.2 requires only that the question be posed in such a way that a finite set of conditions can be written in the contingencies portion of

FIGURE 2
Flowchart of Interpolation Procedure to Determine Internal Rate of Return



the table (e.g., farm size in hectares). Furthermore, the decision rule entries need not only refer to the action row, but may indicate:

1) A further specification of the action, such as the quantity of fertilizer to be distributed, or

2) Instructions to go to another step or to another decision table.

A column may be added which includes all contingencies not otherwise described. This ELSE rule is to be followed when none of the combinations of conditions apply.

A mixed entry table combines limited entry symbols (e.g., *Y*, *N*, *X*) with extended entries. These may include a decision rule to go to another decision table if a particular contingency occurs or the ELSE rule.

EXAMPLES

Limited Entry Decision Table

A capital projects development officer for a major donor agency wanted to ensure that funds released by his agency were matched by the required ratio of funds from the host government.* The government had failed to contribute their share of funds in the past. Often, when the required funds were budgeted, they were later diverted to other programs.

In order to exercise more control over the use of the donor's funds and the requirement for cost-sharing by the government, a Special Segregated Program Account (SSPA) was established. The donor agency mission would then deposit and release funds if the Ministry of Finance had fulfilled its obligations. A limited-entry decision table was prepared to guide the disbursement policy (see figure 1).

The decision table was arranged so that the capital development officer need not examine the other conditions unless the necessary initial conditions occurred, e.g., loan funds are available.

Mixed Entry Decision Table

Computing the internal rate of return (IRR) for a project is an iterative process: the discount rate, r, must be found which gives a net present value, NPV, equal to zero (see Internal Rate of Return, IRR, page 200). However, if one has computed both a positive (NPV_1) and negative (NPV_2) net present value using two different trial discount rates, r_1 and r_2, respectively, the IRR may be interpolated using the following formula:*

$$\text{IRR} = r_1 + (r_2 - r_1) \times \frac{NPV_1}{(NPV_1 - NPV_2)}$$

The steps necessary to calculate the IRR can be represented as a flowchart (see figure 2). Recouching this procedure in the decision table format requires the combination of a sequential procedure with an iterative process. This may be necessary in order to get both positive and negative NPV's (see figure 3).

The ELSE rule was employed where the NPV determined from a trial r is zero, in which case the IRR equals r.

The decision table (figure 3) is a mixed entry table because the iterative actions include extended entries.

An illustration of interpolating the IRR for a project cash flow is given in the technique description (IRR, page 200).

THEORY

Decision tables belong to a class of techniques which are categorized as logical trees or algorithms (Lewis, 1970). The underlying idea is the linking of contingencies (combinations of conditions) with the appropriate action according to a set of prespecified decision rules. The decision table has a one-to-one correspondence with a flowchart (see FLW, page 107). Each rule in the decision table corresponds to a path in the chart. Decision tables may be simplified by applying certain rules of logic so that, if the same actions apply, it is usually unnecessary to show every sequence of alternatives or every combination of conditions. This is treated in more detail in Fergus (1974), Hartman (1968), and McDaniel (1970).

Extended entries add more flexibility to the decision table, but they require more care in construction. Nadler (1970) and Pollack, et al. (1971) give more information on the technique.

BIBLIOGRAPHY

Fergus, R. M. "Decision Tables: What, Why and How." In *Systems Analysis and Techniques*, edited by J. D. Gouger and R. W. Knapp. New York: John Wiley and Sons, 1974, pp. 162-80.

*This example is from a tutorial project by Ted Foley, "Systems Approaches to Integrated Rural Development Program," Development Studies Program, USAID, Washington, D.C., 1976.

*This equation is adapted from J. Price Gittinger, *Economic Analysis of Agricultural Projects* (Baltimore: The John Hopkins University Press, 1972), page 80. Note that the denominator on the right is the sum of the absolute values of the positive and negative NPVs. Gittinger suggests that the difference between r_1 and r_2 be 5% or less.

FIGURE 3
Mixed Entry Decision Table for Determining
Internal Rate of Return by Interpolation

		RULES				
	1. Select trial *r*					
	2. Determine NPV					ELSE
CONDITION STUB	3. What is sign of NPV?	Positive	Negative			
	4. Determine new NPV					
CONDITION STUB	5. What is sign of NPV?	Positive		Negative		
	6. Determine new NPV					
CONDITION STUB	7. What is sign of NPV?		Negative		Positive	
ACTION STUB	IRR += trial *r*					X
ACTION STUB	Iterations until NPV changes sign (or is zero)	Increase *r* by 5 to 10% Go to step 4	Decrease *r* by 5 to 10% Go to step 6			
ACTION STUB	8. Sum the absolute values of NPV and previously computed NPV			X	X	
	9. Divide NPV which is positive by sum computed in step 8					
	10. Compute difference between this trial *r* and previous trial *r*					
	11. Compute product of difference and quotient computed in step 9					
	12. Add this product to lower of the last two trial discount rates					
	13. Result is the IRR					

NOTE: *r* = discount rate; IRR = internal rate of return; NPV = net present value.

Hartman, W.; Matthes, H.; and Proeme, A. *Information Systems Handbook*. Appledoorn, Netherlands: Philips Data Systems, 1968.

Lewis, Brian N. *Decision Logic Tables for Algorithms and Logical Trees*. London: Her Majesty's Stationery Office, 1970.

McDaniel, H. *Applications of Decision Tables*. Brandon/Systems Press, 1970.

Nadler, Gerald. *Work Design: A Systems Concept*. Homewood, Ill.: Richard D. Irwin, 1970, pp. 258-62.

Pollack, S. L.; Hicks, H. T.; and Harmnon, W. J. *Decision Tables: Theory and Practice*. New York: Wiley-Interscience, John Wiley and Sons, 1971.

Computer Simulation Models

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

Computer simulation models simulate dynamic system processes in order to analyze complex interactions.

USES

Computer simulation is used to:

1) Forecast future systems behavior.

2) Forecast the effects different decisions have on system variables.

3) Aid in understanding system processes.

4) Be used in tools like Gaming (GAM, page 124).

5) Compare alternative system behavior or determine optimum system design parameters.

KEY DEFINITIONS

1) A *system* is a collection of components which interact to achieve a common function.

2) A *variable* is a factor word to describe a system which may change value as a function of time.

3) A *parameter* is a quantity with only one value over the entire range of the system behavior being simulated. The distinction between a parameter and a variable is sometimes only a matter of degree of change. In the model, the parameter is assumed not to change during the course of a particular simulation, e.g., "the price of gold" may be a parameter in an economic system.

4) *Verification* is testing a computer simulation program to see that the program functions as intended. It is a process of eliminating logical errors in the program.

5) *Validation* is 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.

SHORT DESCRIPTION

A computer simulation involves:

1) Developing a model of the simulated system.

2) Programming the model in a computer.

3) *Verifying* the internal consistency of the model.

4) *Validating* the model by comparing it with observed system behavior. Past and present data are needed in all stages of computer simulation.

Computer simulations are exploited by changing parameters to correspond with expected changes in the system. Present and future system behavior is then inferred.

ADVANTAGES

1) Computer simulation is useful for problems which cannot be studied analytically. Typically, problems necessitating computer simulation involve detailed models of complex systems with non-linear and probabilistic behavior.

2) Systems which require expensive or impractical experimentation may be simulated in a computer. For example, the performance of a dam or reservoir can be studied using a computer simulation rather than by building different dams.

3) A wide range of alternatives can be studied, since changing computer models is relatively fast and easy.

4) Complex assumptions can be easily incorporated into a computer model. For example, in a macro-economic model, a wide range of assumptions, including those about price stability, exchange rate, limitations of natural resources, and climatic catastrophes, can be incorporated in a simulation model.

5) Computer simulation may provide insight into the causal structure of the system by revealing dynamic behavior.

LIMITATIONS

1) Data may not be available to construct and/or test a computer simulation model.

2) Computer simulation models may become so complex that assumptions are hidden and the ability to infer underlying system processes is lost.

3) Developing large computer simulation models is time-consuming. Verifying and validating entire models are often difficult.

4) A computer simulation provides only a specific instance of system behavior. Generalized inferences do not always follow.

5) Conclusions derived from a computer simulation are only as reliable as the model upon which the simulation is based. The user of the results may forget that the model is an abstraction based on the developer's assumptions. Too much weight may be placed on the results and conclusions because they are quantified.

REQUIRED RESOURCES

LEVEL OF EFFORT

Gathering data, developing a model, and verifying and validating the computer simulations are necessary. Using specialized computer simulation languages will often reduce the amount of effort involved.

Techniques are available that aid in developing models for computer simulation: Oval Diagramming (OVD, page 81), Interaction Matrix Diagramming (IMD, page 92), and Decision Tables (DTB, page 113).

Several computer languages also simplify the process, e.g., DYNAMO, GPSS, and GASP (see Gordon, 1969).

SKILL LEVEL

Knowing about the system being simulated is required. An analyst must have the computer usage skills and the basic statistical knowledge needed to develop and use computer simulation models.

TIME REQUIRED

Time required depends on the number of variables included in the model and the availability of data. Typically, developing the model may take a week; programming the model may need another week; verifying and validating the model take a third week. However, the complexity of the system model (number of variables and relationships) will greatly influence the time it takes to develop, verify, and validate the model. Testing alternatives by simulation may require several runs or it may continue for the duration of the project. These estimates assume that the data required are easily available. Additional time may be needed if Surveys (SVY, page 36), Questionnaires (QTN, page 19), or other tools have to be used to obtain data.

SPECIAL REQUIREMENTS

Access to a digital computer is necessary. Many specialized simulation languages may be used successfully on a remote computer terminal using purchased computer access time.

DESCRIPTION OF TOOL

SUPPLEMENTAL DEFINITIONS

1) *Tuning* is 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 the errors between observed or simulated data.

2) A *continuous model* treats variables that change continuously over time, e.g., population.

3) A *discrete stochastic model* describes the changes in variables at definite points in time, e.g., money supply increases on the day the Federal Bank releases notes. Often, the time interval between these points in time varies randomly.

REQUIRED INPUTS

The purpose for simulation must be stated before a simulation can be developed. Data necessary for modeling the system and for validating results are required, though the data need not be gathered until variables and parameters are defined. If a particular programming language is preferred, a compatible computer must be available.

TOOL OUTPUT

The results from computer simulation models include:

1) A computer simulation model of the system under question.

2) Forecasts of system behavior under different assumptions (e.g., alternative parameter values).

3) A better understanding of the system and its behavior.

IMPORTANT ASSUMPTIONS

All the relevant variables and relationships can be quantified and all necessary data are available. It is assumed that all variables and relationships can be identified and defined explicitly.

METHOD OF USE

GENERAL PROCEDURE

Computer simulation cannot be described fully without reference to a specific type of model or a particular application. The following outlines only the steps basic to all computer simulations.

1. **Define the problem.**
   - 1.1 Recognize the system problem.
   - 1.2 Identify the system boundaries.
   - 1.3 Observe current and past system behavior.
   - 1.4 Formulate problem objectives.

2. **Develop the descriptive model.**
   - 2.1 Identify the important variables and the cause-effect relationships in the system.
   - 2.2 Identify the parameters of the system.
   - 2.3 Select the type of model to be developed.
   - 2.4 Develop the model to represent system behavior.

Two types of models will be discussed:

1) The *continuous model* where the change in the variables is expected to occur continuously (see Forrester, 1969). Computer languages like DYNAMO can be used here.

2) The *discrete stochastic model* where the change in the variables is expected to occur at specific points in time. These models are very popular in simulation. Many languages, including GASP and GPSS, are available for this model.

The model of system behavior may be traced through Flowcharts (FLW, page 107), Oval Diagramming (OVD, page 81), Decision Tables (DTB, page 113), or Interaction Matrix Diagrams (IMD, page 92).

3. **Computerize the model.**
   - 3.1 Select a programming language.
   - 3.2 Program the model.
   - 3.3 *Verify* the model.

4. **Validate the model using observed system data.**
   - 4.1 Tune the simulation model to correspond with past system behavior.
   - 4.2 Design experiments to test parameter values.
   - 4.3 Analyze the results of the experimental simulation.
   - 4.4 Statistically compare results with observed data.

5. **Simulate and infer.**
   - 5.1 Express policies or decisions as changes in parameter values or in some structural relationships.
   - 5.2 After making these changes, simulate the system model behavior and forecast the effects of these changes.

EXAMPLE

Continuous system models have been used by Forrester to model urban dynamics (1969). The Club of Rome has developed a model of the world predicting major changes in population, economy, etc. (Meadows, 1972).

Discrete event simulation has been used in a large and complex model of Nigerian agriculture (Abkin and Manetsch, 1973). Some 22 alternate policies and strategies were tested using this model.

THEORY

There are many types of simulation models that can be used. However, the types discussed above are the most popular and most widely used. Analogue computer simulation, where variables are represented analogously by currents and voltages in an electronic system constructed to resemble the observed system, can also be used. Also

used are more complicated continuous models that include variables which are probabilistic in nature. Forrester (1968) discusses such models.

The use (and misuse) of large computer simulation models for urban problem solving is treated extensively by Brewer (1973). Standard textbooks on simulation methodology include Gordon (1969) and Emshoff and Sisson (1970).

BIBLIOGRAPHY

Abkin, M. H., and Manetsch, T. J. "A Generalized System Simulation Approach to Agricultural Development Planning and Policy Making." *Systems Approaches to Developing Countries*. Proceedings of the IFAL and IFORS Symposium, Algiers, Algeria, May 1973.

Brewer, G. D. *Politicians, Bureaucrats and the Consultant: A Critique of Urban Problem Solving*. New York: Basic Books, 1973.

Emshoff, J. R., and Sisson, R. L. *Design and Use of Computer Simulation Models*. New York: Macmillan, 1970.

Forrester, Jay W. *System Dynamics*. Cambridge, Mass.: The M.I.T. Press, 1968.

Forrester, Jay W. *Urban Dynamics*. Cambridge, Mass.: The M.I.T. Press, 1969.

Gordon, Geoffrey. *System Simulation*. Englewood Cliffs, N.J.: Prentice-Hall, 1969.

Meadows, D. H., et al. *The Limits of Growth*. New York: Universe Books, 1972.

Gaming

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

Gaming provides decision makers with experience in a simulated *problem environment* in order to analyze complex processes.

USES

Gaming is used to:

1) Generate possible alternative actions in a problem situation (operational gaming).

2) Forecast effects of alternative actions.

3) Train present and potential decision makers (management gaming).

4) Provide experience in using different tools that assist in decision making, such as Contingency Analysis (CGA, page 147), Scenarios (SCN, page 164), and Computer Simulation Models (CSM, page 120).

KEY DEFINITIONS

1) The *problem environment* is the set of variables and relationships which are germaine to the decision process under study.

2) *Governing rules* describe the relationships between decisions made by the participants and the resulting changes in the simulated environment. For example, in an economic game a governing rule may dictate that a decision to expand money supply leads to inflation.

3) *Scoring* in games is used as feedback to the participants to reflect the effectiveness of their decisions. Scores are usually related to the objectives of the game. For example, "overall growth rate" may be used as a score in an economic game.

SHORT DESCRIPTION

Gaming consists of a controlled situation where people or teams compete either against each other and/or against a simulated problem environment to attain predetermined objectives. Games include a problem environment, several *governing rules*, and *scoring*, all of which are designed to represent a real situation. In games where two or more teams are participating, one team's decisions influence other teams' reactions and decisions. A single team may compete against a problem environment in which one or more variables are beyond the team's direct control. There are programmed relationships between the players' decisions and the resulting changes in the environment. However, the nature of the relationships is usually not known to the participating teams, and thus participants become involved in analyzing complex processes.

ADVANTAGES

1) Decision makers gain experience without paying the real-life penalties for wrong decisions.

2) A game can be designed to be very flexible and can provide a wide range of problem situations.

3) Because the time element is limited, the player can make as many decisions in a few hours as he would make in a few years in real life.

4) Gaming helps everyone involved, including the analyst who designed the game, to understand a problem.

5) Games have been developed for typical problem environments and can be applied directly. The American Management Association provides a list of such games.

LIMITATIONS

1) Games representing large and complex real situations may be difficult to construct.

2) A game requiring four to fifteen hours requires considerable concentration from the participants.

3) The compressed time element in a game may mislead the decision maker as to the real nature of the dynamic change in the problem environment.

4) Governing rules in a game reflect the designer's knowledge and experience in the problem situation and thus are a limited representation of reality. Often novel approaches, which may be appropriate in real life, work poorly in games, stifling the decision maker's creativity.

REQUIRED RESOURCES

LEVEL OF EFFORT

A considerable amount of effort is required to develop a game for a problem situation. A moderate amount of effort is required from the participants. Some elaborate game situations may use analysts and staff assistants as participants to assist the decision maker.

SKILL LEVEL

Developing a game requires expertise, primarily in the problem environment being simulated. Complex games require a team of experts. For example, developing a game for national economic policy making may require economists to develop the governing rules, psychologists and educators to design the format of intermediate results, computer specialists to automate the game, etc.

The skills required for playing a game are minimal when used for training purposes only. If the game is used to generate alternative actions and forecast their effects, an experienced decision maker needs to participate.

TIME REQUIRED

The time required to develop a game depends on the complexity of the environment being simulated and on the amount of detail required. It also depends on the number of participants. Generally, a few weeks are necessary.

A typical session of game play may vary from two hours to eight or ten hours. Occasionally, games are played over a period of two or three days.

SPECIAL REQUIREMENTS

Games may be played on a digital computer (see Computer Simulation Models, CSM, page 120) so that the programmed relationships are automated. In this case, access to computer facilities, including a remote terminal, is required.

DESCRIPTION OF TOOL

REQUIRED INPUTS

Before the actual playing of the game, there are two stages of preparation:

For the design of a game:

1) Definition of the problem area, e.g., agricultural development programs.

2) Statement of the purpose, e.g., to consider the effect of alternative programs or to train area extension service agents.

3) A design team (as specified in Skills section) should be distinguished from the participating team.

For the playing of a game:

4) Specific starting values of variables.

5) Commitment from the players.

TOOL OUTPUT

Effects of alternate decisions on the simulated environment are obtained, e.g., in an agricultural program game, the "effect of distributing free fertilizers led to misuse of fertilizers and low productivity," while the "effect of increasing number of extension agents and subsidizing fertilizers led to higher productivity." This leads to a greater understanding of the complex processes described in the gaming situation.

IMPORTANT ASSUMPTIONS

Games are used with an implicit assumption that the decision makers obtain an understanding about the problem environment when they participate. This assumption is often challenged. Some educators believe that participants learn only by reacting to the changes in the simu-

lated environment and do not try to understand the reasons for the changes. If this is true, games can have a detrimental effect on a participant's decision-making ability. However, this can be avoided by supplementing the game with lectures or literature about the problem environment.

METHOD OF USE

GENERAL PROCEDURE

1. Design the game.
   - 1.1 Identify the specific purpose of the game.
   - 1.2 Identify how a game will help meet the purposes. See if there are any games currently available that will meet the purposes (see Advantages).
   - 1.3 Identify the decision-making level of the participants. A game designed for top management may be unsuitable for supervisor-level participants.
   - 1.4 Identify the nature of decisions that a participant must make during game play.
   - 1.5 Decide how many teams the game involves and whether the game required the use of a computer.
   - 1.6 Outline a model of the environment (see Tree Diagrams, TRD, page 74; Oval Diagramming, OVD, page 81; and Interaction Matrix Diagramming, IMD, page 192). Identify important variables in the environment and establish the relationships between them in order to determine the relationship between the decisions made by the players and their effects.
   - 1.7 The time period of these relationships must be determined. This period depends on the nature of a game and the decision-making level (strategic, operational) of the participants. For example, the time period could be a week when the participants are to schedule nurses in a rural area. On the other hand, the period would be a year if the participants are to plan for national development.
   - 1.8 Determine the format and content of the intermediate results to be presented to the participant. In a computer assisted game, the intermediate results will be the computer print-out. This should be designed to provide sufficient information for participants to make further decisions and to be realistic, i.e., it provides only the type of information that can be obtained in real situations.
   - 1.9 If necessary, repeat 1.6 through 1.8 to refine details of the model. The players' instruction manual must then be written, outlining the necessary instructions for playing the game. The design of the game itself should be documented separately for subsequent review if necessary.
   - 1.10 Test the game and the instructor manual using trial sessions. This may reveal any errors in the computer program if one is used and any other limitations of the game.

2. Play the game.
   - 2.1 Introduce the participants to the simulated problem environment and familiarize them with the type of decisions they are required to make. The instruction manual for the game should cover this.
   - 2.2 Start the game session by giving initial values to the variables in the game. For example, population, men-women ratio, and fertility rate may be variables initialized in a "demographic game."
   - 2.3 Point out that the participants are required to meet some objectives during game play. Examples of objectives may be "reduce population growth to zero," and "increase per capita nutrition."
   - 2.4 Let the participants play the game.
   - 2.5 Determine the final results of the game—usually some measure of participant performance. The effectiveness of alternative decisions in meeting the objectives can be seen from the final results. These results can be used to make real decisions. The final results can also be used to evaluate the participants if the purpose of the game was training. An optional (but often useful) conclusion to the gaming exercise is to permit the participants to freely discuss the game and their participation.

EXAMPLE

Helmer and Quade describe an approach to the study of a developing economy using operational gaming (Quade and Boucher, 1968, pages 329-33). They discuss using games to analyze the processes of development and the involvement of various experts in the excercise.

Other examples of games applied in a variety of situations can be found in Helmer, 1972, and Kibee, 1961.

THEORY

Gaming is described in the literature as management games, computer simulation games, and operational games (see Quade and Boucher, 1968). Operational games at all

levels are used for training as well as for assisting decision making, particularly in Defense Department applications (e.g., war games).

In industrial situations, management games are used to aid in production planning, scheduling, marketing, and long-term planning.

In the public sector, operational games are used to aid in making decisions, e.g., urban housing policies, mass transit decisions, and economic planning.

BIBLIOGRAPHY

Helmer, Olaf. "Operational Gaming." *Futures* (1972): 149-67.

Kibee, J. M.; Craft, C. J.; and Nanus, B. *Management Games.* New York: Rinehold Publishing, 1961.

Quade, E. S., and Boucher, W. I., eds. *Systems Analysis and Public Policy: Applications in Defense.* New York: American Elsevier, 1968.

List of Cross-References

Benefit-Cost Ratio
CBA, CFA, DIS, IPX, IRR, NPW, SVY
Brainstorming
CBA, DTR, NGT
Cash Flow Analysis
BCR, CBA, CFA, 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 sub-categories, 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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