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(DEVELOPMENT R&D) Chapter 7 covers four forecasting techniques which fit into two categories: extrapolative techniques and intuitive techniques. Extrapolative techniques (Exponential Smoothing Forecasts and Regression Forecasting) base predictions of future behavior on past performance data and assumptions about the processes which generated the data. Exponential Smoothing Forecasts provide short-time forecasts of variables by extrapolating from past data. Regression Forecasting is a mathematical technique for examining the relation between two or more variables based on past data values. Both these techniques are useful in forecasting demands for services or goods and for obtaining economic forecasts. Intuitive forecasting techniques (Scenarios and Delphi) combine observation of past and present conditions with predictions for future performance, constraints, and forces for change. Scenarios forecast the future of a system based upon assumptions about interactions and external conditions. Scenarios help illuminate the interactions of psychological, economic, social, and cultural dimensions in a form that permits understanding many such interactions at once. They are useful for policy decisions. The Delphi is a group process technique obtaining, collating, and directing expert judgment towards a consensus on a particular topic. The experts involved are able to focus on and debate issues anonymously by mail through several rounds of questionnaires.

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VII
Forecast and Prediction

Exponential Smoothing Forecasts
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Delphi

The selected forecasting techniques fit into two categories. Extrapolative techniques (Exponential Smoothing Forecasts and Regression Forecasting) base forecasts of future behavior on past performance data and assumptions about the underlying processes which have generated the data. Intuitive techniques (Scenarios and Delphi) systematically combine the observations not only of past and present conditions, but predictions of future performance, constraints, and forces for change.

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Foreword

This is a *toolbook*.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

William J. Siffin
Director
IDI/PASITAM
June 1977

Preface

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

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

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

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

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

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

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

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

Peter Delp
Nairobi, 1977

Acknowledgments

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

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

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

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

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

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

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

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

The Authors

Abbreviations

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

Introduction

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

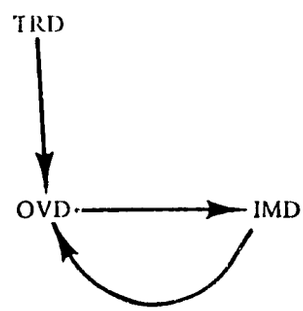
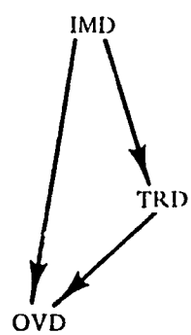
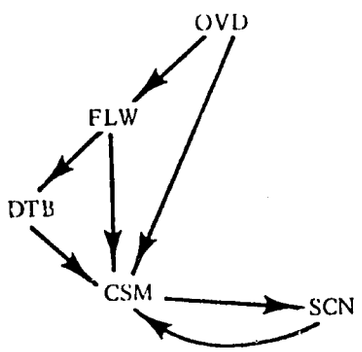


FIGURE 1b



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



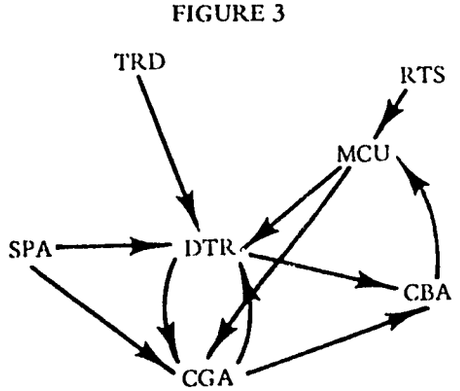
GENERATING AND ANALYZING ALTERNATIVE PLANS OF ACTION

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

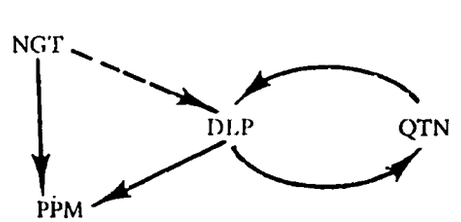
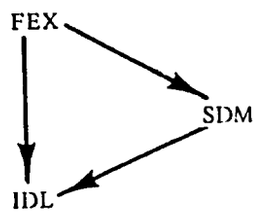


FIGURE 5



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.

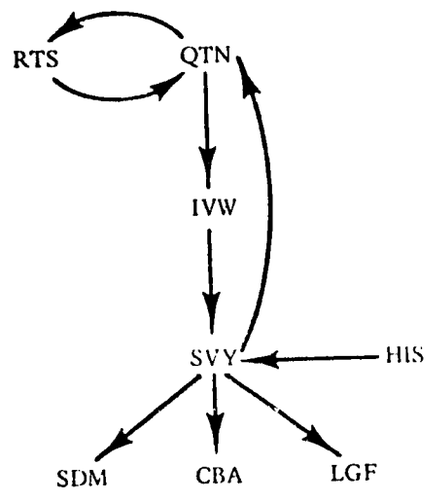
Focusing on function rather than on problems gets people involved in a constructive assessment of what should be, rather than what's wrong and who's to blame. There are sound arguments for both approaches. The IDEALS Strategy often comes under attack because its emphasis on normative specification may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

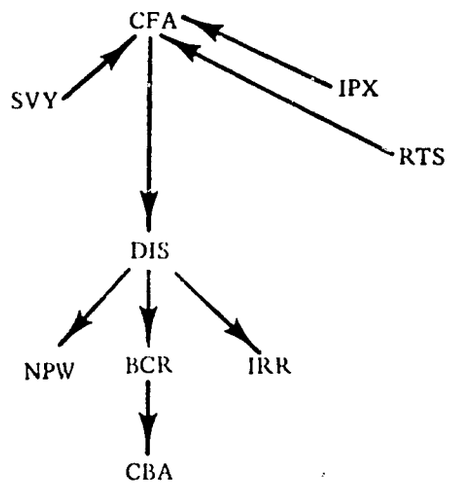
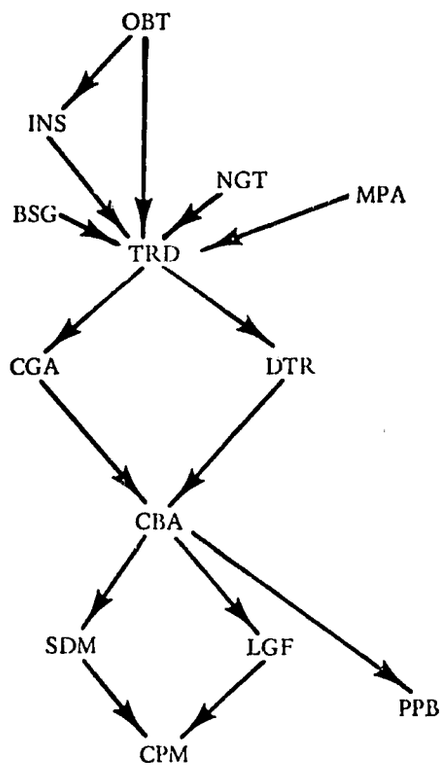


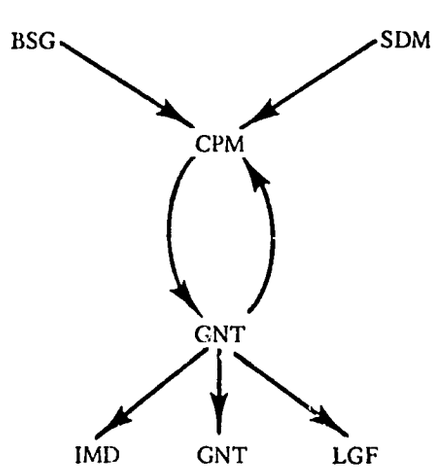
FIGURE 8



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

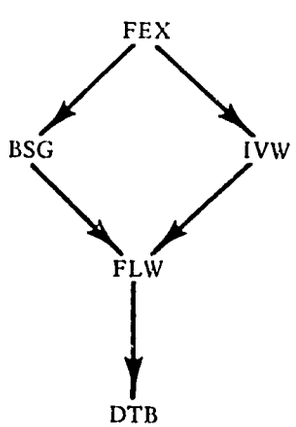
Framework may also be used to sharpen the identification of objectively identifiable indicators of progress. These milestones are shown as vertical lines on specific dates of the Gantt Chart and written on the Critical Path Method network at the appropriate nodes.

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

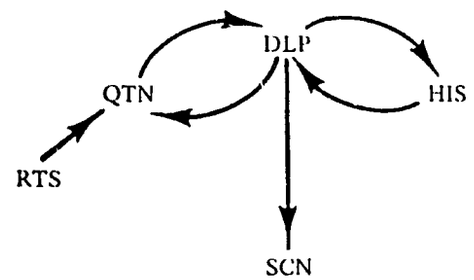


The results of this analysis are presented in the form of flowcharts (FLW, page 107) or decision tables (DTB, page 113). The flowchart uses different symbols to display and analyze complex processes. The decision table presents the decision as a preprogrammed process by specifying the conditions which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

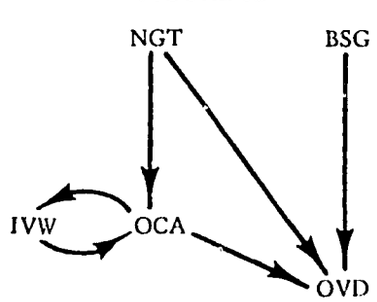


The Delphi technique (DLP, page 168) begins by directing questionnaires to a selected group of prognosticators. The results of each round are summarized for the Delphi group, often in the form of a histogram which aggregates the individual judgments. Rating scales attempt to quantify priorities and opinions.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

Exponential Smoothing Forecasts

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

Exponential smoothing provides short-term forecasts of variables by extrapolating from past data.

USES

Exponential smoothing is used to:

1) Forecast demand for services or goods.
2) Obtain economic forecasts.
3) Forecast any variable where past behavior is expected to continue.
4) Provide forecasts at regular intervals.
5) Trace an underlying trend or pattern for a variable when random fluctuations in the data obscure that trend.

KEY DEFINITIONS

1) The *smoothed value* is an estimate of the average value of the variable being forecast. It is calculated each period by the equation:

$$S_t = S_{t-1} + a(x_t - S_{t-1})$$

where

S_t = the new smoothed value
S_{t-1} = the old smoothed value
a = a smoothing constant
x_t = new datum

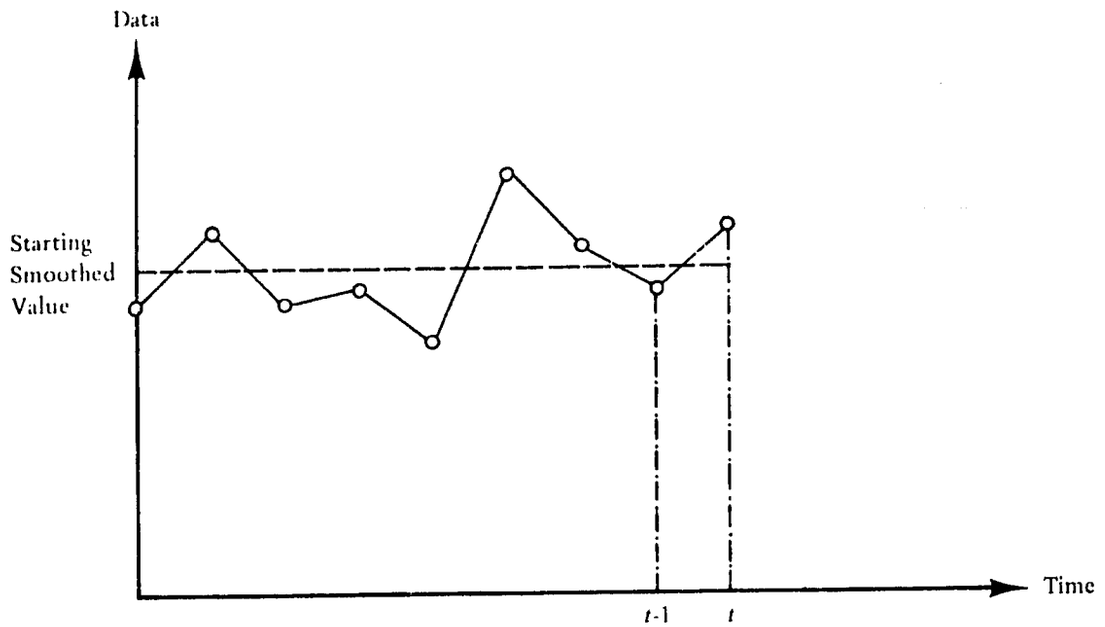
2) The *period* of a time series is the time interval between successive observations of the underlying process. This interval may be a day, a week, a month, or one or more years. For example, the period would be a week if the datum is the weekly total of immunizations performed.

SHORT DESCRIPTION

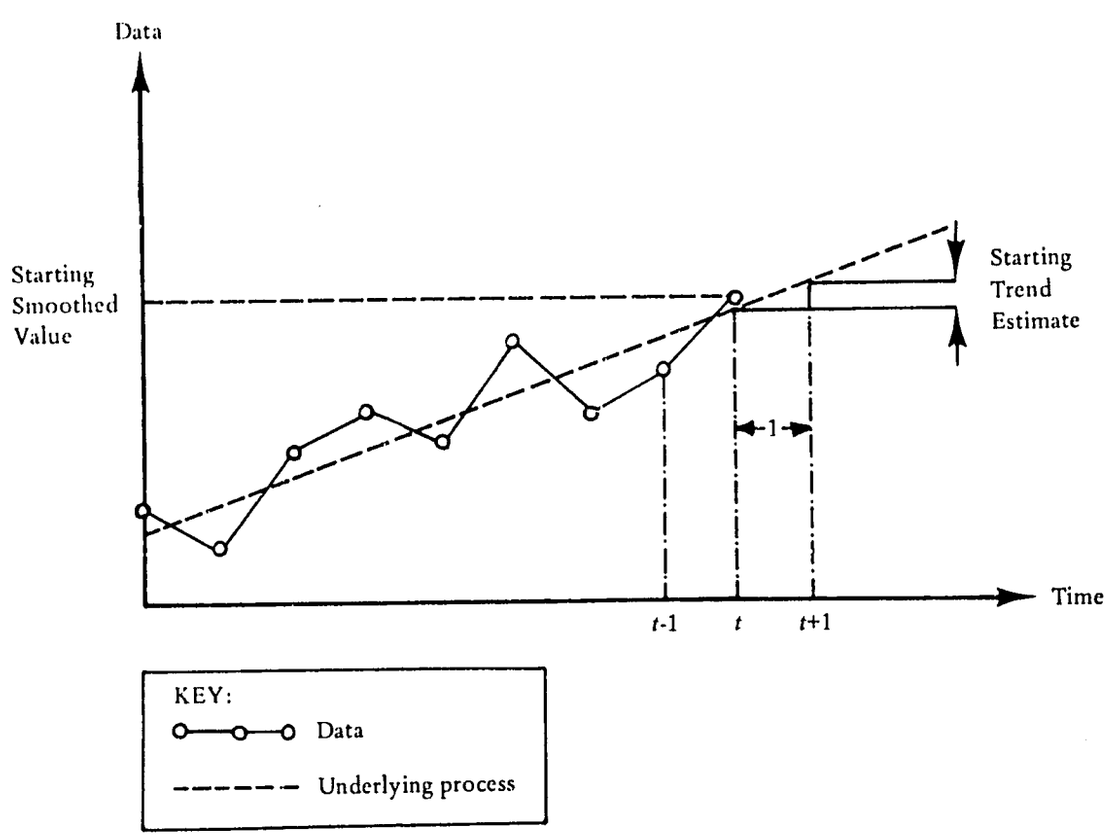
A *smoothed value* of the average of the data is the basis for forecasting by exponential smoothing. This value is calculated for each *period* using the data for that period and the smoothed value from the previous period. The new smoothed value becomes the forecast for the next period if the average value for the variable is expected to remain constant (see figure 1a). However, variables with a steadily increasing or decreasing average (a trend) can also be forecast by obtaining a smoothed value for the average and a smoothed estimate for the trend component. The forecast for the next period is the sum of the two estimates (see figure 1b).

FIGURE 1
Plots of Past Data

a) Plot for a Variable with Constant Average



b) Plot for a Variable with Linear Trend



ADVANTAGES

1) Exponential smoothing is easy to understand and use since it relies on intuition and simple mathematics.

2) When changes occur in the behavior of the variable being forecast, exponential smoothing can continue to be used since gross errors in forecasting smooth out after a few periods.

3) Large quantities of past data need not be retained (see Regression Forecasting, RGF, page 160).

LIMITATIONS

1) Exponential smoothing is not a causal model; it only extrapolates from past data. Since past behavior only partly explains the future, exponential smoothing may not always be sufficient.

2) A more complex smoothing model is necessary to accurately forecast cyclic variations in data (see Montgomery, 1968).

REQUIRED RESOURCES

LEVEL OF EFFORT

Exponential smoothing involves the substitution of numerical values into simple formulae. The effort required is minimal.

SKILL LEVEL

Basic arithmetic skills are needed to use exponential smoothing. Some experience in choosing the *smoothing constant* is necessary to obtain good forecasts.

TIME REQUIRED

Once the smoothing constant has been selected, the forecast calculations are straightforward and require little time. It may be desirable to keep track of the errors in each forecast and take corrective action should they become too large (see Brown, 1965). This requires a minimum of extra time.

SPECIAL REQUIREMENTS

A slide rule or a calculator may be used to do the calculations. A digital computer may be desirable to forecast a large number of variables.

DESCRIPTION OF TOOL

SUPPLEMENTAL DEFINITIONS

1) The *smoothing constant* is a fraction between 0 and 1 that indicates the degree of confidence placed on the most recent datum. It is denoted by "α" in [1].

2) x_t and x_{t-1} are data values observed at time t and t-1 respectively.

3) S_t is the smoothed estimate of the average value of the variable for the time period t.

4) A_t is an estimate for the linear trend for period t.

5) T is the forecast lead time, or the number of periods into the future for which the forecast is being made.

6) α and β denote the smoothing constants whose values lie between 0 and 1.

7) x_{t-1} and x_{t+T} are forecasted estimates of the variable x calculated at time t for the next period and for T periods ahead, respectively.

REQUIRED INPUTS

Some understanding of the variable being forecast helps in estimating any trend that may be observable in past data. The data may be plotted on a graph against time (see figure 1). The variation of the data is shown in these plots. Visual inspection indicates the presence of an increasing trend in the plot shown in figure 1b.

Selecting a smoothing constant is also necessary before forecasting can be done. The function of the smoothing constant is to control the amount of importance given to the past data. The constant is greater than 0 and is usually less than 0.3. The smaller the smoothing constant, the greater is the importance given to past data, signaling confidence that the past behavior of the variable will continue. On the other hand, a large smoothing constant (but always less than 1) gives more importance to the current datum. However, a large smoothing constant may lead to large errors in the forecasts. A value of 0.2 is recommended for most applications.

Initial values for the smoothed estimates are needed before forecasting. The starting smoothed value can be taken from the plot of the past data. When the graph indicates that the data have no trend, only the smoothed value for the average needs to be estimated. This can be taken as the height of the horizontal line drawn through the data (see figure 1a). If the variable appears to follow a trend, starting values for both an average value and a trend component are required.

TOOL OUTPUT

The output is a short-term forecast of the future values of the variable. The forecast is computed from the estimate of the average value or from the estimates of the average value and the trend component, whichever is appropriate.

IMPORTANT ASSUMPTIONS

The model presented here is based on the assumption that the process which produced the behavior of the forecasted variable does not change with time. That is, the variable is assumed to have either a constant average or a constant linear trend. Higher order exponential smoothing models may be used if these assumptions are not valid for a variable (see Brown, 1965).

METHOD OF USE

GENERAL PROCEDURE

Forecasting by exponential smoothing is done in two steps:

1) Updating the smoothed values.
2) Obtaining a forecast from the smoothed values.

In the case of a variable with constant average, step 1 will be used to update the smoothed value for the average. In case of a variable with a trend, step 1 will be used to estimate the trend and the average value by smoothing.

Variable with Constant Average

1. **Update smoothed values.**
   The smoothed value for the average is obtained by the following equation:
   $$S_t = S_{t-1} + a\,(x_t - S_{t-1}) \qquad [1]$$
   The difference between the new datum and the old smoothed value gives an idea of the error in the forecast. A fraction, a, of this error is added to the old smoothed value to obtain a new smoothed value.

2. **Obtain the forecast.**
   The forecast is given by the following equation:
   $$x_{t+1} = S_t \qquad [2]$$
   This equation is used since the variable is assumed to have a constant average estimated by the smoothed value and no trends. When datum for the next period, x_{t+1}, is obtained, the new smoothed value becomes the old smoothed value for the next period, and forecasting is continued by computing the smoothed value for that period. These calculations are repeated.

Variable with Trend

1. **Update smoothed values.**
   Obtain a smoothed value for the average and an estimate for the trend. The equations used for the two are similar. Equation [1] is used to estimate the average. The equation used for estimating the trend is:
   $$A_t = A_{t-1} + \beta\,[(S_t - S_{t-1}) - A_{t-1}] \qquad [3]$$

2. **Obtain the forecast.**
   Add the trend estimate to the smoothed value that has been newly calculated. The forecast is given by the following equation:
   $$x_{t+1} = S_t + A_t \qquad [4]$$
   If forecasting is to be done for more than one time period ahead, the increase (or decrease) due to the trend component needs to be accounted for. The forecast for T time periods in the future is given by:
   $$x_{t+T} = S_t + T\,(A_t) \qquad [5]$$
   Note that in case of a variable with no trend component, the forecast for one period ahead and the forecast for many periods ahead is the same.

   As before, when a new datum is available, the new smoothed value and the trend estimate become the old smoothed value and the old trend estimate for the next period. The calculations are repeated in order to update smoothed values.

Worksheet

A worksheet can be used to facilitate the calculation of forecasts on a regular basis (see figure 2). The columns in figure 2 represent different stages in the calculation, with the forecast given in the final column and the datum given in the first column. Each row corresponds to a time period.

EXAMPLE

It is necessary to forecast the number of births in a district each month in order to procure child immunization medicine. Exponential smoothing is used to forecast the number of births. A slight increasing trend is assumed to be present in the data (see figure 2 for the calculations).

The worksheet shows that the forecast for births in February is 207. The S_{t-1} and A_{t-1} values for March can be written in the row corresponding to March.

THEORY

The basic smoothing equation in exponential smoothing is [1], which can be rewritten as:
$$S_t = a\,(x_t) + (1 - a)\,S_{t-1} \qquad [6]$$

FIGURE 2
Work Sheet for Exponential Smoothing

	1 Data x_t	2 Old Smoothed Value S_{t-1}	3 Difference $x_t - S_{t-1}$ 1 − 2	4 Fraction Added $\alpha \cdot$ $\alpha \cdot 3$	5 New Smoothed Value S_t 2 + 4	6 Old Trend Estimate A_{t-1}	7 Change in Smoothed Value $S_t - S_{t-1}$ 5 − 2	8 Difference $[\ - A_{t-1}]$ 7 − 6	9 Fraction Added $\beta \cdot [\ ]$ $\beta \cdot 8$	10 New Trend Estimate A_t 6 + 8	12 Forecast x_{t+1} 5 + 10
January	205	200	5	1	201	3	1	2	.2	2.8	203.8 ≈204
February	210	201	9	1.8	202.8 ≈203	2.8	2	.8	.08	2.72 ≈2.7	205.7 ≈206
March		203				2.7					

The smoothed value for the previous time period* was given by:

$$S_{t-1} = a(x_{t-1}) + (1-a)S_{t-2} \qquad [7]$$

and the smoothed value for the period before is

$$S_{t-2} + a(x_{t-2}) + a(1-a)S_{t-3} \qquad [8]$$

and so on. By repeated substitution for S_{t-1} into [6] and then for S_{t-2} into [7], we obtain:

$$S_t = a(x_t) + a(1-a)x_{t-1} + \ldots + a(1-a)^n x_{t-n} \qquad [9]$$

From this equation it can be seen that past data (x_{t-1}, x_{t-2}, x_{t-3}, etc.) have decreasing exponential weights. Hence the name exponential smoothing. The weights of the past data decrease with the age of the data because a is less than 1. This makes intuitive sense as more recent data are given more weight. The actual weights depend on the smoothing constant. The earlier discussion on the value of the smoothing constant follows directly from [8].

*t = present time, therefore t-1 is one time period prior, t-2 is two time periods prior, etc.

Similar formulations of exponential smoothing have been developed to forecast data that have a cyclic variation or a combination of a trend and cyclic variation. Montgomery (1968) and Brown (1965) discuss these cases at length.

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Regression Forecasting

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

Regression forecasting obtains the relationships between two (or more) variables based on pairs (or sets) of past data values.

USES

Regression forecasting is used to:

1) Obtain economic forecasts.
2) Forecast demand for services and products.
3) Forecast any variable where past behavior is assumed to continue.

KEY DEFINITIONS

1) An *independent variable* is the non-random variable which is used for forecasting other variables using the regression. M is the independent variable in:

$$B = a + (b \times M) \qquad [1]$$

where

B = number of births
M = number of marriages registered
a,b= constants

2) A *dependent variable* in regression forecasting is the variable being forecast. It is written in the regression equation as being dependent on the independent variable. For example, in [1] the dependent variable is "number of births."

3) A variable is *regressed* on another when the former is dependent on the latter. In [1], the "number of births" is regressed on the "number of marriages registered."

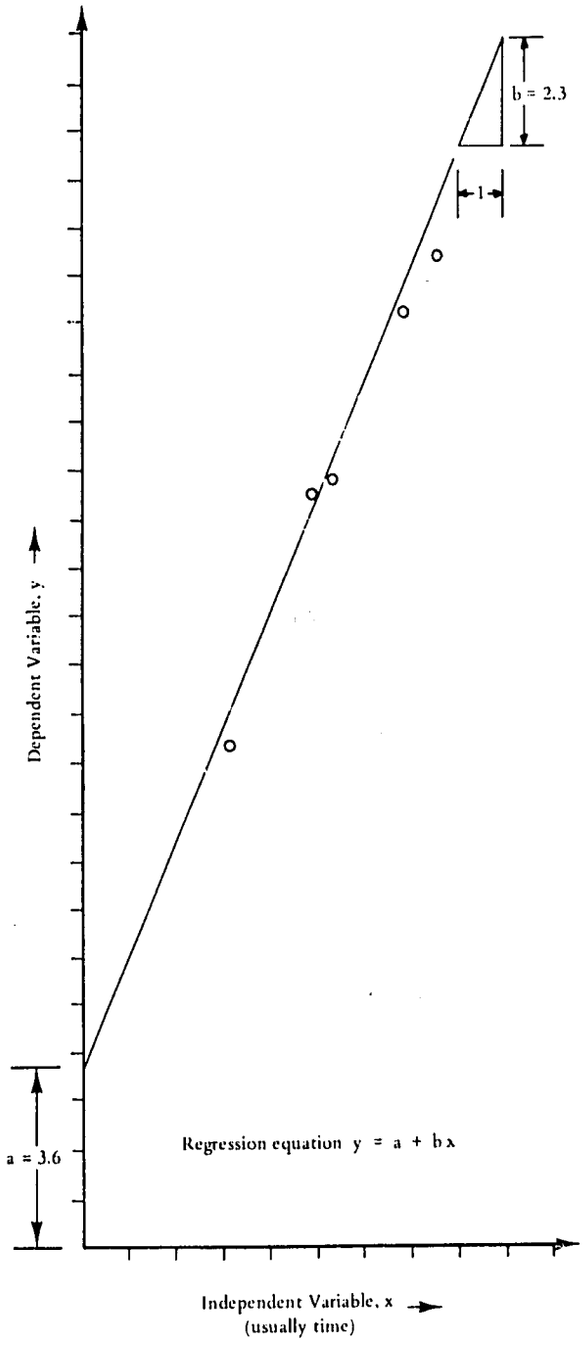
4) *Correlative behavior* is an assumed relationship between two or more variables in which the changes in one variable may be associated with predictable changes in the others. The change, however, is not necessarily cause-effect.

SHORT DESCRIPTION

Regression relates a *dependent variable* with an *independent variable* in the form of a mathematical equation. The independent variable is usually time, and regression extrapolates the past into the future. The equation is obtained from past data gathered in pairs (a value of the dependent variable corresponding to a value of the independent variable).

If the relationship is assumed to be linear, the regression of the dependent variable on the independent variable is a straight line when plotted on a graph (see figure 1). The simple linear regression equation is used to obtain forecasts of the dependent variable for a given value of the independent variable. A dependent variable may be *regressed* on two or more independent variables, but this is

FIGURE 1
Graph of Regression Line



not easily visualized on a graph. The forecasting method is similar, however, to simple linear regression.

ADVANTAGES

1) Regression is a simple and straightforward process.
2) Regression can be used in a wide variety of situations and is often the only recourse for forecasting. For example, in many social and economic contexts, causal or predictive models based on theoretical grounds are difficult to construct. Regression gives an empirical model which can be used for forecasting.

LIMITATIONS

1) Regression models estimate the correlation between variables. This *correlative behavior* is often mistaken as meaning "a change in the independent variable causes a change in the dependent variable." This may lead to false assumptions about causal relationships (see Oval Diagramming, OVD, page 81).

2) Regression forecasting extrapolates the data in order to obtain the forecasts. The relationship obtained from the data does not necessarily hold outside the range of available data, and erroneous forecasts are obtained. For example, the relationship between two variables may be linear only in the region examined and non-linear in other regions.

REQUIRED RESOURCES

LEVEL OF EFFORT

The effort required is minimal if the data for the regression model are available. However, a considerable amount of effort may be required if data collection is necessary. For example, surveys (SVY, page 36) may be needed to obtain the data.

SKILL LEVEL

Some statistical knowledge is needed to fully understand and use regression.

TIME REQUIRED

The time required to gather the data depends on the nature of the variable and the amount of data needed. Adequate regression models can be obtained using 20 to 50 pairs of data points. Once the data are obtained, the calculations require only a few hours. Regression on more than one variable takes more time depending on the number of variables being considered.

SPECIAL REQUIREMENTS

A calculator or a slide rule is useful in making the calculations.

DESCRIPTION OF TOOL

SUPPLEMENTAL DEFINITIONS

1) The *regression coefficient* is the coefficient of the independent variable in a regression equation. In [1], "b" is the regression coefficient.

2) Symbols:
   x is the independent variable
   y is the dependent variable
   a and b are regression coefficients.

REQUIRED INPUTS

Knowledge about the variables defined in the regression equation is needed. Between 20 and 50 sets of data points are needed to obtain the regression equation. The higher the number of data sets, the higher the reliability of the regression equation.

TOOL OUTPUT

The output is the regression equation model relating the variables. The model may then be used to forecast values of the dependent variable for given values of the independent variable.

IMPORTANT ASSUMPTIONS

Regression models assume that the independent variable is deterministic (non-random) and can be measured with an accuracy that is much higher than that involved in measuring the dependent variable. Often both the variables are random, and the variable which can be measured with less error is chosen as the independent variable. However, most often observations of one variable are made at intervals of time. Time becomes the independent variable in the regression equation, and the assumption about the independent variable is then valid.

METHOD OF USE

GENERAL PROCEDURE

Linear regression fits a linear equation between the variables (see figure 1). The *regression coefficients* of the equation are selected so that the data values have minimum deviation from the line.

The following procedure is recommended to develop a regression equation.

1. **Obtain the data.**
   Once the independent and dependent variables are determined, the data values are obtained in pairs, i.e., a datum point for the dependent variable corresponds to each value for the independent variable. The data should be recent and should be representative of the trend. Consider a situation where the total industrial output in a region for the next year is to be forecast. The industrial output is known to be correlated to the annual steel production. The industrial output will be regressed on the steel production. Data for past five years are used to obtain the equation (see figure 2).

2. **Determine the equation coefficients.**
   If the relationship between the variables is assumed to be linear (see figure 1), the regression equation used is:

$$y = a + bx. \qquad [2]$$

   The regression coefficients are calculated using:

$$b = \sum^{n} (x - x')(y - y') / \sum^{n} (x - x')^2 \qquad [3]$$

   where
   x', y' = averages of n data points for x and y
   $\sum^{n}$ = summation of all terms in parentheses computed from data points

   The calculations for [3] are easily done using a table (see figure 2b). The data points for x and y are first filled in and the averages x' and y' calculated. Using these averages, the rest of the table is filled in. The totals for columns $(x\text{-}x')$ and $(y\text{-}y')$ should be zero. This can be used as a check for calculations. The ratio of the totals in columns 5 and 6 then gives the value of b:

$$b = 26.86/11.70 = 2.29.$$

   The coefficient a is calculated by

$$a = y' - bx'. \qquad [4]$$

   In the example,

$$a = 16.2 - (2.29 \times 5.5) = 3.6,$$

   the regression equation is

$$y = 3.6 + 2.29 \times x. \qquad [5]$$

3. **Forecast using the equation.**
   The forecast of a new value of the dependent variable is made by fitting the corresponding new value for the independent variable into the equation. For example, steel production is known to be six million tons. The industrial output is estimated by substituting in [5], so that:

$$(y) = 3.6 + 2.29 \times 6 = 17.34 \qquad [6]$$

   The industrial output (y) is estimated at $17.34 million using the linear regression equation.

EXAMPLE

Many examples of regression analysis may be found in the literature. Fredericks' (1976) analysis of cooperative

FIGURE 2
Regression Computation

a) Data for Forecasting Industrial Output

Year	1970	1971	1972	1973	1974
Steel Production/yr (million of tons)	7.5	6.8	3.1	5.2	4.9
Industrial Output/yr (millions of $)	20.3	19.2	10.3	15.8	15.6

b) Table for Computing Regression Coefficients

	(1) x	(2) y	(3) $x - x'$	(4) $y - y'$	(5) $(x - x')(y - y')$	(6) $(x - x')^2$
	7.5	20.3	2.2	4.1	8.2	4.0
	6.8	19.2	1.3	3.0	3.9	1.69
	3.1	10.3	-2.4	-5.9	14.16	5.76
	5.2	15.8	-0.3	-0.4	.12	.09
	4.9	15.4	-0.6	-0.8	.48	.36
TOTALS	27.5	81.0	0.0	0.0	26.86	11.70
AVERAGES	$x' = 5.5$	$y' = 16.2$	0.0	0.0	$b = \frac{26.86}{11.70} = 2.29$	

movements in West Malaysia is illustrative and instructive. Twelve structural variables were included in the analysis of structural development.

THEORY

Regression equation models are widely treated in statistics texts (Fryer 1966, or Wetherill 1972). The theory is based on summing the squares of the deviation of each data point from the corresponding value of the model, and then selecting coefficients of the model which minimize this sum. If the model equation is a straight line, the coefficients fit a linear regression model. Non-linear regression models are used to fit equation coefficients to data which do not appear to fall on a straight line.

Multiple regression models use the same basic principle to fit the observed data to two or more independent variables. The forecaster is referred to specialized texts (Draper, 1966) for details.

Bedworth (1973) has an excellent presentation of regression forecasting when the independent variable is time.

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Scenarios

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

A scenario forecasts the future state(s) of a *system* based upon assumptions about interactions and external conditions.

USES

Scenarios may be employed to:

1) Identify and clarify major issues for debate among policy makers and interest groups.

2) Formulate a narrative for dynamic behavior of a social system, e.g., for interpreting Oval Diagramming (OVD, page 81).

3) Provide the input for techniques such as Gaming (GAM, page 124).

4) Provide a framework for normative forecasts of desired future conditions.

KEY DEFINITIONS

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

2) A *state scenario* describes conditions and events (the state of the system and the external context) at a single future point in time.

3) A *transient scenario* forecasts the changes in and the alternative actions on a system at various stages in the evolution of the system.

SHORT DESCRIPTION

A scenario is a narrative forecast of the future states of a system. It is developed from a description of the present conditions and an extrapolated forecast of future conditions. The forecast is based on the external constraints to change, and the likely interactions between system variables in the progression from current conditions to some future state.

A scenario may be either a *state scenario* for a single point in the future or a *transient scenario* tracing the evolution of the system over time.

ADVANTAGES

1) Scenarios help illuminate the interaction of psychological, social, economic, cultural, political, and military dimensions in a form that permits understanding many such interactions at once. They are especially useful for policy decisions.

2) Kahn and Wiener (1967) argue that scenarios call attention to the larger range of possibilities that must be considered in the analysis of the future.

3) Scenarios help stimulate and discipline the imagination.

4) Scenarios generally have an illustrative and pedagogical value for the decision maker.

LIMITATIONS

1) It is a formidable task to take into account and successfully predict the interplay of the various dimensions (e.g., social, political).

2) Scenarios suffer from uniqueness: they represent only the views of those experts who constructed them, and there is no guarantee that the future is accurately predicted.

REQUIRED RESOURCES

LEVEL OF EFFORT

The decision maker and the analyst collaboratively define the subject of the scenario. The analyst identifies, organizes, and interacts with a group of experts to understand the present system and to construct the scenarios.

SKILL LEVEL

The analyst and experts should be able to identify the major dimensions and attributes of the present system in order to identify new developments and understand their character and significance.

TIME REQUIRED

The time required depends on the complexity of the system being studied and the time span of the scenario. The analyst and the experts may spend several days constructing from three to five different scenarios which describe the same general situation.

DESCRIPTION OF TOOL

SUPPLEMENTAL DEFINITIONS

1) The *dimensions* of a system are collections of its attributes, where each collection represents a major aspect of the system, e.g., political, economic, social, or psychological.

2) The *attributes* of a system include the elements or components of the system and the interrelationships among them.

3) A *goal* is a value judgment which satisfies one or more human needs, e.g., "to promote equality in schooling."

4) A *driving force* is an attribute of a system which causes changes in the system state over time.

5) The *base system state* is the set of current conditions which describe the essential characteristics of the scenario. It is denoted by $S(t)$, where t is the present time.

6) An *intermediate image*, $S(t + n)$, describes the state of the system after a time interval n.

7) The *external context* represents the constraints on the base system.

REQUIRED INPUTS

Scenario construction requires prior agreement on the kind of scenario (either trend or state), the subject of the scenario, and the time span to be included.

The subject of the scenario is generally a system or sector of a country or region, e.g., the tourist industry or the energy situation for the country of Temasek or the social structure of a river basin population.

The time span varies according to the importance of the system under consideration. The time span of the scenario, for most situations, should cover at least 15 years to project beyond characteristics of the present situation. Future images become increasingly blurred as the time span is extended, effectively limiting a scenario to 30 years.

The analyst may wish to assemble a group of experts, each familiar with a major dimension of the system, though the scenario may be developed using a Delphi (DLP, page 168).

TOOL OUTPUT

The scenario technique generates a narrative description of the future state(s) of the system. The format is the *base system state* description and one or more *intermediate images*, together with a description of the *external context* and the *driving forces* behind the forecasted changes (see figure 1).

One or more scenarios may be constructed:

1) Several alternative state scenarios for a single point in time, or

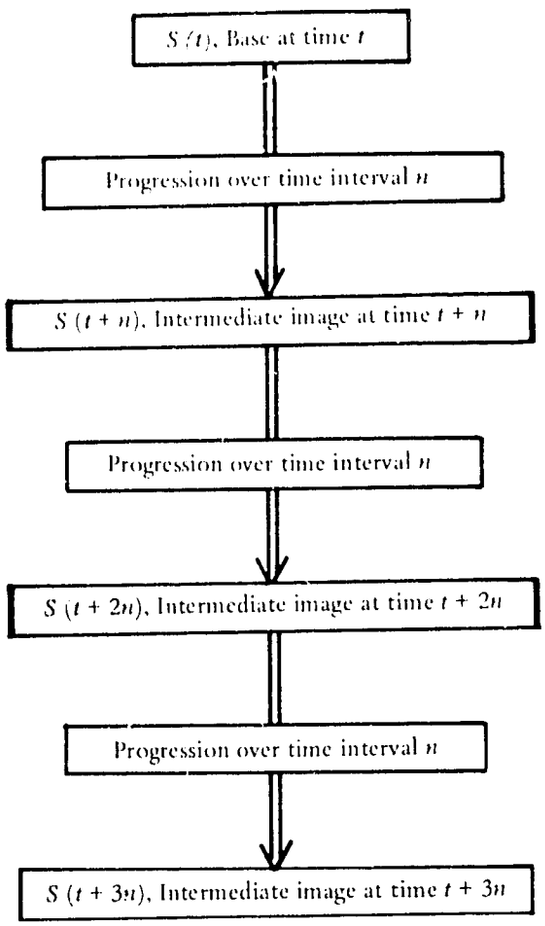
2) One (or perhaps two) transient scenarios which forecast the effects of different policies on the evolution of system conditions.

These scenarios may be compared and contrasted for review by decision makers and interested parties.

IMPORTANT ASSUMPTIONS

A scenario is constructed by extrapolating future conditions from present conditions and foreseeable driving

FIGURE 1
A Standard Format for a Scenario



forces for change. Consequently, a fundamental assumption concerning dynamic system behavior is implied: a system exhibits current conditions which are the result of all the previous current and prior forces on the system. However, social systems are self-organizing and anticipatory, and the current system state may be influenced by anticipated future conditions. Accounting for these factors in scenario construction requires that the analyst be aware of the possible effect of anticipated actions on the future state of the system.

METHOD OF USE

GENERAL PROCEDURE

The following steps describe the development of a transient scenario and are based on the work of Durand (1972) and Gerardin (1973):

1. **Construct the base system state.**
   1.1 Identify the major subgroups in the base system.
   1.2 Identify the attributes of the subgroups.
   1.3 Choose one of the attributes as the driving force for change in the system.

2. **Identify the external context.**
   2.1 Formulate hypotheses about the constraints on change in the base system state.
   2.2 Consider constraints which may change during the time span of the system.

3. **Develop the progression to the first intermediate image.**
   3.1 Identify any trends in the interaction between attributes of the base system for time interval n, where n is typically 5-10 years.
   3.2 Identify any changes in the external constraints for time interval n.
   3.3 If alternative or competing trends are likely, construct an intermediate image at time $t + n$ for each major trend.

4. **Construct the intermediate image.**
   4.1 Using the dimensions and attributes identified in step 1, describe the likely system state or conditions at time $t + n$.
   4.2 Take into account the forces for change, the external constraints, and the trends internal to the system.

5. **Repeat steps 3 and 4 until the desired time span has been covered.**
   5.1 The last intermediate image becomes the new base system state.
   5.2 To progress to the next intermediate image, consider changes for the interval from time $t + n$ to time $t + 2n$, etc.
   5.3 End the scenario with the last intermediate image.

If a normative scenario is being developed, the procedure in step 4 is inverted. Instead of predicting the intermediate image, the analyst tries to identify the alternative actions or policies that are necessary to achieve a desired system state. This is typically an iterative process, where first one set of policies, the internal trends of the system and the external context, are used to forecast a likely progression. The discrepancy with the normative system state is then used to indicate alternative policies until the desired and the predicted intermediate image merge.

EXAMPLE

A scenario was developed for the cattle industry in the country of Temasek. The goal was "to improve the quality of life for all Temasekians." Two criteria indicate achievement of this goal: a decrease of nutritional deficiencies among the population, and an increase in foreign exchange.

The *base system state* was described:

> Four subgroups have been identified: the herdsman, the middlemen, the meat-packing industry and the consumers of beef. The herdsmen are generally nomadic and own 90 percent of the cattle in Temasek. Cattle breeding and feeding practices are inefficient. The nomads have a strong emotional attachment to their cattle as they equate the ownership of cattle with prestige.
>
> The herdsmen sell their cattle to middlemen. The cattle reaches consumers after going through several levels of middlemen, thus inflating the price of beef.
>
> The meat-packing industry is small at present but is owned by a big multi-national company. The beef is packed mainly for export. . . .

The attributes of the subgroups were the value system of each subgroup, the economic linkages between the subgroups, and major institutions. The meat-packing industry was selected as the driving force for the scenario because it wanted to increase its growth rate.

The *external context* may be described as:

> There will be maintenance of favorable trading conditions with the developed countries. No adverse weather conditions will occur. . . .

Starting with the base and external context, the progression was formulated to give the following scenario:

> It is the year 1977. The demand for beef in developed countries is seen to increase greatly over the next seven years. To meet this demand a multi-national company invests 20 million dollars in a meat-packing plant geared for both domestic and overseas consumption of beef.
>
> Educational efforts are carried out to make the herdsmen settle and learn better cattle breeding and feeding practices. This will ensure a regular supply of beef for the meat-packing plant. There is considerable resentment by the herdsmen. Since only a few herdsmen react positively to the efforts, the herdsmen are not allowed to graze on land wherever or whenever they wish thus forcing them to settle.
>
> By 1982 the meat-packing plant has been established and most herdsmen have reluctantly settled. The multi-national company pays the herdsmen high prices for their cattle. The middlemen find themselves being forced out of their traditional supply links. The middlemen, who handle many foodstuffs other than beef, organize into a cohesive unit and in 1985 go on strike. There is mass hoarding of food by housewives and prices increase remarkably. The military is asked to provide trucks for the transportation of essential foodstuffs. . . .

Several such scenarios were formulated for review and evaluation by the decision maker.

THEORY

Scenarios are constructed based on a planning philosophy which might be called "futures-creative" (Gerardin, 1973). Scenarios are effective decision aids if the decision maker accepts such a planning philosophy. A future is to be designed which is in line with stated goals. A future will not be accepted if it is simply an extrapolation or extension of past events.

Scenarios have been used widely and are especially useful for policy making. Kahn and Wiener (1967) constructed scenarios for international political systems. Durand (1972) and Gerardin (1973) recorded several applications in France, including regional development planning. Kraemer (1973) cites a study in urban planning. Brown (1968) describes political scenarios done at the Department of Defense.

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Delphi

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

The Delphi is a group process technique for eliciting, collating, and generally directing informed (expert) judgment towards a consensus on a particular topic.

USES

The Delphi may be used in:

1) Establishing goals and their priorities.

2) Identifying the dimensions and the attributes of a problem.

3) Providing forecasts (e.g., identifying future developments and their effects).

4) Clarifying positions and delineating differences between group members.

5) Gathering information from a group whose members do not meet face-to-face (either by choice or practicality) and wish to retain their anonymity.

SHORT DESCRIPTION

The Delphi is a method whereby individuals are allowed to focus on and debate issues anonymously. The study is typically conducted by mail through several rounds of questionnaires (QTN, page 19). The results of each round are collected, collated, and analyzed by a design team. Based on this analysis, questions for the subsequent round are developed. The Delphi generally promotes convergence of opinions, although it may provide the basis for disagreement.

ADVANTAGES

1) The anonymity provided by the Delphi precludes some undesirable aspects of face-to-face communication, such as dominance by certain personalities and inhibition of expression.

2) A Delphi participant may respond with opinions which more truly represent his or her feelings.

3) Individuals who may not otherwise afford the time required for a group meeting may participate.

4) With the Delphi, a large heterogeneous group can participate on an equal basis.

5) The Delphi is obviously useful when the respondents are geographically scattered.

LIMITATIONS

1) The Delphi is precluded when there is a limited time available to aggregate participants' judgments, because of the delay in gathering and assimilating responses.

2) The Delphi should not be used with individuals who have difficulty reading or expressing themselves in written communication.

3) High participant interest and commitment is assumed or the quantity and quality of responses decreases with successive rounds.

4) Desirable features of a group meeting, such as instant communication and intellectual stimulation, are compromised.

REQUIRED RESOURCES

LEVEL OF EFFORT

The design team will have to spend a significant amount of time designing questionnaires and analyzing completed questionnaires. Integration between the decision maker and Delphi design team is necessary to ensure that the goals or requirements of the decision maker are understood by the design team.

SKILL LEVEL

The design team must be able to establish unbiased questionnaire designs which relate the Delphi exercise to its purpose (see QTN, page 19). The feedback of comments and reactions to the respondents should be succinct and representative without reflecting the bias of the design team. Members of the design team who are knowledgeable in the subject matter greatly facilitate this crucial process.

TIME REQUIRED

Approximately six weeks are required to complete a Delphi exercise which consists of four rounds of questionnaires (see figure 1). Since eight days are allowed for each set of responses (including three days for *dunning*), the Delphi requires only about two weeks of actual effort.

The continual motivation of the respondents is important in order to get a quick response and good return percentage. Consequently, the design team needs to minimize the delay between receipt of questionnaires and transmittal of the next one to participants. Analysis of the returned questionnaires and design of the subsequent questionnaires should begin immediately rather than waiting until the expected return for each round.

DESCRIPTION OF TOOL

DEFINITIONS

1) *Dunning* is the process of recontacting participants who have failed to return their questionnaires.

2) A *target group* is a set of persons with certain common characteristics, e.g., all experts possessing knowledge about a particular problem, or farmers with land in the same river basin.

REQUIRED INPUTS

Since Delphi is a tool to aid decision making, it will be most effective if the decision maker is involved through out the process.

Respondents should be considered who:

1) Have special experience or knowledge to share;
2) Represent a cross-section of opinions; and
3) Can be motivated to participate.

The size of the design team will vary from two to five, in direct proportion to the size of the respondent group. Delbecq, et al. (1975) found that, in their experience, 30 well-chosen respondents were sufficient; few additional ideas were generated by having more participants. About 15% of the selected participants will decline.

For the questionnaire to communicate successfully, the questions should:

1) Be as short as possible.
2) Be adapted to the language most familiar to the respondent's area of expertise (e.g., health or education).
3) Elicit useful responses at the level of abstraction required (i.e., general vs. specific).

TOOL OUTPUT

The output of the Delphi exercise will generally be a convergence of opinion.

One type of output may be a frequency distribution or histogram of forecasts (see HIS, page 131). For example, the respondents may estimate what the legal minimum wage should be for the country of Temasek in 1980 in order to ensure adequate housing and food for citizens. The frequency distribution graph in figure 2 indicates that an interval of $75 to $100 was favored by most respondents as the desirable minimum wage. It also shows that a great majority of the respondents would not set a minimum wage below $75. The mean and standard deviation may be computed for the responses and added to the graph (HIS, page 131).

Another type of output is the ranking of responses to a particular question. For example, the respondents may list the problems they perceive in the health field. The output is a vote on the importance of the problems.

METHOD OF USE

GENERAL PROCEDURE

Delbecq, et al. (1975) recommend that the following steps be followed in designing and implementing a Delphi exercise. This procedure is only one way in which a Delphi exercise may be carried out. The number of rounds of

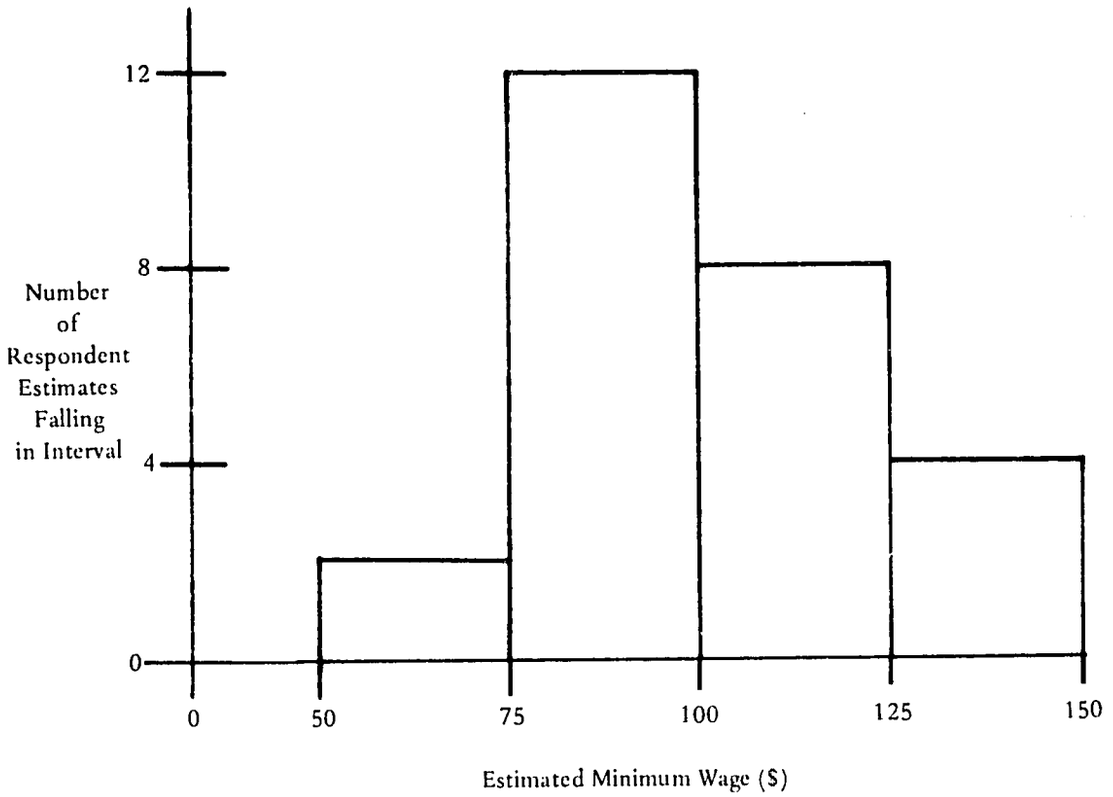
FIGURE 1
Schedule for Delphi

Activities	Minimum Time Required	
1. Develop problem statement	½ day	one day
2. Select respondents	½ day	
3. Contact respondents	2 days	
4. Develop questionnaire #1 and test	½ day	
5. Type and send out	1 day	
6. Response time	5 days	
7. Dunning time (if used)	3 days	
8. Analysis of questionnaire #1	½ day	two days
9. Develop questionnaire #2 and test	½ day	
10. Type and send out	1 day	
11. Response time	5 days	
12. Dunning time (if used)	3 days	
13. Analysis of questionnaire #2	½ day	two days
14. Develop questionnaire #3 and test	½ day	
15. Type and send out	1 day	
16. Response time	5 days	
17. Dunning time (if used)	3 days	
18. Analysis of questionnaire #3	½ day	two days
19. Develop questionnaire #4 and test	½ day	
20. Type and send out	1 day	
21. Response time	5 days	
22. Dunning time (if used)	3 days	
23. Analysis of questionnaire #4	1 day	
24. Prepare report	1 day	
25. Type report and send cut	1 day	
26. Prepare respondents' report	½ day	
27. Type report and send out	1 day	

The minimum time is 47 days, allowing 8 days (including dunning) for each response.

SOURCE: Andre Delbecq et al., *Group Techniques for Program Planning: A Guide to Nominal Group and Delphi* (Chicago, Ill.: Scott Foresman, 1975), p. 87.

FIGURE 2
Frequency Distribution of Estimates of Minimum Wage



questionnaires, the types of questions, the responses required, and the analyses performed will vary depending on the type of application and the actual situation.

1. Determine the basis for a Delphi.
   1.1 A statement of objectives or problems is developed by the decision maker in cooperation with the rest of the design team.
   1.2 Target groups of respondents (e.g., agricultural economists, engineers, planners, etc. in an agricultural development exercise) are generated by the design team. Names of potential respondents are then identified.
   1.3 Telephone or personal contact is made with the potential respondent. The respondent is informed of the objectives of the Delphi, the nature of the respondent group, the obligations involved, how long the Delphi will take, how the Delphi works, and how his or her participation will be mutually advantageous. The safeguards on anonymity may be explained.

2. Design questionnaire #1.
   2.1 The initial task of the respondents is generally to generate a list of items. Examples of such items would be barriers to delivery of services, perceived problems, or potential developments.
   2.2 The design team formulates questions which are consistent with the statement of objectives (see Questionnaires, QTN, page 19).
   2.3 A short cover letter outlines the task and reiterates the agreement reached in the initial contact with the respondent in step 1.

3. Solicit responses for questionnaire #1.
   3.1 If possible, the questionnaire is pretested to ensure that questions are not misinterpreted. The group may be composed of several typical respondents from the Delphi group.
   3.2 The questionnaire and cover letter are distributed to all respondents. Return of the completed questionnaires should be prearranged (e.g., by enclosing self-addressed stamped envelopes).
   3.3 If sufficient questionnaires are not returned by the specified date, dunning, or carefully composed reminders, should be directed to the Delphi group. A response rate of 85% is usually considered acceptable.

4. **Analyze questionnaire #1.**
   4.1 Responses are copied and cut into slips so that each member of the design team has a set for each question. For example, for the question, "What agricultural developments do you foresee for Temasek in the next 15 years?" the slips may read "more effective fertilizers," "lining of irrigation ditches with concrete," etc.
   4.2 Each member sorts the response items for all questions into stacks representing similar responses to a question. The stacks are then labeled, e.g., for agricultural development, "Irrigation," "Education," "Technology."
   4.3 A member of the team reads his stack of labels. Through group discussion, the design team agrees upon categories of responses.
   4.4 Response slips are reordered according to the category labels. Obvious duplications are eliminated, and closely related items are combined. Statements expressing the resulting items within each stack are formulated. The result of this effort constitutes the list of items for questionnaire #2.

5. **Design questionnaire #2.**
   5.1 Questionnaire #2 should help respondents understand, clarify, criticize, and support items identified in questionnaire #1.
   5.2 Several things may be asked of the respondent. He may be asked to forecast when a development may take place or if the items identify potential future developments. He may be asked to identify what impacts such a development might have, or he may be asked to vote on the items. The respondent is encouraged to provide comments, e.g., he may state why he thinks a problem is important.
   5.3 If the respondent is to vote on the items, the rank-order procedure may be used (see Nominal Group Technique, NGT, page 14).

6. **Solicit responses for questionnaire #2.**
   Repeat step 3, including pretest and dunning (if necessary).

7. **Analyze questionnaire #2.**
   7.1 The comments for each item are placed in stacks (see step 4) to be summarized and communicated to the respondent in questionnaire #3.
   7.2 If voting has taken place, the results are aggregated and the items are ranked according to their votes. If quantitative forecasts have been made, a frequency distribution is constructed (see figure 2) and distributed to the respondents in the next questionnaire (see Histograms, HIS, page 131).
   7.3 The responses are reviewed to see if they are useful in achieving the objectives set up in step 1. If necessary, the next questionnaire can be altered by encouraging a different kind of comment or by making responses more specific.

8. **Design questionnaire #3.**
   8.1 This questionnaire aims to explore disagreements identified in questionnaire #2.
   8.2 The results of step 7 the ranking of the items, the aggregated forecasts, and the summarized comments are given to the respondents.
   8.3 The cover letter informs the respondents that they should react to any questions and criticisms and should lobby for or against items they feel strongly about.

9. **Solicit responses for questionnaire #3.**
   Repeat step 3, though a pretest is seldom necessary.

10. **Analyze questionnaire #3.**
    The design team reviews the reactions to the comments and summarizes them in a procedure similar to that outlined in step 4.

11. **Design questionnaire #4 (optional).**
    11.1 This is a final attempt towards consensus.
    11.2 Questionnaire #4 is similar to #3 except that it also provides a summary of respondents' reactions.
    11.3 The respondents consider the final reactions and are asked to provide a vote or quantitative forecast similar to that indicated in questionnaire #2.

12. **Solicit responses to questionnaire #4 (optional).**
    Repeat step 3, omitting the pretest.

13. **Analyze questionnaire #4 (optional).**
    The rankings are totaled for each item to identify its importance. Where forecasts were made, final frequency distributions are constructed.

14. **Closure.**
    The participants are informed of the results to provide a sense of closure.

EXAMPLE

In dealing with a country's economy, the decision maker determines that continued inflation is a major problem. To combat the problem, he must identify the factors causing inflation and its effects. Target groups may be economists, corporation heads, consumer advocates, trade union leaders, and agricultural experts.

Questionnaire #1 asks, "What are the factors which may contribute to inflation over the next five years?" The respondents answer by listing several items they feel are important:

Increase price of oil
Strengthen border defenses
Shortage of rice

Questionnaire #2 lists all the responses, and each respondent provides comments and votes by giving each item a numerical value which corresponds to the importance of that item.

Item	Vote	Comments
Increase price of oil	3	If new sources of oil are found, price increase may be less
Strengthen defenses on border	0	High likelihood of military aid from another country
Shortage of rice	4	Import prices and number of tons of rice imported will increase

The responses for questionnaire #2 are analyzed. The votes are aggregated and comments are summarized. Questionnaire #3 asks for reactions to the aggregated votes and comments. One respondent's reaction may be:

Item	Vote	Comment	Reaction
Strengthen defenses on border	153	High likelihood of military aid from another country	The other country failed to support our country last year despite previous pledges

Questionnaire #4 then circulates all reactions and asks for a final vote.

THEORY

A number of theoretical arguments have been made to support the claim that the Delphi method is superior to conventional uses of groups in problem solving or forecasting. In 1964, Gordon and Helmer laid the foundations for the Delphi. Delbecq, et al. (1975) compared the characteristics and performances of interacting, nominal, and Delphi groups. Dalkey (1969) provided empirical arguments for the relative accuracy of Delphi estimates compared to individual or face-to-face group estimates.

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List of Cross-References

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

Glossary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

DEPENDENT VARIABLE. The variable being forecast (RGF).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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