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Chapter 3 discusses three methods for defining development project objectives. Such objectives are often unspecified or ill-defined. Two of the techniques focus on structuring objectives in a hierarchy (Objective Trees and Intent Structures). Objective Trees aid in defining project objectives and provide a way to rank them in order of importance. An Intent Structure defines project objectives, identifies the persons or organizations who have a vested interest in specific objectives, and describes the logical relationships among the objectives and the interest groups. This technique shows where possible conflicts among interest groups can arise. The third technique (Function Expansion) derives from systems engineering and represents a hierarchical view of the functioning of a system. This method helps the project planner to define the various functions of an organization which will aid in achieving project goals; it also helps to identify problems within the existing system.

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III
Defining Objectives

Function Expansion
Objective Trees
Intent Structures

Defining project objectives is a universal imperative of a systems approach. Objectives are often unspecified, ill-defined, nonconsensual, and/or time-varying. Three techniques were selected which address these characteristics. Two techniques focus on structuring objectives in a hierarchy (Objective Trees and Intent Structures). A third tool derives from systems engineering and represents a hierarchical view of system function (Function Expansion). All three assume that defining objectives is a realizable task.

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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

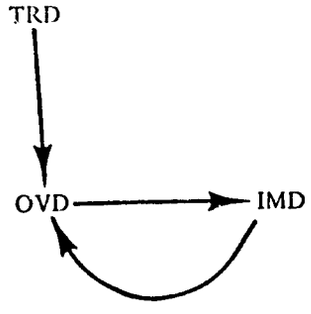
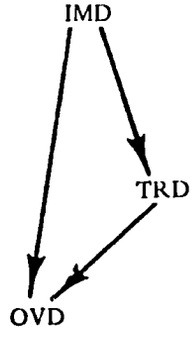
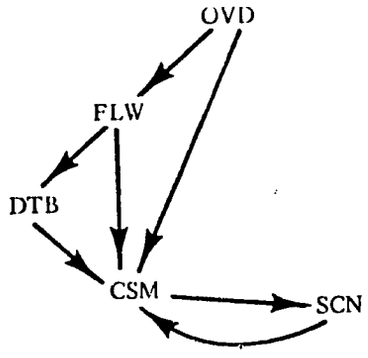


FIGURE 1b



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



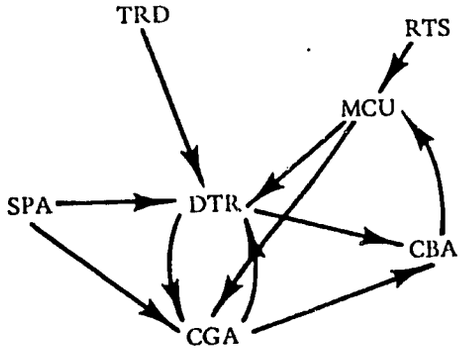
GENERATING AND ANALYZING ALTERNATIVE PLANS OF ACTION

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

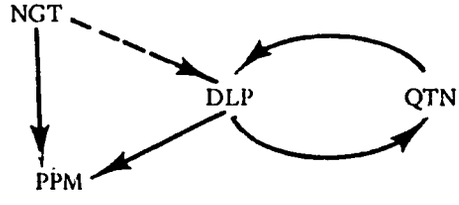
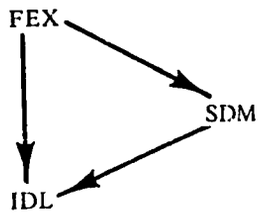


FIGURE 5



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.

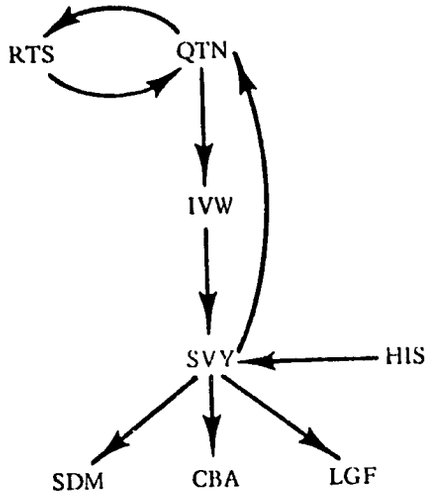
Focusing on function rather than on problems gets people involved in a constructive assessment of what should be, rather than what's wrong and who's to blame. There are sound arguments for both approaches. The IDEALS strategy often comes under attack because its emphasis on normative specification may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

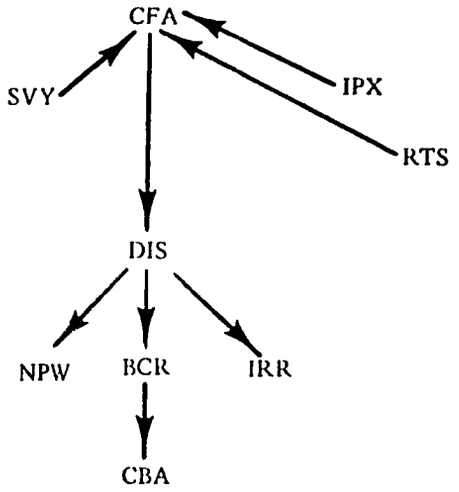
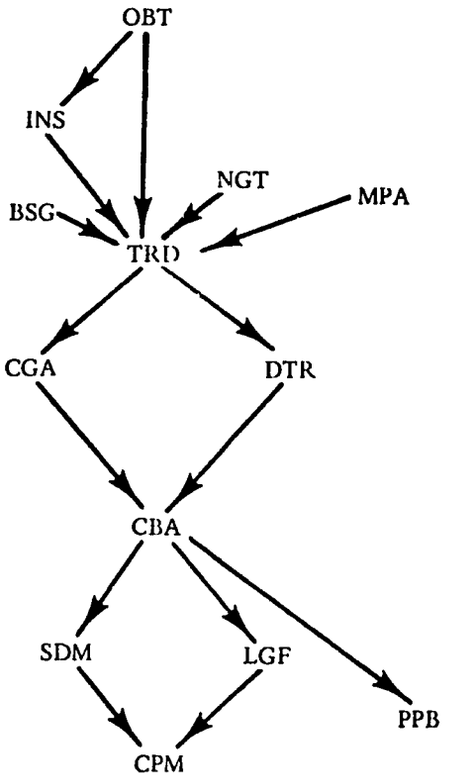


FIGURE 8



THE "CONVENTIONAL" SYSTEMS APPROACH

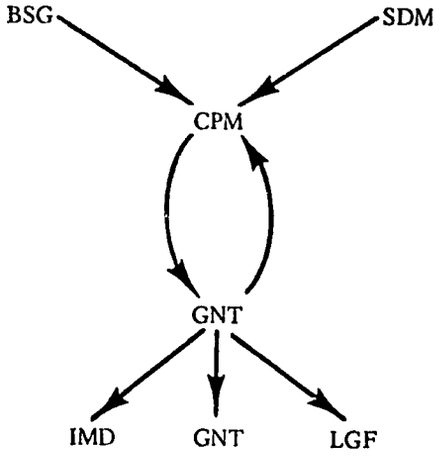
Systems analysis begins with identifying objectives, specifying alternative means, specifying the criteria for selecting among the alternatives, and then synthesizing a system or plan from the choices. A sequence of techniques for applying the systems analysis strategy begins with Objective Trees (OBT, 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.

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

FIGURE 9



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

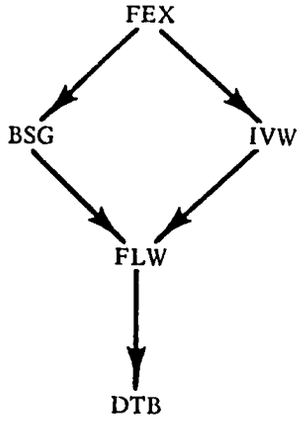
Framework may also be used to sharpen the identification of objectively identifiable indicators of progress. These milestones are shown as vertical lines on specific dates of the Gantt Chart and written on the Critical Path Method network at the appropriate nodes.

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

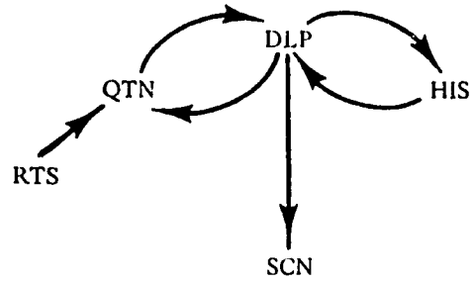


The results of this analysis are presented in the form of flowcharts (FLW, page 107) or decision tables (DTB, page 113). The flowchart uses different symbols to display and analyze complex processes. The decision table presents the decision as a preprogrammed process by specifying the conditions which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

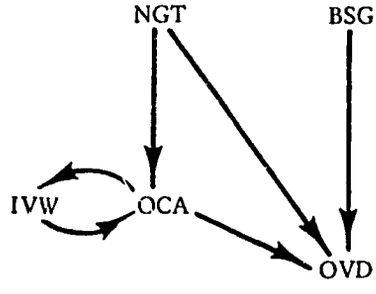


The Delphi technique (DLP, page 168) begins by directing questionnaires to a selected group of prognosticators. The results of each round are summarized for the Delphi group, often in the form of a histogram which aggregates the individual judgments. Rating scales attempt to quantify priorities and opinions.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

Function Expansion

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

Function expansion identifies the *function* of a *system* and relates it to a *function hierarchy*.

USES

Function expansion can be used to:

1) Generate a hierarchy of functions.

2) Select a necessary function in the hierarchy for which a system is to be designed.

3) Communicate and facilitate understanding of the system's function in a hierarchy of systems.

4) Create cohesiveness among group members in moving toward a common function and related project *goals*.

5) Provide input to other tools, e.g., IDEALS Strategy (IDL, page 231).

KEY DEFINITIONS

1) The *function* is the primary concern of a system, e.g., the mission of a project.

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

3) *Function hierarchy* is an ordering of system functions from the most specific to the broadest function (see figure 1).

4) The *goal* of a project is a value judgment which satisfies one or more needs. It measures the effectiveness of achieving a function. For this tool, a goal is typically to minimize costs, maximize profits, or reduce overtime.

SHORT DESCRIPTION

A function expansion is a list of transitive action verbs which describe the functions of systems. A function expansion excludes terms such as "make a profit" or "minimize costs," since these are goals or desired measures of effectiveness for achieving a function. The function of a system describes what a system should achieve; the system output describes what form the achievement takes.

A *function hierarchy* is created from the function expansion list. It corresponds to an expanding perspective on the defined scope of a system – each system is part of a larger system, and so on (see figure 1).

ADVANTAGES

1) Efforts to identify problems with the existing system usually make people defensive and uncooperative. By concentrating on the functions of the system being analyzed or designed, all people may be effectively involved.

FIGURE 1
Function Hierarchy for Employment System

Most Unique Specific Function

1. Provide list of job opportunities
2. Communicate job opportunities to unemployed people
3. Match job specifications with applicant specification
4. Get people and jobs together
5. Find employment for people
6. Fill vacancies in companies and government
7. Have jobs and services carried out
8. Get jobs done
9. Provide services
10. Keep economy functioning
11. Promote general welfare

Most General Function

2) Attention to functions, rather than goals, facilitates alternative idea generation because a goal (as defined above) imples an evaluation criteria. Evaluation must be deferred when generating ideas (see Brainstorming, BSG, page 3).

3) Creativity in developing solutions is encouraged by knowing all the levels in the hierarchy of functions. The decision maker can focus on system function rather than on describing unnecessary current activities.

LIMITATIONS

1) Identifying the real functions of a system may be no easier than identifying problems It requires insight and knowledge about the system.

2) Systems are often composed of many subsystems, each with a variety of functions. Identifying all of them can be taxing. Ordering the function expansion in a hierarchy gives structure or priorities to the functions. There may be no agreement on the final order.

3) Most analysts tend to confuse goals with functions. Specifying a system's goal rather than its function does not really characterize the system's primary concern.

REQUIRED RESOURCES

LEVEL OF EFFORT

A function expansion group exercise must be organized and directed. The Nominal Group Technique (NGT, page 14) is often used to identify functions or purposes, though interacting groups can be used.

SKILL LEVEL

Function expansion group exercises require skill in leadership and experience in group processes. Someone must be able to direct and channel the discussions, avoiding time-consuming digressions about problems and problem identification.

TIME REQUIRED

The time required depends upon:

1) The complexity of the system under study.

2) Previous knowledge of the system or similar systems.

Completing a function expansion typically requires less than a day. In the design process, more time may be required to revise the function hierarchy.

SPECIAL REQUIREMENTS

A group function expansion exercise is facilitated by using a blackboard (or flip chart) and marking pens. Space for posting flip chart pages for easy viewing is desirable.

DESCRIPTION OF TOOL

SUPPLEMENTAL DEFINITIONS

1) A *regularity* is the most frequently occurring (or the most important) condition of several characteristics.

2) *Outputs* are the desired *and* the undesired results of the transformation process of a system. The desired results enable the system to achieve its function.

REQUIRED INPUTS

Developing a function expansion for a system requires:

1) Familiarity with system or source of expressed need.

2) Expertise in leading group processes.

3) Participation of people in the system, users of the system results, experts, and decision makers.

TOOL OUTPUT

A function expansion produces a list of all possible functions of the system, arranged in a hierarchy. This hierarchy can be used as an input to the design of systems using other methods such as the IDEALS Strategy (IDL, page 231).

The hierarchy provides a greater understanding of the system under study and its relation to larger systems, of which the system may be a component.

IMPORTANT ASSUMPTIONS

1) A system is designated as such because it has a function or functions.

2) Every system is part of a larger system.

3) Every system may be divided into subsystems or components.

4) A hierarchy of functions corresponds to the hierarchy of systems (and subsystems).

The System Definition Matrix (SDM, page 67) discusses these assumptions.

METHOD OF USE

GENERAL PROCEDURE

1. **Generate function statements by considering desirable outputs.**
   1.1 Involve concerned people in generating function statements using, for example, a Nominal Group Technique (NGT, page 14). The group should be heterogeneous, involving clients, workers, decision makers, and managers.
   1.2 Define a function statement in the form of a transitive action verb and an object. This allows members of the project group to readily visualize a system's action. Typical functions are:

   Supply services
   Donate manpower
   Distribute health supplies

   1.3 Avoid verbs which imply the movement of the present condition toward a more desirable state. These are more often end goals or objectives, rather than the purpose or primary concern. Some constructions to avoid are:

Increase profits	Optimize material usage
Decrease expenses	Avoid waste
Make money	Increase machine utilization
Improve productivity	

   A function statement is the aim or result "that a system achieves, or is expected to achieve, with no reference to how (who, where, when, etc.) or how well (quantities, qualities) the system operates or is expected to operate" (Johnson, 1975).
   1.4 Avoid tying multiple functions together with words like "and" or "in order to."

2. **Select the most specific primary function of the system.**
   2.1 Select the initial specific function from the list of possible functions by using a comparison test. Ask a question like, "Is the function of the system to (function 1) in order to (function 2) or vice-versa?" For example, is the function of the system to "irrigate fields" in order to "regulate water flow," or is the function to "regulate water flow" in order to "irrigate fields"? Clearly "regulate water flow" is a function of the more narrowly defined system. Similarly, to "irrigate fields" is a more specific function of a system to "grow crops."
   2.2 Write the selected function at the top of a large sheet of paper or flip chart.

3. **Expand the function into a hierarchy.**
   3.1 Ask the group, "What is the most immediate or direct function of this identified function?" For example, the function of the system to "regulate water" is to "irrigate fields." Ask the same question for irrigating fields.
   3.2 Repeat step 3.1 until newly identified functions are beyond the scope of study. The functions are thus arranged in a hierarchy. This process will stimulate the creativity of the group and identify functions that were not on the original list.

4. **Select the function level on which planning and design should concentrate.**
   The recommended solution or system resulting from such efforts should achieve at least this function.

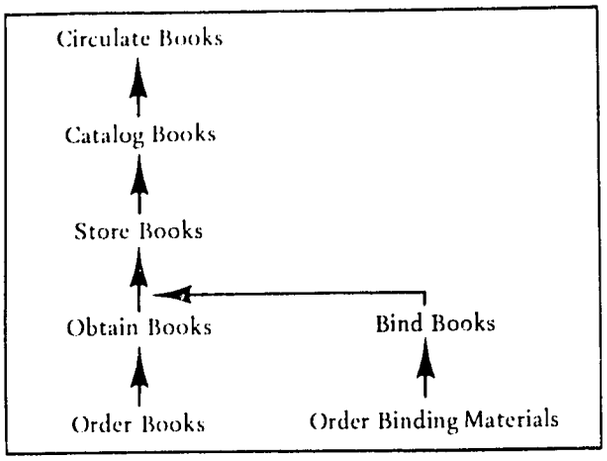
Precautions

1) Do not confuse a goal or end result with a function. "Make a profit" or "decrease poverty" are goals, not functions.

2) Do not branch away from the main function in an attempt to include all possible sub-functions. The function expansion will become too unwieldy. The concept of *regularity* helps avoid this pitfall. If the function expansion is not focussed on the most regular, dominant function in the system, then the expansion may go off on tangential, less important functions.

For example, the function expansion for a library may develop as shown in figure 2. The functions are arranged from the most general to the most specific functions.

FIGURE 2
Forecasting the Function Expansion on the Most Regularly Occurring Concern



3) Do not make big leaps in the function hierarchy. The logical flow from specific to more general functions must be maintained. It is better to be redundant, e.g., rephrasing a function with slightly different words, than to risk being incomplete.

EXAMPLE

A function expansion was to be developed for an employment service system, the initial step in the design of the system. The functions generated in the first step are listed in figure 3. Some were identified as goals rather than functions and were not considered further.

FIGURE 3
Function Expansion List for Employment Service

1) Get people and jobs together
2) Find employment for people
Goal → 3) Reduce unemployment
4) Determine available jobs
5) Determine client job skills
Goal → 6) Increase employment
7) Aid job-seekers
8) Fill vacancies in companies and government
9) Communicate job opportunities to unemployed people
10) Match job specifications with applicant qualifications
11) Provide statistics about unemployment
Goal → 12) Act as a "thermometer" for job needs to advise future careers to students

The most specific function was identified as "to provide list of job opportunities." The function hierarchy was then developed using some of the other functions (see figure 1).

This example is continued in IDEALS Strategy (IDL, page 231).

THEORY

Function expansion is based on the fundamental characteristic of a system: its function (Nadler, 1967). A system is a collection of elements and dimensions which interact to achieve a common function (see System Definition Matrix, SDM, page 67).

Starting with the basic premise that a system is designated as such because it achieves an identifiable function, functions can be identified for a hierarchy of systems. The principle of system hierarchy has two parts:

1) Every system is part of a larger system.
2) Every system can be divided into subsystems or components.

Since each system in a hierarchy of systems has a function, the hierarchy of functions corresponds to the hierarchy of systems. The function hierarchy begins with the most specific primary function and extends to the ultimate, more general function of the largest system of interest (region, state, nation, world, etc.).

Many of these ideas about systems and systems descriptions draw upon the body of knowledge identified as General Systems Theory.

The effectiveness of the group exercise has been supported by empirical research into design strategies (Nutt, 1974).

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Objective Trees

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

The objective tree technique helps to define project *objectives* and provides a way to order them in a hierarchical structure.

USES

An objective tree is used to:

1) Provide a guiding rationale for systems design and evaluation.

2) Indicate how the attainment of sub-objectives contributes to the accomplishment of higher level objectives.

3) Show how objectives for a project are interrelated.

4) Identify criteria for evaluating alternative means.

5) Help assess the level of impact or scope of a project.

6) Provide necessary inputs to other techniques, such as Logical Framework (LGF, page 260) and Planning, Programming, and Budgeting (PPB, page 236).

KEY DEFINITIONS

1) An *objective* is a specific statement of purpose expressing a desired end. The usual form is:

Infinitive + Object + Qualifying Phrases
(see figure 1)

2) A *tree graph* is a set of linked elements where only one link exists between any two factors (see Tree Diagrams, TRD, page 74). The elements in an objective tree are the objective statements or phrases (see figure 1).

3) *Means-ends analysis* is the identification of alternative actions to achieve specified ends.

SHORT DESCRIPTION

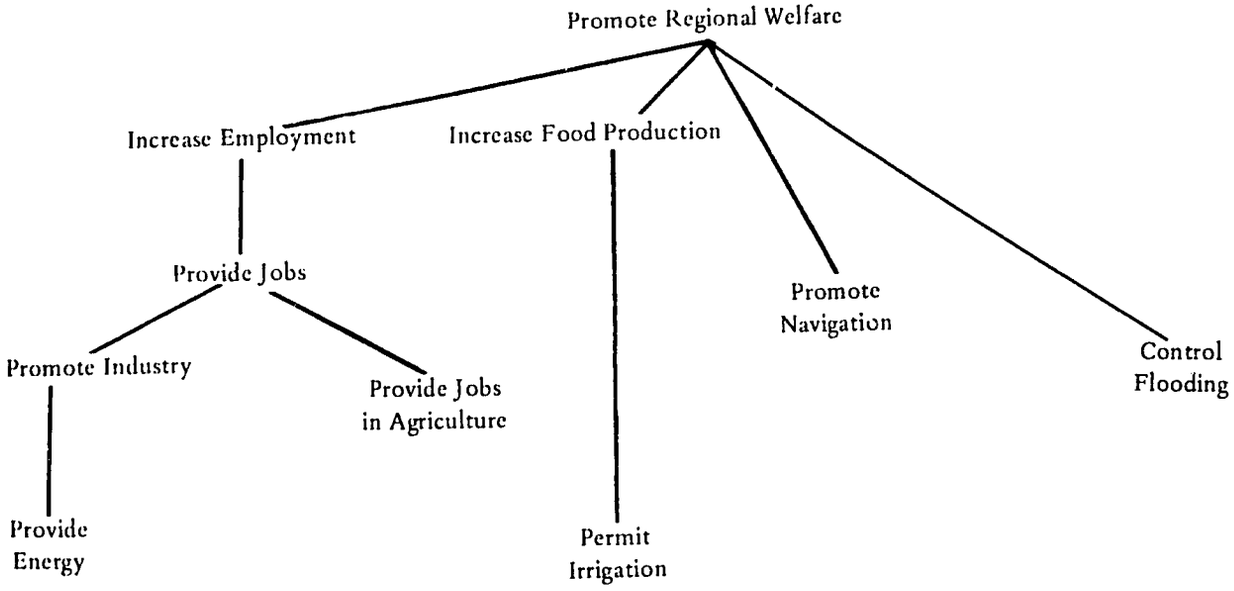
Objective trees may be constructed to aid project design and evaluation. An objective tree consists of project objectives linked hierarchically in a *tree graph*; objectives at a lower level contribute to the attainment of an objective at a higher level (see figure 1). The objectives which are measured to indicate the success of a project are usually found at the lowest level.

Objective trees are one of the many forms of tree diagrams (TRD, page 74) and are closely related to *means-ends analysis*.

ADVANTAGES

1) The objective tree allows a rigorous development of explicit and comprehensive objectives. This helps the design or implementation of a project to achieve the desired ends.

FIGURE 1
An Example of a Partial Objective Tree Developed for a Hydro-Electric Project



2) Since the objectives are made explicit, the diagram is useful to communicate the relationship between objectives to other decision makers and interested groups.

3) Objective trees may incorporate both quantitative and qualitative objectives. Qualitative objectives may be expressed at a lower level of the hierarchy.

4) The process of developing the tree often indicates interlinking or related objectives which might not otherwise be considered.

LIMITATIONS

1) No single objective tree is valid for a particular project. Each person will construct an objective tree in a different manner. There is inherent uncertainty and ambiguity in specifying objectives.

2) The stated and the actual objectives of personnel in an organization may differ significantly. Determining actual objectives is a difficult (if not impossible) task.

3) There may be confusion over means vs. ends. An objective tree structures the statement of goals (or ends) by identifying sub-objective (means) to their attainment.

REQUIRED RESOURCES

SKILL LEVEL

Strong interpersonal skills are useful to successfully obtain the appropriate information for constructing an objective tree. The ability to logically decompose objectives is necessary.

TIME REQUIRED

The time required depends on the ambiguity and uncertainty of the objectives and the level of detail desired for the objective tree. A tree may be constructed within a few hours or over several days, depending on the scope of the project and the clarity of objectives.

SPECIAL REQUIREMENTS

Index cards (or any small uniform blank card) are useful for laying out objectives in a hierarchy.

DESCRIPTION OF TOOL

SUPPLEMENTAL DEFINITIONS

The following definitions are illustrated in figure 2:

1) A *quantitative objective* represents a quantifiably verifiable end or result.

2) A *binary-event objective* either clearly occurs or does not occur.

3) *Qualitative objectives* are judged subjectively to determine if they have been accomplished.

4) A *deterministic measurement* of an objective is where the realization of the objective is unequivocally determined from numerical data.

5) A *probabilistic measurement* of an objective occurs when the attainment of the objective may not be determined with certainty, e.g., because of variability of the data.

6) A *logical measurement* determines whether a binary-event objective has or has not occurred.

7) An *axiological measurement* involves value judgments, where the data necessary to determine accomplishment of an objective are gathered via subjective methods, e.g., interviews (IVW, page 23) or surveys (SVY, page 36).

REQUIRED INPUTS

One step in designing an objective tree involves classifying the types of objectives. Warfield and Hill (1972) classify objectives according to whether they are *quantitative*, *binary-event*, or *qualitative*, as well as by the method used to measure the attainment of the objectives. These classifications are shown with examples in figure 2.

A quantitative objective may be measured either by deterministic or probabilistic methods. A deterministic measurement is made when definite attainment of an objective is determined from numerical data.

A probabilistic measurement is made when the collected data are insufficient to determine with certainty that an objective has been attained. This is the case when data are collected on only a sample of the target population (see Surveys, SVY, page 36).

A binary-event objective clearly occurs or does not occur. Logical measurement is used as a basis for determining whether a binary-event objective has occurred.

Qualitative objectives are those judged subjectively to decide if they have been attained. Axiological measurement, or measurement which is judgmental yet more or less evident, may be accomplished through interviews (IVW, page 23) or surveys (SVY, page 36).

TOOL OUTPUT

The output will be an objective tree which identifies and links objectives (see figure 1). This is essential for other tools, e.g., Intent Structure (INS, page 55) and Planning, Programming, and Budgeting (PPB, page 236).

IMPORTANT ASSUMPTIONS

The major assumption underlying the objective tree is the hierarchical relation between objectives. The objectives for a project may be uncertain or ambiguous because they have not been articulated by the interested parties, and because goals are not constant over time. The objective tree technique assumes that the objectives higher in the tree are less variable over time, and that they are shared by a larger number of interest groups (Granger, 1964).

The assumption that qualitative objectives can be subdivided into quantifiable sub-objectives is implicit in the technique. Its validity does not affect the use of the objective tree to explicitly reveal goals and ends, whether they are measurable or not.

FIGURE 2
Examples of Quantitative, Binary-Event and Qualitative Objectives Classified by Methods of Measurement

Quantitative Objectives

Deterministic Measurement
1. To achieve annual sales of at least $150,000,000
2. To build 150 low-income houses
3. To ship 500 units of the product
4. To increase the school's teacher-student ratio to 40 per 1000
5. To obtain charitable contributions exceeding $100,000.

Probabilistic Measurement
1. To achieve a TV viewing of at least 10 million
2. To produce the product with no more than 1% defective
3. To persuade at least 90% of the drivers to wear seat belts
4. To reduce the crime rate by 50%
5. To increase life expectancy by 10 years.

Binary-Event Objectives

Logical Measurement
1. To land the plane safely
2. To find the lost ship
3. To acquire the new subsidiary
4. To complete construction of the hospital
5. To land a robot on Mars and bring it back safely in this century.

Qualitative Objectives

Axiological Measurement
1. To improve the appearance of the product
2. To provide a pleasant and comfortable ride for passengers
3. To improve the health of the citizens
4. To build a beautiful library
5. To improve employee morale.

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METHOD OF USE

GENERAL PROCEDURE

When beginning the construction of an objective tree, one should not strive for perfection. Initially, getting started is important, for the interaction between objectives cannot become apparent until an initial framework or tree has been constructed. As the tree evolves, one

begins to consider more carefully and refine the tree. Based on the work of Warfield and Hill (1972), the following steps are recommended.

1. Generate an initial list of objectives.
   1.1 Define the problem area.
   1.2 Identify the people who will be involved in designing or directing the project.
   1.3 Elicit their project-related objectives.
   1.4 Identify as many project objectives as possible, without attempting to structure the objectives.

2. Identify an overall objective.
   2.1 Identify an overall objective for the project, to which all other objectives will relate. This objective will reflect a value judgment, and it will need axiological measurement. Examples of such objectives are: "to meet the needs of the community" or "to achieve equality in housing benefits."
   2.2 This objective is positioned at the first level of the tree, i.e., at the top of the tree. All other objectives will be positioned below it.

3. Extend the tree one level down.
   3.1 Select objectives for the next level down from the list generated in step 1, or generate additional objectives by asking "what are the sub-objectives necessary to accomplish these objectives?" This is the branching rule for this type of tree diagram (see Tree Diagrams, TRD, page 74).
   3.2 Draw lines on the tree to connect these lower level objectives to the objective they help achieve.

4. Extend the tree to the next lowest level.
   4.1 Choose one of the objectives listed at the current lowest level of the tree. Identify the sub-objective(s) which help to achieve it.
   4.2 Repeat step 3 for all other objectives at the level most recently constructed. Another level of objectives results when all the objectives in this level are dealt with.

5. Review the tree.
   5.1 Review the tree constructed so far. It may be found that:
      a) Some objectives are missing;
      b) An intermediate level of objectives may be added;
      c) It is possible to extend the tree upwards from the first (top) level; or
      d) An objective at a level is seen to achieve more than one objective at some higher level. In this case, redefinition of the objectives is necessary.
   5.2 If the tree appears complete, go to step 6. Otherwise, return to step 4.

6. Check the measurability of lowest level objectives.
   6.1 Take an objective at the lowest level of the objective tree. Ask the question: Is this objective measurable? This is the stopping rule for the tree diagram. The measurability of an objective depends on two processes:
      a) The selection of a measure or unit by which the attainment of objectives will be assessed. (This measure or unit should be objectively verifiable.)
      b) The design of a measurement scale and data collection process, to aid in determining the degree to which an objective may be reached (see Rating Scales, RTS, page 29).
   6.2 Generally the objectives at the lowest level will be quantitative or binary-event. Quantitative objectives generally have a numerical threshold to indicate what performance is acceptable.
   6.3 If the lowest level objective is not measurable, then extend the objective down one more level, i.e., return to step 4.
   6.4 Repeat step 5 for each of the lowest level objectives.

EXAMPLE

The government of Temasek was considering the construction of a large hydro-electric power project for Mek River Valley. The dam would form a large reservoir with uses other than driving the power plant turbines. In order to understand the alternative objectives of such a large-scale project, the Minister of Planning asked his staff to develop an objective tree.

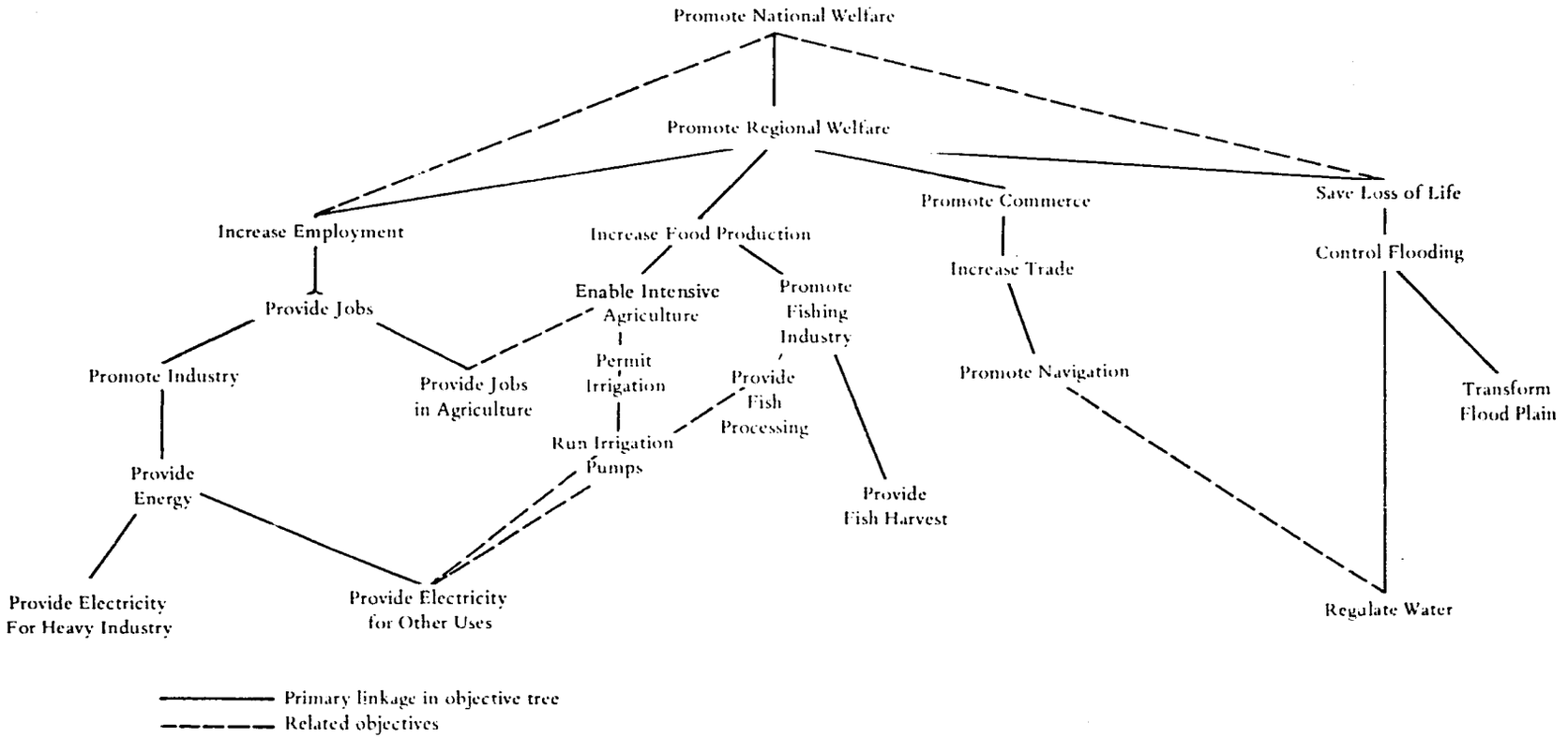
Generating an Initial List of Objectives

The staff identified the problem: provide energy for the growth of the region and country. They assembled a group of industrial leaders, merchants, farmers, and laborers from the region. The Nominal Group Technique (NGT, page 14) was used to identify a list of objectives: provide energy, permit irrigation, promote navigation, control flooding, and promote the welfare of the region.

Identifying an Overall Objective

The group discussed the list and selected the last item as the overall objective. This was the top of the tree. Promoting the region's welfare requires a value judgment since it is not directly measurable. Yet the group shared the view that this was a worthwhile goal.

FIGURE 3
An Example of an Objective Tree Developed for a Hydro-Electric Project



Extending the Tree to Lower Levels

The remaining objectives were positioned in the branches of an objective tree (see figure 1). Then additional objectives were identified, including a higher objective: promote national welfare (see figure 3). This acknowledged that saving lives, increasing employment, and promoting commerce serve higher objectives than those of the region.

One technique for facilitating the construction of the rest of the tree is to list each objective on a separate index card. The index cards may then be laid out on a table to determine their hierarchical relationships. Additional objectives are inserted as needed.

Checking the Measurability of Lowest Level Objectives

The objective tree exercise was completed by considering the measurability of each end of the branches. For example, running irrigation pumps and harvesting fish can be measured quantitatively. However, the transformation of the flood plain is a qualitative objective and must be broken down further in order to identify quantitative measures (e.g., increase in double cropping brought about by farmers who no longer risk flood damage).

Several objectives achieve more than one higher level objective (e.g., providing electricity and regulating water). The staff decided to show the interconnection with broken lines rather than redefining objectives, though the latter may be preferred. Regulating water for irrigation may be at cross-purposes, and the objective tree should reveal this to planners.

This latter point illustrates how the objective tree might be used to influence the scope of the project. The decision makers must decide at which level in the set of objectives the project will be addressed. This in part determines the breadth of of the project, e.g., is the hydroelectric project to address the irrigator's needs as well as the demand for cheap electric power?

This example is developed further in Intent Structures (INS, page 55).

THEORY

The structure of objective trees derives from the theory of graphs and networks (Warfield, 1973). The identification and measurement of the attainment of objectives is rooted in worth assessment and value theory. See, for example, DeNeufville and Stafford (1971).

Interaction matrix diagrams (IMD, page 92) may show the relationships among the multiple objectives. The correspondence between a matrix representation and a tree diagram makes the joint use of the techniques a logical extension of objective trees.

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Intent Structures

PREREQUISITE TOOLS

Objective Trees (OBT, page 49).

USAGE

PURPOSE

An intent structure defines *objectives*, identifies the *owners* associated with each objective, and describes the logical relationships among the objectives.

USES

An intent structure is used in the same manner as an objective tree (see OBT, page 49). In addition, an intent structure:

1) Distinguishes objectives held by various interest groups.

2) Reveals possible conflicts among sub-objectives.

3) Defines alternative objectives in a logically consistent framework.

KEY DEFINITIONS

1) An *owner* is one or more organizations or persons who possess intent for, or have vested interest in, a project. For example, the Ministry of Agriculture's prime objective is the increase of food production; the farmer has an interest in higher farmgate prices.

2) A *logic element* is a symbol indicating the nature of the relationship between two or more objectives at adjacent levels in a hierarchy.

SHORT DESCRIPTION

Objectives for various interest groups, or owners, are defined and arranged hierarchically so that any objective is achieved only if the specified sub-objectives are realized (see figure 1). The owner(s) of each objective is identified on the diagram.

An intent structure may also show the relation among objectives at different levels by connecting *logic elements* (see figure 2). These specify three possible connections: whether all, any, or only one of the sub-objectives must be achieved in order to attain the higher level objective.

An objective tree is simply an intent structure for which all sub-objectives must be realized, and in which the owner of each objective is not designated. Warfield (1973) developed the intent structure to correct deficiencies in the simple objective tree approach.

ADVANTAGES

An intent structure defines the relationships between objectives so that the analyst is encouraged to think about the various interest groups. Consequently, the intent structure may be employed to clarify thinking, to

FIGURE 1
Format for Intent Structure

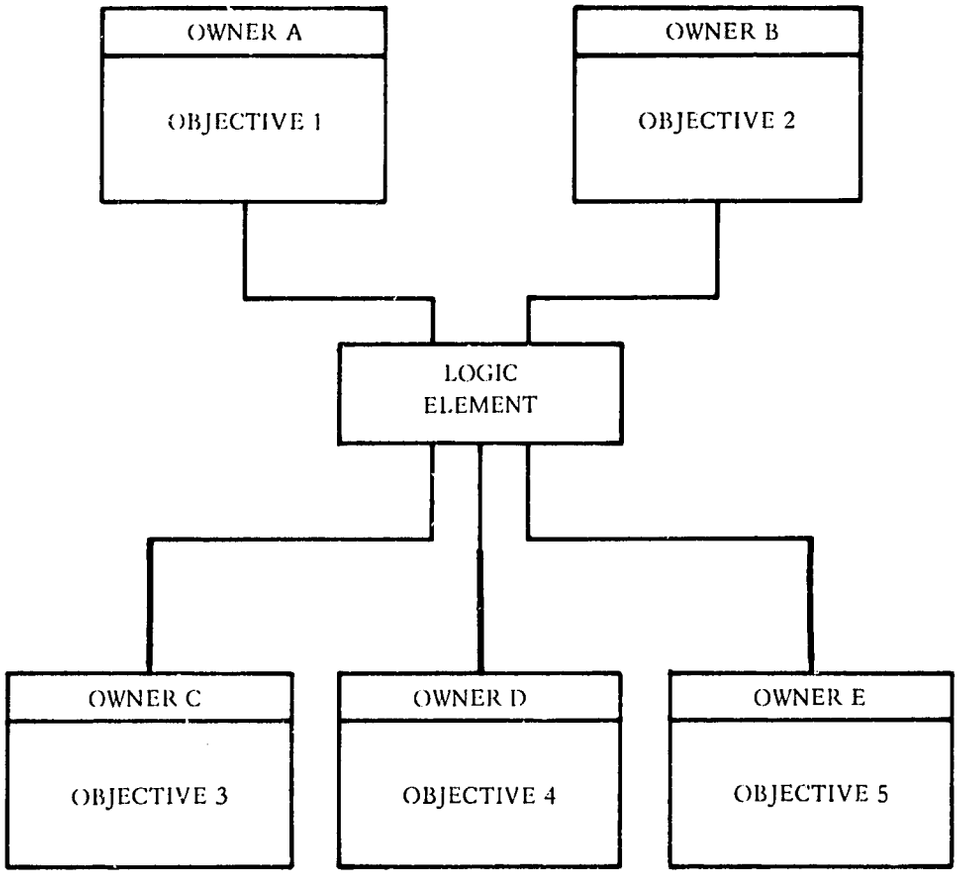


FIGURE 2
Logic Elements for Intent Structures

ELEMENT		LINKING LOGIC
Symbol	Name	For the achievement of the higher level objective:
AND	And	All sub-objectives are necessary
OR	Inclusive Or	Any one or combination of sub-objectives must be attained
XOR	Exclusive Or	Any one, but only one sub-objective must be attained

indoctrinate new personnel, and to identify possible conflicts in objectives.

The logical elements give the analyst the option of describing alternative and interacting objectives, and a means to examine the consistency of relationships.

As the project evolves, the intent structure can be easily modified to incorporate new directions.

LIMITATIONS

There is no single intent structure which is valid for a particular project since people will construct an intent structure differently.

REQUIRED RESOURCES

LEVEL OF EFFORT

The primary task is to identify objectives and associated owners. Representatives of concerned interest groups should be identified for this purpose. The secondary task is to arrange the objectives in an intent structure which reflects the interrelationships of goals.

SKILL LEVEL

In addition to the interpersonal skills necessary to elicit objectives from possibly disparate sources, the analyst must be able to logically sort out the objectives and fill in the missing or unstated sub-objectives. There is no substitute for practice; however, skill at constructing simple objective trees (OBT, page 49) and function expansions (FEX, page 45) is useful.

TIME REQUIRED

If a group discussion technique, e.g., Nominal Group Technique (NGT, page 14) is used to generate objectives, about half a day will be necessary. This does not include the time required to assemble the group. Actual construction of the intent structure should take an additional two to four days, depending on the scope of the project and the number of owners involved.

SPECIAL REQUIREMENTS

The method of construction given in the following sections requires small (3" x 5") cards and tape. Warfield (1973) has developed computer programs for the same purpose.

DESCRIPTION OF TOOL

SUPPLEMENTAL DEFINITIONS

1) The *AND logic element* links sub-objectives to objectives where all sub-objectives must be achieved in order to attain the higher level objective(s) (see figure 3).

2) The *OR logic element* links objectives where the attainment of any one or a combination of sub-objectives will achieve the higher level objective (see figure 4).

3) The *XOR logic element* links mutually exclusive sub-objectives to the higher level objective(s) (see figure 5). One sub-objective alone achieves the higher level objective. Usually the sub-objectives are mutually exclusive only if they are incompatible, or if they compete for the same limited resources.

REQUIRED INPUTS

The intent structure utilizes the input of several people, directly or indirectly associated with the project, to generate the list of objectives. These people and organizational representatives may also be involved in reviewing the finished structure and in modifying it to better reflect their interests relative to the other owners.

TOOL OUTPUT

The most general type of intent structure incorporates both owners and logic elements in a hierarchical structure of objectives (see figure 1). Three modifications are commonly used:

1) The Owner-Free Intent Structure is normally used when the owner is the same throughout the structure, making it unnecessary to list the owner with the objectives.

2) The Logic-Free Intent Structure (or Objective Graph) omits the logic elements from the intent structure. Deletion of the logic may make the intent structure less confusing in some cases, and thus easier to read.

3) The Objective Tree (OBT, page 49) is a special kind of Objective Graph in which the structure of the graph is a tree diagram (TRD, page 74).

IMPORTANT ASSUMPTIONS

Intent structures correct some of the deficiencies which occur when trying to represent complex project objectives as a simple objective tree (see OBT, page 49). However, similar assumptions must hold, i.e., the objectives are discernable and the objectives have some degree of constancy over time. The problem of consensus

FIGURE 3
Use of AND Logic Element

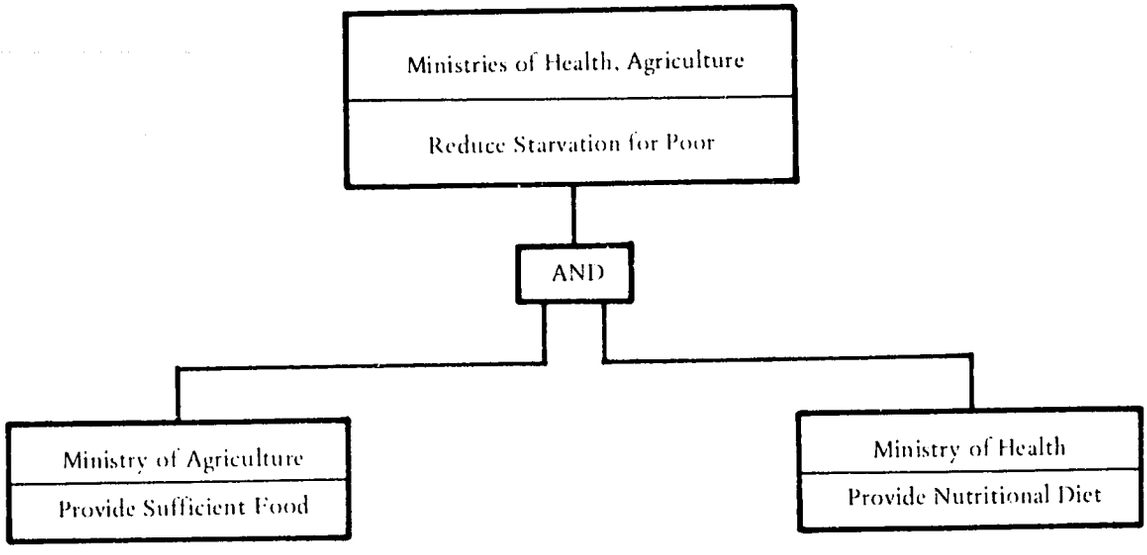


FIGURE 4
Use of OR Logic Element

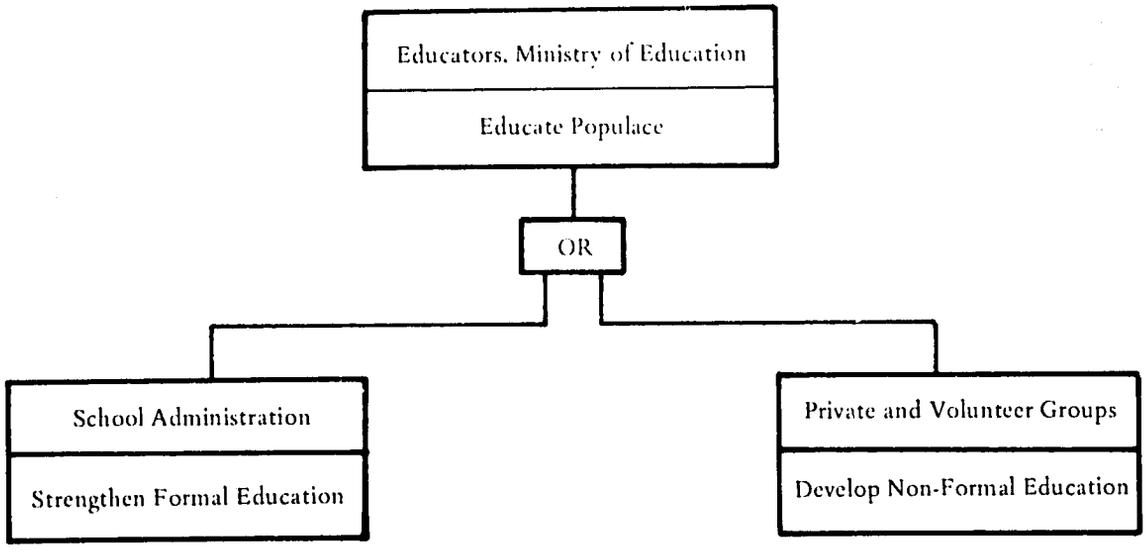
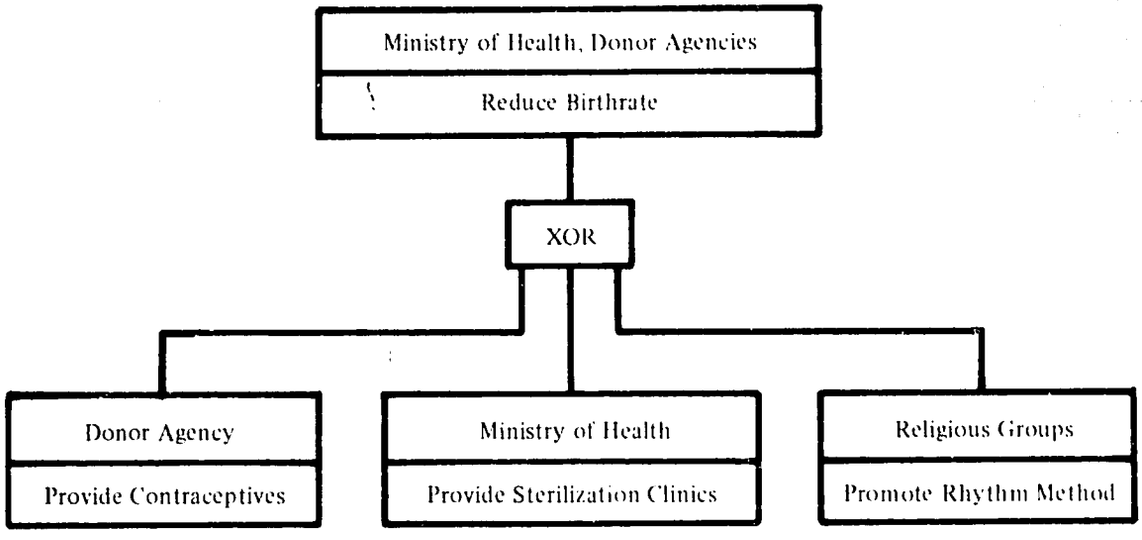
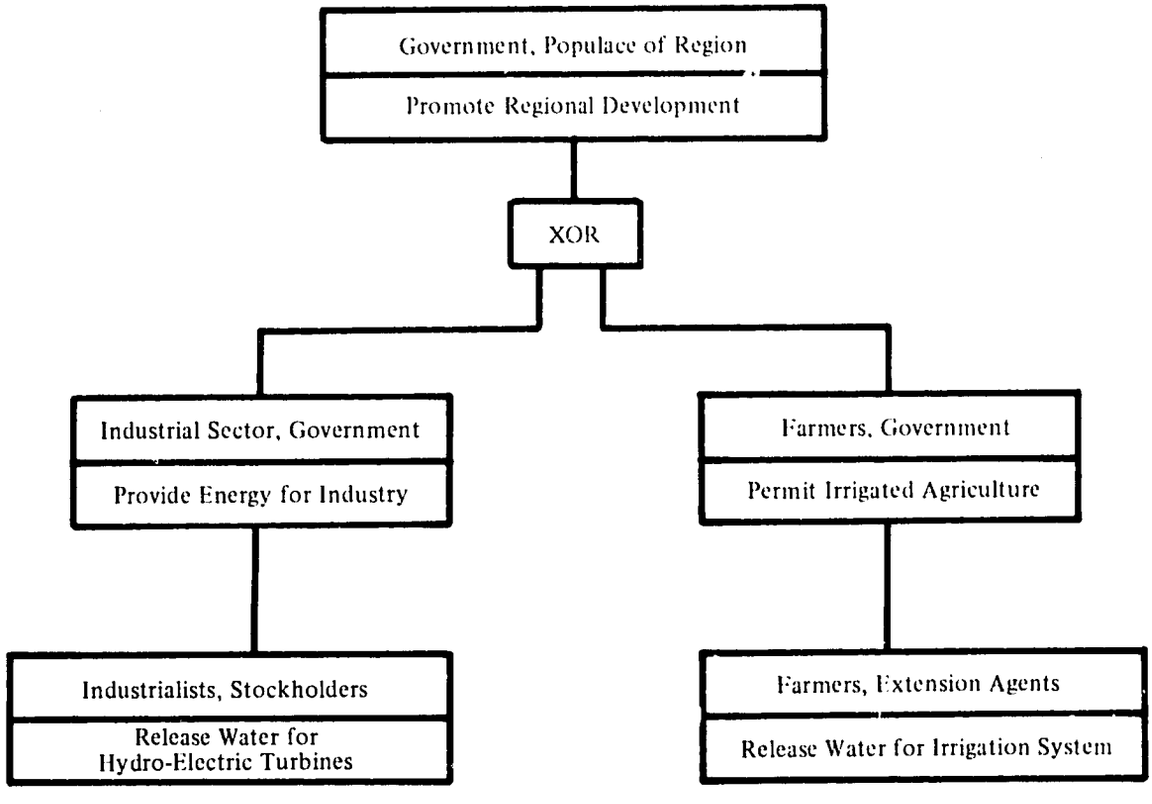


FIGURE 5
Use of the Exclusive OR (XOR) Logic Element

a) Mutually Exclusive Objectives (Means) for Reducing Birthrate



b) Conflicting Objectives for the Use of Reservoir Water



among the various entities associated with the objectives is explicitly treated by identifying owners, assuming that the correct owners can be found.

METHOD OF USE

GENERAL PROCEDURE

Intent structures may be constructed by a procedure similar to the way objective trees (OBT, page 49) are developed (Warfield, 1973).

1. Generate a list of objectives.
   1.1 Identify the owners and owner representatives who have an interest in the project.
   1.2 Generate as many objectives as possible. Make no attempt to structure the objectives. Brainstorming (BSG, page 3) or Delphi (DLP, page 168) may be used to elicit the opinions of the owners/representatives.

2. Construct an intent structure.
   2.1 Write each objective on separate cards and indicate its owner(s).
   2.2 Lay the cards on a flat surface. Begin arranging them in an intent structure. Note:
      a) If objective A must be accomplished in order to accomplish objective B, A lies below B in the structure.
      b) If accomplishment of objective C, either separately or in combination with other objectives, represents an alternative way of accomplishing objective D, C lies below D in the structure.
   2.3 In arranging the cards, begin with any objective level. It is not necessary to begin with the objective at the top of the structure.
   2.4 If, in the process of arranging the objectives, some objectives are missing or are irrelevant, then add new objectives or discard them.
   2.5 Once a suitable arrangement has evolved, tape the cards to a large sheet of paper.
   2.6 Review the intent structure to see if the arrangement is logical.

3. Incorporate the logic elements (optional).
   3.1 Introduce the logic elements into the intent structure by asking if all, any, or only one of the linked sub-objectives must be met in order to attain each objective higher in the structure.
   3.2 Re-examine the owners associated with each objective in light of the logical links between sub-objectives.
   3.3 If necessary, redraw the diagram for distribution to others (e.g., representatives of "owner" organizations). Include a simple key for the logical elements (see figure 2).

EXAMPLE

An objective tree was developed for a hydro-electric reservoir project (see OBT, figure 3, page 53). The objectives for the project included generating energy, permitting irrigation, promoting the fishing industry and navigation, and saving lives and damage through flood control.

An intent structure was prepared which expands on the original objective tree (see figure 6). It included some of the owners of the objectives and the logic elements relating the sub-objectives to higher level objectives. The owners of each of these objectives could be identified in most cases, e.g., farmers desiring irrigation, shippers wanting navigation facilitated, the government and citizens wanting jobs.

All the higher level objectives were brought together under the objective "PROMOTE THE REGIONAL WELFARE" through the logical "OR" relation. Regional welfare is promoted by achieving any one or more of the sub-objectives. However, one might argue that the logic element should be an "exclusive OR" (XOR) because sub-objectives are conflicting. For example, releasing water for irrigation may be completely counter to providing a uniform flow for turbines. The competition between certain sub-objectives can be shown on the intent structure using the logic elements which connect the objectives.

THEORY

Intent structures have been developed by Warfield (March, 1973a), supported by the Battelle Memorial Institute.

Warfield (April, 1973) applies the intent structure technique to the analysis of a U.N. Document, "Towards Accelerated Development: Proposals for the Second United Nations Development Decade," published in 1970. Warfield's intent structure reveals ways to build on a committee planning approach "as well as some of the weaknesses of its [the committee's] product" (page 8-1). In particular, Warfield examines the logic and consistency of the relations among the stated objectives.

This application of the technique emphasizes the utility of the intent structure as a basis for logical analysis of project purposes and goals. The logical relationships between objectives permit the structuring process to be automated on a computer (Warfield, March 1973b). Then, through computer manipulations, the hierarchical relationships are constructed by synthesizing the simple subjective judgments of the relationship between each two objectives. These latter judgments are still the domain of humans, as is the identification of objectives. These points are explored further in Interaction Matrix Diagramming (IMD, page 92).

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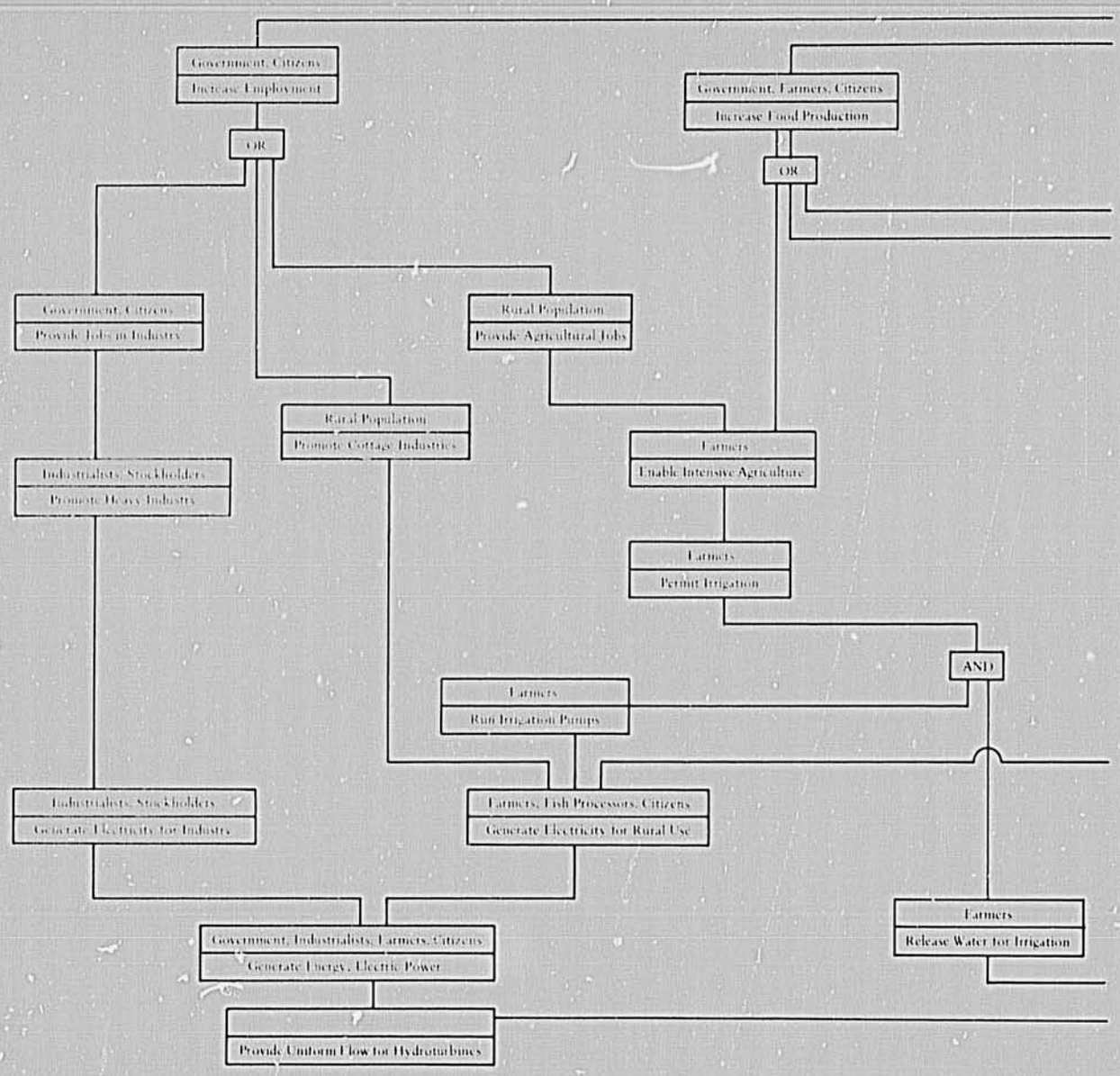
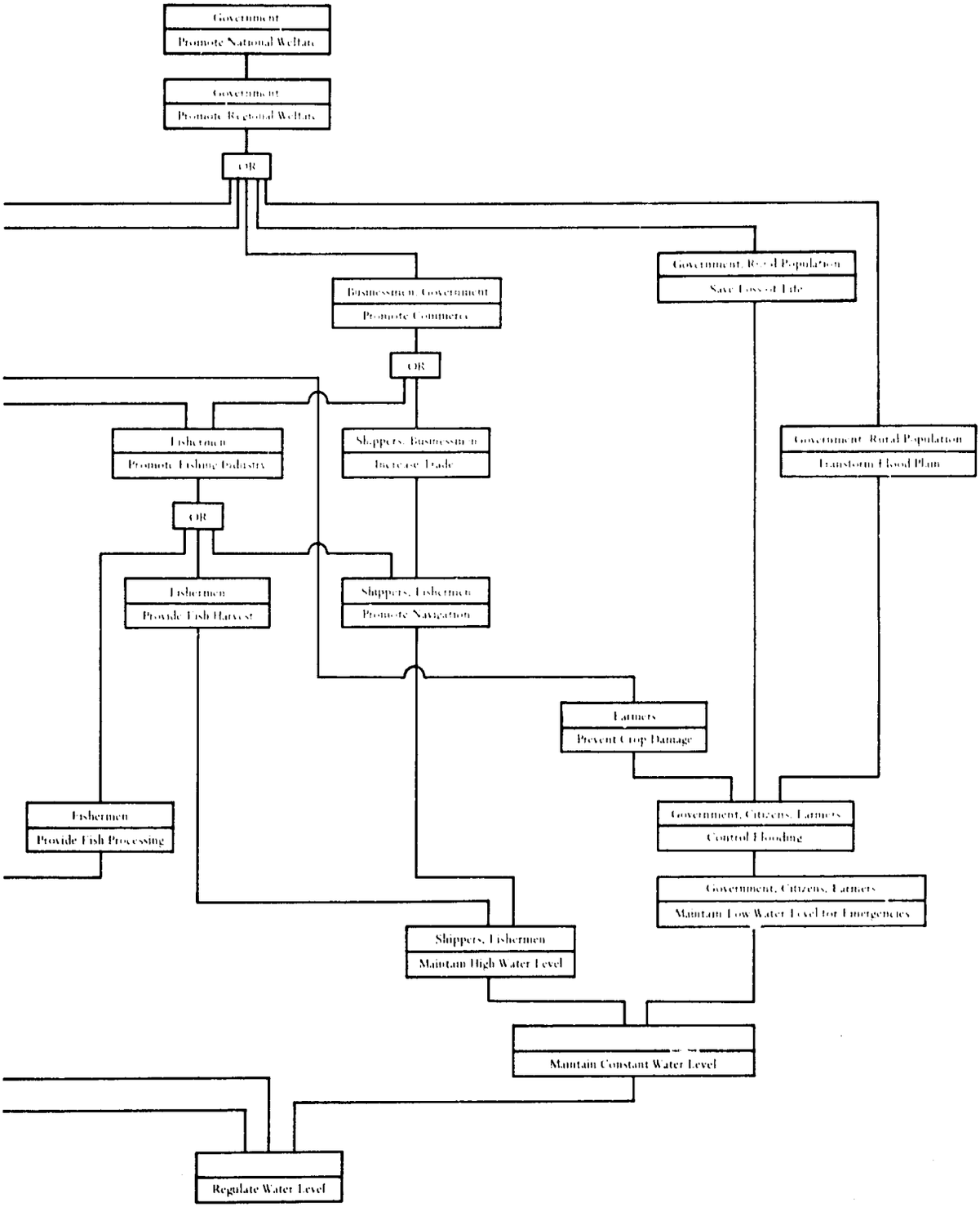
FIGURE 6
Intent Structure for Hydro-Electric Reservoir Project




Government
Promote National Welfare
Government
Promote Regional Welfare
OR
Businessmen, Government
Promote Commerce
Government, Rural Population
Save Lives of Life
OR
Fishermen
Promote Fishing Industry
Shippers, Businessmen
Increase Trade
Government, Rural Population
Transform Flood Plain
OR
Fishermen
Provide Fish Harvest
Shippers, Fishermen
Promote Navigation
Farmers
Prevent Crop Damage
Fishermen
Provide Fish Processing
Government, Citizens, Farmers
Control Flooding
Government, Citizens, Farmers
Maintain Low Water Level for Emergencies
Shippers, Fishermen
Maintain High Water Level
Maintain Constant Water Level
Regulate Water Level

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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