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9. ABSTRACT
(DEVELOPMENT R&D) Chapter 9 discusses six techniques which do not fall within the categories of the other chapters. Two (Program Planning Method and IDEALS Strategy) are comprehensive approaches to project design and implementation. Program Planning Method provides ways to identify and define problems, specify program alternatives to solve the problems, and select and detail programs. The Ideal Design of Effective and Logical Systems (IDEALS) Strategy provides approaches for designing systems and planning for their implementation, for studying problems, and for generating alternative solutions to a problem. A formal system for planning and management (Planning, Programming, and Budgeting) is also described; PPB may be used to plan a program with emphasis on its goals, to prepare a budget that lists expenditures and evaluates outputs according to goals, and to choose from among several projects which meet program goals when resources are limited. Two techniques (Critical Path Method and Gnatt Charts) are described which aid the planning, implementation, and management of complex projects. The Critical Path Method diagrams the sequence of necessary actions for a project and describes the necessary actions needed to complete a project. The time required for each activity is estimated, ~~and the estimated,~~ and the total time for completion of the project and the critical activities in the process can be estimated. Gnatt Charts schedule projects according to available resources and allow project managers to schedule resources and staff assignments against the planned project sequence of activities. The final technique (Logical Framework) is a test approach to planning, documenting, and evaluating projects. Logical Framework has been widely used by USAID Missions to aid in planning a project, to provide measures to evaluate a project, and to state assumptions about casual linkages.

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Planning, Controlling, and Evaluating Projects

Program Planning Method
IDEALS Strategy
Planning, Programming, and Budgeting
Critical Path Method
Gantt Charts
Logical Framework

Several techniques have been selected which do not fall exclusively within any of the major purpose categories. Two (Program Planning Method and IDEALS Strategy) are comprehensive approaches to project design and implementation. A formal system for planning and management (Planning, Programming, and Budgeting) is also described.

Successful implementation and management of complex projects depend on careful attention to details in the planning stage. Diagramming the sequence of necessary activities (Critical Path Method) and scheduling according to available resources (Gantt Charts) assist this process.

Evaluation of a development project must begin with design. The final technique (Logical Framework) is a test approach to planning, documenting, and evaluating projects. Attention is directed to the logical assumptions and verifiable indicators of project achievement.

All these techniques are unified in their attention to planning for implementation, stressing systematic analysis, and emphasizing results.

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Foreword

This is a *toolbook*.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

William J. Siffin
Director
IDI/PASITAM
June 1977

Preface

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

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

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

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

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

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

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

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

Peter Delp
Nairobi, 1977

Acknowledgments

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

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

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

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

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

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

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

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

The Authors

Abbreviations

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

Introduction

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

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

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

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

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

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

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

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

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

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

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

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

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

APPLYING A SYSTEMS APPROACH

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

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

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

TOOL DESCRIPTIONS

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

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

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

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

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

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

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

USING THE SYSTEM TOOLS HANDBOOK

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

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

DEVELOPING SYSTEM MODELS

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

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

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

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

FIGURE 1a

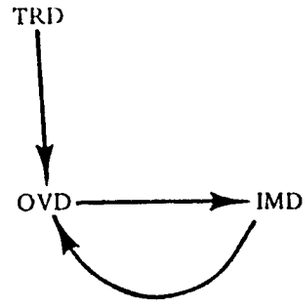
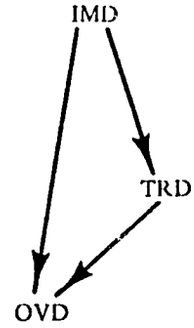
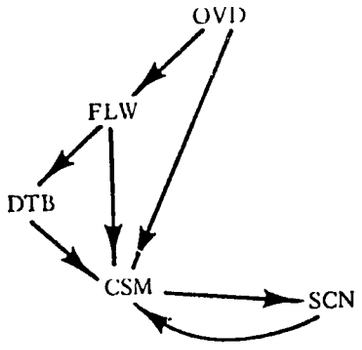


FIGURE 1b



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

FIGURE 2



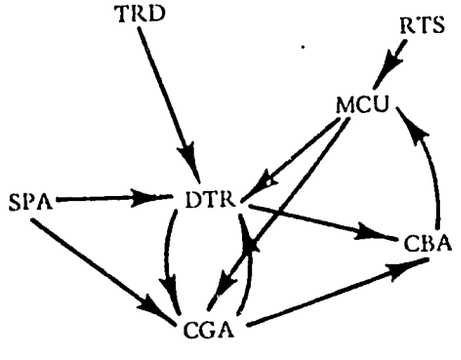
GENERATING AND ANALYZING ALTERNATIVE PLANS OF ACTION

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

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

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

FIGURE 3



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

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

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

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

A NORMATIVE APPROACH TO PLANNING

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

FIGURE 4

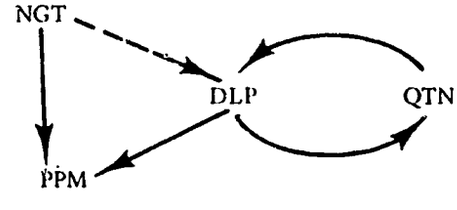
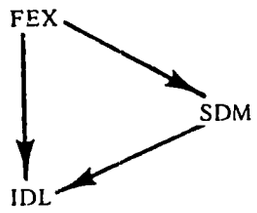


FIGURE 5



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

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

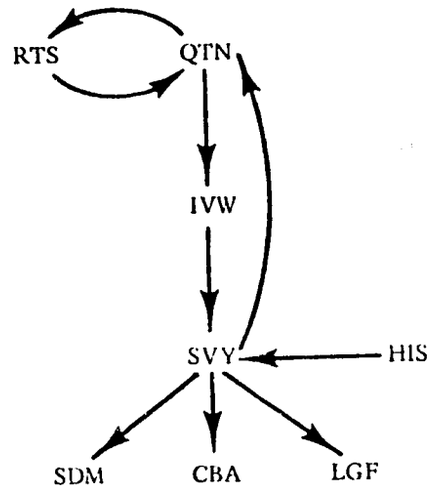
Focusing on function rather than on problems gets people involved in a constructive assessment of what should be, rather than what's wrong and who's to blame. There are sound arguments for both approaches. The IDEALS Strategy often comes under attack because its emphasis on normative specification may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

USING SAMPLE SURVEYS TO GATHER INFORMATION

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

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

FIGURE 6



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

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

PROJECT FINANCIAL ANALYSIS

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

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

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

FIGURE 7

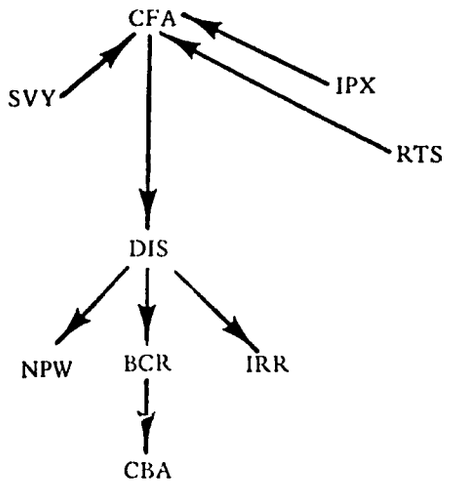
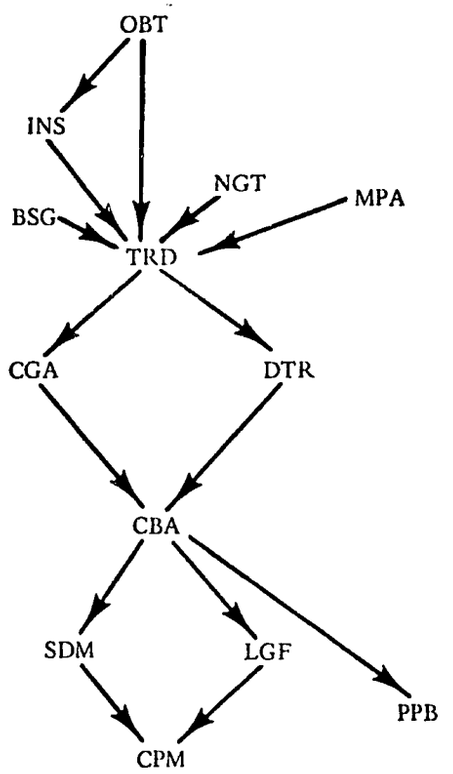


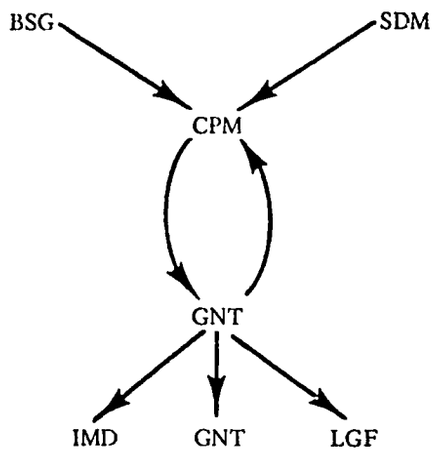
FIGURE 8



THE "CONVENTIONAL" SYSTEMS APPROACH

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

FIGURE 9



PLANNING PROJECT ACTIVITIES FOR IMPLEMENTATION AND CONTROL

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

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

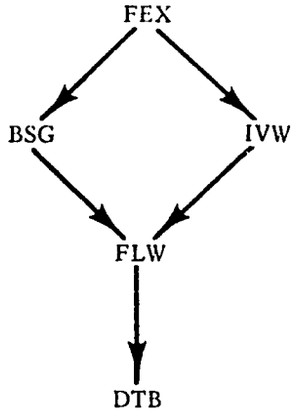
Framework may also be used to sharpen the identification of objectively identifiable indicators of progress. These milestones are shown as vertical lines on specific dates of the Gantt Chart and written on the Critical Path Method network at the appropriate nodes.

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

ANALYSIS AND PROGRAMMING OF DECISION PROCESSES

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

FIGURE 10

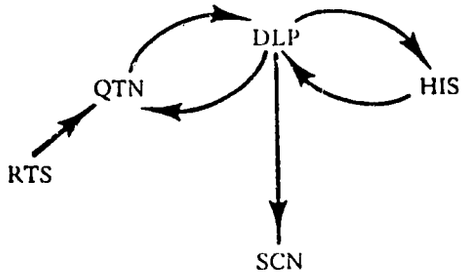


The results of this analysis are presented in the form of flowcharts (FLW, page 107) or decision tables (DTB, page 113). The flowchart uses different symbols to display and analyze complex processes. The decision table presents the decision as a preprogrammed process by specifying the conditions which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

QUALITATIVE FORECASTING

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

FIGURE 11

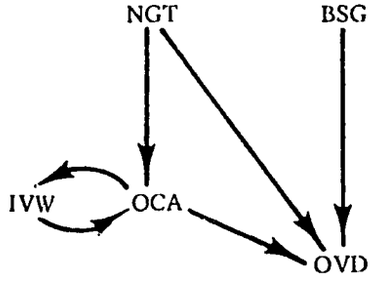


The Delphi technique (DLP, page 168) begins by directing questionnaires to a selected group of prognosticators. The results of each round are summarized for the Delphi group, often in the form of a histogram which aggregates the individual judgments. Rating scales attempt to quantify priorities and opinions.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

PROBLEM ANALYSIS STRATEGIES

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

FIGURE 12



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

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

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

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

CONCLUSIONS

This volume is a collection of techniques drawn from a variety of disciplines and presented in a standard format in order to bring together various means to a common end—better development project design. The organizing theme is a systems approach to project planning. The techniques are means to 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.

Program Planning Method

PREREQUISITE TOOLS

Nominal Group Technique (NGT, page 14).

USAGE

PURPOSE

Program Planning Method provides a comprehensive approach to:

1) Identify and define problems.
2) Specify program alternatives to solve the problem.
3) Select and detail programs.

USES

The Program Planning Method is used to:

1) Coordinate the best use of experts, decision makers, and client/citizens in the planning process.

2) Plan programs in different fields, such as health, urban, and educational planning.

3) Develop consensus in group decision making when people from widely different backgrounds are involved.

4) Legitimize decisions in the minds of the public in order to increase public acceptance of programs.

SHORT DESCRIPTION

Program Planning Method is a systematic and structured planning strategy involving clients or consumers, experts, and decision makers in group processes. The Nominal Group Technique (NGT, page 14) is used in three stages. First, a number of client-problems are identified and rank-ordered. Second, this list is used to generate possible solutions. Resources needed to implement the solution are also listed. Third, the group arrives at the final program.

ADVANTAGES

The originators of the Program Planning Method strategy (Delbecq and Van de Ven, 1971) claim that it:

1) Organizes client, consumer, or community participation.

2) Increases the legitimacy of the program in view of the recipients' (clients/citizens) involvement.

3) Decreases potential resistance to the implementation of the program.

4) Increases the program's effectiveness because all concerned parties participate in the design.

5) Facilitates proper problem identification and reduces the chances of solving the wrong problem.

6) Facilitates the use of outside experts in the planning process.

7) Incorporates the advantages of the Nominal Group Technique (see NGT, page 14).

LIMITATIONS

1) The participation of consumer and client groups may be unfeasible either financially or logistically.

2) The role of the group leader is more important than in single applications of the Nominal Group Technique. The same leader is often in charge of three different groups and thus can control the success of the exercise.

3) Client/citizen participation may have a negative effect on the planning process, e.g., premature expectations may arise.

4) The highly structured nature of the Program Planning Method may stifle effective participation. (See Nominal Group Technique, NGT, page 15, for related limitations.)

REQUIRED RESOURCES

LEVEL OF EFFORT

Members of client groups, experts, and other concerned people must be identified, and the group sessions must be arranged and conducted. This may pose problems of logistics and requires planning.

SKILL LEVEL

Considerable skill is required to direct the Program Planning Method. The group leader must be able to 1) understand and break down the planning process into a discrete series of workable phases; 2) identify and integrate the target reference groups in each phase; and 3) direct the groups so that they perform effectively.

TIME REQUIRED

The Program Planning Method requires three or more sessions of one half day each. There may be a gap of a few days between the sessions. Lead time is needed for organizing groups and meetings.

SPECIAL REQUIREMENTS

The Program Planning Method strategy requires:

1) A meeting room where groups can cluster around a table.

2) Index cards to record the group members' ideas and preferences.

3) Flip charts with large sheets of paper, marking or felt pens, and tape.

DESCRIPTION OF TOOL

DEFINITIONS

1) A *solution component* is the part of a program that is proposed as the solution, e.g., a mobile medical unit in a health care program.

2) *Rank-ordering* is the process of weighing one item against others and then ordering the items by weight on a scale such as importance or priority.

REQUIRED INPUTS

Program Planning Method requires a knowledge of:

1) The problem area, e.g., urban renewal, health care delivery.

2) The target area, e.g., a region, a community, or an ethnic group.

The method also requires that user groups, experts, and decision makers participate.

TOOL OUTPUT

1) A list of consumer or client problems ordered to indicate priorities.

2) Specification of the problem to be solved.

3) Specification of the program designed to solve the problem.

IMPORTANT ASSUMPTIONS

Program Planning Method assumes that problem identification is necessary before planning a program. The best qualified people to identify the problem are the groups affected by potential programs or current inadequate programs. These people are brought together with planners and program personnel to identify problems and to rank them.

Program Planning Method is also based on assumptions regarding change processes in organizations, and the best use of experts in the process (see Delbecq and Van de Ven, 1971).

METHOD OF USE

GENERAL PROCEDURE*

1. **Organize the client group.**
   - 1.1 Identify a cross section of clients or consumers in the program area. Include members of different ages, locations, technical abilities, etc., depending on the nature of the problem or service. For example, in the development of an employment service, the client group would include potential employers, the currently unemployed, the currently employed, and retired people.
   - 1.2 Select a group (usually between 30 and 50 people) that will represent the client population.

*The procedure recommended by Delbecq (1971) should be followed closely by the program planner and group leader.

1.3 Organize a group meeting to discuss common problems in the program area.

2. Identify problems.
   2.1 Divide the group into subgroups of six to nine members according to a common characteristic, e.g., age.
   2.2 Indicate that the decision makers want to understand clients' views.
   2.3 Instruct the group in Nominal Group Technique (NGT, page 14). Stress that the meeting should produce a list of problems not solutions.
   2.4 Request members to list "personal" problems in the program area on one side of the index card and "organizational" problems on the other side. For example, a client in the improvement program for an employment service may list "I do badly in oral interviews" as a personal problem and "the job opportunity list comes too late" as an organizational problem.
   2.5 Let the members list ideas silently for about 30 minutes.
   2.6 Record the generated items on a flip chart one for each subgroup.
   2.7 Using the Nominal Group Technique rank-ordering voting procedure, select the top five priority items on the flip chart.
   2.8 Explain that some members will participate further in development of the program. Have them select three or four representatives.

3. Generate program ideas.
   3.1 Identify external technical and organizational experts whose skills relate to the listed priority items. Identify internal experts from the principal organization connected with implementation of the program.
   3.2 Arrange a group meeting to include these experts and the group's representatives. Explain Nominal Group Technique to them.
   3.3 Prepare and display the list of priority problems generated by the client group and explain each item.
   3.4 Instruct the group to prepare a list of *solution components* and the resources required to implement them. The list should be in two parts: 1) those items currently available and easily procured (written on one side of an index card), and 2) those items to be developed (written on the other side of the card).
   3.5 Allow the members to write silently for about 40 minutes.
   3.6 Compile the lists and display them on a large flip chart.
   3.7 Following a five to ten minute break, reassemble the group and discuss each item briefly.
   3.8 Using the rank-ordering voting procedure, select the components and resources considered to be essential.
   3.9 Explain the rest of the Program Planning Method and have participants elect representatives for further sessions.

4. Generate specific program alternatives.
   4.1 Identify the key administrators and resource controllers who were listed by the second group.
   4.2 Present the program ideas and instruct the group to work out specific alternative programs from the idea list.

5. Design the program.
   5.1 Organize a meeting of representatives from client and expert groups, decision makers, and resource controllers.
   5.2 Present details of alternative programs from step 4 and discuss them briefly.
   5.3 Conduct nominal group voting to arrive at the final design.
   5.4 If a consensus or significant agreement cannot be reached, repeat steps 4 and 5 after a few days delay.
   5.5 The final solution should be satisfactory to all concerned.

EXAMPLE

Though Program Planning Method has only recently been developed, its use has been varied. For example, it was used by the Governor's Task Force for Planning Health Services in the State of Wisconsin in 1972. It was also used by a health planning agency in Texas in 1973 to design health service programs.

THEORY

Delbecq and Van de Ven (1971) developed the Program Planning Method at the University of Wisconsin's Graduate School of Business. The method extends experimental and field research on the use of the Nominal Group Technique to planning processes.

The technique is rooted in empirically derived theories of organizational change processes which specifically ad-

dress the scheduling of client participation and the utilization of multi-disciplinary expertise (see Delbecq, Van de Ven, and Gustafson, 1975).

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IDEALS Strategy

PREREQUISITE TOOLS

Function Expansion (FEX, page 45) and System Definition Matrix (SDM, page 67).

USAGE

PURPOSE

The IDEALS (Ideal Design of Effective and Logical Systems) Strategy provides a comprehensive approach for solving problems by specifying *systems* to achieve a desired *function*.

USES

The IDEALS Strategy can be used to:

1) Design systems and plan for their implementation.
2) Provide a conceptual framework for studying problems.
3) Generate alternative solutions to a problem.
4) Develop products or services.

KEY DEFINITIONS

1) An *ideal system target* 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.

2) *Regularity* is the most frequent or dominant (and occasionally the most important) condition of concern to the project design.

SHORT DESCRIPTION

The emphasis in the methodology is first on "why" and then on "how" the system operates. The function of the system is determined by using Function Expansion (FEX, page 45); and an *ideal system target* for the units or regularity which will meet the function is developed. With this ideal system target as a guide, alternative systems, which incorporate necessary irregularities, are developed which are as close to the ideal as possible. One of these is recommended for implementation, and the details are then specified using the System Definition Matrix (SDM, page 67). The process of implementation is suggested, and measures of evaluation are established.

ADVANTAGES

1) A key concept is to develop an ideal system before specifying the feasible solution. Thus, innovative and effective systems are likely to be developed, rather than patched up versions of existing systems or solutions.

2) Thinking is not inhibited by the recorded characteristics of the current system. The emphasis in IDEALS Strategy is on the function of the desired system rather than on improvement of the current system.

LIMITATIONS

1) The concept of what is ideal or optimal may be difficult for some people to comprehend and apply.

2) The function of a system may not be easily identifiable (see Function Expansion, FEX, page 45).

REQUIRED RESOURCES

LEVEL OF EFFORT

The design process often involves a group of people working on a problem. The effort required is directly proportional to the magnitude and complexity of the problem at hand. Effort is required to expand the system function, to develop an ideal system, and to recommend the feasible solution.

SKILL LEVEL

Some knowledge about the problem area is necessary to solve a problem using the IDEALS Strategy. No special skills are necessary to understand or use the approach. Repeated use of IDEALS Strategy in different contexts enhances its effectiveness.

TIME REQUIRED

The time required is proportional to the magnitude and complexity of the problem being solved. Typically, less than a week is required for preliminary design of products, more than a week for service systems involving people.

DESCRIPTION OF TOOL

REQUIRED INPUTS

The decision maker must have knowledge of the problem area and a statement of the problem at hand.

When solving a problem by the IDEALS Strategy, it may be necessary to use tools such as Brainstorming (BSG, page 3) or Cost-Benefit Analysis (CBA, page 212). Knowledge of such tools or access to an analyst may be needed.

TOOL OUTPUT

The recommendation of a solution is the primary output. The recommended system can be specified in the form of a System Definition Matrix (SDM, page 67). Use of IDEALS Strategy also provides insight into the problem.

Figure 1 gives an example of a possible output for a job information system.

FIGURE 1
Function Hierarchy for IDEALS Strategy

Function Hierarchy

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 industry and government
7. Have jobs and services carried out
8. Get jobs done
9. Provide services
10. Keep economy functioning
11. Promote general welfare

*Function level selected for design of the system.

NOTE: The hierarchy lists the functions from the most unique function at the top to the most general at the bottom.

IMPORTANT ASSUMPTIONS

The IDEALS Strategy assumes that when developing alternatives, creativity is improved by focusing on function and an ideal situation rather than on the problems and limitations of the existing system. The strategy also assumes that functions can be clearly identified for all systems, and that ideal systems are conceivable. However, "ideal" implies optimization, and optimizing a system for all possible conditions is not feasible, hence the *regularity* concept.

METHOD OF USE

GENERAL PROCEDURE

1. Determine the function.

1.1 The function of the system to be developed is identified by using function expansion (FEX, page 45). A hierarchy of functions is developed, and a level in the hierarchy is chosen as the appropriate function for the system.

1.2 Determine the measures or criteria of the system's effectiveness. Select those measures considered necessary and important to ensure the elimination of unnecessary constraints and conditions in the design.

2. **Develop ideal systems targets.**
   2.1 First, try eliminating the function chosen in step 1 to review the necessity of the function and to make certain that only required systems are developed. Preview the function hierarchy and check to see if a different (usually higher) function level may be more appropriate.
   2.2 Identify regularities, which are the primary concern or the most frequent characteristics of the system. The focus on regularities addresses the consistency of the ideal situation. For example, in an irrigation project most of the dry land is on the north side of the river. The regularity concept argues for ignoring the opposite side in initial planning. When an educational system is being designed for a region where a small part of the population is bilingual, the regularity concept recommends that planning begin with instruction given only in the language spoken by the majority.
   2.3 Develop guidelines for the ideal system target based on the identified function and agreed upon measures of effectiveness. For example, some guidelines developed for the design of a fertilizer distribution system may be "least cost of transportation," "most equitable distribution," and "least consumption of fertilizer per unit of food produced." Differentiate between the ideal concepts that are feasible and those that are not currently feasible due to technical or theoretical considerations. Select only those ideal values that are feasible.
   2.4 From the guidelines above, develop appropriate ideal systems. Select one as the ideal system to be the target for subsequent design.

3. **Develop the system to be recommended.***
   3.1 Obtain information concerning the questions raised during the development of the ideal system target. Experiments or analytical calculations may be necessary. The purpose is to determine those facets of the ideal system which need to be altered and those which can remain as they are.

*The ideal system target developed relates only to the regularity conditions. This step takes care of the irregular conditions while staying as close to the ideal system target as possible.

FIGURE 2
Identifying Measures of Effectiveness, Regularities, and Ideal Concepts

a) Measures of Effectiveness - Criteria

Amount of delay in getting employer and applicant together
Cost of arranging the meeting for employer, for applicant, for the agency
Ratio of vacancies to applicants
Ratio of number job applicants matched to number of applicants
Number of interviews per successful match
Total number of clients served

b) Regularities

Applicants come to agency requiring jobs
Applicants are unemployed
  Exception: applicants want reassignment
Employers come to agency expressing need for applicants
  Exception: agency to canvas prospective employers
The output of the agency is the arrangement of interviews
  Exception: physically bring together two parties or be present at the interview

c) IDEALS Concepts

No delay in finding jobs for applicants or applicants finding jobs
Obtain complete specification of applicant skills*
Obtain complete specification of job requirements*
All jobs will have broad specifications
All applicants have marketable skills
All interviews result in jobs
All vacancies are reported
Minimum effort by service in soliciting jobs
Minimum effort by service in finding applicants

*At no cost

FIGURE 3

Preliminary System Definition Matrix for a Job Information System

SYSTEM ELEMENTS	SYSTEM DIMENSIONS*			
	Fundamental	Rate	Control	Interface
Function	To find job vacancies and to maintain records	Find more vacancies than applicants		
Inputs	Information about job openings	Daily reports	Cost per job to be low, daily update	Other employment agencies
Outputs	Reports of job openings presentable to applicants	Daily reports	Weekly update and check of reports	Interview systems, applicant information system
Sequence	Gather information, order and arrange, retrieve, match	Number of jobs per day		Applicant information system
Environment	Economic: service sector, industrial sector. Political: gain support for agency, public cooperation		Maximum public cooperation	Unemployment insurance
Physical Catalysts	Data gathering system records, files, storage/retrieval systems computer			
Human Agents	Liaison officers, employer representation, job counselors	Daily and evening job counseling	Rotate evening shifts per schedule	
Information Catalysts	Government contracts, list of firms, newspapers, trade and professional journals, stock-exchange lists			Applicant information system, other employment agencies

NOTE: See System Definition Matrix (SDM, page 67) for clarification of terminology.

*The future state is omitted in this example but is part of the final design process.

3.2 Identify alternative systems. Group processes, such as Nominal Group Technique (NGT, page 14), may be used. Selecting a feasible system close to the ideal target involves predicting how the system will perform as well as evaluating and comparing different suggestions.

4. Recommend implementation procedures.
This step may involve testing the effectiveness of the system. Training personnel may be required. Establish performance measures for the system and guidelines for future changes in order to effect ongoing improvements in the system.

EXAMPLE

Developing an employment service in a region where unemployment is high is discussed in Function Expansion (FEX, page 45). The function hierarchy developed is given in figure 1. The function level selected in step 1 is "to get people and jobs together." This selection allows maximum flexibility in generating alternative ideal systems which achieve the function. Criteria for evaluating the system are given in figure 2a.

In step 2, regularities and exceptions in the system are identified (see figure 2b). A group process is used to generate the criteria and regularities. Guidelines for ideal systems are developed and listed (figure 2c). Ideal systems as targets are then developed. From the list of criteria and regularities, the following target systems are identified:

1) System to find the maximum number of vacancies.
2) System to assess marketable skills of applicants.
3) System that eliminates interviews.

The first two target systems reflect the need to satisfy criteria, e.g., having a high ratio of vacancies to applicants.

The third system bypasses the function level "getting jobs and people together" to arrive at the function level "fill vacancies" in the function hierarchy. That is, the ideal system for the function level selected, "get people and jobs together," may be a system which accomplishes the higher function of "fill vacancies" as shown in figure 1.

System 1 is selected as target system. Part of this system is another system where information about available jobs is obtained. A preliminary system definition matrix (SDM, page 67) partially specifies the feasible system (figure 3).

An example of applying the strategy to information system design is documented in Nadler et al. (1975). Other examples may be found in health education and industrial applications literature.

THEORY

The IDEALS Strategy was developed by Nadler (1967) and has been used extensively in industry, commerce, public service agencies, and government. A detailed discussion of the strategy is given in Nadler (1970).

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Planning, Programming, and Budgeting

PREREQUISITE TOOLS

Cost-Benefit Analysis (CBA, page 212).

USAGE

PURPOSE

A Planning, Programming, and Budgeting (PPB) strategy makes evaluation part of the program selection process by clearly defining *goals* and evaluating projected outputs prior to selecting a specific program.

USES

PPB may be used to:

1) Plan a program with emphasis on its goals and on how well each alternative meets those goals.

2) Prepare a budget statement that lists expenditures and evaluates outputs according to goals.

3) Choose from among several projects which meet program goals when resources are limited.

SHORT DESCRIPTION

PPB is a comprehensive planning strategy. It structures the decision making process into identification of goals, development of programs to meet those goals, and evaluation of alternative program costs and outputs (or benefits).

First, the *policy* goals of an agency are defined, and then programs are developed to meet the goals. Then, techniques like Cost-Benefit Analysis (CBA, page 212) and Cost-Effectiveness Analysis (CEA, page 219) may be used to determine the resource costs and the projected outputs (benefits) of the program. Estimates of future resource costs and output are specified. This information is then included in a budget statement with the programs arranged by policy goals. Decisions between alternative programs may be made based on the planning, programming, and budgeting goals and a cost-benefit analysis.

ADVANTAGES

1) PPB represents a transformation of budget planning based on resources and input requirements to function-output oriented budget planning and decision making. This approach has advantages for government budget analysis. Resource needs are not merely listed under a department heading; they are grouped by programs where required. This allows a decision maker to evaluate the costs of each program category relative to overall goals.

2) PPB allows the decision maker to re-evaluate ongoing programs each budget year. Automatic continuation of funding is less likely, due to the improved feedback of performance.

LIMITATIONS

1) The initial step of setting goals can be difficult, especially for large government agencies. Because of the

difficulty in reaching agreement, the final goals are often too general to be used for developing or evaluating programs.

2) The necessary data collection is time-consuming. In addition, many decision makers feel that too much information is presented for effective evaluation.

3) Many variables, particularly the outputs, cannot be adequately quantified in a uniform unit measure. In social programs, this is especially difficult.

4) It is difficult to show the relationships of program components to more than one goal in the budget statement.

5) The PPB approach gives the tasks of program development and evaluation to the same decision maker(s). Hence, output measures most favorable to the program evaluation can be selected.

REQUIRED RESOURCES

LEVEL OF EFFORT

PPB is a comprehensive planning technique, and more effort is required as the complexity of the system increases. Decision makers will often be engaged in a continuous effort to define goals, develop programs, and evaluate costs and outputs. When this happens, it is necessary to collect data on costs and outputs for the next budget statement.

Somewhat more effort may be required than simple budgeting and bookkeeping; however, PPB may be considered an alternative to normal budgetary control.

SKILL LEVEL

The user needs a knowledge of systems analysis techniques like Objective Trees (OBT, page 49) and Cost-Benefit Analysis (CBA, page 212). Skills in accounting methods and cost data collection may also be necessary.

TIME REQUIRED

Time required depends on the complexity of the system to be planned, programmed, and budgeted. In many agencies, this is a continuous process.

SPECIAL REQUIREMENTS

A PPB system may be done on a computer, as in other cost-accounting systems. In large organizations, computerized data-handling may be essential for effective planning, programming, and budgeting.

DESCRIPTION OF TOOL

DEFINITIONS

1) A *program category* is a system category under which specific projects, or program sub-categories, are developed: e.g., development of agriculture or health services.

2) A *program sub-category* refers to the specific projects considered under a program category: e.g., a sub-category of agricultural development is hybrid seed research.

3) *Program elements* are the resources or inputs needed to carry on a project.

REQUIRED INPUTS

When developing goals and measurable objectives, the agency or unit responsible for planning must understand the organization's purpose and how other agencies cooperate within the organization.

Knowing the resource requirements and the resources available and having access to cost data are necessary.

TOOL OUTPUT

There are four areas of information for decision making:

1) The defined goals of the agency.

2) Alternative programs to meet those goals.

3) An evaluation of the costs and benefits of each alternative.

4) A means for measuring the results of the program selected for future evaluation.

IMPORTANT ASSUMPTIONS

PPB assumes that well-defined goals can be agreed upon. Using ambiguous goal statements weakens the planning process and the attempts to measure program results versus program goals.

The results of a program must be measurable. However, in social programs such as health care, measuring the increased health level as a result of the program may be difficult, if not impossible. Yet, the planning process assumes that the future output of a program can be adequately estimated.

A project leader, or agency head, must contribute to the presentation of well-defined goals for agency programs and the evaluation of all program results each budget year.

METHOD OF USE

GENERAL PROCEDURE

The procedure is divided into three stages: 1) planning, 2) decision making/implementation, and 3) review.

Planning Stage

1. **Define the goals of the organization or institution.**
   1.1 Determine the type of programs to be developed, and help evaluate the results of the programs. Use techniques such as Function Expansion (FEX, page 45), Objective Trees (OBT, page 49), and Intent Structures (INS, page 55) to identify goals.
   1.2 Initially, state goals in broad terms. Then define each phrase in the goal statement in more detail.

2. **Develop programs to achieve goals.**
   2.1 Gather relevant information. Program development requires extensive knowledge of the relevant social and economic system and of the particular problem to be solved. A wide range of information gathering may first be required. Explore theories on the subject and interview experts. Other tools, such as Delphi (DLP, page 168) or Morphological Analysis (MPA, page 10[illegible]), may be useful.
   2.2 Use this information to develop programs that promise to achieve the defined goals. List programs by types into different *program categories*. When a program involves more than one project, *program sub-categories* will be necessary (see figure 1).
   2.3 Break the program categories or sub-categories into *program elements*, the specific resources needed to carry on the program.

3. **Estimate needed resources (inputs).**
   3.1 Estimate the cost of each program element and determine the average cost per project.
   3.2 Discount all future costs to the present for analysis and comparison on the same basis (see Discounting, DIS, page 184).

4. **Estimate outputs and benefits for each program category.**
   Determine a unit measure of the outputs. For example, an education program category requires a unit measure to estimate the value of a college education, e.g., dollars, number of persons receiving a degree, or number of graduates employed. Information on measuring outputs (benefits) can be found in Cost-Benefit Analysis (CBA, page 212) and the Logical Framework (LGF, page 260).

FIGURE 1
Goals and Programs for the Federal Economic Development Administration

Goal: Economic Development in Depressed Areas
Specific Goal: Increased Jobs in Rural Depressed Areas

Program Categories
A. Education
B. Public Works
C. Business Loans
D. Planning Grants

Program Sub-categories (for Program Category B)
B. Public Works Projects
1. Water/Sewer
2. Industrial/Commercial
3. Other facilities

Program Elements (for Sub-Category B.1)
A. Water/Sewer Engineering Plans
B. Construction material
C. Construction labor

5. **Evaluate program categories (or sub-categories).**
   5.1 Determine which program provides the most outputs for the least cost using cost-benefit analysis.
   5.2 Determine which program best meets the goals of the agency. This goal-related criterion for evaluation distinguishes PPB from a purely economic analysis (as in cost-benefit analysis). Although a number of programs may have a favorable benefit-cost ratio (see BCR, page 194), some programs achieve the stated goals better than others.

Decision Making/Implementation Stage

In the decision-making/implementation stage, the information from the planning stage is presented to the decision maker. The information will include the general and specific goals of the agency, possible program categories, sub-categories and program elements, an analysis of program costs and benefits, and an evaluation of how the program outputs achieve the goals of the agency.

6. **Select program categories and elements.**
   6.1 Evaluate the above information and determine which projects and programs are to be implemented.

6.2 Set priorities and, if necessary, defer implementation of some programs to the next year (e.g., if there are budget constraints).

Review Stage

7. Monitor outputs.
   7.1 Once the program is funded, set up a mechanism to measure program outputs. The unit measures have been established in step 4, so a system of continuous data collection is needed.
   7.2 Determine multiple indicators which may be useful in reviewing program outputs in order to verify the results. An indicator will seldom cover all outputs. These data will be used to evaluate the actual results of the program and will be used in future budget analysis.

8. Develop a computer model of costs and outputs (optional).
   With the information gathered in steps 2-7, a computer model can be developed to estimate changes in the cost or output data and to help evaluate future program changes. For a more detailed discussion, see Tenzer (1969).

EXAMPLE

The goals and programs for a PPB system for the Federal Economic Development Administration are given in figure 1. The program is broken down into four program categories; the public works project is divided into three sub-categories; and program elements for the water/sewer sub-category are shown.

Figure 2 presents an analysis of the second and third *program categories*. The specific goal of creating jobs has been evaluated. Program alternative B, Public Works Project, creates more jobs than alternative C, Business Loans, but at a greater cost of $2,000 per job. Most of the jobs in alternative B will last only as long as the project itself. In alternative C, more of the jobs should be for the life of the business.

Another important evaluation criterion concerns who will receive the basic benefits. Alternative B distinguishes benefits to many residents in the depressed area, particularly because of the water/sewer projects. In alternative C, the basic business loan is a direct benefit to only a small group of business people in the community. The indirect benefits (increased tax base and long-term employment) were not estimated in this example.

FIGURE 2
Analysis of Program Alternatives

Alternative Program B: Public Works Project

	Average Cost Per Project	Average No. of Jobs	Average Investment per Job
1. Water/Sewer	$1,028,000	172	$ 5,976
2. Industrial/Commercial	1,367,000	228	5,995
3. Other facilities	618,000	41	15,073
TOTAL	3,013,000	441	6,832

Alternative Program C: Business Loans

Average Cost Per Project	Average No. of Jobs	Average Investment per Job
$366,000	75	$4,880

SOURCE: Raymond H. Milkman, et al., *Alleviating Economic Distress: Evaluating a Federal Effort* (Lexington, Mass.: D.C. Heath and Co., 1972), chapter 7.

THEORY

PPB was originally developed by the executive branch of the U.S. Federal Government for agency budget preparation. It stems from the application of a systems approach to planning and management. The first task in the conventional systems analysis strategy is to identify objectives, then to find alternative means for achieving the desired ends. The systems analyst then determines measures to evaluate the alternatives and ranks the alternatives according to their effectiveness in reaching desired goals.

A systems approach merges planning, implementation, and evaluation phases in a comprehensive system design. PPB represents one manifestation of the application of this strategy to public institutions primarily the Department of Defense. It has a particular appeal to centralized decision makers because of the appearance of increased accountability, the implied reorganization along functional lines, and the image of scientific "systems" sophistication. This latter point is illustrated by the trend toward automating PPB accounting and reporting procedures with comprehensive management information computer systems.

It is not clear, however, whether PPB really works as intended. There is considerable evidence (for the reasons cited in Limitations) that it does not (see Caldwell, 1973, and Hoos, 1972). Nevertheless, it is an important tool to understand because it has been widely acclaimed (see Hinrichs, 1969) and because it illustrates many aspects of the systems approach. The caution for analysts and decision makers is to be skeptical of any such system (including management information systems) until it is tested and evaluated on its own merits, rather than on the basis of unsubstantiated claims and promises.

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Critical Path Method

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

The Critical Path Method (CPM) is a networking technique for planning and managing projects.

USES

CPM aids in planning and managing the execution of activities in a project where the activities must be performed in a specified sequence. CPM:

1) Identifies critical activities which require special attention from management.

2) Assists in estimating the minimum total time needed to complete the project.

3) Gives the times when activities must be scheduled to complete the project in the minimum time.

4) Serves as a planning and management device to communicate complex procedures to staff and funding sources.

5) Facilitates the construction of Gantt Charts (GNT, page 252).

KEY DEFINITIONS

1) An *activity* is an operation with a well-defined beginning and end, and a specific purpose. Some examples are PREPARE QUESTIONNAIRE and MAIL QUESTIONNAIRE, activities which may be necessary to complete a Survey (SVY, page 36).

2) A *critical activity* is an activity which, if not completed on time, will delay the entire project.

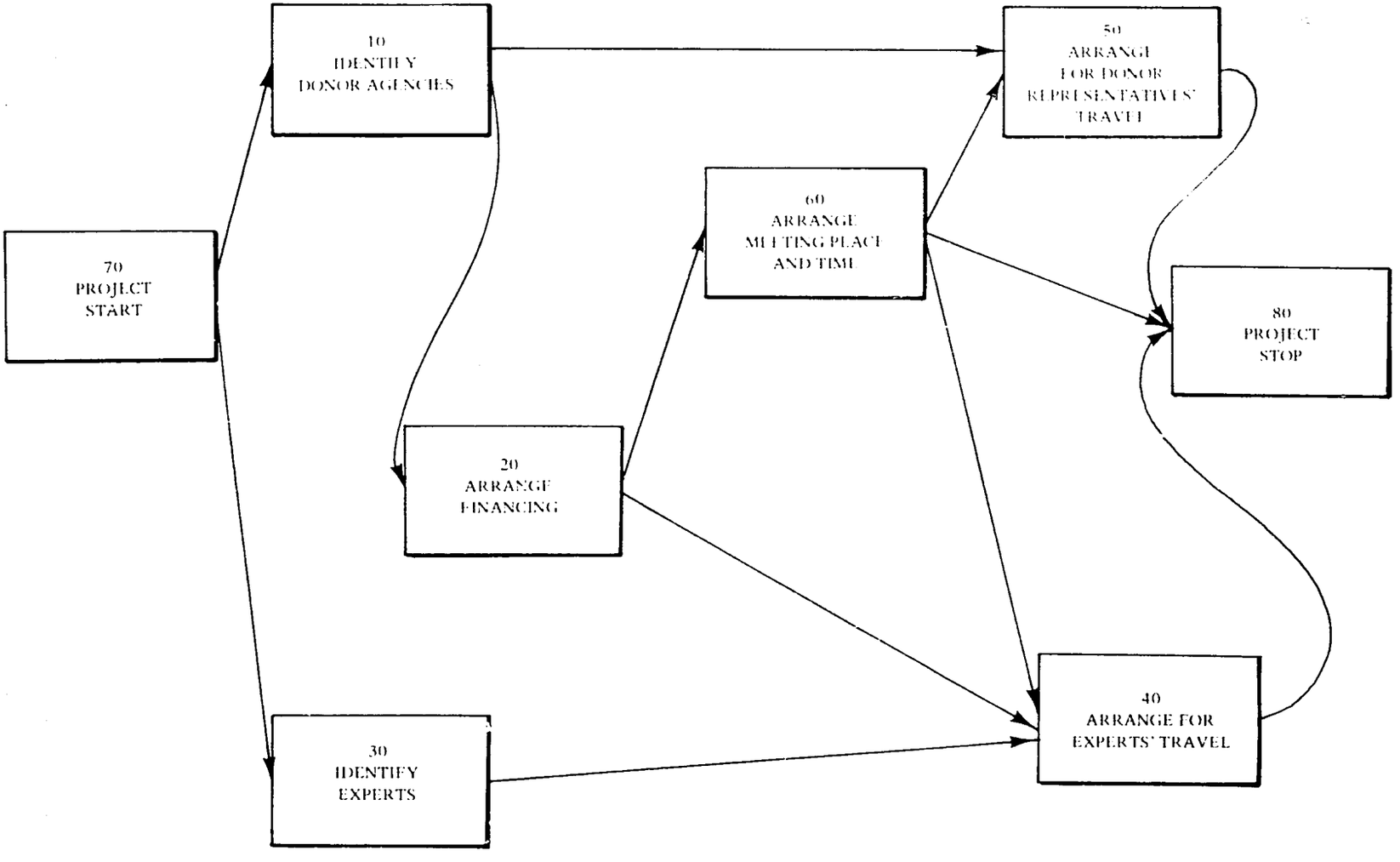
3) The *critical path* is the sequence of critical activities from project start to project finish that determine the shortest project duration.

SHORT DESCRIPTION

The Critical Path Method begins by describing the activities necessary to complete the project. The time required to complete each activity is estimated, taking into consideration the resources available and the desired performance specifications. Arranging the activities in a network shows the logical sequence from start to finish (see figure 1). The *critical path* through the network is computed by determining the activities which are critical to the timely completion of the project. From these calculations, the total time needed to complete the project may be estimated.

The Critical Path Method can be used during the management of the project to direct attention and resources to critical performance areas.

FIGURE 1
Project Network for the Activities Necessary to Arrange a Seminar



ADVANTAGES

1) Using CPM for a project promotes advance planning.

2) CPM provides a concise framework for an ongoing review of project progress.

3) The visual representation of the total project communicates effectively to line personnel, funding agencies, and other interest groups.

4) CPM identifies those activities that must be completed on time in order to end the project as early as possible. Extra attention can be devoted to these critical activities, or resources can be scheduled accordingly.

5) Using CPM frequently results in a significant reduction in project duration by avoiding unnecessary delays (Moder and Phillips, 1964).

LIMITATIONS

1) It is necessary to estimate in advance the exact nature and timing of each activity in the project.

2) The fact that most activities may take less time if resources are shifted from other activities is not treated in the critical path calculations.

3) CPM does not consider additional information that the project manager may have, e.g., the relative skill of different workers or the expected delay in procuring some resources.

4) It is tedious to manually analyze a CPM network containing more than 50 activities.

5) CPM does not consider planning projects when there is limited availability of a particular resource. Gantt Charts (GNT, page 252) may be used in such cases.

REQUIRED RESOURCES

LEVEL OF EFFORT

Drafting a CPM network for a large project can be a significant undertaking. However, when activities are identified during the planning or budgeting stage of the project, the CPM network may actually provide a framework which will reduce the total planning effort.

It may be necessary to update the network during the course of a project. This may be done on a weekly or monthly basis depending on the nature of the project.

SKILL LEVEL

The calculations on a simple network involve no more than simple arithmetic. For larger networks, the calculations are no more complex, but careful bookkeeping is important.

TIME REQUIRED

The time required depends on the number of activities, the decision maker's familiarity with the project, and the difficulty in getting accurate data estimates. Construction of the CPM network, analysis of critical activities, and computation of minimum total project time require one day for projects with less than 50 activities.

SPECIAL REQUIREMENTS

One index card (or something similar) for each activity is needed. Large sheets of paper may be needed to construct the CPM network for a large project. A calculator will be useful for chart computations. A computer is desirable for handling large project networks. Many CPM computer programs are available (see Moder and Phillips, 1964).

DESCRIPTION OF TOOL

SUPPLEMENTAL DEFINITIONS

1) The *duration* of an activity is the estimated time needed to perform the activity.

2) The *predecessor activity* for an activity must be completed before the latter can start.

3) An *immediate predecessor* of an activity is any other activity that immediately precedes it and which must be completed before the activity can start.

4) The *earliest start* (ES) of an activity is the earliest time (measured from the start of the project) when an activity may begin, assuming that all immediate predecessors are completed.

5) The *earliest finish* (EF) of an activity is the sum of its earliest start time and duration.

6) An *immediate successor* of an activity is any activity that immediately follows it and which may not start until completion of the activity.

7) The *latest finish* (LF) of an activity is 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.

8) The *latest start* (LS) of an activity is its latest finish time minus its duration.

9) *Slack* is the amount of leeway allowed in either starting or completing an activity. Slack can be computed in two ways:

$$\text{Slack} = \text{LS} - \text{ES} \qquad [1]$$
$$\text{Slack} = \text{LF} - \text{EF} \qquad [2]$$

which is simply the differences between the latest and earliest starts [1] or finishes [2].

10) A *milestone* is a point in time (specific date) which marks the completion of a sequence of activities or the beginning date for subsequent activities.

REQUIRED INPUTS

The Critical Path Method requires knowledge of the project objectives, and the activities necessary to achieve them, in order to estimate the duration of the different activities and construct the sequence.

TOOL OUTPUT

The CPM gives the minimum total project duration based on the identification of the critical path. The critical path calculations determine the leeway in scheduling each activity: the time interval designated by the earliest and latest start times and the earliest and latest finish times. This information enables the project manager to determine scheduling priorities and concentrate efforts on the critical activities, those activities which have no scheduling leeway or slack.

The CPM is the first step in preparing a Gantt Chart (GNT, page 252) for examination of any potential problems in allocating resources to the project.

IMPORTANT ASSUMPTIONS

All activities necessary to complete the project are known during the planning phase. All activities identified as necessary must be completed, i.e., there is no provision for alternative choices of action contingent upon later information or actions beyond the control of project planners. One may prepare alternative networks for each contingency (see Contingency Analysis, CGA, page 147).

The time estimates for each activity are determinate, i.e., CPM does not permit variation in estimating duration. The durations estimated for each activity are assumed to be independent of the other activity durations. Resources required to complete any activity are not constrained (see Davis, 1966).

METHOD OF USE

GENERAL PROCEDURE

Describing network techniques may be complicated, depending on the level of abstraction. This procedure is an easy approach for relatively simple networks: the analysis proceeds directly on the network. Other procedures which use a complex notation to represent the activities are not necessary unless the procedure is to be carried out on a computer.

1. **Identify and list all activities necessary to complete the project.**
   - 1.1 Briefly describe each activity in the center of an index card (see figure 2).
   - 1.2 Examine the activities and discard or modify any which are too detailed when compared with the other activities.
   - 1.3 Give each activity an identifying number, e.g., 10, 20, 30, etc., leaving intervening numbers for activities which may be included later.

2. **Estimate the duration of each activity.**
   - 2.1 Consider the normal level of resources available to complete the activity.
   - 2.2 Consider the desired specifications for the activity's performance.
   - 2.3 Write the duration at the bottom of each activity card (see figure 2).
   - 2.4 List the activities and their durations (figure 3).

3. **Draw the project network.**
   - 3.1 Place the activity cards on a large sheet of paper.
   - 3.2 Arrange the activities in their logical sequence from left to right, and fasten the cards to the paper.
   - 3.3 Use arrows to connect e ch activity to its immediate predecessors and immediate successors (see figure 4).

FIGURE 2
Activity Card with Location of Notations

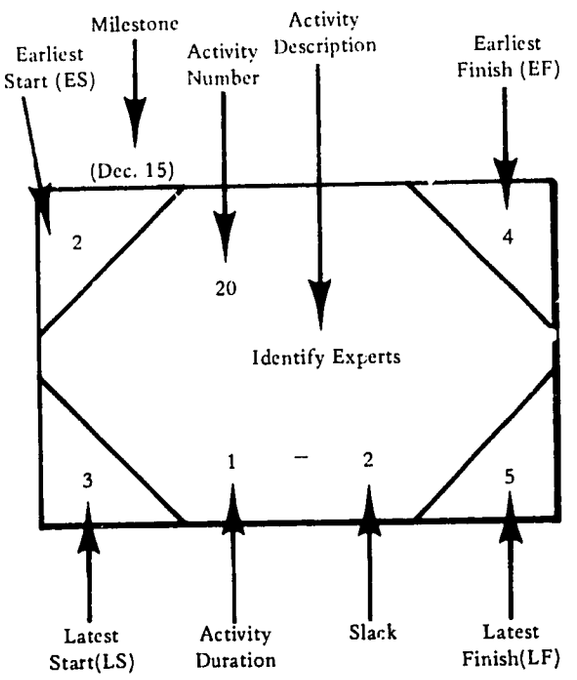


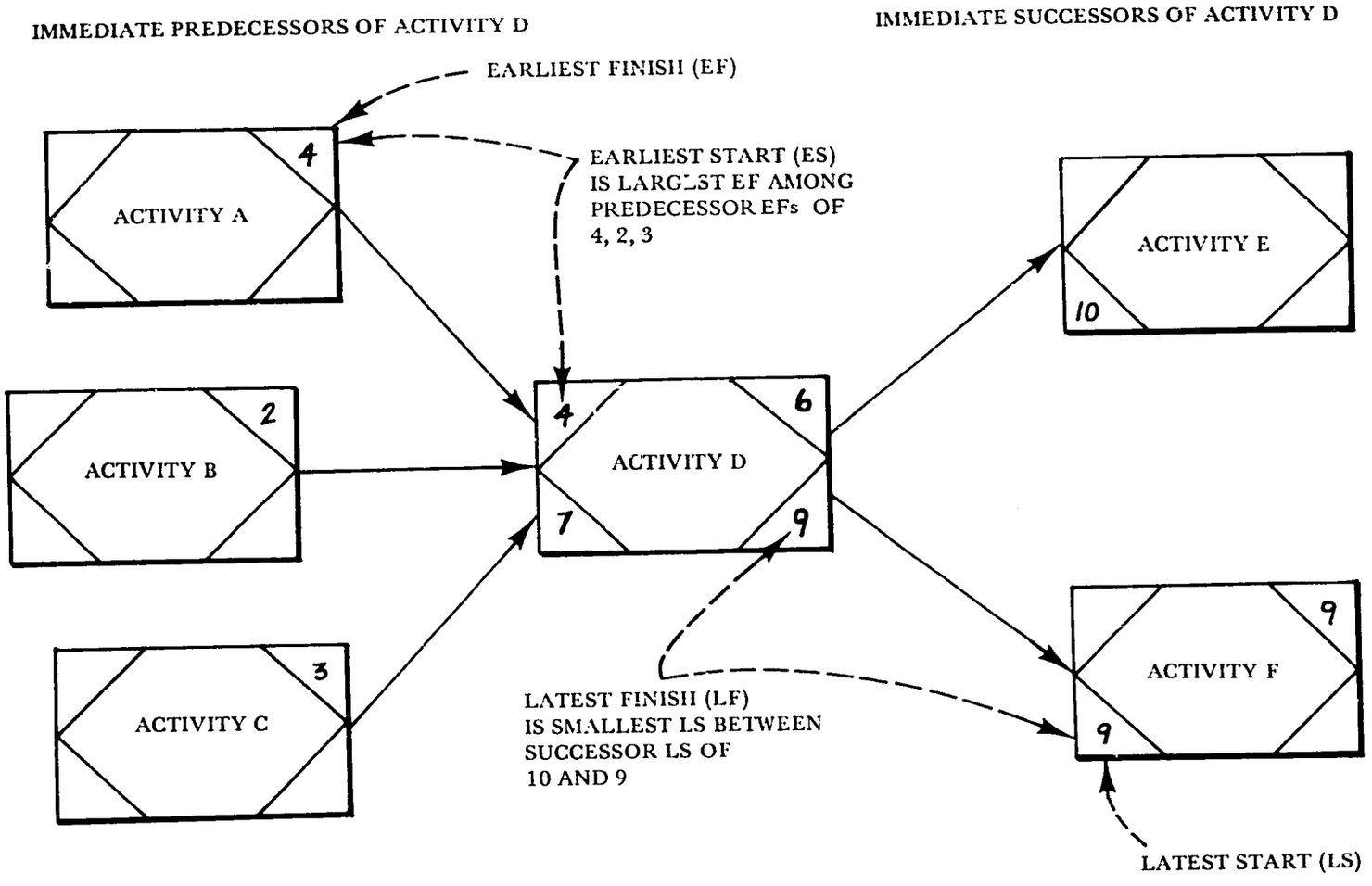
FIGURE 3
Table Format for Computation of Critical Path

PROJECT: NETWORK PLANNER: START DATE: TIME UNITS:

ACTIVITY		DURATION	IMMEDIATE PREDECESSORS	IMMEDIATE SUCCESSORS	START		FINISH		SLACK	STATUS
No.	Description				EARLIEST	LATEST	EARLIEST	LATEST		

FIGURE 4

Immediate Predecessor and Successor Relationships
and the Computation of Earliest Start and Latest Finish Times for an Activity



3.4 Check the network for the logical consistency of activity sequences.

3.5 Enter each activity's immediate predecessors and successors in the table (figure 3) using their identifying numbers.

4. **Identify the PROJECT START and the PROJECT STOP.**

4.1 If the project begins with several simultaneous activities (each having no immediate predecessors), then place a PROJECT START card on the network and connect it with arrows to these activities (see figure 1). This activity has zero duration.

4.2 If the project ends with several simultaneous activities (each having no immediate successors), then place a PROJECT STOP card on the network and connect it with arrows to these activities. This activity has zero duration.

4.3 Assign a reference time of zero to the desired starting date of the project.

5. **Determine each activity's earliest start (ES) and earliest finish (EF).**

5.1 Begin with PROJECT START and work forward through the network.

5.2 Set the ES for the PROJECT START equal to zero.

5.3 Compute the EF for each activity by adding the duration to its ES.

5.4 For each sequential activity with only one immediate predecessor, set the ES equal to the predecessor's EF.

5.5 For each sequential activity with more than one immediate predecessor, set the ES equal to the latest EF of the predecessor activities. The ES of an activity is the earliest time (measured from the start of the project) that an activity may begin assuming that all immediate predecessors are first completed. Therefore, the ES can be no earlier than the EF among the preceding activities (see figure 4). For example, if activity D is preceded by activities A, B, and C, and if the earliest that these activities may be finished is 4, 2, and 3 weeks from project start, respectively, then the earliest that activity D may start is the fourth week of the project, i.e., ES = 4.

5.6 Write the ES and EF on the top corners of the activity card (see figure 2) and enter in the table (figure 3).

5.7 Repeat steps 5.3 through 5.6 until the PROJECT STOP is reached. Note, the ES for an activity may be calculated only after the EFs of all immediate predecessors have been determined.

6. **Determine each activity's latest start (LS) and latest finish (LF).**

6.1 Begin at the PROJECT STOP and work backward through the network.

6.2 Set the LF for the PROJECT STOP equal to its EF.

6.3 Compute the LS for each activity by subtracting the duration from its LF.

6.4 For each activity with only one immediate successor, set LF equal to the LS of the successor activity.

6.5 For each activity with more than one immediate successor, set the LF equal to the earliest LS of the successor activities. The LF of an activity is the latest time (measured from the start of the project) when an activity may be completed without delaying the project. Consequently, the LF must be no later than the LS times for all the activity's immediate successors (see figure 4). For example, if activity D is immediately followed by activities E and F and if the latest that these activities may begin is 10 and 9 weeks, respectively, then the latest that activity D may finish is the ninth week of the project, i.e., LF = 9.

6.6 Write the LS and LF on the bottom corners of the activity card (see figure 2) and enter in the table (figure 3).

6.7 Repeat steps 6.3 through 6.7 until the PROJECT START is reached. Note the LF for an activity may be calculated only after the LSs of all immediate successors have been determined; hence the necessity to pass backward through the network.

7. **Compute the slack times for each activity.**

7.1 Slack is zero for an activity with identical ES and LS or identical EF and LF.

7.2 Otherwise, slack is simply the difference in time between the ES and LS or between the EF and LF of each activity.

7.3 Write the slack at the bottom of each activity card (see figure 2) and enter it in the table.

7.4 Check the calculations for each activity by adding the duration and slack to the earliest start time. The sum should give the latest finish time for the activity.

8. **Identify the critical path for the project.**

8.1 Any activity with zero slack is critical. Mark the status in the table (figure 3).

8.2 The sequence of critical activities from start to finish is the critical path for the project. (There may be more than one critical path.) Mark the critical path on the network diagram with heavy lines on the connecting arrows and/or by shading the critical activity cards in the sequence.

9. **Determine the duration of the project.**
   - 9.1 Examine the sequence of activities to see if all activities are necessary, or if the project method might be changed (Mulvaney, 1969).
   - 9.2 Examine the activities on the critical path to see if they might be shortened in duration.
   - 9.3 Consider the application of additional resources to shorten critical activities.
   - 9.4 Consider a change in specified performance of the activity to shorten the estimated duration.
   - 9.5 Finally, take the duration of the project as the EF of the final activity or PROJECT STOP.

10. **Use the project network to manage the project.**
   - 10.1 Assuming the project is to be completed as early as possible, set the calendar date of the PROJECT START at the earliest feasible time. This becomes the time reference for scheduling all subsequent activities.
   - 10.2 Schedule every activity to start in its ES to LS time interval. Note that there will be no leeway in scheduling critical activities.
   - 10.3 If days are the basic time unit, schedule according to calendar working days (unless overtime is authorized).
   - 10.4 If a deadline for completion of the project has been set and if resources and staff are not available until the last minute, set the PROJECT START date by subtracting the total project time from the deadline.
   - 10.5 Write in significant *milestones* on the network using the elapsed time from the date of the PROJECT START. Milestones usually mark the latest finish date for several simultaneous activity sequences.

EXAMPLE

Though the Critical Path Method is most useful for projects involving 50 or more activities, a simpler example illustrates the technique: a planning seminar which brings experts together with donor agency representatives.

Identify and List All Activities Necessary to Complete the Project

The seminar plan calls for selection of donors and experts and the arrangement of financing, facilities, and travel. These activities are listed in table form (see figure 5). All activities involve about the same level of detail, i.e., minute specification of tasks is omitted at this stage. Many other activities may be necessary to plan a particular seminar, but only six tasks are shown in order to simplify the example.

Estimate the Duration of Each Activity

The durations shown in figure 5 are in time units of weeks. These are estimates based on the number of experts and donor representatives involved in the seminar and the staff available to complete the activities.

Draw the Project Network

The activities are written on index cards and arranged in a logical sequence (see figure 1). Initially, the network may look rather confusing with many arrows crisscrossing. Sometimes rearranging the activity cards and redrawing connecting arrows will clarify the diagram. If crossing two arrows cannot be avoided, use a "bridge" for clarity.

Check the network for consistency. Is the activity sequence logical? Can activities sequenced one after the other be performed simultaneously? Activities 10 and 30 are illustrative.

The immediate predecessors and successors of all activities are noted in the table (see figure 5).

Identify the PROJECT START and the PROJECT STOP

In this example, it is necessary to add both a PROJECT START and a PROJECT STOP activity as the project begins and ends with simultaneous activities. The final activity is not HOLD THE SEMINAR since the project is completed when arrangements for the seminar are finished. This includes setting a date (which may be in several months).

Determine Each Activity's Earliest Start and Earliest Finish

Computation of the earliest start and finish is shown directly on the top corners of each activity card (see figure 6). For example, activity 50, ARRANGE FOR DONOR REPRESENTATIVE'S TRAVEL, is preceded by activities 10 and 60 which have earliest finish times of one and five weeks, respectively. Since activity 50 may start only after all preceding activities are finished, its ES is five weeks from the starting date of the project.

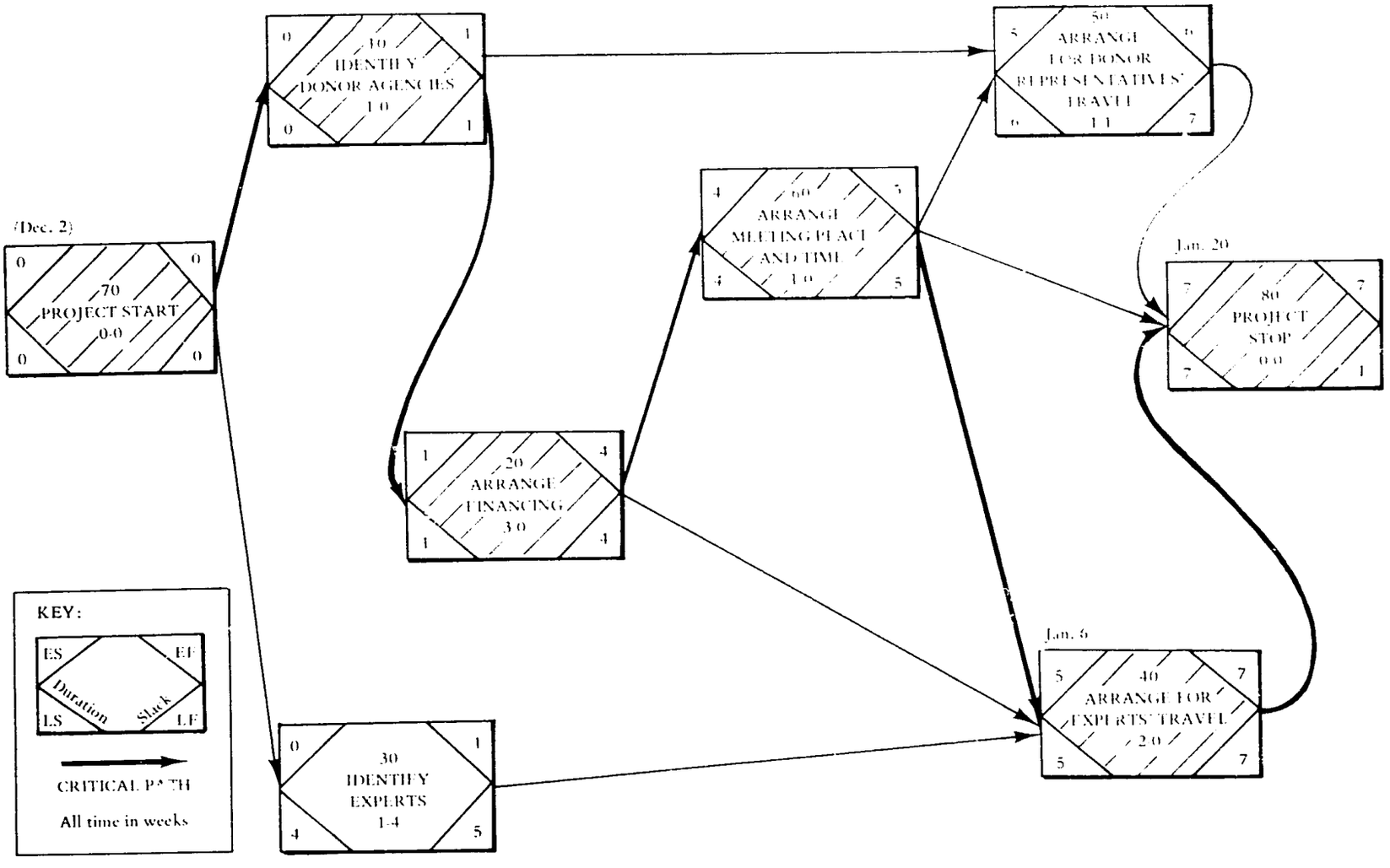
FIGURE 5
Completed Activity Table for Activities to Arrange a Seminar

PROJECT: Arrange Donor Sponsored Seminar NETWORK PLANNER: D. Susskind START DATE: Dec. 2 TIME UNITS: Weeks

No.	ACTIVITY	DURATION	IMMEDIATE PREDECESSORS	IMMEDIATE SUCCESSORS	START		FINISH		SLACK	STATUS
					EARLIEST	LATEST	EARLIEST	LATEST		
10	Identify Donor Agencies	1	70	20, 50	0	0	1	1	0	CRITICAL
20	Arrange Financing	3	10	40, 60	1	1	4	4	0	CRITICAL
30	Identify Experts	1	70	40	0	4	1	5	4	
40	Arrange for Experts' Travel	2	20, 30, 60	80	5	5	7	7	0	CRITICAL
50	Arrange for Donor Representatives' Travel	1	10, 60	80	5	6	6	7	1	
60	Arrange Meeting Place and Time	1	20	40, 50, 80	4	4	5	5	0	CRITICAL
70	PROJECT START	0		10, 30	0	0	0	0	0	
80	PROJECT STOP	0	40, 50, 60		7	7	7	7	0	

FIGURE 6

Completed Project Network Showing Critical Path (Shaded) and Milestones (Dates in Parentheses)



Determine Each Activity's Latest Start and Latest Finish

These times are computed directly by working back through the network (see figure 6). For example, activity 60, ARRANGE MEETING TIME AND PLACE, has three immediate successors, activities 40, 50, and 80 (the PROJECT STOP). These activities have latest starts of five, six, and seven weeks, respectively, from the starting date of the project. Since activity 60 must finish before the following activities can begin, the latest finish is five weeks from the PROJECT START.

The latest start time of the PROJECT START is computed as zero. This provides an easy check of the computations for all activities.

Compute the Slack Times for Each Activity

The slack for each activity is shown on the activity card and in the table (figure 5). Activity 30 has the largest slack—four weeks. Since its ES is week zero and its LF is week five, experts may be identified during any week in this time period. This task has been estimated to take only a week, but it would be wise to schedule it as early as possible (even though there are four weeks of slack).

Identify the Critical Path for the Project

The activities with zero slack are noted in the table (figure 5) by writing "critical" under the status column. The critical path is shown on the network by shading the critical activity cards and darkening the connecting arrows (see figure 6).

Determine the Duration of the Project

The earliest finish of the last activity is seven weeks from the PROJECT START date. Upon examining the critical path, one may conclude that the most likely place to shorten the time is to expedite the arrangements for financing. However, since this is largely beyond the planner's control, the total estimated completion time is seven weeks, the EF for the PROJECT STOP.

Use the Network to Manage the Project

The starting time for the project is to be December 2. When the activities with slack are scheduled, the planning is finished (note that the table, figure 5, is not a schedule). The beginning of activity 40 is selected as a key event in the project and the milestone date of January 6 is shown directly on the network diagram (see figure 6). The project manager assigns staff roles to each task and monitors progress against the planned performance. Construction of a Gantt Chart (GNT, page 252) facilitates these tasks.

This example could be expanded to reflect the many details that go into setting up a seminar and activities prior to the date of the conference may be appended to the network to give the total picture. However, it is usually good practice to start with a network that identifies the gross activities and then to redo the network with a finer breakdown.

THEORY

The Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT) were both developed in the late 1950s (Moder and Phillips, 1964). Originally, the CPM network technique considered the costs of shortening critical activities and thus optimized the timing of the task. PERT permitted three time estimates (pessimistic, optimistic, and most likely) for the duration of each activity. PERT allowed the planners to estimate a date for project completion, including his confidence in the variance of the estimate (Bedworth, 1973).

Subsequently, these two techniques have been expanded and modified, and many other network techniques have been developed. Davis (1966) gave an excellent survey of the treatment of resource allocation in networks. Pritsker and Happ (1966) developed a method which considered the probability of certain activities not occurring (a limiting assumption of CPM).

From the beginning, network techniques have been programmed for digital computers. Moder and Phillips (1964) listed some of the many versions. Efforts to simplify the technique for manual computation draw from the desirable features of both PERT and CPM as well as Gantt or Bar Charts. Mulvaney (1969) gave an excellent treatment which serves as the model for this tool description.

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Moder, J.J., and Phillips, C.R. *Project Management with CPM and PERT.* New York: Rheinhold Publishing, 1964.

Mulvaney, John. *Analysis Bar Charting: A Simplified Critical Path Analysis Technique.* Washington, D.C.: World Bank, Economic Development Institute, 1969.

Pritsker, A.A., and Happ, W.W. "GERT: Graphical Evaluation and Review Technique, Part I, Fundamentals." *Journal of Industrial Engineering* 17 (May, 1966).

Gantt Charts

PREREQUISITE TOOLS

Critical Path Method (CPM, page 241).

USAGE

PURPOSE

The Gantt Chart facilitates planning and managing project activities and resources.

USES

The Gantt Chart is used to:

1) Plan a project to schedule *activities*.

2) Communicate the project plan to others and to mark *milestones* in the project sequence.

3) Determine the minimum project duration, given that some *resources* may be limited.

Project managers may use Gantt Charts to schedule resources and staff assignments and to record actual progress against the planned performance of activities.

SHORT DESCRIPTION

A Gantt Chart displays the schedule of project activities (see figure 1). Each activity is represented by a bar that extends along the time scale. The bar's length is proportional to the *duration* of the activity. The position of the bar along the time scale indicates the starting and ending times for the activity.

The required amount of a limited resource (e.g., manpower) may be tabulated for each unit of time to allow for a direct examination of scheduling problems. Activities may be shifted to keep the total amount of the resource within the limit.

ADVANTAGES

The primary advantage of the Gantt Chart is its simplicity and intuitive appeal. It is a popular scheduling device because the timing of each task is clearly indicated.

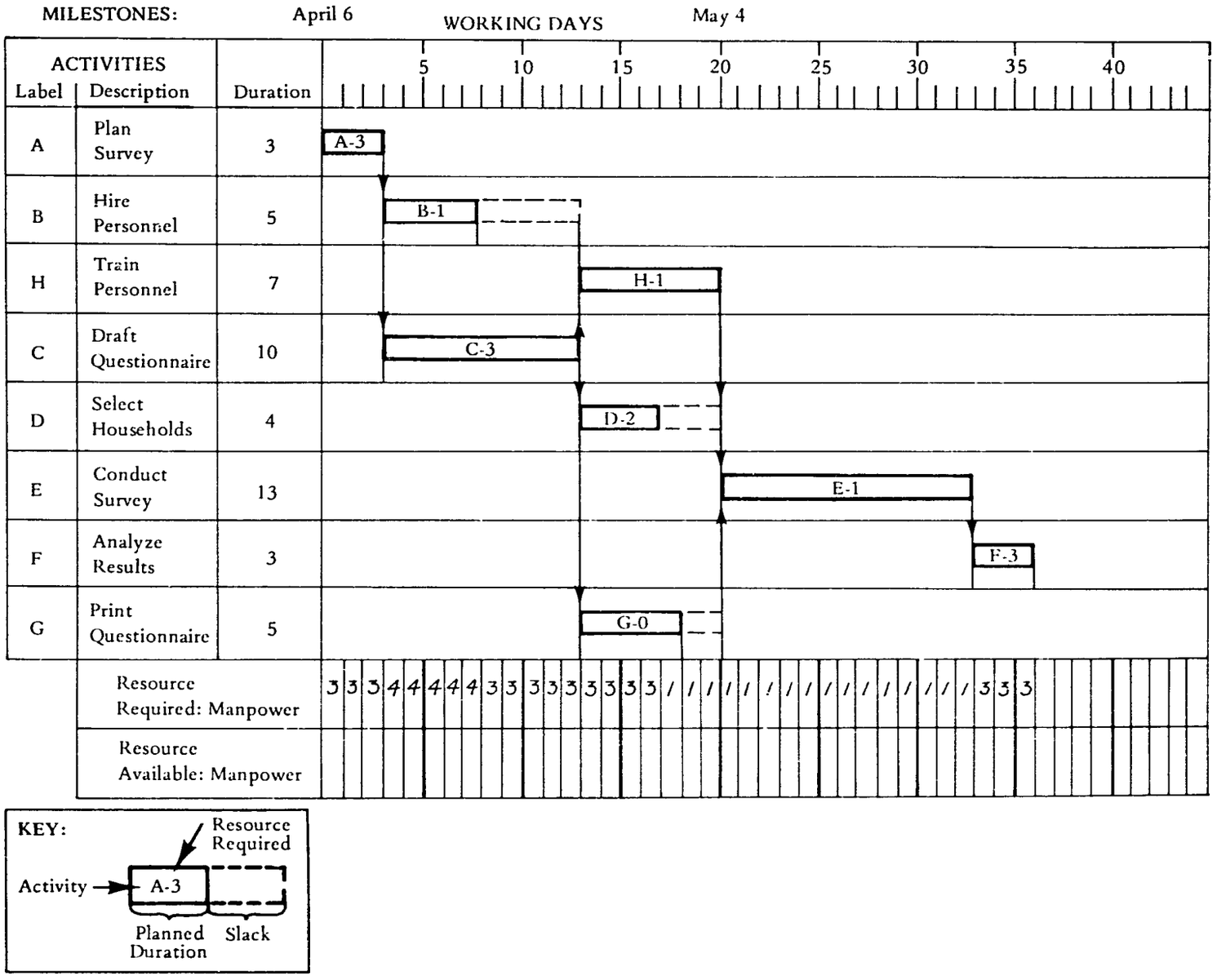
The *critical path* or sequence of *critical activities* is revealed on a Gantt Chart by direct inspection; there will be no leeway in scheduling these activities if the project is to be completed in a minimum time.

Allocation of a limited resource can be explicitly treated on the chart, and activities can be rescheduled or resources shifted from one activity to another.

Milestones may be marked to clearly show important intermediate stages of the project. The project's progress may be marked directly on the Gantt Chart; if preceding activities are not completed at the corresponding milestone, then corrective action is indicated. For example, the 20th working day after project start is a milestone for a survey project (see figure 1).

FIGURE 1

A Gantt Chart Example: Planning and Conducting a Survey



LIMITATIONS

The Gantt Chart does not emphasize the logical sequence of activities as clearly as the network diagrams in the Critical Path Method (CPM, page 241).

If more than one resource is limited, the Gantt Chart technique does not ensure an optimum resource allocation.

REQUIRED RESOURCES

SKILL LEVEL

As in any project planning technique, developing a Gantt Chart requires breaking down a project into its logical and distinct activities. It also requires estimating the duration of activities and resource requirements. Since there is a tradeoff between resources allocated and the duration of an activity, these tasks are enhanced by repeated practice in constructing charts and comparing estimates with actual progress.

TIME REQUIRED

The time required is directly related to the complexity of the project to be scheduled. Experience in estimating resource requirements and task duration shortens chart construction time. Gantt Charts often require updating during project implementation.

DESCRIPTION OF TOOL

REQUIRED INPUTS

Knowledge of the activities necessary to complete a project is the precondition for developing a Gantt Chart. The dates for starting and ending the project fix the time scale of the Gantt Chart. Resource needs and availability must be specified.

TOOL OUTPUT

The primary output is a project schedule depicted by a Gantt Chart. The Chart can then be used to mark the progress of the project and to adjust it according to management decisions.

IMPORTANT ASSUMPTIONS

The Gantt Chart construction assumes that a project may be broken down into clearly distinguishable activities with a definite beginning and end; that is, the time to complete each activity can be accurately determined during the planning phase.

The Gantt Chart technique does not enable optimum allocation of resources—more sophisticated techniques are required (Davis, 1966). However, the technique is useful for graphically sequencing activities to avoid exceeding the amount of a limited key resource. This assumes that the interaction between required resources and the duration of an activity can be specified (e.g., if additional manpower is assigned to the activity, is the duration shortened). Determination of the minimum project duration using a Gantt Chart is depending on these relationships (see Bedworth, 1973).

METHOD OF USE

GENERAL PROCEDURE

A Gantt or Bar Chart is constructed by identifying all the activities involved in the project and determining their sequences. Each activity is drawn as a bar located on a time scale so that the length of the bar corresponds to the duration of the activity and the position of the bar denotes its scheduled start and end (see figure 1).

The following procedure concentrates on constructing a Gantt Chart as a heuristic technique for taking into account the requirements for a limited resource. As such, it extends the Critical Path Method (CPM, page 241).

1. **Construct the CPM network for the project.**
   - 1.1 Diagram the network in order to observe the logical sequence of project activities.
   - 1.2 Compute the earliest (ES) and latest starts (LS) for each activity and the earliest (EF) and the latest finishes (LF) for each activity.
   - 1.3 Compute the slack for each activity and determine the critical path.
   - 1.4 Estimate the minimum project duration.
   - 1.5 Estimate how much of the limited resource is necessary for each activity.

2. **Construct the Gantt Chart for an unlimited resource.**
   - 2.1 Mark off a horizontal time scale approximately one-third greater than the estimated minimum project duration. (If the time unit is in days, then include only working days unless overtime is considered.)
   - 2.2 Draw a horizontal bar for the first activity lying on the critical path by starting at the zero reference on the time scale and extending to the estimated duration of the activity.

2.3 Draw a bar on the chart which corresponds to the duration of the next activity on the critical path. The beginning of the bar must fall on the same vertical time line as the finish of the preceding activity. The bars may be drawn in the same row of the chart or in different rows to facilitate identification of the activity (see figure 1).

2.4 Continue adding bars consecutively until all the critical activities in the path are represented on the chart.

2.5 Make certain that the end of the bar for the last activity falls on a vertical line on the time scale which equals the estimated minimum project duration.

2.6 Add the activities not on a critical path to the chart. The position of the bar is determined by the earliest start and earliest finish times of the project activity.

2.7 Append a bar to the right end of each non-critical activity. The length should equal the slack for the activity (see CPM, page 241).

2.8 Draw vertical arrows between the ends of the bars to show the *predecessor activities* for each activity (see figure 1).

3. Determine resource requirements.

3.1 Write the amount of the limited resource required for each activity directly on the bar.

3.2 Starting with the first time unit on the scale (e.g., day 1 or week 1), add the amount of the limited resource used in all activities scheduled at that time and enter it in the column below the chart (see figure 1).

3.3 Continue calculating the total resources required for the rest of the time units.

3.4 Sum these unit totals to give the total resource requirement for the project.

3.5 Divide this total by the number of time units to give the average resource requirement per unit of time (e.g., man per day, secretaries per week, computer hours per month). This gives an indication of how uniformly the limited resource is used by the scheduled activities.

4. Adjust the schedule for the limited resource.

4.1 Record the amount of the limited resource which is available for each time unit of the project (see figure 1).

4.2 Compare this to the total resource requirement estimated for each time unit.

4.3 If the amount of resource required exceeds the amount available, then the schedule for that time unit must be shifted.

4.4 Within the constraints posed by the logical sequence of activities, shift activities forward or backward along the time scale so that the total resources required do not exceed those available.

4.5 Consider lengthening the duration of non-critical activities to reduce their resource requirement.

4.6 If necessary schedule two simultaneous activities to follow each other sequentially.

4.7 Extend the total project duration, if necessary, to avoid exceeding resource limitations.

4.8 Make certain after any modification of the original schedule that no activity has been shifted such that it starts before all predecessor activities are finished.

5. Use the Gantt Chart to manage the project.

5.1 Indicate the significant milestones by drawing a vertical line through the appropriate date.

5.2 Consider the scheduling of activities with slack: if the activity is scheduled for the earliest start time, the slack will all occur at the end; if the activity is scheduled to start at the latest possible time, the activity will become critical to avoid delays in subsequent activities (and the project).

5.3 Assign staff and other resources to each activity and discuss the schedule and expected performance.

5.4 Develop a reporting system which can be used to mark the progress and completion of each activity on the chart.

5.5 Provide for a periodic staff review of project activities to emphasize the interdependency of the work.

5.6 If the project fails to meet the schedule, update the chart and, if necessary, recalculate the critical path for the remaining activities. This process is facilitated by providing space on charts to add activities and to expand or shift the time scale.

EXAMPLE

A simple Gantt Chart illustrates the activities required to design and executive a survey (SVY, page 36). The example is adopted from Moder and Phillips (1964).

Construct the CPM Network for the Project

The survey task was broken down into eight activities, and the CPM network was constructed (see figure 2). The earliest and latest starts and finishes and the slack for each activity were calculated on the network and tabulated (see figure 3). The minimum duration for the project was estimated to be 36 days.

FIGURE 2
Critical Path Network for Survey Project

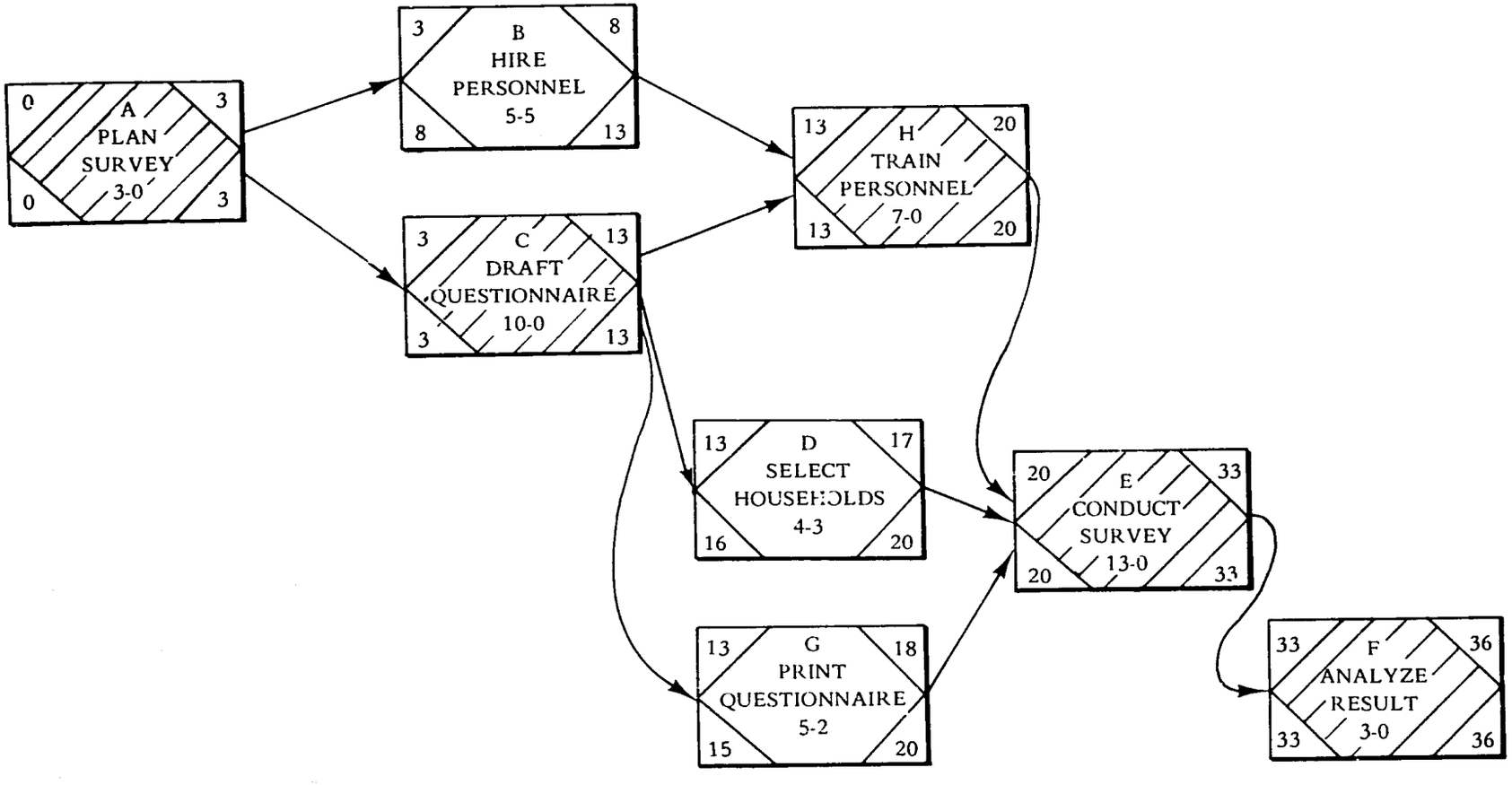


FIGURE 3
Activity Table for Survey Project

PROJECT: Planning and Conducting a Survey NETWORK PLANNER: G. Gallup START DATE: April 6 TIME UNITS: Days

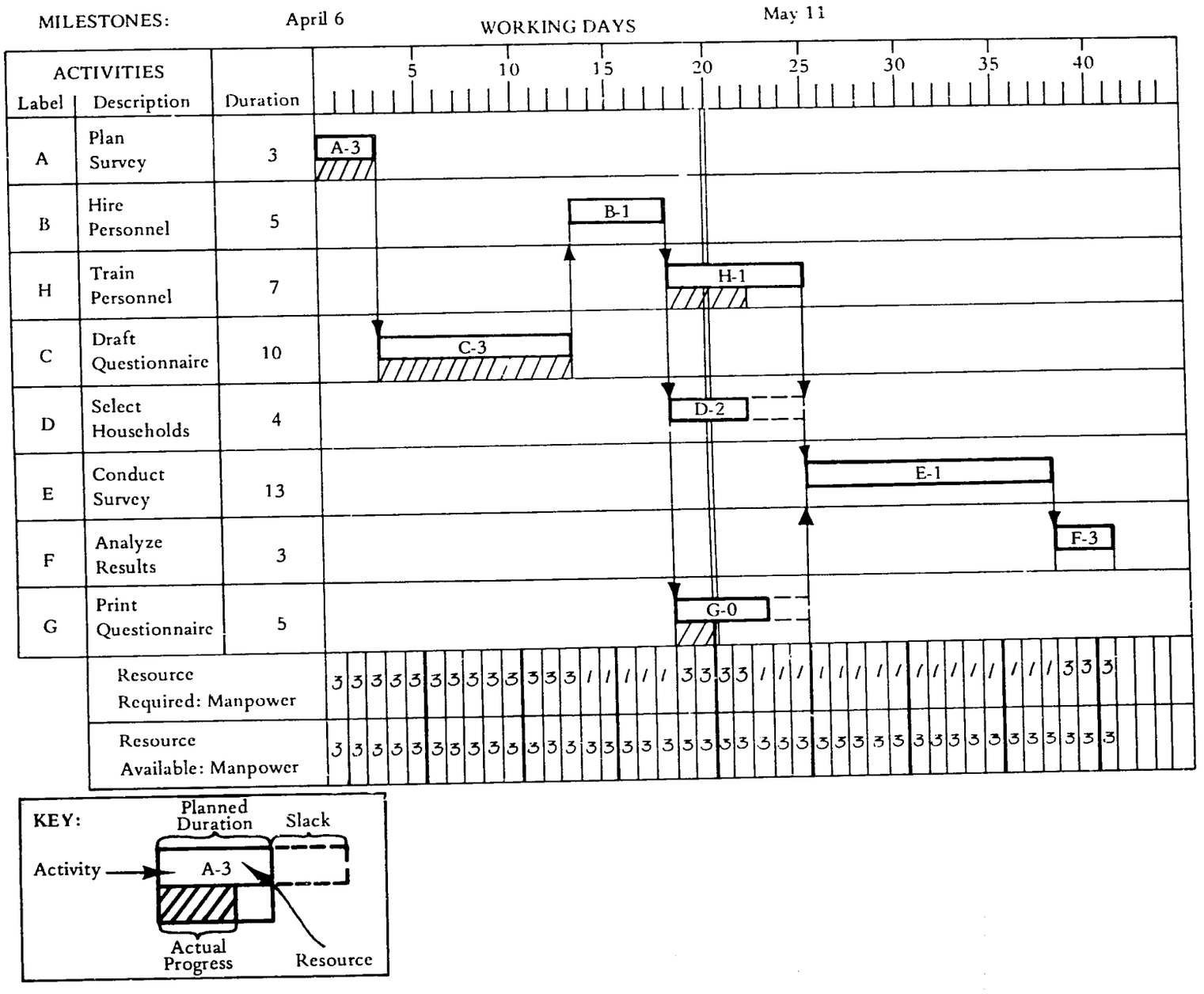
ACTIVITY						START		FINISH			
No.	Description	DURATION	RESOURCE	IMMEDIATE PREDECESSORS	IMMEDIATE SUCCESSORS	EARLIEST	LATEST	EARLIEST	LATEST	SLACK	STATUS
A	PLAN SURVEY	3	3	-	B,C	0	0	3	3	0	Critical
B	HIRE PERSONNEL	5	1	A	H	3	8	8	13	5	
C	DRAFT QUESTIONNAIRE	10	3	A	D,G,H	3	3	13	13	0	Critical
D	SELECT HOUSEHOLDS	4	2	C	E	13	16	17	20	3	
E	CONDUCT SURVEY	13	1*	D,G,H	F	20	20	33	33	0	Critical
F	ANALYZE RESULT	3	3	E	-	33	33	36	36	0	Critical
G	PRINT QUESTIONNAIRE	5	0**	C	G	13	15	18	20	2	
H	TRAIN PERSONNEL	7	1	B,C	E	13	13	20	20	0	Critical

LIMITED RESOURCE: Manpower

*Only one supervisory staff required
**Sent to printers

FIGURE 4

Gantt Chart for Survey Example after Adjustments for Limited Manpower



The limited resource for this example was the staff available for planning and conducting the survey. The manpower necessary for each activity was determined (see figure 3, column 4).

Construct the Gantt Chart for an Unlimited Resource

The Gantt Chart is shown in figure 1. The scale is in working days. Note that the slack for non-critical activities is shown directly on the time scale. This chart represents an early start schedule since the slack period always follows each activity.

Determine Resource Requirements

The total resources for each day were tabulated. The total requirement for the project was 81 man-days; the average daily requirement was 2.44 men.

Adjust the Schedule for the Limited Resource

No more than three staff members are available during the project. Though this exceeded the average requirement, a comparison with the Gantt Chart (figure 1) revealed that four men are needed on days three through eight of the schedule. Hiring personnel to conduct the survey and designing and drafting the questionnaire could not be scheduled concurrently. All three staff members were needed to draft the questionnaire and the duration of that activity remained as estimated. Five days of slack followed the hiring of personnel; this task's manpower requirement could be halved and the duration doubled without delaying the project. Yet, the resources required would still have exceeded those available by half a staff person per day. Assuming that the job of hiring personnel could not be delegated to another part of the organization, the only remaining choice was to reschedule the two activities so that they no longer overlapped.

The revised schedule required a minimum of 41 days, but the manpower requirement remained within the limits for the entire project period (see figure 4). The average daily staff requirement was just under two men. Activity B, HIRE PERSONNEL, became a critical activity in this schedule.

Use the Gantt Chart to Manage the Project

Milestones were added to the Gantt Chart at 25 working days, or May 11, assuming the project began on April 6. The non-critical activities were scheduled to start at their earliest feasible time in order to provide a cushion if time estimates were wrong or delays occurred. The progress as of May 4 (20 working days after the project began) was shown on the chart by cross-hatching the status of each activity. Note that household selection had not started, and attention was given to getting that task underway. However, it was not necessary to redraw the Gantt Chart since there was sufficient slack to complete this task without delaying the project.

THEORY

The construction of a Bar Chart to illustrate the schedule of project activities originates from management practice rather than from a complex theory. However, the Gantt Chart technique as described here draws from two theoretical areas: network scheduling techniques (see, for example, Moder and Phillips, 1964) and resource allocation theory (see Davis, 1966, for a review of relevant theory).

The Gantt Chart technique described in the general procedure section constructs a time-scaled CPM network; that is, a network in which the length of the connecting arrows shows the duration of the activities.

The Gantt Chart provides a graphic record-keeping format for scheduling a limited resource. It does not provide a means for optimum allocation of scarce resources as this is beyond a trial and error approach. The technique has been described as heuristic and, as such, is more an art than a science (see Mulvaney, 1969, and Bedworth, 1973).

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Logical Framework

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

Logical Framework enables the decision maker to identify project purposes and goals and plan for project outputs and inputs.

USES

The Logical Framework has been used widely by USAID Missions to:

1) Aid in planning a project.
2) Provide measures to evaluate a project.
3) State assumptions about causal linkages.

KEY DEFINITIONS

1) The *purpose* of a project is its primary intention or aim; it is the reason why a project is designed.

2) The *goal* of a project is a value judgment which satisfies one or more human needs. A *program* or *sector* goal is the broader objective to which a project contributes.

3) The *outputs* of a project are the desired and undesired results of the transformation process of a system, e.g., patients leaving a hospital, cured or not, are the results of a health delivery system.

4) The *inputs* of a project are the people, information, and/or physical items which enter the system to be transformed by a sequence into the outputs of the system, e.g., for an agricultural development project, inputs may be seeds, money, etc.

5) The *sector* is the larger system of which a project is part, e.g., building a dam is a project in the agricultural sector.

6) *Objectively verifiable indicators* demonstrate that certain desired results are being accomplished.

7) *Means of verification* are the specific mechanisms by which quantitative indications of the accomplishment of a project may be observed.

SHORT DESCRIPTION

The decision maker uses two types of logic to arrive at explicit statements which serve to help in planning or in evaluating a project in progress.

A vertical logic clarifies why a project is being undertaken. It specifies the program or *sector goal,* and project *purposes, outputs,* and *inputs.*

A horizontal logic identifies what is to be produced and the evidence that will signal success. It lists *objectively verifiable indicators, means of verification,* and important assumptions. Figure 1 presents the basic format for the Logical Framework.

FIGURE 1
The "Logical Framework"

PROJECT DESIGN SUMMARY
LOGICAL FRAMEWORK

Life of Project:
From FY _____ to FY _____
Total U.S. Funding _____
Date Prepared: _____

Project Title: _____

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
Program or Sector Goal: The broader objective to which this project contributes	Measures of Goal Achievement:		Assumptions for achieving goal targets:
Project Purpose:	Conditions that will indicate purpose has been achieved: End of project status.		Assumptions for achieving purpose:
Outputs:	Magnitude of Outputs:		Assumptions for providing outputs:
Inputs:	Implementation Target (Type and Quantity)		Assumptions for providing inputs:

SOURCE: Reprinted from Leon J. Rosenberg and Molly Hageboeck, "Management Technology and the Developing World," in *System Approaches to Developing Countries*, Proceedings of the symposium sponsored by IFAC and IFORS, May 28-31, 1973, Algiers, Algeria, page 5. Used with permission.

ADVANTAGES

1) The Logical Framework is simple to understand. It provides a structure for concepts, ensuring that the decision maker thinks through the fundamental aspects of a project design.

2) The framework aids in evaluating a project since both initial goals and final results are clearly delineated (similar to the System Definition Matrix, SDM, page 67). By explicitly identifying how the project is to be evaluated, the decision maker can make realistic estimates of project outcomes and can identify problems which might be encountered.

LIMITATIONS

1) During the planning process, the Logical Framework does not take uncertainty into account. Neither does it allow for the consideration of potential alternative actions.

2) A linear causal sequence is assumed which is an unlikely simplification of the relationships among various project components and elements in the environment (see Oval Diagramming, OVD, page 81).

REQUIRED RESOURCES

LEVEL OF EFFORT

The decision maker must define the project goals, purposes, inputs, and outputs in measurable or objectively verifiable terms. Thus, while the Logical Framework may guide the planning process, it is not a substitute for the considerable effort required to plan effectively.

SKILL LEVEL

The decision maker must be able to think logically and to consider the important attributes, both quantitative and qualitative, of the project.

TIME REQUIRED

Completing the Logical Framework takes from several days to several weeks, depending on the size of the project.

DESCRIPTION OF TOOL

REQUIRED INPUTS

The decision maker needs to identify the project which is part of a program or sector. The success of a program depends on the success of the various projects carried out within that program or sector.

Other tools may be used to complete the Logical Framework. The objective tree (OBT, page 49) can help to structure goals, purposes, and criteria for evaluation. To explore the links between inputs and outputs, interaction matrix diagrams (IMD, page 92) would be useful. To develop a more thorough structure of a system, the System Definition Matrix (SDM, page 67) can be used.

TOOL OUTPUT

The completed Logical Framework matrix is one output of the technique. The other is the contribution that the process makes to the project design or evaluation. By thinking through the horizontal logic, crucial hypotheses about causal linkages may be determined. Developing the horizontal logic forces the planner to think in terms of realizable results. The Logical Framework then serves as a statement which, to some degree, indicates the completeness and soundness of these analytical processes.

IMPORTANT ASSUMPTIONS

Underlying any planning technique of this sort is an assumption of the inherent rationality of project interventions. One need only identify the causal linkages from inputs to outputs to purpose, and the project has been designed systematically. Yet it is not a systems design necessarily, since systems seldom exhibit exclusively linear causality. There are interactions with environmental components, feedback relationships, and complex relationships among the elements of the system. Thus the Logical Framework assumes a simplicity qualified only by entries in the "assumptions" column.

METHOD OF USE

GENERAL PROCEDURE

The recommended procedure is based on the work of Rosenberg and Hageboeck (1973) and the Office of Program Evaluation, USAID (1974). The vertical logic (column 1 in figure 1) clarifies why a project is being undertaken. It characterizes a project as a set of linked hypotheses:

If we provide the following inputs,
then we can produce the requisite outputs.
If we produce those outputs,
then the purpose will be achieved.
If the purpose is achieved,
then the goal will be realized.*

* Leon J. Rosenberg and Molly Hageboeck, "Management Technology and the Developing World," in *Systems Approaches to Developing Countries*, Proceedings of the Symposium sponsored by IFAC and IFORS, May 28-31, 1973, Algiers, Algeria.

FIGURE 2
An Example of a Logical Framework

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
Program or sector goal: Provide universal education geared to needs of Temasek	Measures of goal achievement: (a) Degree of shortage/surplus in various professions	(i) Questionnaires to major industries (ii) Comparison of number of students graduated with objective in 10-year plan	Assumptions for achieving goal targets: Ability of economic sector to provide jobs predicted in 10-year plan
Project purposes: 1. Meet the educational needs of a rural agricultural community	Measures of purpose achievement: (a) Number of students from rural and urban areas proportionate to the population of potential students (b) Research and course directions in School of Agriculture	(i) Demographic data (ii) Opinions of leaders of rural interest groups	Assumptions for achieving purpose: Ability of primary and secondary schools in rural areas to provide students with an adequate foundation for tertiary education
Outputs: 1. Students with degrees in: Agriculture, Science, Engineering	Magnitude of outputs: 500/year 100/year 200/year	Data collection by university	Assumptions for providing outputs:
Inputs: 1. Faculty 2. Students 3. Scholarship program	Implementation target: *Type* — *Quantity* PhD in Ag. — 9 MS in Ag. — 5 MS in Science — 5 PhD in Engr. — 10	Data collection by university	Assumptions for providing inputs: Brain drain is cut by half in five years

1. **Complete the vertical logic.**
   Determine at each lower level the conditions which are necessary and sufficient to achieve the next upper level (see figure 1). The inputs must be necessary and sufficient to produce all the outputs; the outputs must be necessary and sufficient to achieve the purposes, etc. For example, for the construction of irrigation canals covering 2,000 acres (output), there could be several inputs: "20 shovels," "farmer support," and an "irrigation engineer." The analyst must be sure that each input is necessary to achieve the construction of the canals. He should determine if the inputs are sufficient or if some are missing.

2. **Complete the horizontal logic.**
   2.1 At each level of the vertical logic, complete the three part horizontal logic. Determine:
      a) Objectively verifiable indicators which demonstrate that the desired end has been accomplished.
      b) Means of verification, or specific mechanisms through which accomplishment is objectively verified.
      c) Important assumptions which affect the success of the project. Here, the project designer explicitly identifies the uncontrollable factors that may affect project success.

   2.2 Consider objectively verifiable indicators which may or may not be quantifiable. The two step "clarification of evidence" involves identifying first the indicator and then the means of verification. The project designer is encouraged to measure what is important, rather than what is easy to measure.

   2.3 Follow each of the vertical logic levels through the horizontal logic. For instance, after the purpose of the project has been established, fill in the conditions which indicate that the purpose has been achieved according to the means of verification. There may be many indicators which point to success at the purpose level since a single indicator is seldom sufficient to signal success.

   2.4 State the assumptions which underlie the achievement of the project purpose.

EXAMPLE

Consider the educational sector in the country of Temasek. Currently, there is a National University in Bandar Besar, the capital, which is attended mainly by students from urban areas. The northern rural areas, with strong agricultural needs, do not receive enough agricultural education from this university. A project is undertaken to establish a university at Bandar Kechil to serve that area's needs. Figure 2 shows a partially completed Logical Framework for this project.

THEORY

The Logical Framework technique is based on a systems planning model. The vertical logic closely relates to the System Definition Matrix (SDM, page 67). Some theoretical work has been done on identifying social indicators and objectively verifiable indicators (see, for example, DeGreene, 1973).

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List of Cross-References

Benefit-Cost Ratio
CBA, CFA, DIS, IPX, IRR, NPW, SVY
Brainstorming
CBA, DTR, NGT
Cash Flow Analysis
BCR, CBA, CEA, DIS, IPX, IRR, NPW, SVY
Computer Simulation Models
DTB, FLW, GAM, IMD, OVD, QTN, SVY
Contingency Analysis
CBA, CEA, DTR, IDL, MCU, PPM, SCN, SPA
Cost-Benefit Analysis
BCR, CEA, CFA, DIS, IMD, IPX, IRR, MPA, NPW, OBT, OVD, PPB, RTS, SDM, SVY
Cost-Effectiveness Analysis
BCR, CBA, CFA, CGA, CSM, DIS, DLP, IRR, OBT, RTS
Critical Path Method
CGA, GNT, SVY
Decision Tables
CSM, FLW, IRR
Decision Trees
CGA, MCU, SPA, SVY, TRD
Delphi
HIS, NGT, QTN
Discounting
BCR, CFA, IRR, NPW
Exponential Smoothing Forecasts
RGF
Flowcharts
DTB, IMD, SCN, SDM
Function Expansion
BSG, IDL, NGT, SDM
Gaming
CGA, CSM, IMD, OVD, SCN, TRD
Gantt Charts
CPM, SVY
Histograms
DLP, RTS, SPA, SVY
IDEALS Strategy
BS[illegible]BA, FEX, NGT, SDM
Impa[illegible]ncidence 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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