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Chapter 8 presents eight techniques for the financial and economic analysis of development projects. Cast Flow Analysis determines the difference between the incremental costs and the incremental benefits for each year of a project in order to evaluate its financial viability. Discounting provides a basis for analyzing and comparing future streams of costs and benefits by reducing them to their equivalent present worth. Net Present Worth evaluates project net benefits by comparing different time streams of benefits and costs. The ratio of project benefits to project costs (Benefit-Cost Ratio) evaluates the efficiency of project resource use. Internal Rate of Return is a criterion for analyzing projects based on the percentage return on investment. An Impact-Incidence Matrix tabulates the distributions of project costs and benefits to the affected groups in the society. Cost-Benefit Analysis identifies, assesses, and weighs costs vs. benefits to evaluate the financial and economic merits of development projects. Cost-Effectiveness Analysis evaluates the effectiveness relative to the costs of alternative means to the project objectives.

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VIII
Analyzing Projects

Cash Flow Analysis
Discounting
Net Present Worth
Benefit-Cost Ratio
Internal Rate of Return
Impact-Incidence Matrix
Cost-Benefit Analysis
Cost-Effectiveness Analysis

The financial and economic analysis of projects requires the synthesis of many techniques. The primary process is the weighing of project benefits against the costs (Cost-Benefit Analysis). The time stream of benefits and costs must be considered (Cash Flow Analysis) and weighted (Discounting) in order to make project alternatives comparable. Distribution effects are an essential factor in a systems approach to economic analysis (Impact-Incidence Matrix). Various criteria are used to decide the merits of projects (Net Present Worth, Benefit-Cost Ratio, and Internal Rate of Return).

The effectiveness of projects (or systems) is weighed against costs (Cost-Effectiveness Analysis) to evaluate the degree to which various alternatives achieve given objectives. This is a criterion not unlike those used for analyzing benefit-costs, except that benefits are not valued in monetary units.

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

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

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

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

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

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

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

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

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

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

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

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

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

APPLYING A SYSTEMS APPROACH

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

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

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

TOOL DESCRIPTIONS

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

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

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

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

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

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

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

USING THE SYSTEM TOOLS HANDBOOK

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

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

DEVELOPING SYSTEM MODELS

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

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

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

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

FIGURE 1a

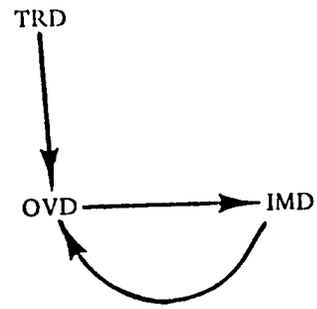
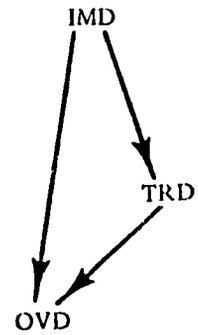
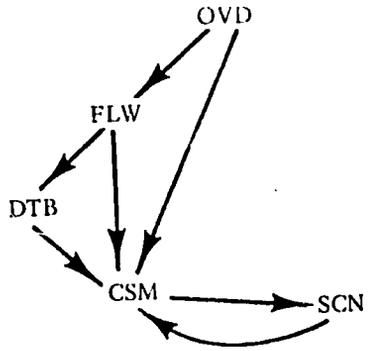


FIGURE 1b



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

FIGURE 2



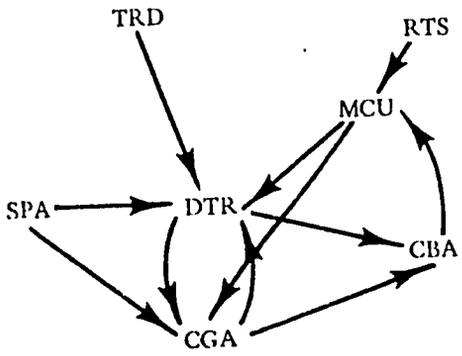
GENERATING AND ANALYZING ALTERNATIVE PLANS OF ACTION

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

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

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

FIGURE 3



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

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

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

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

A NORMATIVE APPROACH TO PLANNING

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

FIGURE 4

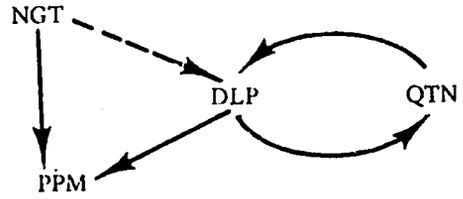
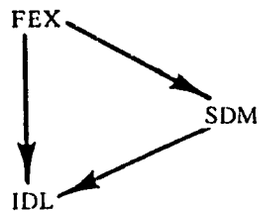


FIGURE 5



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

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

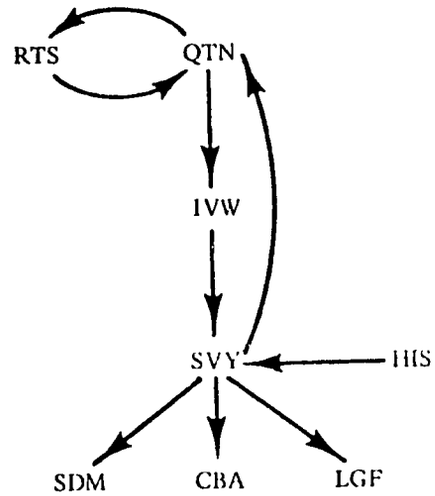
Focusing on function rather than on problems gets people involved in a constructive assessment of what should be, rather than what's wrong and who's to blame. There are sound arguments for both approaches. The IDEALS Strategy often comes under attack because its emphasis on normative specification may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

USING SAMPLE SURVEYS TO GATHER INFORMATION

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

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

FIGURE 6



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

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

PROJECT FINANCIAL ANALYSIS

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

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

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

FIGURE 7

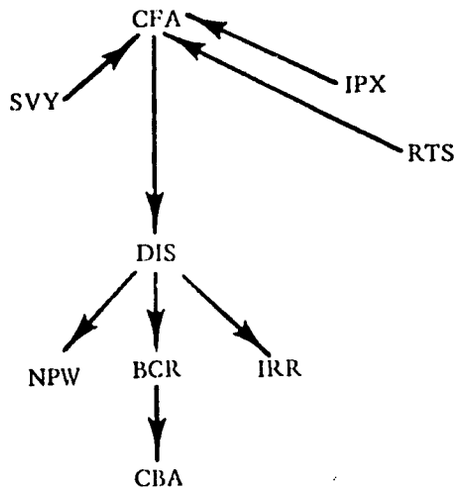
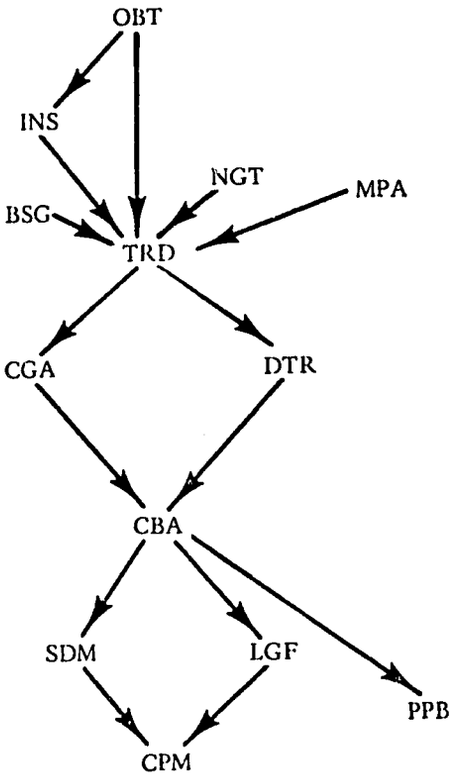


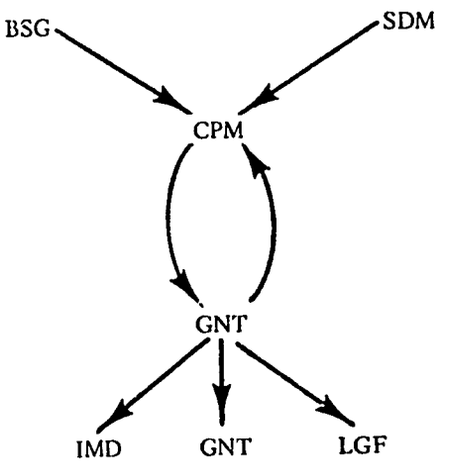
FIGURE 8



THE "CONVENTIONAL" SYSTEMS APPROACH

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

FIGURE 9



PLANNING PROJECT ACTIVITIES FOR IMPLEMENTATION AND CONTROL

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

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

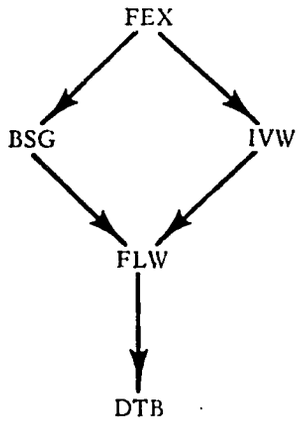
Framework may also be used to sharpen the identification of objectively identifiable indicators of progress. These milestones are shown as vertical lines on specific dates of the Gantt Chart and written on the Critical Path Method network at the appropriate nodes.

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

ANALYSIS AND PROGRAMMING OF DECISION PROCESSES

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

FIGURE 10

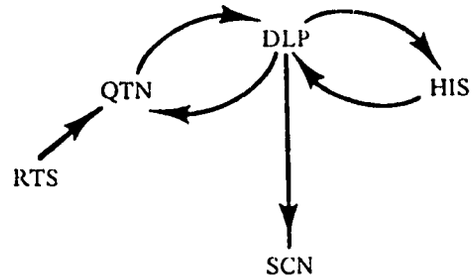


The results of this analysis are presented in the form of flowcharts (FLW, page 107) or decision tables (DTB, page 113). The flowchart uses different symbols to display and analyze complex processes. The decision table presents the decision as a preprogrammed process by specifying the conditions which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

QUALITATIVE FORECASTING

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

FIGURE 11

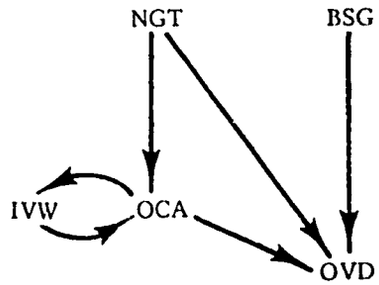


The Delphi technique (DLP, page 168) begins by directing questionnaires to a selected group of prognosticators. The results of each round are summarized for the Delphi group, often in the form of a histogram which aggregates the individual judgments. Rating scales attempt to quantify priorities and opinions.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

PROBLEM ANALYSIS STRATEGIES

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

FIGURE 12



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

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

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

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

CONCLUSIONS

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

Cash Flow Analysis

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

Cash flow analysis determines the difference between the *incremental costs* and the *incremental benefits* for each year of a project in order to evaluate its financial viability.

USES

Analyzing cash flows:

1) Provides an overall picture of the costs and benefits accruing from a project over the estimated life of the project.

2) Enables calculation of the *total cash flow* or the *net incremental benefit* of the project.

3) Indicates any negative cash flow years which may affect project viability.

4) Provides the basis for calculating measures which account for the time value of money (e.g., Net Present Worth, NPW, page 188; Benefit-Cost Ratio, BCR, page 194; and Internal Rate of Return, IRR, page 200).

KEY DEFINITIONS

1) *Incremental costs and benefits* are computed by subtracting the "without project" values from the "with project" values. They represent the changes the project is expected to produce compared to what would otherwise occur. Note that this is not the same as computing "before" and "after" project values, since conditions may be predicted to change whether or not the project is implemented (see Sirken, or Gittinger, 1972).

2) *Annual cash flow* is the net incremental "benefits" for each year of a project and the difference between the incremental benefits and costs.

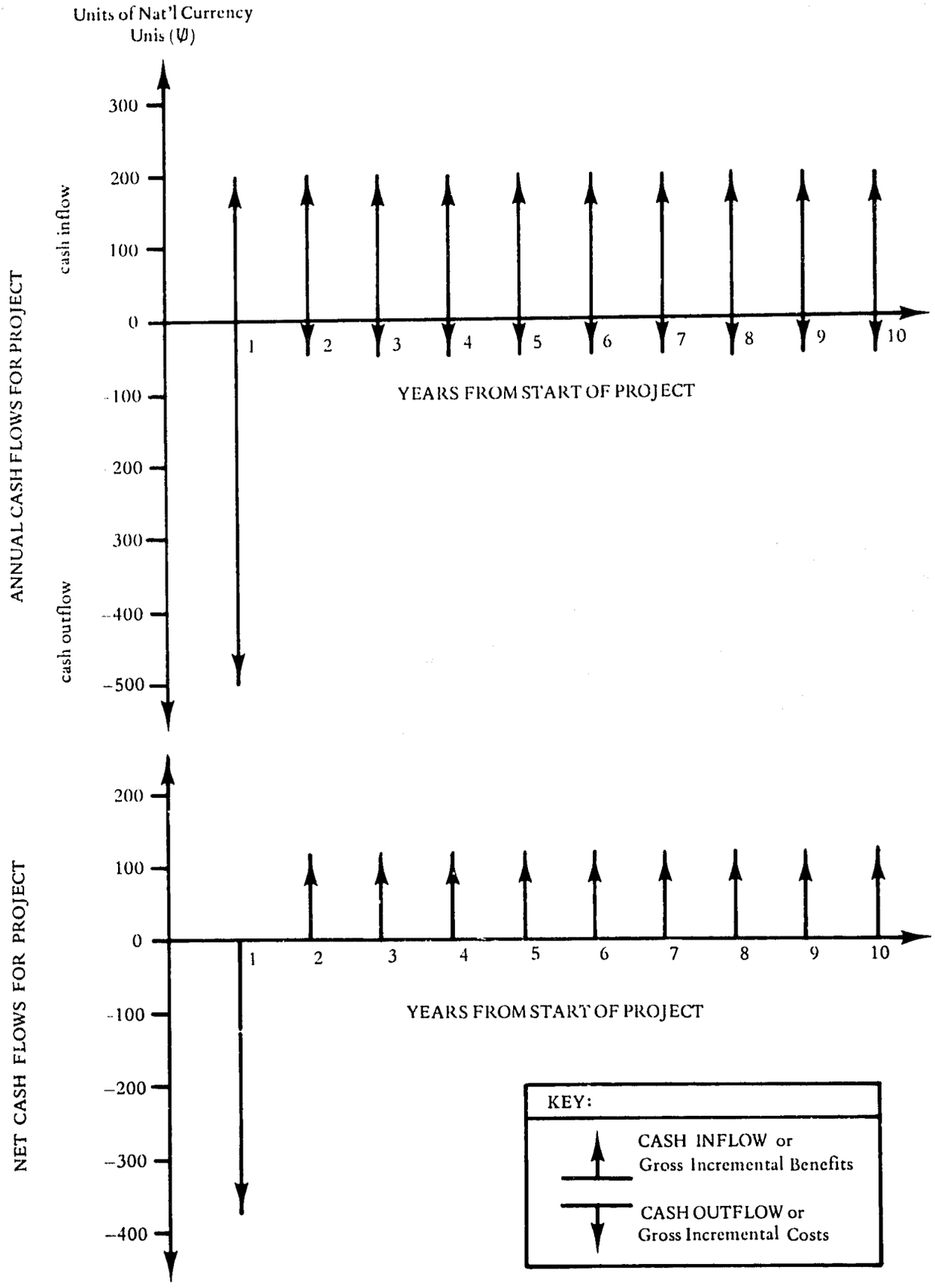
3) *Total cash flow* is the sum of annual cash flows for the life of the project. It is an undiscounted measure* of the aggregate change expected from implementing a project.

4) *Financial analysis* is done from the viewpoint of the individual, group, or business which will directly gain or lose because of the project. All costs and benefits are valued at market prices.

5) *Economic analysis* is done from the viewpoint of the national government and the economy. Taxes, interest, custom duties, etc., are excluded from the calculation of costs and benefits, and labor and foreign exchange may be shadow-priced.

*In contrast to net present worth or other discounted measures (see DIS, page 184).

FIGURE 1
Graphic Illustration of Cash Flow for a Project



6) *Shadow prices* are adjusted market prices which reflect the true benefit or cost to the economy, e.g., the difference between the market (subsidized) price of fertilizer and the world price the government must pay.

SHORT DESCRIPTION

Cash flow analysis is a central part of the financial and economic evaluation of projects. Distinguishing between "with project" and "without project" benefits gives the incremental benefit (Gittinger, 1972) and the changes in benefits that are projected during each year of the project. Incremental costs are computed using the same distinction.

The *annual cash flow* is the difference between incremental benefits and incremental costs in that year. A typical project has an early negative and a later positive cash flow when the incremental benefits exceed incremental costs (see figure 1).

Cash flow analysis for development projects distinguishes between *financial* and *economic* analysis (see Cost-Benefit Analysis, CBA, page 212). This distinction affects the identification and estimation of project costs and benefits. Otherwise, the subsequent computation procedure is the same.

ADVANTAGES

Cash flow analysis shows the changes that the project is expected to bring about in both increased benefits and increased costs. There may be changes in the amounts of benefits or costs as well as in the sources (USDA, 1971). The project may replace an existing service or production arrangement whose costs and benefits represent the "without project" financial situation.

The total cash flow for a project gives an indication of the performance of a project during its life.

A negative annual cash flow may indicate financing problems for the project, and credit may need to be arranged.

LIMITATIONS

The annual cash flow of a project is an aggregated measure of the complex interaction among gross benefits and costs from "with project" and "without project" estimates. As a consequence, many assumptions about individual project-induced changes in the environment may be lost in the aggregate data.

The total cash flow for a project fails to account for the time value of money. Cash flow analysis does not account for benefits or costs which cannot be assigned a monetary value (e.g., good will, customer confidence, or a farmer's sense of security).

REQUIRED RESOURCES

LEVEL OF EFFORT

Cash flow analysis demands extensive data gathering and forecasting of costs and benefits. These tasks should not be underestimated, particularly since cash flow analysis is usually the first step in a sequence leading to an analysis of the economic and financial feasibility of a project.

SKILL LEVEL

Skills in cash accounting, balanced by the ability to judge future disbursements, are essential. If data are available, the subsequent computations are rather mechanical. But at all times the meaning behind the figures must temper their use. This is undoubtedly a skill which must be learned from analyzing related projects in similar environments.

TIME REQUIRED

Several days to several weeks may be required for data gathering. A longer period is necessary if a survey is involved (SVY, page 36). The analysis should not require more than a few hours.

SPECIAL REQUIREMENTS

Budgetary data and computation devices (e.g., hand calculators) are useful.

DESCRIPTION OF TOOL

REQUIRED INPUTS

Cash flow analysis requires an estimation of costs and benefits over the life of a project. Where accounting information is available and reliable, the determination of capital and operating costs and projected profits is straightforward. However, the indirect costs and benefits which may not be easily derived require considerable astuteness and information-gathering.

TOOL OUTPUT

Cash flow analysis gives a pattern of benefits and costs which can be analyzed directly to influence investment decisions (figure 1). For example, if a cash flow in any year is negative, the project may have to be redesigned or credit may have to be provided. Typically, however, the data will be used to compute other criteria of economic feasibility, e.g., the Net Present Worth (NPW, page 188) and the Benefit-Cost Ratio (BCR, page 194).

FIGURE 2

Small Farmer Tractor Utilization: Purchase Option

	YEARS FROM START OF PROJECT										
	1	2	3	4	5	6	7	8	9	10	TOTAL
WITHOUT PROJECT	Unis (Temasek National Currency)										
Gross Costs											
Usual Production Expenses	100	100	100	100	100	100	100	100	100	100	1000
Gross Benefits	160	160	160	160	160	160	160	160	160	160	1600
Net Benefits (Annual Profit)	60	60	60	60	60	60	60	60	60	60	600
WITH PROJECT											
Gross Costs											
Investment Costs (tractor)	500	0	0	0	0	0	0	0	0	0	500
Production Expenses											
Usual Expenses	130	130	130	130	130	130	130	130	130	130	1300
Operating and maintenance of tractor	50	50	50	50	50	50	50	50	50	50	500
Gross Benefits	360	360	360	360	360	360	360	360	360	360	3600
Net Benefits (Annual profit)	(320)	180	180	180	180	180	180	180	180	180	1300
CHANGES DUE TO PROJECT											
Incremental Costs (Cash outflow)	580	80	80	80	80	80	80	80	80	80	1300
Incremental Benefits (Cash inflow)	200	200	200	200	200	200	200	200	200	200	2000
Net Incremental Benefits (Project annual cash flow)	(380)	120	120	120	120	120	120	120	120	120	700
	TOTAL CASH FLOW = Ø 700										

IMPORTANT ASSUMPTIONS

It is assumed that the relevant costs and benefits have been identified and quantified in monetary units. Where this is impossible, the cash flow analysis gives only an abbreviated picture of an investment decision. Other measures, such as Cost-Effectiveness Analysis (CEA, page 219), must then be used.

METHOD OF USE

GENERAL PROCEDURE

1. **Identify the cost and benefit components of the project. Identify the target population – the people who are to directly benefit from the investment or project (see Impact-Incidence Matrix, IPX, page 207).**
   - 1.1 List the costs which will be changed as a result of the project. These include changes in the costs of goods, services, labor, and management identified by contrasting the "with project" and the "without project" situation. The "without project" costs are zero if the investment is not replacing a current practice or productive enterprise.
   - 1.2 List the categories of benefits which will be changed as a result of the project. Increased production efficiency, higher yields, and more marketable products contrast "with project" benefits with the "without project" benefits.
   - 1.3 If the cash flow analysis is part of a financial analysis of the project, identify the costs and benefits which affect the individual, cooperative group, enterprise, or target population. These include taxes, the subsidized prices of inputs, and the prevailing market prices for yields.
   - 1.4 If the cash flow analysis is part of an economic analysis, identify the costs and benefits for the target population which represent a return or cost to the whole society. Taxes are excluded,* and the unsubsidized price of inputs and the world prices of exportable produce are used. Shadow prices must be determined for imported goods and labor (see Gittinger, 1972).

2. **Determine the life of the project or the time span of analysis.**
   - 2.1 Estimate the effective life of any major capital equipment, e.g., tractors, pumps, buildings.
   - 2.2 Estimate the probable time span for the full realization of benefits.
   - 2.3 Select a project life based on these estimates and the knowledge that costs or benefits occurring in more than 20 years have little effect on criteria such as net present worth. The discounted values (see Discounting, DIS, page 184) are small in relation to values in the first decade of a project.

3. **Estimate the gross costs and benefits during each project year.**
   - 3.1 Estimate all quantifiable costs and benefits projected for each project year and enter in a table (see figure 2). These are the "with project" values. A convenient accounting convention is to assume that all costs and benefits are paid at the end of the year in which they occur.
   - 3.2 Estimate the "without project" costs and benefits which will hypothetically occur if the current situation continues in the absence of any investment project. It may be necessary to conduct a survey to determine the average costs and benefits accruing from current practices of the target population (see Surveys, SVY, page 36). Enter these estimates in the table (see figure 2).

4. **Compute the incremental costs and benefits of the project for each year.**
   - 4.1 Subtract the "without project" benefits from the "with project" benefits to give the incremental benefits for each project year and enter in the table as a change due to the project.
   - 4.2 Subtract the gross "without project" costs from the gross "with project" costs to give the incremental costs for each project year and enter in the table as a change due to the project.

5. **Compute the annual cash flows or net incremental benefits.**
   - 5.1 Compute the annual cash flows by subtracting the incremental costs from the incremental benefits to give the net incremental benefit.
   - 5.2 Compute the total cash flow for the life of the project by summing the annual cash flows. The computations in steps 4 and 5 are illustrated in figure 3.

6. **Diagram the annual cash flows (optional).**
   - 6.1 Plot the incremental costs (cash outflow) and benefits (cash inflow) (see figure 1).
   - 6.2 Plot the net incremental benefits (annual cash flow) to reveal the fluctuations in benefits which may occur throughout the project life. (These graphs are particularly useful in computing the Internal Rate of Return, IRR, page 200.)

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*Taxes are not a net benefit to the economy as a whole, only a transfer of resources within the society.

FIGURE 3
Computing the Net Incremental Benefit or Cash Flow Resulting from a Project

	Gross Costs	Gross Benefits	Net
With Project	C	B	B − C
Without Project	C′	B′	B′ − C′
Increment Δ	C − C′ = ΔC Incremental Cost CASH OUTFLOW	B − B′ = ΔB Incremental Benefit CASH INFLOW	ΔB − ΔC Net Incremental Benefit CASH OUTFLOW

EXAMPLE

A small farmer in Temasek (average holding of seven acres) has an average annual production cost of Ψ100 (Ψ = Unis, the Temasek currency note).* These costs include land preparation, cultivation, seed, and other production inputs. The current annual benefits were Ψ160, giving the farmer a net profit of Ψ60 per year.

The Ministry of Agriculture wanted to introduce small walking tractors (five to ten horsepower). A technical analysis of power requirements indicated that such a tractor would enable the farmer to cultivate more intensively (e.g., double cropping) and to expand his holdings, increasing his production by 200% (see Balis, 1974). This would eventually lead to a Ψ360 rise in annual benefits with corresponding production costs of Ψ130.** Tractor costs were initially a Ψ500 investment with Ψ50 for operation and maintenance per year. The estimated life was ten years with no salvage value.

The Ministry of Agriculture field staff prepared a financial cash flow analysis from the viewpoint of a typical farmer (see figure 2). By accounting convention, all costs and receipts were assumed to be paid at the end of each year. For example, the purchase price of the tractor was listed as an expense for the first year.

A diagram of the annual cash flows was constructed to clarify the components of the net incremental benefits. The analyst noted that, in the first year, the farmer would have a negative cash flow of Ψ380. Therefore, many farmers needed financial assistance to purchase the tractor. Feasible loan arrangements were included in subsequent cash flows analyses. The interest costs of borrowing money were entered in the gross "with project" costs.

*In this example, the analysis is financial rather than economic, i.e., the cost estimates are all based on market values.

**It was assumed that the increase in seed, fertilizer, and other costs would be countered by a reduction in labor costs.

The net incremental benefits were estimated at Ψ700 over the ten-year tractor life. Since the farmer would make Ψ700 more than he would otherwise, the project seemed to be justified.*

The economic analysis of the farmer's tractor purchase option would look at the target group as a whole and the impact of the tractor purchases on the economy as a whole. This analysis involves many assumptions about the effective shadow prices for necessary farm inputs (e.g., fuel for the tractors and spare parts), the cost of labor, and effects on foreign exchange. This is beyond the scope of a non-economist. The reader is referred to the many texts on economic analysis (e.g., Gittinger, 1972).

THEORY

Cash flow analysis conceptualizes a stream of cash flowing out of a project or enterprise and an incoming stream. The cash outflow pays for capital goods, services, management, and labor for the project. The cash inflow is the benefit stream or returns to the project. The net cash flow, the difference between cash inflow and outflow, describes the dynamic transactions of the project at yearly intervals.

The description of cash flow analysis is drawn largely from Gittinger (1972) and the Economic Development Institute of the World Bank. The distinction between "with project" and "without project" situations is less critical than the difference between financial and economic analysis. If necessary, "without project" values can be incorporated into the determination of the benefits expected from the project (e.g., reduced labor costs brought about by a product can be treated as an incremental benefit of the project).

However, the difference between financial and economic analysis significantly affects the inputs to the cash

*This example is continued through a sequence of project analysis tools ending with Cost-Benefit Analysis.

flow analysis and the conclusions which may be drawn from the results. Adjustment of market prices by using shadow prices or some other multiplier is a complex process (see, for example, Bruce, 1976; Little and Mirlees, 1968; Squire and van der Tak, 1975; and Weckstein, 1971-72) and is the subject of some debate.

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Discounting

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

Discounting provides a basis for analyzing and comparing future streams of costs and benefits by reducing them to their equivalent *present worth.*

USES

1) Future payments, either single, a uniform series (annuity), or an irregular series can be converted to their present worth by using *discount factors* computed from an appropriate *discount rate.*

2) The difference between payments made now and payments made in the future can be translated into a constant discount rate to measure the preference for present as opposed to future benefits.

3) Discounting permits inclusion of *time preference* in analyzing the net value of a single project, and in comparing two or more projects with dissimilar time-streams of costs and benefits.

KEY DEFINITIONS

1) *Present worth* is the value today of a future payment.

2) *Discount rate* is a percentage rate (usually annual) which equates the present and the future worth of a payment.

3) A *discount factor* is a fraction between zero and one which gives the present worth of one monetary unit spent or received.

4) *Time preference* is the general preference of individuals for present over future receipts and for future over present expenditures.

5) *Opportunity cost* is 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.

SHORT DESCRIPTION

Discounting is a process of converting a single future payment or series of future payments to their equivalent present worth. The computation requires specifying a discount rate from which a discount factor may be determined.

Discounting future payments accounts for the time preference for present rather than future benefits. By discounting, payments that occur at various times throughout the life of a project can be made equivalent to present payments. A complex flow of payments can be converted to a single net figure, facilitating the valuation of one project or a comparison between projects in a way that reflects time preference and *opportunity cost.* It is the reverse of the compound interest process.

ADVANTAGES

1) Discounting provides a logical basis (time preference-opportunity cost) for comparing payments at various times. It facilitates the valuation of a single project or a comparison between projects.

2) Discounting puts more value on near-term than on distant payments. Since more distant forecasts are generally less reliable than short-term forecasts, discounting increases the degree of confidence that the analyst may have in his valuation.

LIMITATIONS

1) Establishing the discount rate is a theoretically complex and practically difficult chore. It may be based on the long-term market interest rates on relatively safe investments, e.g., government bonds are investment securities after taxes. Most analysts would argue that this is too low, and the discount rate should be estimated from the opportunity costs of capital (DeNeufville and Stafford, 1971). Gittinger (1972, page 90) reports that most countries use discount rates of 8% to 15% in their analysis, with 12% being used most often. In practice, a high rate is preferable to a low one.

2) The choice of a particular rate will influence the attractiveness of a project and may determine the ranking among alternative prospects. It is often desirable to repeat the analysis with varying discount rates, all of which are considered reasonable on some basis. If the results differ widely, the decision maker should be made aware of the significance of the choice of rate.

3) The appropriate discount rate, like other interest rates, might be expected to vary over time; yet discounting generally treats the rate as a constant parameter. It is, of course, possible to use varying discount rates for varying future periods if you have a basis for making such detailed forecasts.

REQUIRED RESOURCES

LEVEL OF EFFORT

Discounting can be time consuming, but it is not a difficult task. First, the appropriate discount rate must be determined. Then the discount factor is either computed or read from tables. Finally, the present worth is computed by multiplying the future payment by the discount factor. A pocket calculator and pretabulated discount factors reduce the effort.

SKILL LEVEL

Establishing the appropriate discount rate requires some expertise and subjective judgment. The opportunity cost of capital must be estimated, requiring a knowledge of the best return from alternative sources of investment.

The rest of the discounting process is rather mechanical and has a built-in self-checking process (see General Procedure).

TIME REQUIRED

The time required to discount a series of payments is a function of 1) the number of payments, 2) whether they are uniform or irregular, and 3) the availability of calculators and discount tables. This time is insignificant compared to the effort and time required to estimate the cash flow of future payments (see CFA, page 177).

SPECIAL REQUIREMENTS

A pocket calculator and a set of discount tables not only speed up the process, they help to eliminate simple errors in computation.

DESCRIPTION OF TOOL

SUPPLEMENTAL DEFINITIONS

1) DF $[r/n]$ = discount factor of an amount paid at end of year n at r discount rate (%).

2) ADF $[r/n]$ = annuity discount factor at r discount rate (%) for n years.

3) PW $[r/n]$ = present worth at discount rate r (%) of amount paid during n years.

For example, PW [15%/10] = -500 DF [15%/1] + 120 ADF [15%/10] is the present worth (at a discount rate of 15%) of a single disbursement of 500 units at year 1 and receipts of an annuity of 120 units for 10 years.

REQUIRED INPUTS

Computing the present worth requires:

1) The specification of the appropriate discount rate (see, for example, Hinrichs, 1969).

2) A tabulation of the future payments (costs or benefits) for each year (see Cash Flow Analysis, CFA, page 177).

TOOL OUTPUT

Discounting gives the present worth of a future payment or stream of payments. This discounted value can be

used to compute financial criteria for project evaluation:

1) the net present worth (NPW, page 188);
2) the benefit-cost ratio (BCR, page 194); and/or
3) the internal rate of return (IRR, page 200).

Any one of these measures may be used in the cost-benefit analysis of a single project or multiple projects.

IMPORTANT ASSUMPTIONS

Discounting reflects the preference for benefits now rather than at some later time. This time preference assumes that there is an opportunity cost in waiting to receive the benefits. One cost is the opportunity to invest in an alternative project which will yield a greater return than the amount invested. The second cost is the uncertainty of receiving delayed payments. The risk increases with the period of delay.

METHOD OF USE

GENERAL PROCEDURE AND EXAMPLES

Discounting a Single Future Payment

1. Determine the discount rate, r (see Net Present Worth, NPW, page 188).
2. Compute the discount factor, DF $[r/n]$:

$$DF[r/n] = 1/[1+(r/100)]^n \qquad [1]$$

where

n = number of years hence that the payment will occur

r = discount rate (%)

Or, determine the discount factor from the appropriate discounting table (see Gittinger, 1973).*

3. Multiply the discount factor by the payment amount to get the present worth:

$$PW = \text{Payment} \times DF[r/n] \qquad [2]$$

The present worth of a $200 payment five years hence was computed for discount rates of 10%, 15%, and 20%.

At a discount rate of 10%, the discount factor is:

$$DF[10\%/5] = 1/[1+(10/100)]^5 = 0.621.$$

The present worth is:

$$PW = (\$200 \times 0.621) = \$124.$$

The other discount factors are:

$$DF[15\%/5] = 0.497$$
$$DF[20\%/5] = 0.402,$$

giving present worths of $99 and $80, respectively.

*Discount factors for a single payment are always less than one. Usually, three significant figures are sufficient accuracy.

FIGURE 1
Computing the Present Worth of a Series of Nonuniform Payments

Year	Payment (or receipt)*	Discount Factor at 20%	Present Worth
1	(100)	0.833	(83)
2	(100)	0.694	(69)
3	200	0.579	116
TOTAL	0	2.106	(36)

*Negative amounts are shown in the table in parentheses.

Discounting a Series of Nonuniform Payments

1. Determine the discount rate, r.
2. Construct a table which lists the year and the payment amount in each year (see figure 1).
3. Determine the discount factor for each year at the appropriate discount rate.
4. Determine the present worth of each yearly payment.
5. Compute the sum of the present worths in order to give a single value. (Payments may be both negative expenditures and positive receipts.)

Two $100 expenditures were to be made in consecutive years in order to receive $300 at the end of the third year. The present worth of the three payments was computed by determining the present worth of each payment and summing (see figure 1). Two conventions were used: 1) all payments are assumed to occur at the end of the year (which means that the first expenditure must also be discounted); 2) expenditures are negative amounts (shown in parentheses) and receipts are positive. If the three payments are summed, the investor gains $100. However, using a discount rate of 20%, the sum of the discounted payments is only $22. A higher discount rate would further reduce the present value of the series of payments.

Discounting an Annuity

1. Determine the discount rate, r.
2. Compute the annuity discount factor, ADF $[r/n]$:

$$ADF[r/n] = \sum_{i=1}^{n} 1/[1+(r/100)]^i \qquad [3]$$

where

$\sum_{i=1}^{n}$ = the sum of terms of index i, i ranging from 1 to n.

n = the number of years for which the annuity is to be paid, each payment falling at the end of the year

r = discount rate (%)

The annuity discount factor may be computed from the single payment discount factor:

$$ADF[r/n] = \frac{1-DF[r/n]}{r/100} \qquad [4]$$

Or, the annuity discount factor* may be determined from discounting tables.

3. **Multiply the annuity discount factor by the uniform payment amount to get the present worth of the series of future payments.**

$$PW\,(\text{series}) = \text{payment} \times ADF\,[r/n] \qquad [5]$$

A series of five-year-end payments of $40 each were discounted to determine their present worth at a discount rate of 15%.

The annuity discount factor was computed:

$$ADF[15\%/5] = \frac{1-DF[15\%/5]}{15/100} = \frac{1-0.497}{0.15} = 3.352$$

The present worth is:

$$PW = (\$40 \times 3.352) = \$134.$$

Discounting a Uniform Series of n Payments Which Have Been Delayed d Years

1. **Determine the discount rate, *r*.**
2. **Determine the annuity factors:**

$$ADF\,[r/d]$$
$$ADF\,[r/(n+d)]$$

where

n = number of yearly payments
d = years before first payment is made
$(n+d)$ = year in which final payment will occur

3. **Subtract the present worth of the payments made during the delay from the present worth of the payments as computed from the present to the final payment in year $n+d$.**

$$PW = \text{payment} \times ADF[r/(n+d)] - \text{payment} \times ADF[r/d] \qquad [6]$$

A project which has a life of 15 years required an initial investment of $500 during the first year. The project will yield $1,000 in ten equal payments beginning six years later. If the discount rate is 12%, the present worth of the investment is:

$$\begin{aligned} PW &= \$500 \times DF[12\%/1] \\ &+ \$100 \times ADF[12\%/(5+10)] \\ &- \$100 \times ADF[12\%/5] \\ &= (\$500 \times .893) + (\$100 \times 6.811) \\ &- (\$100 \times 3.605) \\ &= \$446 + \$681 - \$360 \\ &= \$767 \end{aligned}$$

*The factor is often called the series discount factor or the uniform series discount factor.

Note: Although present worths of future payments can be summed algebraically, the discount factors alone may not, e.g., $ADF[r/(n+d)] - ADF[r/d] \neq ADF[r/n]$.

THEORY

Discounting is the reciprocal process to compounding an amount at a fixed interest rate. The discount rate corresponds to the interest rate mathematically. However discounting is used for analyzing projects, the discount rate does not correspond to the interest rate on investments savings. Interest on savings may be much lower than the return rate from a project. The discount rate is selected to correspond to the highest return available from alternative investments. This represents the time value of money (World Bank, 1975) as an opportunity cost. The cost of investments not made (the loss of a higher rate of return) figures prominently in the evaluation of projects using a discounted measure of project worth.

It is possible to evaluate cost and benefit streams at any point in the life of the project. Discounting can be used to determine the equivalent worth of payments after the analysis date, and compounding can be used to determine the equivalent worth of payments occurring before that date. The advantage of using discounting is that the greater weight is placed on cost and benefit estimates in the near future. In fact, the discount factors for discount rates greater than 15% and more than 20 years in the future are negligible. Consequently, these distant estimates (which tend to be increasingly uncertain) figure less in the evaluation of the project.

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Net Present Worth

PREREQUISITE TOOLS

Cash Flow Analysis (CFA, page 177) and Discounting (DIS, page 184).

USAGE

PURPOSE

Net present worth evaluates project net benefits by comparing different time streams of benefits and costs.

USES

Net present worth is used as:

1) A criterion for deciding if a single project should be funded.

2) A criterion for choosing among *mutually-exclusive* projects.

3) An intermediate calculation in determining a project's internal rate of return (IRR, page 200).

KEY DEFINITIONS

1) *Discounted cash flow* is a single value which represents the present worth of the net incremental benefits estimated for each project year. It is computed by discounting annual cash flows at a specified discount rate.

2) *Mutually-exclusive* projects are incompatible alternatives–implementing one precludes implementing the others. A project's alternative time phasings may also be analyzed in this manner.

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

SHORT DESCRIPTION

Net present worth measures a project's financial and economic viability by taking into account a time preference for money. The difference between "with project" and "without project" benefits and the similarly derived incremental costs determine annual cash flows (see CFA, page 177). The net present worth is determined from the *discounted cash flow*. Alternatively, computing the difference of the project's discounted annual incremental benefits and discounted annual incremental costs gives the net present worth.

An appropriate discount rate must be selected in order to estimate the opportunity costs corresponding to delayed benefits and alternative investments. A positive net present worth indicates that the projected return from the project investment is greater than the estimated opportunity to invest elsewhere.

ADVANTAGES

Net present worth reduces benefits and costs occurring at different times to a comparable basis: the equivalent

value today. This permits comparison between alternatives and provides a decision rule for funding a single project.

Net present worth estimates the amount that discounted benefits exceed discounted project costs.

LIMITATIONS

Investment decisions using net present worth as a criterion are often sensitive to the choice of a discount rate. Consider, for example, two projects having identical benefit streams and equivalent total costs. A high discount rate favors the project having lower initial investment but higher annual costs; annual costs are weighted less heavily in the computation of net present worth.

Net present worth gives the size of projected benefits from a project, but it gives no indication of how well the project uses the capital investment—the return on capital. Consequently, net present worth is not a valid measure for rank-ordering projects when funds are limited (Gittinger, 1972, page 92).

REQUIRED RESOURCES

LEVEL OF EFFORT

The major effort is in compiling the necessary cost and benefit data (see Cash Flow Analysis, CFA, page 177). The subsequent determination of net present worth is straightforward once the appropriate discount rate has been determined.

TIME REQUIRED

The first stages of identifying and estimating costs and benefits require the most time. The actual computation is easier with a simple hand calculator and appropriate discount tables (for example, Gittinger, 1973). See Discounting, DIS, page 184.

DESCRIPTION OF TOOL

REQUIRED INPUTS

Computation of the net present worth requires two primary inputs:

1) A description of the annual benefits and costs for the project (Cash Flow Analysis, CFA, page 177).

2) Information on the opportunity cost of capital in order to determine an appropriate discount rate (see Discounting, DIS, page 184).

TOOL OUTPUT

The technique gives a quantitative measure of the gain to be expected from a project measured in terms of its equivalent present worth. This criterion can then be used for funding decisions. Net present worth is also an intermediate calculation when determining a project's internal rate of return (IRR, page 200).

IMPORTANT ASSUMPTIONS

The net present worth criterion assumes that benefits and costs can be discounted at a discount rate which reflects the opportunity cost of tying up project resources for the life of the project.

METHOD OF USE

GENERAL PROCEDURE

1. Determine the incremental benefits and costs for each year of the project (see Cash Flow Analysis, CFA, page 177).

2. Specify the discount rate (see Discounting, DIS, page 184).

3. Determine the present worth of the incremental costs by discounting each annual cost at the discount rate.

4. Determine the present worth of the incremental benefits.

5. Compute the net present worth from the difference:

$$NPW = PW_b - PW_c$$

where PW_b is the present worth of incremental benefits and PW_c is the present worth of incremental costs.

6. Apply the criterion to the evaluation of the project:

a) If NPW is greater than zero, the project is accepted.

b) If NPW is less than zero, the project is not financially acceptable.

c) If NPW equals zero, the project's rate of return is equal to the discount rate (see Internal Rate of Return, IRR, page 200).

7. When comparing the net present worth for two or more mutually-exclusive projects, select the project with the greatest positive net present worth.

EXAMPLE

The annual cash flow for a small farmer tractor utilization project was computed in the Cash Flow Analysis technique (see figure 2, CFA, page 180).

FIGURE 1

Computing the Net Present Worth: Small Farmer Tractor Utilization–Purchase Option

Year	GROSS INCREMENTAL COSTS Investment	Other	Gross	Discount factor at 15%	PRESENT WORTH OF GROSS INCREMENTAL COSTS ₦	GROSS INCREMENTAL BENEFITS ₦	PRESENT WORTH OF GROSS INCREMENTAL BENEFITS ₦	CASH FLOW ₦	PRESENT WORTH OF CASH FLOW ₦
	₦								
1	500	80	580	0.870	505	200	174	(380)	(331)
2	0	80	80	0.756	60	200	151	120	91
3	0	80	80	0.658	53	200	132	120	79
4	0	80	80	0.572	46	200	114	120	68
5	0	80	80	0.497	40	200	99	120	59
6	0	80	80	0.432	35	200	86	120	51
7	0	80	80	0.376	30	200	75	120	45
8	0	80	80	0.327	26	200	65	120	39
9	0	80	80	0.284	23	200	57	120	34
10	0	80	80	0.247	20	200	49	120	29
Total	500	800	1300	5.019	838	2000	1002	700	164

Net Present Worth = Present Worth of Gross Incremental Benefits Minus Present Worth of Gross Incremental Costs

NPW = ₦1002 - ₦838 = ₦164

FIGURE 2

Cash Flow Analysis: Small Farmer Tractor Utilization—Rental Option

	YEARS FROM START OF PROJECT										
	1	2	3	4	5	6	7	8	9	10	TOTAL
WITHOUT PROJECT	Unis (Ψ) (Temasek National Currency)										
Gross Costs											
Usual Production Expenses	100	100	100	100	100	100	100	100	100	100	1000
Gross Benefits	160	160	160	160	160	160	160	160	160	160	1600
Net Benefits (Annual Profit)	60	60	60	60	60	60	60	60	60	60	600
WITH PROJECT											
Gross Costs											
Production Expenses											
Usual Expenses	120	120	120	120	120	120	120	120	120	120	1200
Tractor and operator rental fee	40	40	40	40	40	40	40	40	40	40	400
Gross Benefits	240	240	240	240	240	240	240	240	240	240	2400
Net Benefits (Annual profit)	80	80	80	80	80	80	80	80	80	80	800
CHANGES DUE TO PROJECT											
Incremental Costs (Cash outflow)	60	60	60	60	60	60	60	60	60	60	600
Incremental Benefits (Cash inflow)	80	80	80	80	80	80	80	80	80	80	800
Net Incremental Benefits (Project annual cash flow)	20	20	20	20	20	20	20	20	20	20	200

FIGURE 3

Net Present Worth Calculated from Discounted Cash Flow for Tractor Utilization—Rental Option

Year	Discount factor at 15%	GROSS INCREMENTAL COSTS ₩	GROSS INCREMENTAL BENEFITS ₩	NET INCREMENTAL BENEFITS (CASH FLOW) ₩	PRESENT WORTH OF CASH FLOW ₩
1	0.870	60	80	20	17.4
2	0.756	60	80	20	15.1
3	0.658	60	80	20	13.2
4	0.572	60	80	20	11.4
5	0.497	60	80	20	9.9
6	0.432	60	80	20	8.6
7	0.376	60	80	20	7.5
8	0.327	60	80	20	6.5
9	0.284	60	80	20	5.7
10	0.247	60	80	20	4.9
Total	5.019	600	800	200	100.2

Net Present Worth:

NPW = Sum of discounted annual cash flows for life of project = ₩100.2 = ₩100

Computing NPW using annuity discount factor (see DIS, page 184):

NPW = ₩20 ADF[15%/10] = (20)(5.019) = ₩100

The net present worth of the project was to be calculated using a discount rate of 15%, the assumed opportunity cost of capital. The calculations (see figure 1) gave a net present worth of ₩168. Since this measure was positive, the investment was financially sound.

Farmers in this region also had the option of renting a tractor. The tractor and operator rental fee were estimated at ₩40 for a ten-year period. A cash flow analysis indicated an annual cash flow of ₩20 (see figure 2). The net present worth for this option was also calculated at a 15% discount rate by directly discounting the net incremental benefits (see figure 3). The net present worth was projected to te ₩100 for this option.

Both options had a positive net present worth, but the farmer would gain more by purchasing the tractor since the discounted net benefit is greater.

THEORY

The analytical formula* for the net present worth is:

$$NPW = \sum_{i=1}^{n} (\Delta B_i - \Delta C_i) / [1 + (r/100)]^i$$

where

n = number of years of the project

ΔB_i = gross incremental benefits of the project for year i

ΔC_i = gross incremental costs of the project for year i

r = discount rate (%)

The formula may be modified to include varying discount rates and inflation factors (Fleischer, 1972). But

*See also figure 3, Cash Flow Analysis, CFA, page 182.

each element is an estimate which requires careful judgment by the analyst. The project life, n, must be estimated; the incremental benefits must be estimated and projected, often from sparse data of the "without" project situation. These estimates become more questionable as the project life increases. Finally, one must exercise caution in choosing the appropriate discount rate for the analysis.

Nevertheless, net present worth is a popular means for evaluating projects, partly because it corresponds to the commonly accepted notion of a time preference for money. Tradeoffs with other criteria are discussed further in Cost-Benefit Analysis (CBA, page 212).

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Benefit-Cost Ratio

PREREQUISITE TOOLS

Cash Flow Analysis (CFA, page 177) and Discounting (DIS, page 184).

USAGE

PURPOSE

The ratio of project benefits to project costs evaluates the *efficiency* of project resource utilization.

USES

Benefit-cost ratio is a criterion for project evaluation which is used to:

1) Determine if a project should be funded.
2) Determine the *rank-ordering* of several projects.

KEY DEFINITIONS

1) *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.

2) *Project efficiency* is the ratio of project outputs to inputs, e.g., the production rate for a given resource utilization rate.

SHORT DESCRIPTION

Benefit-cost ratios are computed by comparing the "with project" to the "without project" costs and benefits (see Cash Flow Analysis, CFA, page 177). The time preference-opportunity costs of money are weighed in the computation by discounting the benefit and cost streams (see Discounting, DIS, page 184). The benefit-cost ratio is the present worth of the gross incremental benefits divided by the present worth of the gross incremental costs.

A benefit-cost ratio greater than one means that the project benefits exceed the project costs when discounted at the opportunity cost of capital. The size of the benefit-cost ratio reflects the efficiency of the project. Rank-ordering projects according to the benefit-cost ratio gives the highest priority to the project which uses resources most efficiently.

ADVANTAGES

The benefit-cost ratio reduces the investment decision to a single number which reflects the proportion of total benefits to total costs. When total resources are limited, rank-ordering projects by the benefit-cost ratio maximizes the return for each investment dollar.

LIMITATIONS

The distribution of benefits and costs is not reflected in the benefit-cost ratio. One group in society may benefit at the cost of other groups (see Impact-Incidence Matrix, IPX, page 207).

Precisely because the benefit-cost ratio reduces the criterion to a single dimensionless number, the individual estimates, projections, and assumptions may be lost. Not all benefits can be quantified, nor expressed in monetary units. Hence, the benefit-cost ratio reflects only the economic aspects of efficient resource utilization.

If the projects are mutually exclusive, the benefit-cost ratio may give an erroneous ranking. A project may have a high benefit-cost ratio compared to other projects but a far smaller net present worth. Since the usual objective is to maximize the net benefit, the net present worth criterion is preferred for choosing between mutually-exclusive projects (see NPW, page 188).

REQUIRED RESOURCES

SKILL LEVEL

Judicious use of the benefit-cost ratio requires an understanding of the underlying assumptions used in the assessment. Projects can be erroneously justified by subjective selection of benefit and cost components, alternative valuations of the factors, and selective presentation of the results. The decision maker needs to recognize the relevance and accuracy of the analytic components.

TIME REQUIRED

The major time is spent gathering data. This may include surveying the project area to determine the "without project" situation and gathering baseline data to project the expected benefits of the project (see Surveys, SVY, page 36). The benefit-cost ratio computation for financial analysis is usually a straightforward calculation. An economic analysis requires more time as additional factors must be estimated (e.g., shadow prices for labor, foreign exchange, etc.).

SPECIAL REQUIREMENTS

A calculator and discounting tables simplify the computation procedure.

DESCRIPTION OF TOOL

REQUIRED INPUTS

The benefit-cost ratio requires accurate and reliable data on the relevant costs and benefits projected over the life of the project. These cash flows (see CFA, page 177) must be estimated and discounted according to an assumed discount rate. The latter requires information about the opportunity costs of capital.

TOOL OUTPUT

The ratio of benefits to costs provides a dimensionless criterion for financial evaluation of a project and for comparison of alternative projects. The benefit-cost ratio may be used to redesign project components to improve efficiency.

IMPORTANT ASSUMPTIONS

All benefits derived from the project are identifiable and measurable. The opportunity cost of capital is specified: if the benefit-cost ratio is less than one, the project is not returning as much as the best alternative investment (assuming one exists).

METHOD OF USE

GENERAL PROCEDURE

1. **Determine the incremental benefits and costs of the project for each year of the project life.**
   The incremental costs (benefits) reflect projected changes in costs (benefits) due to the project (see Cash Flow Analysis, CFA, page 177).

2. **Discount the annual incremental benefits and costs to determine their present worth.**
   An appropriate discount rate is selected in the discounting process (see DIS, page 184). This is usually the opportunity cost of capital.

3. **Compute the benefit-cost ratio.**
   $BCR = PW_b / PW_c$
   where PW_b is present worth of gross incremental benefits and PW_c is present worth of gross incremental costs.

4. **Apply the benefit-cost ratio as a criterion for project evaluation according to the following rules:**
   a) If the benefit-cost ratio is greater than or equal to 1.0, consider the project for funding.
   b) If the benefit-cost ratio is less than 1.0, then the project should not be funded.

6. **Apply the benefit-cost ratio as a criterion for selecting projects by rank-ordering the projects according to decreasing benefit-cost ratios.**

EXAMPLES

The projected cash flows of a project to purchase a small tractor were presented in figure 2 of Cash Flow Analysis (CFA, page 180). The benefit-cost ratio determined

FIGURE 1

Computing the Benefit-Cost Ratio for Small Farmer Tractor Utilization—Purchase Option

Year	GROSS INCREMENTAL COSTS Investment	Other	Gross	Discount factor at 15%	PRESENT WORTH OF GROSS INCREMENTAL COSTS ψ	GROSS INCREMENTAL BENEFITS ψ	PRESENT WORTH OF GROSS INCREMENTAL BENEFITS ψ
	ψ						
1	500	80	580	0.870	505	200	174
2	0	80	80	0.756	60	200	151
3	0	80	80	0.658	53	200	132
4	0	80	80	0.572	46	200	114
5	0	80	80	0.497	40	200	99
6	0	80	80	0.432	35	200	86
7	0	80	80	0.376	30	200	75
8	0	80	80	0.327	26	200	65
9	0	80	80	0.284	23	200	57
10	0	80	80	0.247	20	200	49
Total	500	800	1300	5.019	838	2000	1002

BCR = Present Worth of Gross Incremental Benefits/Present Worth of Gross Incremental Costs = ψ1002/ ψ838 = 1.2

FIGURE 2

Cash Flow Analysis: Small Farmer Tractor Utilization—Tractor Cooperative Option

	YEARS FROM START OF PROJECT										
	1	2	3	4	5	6	7	8	9	10	TOTAL
WITHOUT PROJECT	Unis (Ψ) (Temasek National Currency)										
Gross Costs											
Usual Production Expenses	100	100	100	100	100	100	100	100	100	100	1000
Gross Benefits	160	160	160	160	160	160	160	160	160	160	1600
Net Benefits (Annual Profit)	60	60	60	60	60	60	60	60	60	60	600
WITH PROJECT											
Gross Costs											
Usual Production Expenses	120	120	120	120	120	120	120	120	120	120	1200
Tractor Cooperative											
Annual membership fee (tractor maintenance and operating costs)	25	25	25	25	25	25	25	25	25	25	250
Initial Charter fee	150	0	0	0	0	0	0	0	0	0	150
Gross Benefits	270	270	270	270	270	270	270	270	270	270	2700
Net Benefits (Annual profit)	(25)	125	125	125	125	125	125	125	125	125	1100
CHANGES DUE TO PROJECT											
Incremental Costs (Cash outflow)	195	45	45	45	45	45	45	45	45	45	600
Incremental Benefits (Cash inflow)	110	110	110	110	110	110	110	110	110	110	1100
Net Incremental Benefits (Project annual cash flow)	(85)	65	65	65	65	65	65	65	65	65	500

FIGURE 3

Computing Benefit-Cost Ratios for Small Farmer Tractor Utilization—Cooperative Option

Year	GROSS INCREMENTAL COSTS Investment	Other	Gross	Discount factor at 15%	PRESENT WORTH OF GROSS INCREMENTAL COSTS ₦	GROSS INCREMENTAL BENEFITS ₦	PRESENT WORTH OF GROSS INCREMENTAL BENEFITS ₦	CASH FLOW ₦	PRESENT WORTH OF CASH FLOW ₦
	₦								
1	150	45	195	0.870	170	110	96	(85)	(74)
2	0	45	45	0.756	34	110	83	65	49
3	0	45	45	0.658	30	110	72	65	43
4	0	45	45	0.572	26	110	63	65	37
5	0	45	45	0.497	22	110	55	65	32
6	0	45	45	0.432	19	110	48	65	28
7	0	45	45	0.376	17	110	41	65	24
8	0	45	45	0.327	15	110	36	65	21
9	0	45	45	0.284	13	110	31	65	19
10	0	45	45	0.247	11	110	27	65	16
Total	150	450	600	5.019	357	1100	552	500	195

Net Present Worth = Sum of discounted cash flows = ₦195

BCR = Present Worth of Gross Incremental Benefits/Present Worth of Gross Incremental Costs = ₦552/₦357 = 1.54 = 1.5

from gross incremental benefits and costs discounted at 15% is 1.2 (see figure 1). This simply means that the decision to purchase the tractor is financially sound: the expected benefits will outweigh the expected costs for the life of the tractor.

The small farmer has another option: he may form a tractor cooperative. The cooperative would pool the members' resources (or credit) to purchase a larger tractor. Each farmer would pay only the initial charter fee and an annual membership fee. Because the tractor's time is to be shared, the projected gross benefits for each farmer would be less than if he had purchased his own (smaller) tractor.

A cash flow analysis for the individual cooperative member reveals an annual cash flow of ₩125 after an initial cash outflow of ₩25 at the end of the first year (see figure 2). The net present worth for the project is ₩196 at a discount rate of 15%. The benefit-cost ratio is 1.5 (see figure 3). This latter measure treats charter membership in the cooperative as an investment. A similar financial analysis could be conducted from the cooperative's point of view.

The benefit-cost ratio may be computed from an economic analysis of the tractor utilization options. This involves a more sophisticated assessment of costs and benefits (see CFA, page 177), including shadow prices for labor and other inputs, and the sales for increased production (see, for example, Gittinger, 1973).

These examples are continued in Internal Rate of Return (IRR, page 200). The comparison between projects using the benefit-cost ratio is discussed in Cost-Benefit Analysis (CBA, page 212).

THEORY

The analytical formula for the benefit-cost ratio is:

$$\frac{\sum_{i=1}^{n} \Delta B_i \,/\, [1 + (r/100)]^i}{\sum_{i=1}^{n} \Delta C_i \,/\, [1 + (r/100)]^i}$$

where

n = the number of years of the project
ΔB_i = the gross incremental benefits for year i
ΔC_i = the gross incremental costs for year i
r = discount rate (%)

Each parameter of the formula represents an estimate by the project analyst. The estimated costs and benefits grow more uncertain as the number of years from the present increases. However, the discounting process gives more weight to the early project benefits and costs. As with net present worth (NPW, page 188), care must be excercised in establishing the appropriate discount rate.

The relation of benefit-cost ratio to other project criteria is discussed further in Cost-Benefit Analysis (CBA, page 212).

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Internal Rate of Return

PREREQUISITE TOOLS

Cash Flow Analysis (CFA, page 177), Discounting (DIS, page 184), and Net Present Worth (NPW, page 188).

USAGE

PURPOSE

The internal rate of return (IRR) is a criterion for analyzing projects based on the percentage return on investment.

USES

1) The IRR is used as a criterion for evaluating the financial (and economic) advantages of a single project.

2) The IRR is used to rank projects according to the most efficient utilization of resources (see Cost-Benefit Analysis, CBA, page 212).

KEY DEFINITIONS

1) The *internal financial return* of a project is the rate of return derived from a financial analysis of the project cash flows, i.e., from the viewpoint of the individual, enterprise, or group.

2) The *internal economic return* of a project is the rate of return derived from an economic analysis of the benefits and costs to the society or economy of the country.

SHORT DESCRIPTION

IRR is one of three widely used criteria for evaluating the financial and economic viability of projects. Like net present worth (NPW, page 188), IRR is computed from the present worth of gross incremental benefits and costs. Unlike net present worth, IRR does not indicate the present worth of the net incremental benefit, i.e., the equivalent present amount of all future project benefits. Rather, the IRR is an efficiency measure, reflecting the payoff of the project in terms of the precent return on outlays. In this regard, it is similar to the benefit-cost ratio (BCR, page 194).

A project's IRR is the discount rate at which the present worth of the net incremental benefits is exactly zero. Since this cannot be solved analytically, it must be determined by interpolation.

The IRR is compared to opportunity costs to determine if the amount of return on investment is sufficiently high to justify the project. The difference between internal financial return and internal economic return is not only in the assessment of costs and benefits, but in deciding whether the return is sufficient for the individual or for the society, respectively.

ADVANTAGES

The IRR may be computed without specifying the discount rate which corresponds to the opportunity cost of capital. Net present worth and benefit-cost ratio require this specification.

The IRR is the preferred criterion for ranking projects when total funds are limited (Gittinger, 1972).

LIMITATIONS

The IRR cannot be determined if the annual cash flows for a project are always positive (or zero). There must be at least one negative yearly cash flow so that the discounted benefits are equal to the discounted costs.

The computation of the IRR may yield more than one discount rate which gives a zero net present worth. This usually occurs if there are large negative cash flows late in the project. However, most development projects start with an initially negative cash flow followed by a rising stream of benefits from which a single IRR may be computed.

REQUIRED RESOURCES

LEVEL OF EFFORT

Determining the IRR is more difficult than computing net present worth or benefit-cost ratio. There is no analytical solution for the IRR (except for uniform cash flows), and a trial and error process must be followed. The bulk of the effort is in assembling the necessary data for analysis (see Impact-Incidence Matrix, IPX, page 207).

SKILL LEVEL

Since computing the IRR is not a straightforward process, the analyst must be skilled, particularly in interpreting cash flow patterns (see Cash Flow Analysis, CFA, page 177).

TIME REQUIRED

Computing the IRR may take significantly longer than computing net present worth or benefit-cost ratio, but the overall process is primarily constrained by the availability of the appropriate data on cash flows.

DESCRIPTION OF TOOL

REQUIRED INPUTS

A complete analysis of the costs and benefits over the life of the project is required (see Cash Flow Analysis, CFA, page 177).

A criterion level for selecting or rejecting the project must be specified, preferably in advance. This level may be the opportunity cost of capital or the minimum rate of return which a funding agency will accept on the project.

TOOL OUTPUT

The technique gives a single measure, the percent of return on investment, which may be used as a criterion for funding or for ranking projects for funding. The IRR is compared to the specific criterion level, e.g., 15% minimum rate of return. If the IRR is larger, the project is recommended for funding. When ranking projects, those with the largest IRR should be funded first.

IMPORTANT ASSUMPTIONS

IRR assumes that one discount rate will apply during the life of the project. This is not necessarily a limiting assumption, but it does make the measure less flexible than net present worth (see Fleisher, 1972).

METHOD OF USE

GENERAL PROCEDURE

Computing the IRR for a project is basically a trial and error process which starts with a trial discount rate and uses the procedure for computing the net present worth. New discount rates are selected until one gives a zero net present worth.

1. **Determine the incremental benefits and costs for the life of the project.**
   This is essentially the procedure found in Cash Flow Analysis (see CFA, page 177). The net benefit for each year of the project is determined from estimates of "with" and "without" project benefits and costs.

2. **Estimate the discount rate for the first trial computation.**
   Select the discount rate by examining the cash flow pattern rather than by using the opportunity cost of capital. If the project involves large negative cash flows followed by a delay in benefits, then the IRR is relatively low (choose a trial discount rate in the 10% to 20% range). If the project has immediate positive cash flows (benefits are not delayed more than a year or two), then the IRR may be very high (choose a trial discount rate of 50% or more). If the cash flows for the project are never negative in any year of the project, then the IRR is infinite and cannot be used. Net present worth or benefit-cost ratio may be substituted.

3. **Compute the net present worth of the project for the trial discount rate.***
   Designate this value as NPW_1. If NPW is zero, then the

*r_1 = the trial discount rate.

FIGURE 1
Flowchart of Interpolation Procedure to Determine Internal Rate of Return

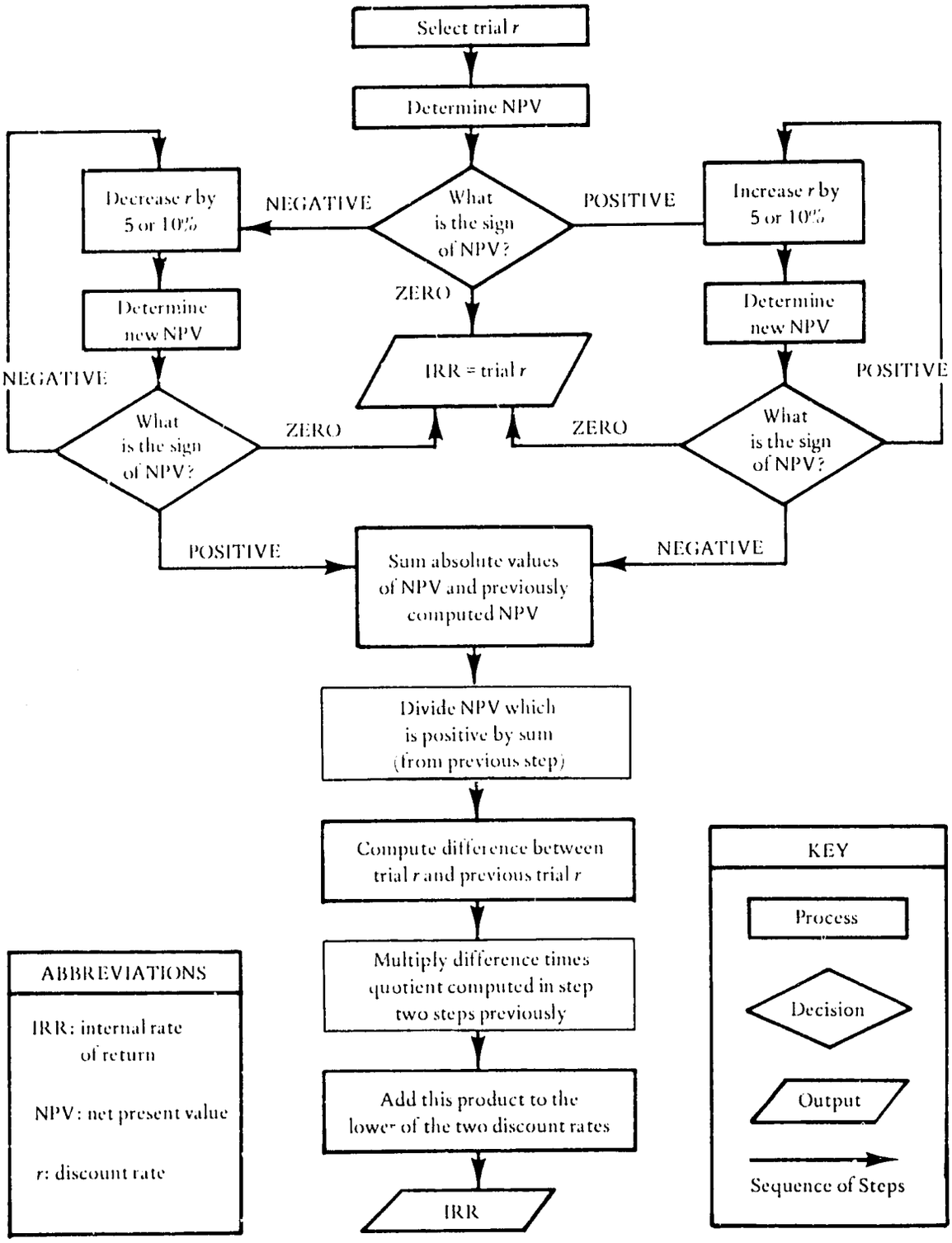

FIGURE 2
The Annual and Total Cash Flows for the Small Farmer Tractor Utilization Options

	OPTIONS		
	Purchase	Rental	Cooperative
Year	Net Incremental Benefits (Cash Flow)*	Net Incremental Benefits (Cash Flow)*	Net Incremental Benefits (Cash Flow)*
1	(380)	20	(85)
2	120	20	65
3	120	20	65
4	120	20	65
5	120	20	65
6	120	20	65
7	120	20	65
8	120	20	65
9	120	20	65
10	120	20	65
TOTAL CASH FLOW	700	200	500

*In Unis (Ø), Temasek National Currency

trial discount rate is the IRR. The first selected discount rate is unlikely to give a zero present worth, and the process must be repeated.

4. **Select a new trial discount rate, r_2.**
   If the NPW_1 is less than zero, select a discount rate smaller than r_1. How much smaller depends on how much NPW_1 is less than zero. Generally, select r_2 equal to 10% less than r_1. If NPW_1 is positive, then select a larger trial discount rate.

5. **Recompute the net present worth using the trial discount rate r_2.**
   Designate this discount rate as NPW_2.

6. **Select trial discount rates and compute net present worths until reaching both a positive and a negative present worth.**
   Increase the discount rate if the net present worth is still positive, and decrease the trial discount rate if the discount rate is negative.

7. **Estimate the IRR by interpolation:**

$$IRR = r_L + [\Delta r \times N_L / (|N_H| + |N_L|)] \qquad [1]$$

where

r_L = lower discount rate
Δr = difference between discount rates
N_L = net present worth for lower discount rate
N_H = net present worth for higher discount rate

Note: The lower and higher discount rates must produce net present worths of opposite signs.

For example the lower discount rate (r_L) is 8% with a net present worth (N_L) of \$100. The higher discount rate is 10% with a net present worth (N_H) of -\$50. The sum of absolute values of the net present worths is \$150. Therefore,

$$\begin{aligned} IRR &= 8\% + [10\% - 8\% (\$100/\$150)] \\ &= 8\% + [2\% (.67)] \\ &= 8\% + 1.34\% \\ &= 9.34\% \end{aligned}$$

To reach a net present worth of zero, the IRR must be 9.34%.

This may be reduced to a simple procedure where the early years have a large negative cash flow and the later years have cash flows that are all positive. The flowchart in figure 1 may be used if the analyst is aware of the possibility that the multiple solutions to the IRR may exist (see Decision Tables, DTB, page 113).

FIGURE 3

Computation of the Internal Rate of Return for the Small Farmer Tractor Options

Algorithms for Net Present Worth

Purchase Option:

NPW[r%/10] = 120 ADF[r%/10] - 500 DF[r%/1]

Rental Option:

NPW[r%/10] = 20 ADF[r%/10]

Cooperative Option:

NPW[r%/10] = 65 ADF[r%/10] - 150 DF[r%/1]

Internal Rate of Return Computations:

Option 1: Tractor Purchase

r%	120	ADF[r%/10]	- 500	[DFR[r%/1]	=	NPW[r%/10]
15		5.02		0.869		167.9
20		4.19		0.833		86.3
25		3.57		0.800		28.4
30		3.09		0.769		-13.7

INTERPOLATION: (see figure 2)

28.4 + 13.7 = 42.1

28.4/42.1 = 0.675

30 - 25 = 5

5 X 0.675 = 3.4

25 + 3.4 = 28.4 or 28% IRR

Option 2: Tractor Rental

IRR cannot be computed since the cash flow is always positive (see figure 2).

(Figure 3 Continued)

Option 3: Tractor Cooperative

r%	65	ADF[r%/10]	- 150	DF[r%/1]	=	NPW[r%/10]
30		3.091		0.769		86.6
40		2.414		0.714		49.8
50		1.965		0.667		27.7
70		1.421		0.588		4.2
80		1.246		0.555		-2.3

INTERPOLATION: 4.2 + 2.3 = 6.5
4.2/6.5 = 0.646
80 - 70 = 10
10 X 0.646 = 6
70 + 6 = 76 or 76% IRR

EXAMPLE

Three options for small farmer tractor utilization have been presented in the prerequisite tools. The options and net annual cash flows are shown in figure 2. The benefit-cost ratio and net present worth for each option were calculated using a discount rate of 15% for the opportunity cost of capital.

The IRRs were calculated (figure 3); the procedure is given in the flowchart (figure 1). To simplify the repetitive calculation, an algorithm was developed (see Discounting, DIS, page 184).

If the farmer purchases the tractor, the estimated IRR is 28%. This is low for an agricultural project, but is well above the estimated rate of return from alternative investments, e.g., the 15% discount rate.

If the farmer joins a tractor cooperative, the IRR is 76%, which is more than double the IRR for purchasing. This indicates that joining the cooperative is the most efficient use of the farmers' limited resources.

The option of tractor rental has an infinite IRR. It cannot be calculated because the annual cash flow is always positive. This happens quite often in the financial analysis of agricultural projects where there is little or no capital investment.

Even though the IRR for the tractor cooperative is most efficient, further analysis is necessary before this alternative is recommended.

The computed IRRs represent the internal financial return of the project. In order to compute the internal economic return of the project, a similar procedure must be followed. However, the valuation of costs and benefits will be for the target group of farmers as a whole, and the prices will be adjusted (shadow-priced) to reflect more accurately the impact on the nation's economy. Because economic analysis is a more comprehensive and time-consuming process, and because many more assumptions are necessary, this task requires skills in macro-economics (see, for example, UNIDO, 1972).

THEORY

The internal rate of return is the discount rate r^* at which the net present worth is zero. It is given by solving the following equation for r^*:

$$\sum_{i=1}^{n} (\Delta B_i - \Delta C_i) / [1 + (r^*/100)]^i = 0 \qquad [2]$$

where

n = number of years of the project
ΔB_i = gross incremental benefits for year i
ΔC_i = gross incremental costs for year i
r^* = internal rate of return (%)

The formula cannot be solved analytically unless the pattern of benefits and costs are uniform. Otherwise, a trial and error approach (as described in the procedure) is necessary.

Considerable debate has addressed the practicality of the IRR as a criterion for project evaluation. Certain pat-

terns of benefits and costs (in particular, a large cost near the end of a project) may result in more than one solution to equation [2]. Gittinger (1972) answers the critics by claiming that the multiple solution problem is not likely to occur for cash flows typical of development projects.

IRR is a widely used criterion for analyzing the financial and economic soundness of development projects. It has been adopted as the principal measure for project appraisal by the US Agency for International Development (USAID, Handbook 3). The distinction between internal financial return and internal economic return underlines the importance of both financial and economic analysis for project evaluation (Gittinger, 1972).

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Impact-Incidence Matrix

PREREQUISITE TOOLS

Benefit-Cost Ratio, BCR, page 194.

USAGE

PURPOSE

An impact-incidence matrix tabulates the distributions of project costs and benefits to the affected groups in the society.

USES

An impact-incidence matrix is used to:

1) Provide a decision maker with detailed information on the distribution of costs and benefits of a project or alternative projects.

2) Identify the relative gain or loss for various groups affected by the project.

3) Break down the benefit and cost data by type of measurement and accuracy.

4) Present measures of effectiveness and other non-monetary project impacts in conjunction with costs and income data.

5) Permit decision makers to examine the inequities in project design with regard to the distribution of benefits and costs.

SHORT DESCRIPTION

An impact-incidence matrix identifies the various groups affected either directly or indirectly by a project, and the cost and benefit measurements by type (see figure 1). The incidence of non-monetary project impacts is also tabulated, including strictly qualitative factors.

With the matrix, the decision maker has an expanded view of the attributes of the decision with regard to possible inequities in distribution. Benefit-cost ratios (BCR, page 194), are presented not only for the project as a whole, but for the affected groups (e.g., different income groups).

ADVANTAGES

1) In contrast to a single economic measure of project merit, the impact-incidence matrix requires the decision maker and the analyst to expand their assessment of a project to its distributional and qualitative impacts.

2) The disparities in impact-incidence among various groups are identified.

3) The type of measurement and the accuracy of the information is identified (e.g., an indirectly measured cost measurement is likely to be more subjective than a direct project cost estimate).

FIGURE 1
Impact-Incidence Matrix for Cost Benefit Analysis

		Impacts			
		Directly estimated $	*Indirectly estimated* $	*Estimated numerically not in* $	*Estimated qualitatively in words*
Groups impacted		a_1 a_2 a_3 ...	b_1 b_2 ...	c_1 c_2 ...	d_1 d_2 ...
Directly	A_1				
	A_2				
	.				
	.				
	.				
Indirectly	B_1				
	B_2				
	.				
	.				
	.				
Special interests	C_1				
	C_2				
	.				
	.				
	.				

NOTE: From *Systems Analysis for Engineers and Managers* by Richard DeNeufville and Joseph H. Stafford. Copyright (c) 1971 by McGraw-Hill Book Company. Used with permission of McGraw-Hill Book Company.

LIMITATIONS

1) Omitting either a group or an impact on a group is lessened by a systematic approach, but the danger still exists. The impact-incidence matrix may give a false sense of a comprehensive search for project impacts, when in fact the matrix is simply the tabulation of the results of that search. The information and analysis task must preceed the matrix tabulation.

2) It is one thing to identify a group affected by a project and another to ascertain the nature and extent of that effect. The skill of the analyst in searching out this information constrains the validity of the impact-incidence matrix as a decision-making tool.

REQUIRED RESOURCES

LEVEL OF EFFORT

Constructing an impact-incidence matrix and preparing summaries to pinpoint the findings is the tip of an iceberg. Lurking below is the difficult task of first identifying the impacts of the project and then identifying the groups that are affected. Where the groups are not immediately apparent, they may be categorized by distribution criteria (e.g., geographic, economic, ethnic). The relevant information can be gathered with a sample survey (SVY, page 36), which can be a major effort.

The information is rarely available from existing statistical data. The data are often so general that they are unreliable, and/or they are out-of-date. Nevertheless, the impact-incidence matrix is a useful format for designing and organizing information-gathering and analysis.

SKILL LEVEL

Cost data may require accounting, economics, and marketing to gather, assess, and interpret. Non-monetary factors require insight and an ability to grasp impacts of a project which are far-reaching and distant (both spatially and temporally). A variety of skills is essential. This suggests using a team approach, guided by systems concepts and forecasting tools (see Oval Diagramming, OVD, page 81).

TIME REQUIRED

The time required to construct an impact-incidence matrix is in direct proportion to the number of different groups affected by the project and the ways in which the project will affect them. An analyst completely familiar with the project environment and with ready access to data sources could construct a preliminary impact-incidence matrix in a week. This would then serve as a guide to estimate the time required for further information-gathering and analysis (anywhere from two to ten weeks).

DESCRIPTION OF TOOL

DEFINITIONS

1) *A multiplier effect* occurs when a project impact on one aspect of an economic system generates a stimulating effect on other aspects, e.g., when a labor generation project gives more money to consumers, which expands the economy, which leads to more jobs, etc.

2) *Direct market values* measure project costs or benefits which are assessed from equivalent market prices, e.g., average wages, construction costs, and price of inputs which are not subsidized.

REQUIRED INPUTS

Before the impact-incidence matrix can be constructed, the technical aspects of the project must be specified with enough detail to assess the likely impacts of the project on the social, economic, and environmental systems. For example, if a power plant is to be constructed and the likely alternates are a conventional fossil fuel burning plant or a nuclear powered plant, a separate impact-incidence matrix is required for each.

The objectives and purpose of the project must be clear in order to identify interest groups and affected organizations and individuals. Function Expansion (FEX, page 45), and intent structures (INS, page 55) are useful for this purpose.

TOOL OUTPUT

The technique results in an impact-incidence matrix which breaks down the elements of a cost-benefit analysis by the groups affected, the type of measurement, and the degree of accuracy. This permits the decision maker to examine the distributional effects of a proposed project as well as aggregated measures, such as the benefit-cost ratio (see BCR, page 194).

IMPORTANT ASSUMPTIONS

The decision to go ahead with a project should not be made on simple economic criteria alone. Other measures are equally important if unintended or unexpected consequences are to be avoided (e.g., one group's failure to participate because of inequities).

Aggregated measures give only a general view of project merits. Disaggregating according to distributional criteria permits a decision maker to exercise judgment based on multiple attributes of the project impact.

METHOD OF USE

GENERAL PROCEDURE

1. **Determine the groups affected by the project.**
   - 1.1 List all groups which are affected by or otherwise associated with the project.
   - 1.2 Categorize the groups by determining whether the project impact will be direct or indirect.
   - 1.3 Consider distributional criteria in categorizing the groups, e.g., geographic, economic, social or age status, occupational, property ownership.
   - 1.4 Identify any special interest groups who stand to gain or lose as a result of the project.
2. **Specify the costs and benefits accruing from the project.**
   - 2.1 Determine the directly estimable costs and benefits using criteria such as willingness to pay for the project product or service as well as *direct market values* for project costs or incomes accruing to each identified group.
   - 2.2 Determine indirectly estimable costs and benefits, such as cost savings and higher land projects as a result of project.
3. **Specify all other impacts of the project.**
   - 3.1 Determine those impacts—internal or external or tangible or intangible—which affect each group.
   - 3.2 As far as possible, quantify the impacts to give a numerical measure (see Multiple Criteria Utility Assessment, MCU, page 32).
4. **Compute the benefit-cost ratios (see BCR, page 194).**
   - 4.1 Add the directly and indirectly measured costs for each group; repeat for the benefits, and compute the benefit-cost ratio or benefits divided by the costs.
   - 4.2 Compute the total of all benefits and all costs across all groups and determine the benefit-cost ratio.

FIGURE 2
Impact-Incidence Matrix Example: Tractor Training Program

GROUP IMPACTED	IMPACTS			
	Directly Estimated	Indirectly Estimated	Estimated Numerically	Estimated Qualitatively
Directly:				
Small farmers (Number)	Reduced tractor maintenance and operating costs (+)	Increased production (+)	Reduced tractor down time (+)	Exposure to better farming practices (+)
University	Educational overhead costs per student*		Hours away from university classes (-)	Field exposure for staff & students (+)
Tractor manufacturers	Increased tractor sales (+) Reduced service revenues per tractor (-) Reduced training costs (+)	Increased implement sales (+)	Hours devoted to service and repair (-)	Goodwill of successful tractor operators (+)
Indirectly:				
Large farmers (Number)		Pool of trained personnel (+)		Increased level of mechanization** (+)
Fuel suppliers	Increased fuel sales (+)			
Farm input suppliers		Increased demand for production inputs (+)		Increased level of mechanization**
Landless laborers (Number)	Decreased farm labor demand (unskilled) (-)	Increased demand for produce handlers (+)	Reduced labor-days per hectare (-)	Migration to cities (-)
Special interest groups:				
Ministry of Agriculture extension service	Education overhead costs (-) Direct costs per student (-) Extension service overhead (-)		Increased contact hours with farmers (+)	Better acceptance of improved farming techniques (+)
Credit institutions		Loan service for increased purchases (+)		

NOTE: (+) positive benefit; (-) negative benefit or costs. These may be replaced by benefit-cost ratio where appropriate.

*Zero net cost for training each student because Ministry of Agriculture reimburses direct costs.

**Including more technicians, manufacturers, parts and maintenance services, implement choices, etc.

5. Prepare a summary of the data in the matrix.
   5.1 Identify those groups that would gain significantly or lose disproportionately as a result of the project.
   5.2 Discuss the significance of the individual and aggregated benefit-cost ratios.
   5.3 Clarify the assumptions about *multiplier effects* or other indirect consequences of the project.
   5.4 Relate non-monetary measures and qualitative impacts to the affected groups and the project.

EXAMPLE

A project to assist farmers with the purchase of small tractors was started without giving full consideration to the farmers' difficulties in learning to use, operate, and maintain tractors. It was initially assumed that the tractor manufacturers would provide a brief training course; but when this was found to be inadequate, the manufacturers balked at providing a more extensive effort. The Ministry of Agriculture proposed to give this task to the Temasek University to be supervised by the Ministry's farm extension. All University costs were to be met with a donor agency loan, making the cost to the farmers nominal.

An impact-incidence matrix was prepared for the project to specify the costs vs. the benefits for the various groups which would be affected (see figure 2). Each entry in the matrix implied a set of assumptions about the training program and the impact of increased tractor utilization on the agricultural system.

A causal sequence of interaction was assumed:

Better utilization of tractors leads to greater acceptance of mechanization and increased production, which leads to more demand for production inputs and decreased demand for unskilled labor leading to higher unemployment for the landless except as balanced by higher volume of production, etc. This was the most likely scenario for the causal interactions in the system (see Oval Diagramming, OVD, page 81).

The analyst assigned values to the quantified impacts. A benefit-cost ratio was computed for the directly and indirectly estimated costs and benefits for each group. The quantifiable benefits outweighed the costs for all groups except the landless.

Consequently, the Ministry of Agriculture modified the training program to permit landless laborers to take part in the course, supported in part by a special tax on all tractor owners holding land in excess of 20 hectares.

THEORY

Cost-benefit analysis has produced an extensive literature which seeks either to rationalize or to discredit its use as a decision-making tool (see, for example, Layard, 1972).

Weighing the benefits against the costs of a course of action makes intuitive sense. However, there is little agreement on how or whether to attempt the task at all.

Maximizing the public welfare is no easy task: deciding what is in the public welfare is the first stumbling block. The impact-incidence matrix addresses the problem of the distribution of the benefits, costs, and other impacts of projects (Lichfield, 1966; Elliot and Picard, 1970). The impact-incidence breakdown is useful because of the juxtaposition of non-monetary measures of effectiveness with distributional projections of costs and benefits. The decision maker is presented with a disaggregation of benefits and costs according to the groups in society who stand to gain or lose by the project (DeNeufville and Stafford, 1971). While this counters a major criticism of cost-benefit analysis (de V. Graff, 1975) the problem still remains of identification and measurement of the incidence and impact of the project.

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Cost-Benefit Analysis

PREREQUISITE TOOLS

Cash Flow Analysis, (CFA, page 177); Discounting, (DIS, page 184); Net Present Worth (NPW, page 188); Benefit-Cost Ratio (BCR, page 194); Internal Rate of Return (IRR, page 200); Impact-Incidence Matrix (IPX, page 207).

USAGE

PURPOSE

Cost-benefit analysis identifies, assesses, and weighs costs vs. benefits to evaluate the financial and economic merits of development projects.

USES

Cost-benefit analysis is used to:

1) Provide a comprehensive analysis of costs and benefits including secondary, indirect, intangible, and societal benefits and costs of a proposed project or program.

2) Provide measures for deciding whether a project is financially viable and, in the process of analysis, to raise questions for consideration in redesign or implementation.

3) Rank projects for funding priority.

4) Decide among alternative policies, strategies, or components of a single program, e.g., for Planning, Programming, and Budgeting (PPB, page 236).

SHORT DESCRIPTION

Cost-benefit analysis is a generic term covering a range of theoretical issues and practical techniques. Because cost-benefit analysis has practitioners in many disciplines, a universal approach has not evolved. This description presents the systems engineering approach which views cost-benefit analysis as a multi-stage process leading to a comprehensive picture of project benefits vs. costs (Bordman, 1973; DeNeufville and Stafford, 1971).

A systems approach using cost-benefit analysis begins by specifying objectives, generating technically feasible alternatives, and then evaluating their economic and social consequences. Techniques for determining evaluation criteria are listed as prerequisites. Cost-benefit analysis is a synthesis of these techniques as well as techniques for identifying objectives, generating alternatives, and gathering cost-benefit data.

Project costs are both direct (e.g., equipment, labor, management, physical resources) and indirect (e.g., displaced workers, pollution, added infrastructure requirements). Similarly, the benefits may be both direct (e.g., increased production, reduced transport costs, increased

earning power, better health) and indirect (e.g., employment generation, support of local service enterprises, upgraded manpower). Some costs and benefits may be intangible (e.g., goodwill, improved morale, aesthetics), but are included in the presentation to decision makers (see Impact-Incidence Matrix, IPX, page 207).

Costs and benefits are identified and valued from three viewpoints:

1) The individual project entity (private or financial analysis).

2) The economic system (public or economic analysis, see Gittinger, 1972).

3) The socio-political-economic system (social cost-benefit analysis).

The second differs from the first in that market prices are adjusted to true equilibrium values using shadow prices or "accounting prices" (Little and Mirlees, 1974) (see Cash Flow Analysis, CFA, page 177). Social cost-benefit analysis is the more controversial approach of using "conversion factors" to weight cost-benefit estimates (Squire and van der Tak, 1975). Subjectively estimated factors incorporate social-political goals into the analysis, e.g., equitable distribution of project benefits favoring employment generation, or promoting independence from foreign goods.

ADVANTAGES

1) Cost-benefit analysis rationalizes the decision-making process to make the best allocation of scarce development resources. Attention is focused on the direct and indirect project impacts. Factors other than cost may enter into the computation and evaluation. Unintended side effects (indirect costs) and unequal distribution of benefits can often be pinpointed.

2) Socially desirable objectives may be explicitly treated as part of the evaluation criteria.

3) A common measurement dimension (monetary units) permits comparing alternatives.

LIMITATIONS

1) Many social costs and benefits cannot be quantified or accurately measured, e.g., the value of educational programs or the benefits of increased health, security, or aesthetics. Quantitative factors receive disproportionate emphasis simply because they are measurable. Cost-effectiveness analysis partly addresses this problem (see CEA, page 000).

2) Selecting projects using the benefit-cost ratio (BCR, page 194) or internal rate of return (IRR, page 200) presupposes that project efficiency is the overriding goal. Yet an efficient project may be ineffective; that is, it may contribute little to achieving development objectives (see Cost-Effectiveness Analysis, CEA, page 219).

3) If a project is of sufficiently large-scale, the increased production or other project outputs will have an impact on prices. Consequently, "no 'partial' measure of project worth is appropriate and much more elaborate analytical procedures must be called into play" (Gittinger, 1972, page 91).

4) Conversion factors for social-cost-benefit analysis are subjectively estimated value judgments. Conflict in values clouds the subsequent cost-benefit analysis (Stewart, 1975).

REQUIRED RESOURCES

LEVEL OF EFFORT

An overall analysis of the project is necessary in order to be aware of its social and economic effects, as well as its direct and indirect costs and benefits. An appropriate unit measure must be developed to evaluate each variable. However, value data are often not readily available. Sophisticated models may be necessary in order to calculate values for social variables (see Squire and van der Tak, 1975). The level of effort will vary with the number of project alternatives and variables being considered. In short, cost-benefit analysis is a difficult and demanding task.

SKILL LEVEL

Considerable skill and judgment are required to identify cost and benefit components, to estimate the changes over the life of the project, and to adjust the values using shadow prices or conversion factors. The latter is a particularly thorny task because of the difficulty, if not the impossibility, of getting the "right" shadow prices. Training in economic analysis and financial accounting is essential.

TIME REQUIRED

Cost-benefit analysis is a time-consuming exercise, particularly when cost and benefit data must be gathered by interview or survey (see SVY, page 36). Careful analysis and weighing of alternatives may take from several days to several weeks.

DESCRIPTION OF TOOL

REQUIRED INPUTS

A formal cost-benefit analysis begins after project goals have been defined and the alternative programs to meet those goals are specified (see Objectives Trees, OBT, page

49, and Morphological Analysis, MPA, page 10). In order to identify the social and economic components of both costs and benefits, a careful analysis of the project and its environment is essential (see Oval Diagramming, OVD, page 81). A systems viewpoint is recommended (see System Definition Matrix, SDM, page 67).

TOOL OUTPUT

A proper cost-benefit analysis presents recommendations to funding sources and decision makers, including:

1) The financial and economic merits of each project relative to minimum acceptable returns on the resources invested.

2) A rank-ordering of alternatives according to decreasing benefit-cost ratios or decreasing internal rates of return.

3) A concise statement of the assumptions inherent in the analysis and, where possible, the sensitivity of economic criteria to changes in assumptions and analytical parameters.

4) A discussion of intangible factors related to both economic and non-economic criteria.

IMPORTANT ASSUMPTIONS

All relevant project benefits and costs are identifiable before the project is implemented. Benefits and costs occurring at different times during the project may be valued at their present worths by assuming a discount rate. The discounting process reflects the time-preference for money, i.e., the opportunity costs associated with committing resources to the project and foregoing other investment alternatives (see Discounting, DIS, page 184).

It is usually assumed that inflation will affect all project alternatives equally and thus is ignored in projecting future cash flows. However, if inflation rates can be accurately estimated for each year of the project, the differential impact on both costs and benefits may be incorporated in the cash flow estimates.*

Weighing costs against projected benefits assumes that a net benefit accrues to society, i.e., that the project recipients may realize a net benefit which does not cause a negative benefit to some other segment of society (Sirken, n.d.). A comprehensive analysis of indirect costs and benefits theoretically reveals such anomalies, but this degree of thoroughness is not always feasible.

*G.A. Fleischer, "Engineering Economic Analysis in Developing Countries," *Technos* (January-March 1972): 27-35.

METHOD OF USE

GENERAL PROCEDURE

As there are numerous texts devoted exclusively to the subtleties of cost-benefit analysis, the following steps sketch the process in the broadest sense.

1. **Identify the cost and benefit components expected to result from project implementation.**
   - 1.1 Identify those groups directly and indirectly affected by the project (see Impact-Incidence Matrix, IPX, page 207).
   - 1.2 Identify and estimate all benefits and costs projected for the life of the project (see Cash Flow Analysis, CFA, page 177).
   - 1.3 Summarize all assumptions of incremental costs and benefits in a clear format for examination by decision makers.

2. Determine the present worth of all future costs and benefits.
   - 2.1 Discount the cash flows to the present using the appropriate discount rate (see Discounting, DIS, page 184).
   - 2.2 Compute the net present worth of the project cash flow (see Net Present Worth, NPW, page 188).

3. Determine the efficiency measures of project performance.
   - 3.1 Compute the benefit-cost ratio (see BCR, page 194).
   - 3.2 Compute the internal rate of return (IRR, page 200).

4. **Consider a project for funding if:**
   - 4.1 The net present worth is zero or positive where net present worth is computed at a discount rate equal to the opportunity cost of capital.
   - 4.2 The benefit-cost ratio is 1.0 or greater (using benefits and costs which have been discounted at a rate equal to the opportunity cost of capital).
   - 4.3 The internal rate of return is not less than a minimum acceptable rate of return, i.e., the opportunity cost of capital (usually specified at 15% or higher).

5. **Rank alternative projects or components of a project.**
   - 5.1 Rank the alternatives in order of descending internal rate of return or benefit-cost ratio measures, unless the alternatives are mutually exclusive.
   - 5.2 If the alternatives are mutually exclusive, select the one with the largest net present worth.

6. **Repeat steps 2 through 4 for each group directly affected by the project (see Impact-Incidence Matrix, IPX, page 207).**

7. **Contrast the financial analysis of the project with the economic analysis by separately computing costs and benefits from the viewpoint of the national economy.***
   - 7.1 Determine the costs and benefits for all directly and indirectly affected groups.
   - 7.2 Estimate the shadow prices for the factors of production.
   - 7.3 Estimate shadow prices for foreign exchange.
   - 7.4 Estimate shadow prices for government price supported commodities.
   - 7.5 Determine conversion factors for societal goals (optional), e.g., weighting benefits by income groups, favoring employment generating projects, promoting independence from foreign goods (see UNIDO, 1972, and Squire and van der Tak, 1975).
   - 7.6 Compute the criteria net present worth, benefit-cost ration, and internal rate of return using the adjusted cash flows.

8. **Complete the analysis with a consideration of non-monetary impacts of the project.**
   - 8.1 Impacts which may be quantified (but not in monetary units) should be listed (see Impact-Incidence Matrix, IPX, page 207).
   - 8.2 Impacts which may be qualitatively estimated should be presented alongside the quantitative data. The relevant impact, importance, or significance of the factors may be assessed to aid decision makers (see Rating Scales, RTS, page 29, and Interaction Matrix Diagramming, IMD, page 92).

EXAMPLE

The Ministry of Agriculture in the country of Temasek commissioned a cost-benefit analysis of the utilization of small tractors by farmers having limited land-holdings (less than 15 hectares).** The project analysts identified the target group and considered three alternative means by which each farmer could acquire a tractor. These alternatives were:

Option 1: Purchase a five horsepower walking tractor.

Option 2: Rent a tractor and services of an operator.

Option 3: Form a cooperative to share in the purchase and maintenance of a 15 horsepower tractor.*

Financial analysis of the options began by estimating the projected cash flows: option (1) was analyzed in Cash Flow Analysis (CFA, page 177); option (2) was analyzed in Net Present Worth (NPW, page 188); and option (3) was analyzed in Benefit-Cost Ratio (BCR, page 194). The cash flows for the three options were summarized in Internal Rate of Return (IRR, page 200). A summary of assumptions which were necessary to contrast the "with" and "without" situations was prepared (see figure 1).

Four measures of financial soundness were computed (see figure 2). Option (1) gives the largest total cash flow over the ten-year life of the project. Option (3) gives the next largest cash flow. Alternative projects compared using the total cash flow criterion must have the same project life, ten years in this case. However, the time value of money is not considered in cash flow comparisons (see Discounting, DIS, page 184).

Discounted measures, net present worth, benefit-cost ratio, and internal rate of return take into account the line streams of benefits and costs. A discount rate of 15% was selected to reflect the best return of money invested in alternative projects.

The net present worth criterion applied to the three options indicates that all are financially feasible. Since the options are mutually exclusive (e.g., the farmer is not likely to rent and purchase a tractor simultaneously), the net present worth may be used to select the best project. Option (3) has the highest net present worth followed by option (1) (see figure 2). This simply means that if the farmer joins a tractor cooperative, the value of his future earnings translated to the present is more than for the other options.

Benefit-cost ratio and internal rate of return measure project efficiency. Ranking the options on the basis of benefit-cost ratio indicates that option (3) gives more benefits per unit of cost than option (2), and option (1) has the lowest ratio (see figure 2). The benefit-cost ratio rankings may differ from the net present worth rankings when there are differences in the relationships between gross benefits and operating costs for the two projects (see Gittinger, 1972, page 65).

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*These steps represent theoretically complex tasks which cannot be covered in a short description. The reader is referred to the project evaluation literature. See, for example, Gittinger, 1972; Little and Mirlees, 1974; Squire and van der Tak, 1975; Hinrichs, 1969; or UNIDO, 1972.

**This example was stimulated by the report by John Balis, "The Utilization of Small Tractors in Integrated Agricultural Development: The Tractor Evaluation Project Applied," Cornell Agricultural Economics Staff Paper No. 74-15 (Ithaca, N.Y.: Department of Agricultural Economics, Cornell University, June 1974).

*A fourth alternative is to continue current practices which utilize animal power. However, this alternative was treated in the cash flow analysis by determining the incremental costs and benefits—the difference between the "with project" and the "without project" costs and benefits.

FIGURE 1
Summary of Assumptions for Small Farmer Tractor Utilization

Projected Increases in Cost and Benefit Data and Percent Change (%Δ)							
		WITH PROJECT[1]					
	WITHOUT PROJECT	Option 1 Purchase		Option 2 Rent		Option 3 Cooperative	
Production Expenses[2]	₩	₩	%Δ	₩	%Δ	₩	%Δ
Usual expenses[3]	100	130	30%	120	20%	120	20%
Operation & maintenance	0	50		40		25	
Investment		500		0		150[4]	
Gross Benefits[5]	160	360	125%	240	50%	270	70%

[1] All costs and benefits are constant over the 10-year project life.
[2] Inflation affects all project costs equally.
[3] Additional costs of seeds and other inputs are compensated by reduced labor costs.
[4] The charter fee for joining the cooperative is an investment in shared ownership of the tractor.
[5] The increased production is realized in the first year of the project.

FIGURE 2
Comparing the Small Farmer Tractor Utilization Options

		Total Cash Flow	NPV ₩	BCR_{all}	BCR_{inv}	IRR %
Option 1	Purchase	700	168	1.2	1.4	28
Option 2	Rent	200	100	1.3	–	∞
Option 3	Cooperative	500	195	1.5	2.5	76
Rank Order of Options*	1st	1	3	3	2	2
	2nd	3	1	2	–	3
	3rd	2	2	1	1	1

*According to criterion.

Computing internal rate of return was not possible for all options* (see Internal Rate of Return, IRR, page 200). The internal rate of return for tractor rental was indeterminate. The third option has a significantly higher internal rate of return than option (1), and on this basis the farmer should join the cooperative rather than purchase his own tractor. However, since the projects were mutually exclusive, the internal rate of return would not normally be used for ranking, since it may give an erroneous ordering (see Gittinger, 1972).

An internal rate of return of 28% for option (1) simply means that this investment would generate a return on capital which would be equivalent to a compound interest rate of 28% per annum. While this was nearly double the estimated opportunity cost of capital, 15%, it was not particularly high for an agricultural project. The internal rate of return for option (3) is more representative of the returns to be expected.

Computing the criteria illustrates the mechanics of cost-benefit analysis. In order to develop a single metric for judging the financial worthiness of projects, many assumptions tend to get further submerged in the manipulations of the data.

The impact-incidence matrix presents not a single measure such as net present worth, but rather a tabulation of individual metrics computed for various groups directly or indirectly affected by the project (see Impact-Incidence Matrix, IPX, page 207). Who benefits and who loses if the small farmer mechanizes those tasks which require human or animal labor? Are all the benefits and costs quantifiable, let alone measurable, in monetary units? Answering these questions adds essential dimensions to cost-benefit analysis as a decision-making tool.

Many examples of cost-benefit analysis may be found in the literature, although only in the past decade has its application in service fields such as family planning, education, and health been documented.

The Gambia case study (Jones, 1972) presents an excellent treatment of the technical side of cost-benefit analysis applied to rice production. Frianeza (1974) has a fairly complete example of cost-benefit analysis applied to the local grape industry in the Phillipines. Bruce (1976) presents a case study of the application of conversion factors to social cost-benefit analysis along with a critique of the approach.

*The IRR may only be calculated if the incremental costs exceed the incremental benefits at least once in the life of the project. Since by convention all costs are computed at year-end, option (2) never has a negative cash flow.

THEORY

Cost-benefit analysis arose in the 1930s as a tool for evaluating water resource projects in the United States. Its application to other fields grew, producing a stream of critical comment (see, for example, Graaff, 1975; DeNeufville and Stafford, 1971; and Hines, 1962) and alternative approaches (Little and Mirlees, 1974, and UNIDO, 1972). The weakness of the cost-benefit approach and its contribution to decision making have been explored (see, for example, Hinrichs, 1969; Kendall, 1971; and Layard, 1972).

The work of Gittinger (1972) and the Economic Development Institute of the World Bank in developing a comprehensive approach to the analysis of agricultural projects provided the basis for the techniques in this set of tools. The problems of applying cost-benefit analysis to other sectors have been reported (see Sirken, n.d., and Divine, 1966), though much remains to be learned about valuing the benefits and the costs of social service programs.

Social cost-benefit analysis, which attempts to weight cost-benefit factors to incorporate societal goals, is a complex process (Squire and van der Tak, 1975). There are many problems with the added complexity and the possibility that value judgments are hidden from decision makers. Many argue that the best analysis presents a broad array of evaluation criteria to the decision maker, rather than attempting to produce a highly aggregated single figure of project merit (Bruce, 1976, and Stewart, 1975).

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Cost-Effectiveness Analysis

PREREQUISITE TOOLS

None.

USAGE

PURPOSE

Cost-effectiveness analysis evaluates the *effectiveness* relative to the costs of alternative *systems.*

USES

Cost-effectiveness analysis is used to:

1) Evaluate alternative means for achieving specified ends, e.g., alternative components of a system or project design.

2) Evaluate and compare alternative projects or systems for the purpose of selecting the most cost-effective alternative.

3) Analyze the trade-offs in varying the size, complexity, or scope of a design, e.g., estimating the cost of increased effectiveness.

KEY DEFINITIONS

1) The *effectiveness* of a project or system is the degree to which the project or system design objectives are achieved.

2) *Project efficiency* is the ratio of project outputs to inputs, e.g., the production rate for a given resource utilization rate.

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

SHORT DESCRIPTION

Cost-effectiveness analysis is a crucial step in a systems analysis strategy. After deciding on objectives, identifying alternative means to achieve the desired ends, and establishing criteria for evaluation, components are selected which maximize cost-effectiveness. Costs and effectiveness are central to the evaluation and design of systems or projects.

The criteria are used in one of two ways to rank alternatives:

1) By least-cost, considering only those alternatives which achieve the specified minimum level of effectiveness.

2) By maximum effectiveness, in which all alternatives have been designed so as not to exceed a specified maximum resource requirement.

Cost-effectiveness analysis is similar to cost-benefit analysis (CBA, page 212) except that the non-monetary performance of the project is estimated.

ADVANTAGES

1) Cost-effectiveness analysis ranks alternatives by a process which is accessible to critical examination, in contrast to intuitive or committee decision-making processes. The technique provides a framework for systematic decision making and "efficient employment of the knowledge, judgment, and intuition of available experts" (Quade, 1968, page 32).

2) While the benefits accruing from a project are often not measurable (particularly in monetary terms), indexes of effectiveness can always be developed from project goal statements.

3) In contrast to *project efficiency* measures, e.g., the benefit-cost ratio (BCR, page 194) and the internal rate of return (IRR, page 200), cost-effectiveness analysis compares the relative achievement of goals.

4) Because cost-effectiveness analysis is a carefully structured approach, the process leading to a decision may be retraced; and new knowledge or different subjective judgments can be used to update recommendations.

LIMITATIONS

The analyst must necessarily limit the scope of a cost-effectiveness study, which may lead to sub-optimization. The most cost-effective alternative may not be the best choice when the larger problem situation is considered.

The complexity of the analysis increases significantly if more than one future situation (contingency) is examined (see Contingency Analysis, CGA, page 147). Consequently, analysts and decision makers tend to restrict the analysis to the most likely contingency.

Projects with different objectives cannot be compared using cost-effectiveness analysis because the scales of effectiveness will differ significantly. Cost-benefit analysis (see CBA, page 212), although limiting the choice to financial or economic criteria, permits a comparison of these projects if benefits can be valued monetarily.

Ranking projects can be inconclusive when more than one measure of effectiveness applies. Often, determining a suitable measure of effectiveness is difficult, if not impossible (e.g., evaluating goal achievement of social service programs).

Cost-effectiveness focuses only on the system and its performance, in contrast to cost-benefit analysis which includes benefits and costs accruing to other elements in the environment. This may not promote better decisions, but cost-benefit analysis alerts the decision maker to these issues.

Cost-effectiveness analysis may be used to choose among projects only if they are alternative means to the same ends. Otherwise, a common measure of effectiveness cannot be identified for evaluating each alternative.

REQUIRED RESOURCES

LEVEL OF EFFORT

The major task in cost-effectiveness analysis is gathering information to measure effectiveness and cost. Once these data are obtained and transformed into quantitative measures, the analysis is essentially complete.

SKILL LEVEL

Considerable judgment must be applied to determine measures of effectiveness and to apply them in the analysis. This is never strictly a mechanical process of translating goals into measures, although construction of a system model is desirable for analyzing performances of large complex systems (or projects).

TIME REQUIRED

A cost-effectiveness analysis may take several days if many projects are to be compared on more than one measure of effectiveness. The actual time required depends primarily on the availability of appropriate information.

DESCRIPTION OF TOOL

SUPPLEMENTAL DEFINITIONS

1) *Resource analysis* is the "process of systematically determining the economic resource impact of alternative proposals for future courses of action" (Fisher, 1968, page 124). It includes not only estimating the direct costs, but measuring the drain on economic resources which could result if various alternatives were selected and implemented, e.g., diverting essential raw materials and skilled manpower to a project.

2) *Sensitivity analysis* is a process of varying the estimated values of selected parameters in the design in order to determine the sensitivity of results to the uncertainty of the estimate. For example, the variation in total system cost is determined for selected values of key system specifications such as size, responsiveness, or reliability.

REQUIRED INPUTS

The objectives must be established (see Objective Trees, OBT, page 49). Alternative means will have to be specified, e.g., various project approaches have been identified.

Cost data must be available to determine the cost for each alternative.

TOOL OUTPUT

Cost-effectiveness analysis presents a rank-ordering of alternatives to aid decision makers. It does not select the best alternative unless non-quantifiable variables such as the political, social, and cultural implications are to be ignored—an unlikely situation for development planning. Consequently, the results of the cost-effectiveness analysis represent one part of the total information desired for project selection.

If project effectiveness is not identifiable as a single measure, the analysis may result in several rankings of effectiveness vs. cost, all of which are presented to the decision maker.

IMPORTANT ASSUMPTIONS

The results of a program or project can be evaluated using a criterion which measures the achievement of objectives. The objectives are determinate, stationary, and stable over the life of the project and consensual among the decision makers (see Objective Trees, OBT, page 49). Although these assumptions are not limiting, they should caution the decision maker and analyst against naively applying a cost-effective criteria without considering their implications.

METHOD OF USE

GENERAL PROCEDURE

1. **Given the project or system goals, identify the measure of effectiveness.**
   - 1.1 Translate each goal into measurable sub-objectives (see Objective Trees, OBT, page 49).
   - 1.2 Repeat 1.1 until quantifiable sub-objectives are identified.
   - 1.3 Select quantifiable objectives which characterize the effectiveness of the project/system.

2. **Construct an effectiveness scale.**
   - 2.1 Determine the units of measurement, e.g., passenger-miles per hour, extension contact hours per farmer.
   - 2.2 If necessary, use a dimensionless index to compare subjective estimates of effectiveness.
   - 2.3 Identify the range of the effectiveness scale, typically 0 to 1 for an index (see Rating Scales, RTS, page 29).

3. **Give alternative means and evaluate their effectiveness.**
   - 3.1 When feasible, construct an analytical model to compute effectiveness estimates for each alternative (see Computer Simulation Models, CSM, page 120).
   - 3.2 When mathematical modeling is not feasible, estimate the effectiveness subjectively. Pooled expert judgments may be used (see Delphi, DLP, page 168), or empirical data may be obtained (either by experiment or pilot study).

4. **Determine costs by making a resource analysis of the alternatives.**
   - 4.1 Determine a basis for costing which is comparable across all alternatives.
   - 4.2 Identify direct costs, both initial and recurrent, and costs associated with making resources (e.g., raw materials and manpower) available to the project (see Cash Flow Analysis, CFA, page 177).
   - 4.3 If the costs are distributed differently in time for each alternative, discount all costs to determine the present worth (see Discounting, DIS, page 184).

5. **Rank-order the alternatives.**
   - 5.1 Compute the ratio of effectiveness to cost for each alternative.
   - 5.2 Plot effectiveness vs. cost (optional).
   - 5.3 Determine the cut-off levels for considering alternatives:
     - a) If a minimum level of effectiveness is required, ignore all objectives which fall below this level. If none exceed the level, either change the specification or identify new alternatives.
     - b) If a maximum level of cost is permitted, ignore all alternatives which exceed this limit. If none has acceptable costs, consider scaling down the scope of the alternatives or identify less costly means.
   - 5.4 Rank-order the remaining alternatives using the ratio of effectiveness to cost. If two or more alternatives have identical ratios, select the most effective or least costly depending on whether a) or b) holds.*

6. **Test the sensitivity of the rankings.**
   - 6.1 Select a variable (cost or effectiveness) for which the estimate is most certain.
   - 6.2 Using either the analytical model or an experimental design, estimate how a small change in this variable will affect the subsequent computation.
   - 6.3 Repeat 6.2 for several values included in the likely range of the variable.

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*Specifying both a minimum level of effectiveness and a maximum acceptable cost may lead to an under-specification of the system. The designer may fail to identify the most cost-effective alternatives.

FIGURE 1
Reliability and Acceptance Rates for Alternative Means of Birth Control

Alternative Means	Probability of Preventing Pregnancy	Average Acceptance Rate for Specific Population	Effectiveness
Male contraceptives	.90	70%	63
Female contraceptives:			
Hormone pills	.95	80%	76
Intrauterine devices	.90	50%	45
Male sterilization	.99	5%	5
Female sterilization	1.00	20%	20

FIGURE 2
Cost Analysis of Alternative Means of Birth Control

Alternative Means	Couple Year(s) of Protection	Estimated Method Cost[1]	Protection Cost Per Year
Male contraceptive	0.0083/condom[2]	Ψ 4.2/condom	Ψ506
Female contraceptive			
Oral	0.0667/cycle[3]	Ψ 30/cycle	Ψ449
Intrauterine	3/IUD[4]	Ψ 60/IUD	Ψ 20
Male sterilization	10[5]	Ψ450	Ψ 45
Female sterilization	10[6]	Ψ900	Ψ 90

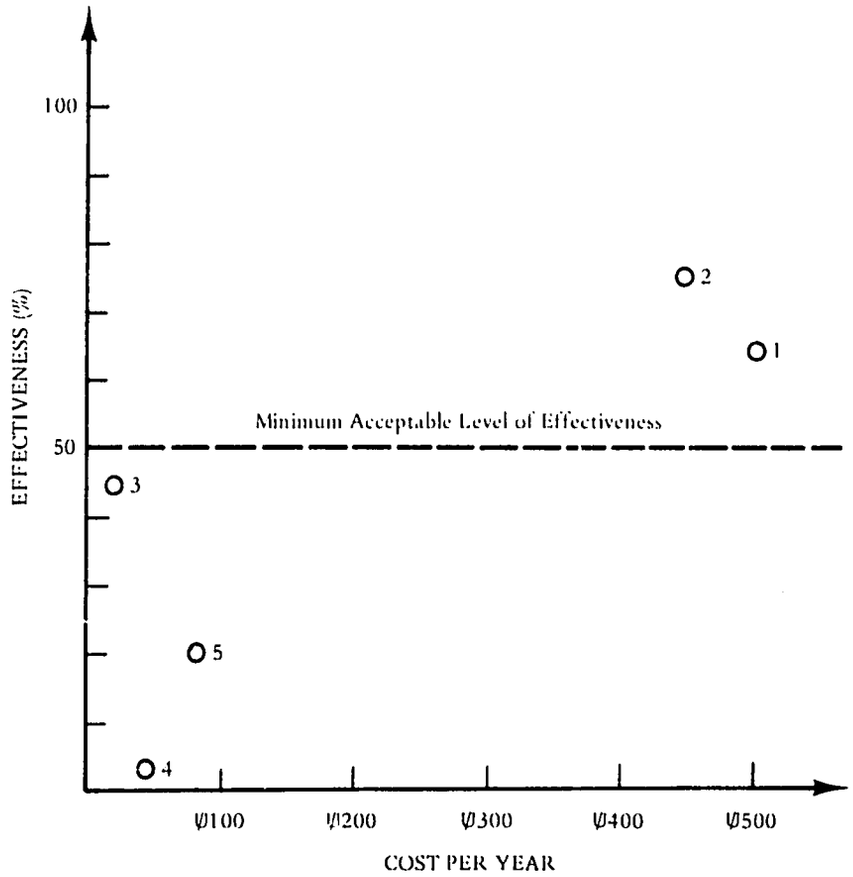
1. Ψ = Unis = the national currency of Temasek.
2. Assuming an average use of 120 condoms per year.
3. Assuming 15 cycles are required each year (including wastage).
4. Assuming each IUD inserted is retained for an average 3 years.
5. Assuming 10 years from average age of sterilization (35) to onset of menopause.
6. Assuming same average age of wife of the man sterilized.

FIGURE 3
Cost-Effectiveness of Alternative Birth Control Means

a) Effectiveness-Cost Ratio

Alternative	Yearly Cost ₱	Effectiveness %	Ratio: Effectiveness to Cost
1. Male contraceptives	506	63	0.12
Female contraceptives			
2. Oral	449	76	0.17
3. IUD	20	45	2.25
4. Male sterilization	45	5	0.11
5. Female sterilization	90	20	0.22

b) Plot of Effectiveness vs. Cost



6.4 Present the sensitivity analysis results to the decision maker as a range of variation in the effectiveness to cost ratio or as a box which indicates the uncertainty on the plot of effectiveness vs. costs.

EXAMPLE

The Temasek Family Planning Council proposed to examine the cost-effectiveness of various means of birth control in use in Temasek. The objective of the project was to determine the best means of birth control for funding. Two criteria were identified: the reliability of the particular method and the percentage of the population accepting that method. The effectiveness was defined as the product of reliability and rate of acceptance (see figure 1).

The next step was to analyze the costs of the alternatives. The measure adopted was the equivalent Couple Year of Protection for each technique (Edmonds, 1975). For example, data indicated that each couple used an average of 120 condoms per year. Then each condom afforded 0.0083 CYP. Similarly, a sterilization operation would protect a couple for the remaining child-bearing years. The corresponding CYP was computed by subtracting the average age at sterilization from the average age for onset of menopause (see figure 2).

The protection cost per year of each birth control technique was computed by dividing the estimated method cost* by the CYP. On a cost basis alone, there were vast differences in the resources required to provide a year of protection by various alternatives.

The costs were compared to the estimated effectiveness (see figure 3). Computing the ratio of effectiveness to cost revealed that an intrauterine device was by far the most cost-effective technique. However, the level of effectiveness was estimated at less than 50% (due to the low rate of acceptance). If 50% were taken as the minimum level of effectiveness, then only oral contraceptives and condoms would be considered.

This analysis considered only the means of birth control. A cost-effectiveness analysis of a birth control program would ultimately have to examine the effects of using various techniques on the birth rate vs. the infrastructure necessary to deliver the techniques. Unfortunately, such an analysis is complicated by 1) the delay in observable changes in birth rate and 2) the multitude of alternative explanations for changes in birth rate. The problem in evaluating cost-effectiveness of these programs is described in Schultz (1972). In an earlier paper, Schultz (1967) formulated an economic model of family planning in order to measure benefits vs. costs.

*These costs ignore the infrastructure required for delivering the various techniques. Although this could be incorporated into each method cost as an overhead component, a separate analysis of the means of delivery is more appropriate.

THEORY

Cost-effectiveness derives from cost-benefit analysis (Rowen, 1969). Defense Department analysts realized that valuing the benefits of weapon systems was not feasible and looked for other measures of system performance. The theoretical analysis of system models and tactical and strategic plans followed (Quade and Boucher, 1968). The technique has been applied to policy planning and project design in fields like social services. The formidable task of valuing benefits is circumvented by using nonmonetary effectiveness scales to compare alternatives.

The role of resource analysis and sensitivity analysis in cost-effectiveness studies is presented by Quade and Boucher (1968). DeNeufville and Stafford (1971) address additional theoretical issues, such as determining the optimum system effectiveness as a function of the cost.

Krueckeberg and Silvers (1974) give an excellent description of cost-effectiveness analysis applied to urban planning and the theoretical basis for selecting among alternative projects using the effectiveness-cost ratio.

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List of Cross-References

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

Glossary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

DEPENDENT VARIABLE. The variable being forecast (RGF).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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