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PRIORITIES MODELING USING GOAL GROWTH PROGRAMMING

AUGUST 1977

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JOINT CONVENTIONAL
AMMUNITION PROGRAM COORDINATING GROUP
DECISION MODELS DIRECTORATE
ROCK ISLAND, ILLINOIS 61201

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER JCAP-DM-T701	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Priorities Modeling Using Goal Growth Programming		5. TYPE OF REPORT & PERIOD COVERED Final Report FY76-77
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Daniel R. Turk		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Decision Models Directorate Joint Conventional Ammunition Program Coordinating Group, Rock Island, IL 61201		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Decision Models Directorate Joint Conventional Ammunition Program Coordinating Group, Rock Island, IL 61201		12. REPORT DATE August 1977
		13. NUMBER OF PAGES 66
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Shortened versions presented December 1976 at the 38th Military Operations Research Symposium, Ft. Eustis, VA and May 1977 at the Joint National TIMS/ORSA meeting, San Francisco, CA. An executive version is scheduled to be in the Fall 77 US Army MANTECH Journal.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Goals, Priorities Management Model	Zero Base Budgeting
Goal Growth Programming	Management by Objectives
Multiple-Attribute Decision Modeling	Portfolio Management
Multiple-Criteria Decision Models	Computer Programming
Mixed Integer Programming	FORTRAN

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The JCAP Priorities Model is a group of programs which evaluates and orders decision alternatives, such as various schedules of projects, for maximum planned growth to multiple goals in accordance with goals and priorities established by the manager himself or by higher authority. The purpose is stated simply as "To develop and rank decision alternatives for maximum achievement of overall management goals, both economic and non-economic". The model answers questions of how, when, where and in what amounts should resources be allocated to competing options in situations where multiple

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objectives prevail. The Priorities Model, in achieving this objective, utilizes a new technique -- GOAL GROWTH PROGRAMMING -- to develop target goal growth paths that reflect both short-range and long-range management priorities. The model then resolves the trade-offs involved so that the final solution does represent the best attainable goal growth plan from among the many combinations of alternatives available.

The starting point for GOAL GROWTH PROGRAMMING is a subjective assessment phase during which management objectives and priorities are assessed and incorporated into the model. The next step, target growth path development, utilizes goal priorities and initial goal status data to automatically generate goal growth trajectories which reflect management priorities. These trajectories or growth paths represent what management would like to achieve over the planning period with respect to each of the goals. A FORTRAN pre-processor program develops these target values over the planning period. Graphical output is available using SIMPLOT subroutines. These target values are presented to the decision maker for review and approval, or adjustment if desired. A second portion of the FORTRAN pre-processor program develops a good portfolio by weighted average techniques to serve as an initial feasible solution. This data as well as the approved target path values, project data and other required data are then set-up as an input file by the pre-processor. A third FORTRAN program generates a matrix file of the governing relationships for the problem. These two files are input to a commercially available mixed integer software package with special capabilities for processing this type of problem.

This mixed integer program operates on the deviational variables between the target goal growth paths and what can be achieved by combination of the alternatives, i.e., the projects, within the given set of constraints. The criteria selected by the decision maker, such as minimizing the sum of under-achievements, then drives the model in its solution for best portfolio to achieve that objective. A selection rule includes other portfolios in ranked order in the final output. Budget envelopes form the principal constraint.

The Priorities Model applies to complex planning problems whose management objectives must consider goals for productivity, economics, and social impact, as well as broad priority levels, goal priorities, and practical resource contraints.

Uses for the model beyond the annual planning, programming, and budget cycle are for Goal Growth Programs, to upgrade formal Management by Objective (MBO) programs, in Project and Program Management, and in Command Review and Analysis Programs. In particular, where goal contributions from each alternative are known the model is applicable for Zero Base Budgeting (ZBB).

JOINT CONVENTIONAL AMMUNITION PROGRAM
COORDINATING GROUP

REPLY TO
ATTENTION OF:

Rock Island Arsenal, IL 61201

15 August 1977

Consistent with the major objectives of the JCAP Coordinating Group to improve the conventional ammunition logistics management decision process, the JCAP Decision Models Directorate has developed, demonstrated, and gained acceptance of models covering a wide spectrum of logistics management activities.

While models developed under the auspices of the JCAP Coordinating Group were to meet the needs of conventional ammunition logistics managers, they have application to most types of logistics management activities. Accordingly, these models are being published to achieve a wider understanding of their existence and their capabilities.

This publication which addresses PRIORITIES MODELING USING GOAL GROWTH PROGRAMMING is an approved JCAP Coordinating Group publication and is disseminated for use by managers and personnel engaged in the technical aspects of modeling for management decision making.

EDWARD J. JORDAN
Executive Director
Joint Conventional Ammunition
Program Coordinating Group

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DANIEL R. TURK

PRIORITIES MODELING

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AUGUST 1977

JOINT CONVENTIONAL AMMUNITION PROGRAM COORDINATING GROUP
DECISION MODELS DIRECTORATE
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PREFACE

This report presents the results of a Priorities Model development program conducted by the Decision Models Directorate of the Joint Conventional Ammunition Program (JCAP-DM) during 1975 and 1976. The main objective of the effort was to develop a modeling tool to apply management priorities in complex decision problems involving both economic and non-economic factors. A major portion of this report examines subjective topics that must be considered in applying priorities modeling concepts. In fact, the major issues presented in Section 1 all interact and must be considered jointly. The presentation differs from conventional technical reports in several ways. First, it is inherently more management oriented. Second, the Goal Growth Management Steps developed in Section 3, although straightforward, are lengthy and involved. In particular, the explanations concerning subjective values for goal priorities quantification may require more than one reading. Next, the concept for representation of decision alternatives as sets of planning portfolios is probably best understood by an intensive review of the example in Section 4. Finally, the in-depth mathematical discussions underlying the approach are presented in the Appendices.

Acknowledgement is especially given to Mrs. Julia A. Bills for typing, typing, and retyping, not only of the final text, but for all of the many forms of briefings, articles, and technical memoranda which eventually evolved into this report.

SECTION 1
INTRODUCTION

1.1 OBJECTIVE

The purpose of this report is to describe a new decision tool for executive decision makers -- the JCAP Priorities Model -- and to indicate how management may use this model in multi-objective decision situations.

1.2 BACKGROUND

The Priorities Model presented in this report has widespread potential. It is a group of procedures and computer programs that evaluate and order decision alternatives for maximum planned growth to multiple goals in accordance with goals and priorities established by the manager. A new technique -- Goal Growth Programming -- was developed to model multiple trade-offs that best reflect management objectives and priorities yet consider the total decision environment.

Among the difficult decisions facing DoD managers are the multiple-objective trade-offs required in the annual planning, programming, and budgeting cycle. The problem is to develop balanced project/program portfolios for the Five Year Defense Plan supported by rationale that leaves the manager no doubt but that he has the most cost-effective and efficient plan to satisfy short and long-range goals and priorities within the logistics and fiscal guidance for the resources involved.

This problem was addressed by the Decision Models Directorate of the Joint Conventional Ammunition Program Coordinating Group (Reference 1) when it was directed to develop a Priorities Model to assist managers in evaluating hundreds of projects diverse in purpose,

1. Jordan, E. J. "Coordinated Management of the Conventional Ammunition Production Base", Defense Management Journal, Vol. 10, No. 5, pp 9-15, October 1974.

character, and scope competing for limited resources. The purpose of JCAP-DM Priorities Model is simply stated as "To develop and rank decision alternatives for maximum achievement of overall management goals, both economic and non-economic". The particular problem addressed was how to select the best portfolio of modernization projects for the Production Base Support (PBS) Program (Reference 2).

1.3 MAJOR ISSUES

In developing a Priorities Model with a systematic approach for rationally balancing multiple objectives that influence a final plan and satisfy needs for documentary justification, many questions must be addressed by the model or the decision maker.

The major issues involved are:

1.3.1 Problem Definition.

What is the basic decision problem? What types of alternatives are available? Who are the decision makers? How stringent are the planning limitations imposed by logistic and fiscal guidance? Are the overall management goals formally defined or must they be synthesized? How should broad program priorities and existing commitments be handled? Must individual project selection be sequential? These and all other significant impacts of potential decisions must be identified, examined, and discussed during problem definition so that the model will reflect the decision environment and accommodate the proper constraints.

1.3.2 Goals and Priorities.

The goals of an organization are multiple, often conflicting. They may vary according to its missions and functions, to its interrelationships with other organizations and management levels,

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2. Pritchard, J. J., "Integral Plans Review All Possibilities", US Army MANTECH Journal, Vol. 1, No. 1, pp 10-13, Fall 1976.

and to its management philosophy. In achieving a set of goals, the decision maker is often hampered by conflicting interests, incomplete and irrelevant information, limited resources, pressing schedules, and scarcity of resources. Evaluating goals and priorities clears the decision environment through developing a goal-subgoal-objective tree-like hierarchy that structures the problem. Branches of the goal tree must end on specific performance measures or on judgmental value estimates. Some goals are measurable, others are subjective. Each branch must be quantified and weighted according to goal priorities. The modeler must identify trade-offs of goal achievement via assessment techniques varying from direct proportionment to statistical assessment of group preferences. The decision maker must be comfortable with weighting factors and variations imposed in the model trade-offs. He is in direct control -- the source of all value judgments.

1.3.3 Data.

It is not enough to merely identify what the performance measures should be. They must be expressed as numerical data having special informational value in the trade-offs. Therefore, all aspects of data processing must be addressed. Is the definition for each factor clear? What data are now collected? Are they appropriate for these goals? If not, can they be reprocessed to suitable form? What new data are needed? Which activities should submit which data? -- when? -- how? Examining existing data packages and interrogating experienced members of review teams are good starting points for realigning the data processing aspects. The problem is to bring order and credibility to a process which often appears as informational chaos.

For the modernization example (stated in Sec. 1.2) only a slight realignment was necessary since the existing package summaries were based on before and after analyses for each factor. This straightforward approach enables the transition from selection by an individual project ranking scheme to the goal growth selection, which is the process described here. Individual project ranking schemes, popular because of their simplicity, tend to mask the true trade-offs available to the decision maker. The rankings, for example, offer no information which would assist in the comparison of twenty small projects versus one large project. This is especially true in multiple objective situations with large numbers of projects competing for selection. This leads to many more possible combinations to be examined. In fact, decision trade-offs based on best goal growth attainment must rely on data which identifies the potential contributions to each goal achievement for each eligible project at each stage of the process. To reiterate, goal improvement data, such as "before and after" or "percentage goal improvement", is a key concept for the discriminations made during Goal Growth Programming.

1.3.4 Choice of Criteria.

The proper choice of criteria depends on the nature of the decision maker. In general, two objectives are common to all decision makers:

They want "return" to be high. This "return" may be interpreted differently by each decision maker in multiple objective situations, and this is precisely the reason for the determination of the goal priorities of the decision maker. But, in whatever sense used, they prefer more of it to less of it. Thus, goal growth attainment is deemed a universal objective.

They would like to have "dependability" in the return. In selecting projects for research and development, dependability is important due to future technological uncertainties. Project selection under uncertainty requires the use of Decision Risk Analysis (DRA) techniques, with attendant increases in data collection, statistical complexity, and interpretation of the decision options.

The Priorities Model presented here does provide the framework for the DRA approach, if required. However, when selecting projects already essentially proven through manufacturing technology programs risk factors are low and effort may be placed on obtaining more dependable information on the projects by uniform data definition, appraisal, and collection procedures. The modeling approach is thereby simplified since no statistical distributions are required. These can be applied, however, for special applications.

The problem of criteria, then, becomes one of a practical selection rule from among the computer program options. Normally, the models' default mode selects portfolios that minimize the sum of under-achievements of goals during a planning period. Overachievements are a bonus. The decision maker may also select from other options that provide the best combination for near-term growth or for best "tracking" goal growth target paths. Thus after the initial run, the decision maker can guide the models' selection process. Computerized graphics allow him to see the results of strategy variations.

1.3.5 Rules of the Game.

A further aspect of problem definition emerges as the modeler investigates the actual decision envelope available to the decision maker. Existing rules, regulations, commitments, guidance, obligational authority levels and even on-going informal procedures tend to restrain the number of viable options. All of these rules of the game must be identified, interpreted, and structured as broad program priority codes which govern the sequences in pre-allocation before the actual decision envelope is known! In effect, a considerable number of projects may be "locked in" to any final plan just to satisfy the rules of the game. Nonetheless, the same types of performance and cost data must be obtained for all pre-allocated projects in order to assess their impact on the status of each goal growth path. Then to be practical, the model must proceed in steps which acknowledge these rules -- as broad program priorities -- before actual goal priorities can operate in the remaining decision space.

1.3.6 Hierarchial and External Impacts.

There are, inherently, several identifiable organizations or individuals at higher and/or lower levels of hierarchy who will be impacted by an amalgamated plan. The preferences of these groups or individuals are different. Since the decision maker desires to achieve a degree of equity among those impacted, the model should be able to forecast and assess those impacts, and predict need for special coordination, justification, or even priority revision.

Similarly, a plan may impact on public issues, overlap other mission and functional areas, or effect special interests. The model should be able to identify and assess these impacts and predict needs for similar coordination efforts. In the Priorities Model, such impacts are examined by varying the goal weighting factors to represent viewpoints of other parties.

SECTION 2

THE PRIORITIES MODEL

2.1 SCOPE

The approach taken to develop a model that addresses the total problem and the major issues described in Section 1 has resulted in the Priorities Model presented in this section. The model consists of a sequence of procedures and programs that evaluates and orders decision alternatives, such as various schedules of projects, for maximum planned growth to multiple goals in accordance with goals and priorities established by the manager himself or by higher authority. The model was developed to perform multiple trade-offs that best reflect management's objectives and priorities with proper consideration given to the total issues of the decision environment.

The section indicates application areas for the Priorities Model and summarizes its technical capabilities and principles of operation.

2.2 APPLICATION AREAS

The Priorities Model may be applied to large complex executive planning problems which must consider in the management objectives, a mixture of

- Productivity oriented goals (readiness, surge, capacity, etc.)
- Economic oriented goals (payback, etc.)
- Social impact goals (safety, environment, etc.)

with concurrent consideration of

- Broad priority levels (guidance, commitments, project sequence, etc.)
- Goal priorities (management preferences), and
- Practical resource constraints (budget, etc.)

In addition to the project selection type of application of the Priorities Model, many other potential application areas exist. Some of the more apparent are in Project and Program Management offices, in Command Review and Analysis programs, in Management by Objectives (MBO), or Zero Base Budgeting (ZBB) programs where the goal growth management approach could upgrade the effectivity of the management process.

2.3 TECHNICAL CAPABILITIES AND OPERATIONS

The JCAP-DM Priorities Model is registered as DoD Logistics Model, Number LD 37254. As a multiple-objective, additive-weighting growth model it can resolve growth plans from 1 to 20 years for up to 9 goals in up to 1000 project/planning periods (e.g., 100 projects over 10 years or 200 projects over 5 years.) A variety of analytical processing programs written in FORTRAN IV are available for subjective assessment evaluation. A pre-processor module, written in FORTRAN IV, enables further shaping of goal growth paths by the decision maker with the added advantage of presenting him with a realistic solution based on the best weighted average growth plan attainable under the goal priorities he has previously defined.

Figure 2.1 indicates typical target goal-achievement paths generated automatically in response to his priority assessment and

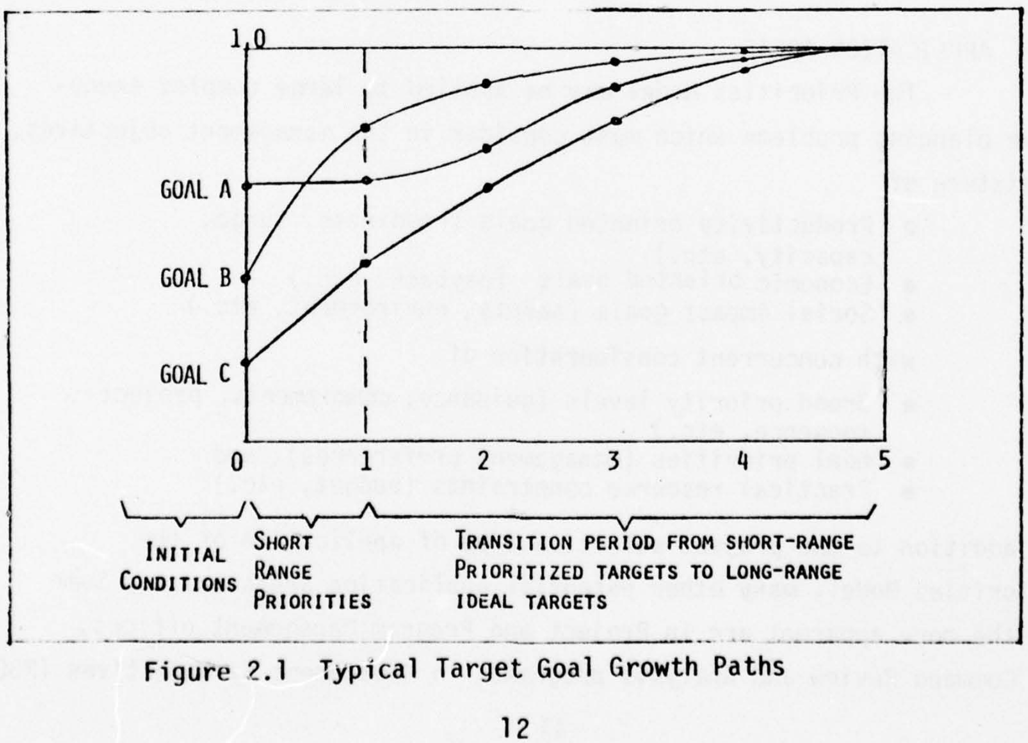

Figure 2.1 Typical Target Goal Growth Paths

current goal status. An overview of the theory which generates the target goal growth paths is presented in Appendix A.

After the target paths are approved or revised and other factors influencing the scope of the investigation (e.g., budget variations and criteria choice) are decided upon, another FORTRAN IV program sets up a file of project data and automatically generates a matrix file of governing relationships. The two files are input into a commercially available software package with special capabilities for this type problem. An overview of the type of equations used in Goal Growth Programming is presented in Appendix B. Equations of this type are converted by the matrix generator into a problem file for mixed-interger solution techniques. In this approach, the deviations

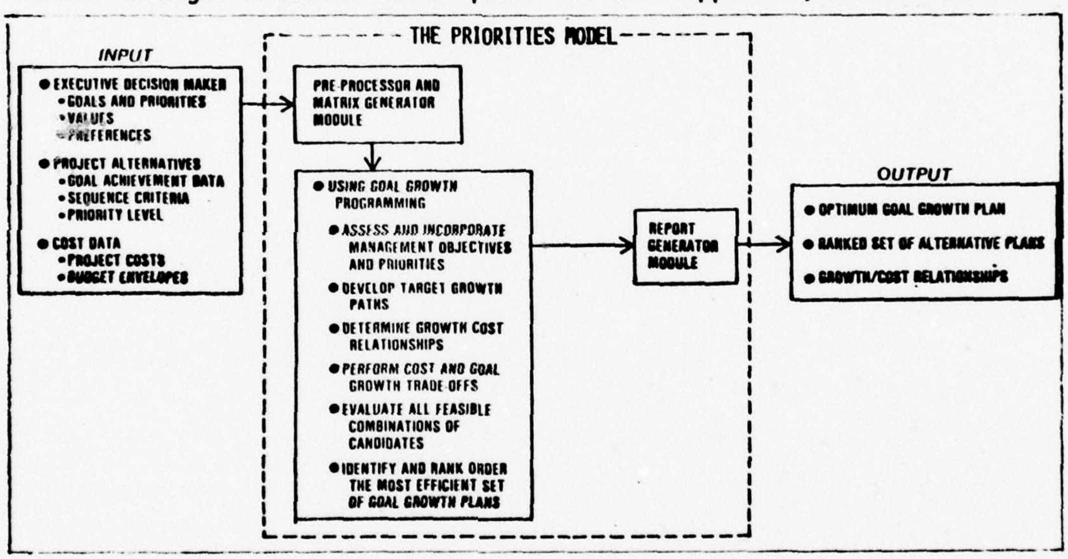

Figure 2.2 Flow Diagram for The Priorities Model

between target goal achievement paths and those achievements possible through combinations of projects (within defined constraints), become underachievement or overachievement variables. The criteria selected, such as minimizing the sum of underachievements, drives the software package to its solution for the portfolio best meeting the objective. A predetermined selection rule, such as the five best plans, includes other portfolios in ranked order in the output. In general, budget envelopes form the principal constraint.

Figure 2.2 summarizes the input requirements, the main processing steps, and the output. The FORTRAN report-generator module adds decision-aiding evaluation measures such as growth/cost index and values of other possible criteria. Its output is incorporated into an analysis of the problem solutions -- A Priorities Model Evaluation Report -- for use by the decision maker.

SECTION 3

MODELING OF A PROBLEM

3.1 OVERVIEW

In this section an overview will be given of ten general steps required to analyze and structure problems for Goal Growth Management using the Priorities Model. The step-by-step approach is advocated to indicate how the major issues raised earlier are addressed within the framework of the Priorities Model.

3.2 BACKGROUND

Goal programming is not new. It was first presented by A. Charnes and W.W. Cooper (Reference 3) as a normative linear programming technique for resolving multiple objective management problems. It has since been further refined by others (References 4, 5, and 6).

What is new is to extend the normative approach from static to dynamic situations in such a way that the decision maker can exercise management planning over the growth achievement rates for his objectives. The extended approach is called "Goal Growth Management". The advocated approach is aimed at simplifying the manager's participation in the process. The Goal Growth Management approach features:

- Minimal time spent in direct management involvement
- Maximal management control over goals and priorities
- Higher management confidence in model credibility
- Greater effectivity of the decision process

Goal growth management is somewhat analogous to investment

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3. Charnes, A. and W.W. Cooper, Management Models and Industrial Application of Linear Programming, New York: John Wiley and Sons, 1961.

4. Lee, S.M., Goal Programming for Decision Analysis, Philadelphia: Auerbach, 1972.

5. Golding, E.I., "Goals Measurement System (GMS) - A Quantitative Procedure for Evaluating Program Effectiveness", Interfaces, Vol. 3, No. 1, pp. 21-29, November 1972.

6. Gibbs, T.E., "Goal Programming", Journal of Systems Management, pp. 38-41, May 1973.

growth theory in the sense that the portfolios selected represent the best way to achieve objectives. Unlike investment theory where the value of the net return from the investment is measured in the same monetary units, attempts to equate other types of goal attainment to specific monetary values have usually failed because of the difficulty of establishing authoritative universal standards for conversion and interpretation of measures. Hence, such monetary value solutions have been of little practical use to decision makers in multiple attribute problems.

Fortunately, sound rationale developed by Fishburn (Reference 7), Raiffa (Reference 8), and others (References 9 through 13) enables the modeler to capture and quantify the decision maker's values, preferences, and trade-offs through subjective assessment of his so-called "utility" functions. A variety of approaches are available. A 1975 survey (Reference 14) of over 150 forecasting and planning techniques indicated a core of 12 main methods. Whichever procedure is best depends upon many factors and the application. Initial assessments serve as a basis for further discussions and modification. After a few iterations the utility functions should closely represent

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7. Fishburn, P.C., Utility Theory for Decision Making, New York: John Wiley and Sons, 1970.

8. Raiffa, H., Decision Analysis, Reading, Mass.: Addison-Wesley, 1968.

9. Schlaifer, R.O., Analysis of Decision Under Uncertainty, New York: Mc-Graw-Hill, 1969.

10. Keeney, R.L. and K. Nair, "Decision Analysis for the Siting of Nuclear Power Plants - The Relevance of Multi-Attribute Utility Theory", Proceedings of the IEEE, Vol. 63, No. 3, pp. 494-501, March 1975.

11. Byington, S.R., "Reducing Uncertainty in Interchange Desing Evaluations", Public Roads, Vol. 38, No. 4, pp. 141-149, March 1975.

12. Cochrane J.L. and M. Zeleny, Ed., Multiple Criteria Decision Making, Columbia, South Carolina, University of South Carolina Press, 1973.

13. Dyer, J.S., "Interactive Goal Programming", Management Science, Vol. 19, No. 1, pp. 62-70, September 1972.

14. Mitchell, A. et al, Handbook of Forecasting Techniques, IWR Contract Report 75-7, Institute of Water Resources, US Army Corps of Engineers, Fort Belvoir, Virginia, December 1975.

the decision maker's preferences. The capturing and the modeling of these preferences is the cornerstone for the rest of the Goal Growth Management approach. The assessment process is described in more detail in the steps which follow.

3.3 THE GOAL GROWTH MANAGEMENT STEPS

3.3.1 Step 1. Identify the Players and Their Roles.

The heart of any priorities modeling problem is management Participation. In fact, the model must contain the goals and objectives of the executive decision maker and the relative priorities he associates with each goal.

The first task then is to identify the players, their roles and the procedures and channels for data needs in later steps. Figure 3.1 indicates the cast involved in participative decision making, that is, the decision maker, his staff and the decision modeler -- and their roles. The executive decision maker participates as the source of all goals and objectives pertinent to the decision problem and for the values he wishes associated with them. After defining the problem and priorities he will direct the modeling operations from time to time whenever executive decisions or approvals are needed. He will also utilize the results of everyone's combined efforts -- the options that are output by the model -- in his final decision process.

The role of the staff and other specialists is supportive to both the decision maker and to the decision modeler -- as sources of expertise and data. The identification of all parties and the extent of their interaction is needed in any situation requiring joint decision making.

The role of the decision modeler is to convert all source information into model data in such a way that the model will reflect the decision maker's goals and priorities. The computations carried out in the model itself will then be able to select and combine the decision alternatives into a small set of efficient planning portfolios for the decision maker's final selection.

Throughout the entire participative decision process, the idea is to establish a framework for consideration of the major factors and groups which bear on the management decision.

PARTICIPATIVE DECISION MAKING

CAST:	ROLES:
EXECUTIVE DECISION MAKER	• ESTABLISH GOALS AND PRIORITIES • DELEGATE INFORMATION RESPONSIBILITY • APPROVE TARGET GROWTH PATHS
MANAGERS AND STAFF	• ADVISE, COORDINATE, AND EVALUATE • PROVIDE SPECIALIZED EXPERTISE • MONITOR INPUT/OUTPUT
DECISION MODELER	• CONVERT INPUT TO MODEL FORMAT • GENERATE THE MODEL • OPERATE THE MODEL • PROVIDE MODEL OUTCOMES (PORTFOLIOS)

Figure 3.1 The Players and Their Roles in Participative Decision Making

3.3.2 Step 2. Identify the Goal Set.

The basis for evaluation and true objective to be considered in multiple objective problems is simply "goal achievement." The question which immediately follows is -- "What are the overall management goals"? Endeavors to answer this question may reveal that no nicely structured ready-made list of goals exists. This was the case for the DoD Conventional Ammunition Program. The ten "corporate" goals shown in Figure 3.2 were synthesized from many sources and cast in the structural format used for DARCOM "corporate" goals. Such a goal set for the timeframe of interest is, in effect, a normative description of the corporate image -- which cites specific goals to improve, to foster and to update within the framework of managerial control. The first two goals concern the primary mission -- readiness -- and both Goal 3 and

GOALS: DOD CONVENTIONAL AMMUNITION PROGRAM

1. IMPROVE READINESS OF THE PRODUCTION BASE
2. IMPROVE READINESS OF THE LOGISTICS BASE
3. REDUCE COST OF BOTH BASES
4. IMPROVE PRODUCTION & PROCUREMENT PROCESSES
5. IMPROVE QUALITY OF WORK FORCE
6. IMPROVE IN SPECIAL CONCERN AREAS SUCH AS SAFETY, ECOLOGY, AND SECURITY
7. MANAGE AND OPERATE AT MINIMUM APPLICATION OF RESOURCES
8. IMPROVE EQUAL EMPLOYMENT OPPORTUNITIES (EEO) RATIOS
9. IMPROVE THE WORKING AND LIVING ENVIRONMENT
10. FOSTER AND UPGRADE CREATIVITY AND INITIATIVE

Figure 3.2 Goals of the DoD Conventional Ammunition Program

Goal 7 address economics, although from different viewpoints. The manner by which each goal should influence decision problems varies considerably according to the problem and the span of managerial control. For example, most of the special concern sub-topics of Goal 6 become major non-economic factors to be considered when evaluating modernization alternatives for the production base. On the other hand, Goal 8 (EEO) might influence a decision maker's staffing policy but have little or no influence on base modernization planning decisions.

These goals purposely addressed the entire DoD Conventional Ammunition Program in accordance with new responsibility for production and logistics under one manager at "corporate" level. They were then subdivided into more specific sub-goals and objectives supplemented by narrative guidance for each goal. Figure 3.3 indicates this type of breakout using Goal 4 as an example. Progress at attaining prespecified targets for sub-goals or objectives of this type is often regularly tracked at periodic command level review and analysis

GOAL NO. 4 IMPROVE THE CONVENTIONAL AMMUNITION PRODUCTION AND PROCUREMENT PROCESSES

GUIDANCE. THE ATTAINMENT OF THIS GOAL REQUIRES BOTH APPLICATION OF IMPROVEMENTS TO THE PRODUCTION TECHNOLOGY BASE AND IMPROVED SURVEILLANCE OF PRODUCTION TO RECOGNIZE POTENTIAL SCHEDULE SLIPPAGES AND OTHER CONTRACT DELINQUENCIES AS EARLY AS POSSIBLE IN ORDER THAT TIMELY CORRECTIVE ACTION CAN BE INITIATED.

GOAL-OBJECTIVE PAIR 4-1: IMPROVE PRODUCTION PROCESSES THRU MM&T

PAIR 4-2: DEVELOP AND OBTAIN MORE REALISTIC CONTRACTS

PAIR 4-3: IMPROVE VISIBILITY FOR HIGH PRIORITY/LARGE VOLUME PROGRAMS

Figure 3.3 Example Goal-Objective Pairs

presentations. Such objectives are likely to be too broad to be directly useful in analyzing and evaluating specific decision alternatives and, thus, require further division into lower-level more specific objectives. In this manner the goal-objective hierarchy of the organization is started. Eventually such relationships must arrive at specific quantifiable data elements or measures. Before discussing the more detailed expansion of goal trees it should be noted, however, that a matrix structure, as in Figure 3.4, may be used to assess various viewpoints.

EXAMPLE GOAL WEIGHTS - VARIOUS MANAGERS

GOAL	DOD INSTALLATIONS & LOGISTICS	SINGLE MANAGER FOR AMMUNITION	ARRCOM DIRECTOR PRODUCTION	GOGO/GOCO AMMUNITION PLANT MANAGER
1 - READINESS-PRODUCTION BASE	.05	.38	.15	--
2 - READINESS-LOGISTICS BASE	.30	.09	.07	--
3 - OPERATING/MAINTENANCE COST REDUCTION	.15	.03	.08	.25
4 - PROCESS IMPROVEMENT (PRODUCTION & PROCUREMENT)	.05	.16	.35	.05
5 - UPGRADE MANPOWER	.05	.04	.08	.15
6 - SPECIAL TOPICS	.10	.12	.05	.20
7 - MINIMIZE RESOURCES	.20	.16	.10	.10
8 - EQUAL EMPLOYMENT OPPORTUNITIES PROGRAM	.05	.01	.02	.10
9 - UPGRADE {EQUIPMENT, FACILITIES, COMMUNICATIONS}	.03	.01	--	.10
10 - MOTIVATE & CHALLENGE	.02	--	.10	.05

(WEIGHTING ASSIGNMENTS SUM=1.0)

Figure 3.4 Matrix for Analysis of Hierarchial or External Views

Presumably each decision maker within the complex management structure involved in the DoD Conventional Ammunition Program should be able to select and weight the goals that represent:

1. His own most significant managerial control area
2. Areas with hierarchial or external impact potential that might influence his decision policies.

Certain of the numerical values are boxed to emphasize that the most important factors to a specific decision maker are usually easiest to estimate. Even though the weight may legitimately vary considerably according to managerial insights and interpretation of mission, the evaluation of any amalgamated plan against carefully estimated priorities for other entities may provide a substantial management assist by pre-evaluation of other hierarchial or external impacts.

3.3.3 Step 3. Form the Goal-Objective Hierarchy.

The ten generalized goals and associated goal-objective pairs form the starting position for developing sub-objectives at succeedingly lower levels. Such a hierarchial ladder, or goal-tree, eventually arrives at branches where effectiveness measures can be specified either as specific quantified performance measures or as judgmental, qualified, value estimates. Figure 3.5 shows in skeletal

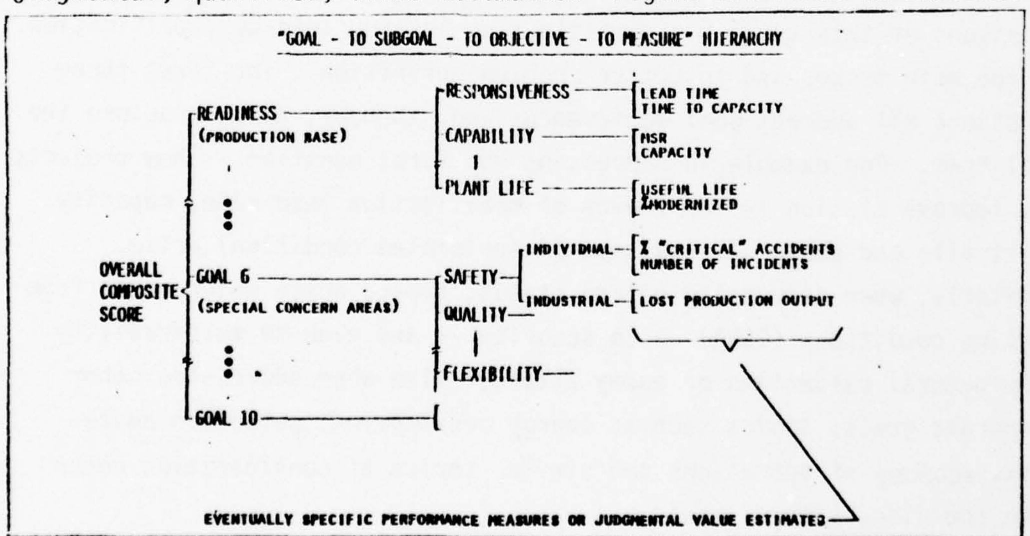

Figure 3.5 Generalized Goal Hierarchy Concept

form the concept for a goal tree set up to include all of the ten goals with examples of effectiveness measures on the right.

In theory, a composite score for all ten goals can be obtained by rolling back to the left from the sub-scores obtained for each of the ten goals. This assumes that the basis for scoring employs proper techniques to obtain and apply the decision maker's relative preferences at the various junctions which occur in the goal hierarchy. This approach is beneficial when the decision analysis involves only a small number of alternatives which must be examined in great detail such as site selection problems (Reference 10).

For the project portfolio type problem addressed by the Priorities Model, a simpler goal structure is sought. An approach was developed for the goal structure by considering six basic questions which could be addressed to base modernization projects:

1. How much will it, the project, improve base performance?
2. How much will it improve the hazard status of the base? -- How safe is it?
3. How well will it accomplish other management goals? -- Any fringe benefits?
4. Can we afford it?
5. How mandatory is it?
6. What are the chances for success?

Questions of this type in a participative session lead to clarification of the main issues and to better problem definition. The first three questions all address goal achievement and, thereby, help structure the goal tree. For example, in addressing the first question -- how projects may improve mission -- the topics of mobilization lead time, capacity shortfalls and state of readiness (deteriorated condition) arise. Similarly, when discussing hazard status, topics arise which range from working conditions (OSHA) -- to security -- and even to vulnerability from natural calamaties or enemy attack. Also when addressing other corporate goals, topics such as energy consumption, pollution abatement, economy of operations and similar topics of consideration enter into the discussion of goals.

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The last three questions which address budget, risk, and broad program priorities, clarify the constraints in a goal growth problem. A simplified goal tree structure of the type shown in Figure 3.6 does emerge after answering these questions. The primary

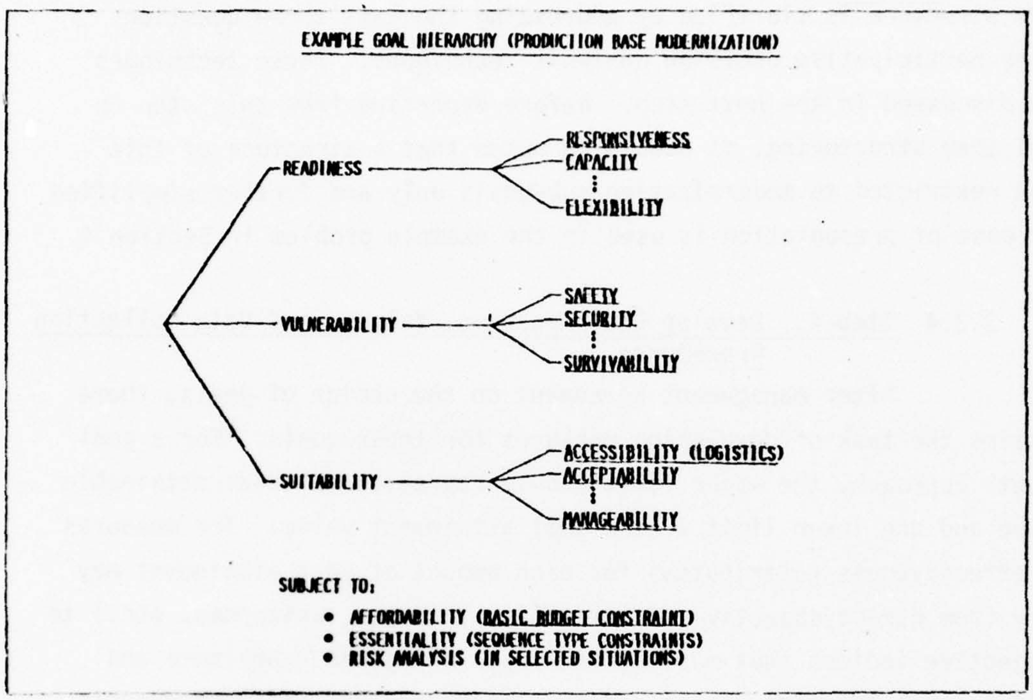

Figure 3.6 Simplified Goal Tree for Production Base Projects with Candidate Sub-Goals

three goals address, respectively, a goal for main performance capabilities, a goal for maintaining and protecting those capabilities, and a goal for general compliance to external influences. The terminologies used for each goal and candidate sub-goal are deliberately chosen to enable transition to the use of probability distributions for selected applications whenever risk analysis is required. A few examples are capacity -- the ability to produce; condition -- the ability to perform (state of base or antiobsolescence); safety -- the ability to avoid accidents (per OSHA standards); and accessibility -- the ability to supply and be supplied (integrated logistics).

In general, the candidate sub-goals indicated cover both base modernization and base expansion missions. The attainment of the goals in the tree is subject to constraints such as the budget, broad program priorities, or sequencing constraints, and, of course, risk. The specific constraints and the manner in which they enter the problem structure is clarified by addressing the last three questions using participative decision analysis techniques. These techniques are discussed in the next step. Before departing from this step on goal tree structuring, it should be noted that a structure of this type restricted to modernization sub-goals only and further simplified for ease of presentation is used in the example problem in Section 4.

3.3.4 Step 4. Develop Goal Measures, Values, and Data Collection Procedures.

After management agreement on the choice of goals, there remains the task of developing measures for these goals. For a goal growth approach, the upper limit should represent an ideal attainable value and the lower limit a zero goal attainment value. The measures of effectiveness (attributes) for each amount of goal attainment may vary from direct objective measures (e.g., months, units/man, etc.) to subjective indices that must be developed using the experience and professional judgment of the decision maker and his staff of experts.

The development of subjective measures and their utility values to the decision maker are the main thrusts of a subjective assessment phase. Techniques of various depth , ranging from classical utility theory and indifference techniques through scenario evaluations accompanied by statistical analysis of the decision makers preference function, are useful for this phase. No matter which techniques are used the success of the result depends upon the degree of credibility that the measures and values invoke in the decision maker and his staff and upon their fidelity in capturing the true preferences of the decision maker. Equally, or perhaps more important, is the follow-on implementation of practical, easy-to-understand procedures for consistent estimation and transformation of the measures to standard format for data processing operations. Another concept to keep in mind during the development of the measures is that each alternative is evaluated within the model on the basis of its improvements to each goal measure and, therefore, before and after analyses by the persons responsible for data collection are inherent to the process.

Suppose, for example, that a measure on an Operator Environment goal factor is to be evaluated. Typical procedures, as indicated, by the summary steps in Figure 3.7, would specify in detail how to obtain and enter existing and proposed effect values and how to convert the improvement in the goal factor to a rating on the project

TYPICAL FACTOR METHODOLOGY

(OPERATOR ENVIRONMENT)

STEP 1: OBTAIN EXISTING MEASURE FOR EACH PHYSICAL CONDITION (LIGHTING, NOISE, SKIN CONTAMINANTS, TEMPERATURE, HUMIDITY, VENTILATION)

STEP 2: OBTAIN WEIGHTED SUMMARY VALUE PER INSTRUCTIONS

STEP 3: CONVERT TO GROSS ENVIRONMENTAL RATING AS A FUNCTION OF THE NUMBER OF AFFECTED PERSONNEL (PER FURNISHED CHART)

STEPS 4-6: REPEAT STEPS 1-3 FOR PROPOSED CONDITIONS

STEP 7: ENTER DATA IN TABLE AND COMPUTE DIFFERENCES. SUM TO OBTAIN TOTAL ENVIRONMENTAL IMPROVEMENT RATING

STEP 8: CONVERT THE RATING TO AN EFFECT FACTOR USING "UTILITY" TYPE CONVERSION

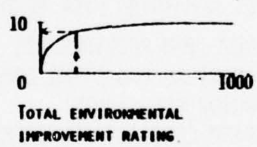

Figure 3.7 Rating Methodology for an Operator Environment Goal Factor

submission form. The last step to convert the improvement rating to an effect factor is particularly important. It indicates the official policy for the value or utility of the improvement, as established and approved by the transformation. A rule of this type may be represented by either a continuous curve as shown or a finite set of utility values corresponding to a set of ranges of improvement. In summary, formal analysis of the goal measures, of their utility value to the decision maker, and of the data collection procedures is essential to provide the consistent and meaningful data needed for subsequent goal growth process steps.

3.3.5 Step 5. Determine Other Rules of the Game.

The main objective of this step is to pause while resolving data oriented problems to determine any other factors or rules which should be incorporated into the problem so that appropriate data and procedures are considered at the same time.

Typically, broad program priority designations, such as I, II and III in Figure 3.8, are a popular classification scheme to denote the level of management interest or criticality of a program. Broad program priorities are treated on a transitive basis in the Priorities Model. The rule is to allocate all projects of the highest broad priority level, for best goal growth possible within the

BROAD PRIORITY LEVELS

(HYPOTHETICAL)

- **PRIORITY I** — MEET CURRENT REQUIREMENTS OR ARE DESIGNATED FOR INTENSIVE MANAGEMENT
- **PRIORITY II** — MEET REMAINING FYDP REQUIREMENTS WHICH ADDRESS:
  - NEW ITEM REQUIREMENTS
  - CRITICAL END ITEMS/COMPONENTS
  - PRIOR FME STARTS
  - FIRM CONTRACT REQUIREMENTS
  - CRITICAL BASE DEFICIENCIES (SAFETY, SECURITY, OTHER)
- **PRIORITY III** — MEET REMAINING REQUIREMENTS IN OPTIMAL MANNER TO ACHIEVE GOALS:
  - READINESS
  - FLEXIBILITY
  - SAFETY
  - INDUSTRIAL PROTECTION
  - SECURITY
  - STABILITY

  SUBJECT TO:
  - AFFORDABILITY (BUDGET)
  - ACHIEVABILITY (RESOURCE LIMITS)
  - INTEGRATED LOGISTICS SUPPORT

Figure 3.8 Broad Program Priority Levels annual budget. This allocation is repeated for each successive broad priority level as long as the remaining budget is not exceeded. Procedures for encoding broad priority levels to the individual projects must be resolved and incorporated with other data processing considerations.

In some cases other "rules of the game" may apply within or across these broad priority levels. These tend to create special constraints which must be formulated by the modeler. One major type of special constraint occurs when two or more alternatives have sequency or concurrency relationships, e.g., B cannot be selected alone or before A; but if A is selected, B must also be selected in the next time period and so forth. In some cases other data requires encoding as geographical locations, secondary goal measures, cross-indices to product or family groups, etc. Participative decision analysis provides procedures for formalizing all such rules, factors, attributes and for integrating them into the framework of the problem.

3.3.6 Step 6. Assess Current Priorities and Needs.

Assessing the current goal priorities of the decision maker is a critical step. Its objective is to determine the relative importance he associates with achievement of each goal in the near future. These current goal priorities help shape the target goal growth paths of Appendix A that in turn enable identification of the best options available from combinations of individual alternatives. Their criticality necessitates elicitation and assessment of subjective values from the decision maker, and warrants any extra time or effort spent iteratively until he is satisfied.

Goal assessment techniques vary considerably. One approach, adapted from Keeney (Reference 10) and others, elicits the decision makers' current views and consolidates them into a single management preference function. This technique uses lottery comparisons to esta-

10. Loc. Cit.

blish indifferences between trade-offs among goal achievements in such a manner that goal priority values are obtained which closely represent his "true" preferences. An example of this method is presented below. It assumes that previous similar effort from Step 4 has established the individual utility curves, V_i, i=1,2...,5, as shown in Figure 3.9 for a five-goal base modernization problem.

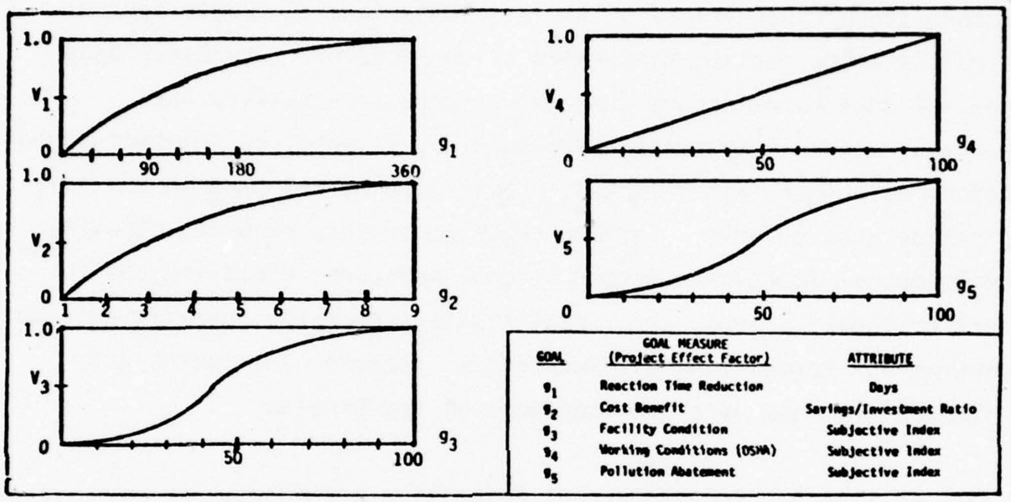

Figure 3.9 Hypothetical Utility Curves of Five Typical Goals

It is helpful in determining the current goal priorities to express the total value ,V, of overall goal attainment as a function of the individual goal attainment g_i,i=1,2...,n such that

$$V\ (g_1,g_2,\ldots,g_n) = \sum_{i=1}^{n} W_i V_i(g_i) \qquad (3.1)$$

where

n is the number of goals

W_i is the goal priority (weight) of the i^{th} goal, and

V_i is the utility or value function of the i^{th} goal.

By scaling convention it is required that V and the V_i both be scaled to unity and

$$\sum_{i=1}^{n} W_i=1 \qquad (3.2)$$

The most important issue of trade-offs between goals is addressed by assessing the $W_{i's}$ in Equations (3.1) and (3.2). For the 5 goal example the extreme values are

$$\begin{array}{lll} V_1\ (0)=0 & & V_1\ (360)=1 \\ V_2\ (1)=0 & & V_2\ (\ 9\ )=1 \\ V_3\ (0)=0 & \text{and} & V_3\ (100)=1 \\ V_4\ (0)=0 & & V_4\ (100)=1 \\ V_5\ (0)=0 & & V_5\ (100)=1 \end{array} \qquad (3.3)$$

indicating that value increases with higher values of each of the goal measures. Clearly, it follows that the total values at the extremes can be expressed by

$$V\ (0,1,0,0,0)=0 \quad \text{and} \quad V\ (360,9,100,100,100)=1 \qquad (3.4)$$

to be consistent with Equation (3.1).

The decision maker is asked to rank order which goal he would like to achieve first given that all had started at the worst level. Suppose his response is to move g_1 from zero days reduction in mobilization reaction time to 360 days reduction, and that his next preference would be to move the g_3 facility condition index from 0 to 100, and that following those his preferences are g_2 from 1 to 9, g_4 from 0 to 100 and g_5 from 0 to 100 in that order. This implies a transitive ordering of the weighting factors of Equation (3.1) such that

$$W_1 \quad W_3 \quad W_2 \quad W_4 > W_5 \qquad (3.5)$$

At this point lottery techniques are used to face the trade-off issues. The decision maker is asked to consider, starting with all goal status at their worst levels, his preference between changing either

a) g_1 from 0 to some intermediate value g_1*, or

b) changing g_3 from 0 to 100.

Suppose he preferred change b, but if g_1 were changed from 0 to another intermediate value g_1** of 180 he would be indifferent. It follows that his preference for the two different values are equal so

$$V\ (180,1,0,0,0) = V\ (0,1,100,0,0) \qquad (3.6)$$

Evaluating both sides of Equation (3.6) with Equations (3.1) and (3.2) *yields*

$$W_1V_1(180)=W_3 \qquad (3.7)$$

Assume similar trade-offs between g_2 and g_1, between g_4 and g_1 and between g_5 and g_1, are considered in the same manner, where the decision maker agrees that starting at the worst level, changing g_1 to 160 is equally desirable from an overall point of view as changing g_2 to 9. Then it follows, as before, that

$$W_1V_1(160)=W_2 \qquad (3.8)$$

By similar procedures suppose

$$W_1V_1(90)=W_4 \qquad (3.9)$$

and

$$W_1V_1(65)=W_5 \qquad (3.10)$$

By evaluating Equation *(3.1) at the upper value and using* Equations (3.3) and (3.4) then

$$1=W_1+W_2+W_3+W_4+W_5 \qquad (3.11)$$

Substituting values of $V_1(g_1)$ obtained from Figure 3.9 for the 4 indifferent values of g_1 in Equations (3.7) through (3.10) results in

$$.77W_1=W_3 \quad \text{and} \quad .47W_1=W_4$$
$$.73W_1=W_2 \qquad\qquad .37W_1=W_5 \qquad (3.12)$$

It follows from Equation (3.11) that W_1=.30 since $1=W_1(1+.73+.77+.47+.37)$

The remaining $W_{i's}$ are determined by back substitution in Equation (3.12). The result, Table 3.1, is a complete assessment of the decision maker's current goal priorities. These values play an important role in the goal growth theory presented in Appendix A.

TABLE 3.1 CURRENT GOAL PRIORITIES FROM TRADE-OFF ASSESSMENT

GOAL	GOAL MEASURE	GOAL PRIORITY
g_1	Reaction Time Reduction	.30
g_2	Cost Benefit	.22
g_3	Facility Condition	.23
g_4	Working Conditions (OSHA)	.14
g_5	Pollution Abatement	.11

The second facet of this step is to determine any other evaluation requirements the decision maker wishes to pursue. This is a preliminary investigation into the types of "what if" questions that express his major areas of concern. For example, he may wish to know the effect on portfolio composition caused by rising or falling budget modes or by ranges in goal priority values that express his trade-off position to accommodate other views, Figure 3.4. The completion of this step provides all the initial management input data for the Prioities Model previously indicated in Figure 2.2.

3.3.7 Step 7. Evaluate Goal Growth Paths.

The purpose of this step is to present the target goal growth paths to the decision maker for his evaluation as generated from his goal priorities and initial condition data for the goals. The paths are generated in a pre-processor module according to the procedures outlined in Appendix A and are presented in graphical format to the decision maker for his review and adjustment. A primary issue to be resolved prior to generation of the target goal growth paths is the existing achievement level for each goal measure. If precise data is lacking on these initial conditions, different sets of paths may be generated which correspond to various sets of estimated initial values, thereby indicating the sensitivity of target trajectories to variation in input conditions.

If, however, all data for the individual projects and for the initial conditions are available, this step may be combined with Step 8 to expedite processing.

3.3.8 Step 8. Evaluate Preliminary Solutions.

A second stage of the pre-processor provides preliminary solutions for each strategy (of interest), that is, for each set of goal priorities and each set of budget variations that were to be investigated. These preliminary solutions are realistic. They indicate the best attainable goal growth plan for each strategy based upon a weighted average method presented in the last part of Appendix B. These solutions enable the decision maker to observe potential goal attainment under various strategies. They provide him with a preliminary overview of the decision environment. Steps 7 and 8 may be recycled with relative ease until the decision maker's evaluation is complete.

The preliminary evaluation is considered complete when final decisions have been reached on all factors which affect the scope of processing by the main computation module of the Priorities Model. These primary factors are his goal priorities, the initial conditions, the budget variations, and the broad program priorities to be considered. These factors are input into a matrix generator module which sets up the problem for solution using commercially available mixed-integer software packages.

3.3.9 Step 9. Determine Best Decision Alternatives by Goal Growth Runs.

This step in the overall sequence of the Priorities Model is concerned with the actual processing performed by the main computation module. Starting with the preliminary solution provided by Step 8 this module improves upon it in the sequence of steps outlined in the flow diagram, Figure 2.2, until the optimum goal growth plan is attained for each specified strategy. In addition, for each strategy, a prespecified number of next best alternative plans is attained.

Each set of plans comprises the set of best decision alternatives for that strategy to meet the goal growth objectives of the manager. Each plan is, in itself, a portfolio indicating a specific manner for combining and scheduling projects to achieve goal growth. The composite set of all plans represent the best alternatives available to the decision maker.

3.3.10 Step 10. Evaluate Alternatives and Submit for Decision.

The final step of the Priorities Model operations is performed in two parts, one by a report generator module in the program and a second by the modeler. The report generator module extracts the pertinent cost and growth performance data for each portfolio and restructures it into management-oriented report format, both tabularly and graphically. This output is analyzed and incorporated into a summary evaluation report on all the alternatives for use by the decision maker and his staff in reaching a final decision.

The Goal Growth Management approach presents a method for resolving large complex decisions of the type described. It structures problems to incorporate growth for primary and secondary mission goals. The quantification of goal measures and goal priorities leads to a better understanding of the problem and to an increased confidence in the final portfolio alternatives presented him for decision.

SECTION 4
BASE MODERNIZATION PLANNING EXAMPLE

4.1 PROBLEM DESCRIPTION

The base modernization planning example described in this section is a representative application of the Priorities Model. It demonstrates the main concepts of Goal Growth Programming and the types of portfolios produced for the decision maker's evaluation.

The objective of the example problem is to obtain the "best" goal growth portfolio for a five year planning period from among nine projects which must also compete under budget limitations. It is assumed that Steps 1 through 4 have been completed using subjective assessment techniques such that 1) the individual utility curves of the goals are known, 2) all data collection on costs and goal improvement for the projects has been completed, and 3) initial condition values of goal status have been obtained, as indicated in Tables 4.1 and 4.2. The individual utility curves for the 4 goals of Table 4.1 are assumed identical to those for the same goals in Figure 3.9.

It is also assumed that the budget for the plan totals 1.65 million dollars over the five year period with guidance to allocate it more or less uniformly about a 0.33 million average annual budget. To keep the example simple it is assumed that Step 5 operations have indicated no broad priority levels or sequence type constraints are involved. (This assumption enables the basic mixed integer formulation presented in Appendix B to apply for the main computations of Step 9 without modification).

TABLE 4.1 GOAL MEASURES AND INITIAL CONDITIONS FOR THE BASE MODERNIZATION PLANNING EXAMPLE

GOAL	GOAL MEASURE	INITIAL CONDITION
g_1	Cost Benefit	.28
g_2	Facility Condition	.55
g_3	Working Conditions (OSHA)	.74
g_4	Pollution Abatement	.66

TABLE 4.2 PROJECT COST AND GOAL IMPROVEMENT DATA FOR THE BASE MODERNIZATION PLANNING EXAMPLE

	PROJECT ALTERNATIVES								
	1	2	3	4	5	6	7	8	9
COST BENEFIT	.0246	.0554	.0276	.0049	.0549	.0151	.0088	.0960	.0450
FACILITY CONDITIONS	.0128	.0818	.1238	.0813	.0363	.0062	.0074	.0921	.0335
WORKING CONDITIONS	.0916	.0526	.0079	.0183	.0236	.0255	.0186	.0377	.1091
POLLUTION ABATEMENT	.0362	.0512	.0605	.0228	.1037	.0914	.1231	.0162	.0280
COST ($M)	.173	.287	.250	.247	.327	.210	.256	.231	.237

The subjective assessment of the manager's trade-offs is assumed to be conducted as previously outlined in Step 6. In particular, the manager's goal ranking, given by $W_2 > W_1 > W_3 > W_4$, is supplemented by indifference assessments as follows:

$$
\begin{aligned}
&V(1,58,0,0)=V(9,0,0,0) &\text{or}\quad &W_2V_2(58)=W_1 \\
&V(1,41,0,0)=V(1,0,100,0) &\text{or}\quad &W_2V_2(41)=W_3 \qquad (4.1)\\
&V(1,33,0,0)=V(1,0,0,100) &\text{or}\quad &W_2V_2(33)=W_4
\end{aligned}
$$

Equation (4.1) expresses management indifference between a Cost Benefit of 9 and Facility Condition of 58; between Working Condition of 100 and Facility Condition of 41; and between Pollution Abatement of 100 and Facility Condition of 33. Solution for the W_i's indicates current goal priorities of 0.315, 0.410, 0.172, and 0.103, for Goals 1 to 4, respectively.

The only remaining information needed to complete the problem definition concerns the budget. It is assumed, in view of the budget guidance, that the manager wishes to examine planning portfolios under various budget modes. For demonstration value, five uniform annual ceilings (140%, 125%, 120%, 100%, and 85%) are assumed. Also two modes representing changing budget modes are assumed; one rising from 100% to 150% over the period and the second falling from 100% to 80% at the end of the period.

4.2 TARGET PATH GENERATION

Based on the initial conditions and current goal priorities, the full set of target goal growth paths is generated as indicated by Figure 4.2. The detail values obtained are listed in Table 4.3. Goal 2, the lead goal, is at the top followed closely by Goal 1 which has roughly 3/4 the priority of the lead goal. The "S" shaped paths for Goal 3 and 4 occur automatically because of their relatively low priority coupled with high initial conditions. It is assumed that the decision maker approves these target growth paths thereby completing Step 7.

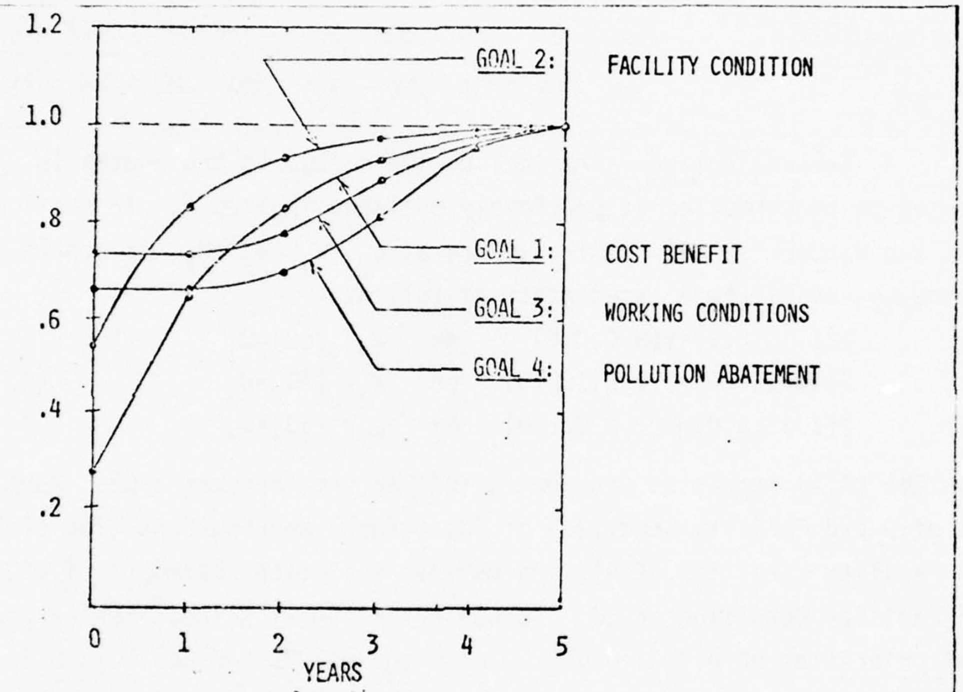

Figure 4.2 Goal Growth Paths Generated from Current Goal Priorities and Initial Conditions

TABLE 4.3 GOAL GROWTH TARGET VALUES FOR THE BASE MODERNIZATION PLANNING EXAMPLE

	YEAR				
GOAL	1	2	3	4	5
1	.641	.898	.972	.994	1.0
2	.834	.939	.978	.992	1.0
3	.740	.781	.878	.967	1.0
4	.660	.714	.840	.956	1.0

4.3 PRELIMINARY SOLUTIONS FOR VARIOUS BUDGETS

Figure 4.3 presents the portfolios output from the pre-processor in response to the manager's request for a preview of project selections likely under various budget restrictions, using the best weighted average growth selection rule of Appendix B.

PORTFOLIOS FOR VARIOUS BUDGET CONDITIONS

PORTFOLIO	BUDGET MODE	YEAR 1	2	3	4	5
I	140% UNIFORM	[1, 8]	[3, 6]	2	5	9
II	125% UNIFORM	[1, 8]	2	3	5	9
III	120% UNIFORM	8	[1, 6]	2	3	5
IV	100% UNIFORM	8	2	3	5	9
V	.85% UNIFORM	8	3	9	1	4
VI	100-150% RISING	8	[1, 6]	2	3	[9, 4]
VII	100-80% FALLING	8	2	3	9	1

Figure 4.3 Preliminary Planning Portfolios Selected by the Weighted Average Growth Algorithm for Various Budget Constraints

Portfolio I, developed under a maximum of not more than 40% over the average budget guidance in any one year, schedules 7 of the 9 available projects in the five year plan. Although 22% over budget in the first year and 39% over in the second, the total cost of $1.725M is only 3.9% over the total budget.

Portfolios II and III schedule only 6 of the 9 projects and although both are overbudget in only one year, they each total to only approximately 90% of the five year budget.

Portfolio IV and V, which schedule only 5 projects, are both far below the five year expected budget.

Portfolio VI also manages to schedule 7 of the 9 projects. It also is the only portfolio near the total budget (at 99.1%).

Portfolio VII indicates a likely sequence for a more austere decreasing budget envelope.

The costs, schedules and other data on goal achievement are all reviewed by management. On the basis of the information available management's preferential ordering of the portfolios on the basis of goal growth potential might be

I VI II III IV VII V

To endorse Portfolio I, a major decision facing management would be fund availability in the first two periods. In this example it is assumed that management, with this preview, makes no changes in goal priorities and requests more detailed information from the main computations (Step 9) again using the 140% annual budget ceiling.

4.4 MAIN PROGRAM GOAL GROWTH OUTPUT

Figure 4.4 indicates typical portfolios output from the main

PORTFOLIO	PROJECTS BY YEAR SCHEDULED 1	2	3	4	5	SUM OF UNDERACHIEVEMENTS	TOTAL COST	GROWTH/COST INDEX
MULTI-YEAR FUNDING	[8 / — / 3] ↘	[2 / — / 4 / 3] ↘	[9 / — / 5 / 4] ↘	[1 / — / 6 / 5] ↘	[7 / — / 6]	1.9067	2.218	.2365
A	[1 / 8]	[3 / 6]	2	5	4	2.4883*	1.725	.2330††
B	[1 / 3]	[6 / 8]	2	5	4	2.5250	1.725	.2296
C	[1 / 8]	[3 / 6]	9	2	5	2.5811	1.715	.2259
D	[6 / 8]	2	[1 / 3]	4	9	2.6263	1.635**	.2329††
E	3	[1 / 2]	[6 / 8]	4	9	2.7049	1.635†	.2261

* OPTIMAL BY UNDERACHIEVEMENT CRITERIA
** OPTIMAL BY TOTAL COST CRITERIA
† OPTIMAL BY FIRST YEAR COST CRITERIA
†† OPTIMAL BY GROWTH/COST INDEX CRITERIA

Figure 4.4 Selected Portfolios from Main Program Output

computation phase. The portfolios listed were selected to indicate the capability to obtain certain types of information. For example, the first portfolio, labeled "Multi-Year Funding", is the first output of the program -- the conventional linear programming optimal solution. It allows multi-year portioning of each project and, thereby, indicates the minimal sum of underachievements under all possible combinations of splitting up the projects. It selects all of project 8 and 92% of project 3 in the first year. This is followed in the second year by all of project 2, the remainder of project 3, and 63% of project 4 -- and so forth. This portfolio not only serves as the reference on the best possible solution, but also indicates where more gain may be obtained by splitting projects, if feasible, or which projects might be best for planned late starts. It discloses a way to schedule all 9 projects in the five year plan for optimal goal growth. Its total cost is thus the sum of all 9 project costs. The growth/cost index in the last column provides a measure of achievement per dollar -- the higher this is the better.

After obtaining this optimal solution, the program switches to the mixed integer mode where various integer solutions are obtained, each better than the last until the optimal is reached, Portfolio "A" here. As previously mentioned, four other portfolios obtained along the way were selected for comparative purposes to illustrate the type of decision options which may be presented to the decision maker.

First a general observation is made that all the portfolios contain 7 projects and, therefore, cost less than the reference which had 9. Portfolio "B", included for comparison with "A", is just a shift of projects 3 and 8 and, therefore, has the same total cost. However, its goal growth achievement is not as good as "A's" since it has a higher sum of underachievements and clearly is less efficient economically since its growth/cost index is lower.

The next Portfolio "C" is optimal for the next lower total cost level of 1.715. Portfolio "D" is optimal from the point of view of total cost and is below the expected five year budget. Portfolio "E", like "D", is below the five year budget and also is best (for the cases shown) for a firm first year budget of 100%. It's efficiency is also better than that of "C" which costs more.

The portfolios presented display a wide set of options to different types of criteria. In practice, budget constraints are not only tighter but are defined for each year (see Equation B8). In addition many more projects compete. The set of alternative portfolios under those conditions is presented to the decision maker in rank order to the criteria of his choice, supplemented by goal growth plots.

Goal growth paths for the "winning" plan, Portfolio "A" are shown in Figure 4.5. In each case the targeted growth is the solid line, and the actual growth from Portfolio "A" is dashed. It is

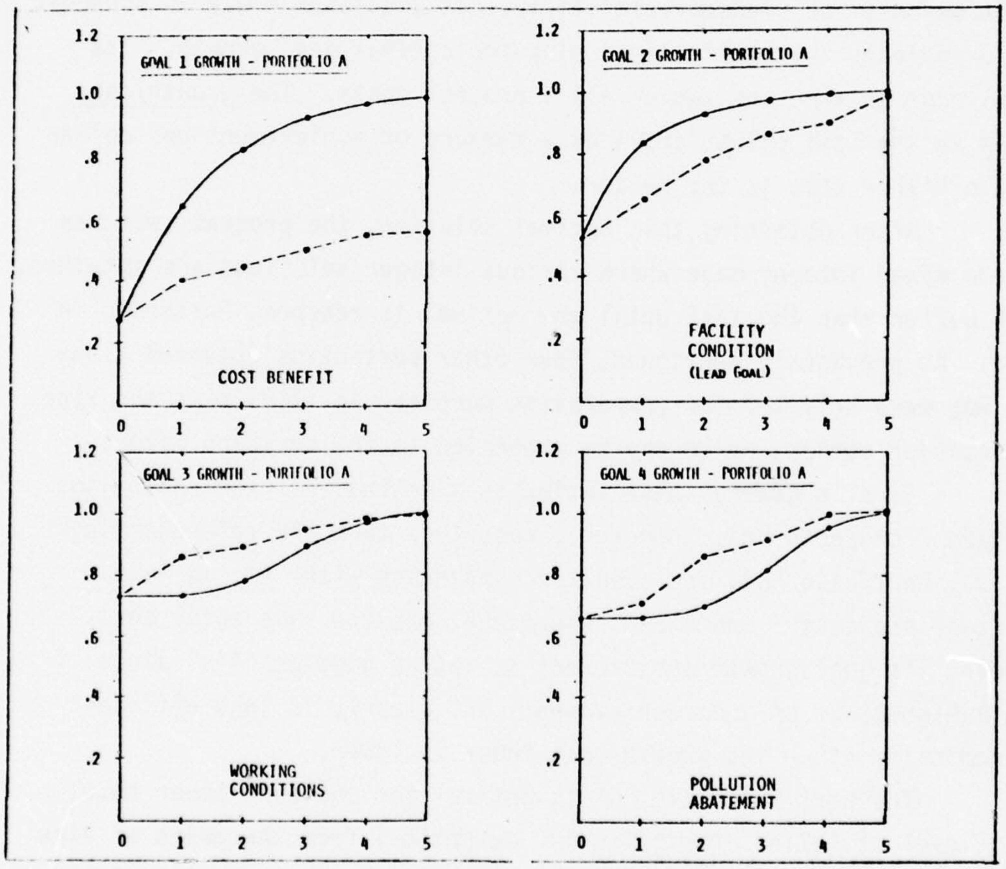

Figure 4.5 Goal Growth Paths of Portfolio A

obvious that the growth achievement for Goal 2, the lead goal is planned to progress steadfastly toward the target. It is also obvious that Portfolio "A" is an overachiever with respect to Goals 3 and 4. To summarize to this point, Portfolio "A" does represent a good plan to improve Facility Condition, to improve Working Conditions and to meet Pollution Abatement objectives.

On the other hand, the goal growth exhibited for the first goal, Cost Benefit, appears poor in comparison. The growth is not only the best attainable from the data and the goal priorities input, but is also a respectable accomplishment in anyone's book. It states that in five years the production base will be operating at a cost benefit goal level of 0.56 which translates to 3.3 on the 1 to 9 scale of Figure 3.9 meaning a 3.3 Savings to Investment Ratio! The real issue is whether Cost Benefit is a goal that legitimately should compete with other base performance goals. It would appear equally reasonable to incorporate this important decision measure into the set of broad program priorities and at the same time develop a measure for base operating and maintenance costs to compete with other base performance measures.

Should a similarly severe underachievement occur in one of the other performance goals, it would immediately alert management to a different type of problem. Either the ideal level goal value would be unrealistic or a shortage would exist for projects aimed at the goal. In the first case the problem is subjective and not untypical of the difficulties encountered in developing goal growth decision procedures. It may be resolved by establishing a realistically attainable goal level as the "ideal" value. In the second case, the manager is alerted that a need exists to intensify efforts toward the goal.

SECTION 5
SUMMARY AND CONCLUSIONS

Goal growth techniques, properly applied and executed in complex decision problems, lead to a better understanding of the issues and the objectives. The definitions of goals, values and priorities are made visible and, thereby, clarify the decision environment. Specific benefits attribute to the Priorities Model are presented in Figure 5.1.

(1) Through Goal Growth Programming, the model evaluates and ranks decision alternatives for maximum achievement of overall management goals. Consider the first benefit listed. The model does not merely output a single solution -- it does more. It screens out all but the best combinations. It selects and combines these into a small efficient set for the decision maker's final selection. It does this according to his approved goal growth paths thereby providing

THE JCAP PRIORITIES MODEL -- THROUGH GOAL GROWTH PROGRAMMING -- EVALUATES AND RANKS DECISION ALTERNATIVES FOR MAXIMUM ACHIEVEMENT OF OVERALL GOALS AND:

- PROVIDES OPTIONAL PLANNING PORTFOLIOS WHICH ARE LOGICALLY CONSISTENT WITH MANAGEMENT GOALS AND OBJECTIVES
- INCORPORATES CURRENT PRIORITIES INTO MEDIUM OR LONG-RANGE PLANNING
- ENABLES INTEGRATED INTER-MANAGEMENT PLANNING AND VISIBILITY FOR HIGH LEVEL GOALS
- OFFERS ALTERNATIVE PLANS WHICH ARE OPTIMAL FOR VARIOUS BUDGET CONSTRAINTS OR STRATEGIES
- DETERMINES BEST REMAINING OPTIONS AFTER INCORPORATING MANAGEMENT OVERRIDES
- INDICATES CRITICAL PROBLEM AREAS
- PROVIDES A METHOD FOR PROCESSING VAST AMOUNTS OF COMPLEX INFORMATION

Figure 5.1 Benefits of the Priorities Model and Goal Growth Programming consistent and logical planning rationale. The method for achievement of overall management goals may be applied to any formalized Management by Objectives system.

(2) The target goal growth curves incorporate current priorities into long-range planning. In addition, graphical presentations are in themselves beneficial because they portray what the decision maker wishes to attain taking his current guidance and priorities into account.

(3) The application of hierarchial multi-level goal structures incorporating high-level goals across organizational lines makes possible significant contributions in integrated management and visibility for goal attainment. In addition, by synthesizing goal priorities from other viewpoints, valuable insights can be obtained concerning impacts of decisions on others.

(4) The optimal planning portfolios obtained under various budget constraints provide the decision maker and his staff with valuable information for current and contingency planning.

(5) The provision for optimizing in the remaining decision space after including all pre-selected alternatives, regardless of source, is a planned benefit which had its origin in the model specifications.

(6) Both subjective and objective problem areas are surfaced as indicated in the example problem.

(7) The model provides a method for processing large complex decision problems having multiple objectives and multiple attributes with full management approval and direction at key stages of the decision process, including Zero-Base Budgeting (Reference 15).

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APPENDIX A

BASIC ASSUMPTIONS AND MATHEMATICAL FORMULATION -- FOR TARGET GOAL GROWTH PATHS

A.1 BASIC ASSUMPTIONS

The mathematics for the target goal growth paths which are utilized by the Goal Growth Programming techniques of the Priorities Model encompass the following basic assumptions:

(1) Any goal, that is, a value measure that the decision maker wishes to achieve, can be normalized with an ideal value of one and a minimum of zero. Goal achievement, however, may exceed the ideal.

(2) The value of the initial condition for each goal measure is known. This value, required for generation of the target goal growth paths (trajectories), may be any value greater than or equal to zero. If an exact value cannot be determined or a reasonable estimate of the initial status cannot be made, a zero value may be assumed without penalty.

(3) The relative goal priorities of the decision maker are known quantitatively such that the greater the numerical value the greater the preference. These goal priorities or weights should be scaled, if necessary, so that the sum of all goal priorities equals one.

(4) Standard decision tree techniques apply for additive weighting and consolidation of composite goal measures such that perfect overall goal attainment is one and goal priorities are preserved.

(5) Since in the long run full achievement of all goals is desired, all goal targets are set to their ideal value of one at the end of the planning period. This assumption infers that in the long range all goals have identical long range priority (if this does not seem reasonable, the ideal values should be rescaled).

(6) The lead goal, that is, the goal assigned the highest initial priority, will have a trajectory based on exponential growth theory such that it starts from its initial value and aims at the ideal target value of one. (Note: The fact that exponential growth values do not actually reach a value of one until infinity is of no practical

consequence since all goal targets are set to one at the end of the planning period by the fifth assumption).

(7) The first period value of the lead goal path, as attained by exponential growth theory, is always sufficiently large to permit establishment of a set of first period target values for the remaining goals in direct proportion, by the ratio of their goal priorities to that of the lead goal. This assumption makes use of the decision maker's currently known or short range priorities to establish first period goal targets.

(8) No target goal paths may decrease. This implies that the decision maker is unwilling to accept any lowering of a target value as a trade-off technique. It further means that any first period goal targets obtained under the seventh assumption which are smaller in value than their initial conditions, will be replaced by their initial conditions in subsequent trajectory calculations.

(9) "Smoothed" goal growth paths for the remaining goals can be automatically determined which pass through their first period values and the ideal target value of one at the end of the planning period. This assumption acknowledges that intermediate target values can be generated for the remaining goals to provide an orderly transition from their first period targets obtained under assumptions (7) and (8) to the long range ideal target.

Thus, <u>with only two sets of input data</u>

- The soft data for the goal priorities and
- The hard data for the initial conditions,

<u>a complete set of target goal paths may be established</u>.

The generation of paths to these assumptions is carried out automatically by Equations (A1) through (A5) below, in accordance with logic which tests the input status and goal priorities to determine which category of equation should apply to each goal.

A.2 GENERATION OF TARGET PATHS

First, the path of the lead goal is generated to achieve exponential growth, Figure A1. Its values are given by

$$g(t) = \begin{cases} 1 - (1-g_o)\exp(-t) , & 1 \le t < T \\ 1 & t = T \end{cases} \qquad \text{(A1)}$$

where g_o is the initial value and T is the length of the planning period in years.

The value g(1) of the lead goal obtained from Equation (A1) is used to obtain first period goal targets for each of the other goals by direct priority ratio or override in accordance with the assumptions stated above. The result for each of the remaining goals is such that its value g(1), written as g_1, is always greater than or equal to g_o for the goal.

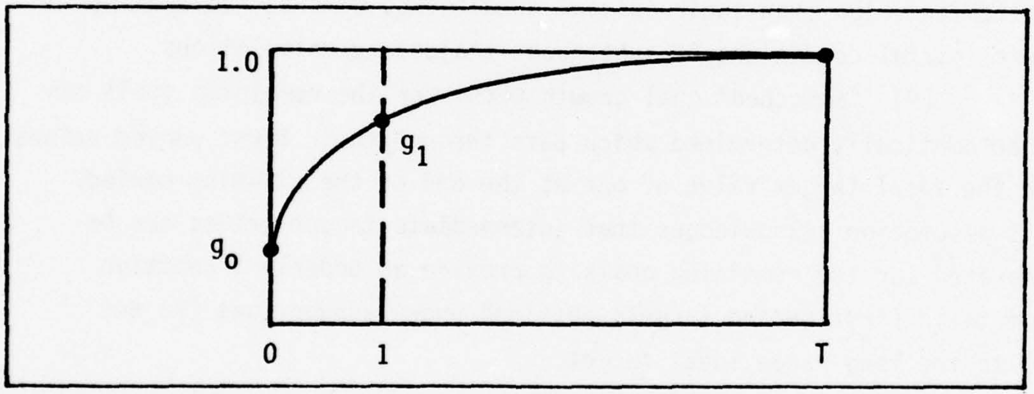


Figure A1 Generation of Lead Goal Growth Path

In cases where g_1 equals g_o, a sigmoidal growth path is generated by a modified Maxwell type of equation. This case, Figure A2, has values given by

$$g(t) = \begin{cases} g_1 + (1-g_1)\left(\frac{t-1}{T-1}\right)^2 \exp\left[1 - \left(\frac{t-1}{T-1}\right)^2\right] , & 1 \le t < T \\ 1 & t = T \end{cases} \qquad \text{(A2)}$$

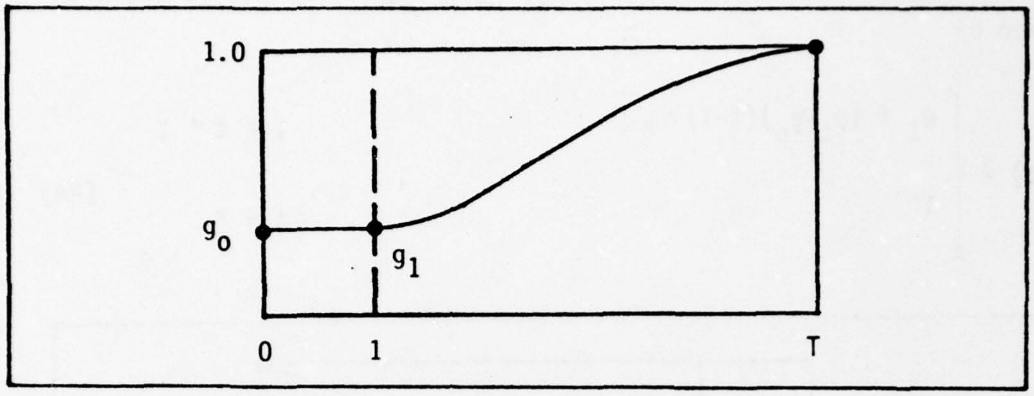


Figure A2 Generation of Sigmoidal Growth Path

In the remaining cases where g_1 is greater than g_o, the initial slope is defined as $\dot{g}_1 = g_1 - g_o$. If this slope is extended, its intercept value at t=T can be greater than 1, at 1 exactly, or below 1. The equations which govern for these three cases are an exponential integral type, a linear type, and a combined Maxwell and linear type, respectively.

For the first or exponential integral type growth, Figure A3, values are given by

$$g(t) = \begin{cases} g_1 + \dfrac{(1-g_1)}{1 - \exp(-a(T-1))}\left[1 - \exp(-a(t-1))\right], & 1 \le t < T \\ 1 & t = T \end{cases} \qquad \text{(A3)}$$

where the shaping factor, a, is computed internally.

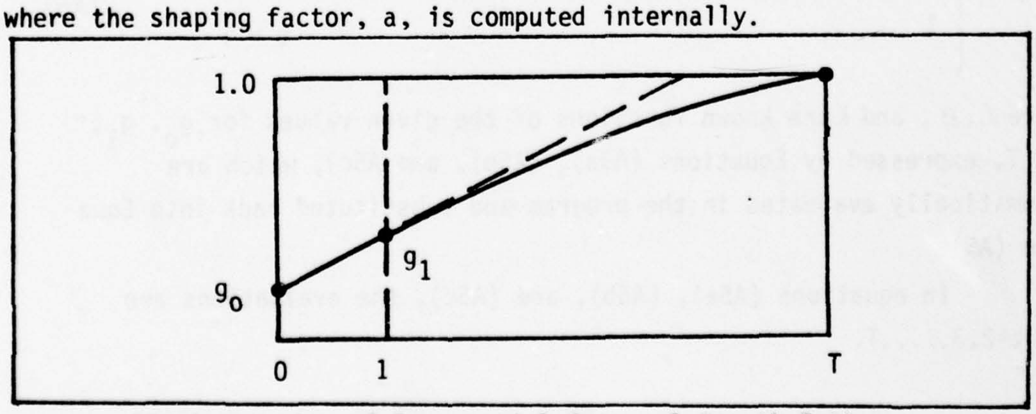


Figure A3 Generation of Exponential Integral Growth Path

For the second or linear type growth, Figure A4, values are given by

$$g(t) = \begin{cases} g_1 + (g_1 - g_o)(t-1) \ , & 1 \le t < T \\ 1 & t = T \end{cases} \qquad \text{(A4)}$$

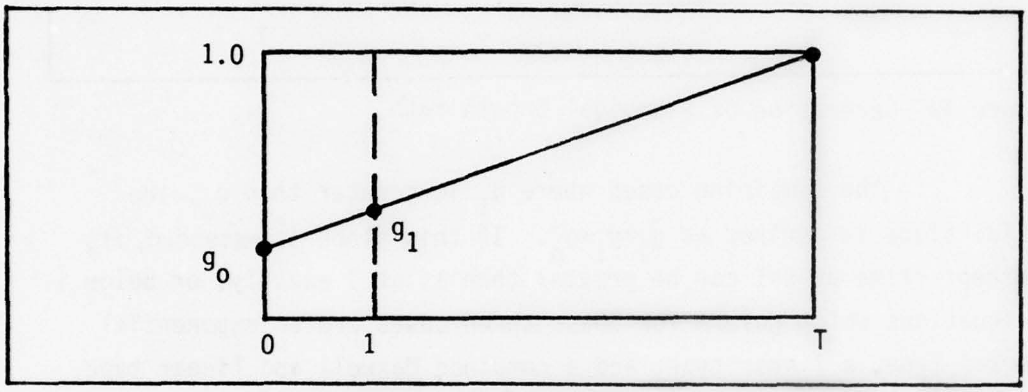


Figure A4 Generation of Linear Growth Path

For the third type, a combination which superimposes linear and sigmoidal growth characteristics, Figure A5, the values are given by

$$g(t) = \begin{cases} g_1 + \gamma \left\{ \beta(t-1) + \dfrac{4(t-1)^2}{\alpha^3 \sqrt{\pi}} \ \exp\left[- \dfrac{(t-1)^2}{(T-1)^2} \right] \right\} \ , & 1 \le t < T \\ 1 & t = T \end{cases} \qquad \text{(A5)}$$

where α, β, and γ are known functions of the given values for g_o, g_1, and T, expressed by Equations (A5a), (A5b), and (A5c), which are automatically evaluated in the program and substituted back into Equation (A5).

In equations (A5a), (A5b), and (A5c), the evaluations are for t=2,3,...,T.

$$\alpha = \sqrt{\frac{(g_1 - g_0) + (T-1)^3}{g_1 + (g_1 - g_0)(T-1)/2}} \qquad \text{(A5a)}$$

$$\beta = \frac{8(T-1)}{\alpha^3 \sqrt{\pi}} \left[\frac{(T-1)^2}{\alpha^2} - 1 \right] \exp\left[-\left(\frac{T-1}{\alpha} \right)^2 \right] \qquad \text{(A5b)}$$

$$\gamma = \frac{(1-g_1)}{\beta(T-1) + \frac{4(T-1)^2}{\alpha^3 \sqrt{\pi}} \exp\left[-\left(\frac{T-1}{\alpha} \right)^2 \right]} \qquad \text{(A5c)}$$

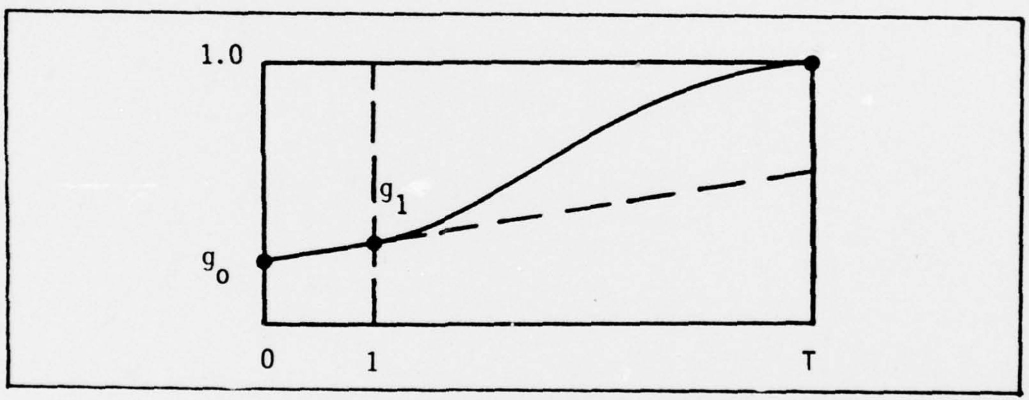


Figure A5 Generation of Combined Growth Path

These equations work well for planning periods of five or less years. Target values for longer planning periods may be obtained either by stretching out the five year values to fit the planning period, or by introducing scaling parameters into the equations.

This set of automatically generated target goal growth paths is presented in graphical format to the decision maker for assessment. He may choose to accept them, override them with any other path value, or may realign his goal priorities and request new graphics using them. Their entire character is normative. The paths should thus reflect the priorities and goal growth objectives of the decision maker for they, in turn, govern the selection of alternatives during the Goal Growth Programming calculations of Appendix B.

APPENDIX B

GOAL GROWTH PROGRAMMING FORMULATION

B.1 GENERAL APPROACH

Goal Growth Programming is a dynamic computational process which selects and schedules the available alternatives in such a way that their cumulative achievement toward each goal best attains the manager's objective for meeting the previously established targets for goal growth. The difference between the cumulative achievement toward a goal for some combination of alternatives and the corresponding goal target is thus a deviation which depends upon the combination of alternatives. Each deviation of say, the i^{th} goal in the t^{th} time period, as indicated in Figure B1, is expressed either as an underachievement variable, UA_{it}, or as an overachievement variable, OA_{it}. Each combination of the available alternatives is thereby characterized by a set of underachievement and overachievement variables that in turn describe the set of deviations from the set of target goal growth values applicable at that point in the planning period. The ability of mixed integer programming to readily handle deviational variables permits the obtaining of true optimum portfolios.

A second approach for the best affordable portfolio based on weighted-average growth is useful for good, but nonexact, solutions. It is described after the mixed integer formulation for Goal Growth Programming.

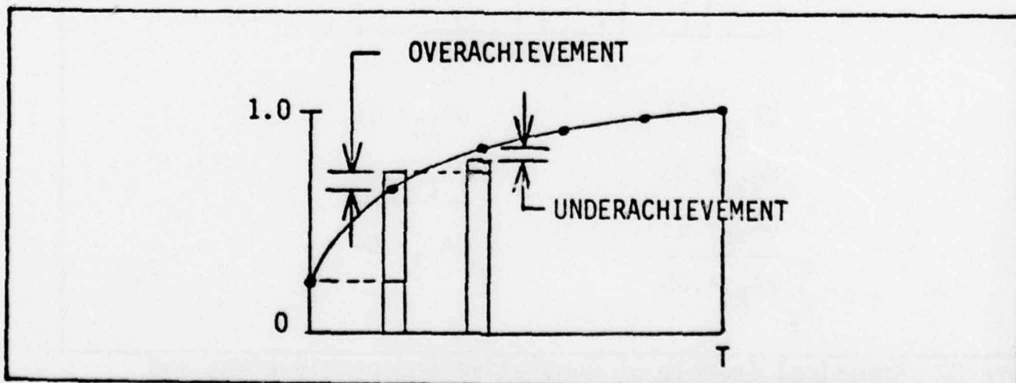


Figure B1 Underachievement and Overachievement Variables

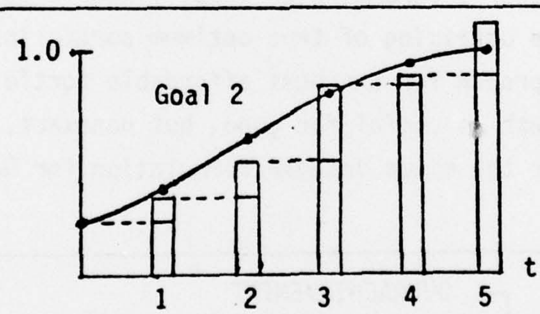
B.2 THE OBJECTIVE FUNCTION CHOICES

The criterion which controls the computation and eventually selects the optimum combination, or portfolio, is called the objective function. A choice exists in the Priorities Model for any one of four objective functions as the active criterion, with the values of the other three output as reference measures.

The criterion, Equation (B1), normally used for planning applications, minimizes the sum of the underachievement of all goals over the planning period. It is expressed as

$$\min \sum_{i} \sum_{t} UA_{it} \qquad (B1)$$

It is the default case. Figure B2 indicates an example where the contribution from Goal 2 to Equation (B1) would be .06 in value. With this objective function overachievements are bonuses. It's general effect is to approach the target growth paths from underneath thereby implying the most achievement without a severe deficit for one of the goals.



$UA_{21}=.01$ $\qquad$ $OA_{23}=.01$

$UA_{22}=.03$ $\qquad$ $OA_{25}=.03$

$UA_{24}=.02$

$\sum_t UA_{2t}=.06$ $\qquad$ $\sum_t OA_{2t}=.04$

Figure B2 Numerical Example of Cumulative Underachievement and Overachievement

The second criterion represents a tracking type objective. It minimizes the sum of both the over- and the underachievements. The same example would yield a contribution of .10 from goal 2 to this objective function. It is expressed by

$$\min \sum_{i} \sum_{t} (OA_{it} + UA_{it}) \qquad (B2)$$

This criterion penalizes over- and underachievements equally and thus, selects a combination as optimum which best tracks all the goals, i.e., the combination with the least total of absolute deviations.

The other two objective functions are unitized measures which are to be maximized. The first of these, called the Achievement Index, incorporates a factor automatically calculated within the program such that no underachievements in any time period results in a perfect score of 1 while worst case underachievements of 1 in every period would yield zero. The effect of the factor, a form of discounting which places more premium on near than future goal attainment, is twofold. First, it enables the formulation of the Achievement Index as a common measure, always between zero and one, for comparison of different output sets. Second, should several portfolios tie or be negligibly close by the first criterion, the one with the highest Achievement Index would indicate the soonest goal achievement. The Achievement Index is the value obtained for the objective function given by

$$\max \left[1 - \sum_{i} \sum_{t} F_t UA_{it} \right] \qquad (B3)$$

where the factor, F_t is equal to exp (-Rt) and R is a function of the planning period T such that

$$\sum_{t=1}^{T} \exp(-Rt) = 1 \qquad (B4)$$

Thus, the greater the Achievement Index the greater the "near" achievements, or more precisely, the less the sum of the "near" underachievements. It is mainly used as an auxilliary performance measure.

The fourth objective function utilizes the same factor on the overachievements as well, thereby, providing a parallel type comparative measure, the Absolute Index, to observe when minimizing the absolute deviations. Its value is given by

$$\max \left[1 - \sum_{i} \sum_{t} F_t (OA_{it} + UA_{it}) \right] \quad (B5)$$

The greater the Absolute Index, the closer the tracking in near time periods. Perfect tracking yields a value of one.

B.3 BASIC ASSUMPTIONS AND FORMULATIONS

The basic assumptions for the data are simple yet essential. First, it is assumed that the entire cost distribution of an alternative is expressed as one total value incurred only when an alternative is selected. Second, it is assumed that each goal achievement for every alternative is expressed in decimal form so as to represent the incremental worth after a utility transformation. This assumption removes the burden of evaluating marginal worth trade-offs from the computer solution program and thereby simplifies its procedures by allowing additive weighting. It does require the early establishment and approval of the utilities, i.e., preference functions of the decision maker(s) and standard procedures for data definition and collection which facilitates uniform interpretation of the measures*.

Most of the basic assumptions underlying both the mixed integer approach and the weighted average approach are identical although their mathematical formulations vary. The basic formulations presented in this section are the ones utilized for solution of the example problem in Section 4 by mixed integer programming. Although additional formulation is required for special constraints, such as alternative sequencing (broad program priorities), grouped sets, or other conditional constraints, the formulations here are basic to all goal growth problems.

*The Project Effect Factors previously discussed meet this assumption for data on alternatives for modernization projects.

(1) An alternative can only be selected in one time period. Thus for each j^{th} alternative, j=1,...,M

$$\sum_t O_{jt} \leq 1 \qquad t = 1,\ldots,T \quad (B6)$$

where, O_{jt} is an integer selection variable given by

$$O_{jt} = \begin{cases} 1 & \text{if alternative } j \text{ is selected in the } t^{th} \text{ time period} \\ 0 & \text{otherwise} \end{cases}$$

For problems like the example where O_{jt} is the only integer variable, it follows that there are M times T integer variables.

(2) Goal status accumulates additively for each i^{th} goal, i=1,...,N. Thus,

$$\left.\begin{aligned} GO_i + \sum_j D_{ij} O_{j1} &= A_{i1} & t &= 1 \\ A_{i,t-1} + \sum_j D_{ij} O_{jt} &= A_{it} & 2 &\leq t \leq T \end{aligned}\right\} \quad (B7)$$

where

GO_i is the initial value of the i^{th} goal

D_{ij} is the incremental value of the i^{th} goal by the j^{th} alternative, e.g., Project Effect Factor

A_{it} is the actual value of the i^{th} goal status at time t

(3) The total cost of alternatives selected in any period t must be within a prespecified band of budget tolerances. Thus, for each t,

$$(1 - PU)B_t \leq \sum_j C_j O_{jt} \leq (1 + PO)B_t \qquad (B8)$$

where

C_j is the cost of the j^{th} alternative

B_t is the budget for the t^{th} period

PU and PO are the percentages under and over budget, respectively, expressed as decimals. These can be time dependent if subscripted by t.

(4) The amount of over- or underachievement of the i^{th} goal in the r^{th} time period is its absolute deviation, a positive quantity. Thus, for each i^{th} goal and t^{th} time period.

$$A_{it} + OA_{it} + UA_{it} = G_{it} \qquad \text{(B9)}$$

where

OA_{it} and UA_{it} are the over- and underachievement variables, respectively, whichever occurs, of the i^{th} goal in the time period

G_{it} is the target growth value for the i^{th} goal in the t^{th} time period as finalized by the decision maker from the g_t values developed for target goal growth paths per Appendix A.

Equations for the assumptions above, expressed in the program as constraints, and for the objective functions comprise the types of governing relationships needed for optimum solution of goal growth problems by a commercially available mixed integer software package.

B.4 WEIGHTED AVERAGES - A SECOND APPROACH

The purpose of a second approach to portfolio selection is twofold. First, it enables a preview of the type of portfolio likely to be selected concurrently with the examination of the target goal growth paths generated by the program. Second, it provides a good "starting solution" for the mixed integer main computation module. The selection algorithm does not consider deviations from the goal paths, and, in fact, is oblivious to them. Instead it operates by selecting, in each successive time period, affordable combinations of alternatives which yield the best weighted average growth per dollar within the budget limit for each time period.

The first step in the algorithm is to assign a value measure, Z_j, to each j^{th} alternative using the relationship

$$Z_j = \frac{\sum_i W_i D_{ij}}{C_j} \tag{B10}$$

which provides a measure, for each alternative, of its prioritized (weighted) average goal growth per dollar.

The alternatives are then ranked in order of their Z_j values. Allocation within the budget is made on the basis of the best affordable combination. The process is repeated in each successive time period by selecting a best value combination from among the remaining alternatives for that period. The time allocation yields a realistic portfolio developed along overall value lines. In some cases, particularly when the data is well behaved, the solution is close to optimal, as occurred in the example problem presented earlier.

Since only current goal priorities are used, the algorithm neglects the transition values of goal priorities as they change from their first period value to 1/n at the end of the planning period. Hence, the algorithm is kept simple yet effective and practical for its intended use.

APPENDIX C

SCOPE OF JCAP DECISION MODELING

C.1 INTRODUCTION

The JCAP Priorities Model presented in the report is one of nine decision models developed expressly for ammunition managers by the Decision Models Directorate (DMD) of JCAP. The purpose of this Appendix is to inform managers of the background of (1) JCAP and (2) JCAP decision modeling capabilities available for support to ammunition management.

C.2 BACKGROUND

The Joint Conventional Ammunition Production Coordinating Group (JCAP/CG), see Figure C1, exercises coordinated joint Service management of the DOD ammunition program. This group was officially chartered May 24, 1972 by the Joint Logistics Commanders with authorization to coordinate and take action on all conventional ammunition production base activities and programs in order to achieve efficient, effective, and economic management of the base. The scope of the charter was expanded by the JLC on July 9, 1974 to include all conventional ammunition logistics programs and activities.

The Coordinating Group, which meets quarterly, represents the Joint Logistics Commanders in approving all policies and procedures for coordinated management of conventional ammuntion. Current members of this group are: Army, MG William B. Eicher (Chairman), Commander US Army Armament Materiel Readiness Command; Navy, RADM Donald P. Hall, Commander Naval Sea Systems Command; Air Force, BG George L. Schulstad, Commander Ogden Air Logistics Center; and Mr. Edward J. Jordan, Executive Director, JCAP.

A joint Service Operating Group (JCAP/OG), which meets monthly, is the operating arm of the Coordinating Group. This Group, which is staffed by military personnel of the 06 level and civilians at the GS-15 level, is chaired by the Executive Director. This group directs and reviews the effort of the JCAP Task Groups and the full time JCAP staff organizations shown in Figure C1. In addition, the Executive Director directs and controls the full time JCAP organization.

The JCAP/CG and the Decision Models Directorate will continue in operation after implementation of the Single Manager assignment. However, the primary mission of JCAP now and in the future is support of the Single Manager. Approximately 75 percent of the Decision Models Directorate current workload is directly related to the Single Manager mission and this percentage is increasing daily.

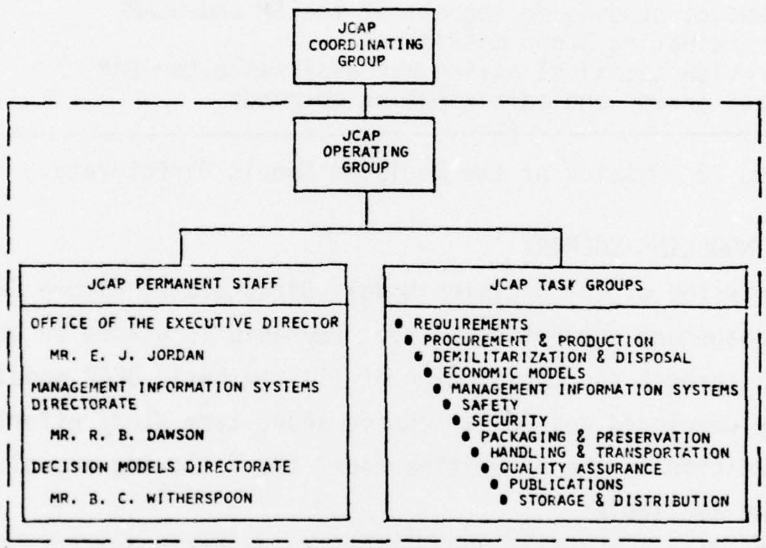


Figure C1 JCAP Organizational Chart

The JCAP Coordinating Group, to achieve its mission, directed the Decision Models Directorate to develop a set of dynamic economic models specifically to support management of the conventional ammunition production base in answering the questions of how, when, where, and to what extent should resources be planned and committed to best achieve the primary mission - maximum overall readiness - consistent with guidance received and base capabilities. The output from each model supports the decision-making process by identifying a set of best available alternatives to the manager for his evaluation and selection. These models are all operational and available. Demonstration phase operations of these models has disclosed over one billion dollars of documented savings, avoidances and cost deferrals! This translates to a payback ratio, for the full time JCAP organizations, in the order of 200 to 1 based on approximately four million dollars sunk costs.

- Support the Single Manager (SM) mission
- Develop and apply decision models to support the conventional ammunition management process
- Establish an integrated data base management system for model operations
- Conduct studies in support of the SM and JCAP Coordinating Group missions
- Provide technical advice and assistance to JCAP task groups and participating commands

Figure C2 Mission of the Decision Models Directorate

C.3 DECISION MODELING SUPPORT

The mission of the Decision Models Directorate, Figure C2 (above), is management support oriented. Emphasis is placed on quick responsiveness through the application of (1) the basic JCAP model family already developed and (2) intensive short-term study efforts.

In addition to the Priorities Model the following are also operational and available:

- The Item Acquisition/Production Trade-Off Model
  for maximizing item readiness at least cost
- The Materiel Acquisition Planning Model
  for maximizing overall readiness within budget constraints
- The Industrial Preparedness Model
  for mobilization planning (items, components, facilities)
- The Maintenance Model
  for least cost layaway and maintenance policy for idle facilities
- The Production Facilities Life Cycle Cost Subsystem
  for least total cost modernization, expansion and workloading of the production base
- The Multiple-Bid Evaluation Model
  for economic analysis of complex procurement actions

- The Demilitarization and Disposal Model
  for integrated demil planning and workloading
  at least cost
- The Packaging/Containerization Life Cycle Cost Model
  for evaluation from design through disposal

The Directorate works on a continuing basis with the primary functional areas and the ammunition community. Upon receipt of the data from the functional areas, a thorough and complete analysis with alternatives and recommendations is provided by the Directorate. The Directorate has demonstrated:

- Responsiveness
- Productivity
- Proven Capabilities

For further information, contact Mr. Bernard C. Witherspoon, Director, Decision Models Directorate, Joint Conventional Ammunition Program Coordinating Group, ATTN: JCAP-DM, Rock Island Arsenal, IL 61201; or call AUTOVON 793-5262/6538 or Commercial (309) 794-5262/6539.

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