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INFORMATION SERVICE PLANNING AND EVALUATION: A GOAL PROGRAMMING--ETC(U)

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6 INFORMATION SERVICE PLANNING AND EVALUATION:

A GOAL PROGRAMMING APPROACH

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ABSTRACT OF THE THESIS

INFORMATION SERVICE PLANNING AND EVALUATION: A GOAL PROGRAMMING APPROACH

by THOMAS J. McGEEHAN, Ph.D.

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This paper discusses a generalized resource allocation and program planning model to aid information service managers optimize the value of an information program to their parent organization. The technique which is investigated is goal programming that incorporates both quantitative criteria and ordinal priorities into a common decision making system. It is a particularly powerful tool for dealing with a decision making environment in which there are conflicting goals and objectives.

For the model which is described, thirty projects of a proposed operating program are evaluated in terms of fifty goal criteria representing six classes of organizational goals, including (1) the range of available staff for information services, (2) the available budget, (3) the diversity of the overall program, (4) the capability of the information program to provide mandated functions, (5) concentration on basic services and products, and (6) concern over the agency's ability to keep pace with the demands for new and improved products and services.

The model is presented in a simulated operational environment using real data and planning objectives defined by administrators of a national information agency. The model provides three principal types of quantified information: (1) identification of the optimal resource allocation for achieving all desired goals as nearly as possible, (2) the degree of goal attainment provided with given inputs, and (3) the relative degree of goal attainment provided by alternative goal priorities and goal levels. In addition, goal programming is shown to provide valuable insight to the points of conflict within the decision environment defined by the model. Moreover, goal programming results can be used to show trade-offs such as the cost/benefit implications of altering planning goals and objectives. The latter feature can be used to help resolve conflicts in the planning objectives set for an information agency by diverse administrators in a complex organization.

The approach taken in the study consists of the four following steps. (1) An extensive literature search was made to review quantitative measures of information service for program evaluation. (2) The decision environment was analyzed to define the scope of the model by identifying the decision variables, the restrictions and constraints on the variables, and the criteria for defining a good or improved solution. (3) The decision environment was characterized in a linear mathematical model. Since information services tend to be labor intensive operations, labor was the key resource incorporated into the model. If a certain number of labor hours spent on certain projects represented management's goal for providing a basic level of service then a formula to that effect was developed as a goal constraint for the model. Data for the model was obtained from interviews conducted with managers of the information agency and also administrators from the parent organization whose programs relied on information service support. (4) The performance of the models was investigated in a series of iterative steps that included calculating solutions, analyzing results, reformulating the model and conducting a comparative analysis of the results.

The overall results demonstrate that goal programming supplements a traditional decision making process in several key ways, (1) it helps define the decision environment in unambiguous terms, (2) it provides a systematic procedure for considering alternative decision strategies, (3) it ensures that all key elements are considered in relative position of priority each time a decision strategy is evaluated, and (4) it helps decision makers establish priorities for proposed operating programs.

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CHAPTER I. INTRODUCTION

This research is concerned with evaluating information services in terms of organizational goals. It addresses the problem faced by information program administrators having to choose among alternative services and products in a limited resource environment. Specifically, it is an investigation of the applicability of an operations research technique, goal programming, as an aid for determining a satisfactory allocation of resources among alternative information projects, in an operational setting, such that the assignment of resources is consistent with organizational goals, objectives and priorities.

The goal programming technique is an extension of linear programming that can be made to correspond closely to actual decision making processes where priority setting is essential. It involves goal and priority setting followed by a systematic search for practical solutions to program planning and policy dilemmas that result from multiple conflicting goals and subgoals which must be served simultaneously. Using quantitative techniques for problem solving similar to linear programming, goal programming also incorporates ordinal values into the problem structure, in much the same manner as an operating administrator might do, to express subjective or judgemental dimensions relevant to decision making problems.

Since little progress has thus far been made in developing a strictly quantitative approach to information service program evaluation, the questions arises whether goal programming, with its combined use of quantitative measures and judgemental dimensions, can be successfully applied to the problem of assessing the value of various information projects, products and services to overall program objectives and mandates. If so, greater progress stands to be made in applying management science principles to the resource allocation problem in the field of information service management.

1.1 THE OBJECTIVE OF THE STUDY

It is the objective of this study to develop a pragmatic goal programming model which reflects the complexity of the decision environment of a major information service agency and test its application potential for resource allocation and program evaluation. The study has two aspects. The first aspect has to do with setting up the problem and developing a model that relates information products, projects and services to organizational goals in a quantitative manner. The second aspect has to do with demonstrating the use of the model for program evaluation and resource allocation.

1.2 SIGNIFICANCE OF THE STUDY

Administrators of information service agencies--including libraries, specialized information centers and documentation centers--often are faced with demands for new services from users or proposals from their professional staff to develop new products and services which are technologically feasible but not provided for in the budget. In recent years, they have often had to deal with budget cuts, as well. Consequently, choices have to be made.

Moreover, the organizations and governmental bodies that fund information services are increasingly applying formal accountability systems such as Program-Planning-Budgeting-System (PPBS) or Zero-Based Budgeting to their planning cycles. As a result, even long-standing basic products and services are having to be justified on a routine basis. To be sure, in the current limited resource environment, service agencies cannot request prodigious sums of money for operating programs and new services without clear justification in terms of goals and expected results.

Quantification techniques such as systems benefit projections, costs and user studies go far in helping to make some of the difficult decisions. However, data alone do not resolve the decisions, especially when there are differences about the essential value of the various services to diverse user groups or to the organizational goals as a whole.

Decision analysis techniques, usually based on a model of the decision environment, do provide tools to resolve questions about alternative program strategies and the effects of various adjustments in resource allocations among projects. If appropriate, models also help provide a consistent basis for decision making from the operating level up through the administrative approval cycle. However, there has been a paucity of research involving the application of models to information service problems, and those models which have been developed have met with little acceptance among the information service agencies. Either they have been too complex to be practical, or the data they require could not be captured practically, or they have required the creation of artificial utility functions that are more acceptable in theory than in practice. Moreover, information service administrators may often lack training in scientific management techniques, which limits the acceptance of models for practical application.[1]

In order to be practical, an information services decision model has to be flexible, avoid excessive complexity, and have the capability of incorporating a good deal of subjective judgement into the model in lieu of "hard data" in order to establish a value basis for decision making. Goal programming, which is a relatively recent modification and extension of linear programming, appears to have many of the characteristics that would overcome the kinds of problems encountered by previous information service modeling efforts. Thus, it was selected as the focus of this research.

1.3 WHO NEEDS GOAL PROGRAMMING?

It should be recognized at the outset that goal programming is a fairly sophisticated technique which requires a certain amount of time to implement. Managers must be trained to use the technique effectively, and the model must be constructed for each environment. Therefore, the size of the problem to be resolved must be large enough to warrant an investment in the tool.

Large, complex institutions with many diverse program elements and hundreds of thousands of dollars worth of resources to manage are likely to find an investment in goal programming practical today. Smaller institutions will have to wait for the development of prototype models. However, administrators of institutions of all sizes are apt

[1]The reader is referred to the literature review in Chapter II for a fuller explanation of the above statements.

to benefit from the use of a technique that leads to more rational decision making.

As a minimum, the administrator who would use the goal programming technique must be willing to approach decision making in a rational manner, and be able to provide a priority structure of operational goals in relationship to their organizational importance. In addition, for most problems, a computer must be available to derive solutions.

1.4 WHY GOAL PROGRAMMING?

Goal programming is a mathematical model building technique derived from linear programming that appears to be particularly appropriate for an operating information service environment. As described by Sang M. Lee (58), it has been developed specifically for solving decision problems in which goals set by management are achievable only at the expense of each other. Thus, it is well suited for dealing with goals that are in conflict and/or use incommensurable units of measure which in an information service environment may include (a) labor hours devoted to certain services, (b) the number of items circulated to users, (c) the number of queries answered, or (d) the number of books cataloged over time.

Furthermore, goal programming is capable of dealing with more than one set of objectives such as might be established by various constituents of an information service unit, including diverse user groups and/or administrators holding different positions in the organizational hierarchy which includes the information service agency. This feature of goal programming is one of its most interesting because it facilitates a rational approach to resolving differences among administrators, particularly where service goals are viewed as being in conflict with fiscal goals. More will be said about the exploitation of this feature in Chapter IV, in conjunction with the discussions on applying the goal programming approach to an actual information service environment.

1.5 THE GOAL PROGRAMMING APPROACH

The discussion up to this point has been concerned with providing a rationale for the research to be presented. Beginning with this section, we turn to an explanation of the methods and procedures used in the study. While the general theme of the study is the application of operations research to information service planning, the specific OR tool utilized in the study is the goal programming method described by Lee (58).

Goal programming is an extension of linear programming. Linear programming is a highly developed set of mathematical techniques and algorithms particularly useful for solving decision problems involving resource allocation. Linear programming is concerned with finding optimal solutions to problems with linear objective functions and linear constraints.

A linear programming problem must be either a single objective function (one "goal" to be satisfied) or multiple objectives, all of which must be reduced to a single commensurable unit of measure (unidimensionality).

On the other hand, goal programming handles multiple goals in multi-dimensions. Each "goal" is formulated as a "goal constraint".

The left hand side of the goal constraint consists of the decision variables (x) and their coefficients (α) plus negative and positive deviational variables (d^- and d^+). The deviational vairables, if they take on any values in the solution, indicate deviations from the goal criterion. The goal criterion β_i is stated as one number on the right hand side of the constraint equation.

The objective function (Z) is stated in terms of the deviational variables (d_i), for which management must specify the priorities of avoiding underachievement (d_i^-) and overachievement (d_i^+) of each goal. In goal programming, then, the task is to minimize Z by minimizing the values of the deviational variables within the given set of constraints, according to the relative importance (W_i) and/or pre-emptive priority values (P_k) assigned to them individually.

The general goal programming model can be expressed mathematically as:

$$\text{Minimize } Z = \sum_{k=1}^{s} P_k \left(W_i^- d_i^- + W_i^+ d_i^+\right) \qquad \text{(objective function)}$$

$$\text{subject to: } \sum_{i=1}^{m} \left(\sum_{j=1}^{n} \alpha_{ij} X_j + d_i^- - d_i^+ \right) = \beta_i \qquad \text{(goal contraints)}$$

where $X_j \geq 0$ for $j = 1, 2, \ldots, n$

and $d_i^-, d_i^+ \geq 0$ for $i = 1, 2, \ldots, m$.

However, for the purpose of explanation a somewhat less abbreviated version will be introduced to show the matrix structure of the goal constraints, as follows:

$$\text{Minimize } Z = \sum_{k=1}^{s} P_k \, (W_i^- d_i^- + W_i^+ d_i^+)$$

subject to:

$$\alpha_{11} X_1 + \alpha_{12} X_2 + \dots + \alpha_{1n} X_n + d_1^- - d_1^+ = \beta_1$$

$$\alpha_{21} X_1 + \alpha_{22} X_2 + \dots + \alpha_{2n} X_n + d_2^- - d_2^+ = \beta_2$$

$$\vdots$$

$$\alpha_{m1} X_1 + \alpha_{m2} X_2 + \dots + \alpha_{mn} X_n + d_m^- - d_m^+ = \beta_m$$

$X_j, d_i^-, d_i^+ \geq 0$ for all i, j where

β_i are the m goal criteria

X_j are the n variables associated with the m goals. These are the decision variables in the problem.

α_{ij} is an m x n matrix of the coefficients of the n variables which express the quantitative relationships between decision variables and the m goals

d_i^+ is the amount of positive deviation (over achievement) in goal i

d_i^- is the amount of negative deviation (under achievement) in goal i

Both d_i^+ and d_i^- may be 0, but for any $d_i^+ > 0$ the corresponding $d_i^- = 0$ and conversely if $d_i^- > 0$ then $d_i^+ = 0$

To form the objective function, each deviational variable d_i^+ and d_i^- must be ranked according to preemptive priorities from the most important to the least important. In this way, the lower priority goal criteria will be met only after higher priority goal criteria are achieved. If there are s priorities, they have the relationship

$$P_1 >>> P_2 >>> \cdots >>> P_{k-1} >>> P_k >>> P_{k+1} >>> \cdots >>> P_s$$

This means that the minimization of the value of d_i^+ and d_i^- associated with P_k will always be considered less important than the minimization of the value of d_i^+ and d_i^- associated with P_{k-1}.

A final note which should be made concerning the objective function is that within priorities (each P_k) further differentiation is possible by assigning numerical weights (W_i) to the various deviational variables. This would allow, for example, the achievement of one goal with a given priority to be twice or three times as important as the achievement of another goal with the same priority. (A more comprehensive explanation of the goal programming approach, together with a discussion of the graphical and simplex procedures to solve goal program problems, is found in the literature, especially Chapters IV and V of Lee (58).)

The goal programming approach has five steps:

1. Define and formulate the problem.
2. Calculate an initial solution.
3. Analyze the solution and review priorities.
4. Calculate an alternative solution.
5. Repeat steps 3 and 4 until a satisfying solution is reached.

A simple illustration now follows to demonstrate the general steps in applying the goal programming method to an information service problem.

STEP 1. Definition and Formulation of the Problem

Assume that a progressive information service agency requires two classes of output from its operating program (a) basic services for today's users and (b) investment projects to ensure the development of adequate capabilities for future demands. Moreover, these outputs are targeted to organizational goals. Further assume that the agency uses two kinds of resources, a collection of materials and professional labor hours. All other factors are neglected to simplify the illustration. This example is based on a goal programming model developed by Pitkanen (95). The basic goal-setting problem is illustrated in Figure 1-1. This basic approach to the goal-setting problem is followed, in a more complex form, in the information service model to be discussed in Chapter III.

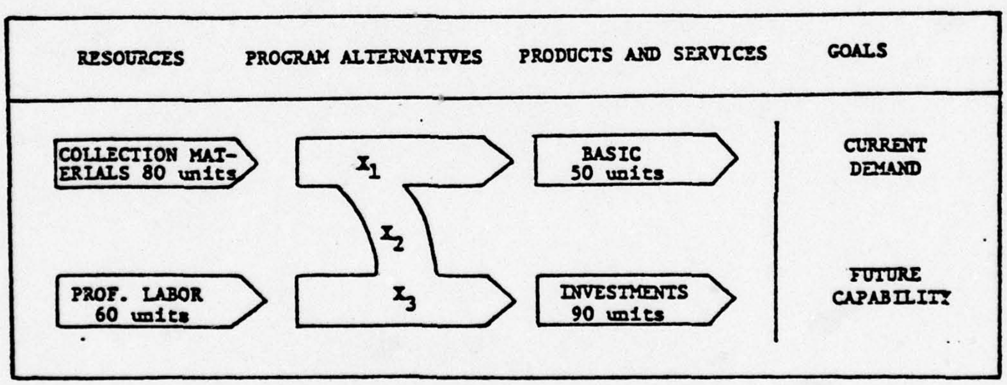

Figure 1-1. Goal-Setting Problem

In this example it is the administrator's judgement that the desirable levels of output and resources are as shown in Figure 1-1. Furthermore, collection materials are needed for both types of output, but only professional labor hours are required for investment projects. In this illustration, one unit of purchased materials and services results in one unit of output of either type. For example, a book added to a collection has the same value as its purchase price whether it is added for the basic collection or as a "growth" item. However, it takes two units of professional labor to produce one unit of creative output (perhaps devoted to the design of new services). The administrator is faced with the problem of evaluating alternative uses of the resources designated as X_1, X_2 and X_3. X_1 represents the use of collection materials in providing basic services. X_2 represents the use of collection materials as "investment" to ensure the agency's future capability. X_3 is professional labor used to design and plan new services and products.

On first consideration, the administrator might list the following goals and priorities:

First: Produce at least the full 50 units of basic products and services.

Second: Produce exactly 90 units of investment products and services.

Third: Use at least 80 units of collection materials and 60 units of labor.

Fourth: Do not exceed 120 units for the combined resources utilized.

Fifth: Minimize the use of combined resources as much as possible.

In the planning and evaluation process, the numbers associated with input and output values are considered as "targets". Thus, they are not necessarily firmly fixed. Nevertheless, the ideal solution would be one that simultaneously achieves all five priorities, providing neither more nor less than the values specified in the problem. Thus, it can be stated that the administrator's objective is to minimize any deviation from the stated goals.

Figure 1-2 presents the goal programming problem in mathematical form.

$$\text{Minimize } Z = P_1 d_1^- + P_2(d_2^- + d_2^+) + P_3(d_3^- + d_4^-) + P_4 d_5^+ + P_5(d_3^+ + d_4^+)$$

$$\begin{array}{lrrrcr}
\text{Subject to:} & X_1 & & + d_1^- - d_1^+ & = & 50 \\
& & X_2 & + 0.5\,X_3 + d_2^- - d_2^+ & = & 90 \\
& X_1 + & X_2 & + d_3^- - d_3^+ & = & 80 \\
& & & X_3 + d_4^- - d_4^+ & = & 60 \\
& X_1 + & X_2 + & X_3 + d_5^- - d_5^+ & = & 120
\end{array}$$

$$X_1,\ X_2,\ X_3,\ d_1^-,\ d_2^-,\ d_3^-,\ d_4^-,\ d_5^-,\ d_1^+,\ d_2^+,\ d_3^+,\ d_4^+,\ d_5^+ \geq 0$$

Figure 1-2. *Problem Formulation Example*

STEP 2. Calculate an Initial Solution

Using the procedure described by Lee (58), the problem is solved such that a satisfactory solution is first sought for the highest priority factor, then the second highest, and so forth until all the priorities have been achieved or as many as possible before conflicts are encountered. Then the optimal compromise is calculated.

In this case, the initial solution offered by the model is as follows:

A.	Basic Otuput	produce	50 units (as desired)
B.	Investment Output	produce	90 units (as required)
C.	Collection Materials	use	110 units (30 more than desired)

D. Professional Labor	use	60 units (as desired)
E. Budget	requires	170 resource units (this solution will cost 50 units more than planned)

STEP 3: Analyze the Solution and Review Priorities

If the administrator or higher funding authorities were to reject the higher cost solution, the administrator's problem then becomes to optimize the allocation of resources within the budget of 120 resource units. In this case the priorities could be reordered as follows:

First: Produce at least 50 units of basic products and services.

Second: Produce exactly the 90 units of investment products and services, but also do not exceed 120 cost units for the combined resources utilized.

Third: Use at least 80 units of collection materials and 60 units of labor.

Fourth: Do not exceed 60 units of professional labor.

Fifth: Do not exceed 80 units for collection materials.

Based on the above selection of priorities, the objective function now becomes:

$$\text{Minimize } Z = P_1d_1^- + P_2(d_2^- + d_2^+ + d_5^+) + P_3(d_3^- + d_4^-) + P_4d_4^+ + P_5d_3^+$$

STEP 4. Calculate an Alternative Solution

The consequences of this reordering of priorities can then be calculated using the revised objective function. This leads to the following alternative solution:

A. Basic Output	produce	50 units (as desired)
B. Investment Output	produce	70 units (cut back by 20 units)

C.	Budget	require	120 resource units (as called for)
D.	Collection Materials	use	120 units (40 more than desired and 10 more than the first solution)
E.	Professional Labor	use	None (the staff has been eliminated by the cost factor in favor of the more cost effective resource)

STEP 5. Iterate on Steps 3 and 4 until a Satisfactory Solution is Found

Now, with the consequences of the two alternatives clearly apparent, the administrator is prepared to consider the policy implications of (a) increasing the budget (Alternative 1) or (b) eliminating the professional staff (Alternative 2). The higher administration or funding authorities may also be involved at this point.

In the event that neither solution is satisfactory, the administrator and/or the funding authorities continue to explore alternatives until a satisfactory program is identified. They may either continue to explore the consequences of adjusting priorities or they may explore the consequences of actually changing their goals and performance targets.

1.6 BASIC APPROACH TO THE STUDY

In order to develop a goal programming application in an operating information service environment, it is necessary to secure the cooperation of an active agency which has the capability to provide (a) a program to evaluate, (b) a set of goals, and (c) supporting operational data. The Defense Documentation Center (referred to in the study as DDC or "the agency") agreed to collaborate in this regard. DDC provided the operating environment, a program budget, the data for the model, and the administrative judgment needed to conduct a pragmatic test of goal programming in a significant operating environment.

Furthermore, the agency is currently engaged in a significant long-range planning effort which has produced a variety of recommendations to undertake projects that are technologically feasible in the planning period 1978 to 1988.[2] The task remaining for the agency is to prepare budget programs over the next decade to deal with the long-range requirements while at the same time meeting the administrative requirements of its top management.

Since choices will have to be made in each annual program budget and there is no objective basis for deciding among alternatives, the situation provides a prototype application well suited for testing the goal programming method for program evaluation and resource allocation. The approach taken in this study consists of four basic steps:

STEP 1

An extensive literature search was made to review quantitative measures of information service useful for program evaluation. The results of this effort are discussed in Chapter II.

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[2] For the detailed discussion of the study, see AUERBACH Associates, Inc., DDC 10 Year Requirements and Planning Study: Final Report, June 13, 1976. 2 Volumes (AUER 2325/2326-TR-5; AD-A024 700, AD-024 701).

STEP 2

The second step consists of analyzing the decision environment to yield a statement of the problem's elements. These include the controllable or decision variables, the restrictions or constraints on the variables, and most important, the objectives for defining a good or improved solution. The decision variables for the study consist of the projects vying for resources. The constraints and the criteria for defining a good or improved solution were elicited through face to face interviews conducted with administrators involved in making the choices. These constraints and criteria provide the basis for the goal constraints in the model. Step 2 determines the scope of the decision problem to be modeled. It involves substantial judgment since the point of developing any model is to reduce a problem to essential elements only. Every decision problem has a multiplicity of impacts, some are crucial and others are peripheral. The process of delimiting a problem to essentials while incorporating all key factors has been called "the art of management science". Chapter III discusses this process in further detail.

STEP 3

This step has to do with building the model. The structure defined in Step 2 is transformed into mathematical form to represent the interrelationships among the problem elements. For example, the way in which the various decision variables relate to the criteria for a good solution must be defined in a way meaningful to management. In other words, if a certain number of manhours spent on projects represents management's goal for providing a basic level of service then a formula to that effect is developed as a goal constraint using the data inputs provided from operating statistics and the interviews held with administrators. It should be obvious that the artfulness with which Steps 2 and 3 are accomplished determine the degree of success in applying a particular model to a given problem. There is no standard procedure and details of model formulation must be tailor-made for each application.

For this study, 50 goal constraints representing six classes of criteria for a good solution are defined:

- The labor resources in man-years available in the planning period
- The budget available in the planning period
- The labor resources necessary to produce the agency's basic products and services
- The labor resources necessary to improve the level of services as an investment for the future
- Target levels for the distribution of man-years among projects to achieve a balanced program considering:
    - Services to the two main groups of users (a) managers, and (b) scientists and engineers
    - Services to support the agency's library constituency
    - Responsiveness to the organizational goals identified by the administrators
    - Responsiveness to user needs for (a) timely and (b) comprehensive service
- The planned allocation of man-years to the specific projects anticipated in the planning period

It was inferred from the interviews that a program that could meet these criteria would meet with the approval of the administration of the agency as well as the agency's various constituencies and funding authorities. Chapter III provides a description of the model constructed for this study.

STEP 4

The fourth step has to do with performing the analysis. Given the initial model and the parameters provided by the administrators, a mathematical solution is calculated. The results are reviewed with management, and as necessary, additional solutions are explored under modified parameters. A major part of the analysis consists of determining the sensitivity of the solution to the model's construction, and in particular, to the priority structure provided by management. Therefore, a series of computer runs are conducted and the impact of varied input parameters on the solution are analyzed in Chapter IV of this dissertation.

1.7 LIMITATIONS TO THE STUDY

The following limitations are inherent in a study of this kind.

- Management must be able to formulate its goals and define its priorities accurately.
- The model is designed specifically for the collaborating agency's environment. Other applications would be expected to have different goals, priorities and programs necessitating a reformulation of the model for each application.
- The model derived in this study has been limited in scope to an annual planning cycle, although it is possible to formulate a multi-time period model.
- The model is designed for an agency with a preexisting program budget. Therefore, significant modifications in the procedures may be required if an application is attempted in an environment where a program budget does not exist.

In addition, certain limitations are attributable to the underlying assumptions of linear mathematical theory on which the goal programming technique is based.

- Proportionality: Goal programming is an extension of linear programming. This implies that the objective function, constraints, and goal relationships must be linear. The measure of goal attainment and resource utilization must therefore be proportional to the level of each activity conducted individually.

- Additivity: The condition that goal attainment and resource utilization be proportional to the level of each activity conducted individually does not ensure linearity. A non-linearity may occur if there exist joint interactions among some activities of the goal attainment or the total utilization of resources. To ensure linearity, therefore, the activities must be additive in the objective function and constraints.

- Divisibility: Fractions of decision variables must be acceptable in the solution. The optimum solution of a goal programming problem often yields non-integer values for the decision variables.

- Deterministic: All of the model coefficients must be constants. In other words, the problem requires a solution in a static decision environment. However, in reality the decision environment is usually dynamic rather than static, Therefore, the model coefficients are neither known nor constant. This limitation is a most critical one, as goal programming models are usually formulated for future decision making. The model coefficients are based on forecasts of future conditions.

Furthermore, in the application of the model as developed in this study, several a priori assumptions were made:

- The data included in the model are assumed to be a valid representation of the agency's operating environment.

- The relationships among the program elements are assumed to be linear.

- There is a proportional relationship assumed between the number of man-years allocated to a project and productivity.

- Organizational goals are assumed to be valid program evaluation criteria.

- The computer programs used in the study accurately implement the simplex algorithm for solving goal programming problems, as described by Lee (58).

In summary, the Introduction has attempted to answer the question, what it this study about? The next chapter addresses the question of how this research relates to other major studies in order to establish a framework for assessing the general applicability of goal programming as a practical tool for information service management.

CHAPTER II. QUANTITATIVE DECISION ANALYSIS APPLIED TO INFORMATION SERVICE ADMINISTRATION- A LITERATURE REVIEW

This chapter reviews the progress reported in information science and related literature for making quantitative analysis techniques available to managers of information service programs. The literature of goal programming is also reviewed in order to initiate the assessment of the applicability of goal programming for the information service environment.

Two considerations that are essential for accepting goal programming as a practical tool for information services managers are put forward in this chapter. First, that there is a need for a comprehensive decision analysis tool as an aid for information service evaluation in planning and resource allocation. Second, that goal programming has been applied successfully in a variety of environments to a broad range of decision problems including the resource allocation problem, which establishes it as a valid tool of operations research. Support for these two propositions is found, we believe, in the review of the literature that follows.

The review will concentrate on the following key topics:

- Progress to date - an overview of quantified analysis of information services
- Information service decision models
- Goal programming models

2.1 WHAT DECISION ANALYSIS ENCOMPASSES

Decision analysis may be interpreted in a general sense as the use of the scientific method to solve management problems, or in a narrower sense as the application of rational mathematical techniques to management. The essence of decision analysis is model building. Decision analysis is distinguished from the generic field of operations research (also called management science) by its emphasis on the need for an integration of quantitative analysis with environmental and behavioral aspects of the decision-making process. Therefore, decision science encompasses a broader spectrum of the decision-making process than the processes of quantification alone. It is in the broader context that this review has been conducted.

2.2 PROGRESS IN QUANTIFICATION AND MEASUREMENT OF INFORMATION SERVICES

The literature of information service quantification and measurement techniques strongly suggests that the field has not progressed very far into decision science. Measurement techniques in the current literature concentrate on narrow aspects of operating systems. They usually lack the involvement of environmental aspects and organizational goals and objectives. Thus, they are not consistent with decision-making. Hindle and Raper (41), for example, conclude that the achievements in quantitative evaluation for analysis of informational policy must be regarded as "disappointing". They report a particular lack of methods to develop detailed knowledge of resource allocation problems. In this respect, they are supported by Ford (36), who concluded a review of research in user behavior by stating that "we have measured almost every conceivable characteristic of the user, but without any attempt to use these data to clarify resource allocation issues".

The progress that is conceded applies to the evaluation of public libraries and academic libraries (Hamburg, 39; Bommer 6; and University of Durham, 117). By contrast, the use of quantitative techniques for overall design and evaluation of specialized information services appears to be virtually unexplored territory (Hindle and Raper, 41).

Despite such negativism, actual progress may be somewhat better than the progress perceived by the reviewers. Lynch (83) suggests that the practical art of information service management may be ahead of the research and theory. In practice, managers are forced to use intuitive judgement and uncomplicated quantification measures in decision analysis. In practice, they do reflect the influence of their operating environments. Moreover, model building has developed a growing interest in the past five years, although the number of practical applications are few. Bommer (7) suggests the problem preventing more wide-spread applications of quantitative techniques may be that too much attention has been devoted to the construction and solution of complex mathematical models which ignore the value of simple and direct measures that are actually more useful to the decision-maker. Lee (58), who has specialized in applying goal programming models to a wide variety of management problems, also advocates the construction of models which are "a great deal simpler than reality".

Furthermore, techniques that serve more to demonstrate the mathematical prowess of the modeler than to assist the decision-maker have a tendency to show up more readily in the literature than more direct and pragmatic techniques, which may partially account for the paucity of reports of practical techniques suited for decision analysis in information service organizations.

The Cause for Optimism

Swanson (114) provides additional optimism in an extremely well balanced and comprehensive review of the state-of-the-art of evaluation studies. Her only agreement with other reviewers is that additional investigation into quantitative decision-making is clearly warranted. She contends that although the state-of-the-art of evaluation studies is still deficient, the deficiencies are a result of the embryonic stage of the field's development, combined with the variety and complexity of the decision environment it must address in evaluating information services. She concludes:

> To date, investigators have had the resources to probe only a small part of the whole, trying to formulate methodology as well as acquire data. This is seen as an expected phenomenon in the emergence and development of a body of knowledge, and more piecemeal study is anticipated before patterns appropriate to particular types of study are discernible.
> (Swanson, 114, p. 154-155)

The progress that has been reported over the past six to seven years is actually encouraging despite the fact that decision analysis procedures, definitive observational techniques, units of measure and theories have not yet emerged. While it is not yet possible for an investigator or manager to go to the literature and find a "cook book" type of article that tells what to measure, how to measure and how to interpret the results, studies, such as Hamburg's (39) for example, show that the use of measurement for decision-making in the information service environment is feasible.

Examples of Progress

Significant progress is noticeable in just the growing concern being expressed for understanding the reasons behind measurement. Particularly since 1972, investigators have shown increasing awareness of the importance of recognizing that different system goals mandate different evaluative measures. In addition, they recognize that failure to discuss goals with evaluation provides only superficial indications of system effectiveness (Ladendorf, 55).

Wilson (124) describes 1972 as the pivotal year marking the passage of an era in which management accepted on faith the value of information. By then, the literature began to reflect a serious need to measure the effects and contributions of information products and services. About this time, the purpose of measurement took new directions concerned with costs, benefits, and welfare economics.[1]

The measurement techniques then available in the information service field were inadequate for demonstrating the purposes and effects of information products and services. Evans et al. (33) were disturbed by the fact that tools developed to that time failed to make their use clear. Of the five to seven hundred studies they reviewed, very few identified the goals or the importance of a given service to the achievement of those goals. The early tools did not indicate what "good" information service provided. Consequently, management's interpretations of the quantified data were difficult and confusing.

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[1]Welfare economics attempts to assess the beneficial consequences of actions to groups or individuals served by the actions.

They were further dismayed over a general lack of consideration for the total service program.

Lancaster (56) said about the techniques available in 1970 that they may not have been able to measure the value of what information services were doing but "what they are doing, they are doing very well". How well they were doing is debatable since he also questioned whether it was "up to us to discuss 'ultimates'".

Very soon after these reviews, investigators began to reflect the need to consider the "ultimates." Although the information science literature on evaluation continued to be dominated by studies on retrieval measures or cost analysis, the library science literature produced a series of outstanding studies involving the use of quantified measures for evaluation of overall system performance measured against goals.

Hamburg et al. (39) have produced the most practical and generalized methodology for overall information service program evaluation to date. They describe a framework for planning and decision making in which operations and resources expressed within a program structure can be evaluated in terms of exposure hours. Exposure hours are the consequence of library programs. Exposure is measured as the sum of occurrences when individuals borrow documents, use them in-house, obtain them through interlibrary loan or receive reference assistance. The project goal was to maximize exposure hours for given resources. The main difficulty they encountered was in trying to express everything in terms of one measure.

DeProspo et al. (31) about the same time as Hamburg took a multidimensional approach to measurement indicating various user demands on library resources. The factors they measure are traditional library elements: hours, circulation, use of equipment, and so forth. This study is an example of the use of uncomplicated, although not simplistic, measures to provide meaningful management data. They do not attempt to create a single dimension unit of measure, but they make the point that while their several measures indicate the use of library resources, the managers must determine whether these measures express operational objectives, and if so, what the criterion levels are for satisfactory operation.

The use of measures for program evaluation across several loosely interdependent organizations was implemented in the academic library environment by the MRAP (Management Review and Analysis Program) (Webster, 121).

Bommer (6) has built upon the sophisticated work of Morse (90) and developed a management system for effective decison-making and planning in a university library.

Conclusions Regarding the State-of-the-Art

Three significant conclusions can be reached as a result of the progress in information service measurement since 1972:

1. Although it is necessary to develop a unique methodology in order to use quantification techniques successfully, those organizations able to commit sufficient resources to the task can implement useful programs. There are no intrinsic impediments in the nature of information service itself (Hindle and Raper, 41; Leimkuhler and Billingsley, 81; and Swanson 114).

2. The complexity of decision-making in the information service environment is a significant problem which can benefit from the use of well planned quantification techniques (Buckland 10, Cooper 26, DeProspo 31, and Millham 87).

3. Although methodology (how to collect and use measures) is important, it is secondary to the rationale behind a study (what to measure and why). Moreover, when quantification is not considered in relationship to goals and objectives expressed as performance criterion, no methodological sophistication can cure conceptual deficiencies. Clearly this is the principal area in need of more research. (DeProspo 31, Swanson 114, Smith and Wechsler, 109).

2.3 INFORMATION SERVICE DECISION MODELS

Model building provides the conceptual framework to coordinate all that is known about various aspects of an organizational environment. Therefore, models facilitate decision-making in accordance with overall objectives. The term "model" is often used loosely to refer to any attempt to conceptualize such a framework. However, for decision analysis applied to this study, the most useful models are mathematical in nature. The use of mathematics is important not only for defining and measuring important system variables, but also for the power of mathematical theory which helps maintain consistent patterns of problem conceptualization throughout the decision analysis process.

Mathematical models relevant to information service decision-making will be reviewed in this section. In particular, the compatibility of existing models with the goal programming approach will be considered.

Resource Allocation Models

The resource allocation problem has been addressed by Bookstein (5). His approach combines queuing theory and dynamic programming, which is not well suited to the current capabilities of the goal programming approach. Moreover, the mathematics are somewhat complex and the data needed to implement the model need to be determined through a systems analysis of alternative program designs. Consequently, the application of the model to routine problem solving is likely to be limited. However, the model is noteable because Bookstein provides an interesting quantitative model of two important information service problems: (a) the optimal allocation of resources to sequential processes such as those for inputting data and documents into an information system; and (b) the optimal distribution of computer terminals according to work-load patterns.

Another relevant approach to the resource allocation problem of service agencies is suggested by Crecine (27) in an application from outside the information service field. Crecine looks at resource allocation in the context of a municipal budgeting problem. Using a simulation model, he describes an approach to computer-aided problem solving involving the allocation of public resources to proposed programs on the basis of non-market factors. The approach is practical. It takes into account the political nature of public resource budgeting and works on the principle of achieving a balanced budget rather than attempting to meet some nebulous criterion of public satisfaction.

The distinction between political choice and market choice is an important one to remember in selecting practical performance criteria for program evaluation involving public resources. This issue is further explored by Raffel (100) and Vickers (119).

Information Center Location Problem

Kraft and Hill (53) describe a location model for optimizing the placement of information centers. The model is formulated as a linear programming problem. It is an interesting model because of its possible applicability to the problems of locating remote terminal access centers for computer-based information services.

Kochen and Deutsch (51) make an attempt at a general quantitative theory of decentralization applicable to information service facilities. They express the number of facilities as a function of demand rates, distances, speed and cost of transport, the value of waiting for results and the cost of decentralized facilities. The model tends to suggest smaller, more numerous and more dispersed facilities.

Economic Models

Scholz (108) recently described a methodology that could be useful for calculating the probably effectiveness of various data bases in meeting user needs. This type of data would be helpful in determining whether or not new data bases should be added to an information service's basic service program. However, the report is preliminary and its practicality will have to be judged after the general model is completed.

Price (97) presents a rather flexible model that he claims can be used for a wide variety of cost control projects.

A study currently in progress at Purdue University (99) is directed toward a financing and pricing policy for industrial information analysis centers (IAC). A broader, though less detailed view of industrial IAC resource allocation, is also reported for future application in a decision-making model. The model seems to be inclined toward the use of user satisfaction criteria.

Decision Models for Library Services

This section highlights the more significant library service models. Morse (90) provided the earliest significant work on quantification of library service for decision-making. His formulations address most of the traditional library functions such as book selection, circulation and collection uses. Morse recognized a number of limitations in his units of overall measure that use past records of demand to predict future demand. However, much of the subsequent work on library models relied on Morse (Bommer 6; Hamburg et al. 39).

A second early study, the PEBUL project (Project for Evaluating the Benefits from University Libraries, 1969), demonstrated that benefits from libraries can be measured by observing users' behavior in conjunction with administrative decisions. In this manner the PEBUL methodology successfully applied quantitative techniques to attributes of performance (University of Durham, 117).

Hamburg et al. (39) developed an outstanding quantitative approach to the problem of evaluating information service problems in a decision-analysis context. They provide for both behavioral and environmental considerations in their approach to optimizing a measure of exposure hours calculated for the various library functions. Their only limitations are those inherent to the undimensional aspects of measuring all output of the library in terms of one unit of measure. The methodological difficulty of formulating a very complex problem in terms of a single unit of measure was explored by Huber (42) as well as Charnes and Cooper (13). Investigations similar in methodology to Hamburg et al. were carried out in the university library context by Bommer (6), Buckland (8), Burr (12), and Kantor (45).

A number of investigators addressed the problem of how to structure a program in order to make the most from available resources. Urquhart (118) discusses the broad prospects for information services in competing for national resources and suggests that planning must be dictated by the limited available resources. Millham (87) and Rouse (103) describe models for the public library and a university library respectively to assist in conducting a trade-off analysis among alternative programs measured against a set of management criteria.

NELINET used operations analysis of its internal processes in combination with a market-research methodology to evaluate potential products and generate data that were used to make decisions about its line of products and services (New England Board of Higher Education, 92).

2.4 MEASUREMENT OF INFORMATION SERVICES

Measurement is important in the decision analysis process because it provides the content of the mathematical formulations of the model. Numerical data serve to establish quantitative relationships among the components of the decision-making system represented by the model. Too often, the functional nature of measurement is overlooked and an unwarranted mystique is attributed to the numbers holding them to be absolute values. What is needed for decision-making is the simplest measures which will suffice for deriving pragmatic relationships in the decision problem.

The point was made previously in this chapter that standard measurement techniques for evaluating information service programs do not exist. Neither is there consensus on the type of measurement techniques appropriate to particular types of study. Consequently, it is not possible to obtain from the literature measures of information services which are universally applicable to the goal programming approach. Therefore, studies which attempt to measure information service factors in a scientific fashion have been included in the bibliography mostly to serve a reference function and stimulate thinking about meaningful quantitative techniques on the part of those who would use goal programming in decision analysis.

Nevertheless, to employ quantitative techniques on a practical level, it is important for the information service manager to understand the characteristics of valid measures and also to consider the types of measures that have been employed usefully in other goal programming formulations.

Functionality of Measurement

Quantification in evaluation is often looked upon as a means of ensuring objectivity in the evaluative process. Certainly, it is an aid in that respect but quantification alone will not ensure it. Nor is objectivity related to the exactness of the measures used. The nature of measurement is characterized by Kaplan:

> Measurement, in short, is not an end in itself. Its scientific worth can be appreciated only in an instrumentalist perspective, in which we ask what ends measurement is intended to serve, what role it is called upon to play in the scientific situation, what functions it performs in inquiry.
>
> The failure to recognize this instrumentality of measurement makes for a kind of mystique of quality, which responds to numbers, as though they were the repositories of occult powers. (Kaplan 46, p. 171-172).

In a later passage, Kaplan adds that "exactness is not as important for scientific status as is objectivy."

Thus, measures are seen to be instruments in decision analysis and a variety of techniques may be equally appropriate for a given situation and purpose. The validity of the measure according to Kaplan (46) rests in whether the measure has value to those using it and they can "do something meaningful with it". Thus, the first characteristic of valid measurement is that validity depends on the context in which the measurement is used and the inferences taken from it.

Quantified Evaluation

Quantification used for evaluation is merely the use of numbers to measure value. Inherently, it involves a combination of basic assumptions underlying the activity being evaluated. Thus, for evaluation, measures represent approximations of value (Suchman, 111).

Certainly, to transform qualitative information service values into measurable factors requires a reasonably precise definition of "qualities" such as comprehensiveness, timeliness, accessibility and user satisfaction. Precision in this sense means to artificially establish a value scale. Evaluative measurement can then be made in ordinal or comparative terms if need be. Such measures may lack exactness, but if they are used objectively they are valid in a true scientific sense.

Consequently, a second characteristic of valid measurement is that it may have a subjective basis if the measures are applied uniformly.

Measures Useful in Decision Analysis

Decision analysis takes a pragmatic approach to quantification. It employs measures of only the essential elements of the problem being modeled, and then using the modeling process, searches for a formulation to use the available data (Lee, 58). Consequently, the development of a practical decision analysis model need not wait until exact measurement schemes are developed to fit the decision problem. The main prerequisite for using the pragmatic approach to measurement is that management must be willing to express at least an ordinal importance for goals in a linear decision system.

Values based on intuitive judgement of decision makers who have proven ability are a valid source of measures useful in decision analysis. Numerical procedures may include the use of value scales based on management judgement, ordinal scales, or measures derived through a very systematic analysis. The only requirement is that the numbers and scales must have meaning to management.

2.5 GOAL PROGRAMMING MODELS

In this section, the acceptance of goal programming as a valid tool of established operations researchers is considered. As noted previously, goal programming is a decision analysis technique derived from linear programming. It emerged from the work of Charnes and Cooper in the 1950's. The name was given to the technique in their well respected book on applications of linear programming to industrial problems (13). The concept of programming to goals first emerged as an issue for unsolvable linear programming problems. Charnes and Cooper describe the concept as follows:

> Closely related to the analysis of contradictions in unsolvable problems is the issue which will be called "goal attainment". Management sometimes sets such goals even when they are unattainable within the limits of available resources for a variety of reasons....Any constraint incorporated in the functional will be called a "goal". Whether goals are attainable or not, an objective may then be stated in which optimization gives a result which comes as close as possible to the indicated goal. (Charnes and Cooper 13, p. 215-216).

Charnes and Cooper are respected primarily for popularizing linear programming through their success in formulating a wide variety of problems using linear programming techniques.[2] Among the applications for which they have suggested goal programming models are media planning (14), (15), manpower planning (18), budget control (19), (20) and organizational goal attainment (21).

The goal programming aspects were improved by Ijiri (17), (43) who added the concept of pre-emptive priorities to the solution of conflicting goals, thus making the technique correspond closely to intuitive decision making patterns of operating managers.[3] Contini (25) examined the goal programming method under conditions of

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[2]For a general presentation of the basic principles of linear programming see Churchman (22).

[3]The significance of pre-emptive priority is made clear in Chapter III.

uncertainty, introducing stochastic methods. Jaaskelainen (44) used goal programming to solve production planning problems. Pitkanen (95) explored goal programming's application to public administration, and Ruefli (105) has been working with Charnes on the application of linear programming to the popular Planning-Programming-Budgeting System (PPBS) in which goal programming is likely to apply. Trinkl (115) has also explored the applicability of goal programming to PPBS. Further strides in developing goal programming as a practical technique are likely to result from the work of three researchers, who have developed interactive goal programming methods (Dyer 32, Zionts and Wallenius 126), which permits a manager to examine a goal programming problem while on-line to a computer that provides rapid results for evaluation and iterative examination.

Pitkanen's Application

Of the models cited above, the model by Pitkanen (95), developed for his doctoral research, should be especially noted as one that has contributed to this research effort. This model was concerned with setting goals related to public expenditure decisions. Pitkanen regarded the quantification problem as one of setting targets for desired levels of resource utilization from several pools, and targets for output in terms of consumption goods and services (those that are part of the basic public program) and investment goods and services (those designed to improve the services themselves). The focus of this study was on establishing priorities for various incompatible and incommensurable objectives. Pitkanen emphasized that the goal programming approach had general applicability in public administration by ensuring that in the planning process, goal setting would always precede the detailed preparation of plans. Coincidentally, Mintzberg et al. (88) pointed out the significance of Pitkanen's observation following an intensive study of 25 strategic decisions. They conclude that organizations tend to formulate only one fully detailed plan for evaluation. They find that, typically, goals tend to be formulated with precision after decisions have been made regarding preferred courses of action and not before.

Gibbs' Application

Gibbs (38) used goal programming for choosing among alternative resource goals in a situation where a corporate computer systems and planning group desired to develop a training program for its systems analysts. His model solved a resource allocation problem with respect to the use of contract services versus in-house staff based on relative cost and effectiveness measures. Gibbs used a standard linear programming computer solution package. Therefore, in order to give priorities to his goal statements, he had to provide a weighted measure of the relative value of each goal rather than a simple ordinal ranking. However, his model did provide valid solutions to the problem he posed.

Lee's Applications

By far, Lee (58-79) has made the most significant strides in developing goal programming as a practical tool for operating managers. He has improved both the technical capabilities of the technique itself and extended its application through a variety of model formulations in diverse decision-making environments. His book, Goal Programming for Decision Analysis (58), offers a treatise on model formulation and solution algorithms. In addition, it lists a complete computer program based on a simplex algorithm for solving problems with up to 125 variables and ten preemptive priority levels. The program, written in FORTRAN IV, was implemented without modification on IBM 370 and UNIVAC 1108 equipment for this study and used to compute the solutions.

Among the developments attributable to Lee are (a) the extension of goal programming to integer problems (62, 67, 68, 77), (b) the solution of the classical transportation problem using goal programming methods (72), and (c) a modification of the warehouse distribution problem, which uses a goal programming approach to solve a multi-criteria school busing problem in order to reflect such goals as providing educational opportunity to children, achieving racial balance, avoiding over crowding among the schools, encouraging neighborhood schools and minimizing costs (75).

Lee has defined three areas of decision-making in which goal programming can be effectively applied.

1. Allocation Problems - where the problem is to analyze the optimum combination of input resources to achieve certain goals set for outputs such that the total goal attainment can be maximized for the organization,

2. Planning and Scheduling Problems - where to accomplish desired outputs, the optimum combination of inputs in certain time periods must be identified,

3. Policy Analysis - where for government agencies and not-for-profit organizations, the basic decision problem involves the assignment of priorities to various goals and the development of programs to achieve these goals. Through the application of goal programming, the organization is able to ascertain the soundness of its policies.

One of the objectives of this study is to demonstrate a fourth area of application, namely to resolve policy differences between various levels of management where compromises in goal priorities are necessary.

Specific models have been successfully demonstrated by Lee et al. in the following areas:

- Municipal economic planning (79)
- Resource allocation for hospital administration (59)
- Sales effort allocation (63)
- Academic resource allocation (64)
- Financial planning (66)
- Capital budget planning (67, 70)
- Urban renewal planning (68)
- Stock portfolio selection (69)
- Production scheduling (73)
- University admissions planning (74)
- School busing (75)
- Marketing decisions (78)

The influence of Lee is so pervasive in the methodology for formulating the information service evaluation model in the following chapter that it is difficult to single out specific aspects which have been employed. If any one model stands out as influential, it is the academic resource allocation model (64). In that approach, Lee established relationships between the utilization of various categories of labor resources and the value of their output to the university. This was followed by a search for an optimal allocation of resources which best satisfied the objectives the university had set for itself to ensure a quality program. In a general sense, it was the academic resource allocation model that provided the insight and perspective necessary to develop a meaningful model of the information service program planning environment. To demonstrate the methodology by which the problem was conceptualized and the model formulated is the task of Chapter III.

CHAPTER III. MODEL FORMULATION

To carry forward this inquiry of the applicability of goal programming for information service program evaluation and resource allocation, this chapter now presents a general methodology for developing an appropriate model in an operating environment. It is general in the sense that the approach to formulating the model can be followed for any information service environment, although the specific goals, variables and constraints will be different in each application. For that matter, even as the present model is used repeatedly in the same environment, it should be apparent that the model will have to be reformulated from time to time to take account of modified circumstances and new data.

The procedures, terminology and notations used in this formulation are those described by Lee (58, Chapter 3). Model development follows a sequence of four steps: (1) determination of model objectives and priorities from management, (2) identification of the decision variables, (3) formulation of the goal constraints, and (4) analysis of the model solution and its implications. In this chapter, the first three steps are discussed in detail. It will be the task of Chapter IV to discuss Step 4.

3.1 DETERMINATION OF MODEL OBJECTIVES AND PRIORITIES

As noted in Chapter I, formulating a decision analysis model is partially an art. The model is a representation of reality which has to have an underlying rationale that is meaningful to the decision maker who would use it. This model is based on the rationale that an information service unit, whether a library or a specialized information center, exists to perform specific functions required by the community it serves. It follows, then, that the value of the information service unit is directly proportional to its ability to meet its total obligations. In turn, the product and service outputs can be evaluated in terms of the relative contribution each makes toward meeting specific obligations. Once a direct relationship is established between (a) specific products and services, and (b) specific obligations, or desired results, then it is possible to set objective criteria and priorities for each obligation and determine an optimal allocation of resources such that resources go first to those products and services that are "most" important and only afterward to products and services of "less" importance to meeting the total organizational obligations of the information service unit.

Furthermore, it is part of the underlying rationale that an information service unit has a heterogeneous community to serve. Members differ in their need for certain products and services, the timeliness of service and the information content of the products. Indeed, some members of the community are concerned only with minimizing the cost of the services. Inevitably such demands conflict with one another. The program administrator's job, in this instance the information service administrator, is to balance the use of available resources among the possible program outputs and satisfy as many obligations as possible.

As a practical matter, the functions required of an information service unit are defined by the administrators and managers responsible for the program, and their superiors. In a complex organization that is hierarchically structured, there are usually additional administrators whose programs depend on information support who would have input as well. The model objectives and priorities, therefore, are based on goal criteria specified by all such administrators concerned with the need for information services. Use and user need data also can be considered as input to the target setting process if such data are available.

Overview of the Decision Environment

The present model was formulated with the collaboration of the Defense Documentation Center (DDC), which supported this research. DDC is a field activity of the Defense Logistics Agency of the Department of Defense (DOD). It makes available from one central depository thousands of research and development reports produced by United States military laboratories and their contractors. The DDC also operates computer-based retrieval systems for the distribution of management and technical information.

DDC collects, processes, retrieves, and distributes technical information in all of the scientific disciplines and engineering fields of interest to the DOD, which is referred to as DOD Research, Development, Test, and Evaluation (RDT&E) activities. The information relates to either (a) technical reports (stored in the Technical Report Data Bank) or (b) on-going and planned research and development work being conducted by or for the DOD (stored in the R&D Management System, primarily the Research and Technology Work Unit Information System).

As is generally the case with information services, the DDC program is labor intensive. Thus, labor is the principal resource of interest in resource allocation decision making.

The specific objectives and priorities for the model were derived from an interview survey of DOD administrators concerned with DDC's information program. We further augmented and refined the survey findings in discussions with DDC's operating managers in order to set specific criteria for evaluating the agency's information program. In order to provide a clear framework for developing the model within a planning context, we chose to use data from the agency's up-coming program budget for 1978.[1] Of course, the model can be used with any year's data but the variables, goal criteria and some of the constraints of the model may have to be revised.

Model Objectives and Priorities

The information service evaluation problem involves service, fiscal, and in this instance, national defense objectives and implications. In order for DDC, henceforth referred to as "the agency",

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[1]Defense Documentation Center, Research, Development, Test and Evaluation (RDT&E) Program/Budget, Fiscal Years 1976/1977/1978. 27 August 1976. Defense Supply Agency, Department of Defense, Washington, D.C.

to be effective, the DOD administrators viewed six goals as key. These are:

- Use the number of man-years available in the planning period (1978)
- Work within the budget available in the planning period
- Provide enough resources to ensure production of the agency's basic products and services
- Provide enough resources to development projects to improve the level of services as an investment for future needs
- Provide resources to all the projects included in the proposed 1978 project plan.
- Achieve overall program balance according to various user/service needs including:
  - provide services of interest to the agency's two classes of users: (a) managers and (b) scientists and engineers
  - provide service to libraries upon request
  - provide aid in identifying and locating information, as opposed to specific documents
  - provide access to agency-held documents
  - provide access to documents and information from remote locations
  - promote the use of information products and services
  - be responsive to the need for timely service to users
  - be responsive to the need for maintaining a comprehensive archival collection

These six goals, in turn, are expressed in terms of 50 specific goal criteria in several different dimensions, shown in Table 3-1 as a_i, $i = 1,2,\ldots,50$. Moreover, there are inherent conflicts among the goals. For example, the service goals (e.g., a_{38}, a_{39}, a_{40} and a_{50}) tend to conflict with the fiscal goals (a_1 and a_3) representing budget and manpower limitations. The goals to achieve program balance (a_{42} - a_{50}) are likely to conflict with the goals to fund the projects specified

TABLE 3-1. MANAGEMENT OBJECTIVES AND THREE ALTERNATIVE PRIORITY STRUCTURES

Symbol	Goal Criteria: Criterion (and Assigned Value)	Source of Criterion Values	Priorities (by Run) 1	2	3
a_1	Upper limit on the total staff size (10% over the previous year, or 491 man-years)	Estimated by management	P_2	P_2	P_2
a_2	Minimum staff size (at least 454 man-years)	1978 Program/Budget	P_1	P_1	P_1
a_3	Maximum total labor costs ($8,778,000)	1978 Program/Budget	P_8	P_9	P_3
a_4	Desired ratio of basic projects to investment projects (at least 85% basic to 15% investment)	Estimated by management	P_5	P_4	P_5
a_5	Desired basic program diversity (at least 363 "diversity" units)	Based on data from 1978 Program/Budget	P_6	P_7	P_8
a_6	Desired ratio of investment projects to basic projects (at least 15% investment to 85% basic)	Estimated by management	P_5	P_4	P_5
a_7	Desired investment program diversity (at least 68 "diversity" units)	Based on data from 1978 Program/Budget	P_6	P_7	P_8
a_8-a_{37}	Specific distribution desired for the 30 projects included in the proposed 1978 project plan. (The proposed staffing plan in man-years per project is shown in Table 3-2)	1978 Program/Budget	P_7	P_3 and P_8*	P_4 and P_9*

* Projects a_{24}, a_{25}, a_{27}, a_{33}, a_{35}, a_{36} and a_{37} are assigned to priority P_8 for run 2 and P_9 for run 3.

TABLE 3-1. (Continued)

Goal Criteria: Symbol	Goal Criteria: Criterion (and Assigned Value)	Source of Criterion Values	Priorities (by Run) 1	2	3
a_{38}	Desired ratio of service to support RDT&E managers compared to service to support RDT&E scientists and engineers (1:7 in man-years)	Estimated by management	P_4	P_6	P_7
a_{39}-a_{41}	Service requirements to process requests for technical reports from libraries (measured as a productivity factor) (a_{39} = 97% of the expected demand, which management estimates will come from non-library sources = 355,020 technical report requests) (a_{40} = 3% more than a_{39}, that is at least 3% more productivity to supply the minimum level of demand expected from libraries = 365,671 technical report requests) (a_{41} = 10% more than a_{39} to supply the maximum demand expected from libraries = 390,522 technical report requests)	Estimated by management from the 1978 Program/Budget	P_3	P_5	P_6

TABLE 3-1. (Continued)

Symbol	Goal Criteria Criterion (and Assigned Value)	Source of Criterion Values	Priorities (by Run) 1	2	3
a_{42}-a_{48}	Desired % of basic and/or investment projects to meet four information service goals Provide information access a_{42} = 18% of the total basic program a_{43} = 25% of the total investment program Provide access to agency-held documents a_{44} = 52% of the total basic program a_{45} = 25% of the total investment program Provide remote access to documents and information a_{46} = 10% of the total basic probram a_{47} = 15% of the total investment program Promote use of information products and services a_{48} = 5% of the total basic program	Derived from the survey of administrators	P_4	P_6	P_7
a_{49}	Desired % of total program devoted to providing less than 24 hour turn-around service (20%)	Estimated by management	P_4	P_4	P_5
a_{50}	Desired % of total program devoted to conserving RDT&E technical reports (20%)	Estimated by management	P_4	P_4	P_5

at the levels in the program plan (a_8 to a_{37}). In addition, any of the goals may represent the objectives of one level of management, while some others may represent the objectives of a higher or lower level. In this research, three different sets of priorities (P_k)'s, corresponding to three separate computer runs, will be investigated in order to test the model for its ability to assist a decision maker in evaluating program alternatives and identifying the optimal allocation of resources which best resolves the conflicts and satisfies as many criteria as possible. The last three columns of Table 3-1 show the specific priorities assigned to the 50 goal criteria ($P_k \ggg P_{k+1}$) within each of the three priority structures used in the research. Also shown in the table are the sources from which specific criterion values were obtained.

3.2 DECISION VARIABLES

A primary operation of the information service evaluation model is to determine how many man-years of effort should be allocated to each of the 30 projects included in the proposed 1978 project plan. Staffing levels for the 30 projects constitute the decision variables. A descriptive summary of the decision variables is shown in Table 3-2. Seventeen of the variables, x_{10} through x_{24} and z_{52}, correspond to:

- Projects that result in the output of products and services for current consumption by the agency's users. These are projects which make up the agency's <u>basic program</u> (B).

Five of the variables, y_{30} through y_{33} and y_{44}, correspond to:

- Projects which have an element of development effort and are intended to result in new and improved products and services. These are the project which make up the agency's <u>investment program</u> (I).

Four of the variables, y_{40} through y_{43}, correspond to projects that have both a basic component (B) and an investment component (I).

In addition to the above categorization, the proposed 1978 project plan classified the 30 projects into the following six groups, as shown in Table 3-2:

1. Data-based information services projects (x_{10} - x_{19})
2. Technical report services (x_{20} - x_{25})
3. Investigation of new information systems, services and products (y_{30} - y_{33})
4. Computer systems (y_{40} - y_{44})
5. Management and administration (z_{50} - z_{53})
6. Services provided to other government agencies (z_{60})

3.3 GOAL CONSTRAINTS

In goal programming models, the goal constraints represent the decision maker's planning parameters. The purpose of the model is to achieve all the goals and objectives as closely as possible. This is accomplished by minimization of either the negative (d_i^-) or positive (d_i^+) deviations from the goal criteria (a_i) in accordance with certain assigned preemptive priority values (P_k) such that the set of goal constraints is always satisfied as nearly as possible. In the information service program evaluation model under development in this study, the 50 goal constraints that are to be satisfied fall into the following categories:

TABLE 3-2. DECISION VARIABLES

Symbol	Project Description (and Assigned Staffing Levels)	Basic/Investment
Data base services		
x_{10}	Research and technology work unit data base input (a service to aid technical managers keep current on the status of on-going RDT&E projects being conducted by or for the DOD) (a_8 = 13 man-years)	B
x_{11}	Research and technology work unit data base output (a_9 = 13 man-years)	B
x_{12}	Scientific and technical information storage and retrieval data bank (an automated IS&R system for accessing DOD technical reports) (a_{10} = 1 man-year)	B
x_{13}	R&D program planning data base input (a service primarily to aid technical managers and program administrators identify planned programs in order to avoid duplicating efforts (a_{11} = 2 man-years)	B
x_{14}	R&D program planning data base output (a_{12} - 1 man-year)	B
x_{15}	Independent R&D data base input (a service to identify R&D of interest to DOD but not conducted under DOD contract (a_{13} = 4 man-years)	B
x_{16}	Independent R&D data base output (a_{14} = 2 man-years)	B
x_{17}	RDT&E on-line terminal services (a_{15} = 15 man-years)	B
x_{18}	RDT&E on-line terminal service extension to Boston (a_{16} = 2 man-years)	B
x_{19}	RDT&E on-line terminal service extension to Los Angeles (a_{17} = 2 man-years)	B

TABLE 3-2. (Continued)

Symbol	Project Description (and Assigned Staffing Levels)	Basic/Investment
Technical report services		
x_{20}	Technical report input (acquisition, indexing, cataloging, and so forth (a_{18} = 91 man-years)	B
x_{21}	Technical report announcement (publication of announcement bulletins and lists) (a_{19} = 10 man-years)	B
x_{22}	Technical report distribution upon request (a_{20} = 62 man-years)	B
x_{23}	Technical report automatic distribution (fulfillment of standing requests by topic) (a_{21} = 7 man-years)	B
x_{24}	Technical report primary distribution (initial distribution of RDT&E technical reports) (a_{22} = 1 man-year)	B
x_{25}	Technical report bibliographies (selected topics (a_{23} = 23 man-years)	B
Investigation of new information systems, etc.		
y_{30}	Advanced distribution systems (a_{24} = 0 man-years)	I
y_{31}	Integrated R&D Information system (to allow user interplay with all information resources) (a_{25} = 3 man-years)	I
y_{32}	Natural language system (to allow users to use uncontrolled terminology when interacting with the technical data bases) (a_{26} = 5 man-years)	I
y_{33}	General systems (overall improvement in all products and services) (a_{27} = 1 man-year)	I

TABLE 3-2. (Continued)

Symbol	Project Description (and Assigned Staffing Levels)	Basic/Investment
Computer systems		
y_{40}	Support of the RDT&E data base services (a_{28} = 5 man-years)	B = 80%/I = 20%
y_{41}	Support of the technical report services (a_{29} = 7 man-years)	B = 80%/I = 20%
y_{42}	Integrated systems (a_{30} = 19 man-years)	B = 40%/I = 60%
y_{43}	Support of the RDT&E on-line systems (a_{31} = 17 man-years)	B = 50%/I = 50%
y_{44}	Computer system redesign and implementation (complete overhaul of the automated systems) (a_{32} = 25 man-years)	I
Management and administration		
z_{50}	General administration (a_{33} = 80 man-years)	
z_{51}	Promotion of services (a_{34} = 4 man-years)	
z_{52}	Technical terminology (maintenance of a standard vocabulary) (a_{35} = 19 man-years)	B
z_{53}	Maintenance of a central registry of authorized users (a_{36} = 5 man-years)	
Services provided to other government agencies		
z_{60}	Interagency cooperation (a_{37} = 15 man-years)	

A. Total number of staff

B. Total labor cost

C. Basic services

D. Investment services

E. Individual target levels for the 30 projects

F. Overall program balance, including:

- Classes of users being served
- Balance among four information service goals for:

  I. Providing access to information (as opposed to documents)

  II. Providing access to documents

  III. Providing remote access to documents and information

  IV. Promoting information products and services

G. Timeliness of service to users

H. Archival comprehensiveness of the agency's collection

We turn now to a detailed discussion of the goal constraints that are to be formulated in each of the above categories for inclusion in the model.

A. Total Number of Staff

The total staff planned for the agency's 1978 budget equals 454 man-years. However, among the operational objectives it was indicated that the absolute limit on budget increases is 10% over the previous year. Since labor is the dominant element in the budget, a constraint is formulated to set the absolute limit of 491 (10% over 1977) on the number of man-years. A second constraint is formulated for the more flexible ? goal criterion of 454 man-years.

Since it is known at the agency that in-house positions are more difficult to justify than total dollar increases, the difference between 454 and 491 could be considered a recommendation to supplement in-house staff with contract staff, should the solution exceed the 454 man-year goal criterion. The two goal constraints are:

A.1 Maximum Allowable Staff

$$\sum_{j=10}^{25} x_j + \sum_{j=30}^{44} y_j + \sum_{j=50}^{60} z_j + d_1^- - d_1^+ = a_1 \qquad (1)$$

A.2 Minimum Number of Staff

$$\sum_{j=10}^{25} x_j + \sum_{j=30}^{44} y_j + \sum_{j=50}^{60} z_j + d_2^- - d_2^+ = a_2 \qquad (2)$$

where d_1^+ = number of man-years in excess of 491 and d_1^- = number of man-years less than 491; and d_2^+ = number of man-years in excess of 454 and d_2^- = number of man-years less than 454. The purpose of this dual constraint formulation is to facilitate specification of a goal criteria range for a staff size between 454 and 491 man-years.

(1) represents the upper limit goal and (2) represents the lower limit goal.[2]

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[2]For the formulation presented in this dissertation, j = (10, 11, 12, ..., 25) for x_j, and (30, 31, 32, 33, 40, 41,..., 44) for y_j and (50, 51, 52, 53, 60) for z_j.

B. Total Labor Cost

Cost minimization is always a key decision making factor in information service planning. Since labor is the principal cost item in the present model, the labor cost alone is used as a cost goal criterion (a_3). Minimization of program costs can be achieved by minimizing d_3^+ in the following constraint:

$$\sum_{j=10}^{25} c_j x_j + \sum_{j=30}^{44} c_j y_j + \sum_{j=50}^{60} c_j z_j + d_3^- - d_3^+ = a_3 \qquad (3)$$

where c_j = average labor cost per man-years per project, d_3^+ = costs in excess of a_3 and d_3^- = costs less than a_3. It should be apparent that if a_3 is assigned the value 0, then d_3^+ represents the total cost of the model solution. The values of c_j included in the 1978 budget are shown in Table 3-3. In-house and contract service labor costs are assumed to be equal.

If the decision maker wishes to calculate the overall costs of the agency's 1978 program, the following forumla can be used after the model calculates the labor cost:

$$\text{Total Cost} = a_3 + (d_3^+ - d_3^-) + (\text{non-labor costs})$$

C. Basic Services

An effective basic program of products and services must be maintained to meet and supply current service demands as well as keep the confidence and support of the top administration. Moreover, the basic program should constitute a signficant proportion of the

TABLE 3-3. LABOR COSTS FOR 1978 PROJECTS

Variable	C_j (\$000)
x_{10}	13.92
x_{11}	19.85
x_{12}	20.0
x_{13}	16.0
x_{14}	20.0
x_{15}	17.0
x_{16}	15.50
x_{17}	21.74
x_{18}	21.74
x_{19}	21.74
x_{20}	18.01
x_{21}	14.1
x_{22}	15.65
x_{23}	17.0
x_{24}	25.0
x_{25}	21.43
y_{30}	0.0
y_{31}	27.0
y_{32}	23.60
y_{33}	23.0
y_{40}	29.80
y_{41}	21.71
y_{42}	22.05
y_{43}	23.0
y_{44}	22.16
z_{50}	20.4
z_{51}	20.4
z_{52}	23.84
z_{53}	13.0
z_{60}	19.07

total 1978 program. In the present model, the desired mix between the two kinds of programs has been determined to be 85% basic and 15% investment. Accordingly, the labor resources made available to the projects designated as components of the "basic" program as shown in Table 3-2 should equal 85% of the total labor resources available to all basic and investment programs. This goal is expressed by:

$$\sum_{j=10}^{25} x_j + .80\ (y_{40} + y_{41}) + .40\ y_{42} + .50\ y_{43} + z_{52}$$

$$- \left[(a_4) \left(\sum_{j=10}^{25} x_j + \sum_{j=30}^{44} y_j + z_{52} \right) \right] + d_4^- - d_4^+ = 0 \qquad (4)$$

where $a_4 = 85/100$. It should be observed that projects y_{40}, y_{41}, y_{42} and y_{43} have both basic and investment elements represented in their labor resources. For these four projects, the respective proportions of basic service shown in the above constraint are based on Table 3-2. d_4^+ = basic resources in excess of 85% (drawn at the expense of the investment program) and d_4^- = basic service less than 85%.

However, management generally would not be satisfied with a solution that provided 85% of service resources to the basic program unless it could also be shown that the program had sufficient diversity such that it contributed to meeting all the agency's mandated obligations. Some proposed projects tend to serve multiple ends and therefore it was desired to specify weights in favor of such projects in the allocation of resources.

A constraint to maximize the allocation of resources to the most goal diversified projects (those simultaneously serving multiple goals) can be expressed in terms of goal criterion a_5 as follows:

$$\sum_{j=10}^{25} D_j x_j + .80 \quad (D_{40} y_{40} + D_{41} y_{41}) +$$

$$.40 \quad (D_{42} y_{42}) + .50 \ (D_{43} y_{43}) + D_{52} z_{52} + d_5^- - d_5^+ = a_5 \qquad (5)$$

where D_j = a weighted measure of the goal diversity calculated for each proposed project. The values of D_j were calculated in concert with management for the basic projects included in this model, and are shown in Table 3-6. D_j is the product of two measures (s_j and m_j) which imply two views of goal diversity. $D_j = \pi \ s_j \ m_j$, where each s_j = a weighted score for the contribution each proposed project can make to specific organizational goals; and m_j = the percentage of manpower that management plans to allocate to each project (under the assumption that the projects which use the most man-power tend to have the most diversified utility). If it is assumed that the agency's goals will tend to change from planning period to planning period, it should be recognized that the inclusion of m_j in the calculation of D_j will tend to have a stabilizing effect on labor allocation that resists drastic reassignment of the staff from project to project as goals change. Staff stability is important to morale and productivity. As such, it is reasonable to represent it as a factor in the model.

s_j is a weighted score based on 14 factors (sv) selected by management to represent a measure of the value of each proposed project's contribution to mandated obligations. The summations shown in Table 3-4 thus represent the service versatility measures for the proposed projects.

m_j is the percentage of the total manpower that management is willing to allocate to specific projects. The values calculated for the 1978 planning period for all projects (x, y and z) are shown in Table 3-5.

The value of goal criterion a_5 for constraint (5) is an artificially high number (363). By minimizing d_5^-, the negative deviation from a_5, the model is forced to allocate resources to these decision variables (projects) with the highest D_j coefficients. The value of $a_5 = 363$ is based on the number of man-years available in the 1978 budget for the basic projects. It should be apparent that since D_j is always <1, 363 is an unattainable value in this instance.

D. Investment Services

If a service agency is to remain viable, it must continually improve its capabilities to meet future demands. This requires the use of labor resources to improve its performance capabilities through development projects. The approach to formulating the investment service constraints is analogous to the approach for basic service. Therefore, using the same approach as equation (4), equation (6) can be written to specify the target of 15% for the level of investment effort desired.

TABLE 3-4. SERVICE VERSATILITY SCORES FOR PROPOSED PROJECTS*

Factor / Variable	sv_1	sv_2	sv_3	sv_4	sv_5	sv_6	sv_7	sv_8	sv_9	sv_{10}	sv_{11}	sv_{12}	sv_{13}	sv_{14}	$\sum = s_j$
x_{10}	1													1	2
x_{11}	1				2		1	2			1				7
x_{12}	1		1			1	1	2							6
x_{13}	1												1		2
x_{14}	1				2			2							5
x_{15}	1														1
x_{16}	1				2			2							5
x_{17}	1	1				1	1	2		1		1			8
x_{18}	1	1				1	1	2		1					7
x_{19}	1	1				1	1	2		1					7
x_{20}		1	1										1	1	4
x_{21}		1				1	1	2			1	1			7
x_{22}		1				1	1	2			1	1			7
x_{23}		1				1	1	2			1	1			7
x_{24}		1				1		2							4

* The scores in the table were provided by the agency's management.

TABLE 3-4. (Continued)

Factor / Variable	sv_1	sv_2	sv_3	sv_4	sv_5	sv_6	sv_7	sv_8	sv_9	sv_{10}	sv_{11}	sv_{12}	sv_{13}	sv_{14}	$\sum = s_j$
x_{25}	1	1	1			1	1	2			1	1			9
y_{30}	1	1				1		2							5
y_{31}	1		1			1	1	2							6
y_{32}	1					1	1	2							5
y_{33}	1	1													2
y_{40}	1								3						4
y_{41}		1							3						4
y_{42}	1								3						4
y_{43}	1	1							3	1					6
y_{44}	1	1							3						5
z_{50}															
z_{51}				1											1
z_{52}	1														1
z_{53}															
z_{60}			1												1

TABLE 3-4. (Continued)

Where:

sv_1 = 1 point if the program provides aid in locating information as opposed to documents.

sv_2 = 1 point for programs which provide access to documents held by DDC.

sv_3 = 1 point for programs which provide access to documents in remote locations.

sv_4 = 1 point for programs which promote the use of information products and services.

sv_5 = 2 points for programs serving primarily RDT&E managers.

sv_6 = 1 point for programs serving primarily Scientists and Engineers.

sv_7 = 1 point for service to non-DOD users.

sv_8 = 2 points for programs serving libraries or other intermediary information organizations.

sv_9 = 3 points for programs providing ADP systems support for the overall program.

sv_{10} = 1 point for timeliness of service (24 response time)

sv_{11} = 1 point for volume of use (5 most used products or services)

sv_{12} = 1 point for user satisfaction (5 most well received products/services)

sv_{13} = 1 point for collection comprehensiveness.

sv_{14} = 1 point for conservation of the products of DOD RDT&E Research.

TABLE 3-5. PROPORTION OF RESOURCES TARGETED FOR 1978 PROJECTS

Variable	Variable % (m_j)
x_{10}	.028
x_{11}	.028
x_{12}	.002
x_{13}	.004
x_{14}	.002
x_{15}	.009
x_{16}	.004
x_{17}	.033
x_{18}	.004
x_{19}	.004
x_{20}	.199
x_{21}	.022
x_{22}	.136
x_{23}	.015
x_{24}	.002
x_{25}	.05
y_{30}	0
y_{31}	.007
y_{32}	.011
y_{33}	.002
y_{40}	.011
y_{41}	.015
y_{42}	.042
y_{43}	.037
y_{44}	.061
z_{50}	.175
z_{51}	.009
z_{52}	.042
z_{53}	.011
z_{60}	.033
Total	1.000

TABLE 3-6. PROJECT DIVERSITY COEFFICIENTS (BASIC PROGRAM)

Variable	s_j Service Versatility Score	m_j % of Proposed Manpower Allocation	$D_j = \pi s_j m_j$ Project Diversity
x_{10}	2	.028	.056
x_{11}	7	.028	.196
x_{12}	6	.002	.012
x_{13}	2	.004	.008
x_{14}	5	.002	.010
x_{15}	1	.009	.009
x_{16}	5	.004	.020
x_{17}	8	.033	.264
x_{18}	7	.004	.028
x_{19}	7	.004	.028
x_{20}	4	.199	.796
x_{21}	7	.022	.154
x_{22}	7	.136	.952
x_{23}	7	.015	.105
x_{24}	4	.002	.008
x_{25}	9	.050	.450
y_{40}	4	.011	.044
y_{41}	4	.015	.060
y_{42}	6	.042	.168
y_{43}	5	.037	.222
z_{52}	1	.042	.042

$$\sum_{j=30}^{33} y_j + .20\ (y_{40} + y_{41}) + .60y_{42} + .50y_{43} + y_{44}$$

$$- \left((a_6) \left(\sum_{j=10}^{25} x_j + \sum_{j=30}^{44} y_j + z_{52} \right) \right) + d_6^- - d_6^+ = 0 \qquad (6)$$

where $a_6 = 15/100$ and d_6^- = investment services less than 15% of the service program and d_6^+ = investment services in excess of 15%.

As in the case of the basic program, the investment program can also be weighted to reflect the diversity of impact each proposed project would have on meeting the full range of organizational goals. Accordingly, a goal diversity constraint for the investment program can be expressed by:

$$\sum_{j=30}^{33} D_j\ y_j + .20\ (D_{40}\ y_{40} + D_{41}\ y_{41} + .60\ D_{42}\ y_{42} +$$
$$.50\ D_{43}\ y_{43} +$$
$$D_{44}\ y_{44} + d_7^- - d_7^+ = a_7 \qquad (7)$$

where D_j = a weighted measure of the goal diversity calculated in the same manner as described for goal constraint (5). D_j values for the investment projects are shown in Table 3-7, and are calculated as products of the corresponding values of s_j and m_j derived from Table 3-4 and 3-5 respectively.

E. Individual Target Levels for the Thirty Projects

A major purpose of the present study is to demonstrate the feasibility of developing a goal programming model for evaluating an agency's proposed information service program plan in terms of its organizational goals, objectives and priorities. Central to the agency's proposed program are 30 individual projects consisting of basic service programs (x_j's), investment programs (y_j's), and other ancillary programs (z_j's). Included in the proposed program budget are 30 goal criteria, $a_8 - a_{37}$, among others, whose values ($a_8 = 13$, $a_9 = 13, \ldots, a_{37} = 15$) represent desired staffing levels in man-years for the 30 projects. The x_j's, y_j's, and z_j's corresponding to the projects constitute the decision variables of the model and must themselves be expressed in the form of goal constraints as shown below. The generalized forms of these 30 constraints are as follows:

$$x_j + d_i^- - d_i^+ = a_i \quad \text{for } i = 8,9,\ldots, 23 \text{ and } j = 10,11,12,\ldots,25 \tag{8}$$

$$y_j + d_i^- - d_i^+ = a_i \quad \text{for } i = 24,25,\ldots,32 \text{ and } j = 30,31,32,33,\ 40,41,42,43,44 \tag{9}$$

$$z_j + d_i^- - d_i^+ = a_i \quad \text{for } i = 33,34,\ldots,37 \text{ and } j = 50,51,52,53,\ 60 \tag{10}$$

where, for $i = 8,9,\ldots,37$ a_i = the number of man-years targeted for each project in the proposed program as shown in Table 3-2; d_i^- = negative deviation from the proposed assignment and d_i^+ = excess staffing provided to a project by a solution of the model.

A solution of the model consists of computing numeric values (in man-years) for the decision variables, x_j, y_j, and z_j, in such a manner that the values satisfy the complete set of goal constraints in accordance with the priorities assigned to the 50 goal criteria.

TABLE 3-7. PROJECT DIVERSITY COEFFICIENTS (INVESTMENT PROGRAM)

Variable	s_j Service versatility score	m_j % of proposed manpower allocation	$D_j = \prod s_j m_j$ Project Diversity
y_{30}	5	0	0
y_{31}	6	.007	.042
y_{32}	5	.011	.055
y_{33}	2	.002	.004
y_{40}	4	.011	.044
y_{41}	4	.015	.060
y_{42}	4	.042	.168
y_{43}	6	.037	.222
y_{44}	5	.061	.305

F. Overall Program Balance

The modeling of user service goals can be rather complicated and involve a large number of program inter-relationships in the construction of the goal constraints. In order to set forth a general procedure for achieving balance among program goals, the goal programming approach provides a mechanism for stating explicit program targets involving discrete service values common to most information service agencies. Certain targets are provided in terms of (a) the proportion of service that the administration wishes to have provided to various classes of users, and (b) the distribution of service resources (labor) among service programs for which the agency is accountable to its parent organization.

The following set of goal constraints specify what the administrators in the agency under study regard as a balanced level of program responsiveness to the organization's information service goals.

F.1 Classes of Users Being Served

The classes of users for which management has expressed particular concern are:

- RDT&E managers
- RDT&E scientists and engineers
- Libraries and other intermediary information agencies

Service Ratio (Managers to Scientists and Engineers)

Administrators who provided a definition of goals for use in the present model were naturally concerned with providing services to support the needs of RDT&E managers. Many such administrators were themselves in fact users of the management type services.

However, it was necessary to recognize that the bulk of the agency's responsibilities is related to the technical report program, which is principally useful to scientists and engineers. Goal criteria a_{38} specifies a desired ratio of 1 to 7 (1:7) between man-year services to support managers and man-year services to support scientists and engineers. The service ratio goal constraint can be expressed as follows:

$$\left((7)\left(x_{10} + x_{11} + x_{13} + x_{14} + x_{15} + x_{16}\right)\right) - \Big(x_{12} + \sum_{j=17}^{19} x_j + \sum_{j=21}^{25} x_j + \sum_{j=30}^{32} y_j\Big) + d_{38}^{-} - d_{38}^{+} = 0 \qquad (11)$$

where x_{10}, x_{11}, x_{13}, x_{14}, x_{15} and x_{16} have been designated by management as essential to serving managers, and x_{12}, x_{17}, x_{18}, x_{19}, x_{21} through x_{25} and y_{30} through y_{32} are designated as services primarily for scientists and engineers.

Service to Libraries

Management considers libraries, which often act as intermediaries between the agency and its user constituency, to be valuable surrogates for distributing the agency's services and products. In addition, libraries help alleviate the problems inherent in providing a nation-wide service to a large heterogeneous community from one central location. Consequently, management has expressed specific goals for meeting estimated demands from libraries.

One of the most important determinants of the agency's performance with respect to serving libraries is its capability to process technical report requests, project x_{22}. If we assume that for the labor resources allocated to project x_{22} the first commitment is to process requests received directly from individual users, then only resources over and above those needed for direct service can be utilized for serving libraries. In order to permit management to specify (1) a minimum level of staffing for technical report processing that would serve direct user requests, (2) a level of staffing to provide at least minimum support to libraries, and (3) a level of staffing to accommodate maximum support to libraries, the following goal constraints can be formulated:

$$P_{22} \quad x_{22} + d_{39}^- - d_{39}^+ = a_{39} \tag{12}$$

$$P_{22} \quad x_{22} + d_{40}^- - d_{40}^+ = a_{40} \tag{13}$$

$$P_{22} \quad x_{22} + d_{41}^- - d_{41}^+ = a_{41} \tag{14}$$

P_{22} is a function of productivity calculated from operational data as follows: $P_{22} = \frac{O_{22}}{M_{22}}$

where O_{22} = total estimated output demand for technical reports from project x_{22} in the 1978 planning period and M_{22} = total estimated man-years of effort required by project x_{22}. For 1978, management has provided the following data: O_{22} = 366,000 technical report requests, M_{22} = 62 man-years. Therefore, P_{22} = 5903 technical report requests processed per man-year.

a_{39} = 97% of O_{22} (or 355,020 technical reports), which management estimates is the level of direct demand from users. a_{40} = 3% over a_{39} (or 365,671 technical reports), which management estimates would be sufficient to provide a minimum level of service to libraries. a_{41} = 10% over a_{39} (or 390,522 technical reports), which management estimates would allow maximum service to libraries.

d_{39}^- = the number of technical report requests less than the minimum needed to serve users directly (a_{39}) which the staff of project x_{22} will be able to process and d_{39}^+ = any excess capability over the minimum needed to serve users. d_{40}^- = the number of technical reports less than the minimum needed to serve libraries which the staff will be able to process and d_{40}^+ = any excess capability over the minimum needed to serve libraries. d_{41}^- = the number of technical reports less than the maximim needed to serve libraries, and d_{41}^+= excess capability for processing technical reports over the maximum estimated need.

F.2 Balance Among Four Information Service Goals

An important consideration in evaluating the appropriateness of a given information service program for a specific organizational environment is the proportional distribution of resources relative to the functions for which the information service is accountable. Hence, an optimal program is one where the resources are utilized for the purposes management intends them to be used. This consideration can be viewed as a problem of achieving a well-balanced program in which specific service function levels, in terms of the percentage of labor devoted to certain functions, are designated as performance targets for the information program. The levels may then appear in the goal constraints as explicit values to be attained. The present model takes account of four information service functions that were of interest to the agency's administrators:

- Providing access to information as opposed to documents
- Providing access to agency-held documents
- Providing remote access to documents and information
- Promoting the use of information products and services

For the first three service functions represented in the model, discrete goal values could be identified by the administrators for both the basic services and the investment effort. For the fourth service function, the basic/investment distinction was not relevant. The remainder of this section is concerned with formulating seven goal constraints to represent the desired balance among the above four information service goals that the agency's administrators have deemed appropriate to achieve.

I. Desired Proportion of the 1978 Program Concerned with Providing Access to Information (as Opposed to Documents)

The first information service function of interest to management involves the percentage of the total basic labor force which is devoted to providing information services as opposed to documents. The desired percentage (a_{42}) can be achieved by minimizing d_{42}^- and d_{42}^+ for the basic component of the program in the following goal constraint:

$$\left(\sum_{j=10}^{25} I_{42j} x_j + \sum_{j=30}^{44} I_{42j} y_j + \sum_{j=50}^{60} I_{42j} z_j \right) - \qquad (15)$$

$$\left((a_{42}) \left(\sum_{j=10}^{25} x_j + .8(y_{40} + y_{41}) + .4y_{42} + .5y_{43} + z_{52} \right) \right) +$$

$$d_{42}^- - d_{42}^+ = 0$$

where I_{42j} = information service coefficients that indicate management's identification of the jth project with regard to its fulfilling organizational goal criterion a_{42}. Zero indicates it does not serve this function, 1 indicates it serves the function fully. Values less than 1 indicate the percentage of the program contributing to goal a_{42}. Values for I_{42j} are shown in the first column of Table 3-8. d_{42}^- = negative deviation from the desired goal and d_{42}^+ = over emphasis of this goal.

TABLE 3-8. VALUES OF INFORMATION SERVICE COEFFICIENTS

	I_{42j}	I_{43j}	I_{44j}	I_{45j}	I_{46j}	I_{47j}	I_{48j}
x_{10}	1	0	0	0	0	0	0
x_{11}	1	0	0	0	0	0	0
x_{12}	1	0	0	0	0	0	0
x_{13}	1	0	0	0	0	0	0
x_{14}	1	0	0	0	0	0	0
x_{15}	1	0	0	0	0	0	0
x_{16}	1	0	0	0	0	0	0
x_{17}	1	0	1	0	0	0	0
x_{18}	1	0	1	0	0	0	0
x_{19}	1	0	1	0	0	0	0
x_{20}	0	0	1	0	.044	0	0
x_{21}	0	0	1	0	0	0	0
x_{22}	0	0	1	0	0	0	0
x_{23}	0	0	1	0	0	0	0
x_{24}	0	0	0	0	0	0	0
x_{25}	0	0	1	0	0	0	0
y_{30}	0	1	0	1	0	0	0
y_{31}	0	1	0	0	0	1	0
y_{32}	0	1	0	0	0	0	0
y_{33}	0	1	0	1	0	0	0
y_{40}	.80	.20	0	0	0	0	0
y_{41}	0	0	.80	.20	0	0	0
y_{42}	.40	.60	0	0	0	0	0
y_{43}	.50	.50	.50	.50	.50	0	0
y_{44}	0	1	0	1	0	0	0
z_{50}	0	0	0	0	0	0	0
z_{51}	0	0	1	0	0	0	1

TABLE 3-8. (Continued)

	I_{42j}	I_{43j}	I_{44j}	I_{45j}	I_{46j}	I_{47j}	I_{48j}
z_{52}	1	0	0	0	0	0	0
z_{53}	0	0	0	0	0	0	0
z_{60}	0	0	0	0	0	0	0
Goal Criteria	a_{42}	a_{43}	a_{44}	a_{45}	a_{46}	a_{47}	a_{48}
Desired Percentage	18%	25%	52%	25%	10%	15%	5%

For the investment aspect of the 1978 program the analogous goal constraint concerning access to information is expressed by:

$$\left(\sum_{j=10}^{25} I_{43j}x_j + \sum_{j=30}^{44} I_{43j}y_j + \sum_{j=50}^{60} I_{43j}z_j\right) -$$

$$\left(\left(a_{43}\right)\left(\sum_{j=30}^{33} y_j + .2(y_{40} + y_{41}) + .6y_{42} + .5y_{43} + y_{44}\right)\right) +$$

$$d_{43}^{-} - d_{43}^{+} = 0 \qquad (16)$$

where I_{43j} = the contribution of the jth project with regard to goal criterion a_{43}. Values of I_{43j} are found in Table 3-8.

II. <u>Desired Proportion of the 1978 Program Concerned with Providing Access to Documents</u>

Goal criterion a_{44} concerns management's desire to have 52% of its basic program devoted to providing access to documents. The goal criterion encompasses projects concerned with placing documents into the agency's inventory as well as those projects concerned with retrieving documents on demand. The general goal constraint can be expressed by:

$$\left(\sum_{j=10}^{25} I_{44j}x_j + \sum_{j=30}^{44} I_{44j}y_j + \sum_{j=50}^{60} I_{44j}z_j\right) -$$

$$\left(\left(a_{44}\right)\left(\sum_{j=10}^{25} x_j + .8(y_{40} + y_{41}) + .4y_{42} + .5y_{43} + z_{52}\right)\right) +$$

$$d_{44}^{-} - d_{44}^{+} = 0 \qquad (17)$$

where I_{44j} = information service coefficients from Table 3-8 that identify the 1978 projects associated with goal criterion a_{44}.

For the investment aspects of the program, where management has assigned a value of 25% to goal criterion a_{45}, the goal constraint is:

$$\left(\sum_{j=10}^{25} I_{45j}x_j + \sum_{j=30}^{44} I_{45j}y_j + \sum_{j=50}^{60} I_{45j}z_j\right) -$$

$$\left(\left(a_{45}\right)\left(\sum_{j=30}^{33} y_j + .2(y_{40} + y_{41}) + .6y_{42} + .5y_{43} + y_{44}\right)\right) +$$

$$d_{45}^{-} - d_{45}^{+} = 0 \qquad (18)$$

where I_{45j} = information service coefficients from Table 3-8 for goal criterion a_{45}.

III. <u>Desired Proportion of the 1978 Program Concerned with Providing Remote Access to Documents and Information</u>

A third information service function of interest to management is concerned with providing remote access to the agency's documents and information. On-line terminal access to the agency's data bases is included in this goal. The general goal constraint for the basic program for this third information function is expressed by:

$$\left(\sum_{j=10}^{25} I_{46j}x_j + \sum_{j=30}^{44} I_{46j}y_j + \sum_{j=50}^{60} I_{46j}z_j \right) -$$

$$\left(\left| a_{46} \right| \left(\sum_{j=10}^{25} x_j + .8(y_{40} + y_{41}) + .4y_{42} + .5y_{43} + z_{52} \right) \right) +$$

$$d_{46}^{-} - d_{46}^{+} = 0 \tag{19}$$

where I_{46j} = information service coefficients from Table 3-8 that identify the projects associated with goal criterion a_{46}.

The analogous goal constraint for the investment aspect of the program concerned with improving the agency's capability to provide remote access service is expressed by:

$$\left(\sum_{j=10}^{25} I_{47j}x_j + \sum_{j=30}^{44} I_{47j}y_j + \sum_{j=50}^{60} I_{47j}z_j \right) -$$

$$\left(\left| a_{47} \right| \left(\sum_{j=30}^{33} y_j + .2(y_{40} + y_{41}) + .6y_{42} + .5y_{43} + y_{44} \right) \right) +$$

$$d_{47}^{-} - d_{47}^{+} = 0 \tag{20}$$

where I_{47j} = the information service coefficients from Table 3-8 for goal criterion a_{47}.

IV. Desired Proportion of the 1978 Program Concerned with Promoting Information Products and Services

The fourth of the information service goals with which management expressed concern has to do with promoting the use of information products and services. Proceding on the assumption that the effective use of prior R&D findings represented savings in time and money to the government, management reasoned that special efforts were desirable to encourage and train potential users of the agency's systems to utilize its materials and services. The goal can be expressed by:

$$\left(\sum_{j=10}^{25} I_{48j}x_j + \sum_{j=30}^{44} I_{48j}y_j + \sum_{j=50}^{60} I_{48j}z_j\right) -$$

$$\left(\left(a_{48}\right)\left(\sum_{j=10}^{25} x_j + .8(y_{40} + y_{41}) + .4y_{42} + .5y_{43} + z_{52}\right)\right) +$$

$$d_{48}^{-} - d_{48}^{+} = 0 \qquad (21)$$

where I_{48j} = information service coefficients from Table 3-8 that identify the projects responsible for promoting the use of the agency's services.

G. Timeliness of Service to Users

In addition to incorporating balance among information service goals, the goal programming approach can also specify the level of resources to be used to meet service criteria valued by various classes of users. For example, the management of the agency under study chose to specify that the agency's services should have the characteristics of (a) timeliness and (b) archival comprehensiveness. If certain ones of the 1978 projects are identified as being able to satisfy either criterion, then goal constraints representing these user needs can be included in the model. Table 3-9 identifies the projects in the 1978 program budget that fulfill the two "user

TABLE 3-9. VALUES OF USER NEED COEFFICIENTS

	T_j	A_j
x_{10}	0	0
x_{11}	0	0
x_{12}	0	0
x_{13}	0	0
x_{14}	0	0
x_{15}	0	0
x_{16}	0	0
x_{17}	1	0
x_{18}	1	0
x_{19}	1	0
x_{20}	0	1
x_{21}	0	0
x_{22}	0	0
x_{23}	0	0
x_{24}	0	0
x_{25}	0	0
y_{30}	0	0
y_{31}	0	0
y_{32}	0	0
y_{33}	0	0
y_{40}	0	0
y_{41}	0	0
y_{42}	0	0

TABLE 3-9. (Continued)

	T_j	A_j
y_{43}	1	0
y_{44}	0	0
z_{50}	0	0
z_{51}	0	0
z_{52}	0	0
z_{53}	0	0
z_{60}	0	0
Desired Percentages	20%	20%

need" criteria of timeliness of service (T_j) and archival comprehensiveness (A_j). Zero in the table indicates that a project does not meet the specified criterion while a 1 indicates that it does.

The first "user need" goal identified by management concerns the need for users to have timely service. Computer services, particularly the on-line services, are the key factor in meeting this goal, according to management. The goal is expressed by the following constraint:

$$\left(\sum_{j=10}^{25} T_j x_j + \sum_{j=30}^{44} T_j y_j + \sum_{j=50}^{60} T_j z_j \right) -$$

$$\left(\left[a_{49} \right] \left(\sum_{j=10}^{25} x_j + .8(y_{40} + y_{41}) + .4y_{42} + .5y_{43} + z_{52} \right) \right) +$$

$$d_{49}^{-} - d_{49}^{+} = 0 \tag{22}$$

where T_j = the timeliness coefficients from Table 3-9 that identify the projects associated with goal criterion a_{49}.

H. <u>Archival Comprehensiveness of the Agency's Collection</u>

The final user need goal expressed by management concerns the need for the agency to maintain a comprehensive collection of materials. Two purposes are served by this goal. First, users who value the capability to retrieve all materials relevant to their research interests from one agency would be served by this criterion. Second, from the parent organization's point of view, it is necessary for the agency to provide an archival service to conserve the organization's extensive investment in scientific and technical research and development. This goal is achieved by minimizing d_{50}^- and d_{50}^+ in the following constraint:

$$\left(\sum_{j=10}^{25} A_j x_j + \sum_{j=30}^{44} A_j y_j + \sum_{j=50}^{60} A_j z_j \right) -$$

$$\left(\left(a_{50} \right) \left(\sum_{j=10}^{25} x_j + .8(y_{40} + y_{41}) + .4y_{42} + .5y_{43} + z_{52} \right) \right) +$$

$$d_{50}^- - d_{50}^+ = 0 \qquad (23)$$

where A_j = the archival comprehensiveness coefficients from Table 3-9 that identify the projects responsible for archival functions.

3.4 SUMMARY OF THE MODEL

A summary of the complete model is now presented. The formulation presented in this chapter is a realistic model of the decision environment described in the study. However, it should be recognized that there could be any number of variations of the model, some of which might be even more suitable for application than the formulation developed here. Indeed, additional variables or a finer breakdown of the 30 program variables presented here might have added more precision to the analysis, which follows in Chapter IV. Additional constraints, too, might have provided the model with greater sensitivity. Nevertheless, the primary concern of this first application of the goal programming approach to the information services field is with the demonstration and development of the methodology.

This chapter has illustrated the general methodology through applying the goal programming approach to the development of a model for resource allocation and program evaluation in the information services environment. The next and final chapter demonstrates the application and solution capability of the model for decision making. In that chapter, three solutions will be developed and analyzed. The first solution is intended to demonstrate how goal programming solutions provide insights to the decision environment that often result in modifications of the model that are based on the decision maker's new perspective of the decision problem. The second solution is based on a significant revision of the model to demonstrate the flexibility of goal programming in dealing with parameter changes. The third solution demonstrates how the model provides insights to the cost/benefit trade-offs involved in alternative priority structures.

As the iterative manner in which the goal programming approach proceeds is demonstrated, one may be impressed with the number of alternative model formulations that are suggested with each solution. Thus, it will be apparent that the three solutions presented in Chapter IV represent only a limited number of modifications that a decision maker would be likely to explore before accepting a final solution as satisfactory.

There now follows a complete summary of the model formulation that will be used in Chapter IV to obtain the first solution of the model. Subsequent formulations for additional solutions will be explained in detail in Chapter IV as the analysis proceeds.

A. Objective Function and Priority Structure

First solution: Minimize $Z = P_1(d_2^-) + P_2(d_1^+) + P_3(d_{39}^- + d_{40}^- + d_{41}^+) + P_4(d_{38}^- + d_{42}^- + d_{43}^- + d_{44}^- + d_{45}^- + d_{46}^- + d_{47}^- + d_{48}^- + d_{49}^- + d_{50}^- + d_{38}^+ + d_{42}^+ + d_{43}^+ + d_{44}^+ + d_{45}^+ + d_{46}^+ + d_{47}^+ + d_{48}^+ + d_{49}^+ + d_{50}^+) + P_5(d_4^- + d_6^-) + P_6(d_5^- + d_7^-) + P_7(d_8^- + d_9^- + d_{10}^- + d_{11}^- + d_{12}^- + d_{13}^- + d_{14}^- + d_{15}^- + d_{16}^- + d_{17}^- + d_{18}^- + d_{19}^- + d_{20}^- + d_{21}^- + d_{22}^- + d_{23}^- + d_{24}^- + d_{25}^- + d_{26}^- + d_{27}^- + d_{28}^- + d_{29}^- + d_{30}^- + d_{31}^- + d_{32}^- + d_{33}^- + d_{34}^- + d_{35}^- + d_{36}^- + d_{37}^-) + P_8(d_3^+)$

B. Goal Constraints (Reference to text)

Maximum Allowable Staff

$$\sum_{j=10}^{25} x_j + \sum_{j=30}^{44} y_j + \sum_{j=50}^{60} z_j + d_1^- - d_1^+ = 491 \qquad (1)$$

Minimum Number of Staff

$$\sum_{j=10}^{25} x_j + \sum_{j=30}^{44} y_j + \sum_{j=50}^{60} z_j + d_2^- - d_2^+ = 454 \qquad (2)$$

Total Labor Cost

$$\sum_{j=10}^{25} c_j x_j + \sum_{j=30}^{44} c_j y_j + \sum_{j=50}^{60} c_j z_j + d_3^- - d_3^+ = 0 \qquad (3)$$

Ratio of Basic to Investment Services

$$\left(\sum_{j=10}^{25} x_j + .80(y_{40} + y_{41}) + .40y_{42} + .50y_{43} + z_{52}\right) - \left(.85\left(\sum_{j=10}^{25} x_j + \sum_{j=30}^{44} y_j + z_{52}\right)\right) + d_4^- - d_4^+ = 0 \tag{4}$$

Basic Program Diversity

$$\sum_{j=10}^{25} D_j x_j + .80(D_{40}y_{40} + D_{41}y_{41}) + .40(D_{42}y_{42}) + .50(D_{43}y_{43}) + D_{52}z_{52} + d_5^- - d_5^+ = 363 \tag{5}$$

Ratio of Investment Services to Basic Services

$$\left(\sum_{j=30}^{33} y_j + .20(y_{40} + y_{41}) + .60y_{42} + .50y_{43} + y_{44}\right) - \left(.15\left(\sum_{j=10}^{25} x_j + \sum_{j=30}^{44} y_j + z_{52}\right)\right) + d_6^- - d_6^+ = 0 \tag{6}$$

Investment Program Diversity

$$\sum_{j=30}^{33} D_j y_j + .20(D_{40}y_{40} + D_{41}y_{41}) + .60D_{42}y_{42} + .50D_{43}y_{43} + D_{44}y_{44} + d_7^- - d_7^+ = 68 \tag{7}$$

Individual Target Levels for the 30 Projects

- Basic Projects (8)

$$x_{10} + d_8^- - d_8^+ = 13$$
$$x_{11} + d_9^- - d_9^+ = 13$$
$$x_{12} + d_{10}^- - d_{10}^+ = 1$$
$$x_{13} + d_{11}^- - d_{11}^+ = 2$$
$$x_{14} + d_{12}^- - d_{12}^+ = 1$$
$$x_{15} + d_{13}^- - d_{13}^+ = 4$$
$$x_{16} + d_{14}^- - d_{14}^- = 2$$
$$x_{17} + d_{15}^- - d_{15}^+ = 5$$
$$x_{18} + d_{16}^- - d_{16}^+ = 2$$
$$x_{19} + d_{17}^- - d_{17}^+ = 2$$
$$x_{20} + d_{18}^- - d_{18}^+ = 91$$
$$x_{21} + d_{19}^- - d_{19}^+ = 10$$
$$x_{22} + d_{20}^- - d_{20}^+ = 62$$
$$x_{23} + d_{21}^- - d_{21}^+ = 7$$
$$x_{24} + d_{22}^- - d_{22}^+ = 1$$
$$x_{25} + d_{23}^- - d_{23}^+ = 23$$

- Investment Projects (9)

$$y_{30} + d_{24}^- - d_{24}^+ = 24$$
$$y_{31} + d_{25}^- - d_{25}^+ = 3$$
$$y_{32} + d_{26}^- - d_{26}^+ = 5$$
$$y_{33} + d_{27}^- - d_{27}^+ = 1$$
$$y_{40} + d_{28}^- - d_{28}^+ = 5$$
$$y_{41} + d_{29}^- - d_{29}^+ = 7$$

$$y_{42} + d_{30}^{-} - d_{30}^{+} = 19$$

$$y_{43} + d_{31}^{-} - d_{31}^{+} = 17$$

$$y_{44} + d_{32}^{-} - d_{32}^{+} = 25$$

- Management and Administration (10)

$$z_{50} + d_{33}^{-} - d_{33}^{+} = 80$$

$$z_{51} + d_{34}^{-} - d_{34}^{+} = 4$$

$$z_{52} + d_{35}^{-} - d_{35}^{+} = 19$$

$$z_{53} + d_{36}^{-} - d_{36}^{+} = 5$$

$$z_{60} + d_{37}^{-} - d_{37}^{+} = 15$$

Overall Program Balance: Ratio of Services to Managers vs. Scientists and Engineers

$$\left|(7)\ (x_{10} + x_{11} + x_{13} + x_{14} + x_{15} + x_{16})\right| - \left|x_{12} + \sum_{j=17}^{19} x_j + \sum_{j=21}^{25} x_j + \sum_{j=30}^{32} y_j\right| + d_{38}^{-} - d_{38}^{+} = 0 \qquad (11)$$

Service to Libraries

- Base-line Services for Direct Users

$$P_{22}x_{22} + d_{39}^{-} - d_{39}^{+} = 355{,}020 \qquad (12)$$

- Minimum Service for Libraries

$$P_{22}x_{22} + d_{40}^{-} - d_{40}^{+} = 365{,}671 \qquad (13)$$

- Maximum Service for Libraries

$$P_{22}x_{22} + d_{41}^{-} - d_{41}^{+} = 390{,}522 \qquad (14)$$

Overall Program Balance: Balance Among the Following Four Information Service Goals

(1) Providing Access to Information (as Opposed to Documents)

- Basic Program

$$\left(\sum_{j=10}^{25} I_{42j}x_j + \sum_{j=30}^{44} I_{42j}y_j + \sum_{j=50}^{60} I_{42j}z_j \right) -$$

$$\left(\left(.18\right) \left(\sum_{j=10}^{25} x_j + .8(y_{40} + y_{41}) + .4y_{42} + .5y_{43} + z_{52} \right) \right) +$$

$$d_{42}^{-} - d_{42}^{+} = 0 \qquad (15)$$

- Investment Program

$$\left(\sum_{j=10}^{25} I_{43j}x_j + \sum_{j=30}^{44} I_{43j}y_j + \sum_{j=50}^{60} I_{43j}z_j \right) -$$

$$\left(\left(.25\right) \left(\sum_{j=30}^{33} y_j + .2(y_{40} + y_{41}) + .6y_{42} + .5y_{43} + y_{44} \right) \right) +$$

$$d_{43}^{-} - d_{43}^{+} = 0 \qquad (16)$$

(2) Providing Access to Documents

- Basic Program

$$\left(\sum_{j=10}^{25} I_{44j}x_j + \sum_{j=30}^{44} I_{44j}y_j + \sum_{j=50}^{60} I_{44j}z_j \right) -$$

$$\left(\left(.52\right) \left(\sum_{j=10}^{25} x_j + .8(y_{40} + y_{41}) + .4y_{42} + .5y_{43} + z_{52} \right) \right) +$$

$$d_{44}^{-} - d_{44}^{+} = 0 \qquad (17)$$

- Investment Program

$$\left(\sum_{j=10}^{25} I_{45j}x_j + \sum_{j=30}^{44} I_{45j}y_j + \sum_{j=50}^{60} I_{45j}z_j\right) -$$

$$\left(\left(.25\right)\left(\sum_{j=30}^{33} y_j + .2(y_{40} + y_{41}) + .6y_{42} + .5y_{43} + y_{44}\right)\right) +$$

$$d_{45}^{-} - d_{45}^{+} = 0 \qquad (18)$$

(3) Providing Remote Access to Documents and Information

- Basic Program

$$\left(\sum_{j=10}^{25} I_{46j}x_j + \sum_{j=30}^{44} I_{46j}y_j + \sum_{j=50}^{60} I_{46j}z_j\right) -$$

$$\left(\left(.1\right)\left(\sum_{j=10}^{25} x_j + .8(y_{40} + y_{41}) + .4y_{42} + .5y_{43} + z_{52}\right)\right) +$$

$$d_{46}^{-} - d_{46}^{+} = 0 \qquad (19)$$

- Investment Program

$$\left(\sum_{j=10}^{25} I_{47j}x_j + \sum_{j=30}^{44} I_{47j}y_j + \sum_{j=50}^{60} I_{47j}z_j\right) -$$

$$\left(\left(.15\right)\left(\sum_{j=30}^{33} y_j + .2(y_{40} + y_{41}) + .6y_{42} + .5y_{43} + y_{44}\right)\right) +$$

$$d_{47}^{-} - d_{47}^{+} = 0 \qquad (20)$$

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(4) Promoting Information Products and Services

$$\left(\sum_{j=10}^{25} I_{48j}x_j + \sum_{j=30}^{44} I_{48j}y_j + \sum_{j=50}^{60} I_{48j}z_j\right) -$$

$$\left(\left(.05\right)\left(\sum_{j=10}^{25} x_j + .8(y_{40} + y_{41}) + .4y_{42} + .5y_{43} + z_{52}\right)\right) +$$

$$d^-_{48} - d^+_{48} = 0 \qquad (21)$$

Overall Program balance: Timeliness of Service to Users

$$\left(\sum_{j=10}^{25} I_{49j}x_j + \sum_{j=30}^{44} I_{49j}y_j + \sum_{j=50}^{60} I_{49j}z_j\right) -$$

$$\left(\left(.2\right)\left(\sum_{j=10}^{25} x_j + .8(y_{40} + y_{41}) + .4y_{42} + .5y_{43} + z_{52}\right)\right) +$$

$$d^-_{49} - d^+_{49} = 0 \qquad (22)$$

Overall Program Balance: Archival Comprehensiveness of the Agency's Collection

$$\left(\sum_{j=10}^{25} I_{50j}x_j + \sum_{j=30}^{44} I_{50j}y_j + \sum_{j=50}^{60} I_{50j}z_j\right) -$$

$$\left(\left(.2\right)\left(\sum_{j=10}^{25} x_j + .8(y_{40} + y_{41}) + .4y_{42} + .5y_{43} + z_{52}\right)\right) +$$

$$d^-_{50} - d^+_{50} = 0 \qquad (23)$$

CHAPTER IV. RESULTS, ANALYSIS AND CONCLUSIONS

In Chapter III a formulation of the goal programming model was developed for the information services field. The terminology and notations developed in that chapter will be followed here in the analysis of the model. As the concluding chapter of the dissertation, it remains for us to demonstrate how the goal programming model formulated in the last chapter can be applied in order to obtain a solution of the model that will be satisfactory to the decision maker within the limits of the resource constraints and goal priority structure set by management.

As we indicated in Chapter III, a major advantage of the goal programming approach is that it can provide the decision maker with an iterative tool for the optimization of possibly conflicting objectives in a decision environment often characterized by limited resources. This feature of goal programming is based on the fact that the model provides the best solution possible for any given set of constraints and goal priority structure: modify the constraints and/or priority structure in the model, and the solution itself undergoes modification. Hence, where the model yields a solution that shows some goals cannot be achieved under the desired policy and where trade-offs must therefore occur due to limited resources, the goal programming approach allows judicious use to be made of this information by providing the decision maker the option of redefining or requantifying objectives and constraints as well as critically reviewing and re-ordering the goal priorities in order to obtain a new solution more satisfying than the previous one. In this manner the model has the capability of undergoing repeated reformulation until a solution is obtained that represents for the decision maker an acceptable allocation of limited resources for achieving a set of potentially conflicting objectives.

Goal programming solutions provide three principal types of information: (1) identification of the optimal resource allocation for achieving all desired goals as nearly as possible, (2) the degree of goal attainment achieved under the given constraints and priority structure of the goals, and (3) the relative degree of goal attainment provided by alternative goal priority structures and goal levels. In addition, goal programming solutions can provide valuable insight concerning the points of conflict within a given decision environment. Moreover, analysis of the effects of parameter changes involving variations of goal levels and priority structures can show trade-offs such as the cost/benefit implications of altering planning goals and objectives. For this dissertation, the latter two features are particularly interesting because they can be exploited to help resolve goal conflicts among various levels of management and/or various user constituents of an information service agency. When goal conflicts are not resolved, contradictory criteria often thwart program evaluation efforts.

In order to demonstrate the goal programming approach, the next three sections of the chapter show the results of modifying several constraints and incorporating three different goal priority structures into the objective function of the basic model formulated in the preceding chapter. For the initial assignment of goal priorities incorporated in the formulation shown in Chapter III, a computer solution of the model is obtained and presented in section 4.1.[1] The results of this first solution are painstakingly analyzed, and the reasons are fully explained why and how the goal priority structure and constraints of the model are modified in order to obtain a second solution of the model. The ramifications of this solution are discussed in section 4.2, as well as the rationale for modifying the model a third time. The results of the latter and final modification of the model are presented in section 4.3. Section 4.4 closes the dissertation by considering several major research findings that result from the study.

4.1 THE FIRST SOLUTION OF THE MODEL

Recall from Chapter III that the proposed program for which specific target levels of staffing had been set (a_8 - a_{37}) was listed as the seventh goal priority (P_7) in the initial model. It was followed only by the general cost minimization goal (a_3), which had been assigned the lowest priority (P_8). The purpose of the latter assignment, in effect, was to eliminate cost as a factor in the solution by showing the calculated cost of the solution as positive deviation (d_3^+) when the goal level of a_3 is equal to zero. At priority levels one through six (P_1 to P_6), the service and fiscal

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[1]A modified simplex algorithm, programmed in FORTRAN IV by Lee (58, Chapter 6), was used on the Rutgers IBM 370 computer for computation of the three solutions presented in this chapter.

goals provided by the agency's administrators from various management levels were listed. This initial priority structure was intended to superimpose a set of organizational goals, represented by the administrators' service and fiscal goals, upon a proposed program plan in order to determine the compatibility of the program with the organizational goals. Essentially, as a low order goal, the program plan will be attained only if it is compatible with the goals that have been assigned higher priorities. For a detailed account of the first formulation of the model, the reader is referred to section 3.4 of Chapter III.

Results

The results of the first solution are shown in Tables 4-1 and 4-2. As Table 4-1 shows for the first solution, three goals have been fully achieved at a projected cost of $8,333,328. Goals not achieved include the overall program balance goal, the basic/investment program balance goal, and the goal to attain diversified services responsive to a wide range of user groups and user needs. Moreover, the 1978 proposed program plan (a_8 - a_{37}) was not supported by this first solution; only 12 of the 30 projects are represented in the solution (see Table 4-2). It is interesting to note that the calculated cost of the first solution is 5.3% less than the cost of the proposed program. (The cost of the proposed program is equal to the sum of the products of the cost per project man-year, c_j from Table 3-3 in Chapter III, times the proposed project staffing represented by a_8 - a_{37}, which is equal to $8,778,000.)

TABLE 4-1. GOAL ATTAINMENT FOR SOLUTION ONE

P_1	Staff limit at most 491	Achieved
P_2	Staff size at least 454	Achieved
P_3	Service to libraries	Achieved
P_4	Overall program balance	Not achieved
P_5	Basic/investment balance	Not achieved
P_6	Program diversity	Not achieved
P_7	Proposed program plan	Not achieved
P_8	Cost minimization	$8,333,328

TABLE 4-2. COMPUTED LABOR ALLOCATION IN MAN-YEARS FOR ACHIEVING ALL GOALS AS NEARLY AS POSSIBLE (SOLUTION ONE)

Data Base Services

x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}
0	20.9	0	0	0	0	0	<1	0	0
(13)	(13)	(1)	(2)	(1)	(4)	(2)	(15)	(2)	(2)

Technical Report Services

x_{20}	x_{21}	x_{22}	x_{23}	x_{24}	x_{25}
56.3	0	61.9	0	0	0
(91)	(10)	(62)	(7)	(1)	(23)

New Information Systems Investigations

y_{30}	y_{31}	y_{32}	y_{33}
42.2	42.2	0	0
(0)	(3)	(5)	(1)

Computer Systems

y_{40}	y_{41}	y_{42}	y_{43}	y_{44}
0	0	0	56.3	0
(5)	(7)	(19)	(17)	(25)

Management, Administration and Services to Other Agencies

x_{50}	z_{51}	z_{52}	z_{53}	z_{60}
148.4	4	1.6	5	15
(80)	(4)	(19)	(5)	(15)

Total = 454

Numbers in parentheses represent the original labor allocation in the 1978 program/budget.

The disparity between (a) the computed staff allocation plan represented in the initial solution, which attempted to provide a program responsive to the organizational goals, and (b) that of the proposed program demonstrates that the proposed program and the organizational goals are not in concert. However, it should also be noted that the organizational goals themselves are in conflict with each other. Ostensible conflict is indicated by the fact that goal priorities P_4, P_5 and P_6, representing key organizational goals, were not achieved. Recall from Chapter I that the goal programming solution is optimal at the point that any improvement of a low order goal (P_{k+1}) would conflict with the attainment of a higher order goal (P_k). Thus, our interest is directed toward goal levels P_4, P_5 and P_6 in order to gain insight to the goal conflicts indicated by the first solution.

Appendix A provides a comparison of the contribution of each decision and deviational variable to the objective function at each priority level as calculated for the first optimal solution. Recall that goal programming utilizes a simplex minimization procedure. In order to "improve" a solution, according to the algorithm, we must identify the variable making the largest positive contribution to the objective function (Z) at the highest unattained priority level and replace it. Appendix A has been highlighted to show that d_{45}^- and d_{47}^- are tied for the highest positive score at the fifth priority level. However, further study of Appendix A indicates that d_{45}^- and d_{47}^- have a non-positive contribution at the fourth priority level of the objective function. Thus, an improvement at the fifth priority level would be off-set by a deterioration at the fourth priority level. A direct conflict between priorities P_4 and P_5 is indicated.

A closer look at the solution indicates the reason for the conflict. Table 4-3 shows a comparison of the deviations associated with the conflicting goals. At priority level P_5, row 4, which is concerned with allocating 85% of the resources to basic products and services, is underachieved by approximately 70 man-years. Row 6, concerned with the investment program, is over attained by an equal amount. When these values are used to compute a basic to investment ratio for solution one, the ratio is seen to be 60:40 rather than the 85:15 called for by management. Now consider that priority four (P_4) is also concerned with the distribution of resources among basic and investment efforts. Note that both rows 45 and 47, which we recall from Chapter III are investment goals, are fully attained with neither positive nor negative deviation indicated in the solution. Obviously, a program more oriented to the basic products and services, namely one that approximates 85% of the total service program, can be had at the expense of 70 man-years of staff drawn from either or both the investment service goals to improve access to documents (a_{45}) and provide remote access services (a_{47}).

Another matter of interest in the solution concerns the reasons underlying the allocation of labor resources for the 30 projects shown in Table 4-2. The largest allocation (33%) is for management and administration efforts. The reason for this can be accounted for by the lack of involvement of general administration (z_{50}) in the decision structure at fourth, fifth and sixth priority levels. This fact can be confirmed by referring to Table 3-8 and

TABLE 4-3. VALUES OF THE DEVIATIONAL VARIABLES IN SOLUTION ONE

Goal Criteria Values		Deviation		Conflicting Goals
	a_i	d_i^+	d_i^-	
1	491	0.0	37.0	
2	454	0.0	0.0	
3	0	8333.3	0.0	
4	0	0.0	70.0	P_5
5	363	0.0	282.6	
6	0	70.4	0.0	P_5
7	68	0.0	60.0	
8	13	0.0	13.0	
9	13	7.9	0.0	
10	1	0.0	1.0	
11	2	0.0	2.0	
12	1	0.0	1.0	
13	4	0.0	4.0	
14	2	0.0	2.0	
15	15	0.0	14.9	
16	2	0.0	2.0	
17	2	0.0	2.0	
18	91	0.0	35.0	
19	10	0.0	10.0	
20	62	0.0	0.1	
21	7	0.0	7.0	
22	1	0.0	1.0	
23	23	0.0	23.0	
24	0	42.2	0.0	
25	3	39.2	0.0	
26	5	0.0	5.0	
27	1	0.0	1.0	
28	5	0.0	5.0	
29	7	0.0	7.0	
30	19	0.0	19.0	
31	17	39.3	0.0	
32	25	0.0	25.0	
33	80	68.4	0.0	
34	4	0.0	0.0	
35	19	0.0	17.4	
36	5	0.0	0.0	
37	15	0.0	0.0	
38	0	0.0	0.0	P_4
39	355020	10652.4	0.0	
40	365671	0.0	0.0	
41	390522	0.0	24851.0	
42	0	0.0	0.0	
43	0	42.2	0.0	
44	0	0.0	0.0	
45	0	0.0	0.0	
46	0	2.5	0.0	P_4
47	0	0.0	0.0	
48	0	0.0	10.1	
49	0	0.0	0.0	
50	0	0.0	0.0	

goal constraints (4) and (5) in Chapter III. Thus, the assigned priority structure for the first solution allows maximum flexibility regarding this category of labor. This means that excessive allocation of labor to the management and administrative program elements is not restrained by any of the program balance goals. Consequently, a constraint probably should be added to the model which puts a ceiling on the level of general administrative staff desired.

The allocation of 61.9 man-years of effort to the technical report distribution service (x_{22}) is easily accounted for by the high priority (P_3) given to service to libraries, which is a service solely assigned to project x_{22}.

The remaining allocations relate to the sixth priority level (P_6), which is concerned with program diversity. Table 4-4 shows a comparison of the labor allocation results with the diversity coefficients computed for the goal constraint equations (5) and (7) in Chapter III. Considering that the goals to achieve a desired balance of service were attempted at priority levels P_4 and P_5, and thus bore a dominant influence on the first solution, we can observe a fairly consistent relationship between the projects which received resources and those with relatively high diversity coeffieients. While the relationship is not strictly proportionate, it should be observed that in the four categories of projects shown, the resources tend to be concentrated in projects with the highest or second highest values of D_j.

TABLE 4-4. COMPARISON OF LABOR ALLOCATION RESULTS FOR SOLUTION ONE AND THE DIVERSITY COEFFICIENTS (D_j)

Data Base Services

Project	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}
Allocation		20.9						<1		
D_j	.056	.196	.012	.008	.01	.009	.02	.264	.028	.028

Technical Report Services

Project	x_{20}	x_{21}	x_{22}	x_{23}	x_{24}	x_{25}
Allocation	56.3		61.9			
D_j	.796	.154	.952	.105	.008	.45

Investment in New and Improved Products and Services

Project	y_{30}	y_{31}	y_{32}	y_{33}
Allocation	42.2	42.2		
D_j	0.0	.042	.055	.004

Computer Systems

Project	y_{40}	y_{41}	y_{42}	y_{43}	y_{44}
Allocation				56.3	
D_j	.044	.06	.168	.222	.305

Management, Administration and Services to Other Agencies

Project	z_{50}	z_{51}	z_{52}	z_{53}	z_{60}
Allocation	148.4	4	1.6	5	15
D_j	0	0	.042	0	0

Analysis with Implications for Decision Making

The initial model formulation was designed primarily to evaluate the compatibility of the staffing levels for the proposed program with the organization's service and fiscal goals provided by administrators concerned with the direction and emphasis of the agency's service program. The results show that the program staffing and the service and fiscal goals are not in concert. However, a more important result of the first solution is that specific contradictions among the service and fiscal goals have been identified.

The type of information provided by solution one is valuable to management for use in resolving the conflicts. Goal setting and priority ranking are likely to be the most difficult problems encountered in constructing a model. Encountering initial goal conflicts that are more apparent than real is to be expected. Indeed, it is highly improbable that a diverse group of managers and administrators at various levels of authority in a complex organization have the detailed knowledge or time to define a common and fully compatible goal structure for information services. Moreover, many managers have only a narrow perspective of how an information service agency serves its parent organization. Nevertheless, when presented with specific information regarding goal conflicts, managers whose goals appear to conflict may easily resolve the problem. Otherwise, the problem can be resolved at a higher level of management. The key to resolving the problem is the availability of specific information about the conflict in a meaningful decision making context. Thus, the first solution is useful as an aid for defining a consistent set of goal criteria and priorities for evaluating an information service program.

To emphasize how the results of the first solution can be used for decision making, let us consider some of the effects that might have an influence on subsequent model formulations. A direct effect might be that a goal level would be changed. For example, as a trade-off, administrators concerned with obtaining a distribution ratio of 85% to 15% for the basic and investment program elements might revise the levels of goal criteria a_4 and a_6 to reflect the solution results which indicated that a basic to investment ratio closer to 60% to 40% would be needed in order to support goal criteria a_{45} and a_{47}.

If the resource allocation discrepancy between the proposed program plan and the model is a result of incomplete or vague goal setting by management or the model builder, then another likely effect is that the managers who put forth the proposed program plan would be forced to define clearer goals in order to justify each project in the proposed program plan in terms of organizational objectives and responsibilities. Projects that cannot be so justified would be in jeopardy of losing their resources to projects which can be justified. Consequently, additional goal constraints might have to be added to the model; but at the same time, the program would be defined in a model formulation having common meaning to all levels of management. In a complex environment, several iterations of goal definition and priority setting may be required before a satisfactory model formulation is finally accepted.

When the formulation of the model is apparently complete, projects which experienced managers intuitively regard as justified may still remain unsupported by the model. If so, then a third type of effect may be seen. The decision maker using the model may review how each of the unsupported projects has been related to the organizational goals and find that it would be appropriate to move a project from one category of service to another. For example, Table 4-2 shows that there is virtually no support provided in the first solution for the on-line data base services x_{17}, x_{18}, and x_{19}. Recall from Chapter III that these projects are justified as providing remote access to information, but are coded as basic services. It is interesting that the fundamental conflict in the first model involves precisely those two parameters, where the investment projects are supported at the expense of basic projects. Suppose, then, that x_{18} and x_{19} were to represent prototype efforts to extend the basic program, x_{17}. If the decision maker prefers to support the on-line projects more so than one of the investment projects supported in the first solution, he may decide to reconsider the appropriate goal constraints. Thus, the prototype on-line projects x_{18} and x_{19} would be characterized in the program plan as investment efforts. Of course, changes of this nature must be considered carefully by management and must be fully justified.

Despite the fact that many apparent goal conflicts can be reconciled in the manner just described, real conflicts are likely to remain that can be resolved only by readjustment of goal priorities. In addition, for an extremely complex environment like the information services environment of the agency under study, it is possible that the optimum labor distribution may not always be achievable in practice.

When a more pragmatic plan must be adopted, the question arises concerning where and how significantly will the plan adversely affect the attainment of organizational goals desired by higher management. By revising the model such that those projects which are considered to be essential to the agency's operation are put at a higher priority than the attainment of the organization goals, a second solution can be developed which shows the degree of goal attainment that will result.

4.2 THE SECOND SOLUTION OF THE MODEL

In the second formulation the model has been revised to reflect a division of the thirty projects in the 1978 Program/Budget plan into two groups: (a) those considered essential to day to day operations by management, and (b) those considered less essential. The less essential projects include y_{30}, y_{31}, y_{33}, z_{50}, z_{52}, z_{53} and z_{60}. The remaining 23 projects will be referred to hereafter in the dissertation as the essential projects. For the second solution, a goal priority level of P_3 was assigned by management to the 23 projects in the essential plan, and the lower priority level of P_8 was assigned to the less essential projects.

In addition, since a major objective of this chapter is to demonstrate the diverse capabilities of the goal programming technique, let us suppose that, based on the results of the first solution, management wishes to make several other modifications to the model.

In this way, the flexibility of the goal programming technique to deal with changes of the type discussed herein will be readily demonstrated.

Table 4-5 provides a comparison of the priority structures used to obtain the first and second solutions. Goal priorities P_1, P_2 and P_3 for the second solution have been explained above. Referring to the remaining priorities for solution two, as shown in Table 4-5, we observe that the fourth goal priority P_4 is now concerned with (a) the basic-to-investment program ratio of 85% to 15%, (b) responsiveness in the information program to users' needs for timely service, and (c) the archival need to conserve the agency's collection of materials. This change reflects a view expressed by the agency's management, following a review of the first solution, that in order for the operating plan to receive the support of top management within the parent organization, the plan must be shown to be heavily oriented to producing fundamental products and services. Furthermore, the agency's management regarded the goals for timely service and archival comprehensiveness to be its most important goals and therefore, the ones which they most preferred not to compromise.

For the second solution, the provision of service to libraries becomes goal priority P_5. Goal priority P_6 concerns the desired distribution of labor according to specific information service goals. P_6 represents the goals which management stated could be compromised, if necessary. Priority P_7 is assigned to the program diversity goal constraints. At priority P_8 are the proposed projects which are considered by management to be less than essential.

TABLE 4-5. COMPARISON OF THE GOAL PRIORITY STRUCTURES OF SOLUTIONS ONE AND TWO

Goal Criteria (a_i)		Solution 1		Solution 2	
		d^-	d^+	d^-	d^+
A. Total Staff					
a_1 (491)		-	P_2	-	P_2
a_2 (454)		P_1	-	P_1	-
B. Total Cost					
a_3 (0)		-	P_8	-	P_9
C. Basic Services					
a_4 (85%)		P_5	-	P_4	P_4
a_5 (363)		P_6	-	P_7	0
D. Investment Services					
a_6 (15%)		P_5	-	P_4	P_4
a_7 (68)		P_6	-	P_7	0
E. Target Levels for Individual Programs in man-years					
a_i	proj.				
a_8 (13)	x_{10}	P_7	-	P_3	-
a_9 (13)	x_{11}	P_7	-	P_3	-
a_{10} (1)	x_{12}	P_7	-	P_3	-
a_{11} (2)	x_{13}	P_7	-	P_3	-
a_{12} (1)	x_{14}	P_7	-	P_3	-
a_{13} (4)	x_{15}	P_7	-	P_3	-
a_{14} (2)	x_{16}	P_7	-	P_3	-
a_{15} (15)	x_{17}	P_7	-	P_3	-

TABLE 4-5. (Continued)

Goal Criteria (a_i)			Solution 1		Solution 2	
	a_i	proj.	d^-	d^+	d^-	d^+
a_{16}	(2)	x_{18}	P_7	-	P_3	-
a_{17}	(2)	x_{19}	P_7	-	P_3	-
a_{18}	(91)	x_{20}	P_7	-	P_3	-
a_{19}	(10)	x_{21}	P_7	-	P_3	-
a_{20}	(62)	x_{22}	P_7	-	P_3	-
a_{21}	(7)	x_{23}	P_7	-	P_3	-
a_{22}	(1)	x_{24}	P_7	-	P_3	-
a_{23}	(23)	x_{25}	P_7	-	P_3	-
a_{24}	(0)	y_{30}	P_7	-	P_8	-
a_{25}	(3)	y_{31}	P_7	-	P_8	-
a_{26}	(5)	y_{32}	P_7	-	P_3	-
a_{27}	(1)	y_{33}	P_7	-	P_8	-
a_{28}	(5)	y_{40}	P_7	-	P_3	-
a_{29}	(7)	y_{41}	P_7	-	P_3	-
a_{30}	(19)	y_{42}	P_7	-	P_3	-
a_{31}	(17)	y_{43}	P_7	-	P_3	-
a_{32}	(25)	y_{44}	P_7	-	$2P_3$	-
a_{33}	(80)	z_{50}	P_7	-	P_8	-
a_{34}	(4)	z_{51}	P_7	-	P_3	0
a_{35}	(19)	z_{52}	P_7	-	P_8	-
a_{36}	(5)	z_{53}	P_7	-	P_8	0
a_{37}	(15)	z_{60}	P_7	-	P_8	0

TABLE 4-5. (Continued)

Goal Criteria (a_i)	Solution 1		Solution 2	
	d^-	d^+	d^-	d^+
F. Overall Program Balance Goals				
a_{38} (1:7)	P_4	P_4	P_6	P_6
a_{39} (355,020)	P_3	-	P_5	-
a_{40} (365,671)	P_3	-	P_5	-
a_{41} (390,000)	-	P_3	-	P_5
a_{42} (18%)	P_4	P_4	P_6	P_6
a_{43} (25%)	P_4	P_4	P_6	P_6
a_{44} (52%)	P_4	P_4	P_6	P_6
a_{45} (25%)	P_4	P_4	P_6	P_6
a_{46} (10%)	P_4	P_4	P_6	P_6
a_{47} (15%)	P_4	P_4	P_6	P_6
a_{48} (5%)	P_4	P_4	P_6	P_6
G. Timeliness				
a_{49} (20%)	P_4	P_4	P_4	P_4
H. Archival Conservation				
a_{50} (20%)	P_4	P_4	P_4	P_4

As noted earlier, these are y_{30}, y_{31}, y_{33}, z_{50}, z_{52}, z_{53} and z_{60}. Finally, priority P_9 is the cost minimization goal. Thus, significant reordering of goal priorities has been effected.

Furthermore, observe from Table 4-5 that five values of d_i^+, namely d_5^+, d_7^+, d_{34}^+, d_{36}^+ and d_{37}^+, have been changed between the first and second solution. These d_i^+ variables were eliminated from the model. Due to a practical limitation of 125 variables, including deviational and decision variables, in the computer program used to computed solutions, management was asked to identify specific goals from the 50 goal constraints for which positive deviation was least desirable. Since the model consists of 30 decision variables and 100 deviational variables, five variables had to be deleted. Two goal criteria, a_5 and a_7, were unattainably high values in the initial model for which positive deviation (d_i^+) was unfeasible. Therefore, d_5^+ and d_7^+ could be deleted, thereby ensuring zero positive deviation. In view of the fact that no ceiling for administration, support services and services to other agencies (category z_j) had been included in the model, management selected three z_j projects to have a ceiling imposed on them which, in effect, permitted no positive deviation from the original target. The projects include z_{51}, z_{53} and z_{60}. Thus, five d_i^+ variables were eliminated from the model. Note that among the z_j projects, z_{50} and z_{52} have not been altered. This reflects the fact that a manager can be extremely selective in making such changes if the decision environment warrants selectivity. For example, it is reasonable to assume that z_{50}, general administration, offers the decision maker the greatest flexibility with respect to final staff assignments; and, z_{52}, the technical terminology project is an el-

ement in several of the service goal constraints.
Hence, a decision maker may regard absolute limits on these latter two projects to be impractical, although he has expressed a general concern for limiting the allocation of resources to z_j projects.

Another option for model modification available to the decision maker, which will now be demonstrated, involves assigning numerical weights, W_i, to specific deviational variables. Thus, if it is so desired, the decision maker can specify minimization of one or more designated variables at W_i times the values of other variables at the same priority level. By way of example, in the present application, the decision maker who reviewed the first solution and provided the input to the second formulation indicated that within the essential program there was one project, y_{44} (Computer System Redesign) that was twice as important as any other project. As justification for this weighting, the decision maker indicated that a general upgrading of the agency's computer systems was expected to result in all-around improvements in the agency's basic program as well as the investment program. Thus, a two-fold benefit was expected from project y_{44}. Therefore, in the second formulation d_{32}^- was assigned a weighted priority where $W_{32} = 2$ for P_3 meaning that within P_3, underattainment of a_{32} for project y_{44} had twice the impact as underattainment of any other essential program project.

Results

The results of the second solution are presented in Tables 4-6 and 4-7. For this solution, complete goal attainment is indicated for five of the nine goal priorities. This is an improvement over the first solution. However, the projected cost is now $9,313,566,

TABLE 4-6. GOAL ATTAINMENT FOR SOLUTION TWO

P_1	Staff limit at most 491	Achieved
P_2	Staff size at least 454	Achieved
P_3	Essential projects	Achieved
P_4	Basic/investment balance Timeliness of service Conservation of materials	Achieved
P_5	Service to libraries	Achieved
P_6	Information Service goals	Not achieved
P_7	Program diversity	Not achieved
P_8	Less essential projects	Not achieved
P_9	Cost minimization	$9,313,566

which exceeds the cost of the originally proposed program plan by $535,566, or approximately 6%. The three sets of goals not achieved include (a) the goals to provide a program balance among the seven information service goals and the managers-to-engineers service goal, (b) the program diversity goal, and (c) the distribution of labor to projects not included among the essential projects--the projects designated as less-essential by management.

If we recall that the program diversity goals have high artificial values which are unattainable and that their purpose is to draw support for only the most diversified projects, then we can consider the goal to provide a program balance among the information service goals to be the only unattained goal of importance. It should be noted, however, that any effort to improve the attainment of

TABLE 4-7. COMPUTED LABOR ALLOCATION IN MAN-YEARS FOR ACHIEVING ALL GOALS AS NEARLY AS POSSIBLE (SOLUTION TWO)

Data Base Services

x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}
13	13	1	2	1	4	2	67.7	2	2
(13)	(13)	(1)	(2)	(1)	(4)	(2)	(15)	(2)	(2)

Technical Report Services

x_{20}	x_{21}	x_{22}	x_{23}	x_{24}	x_{25}
91	10	66.2	7	1	68.4
(91)	(10)	(62)	(7)	(1)	(23)

New Information Systems Investigations

$*y_{30}$	$*y_{31}$	y_{32}	$*y_{33}$
14.8	0	5	0
(0)	(3)	(5)	(1)

Computer Systems

y_{40}	y_{41}	y_{42}	y_{43}	y_{44}
5	7	19	19.3	25
(5)	(7)	(19)	(17)	(25)

Management, Administration and Services to Other Agencies

$*z_{50}$	z_{51}	$*z_{52}$	$*z_{53}$	$*z_{60}$
12	4	8.7	5	15
(80)	(4)	(19)	(5)	(15)

Total = 491 (454)

* Denotes projects not included in the essential program plan and considered less essential by management. Numbers in parentheses represent the original labor allocation in the 1978 Program/Budget.

the program balance goals (P_6) will conflict with the goal to achieve a desired ratio of 85% to 15% between the basic and investment programs (P_4). This we can surmise from the previous solution as well as by again referring to Appendix A and comparing in solution two the simplex values for each decision and deviational variable. The significant values are highlighted in the Appendix to show that the point of conflict is indeed between goal priorities P_6 and P_4, and concerns the deviational variable d_6^+ which relates to achieving an investment program of 15%, thus confirming the expected result.

The labor allocation computed for solution two is shown in Table 4-7. Some level of support is indicated for twenty-eight of the thirty projects. Only two investment projects, relating to new information systems investigation, are without support.

For a more detailed look at the results of the second solution, it is helpful to refer to Table 4-8 and compare the positive and negative deviations indicated for the fifty goal criteria. According to Table 4-8, the staff size is at the upper limit of 491 as specified by a_1, therefore, the positive deviation associated with a_2 is not significant. The cost of the solution is $9,313,566 as shown by d_3^+. The goals expressing a desire to have a program of 85% basic services and 15% investment services, a_4 and a_6 respectively, are attained exactly. Goals a_5 and a_7 are the program diversity goals for which the negative deviations shown are not significant. The levels of staffing for the 30 proposed projects, including the essential program at priority level P_3, are expressed in rows eight through thirty seven of Table 4-8. For solution two, five of the desired staffing levels are exceeded, where four are projects

TABLE 4-8. VALUES OF THE DEVIATIONAL VARIABLES FOR SOLUTION TWO

Goal Criteria (a_i)			Deviation		Priority
			d_i^+	d_i^-	
1		491	0.0	0.0	P_1
2		454	37.0	0.0	P_2
3		0	9313.6	0.0	P_9
4		0	0.0	0.0	P_4
5		363	0.0	223.5	P_7
6		0	0.0	0.0	P_4
7		68	0.0	55.9	P_7
8	x_{10}	13	0.0	0.0	P_3
9	x_{11}	13	0.0	0.0	P_3
10	x_{12}	1	0.0	0.0	P_3
11	x_{13}	2	0.0	0.0	P_3
12	x_{14}	1	0.0	0.0	P_3
13	x_{15}	4	0.0	0.0	P_3
14	x_{16}	2	0.0	0.0	P_3
15	x_{17}	15	52.7	0.0	P_3
16	x_{18}	2	0.0	0.0	P_3
17	x_{19}	2	0.0	0.0	P_3
18	x_{20}	91	0.0	0.0	P_3
19	x_{21}	10	0.0	0.0	P_3
20	x_{22}	62	4.2	0.0	P_3
21	x_{23}	7	0.0	0.0	P_3
22	x_{24}	1	0.0	0.0	P_3

TABLE 4-8. (Continued)

Goal Criteria(a_i)			Deviation		Priority
			d_i^+	d_i^-	
23	x_{25}	23	45.4	0.0	P_3
24	y_{30}	0	14.8	0.0	P_8
25	y_{31}	3	0.0	3.0	P_8
26	y_{32}	5	0.0	0.0	P_3
27	y_{33}	1	0.0	1.0	P_8
28	y_{40}	5	0.0	0.0	P_3
29	y_{41}	7	0.0	0.0	P_3
30	y_{42}	19	0.0	0.0	P_3
31	y_{43}	17	2.3	0.0	P_3
32	y_{44}	25	0.0	0.0	$2P_3$
33	z_{50}	80	0.0	68.0	P_8
34	z_{51}	4	0.0	0.0	P_3
35	z_{52}	19	0.0	10.3	P_8
36	z_{53}	5	0.0	0.0	P_8
37	z_{60}	15	0.0	0.0	P_8
38		0	0.0	0.0	P_6
39		355020	35501.9	0.0	P_5
40		365671	24851.0	0.0	P_5
41		390522	0.0	0.0	P_5
42		0	55.7	0.0	P_6
43		0	0.0	46.9	P_6
44		0	93.9	0.0	P_6

TABLE 4-8. (Continued)

Goal Criteria (a_i)		Deviation		Priority
		d_i^+	d_i^-	
45	0	0.0	62.9	P_6
46	0	0.0	31.8	P_6
47	0	0.0	68.2	P_6
48	0	0.0	18.7	P_6
49	0	0.0	0.0	P_4
50	0	0.0	0.0	P_4

of the essential program. Four projects are under-staffed, none of which belong to the essential program. Assigning a weighted value to project y_{44} had no apparent effect on the solution since y_{44} is achieved exactly as desired. The library service goals a_{39}-a_{41} at priority level P_5 are maximized. It is at priority level P_6 where the most interesting deviations in solution two are observed. One goal is fully attained, namely a_{38}, the goal to distribute labor resources among services for managers and scientists and engineers at a ratio of 7 to 1. However, over-achievement is indicated for goals a_{42} and a_{44}, specifying that 18% of the service program should be devoted to basic projects concerned with providing access to information and 52% should be devoted to basic projects providing access to documents. On the other hand, under-achievement is indicated for the goals to devote 25% of the operating program to investment efforts concerned with providing access to information (a_{43}), 25% to investment efforts to provide access to documents (a_{45}), and 15% to investment efforts having to do with providing remote access services (a_{47}). In addition, the goals to devote 10% of the program to providing basic services concerned with remote access to information (a_{46}) and 5% of the program to promoting the use of the agency's products and services (a_{48}) are unattained. Finally, the goals to have 20% of the program devoted to providing timely service and another 20% devoted to the agency's archival function were assigned priority level P_4 for the second solution, and the results indicate that they have been achieved.

Analysis

The results of solution two differ considerably from the results of solution one. In solution two the labor resources are assigned principally to the essential program although the allocation is not limited exclusively to essential projects. The size of the staff has increased from the minimum of 454 man-years to the maximum of 491 man-years, and the cost of the solution has risen significantly so that it exceeds the cost of the original program plan by 6%.

Another noteworthy change is that the second solution meets the criteria to have a program that is 85% basic services, which was under-achieved in the first solution. As a result, all of the information service goals concerned with the investment aspects of the program are under-achieved. In the first solution they had been met or exceeded.

If we consider the information service goals to represent the particular interests of various administrative and user constituents served by the information service agency, as we have throughout the dissertation, then the degree to which specific goals have been compromised by the essential-project-program provides insight into the source and level of dissatisfaction that can be expected when the essential-project-program is implemented. The magnitude of the deleterious effects of the essential-project-program on the individual information service goals is best seen as the percentage by which solution two deviates from the goal levels desired by management. Table 4-9 provides a comparison of the effects of the essential-project-program on the goals that were unachieved at priority level P_6.

TABLE 4-9. DEVIATION OF SOLUTION TWO FROM TARGET GOAL LEVELS OF PRIORITY P_6*

Goal	Desired Level		Solution Two		% Deviation of Solution Two from target goal levels
	a_i	Man-years	%	Allocation	$(((\text{column } 3)-a_i)/a_i)$
Provide access to information					
Basic (a_{42})	18%	81.9	28%	137.6	+ .56
Investment (a_{43})	25%	113.8	14%	66.9	- .44
Provide access to documents					
Basic (a_{44})	52%	236.6	73%	330.5	+ .40
Investment (a_{45})	25%	113.8	11%	50.9	- .56
Provide remote access					
Basic (a_{46})	10%	45.5	3%	13.7	- .70
Investment (a_{47})	15%	68.3	0%	0	- 1.00
Promote the agency's products and services (a_{48})	5%	22.8	1%	4.1	- .80
Total	150%	682.7			

* Data for this table were derived from the formulae (15), (16), (17), (18), (19), (20), and (21) for a_{42}, a_{43}, a_{44}, a_{45}, a_{46}, a_{47} and a_{48}, respectively as provided in Chapter III. The desired level of man-years represents the level of staffing that would have been devoted to each indicated goal if the target had been met by the solution. % indicates the actual percentage of the total service program provided by the solution to each indicated goal. The allocation column refers to the sum of x_j, y_j and z_j computed from solution two for each indicated goal.

The degree to which the support levels in solution two deviate from the target goal levels provided by management for the various information service goals ranges from +.56 to -1.00. While the basic program element concerned with providing access to information was overattained by 56%, the program element to invest in development of products and services to meet future demands for remote access services was totally unattained. Thus, based on the scale indicated by Table 4-9, the allocation scheme provided by solution two can be evaluated as (a) strong in providing basic services to provide access to information and access to documents, (b) generally weak in the areas of investment projects, and (c) also weak in providing basic remote access services and promoting the agency's products and services.

There is nothing that can be done to completely reconcile the information service goals as shown by the fact that together they call for 150% of the total resources. Therefore, management must accept the fact that the information service program will fail to meet certain of its expectations.

Now let us suppose that, despite the fact that the administrators originally said that a 10% budget increase was reasonable, additional funds cannot be obtained. In order to determine where cutbacks should be considered to meet this circumstance, a third and final computer solution will now be developed.

4.3. THE THIRD SOLUTION OF THE MODEL

For the third solution, the cost minimization goal is assigned to the priority level P_3, preceding all goals except the staff range goals. The value of the cost criterion goal, a_3, is therefore changed from zero to $8,778,000, which was the cost of the program originally proposed by the operating level managers in the 1978 Program/Budget. In most other respects the formulation of the model for solution three is unchanged from the formulation for solution two. However, goal level priorities have been adjusted because the cost minimization goal is inserted at priority level P_3.

Table 4-10 provides a comparison of the priority structures for the three formulations of the model for solutions one, two and three. The priority rankings for solution two represented a pragmatic program planning situation. However, it was in a sense an ideal decision structure because it was not concerned with the total cost of the solution. Solution three must achieve the pragmatic goals of solution two within the budget limit set at priority level three, P_3. The significant difference between the formulations for solution two and solution three is that solution two was influenced only by benefit considerations and solution three is based on cost and benefit criteria. Therefore, a comparison of the results of the third solution with those of the second solution provides insight into the cost/benefit trade-offs between the two solutions.

Results

The results of the third solution are presented in Tables 4-11 and 4-12.

The same three sets of goal priorities that were not achieved in the second solution are again not achieved in solution three. Because the goal to avoid a deficit has been introduced,

TABLE 4-10. COMPARISON OF THE GOAL PRIORITY STRUCTURES OF SOLUTIONS ONE, TWO AND THREE

Goal Criteria (a_i)			Solution 1		Solution 2		Solution 3	
			d^-	d^+	d^-	d^+	d^-	d^+
A. Total Staff								
a_1 (491)			-	P_2	-	P_2	-	P_2
a_2 (454)			P_1	-	P_1	-	P_1	-
B. Total Cost							$a_3 = 8{,}778$	
a_3 (0)			-	P_8	-	P_9	-	P_3
C. Basic Services								
a_4 (85%)			P_5	-	P_4	P_4	P_5	P_5
a_5 (363)			P_6	-	P_7	0	P_8	0
D. Investment Services								
a_6 (15%)			P_5	-	P_4	P_4	P_5	P_5
a_7 (68)			P_6	-	P_7	0	P_8	0
E. Target Levels for Individual Programs in man-years								
a_i		proj.						
a_8	(13)	x_{10}	P_7	-	P_3	-	P_4	-
a_9	(13)	x_{11}	P_7	-	P_3	-	P_4	-
a_{10}	(1)	x_{12}	P_7	-	P_3	-	P_4	-
a_{11}	(2)	x_{13}	P_7	-	P_3	-	P_4	-
a_{12}	(1)	x_{14}	P_7	-	P_3	-	P_4	-
a_{13}	(4)	x_{15}	P_7	-	P_3	-	P_4	-
a_{14}	(2)	x_{16}	P_7	-	P_3	-	P_4	-
a_{15}	(15)	x_{17}	P_7	-	P_3	-	P_4	-

TABLE 4-10. (Continued)

Goal Criteria (a_i)			Solution 1		Solution 2		Solution 3	
a_i		proj.	d^-	d^+	d^-	d^+	d^-	d^+
a_{16}	(2)	x_{18}	P_7	-	P_3	-	P_4	-
a_{17}	(2)	x_{19}	P_7	-	P_3	-	P_4	-
a_{18}	(91)	x_{20}	P_7	-	P_3	-	P_4	-
x_{19}	(10)	x_{21}	P_7	-	P_3	-	P_4	-
x_{20}	(62)	x_{22}	P_7	-	P_3	-	P_4	-
x_{21}	(7)	x_{23}	P_7	-	P_3	-	P_4	-
x_{22}	(1)	x_{24}	P_7	-	P_3	-	P_4	-
x_{23}	(23)	x_{25}	P_7	-	P_3	-	P_4	-
x_{24}	(0)	y_{30}	P_7	-	P_8	-	P_9	-
a_{25}	(3)	y_{31}	P_7	-	P_8	-	P_9	-
a_{26}	(5)	y_{32}	P_7	-	P_3	-	P_4	-
a_{27}	(1)	y_{33}	P_7	-	P_8	-	P_9	-
a_{28}	(5)	y_{40}	P_7	-	P_3	-	P_4	-
a_{29}	(7)	y_{41}	P_7	-	P_3	-	P_4	-
a_{30}	(19)	y_{42}	P_7	-	P_3	-	P_4	-
a_{31}	(17)	y_{43}	P_7	-	P_3	-	P_4	-
a_{32}	(25)	y_{44}	P_7	-	$2P_3$	-	$2P_4$	-
a_{33}	(80)	z_{50}	P_7	-	P_8	-	P_9	-
a_{34}	(4)	z_{51}	P_7	-	P_3	0	P_4	0
a_{35}	(19)	z_{52}	P_7	-	P_8	-	P_9	-
a_{36}	(5)	z_{53}	P_7	-	P_8	0	P_9	0
a_{37}	(15)	z_{60}	P_7	-	P_8	0	P_9	0

TABLE 4-10. (Continued)

Goal Criteria (a_i)	Solution 1		Solution 2		Solution 3	
	d^-	d^+	d^-	d^+	d^-	d^+
F. Overall Program Balance Goals						
a_{38} (1:7)	P_4	P_4	P_6	P_6	P_7	P_7
a_{39} (355,020)	P_3	-	P_5	-	P_6	-
a_{40} (365,671)	P_3	-	P_5	-	P_6	-
a_{41} (390,000)	-	P_3	-	P_5	-	P_6
a_{42} (18%)	P_4	P_4	P_6	P_6	P_7	P_7
a_{43} (25%)	P_4	P_4	P_6	P_6	P_7	P_7
a_{44} (52%)	P_4	P_4	P_6	P_6	P_7	P_7
a_{45} (25%)	P_4	P_4	P_6	P_6	P_7	P_7
a_{46} (10%)	P_4	P_4	P_6	P_6	P_7	P_7
a_{47} (15%)	P_4	P_4	P_6	P_6	P_7	P_7
a_{48} (5%)	P_4	P_4	P_6	P_6	P_7	P_7
G. Timeliness						
a_{49} (20%)	P_4	P_4	P_4	P_4	P_5	P_5
H. Archival Conservation						
a_{50} (20%)	P_4	P_4	P_4	P_4	P_5	P_5

TABLE 4-11. GOAL ATTAINMENT FOR SOLUTION THREE

P_1	Staff limit at most 491	Achieved
P_2	Staff size at least 454	Achieved
P_3	Avoid deficit costs	Achieved
P_4	Essential program plan	Achieved
P_5	Basic/investment balance Timeliness of service Archival Conservation of materials	Achieved
P_6	Service to libraries	Achieved
P_7	Information Service goals	Not achieved
P_8	Program diversity	Not achieved
P_9	Less essential program elements	Not achieved

TABLE 4-12. COMPARISON OF LABOR ALLOCATION COMPUTED FOR SOLUTION TWO AND SOLUTION THREE

Data Base Services

Variable	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}
1978 Prog/ Budget	(13)	(13)	(1)	(2)	(1)	(4)	(2)	(15)	(2)	(2)
Sol. 2	13	13	1	2	1	4	2	67.2	2	2
Sol. 3	13	13	50.5	2	1	4	2	67.2	2	2
*Cost rank	20	14	13	18	13	17	19	9	9	9

Technical Report Services

Variable	x_{20}	x_{21}	x_{22}	x_{23}	x_{24}	x_{25}
1978 Prog/ Budget	(91)	(10)	(62)	(7)	(1)	(23)
Sol. 2	91	10	66.2	7	1	68.4
Sol. 3	91	10	62	7	1	23
*Cost rank	16	20	18	17	13	11

New Information Systems Investigations

Variable	y_{30}	y_{31}	y_{32}	y_{33}
1978 Prog/ Budget	(0)	(3)	(5)	(1)
Sol. 2	14.8	0	5	0
Sol. 3	10.8	4	5	0
*Cost rank	22	2	5	6

* Projects are ranked from one for the most costly per man-year to 22 for the least costly. Data are based on Table 3-3 from Chapter III. Numbers in parentheses represent the original labor allocation in the 1978 Program/Budget.

TABLE 4-12. (Continued)

Computer Systems

Variable	y_{40}	y_{41}	y_{42}	y_{43}	y_{44}
1978 Prog/ Budget	(5)	(7)	(19)	(17)	(25)
Sol. 2	5	7	19	19.3	25
Sol. 3	5	7	19	19.3	25
*Cost rank	1	10	8	6	7

Management, Administration and Services to other Agencies

Variable	z_{50}	z_{51}	z_{52}	z_{53}	z_{60}
1978 Prog/ Budget	(80)	(4)	(19)	(5)	(15)
Sol. 2	12	4	8.7	5	15
Sol. 3	0	4	8.7	0	0
*Cost rank	12	12	4	21	15

Total 1978 Program/Budget	454
Solution 2	491
Solution 3	458.5

achievement is now indicated for six goals. Using the simplex values from Appendix A to compare the decision and deviational variables at each priority level, we can verify that further improvement of the unattained program balance goal is again precluded by the goal to have an investment effort equal to exactly 15% of the basic service program.

The most significant results concern the redistribution of the labor resources from that obtained in solution two. There were eight projects affected by the introduction of the cost goal at priority level P_3 as shown in Table 4-12 with a net loss of 32.5 man-years of effort. It is interesting to note that there is no direct correlation between the project cost per man-year and the changes in labor distribution from the previous solution. The highest cost project, y_{40}, had no change. The second highest cost project, y_{31}, gained four man-years despite the introduction of the cost reduction goal. The lowest cost project, y_{30}, actually lost four man-years of effort. The projects most sensitive to the cost constraint are x_{12} which gained an additional 49.5 man-years of effort and is ranked thirteenth in cost, and x_{25} which lost 45.4 man-years of labor and is ranked eleventh.

Analysis

The primary objective of solution three was to investigate the effects of changing a single parameter of the model, namely the cost parameter, which imposed a cost reduction goal on the results of solution two. The most obvious result is that the total labor allocation was reduced. The reduction, however, was not made on the basis of cost alone. There were very costly projects which gained resources while low cost projects lost resources. Thus, while it is extremely hard to generalize exactly what trade-offs were made, it appears clear that the reduction reperesnts a cost/benefit compromise.

Another aspect of solution three concerns the relative degree of goal attainment achieved by the two alternative model formulations. Solution three attained six goal priority levels as opposed to five in solution two. More interesting is the change in the degree of attainment of the unattained information service goals which went from priority level P_6 in solution two to priority level P_7 in solution three. Table 4-13 compares the percent of deviation from the target goals provided by management for the unattained information service goals in solution two and solution three. The results of the third solution indicate that even greater emphasis will be given to the basic program to provide access to information than was provided in solution two. In fact, the goal (a_{42}) will be exceeded by 122%. The goal to provide basic services that provide access to documents will be closer to its target at 19% over target as compared to 40% over target in solution two. In proportion, the other information service goals have not been significantly affected. Thus, solution three is probably a better labor allocation plan than solution two.

As a final note, it should be pointed out that the third solution provides only a near optimal solution. Models are only a reflection of reality. The decision maker would be expected to use the results as a tool to aid in the decision process, but not as an absolute answer to the resource allocation problem. Thus, it is of

TABLE 4-13. DEVIATION OF SOLUTION THREE AT PRIORITY P_7 COMPARED TO ORIGINAL TARGET GOAL LEVELS AND SOLUTION TWO*

Goal Criteria	Desired Level		Solution Two			Solution Three		
	a_i	Man-years	%	Man-years	Δ	%	Man-years	Δ
Provide access to information								
Basic (a_{42})	18%	81.9	28%	137.6	+.56	40%	182.4	+1.22
Investment (a_{43})	25%	113.8	14%	66.9	-.44	15%	67	- .40
Provide access to documents								
Basic (a_{44})	52%	236.6	73%	330.5	+.40	62%	284.0	+ .19
Investment (a_{45})	25%	113.8	11%	50.9	-.56	10%	46.9	- .60
Provide remote access								
Basic (a_{46})	10%	45.5	3%	13.7	-.70	3%	13.7	- .70
Investment (a_{47})	15%	68.3	0%	0	-1.0	1%	4.0	- .93
Promote the agency's products and services (a_{48})	5%	22.8	1%	4.1	-.80	1%	4.0	- .80

* Data for solutions two and three are derived as explained in TABLE 4-9.

Δ Represents the percent of deviation between the desired goal level, expressed as a percentage of the total service program (a_i), and the actual percentage of the service program provided by the solution to each indicated goal (%).

no consequence that the decision maker who would use solution three would probably make final adjustments to the labor allocation plan--such as those needed to provide a minimum level of administrative support, which was virtually eliminated in the third solution.

4.4 CONCLUSIONS OF THE STUDY

In the past decade information service managers have found it increasingly necessary to justify their programs in an administrative environment where there are insufficient resources to support all proposed program elements, regardless of how desirable they might be. Consequently, serious attention has been given to the problem of evaluating information services. Those agencies and individuals who have attempted to use mathematical techniques, including model building, as evaluation tools have tended to concentrate their efforts on diagnostic procedures directed toward improving the effectiveness or cost/effectiveness of internal processing operations. They have generally neglected or avoided direct consideration of the value derived from the information products and services offered by an information service agency. Moreover, unique organizational values and bureaucratic decision structures which greatly influence decision processes have been ignored as evaluation criteria. In this research, the goal programming approach has been investigated because it is a tool which allows a manager to optimize the allocation of information service resources while considering explicit but sometimes conflicting organizational objectives.

The principal proposition advanced on behalf of this dissertation is that the goal programming approach to resource allocation and program evaluation can be demonstrated as a useful tool for information services managers in an operating environment. Based upon the results, the general conclusion of the study is that goal programming can and does supplement the traditional decision making process in several important ways.

One principal advantage of goal programming for the information service field is that it helps define a decision environment in unambiguous terms. Every discretionary program element is categorized as to how it serves an organizational purpose. Managers who may lack expertise in information science and are unable to judge the merits of specific information processes are nonetheless able to deal with the question of whether or not the purpose served by the process is appropriate for the organization as a whole. Thus, a common decision structure is provided for all levels of management.

Developing and solving the goal programming model provides valuable insight concerning the points of conflict within a given decision environment. As a result, information managers may resolve many apparent goal conflicts that arise from misunderstandings or goal setting with too narrow a perspective. When goal conflicts can not be resolved within the framework of the model, the model points out where and to what extent some goals cannot be achieved under a given goal structure.

Furthermore, the model allows a decision maker to undertake a systematic evaluation of alternative decision structures while ensuring that all key elements of the basic problem are considered according to a consistent logic each time a decision strategy is evaluated. Where there is uncertainty or conflict in an organization concerning the appropriate objectives for the information service agency, the model helps a decision maker establish priorities for a proposed operating program.

Perhaps the greatest strength of goal programming, which sets it apart in utility from other modeling techniques, is its great flexibility which allows model manipulation with numerous variations of constraints, goal priority structures and goal levels.

The purpose of this research has been to direct development of the methodology toward applying goal programming to the resource allocation and program evaluation problem in the information services environment. It represents the first application of the technique to the information field. Without doubt, the precision of the measures used in the present model could be refined. For example, the power of the model would be increased significantly if a scale could be developed to relate the specific program elements to the organizational goals in a proportional manner. The scope of the model could be expanded to represent a multi-unit network of information agencies such as those in a library consortia. The scope could also be expanded in another direction to incorporate a multi-year planning environment.

In a general sense, the model is appropriate for use in any information service agency. Other formulations for environments such as a research library or a public library offer an opportunity to investigate the influence of various user constituencies on the planning objectives of public institutions. In this regard, it would be interesting to reformulate a previously developed library planning model--such as the one developed by Hamburg, et al. (39)--as a goal programming model and compare the results.

Additional research opportunities exist for making further use of the particular model and data developed in this dissertation. Additional sensitivity analysis and parametric analysis could be carried out with the present data. Sensitivity analysis is concerned with determining the effects of a single change in parameters. Parametric analysis is a systematic analysis of changes in a goal programming solution concerned with determining the magnitude of simultaneous changes in the model parameters. Parametric analysis involving restructuring the overall program balance goals at discrete priority levels is one obvious possibility for further research in this area.

For the researcher who is interested in organizational theory, such concerns as departmental interactions, boundary conditions and the bureaucratic decision structure are important research areas which would seem to lend themselves to investigation through goal programming techniques. These suggestions are offered as possibilities for extending the application of the goal programming approach to the problems of information service management in general. They may not be necessary or desirable for the particular information service environment chosen for this research.

The information service management field, however, is one that is generally subject to a multi-criteria decision making environment. This being so, its environment would thus seem ripe for analysis by the goal programming approach in that it has now been demonstrably shown that goal programming can provide information service decision makers with useful information for logical and defensible planning.

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Appendix

The Simplex Criterion (Zj - Cj)
for Solutions One Two and Three

The simplex criterion as used in Lee's method of goal programming is an m X n matrix where m represents the number of preemptive priority levels and n is the number of variables in the model, including both choice and deviational variables.

The simplex criterion is used to identify the optimum column.[1] The selection of the optimum column is based on the per-unit contribution rate of each variable in achieving the highest unattained goal. The selection is made by examining the $Z_j - C_j$ values. Unattained goals are indicated by the presence of positive $Z_j - C_j$ values. When the highest unattained goal priority is determined, the optimum column is identified as the variable column that has the largest postive $Z_j - C_j$ value. The variable in that column will enter the solution base in the next tableau if there is no conflict indicated with a higher priority goal shown by a negative $Z_j - C_j$ value in the optimum column.

The n variables in the model are displayed as n columns in the $Z_j - C_j$ matrix. Therefore, for the present model, the matrix consists of 50 negative deviational variables (d_i^-), 45 positive deviational variables (d_i^+) and 30 choice or decision variables (x_j, y_j, z_j). They are listed from left to right in rows of ten variables each. The negative deviational variables are listed first, followed by the positive deviational variables, followed by the decision variables.

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[1]It is assumed that the reader understands the significance of the $Z_j - C_j$ values in the simplex method of linear programming. For detailed discussion of the simplex method of goal programming, consult Lee (58, Chapter 5).

PRINT-OUT OF SIMPLEX CRITERION FOR SOLUTION ONE

THE ZJ-CJ MATRIX

PRIORITY 8

0.0	20.400	-1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.000	0.0
0.0	0.0	0.0	0.0	0.000	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	-7.400	-1.330	-0.570	0.0	-0.003
0.0	-33.375	0.0	-28.071	-57.785	0.000	-30.785	0.0	25.400	-11.134
0.0	-20.400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.0	0.0	0.0
0.0	0.0	-0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.570	0.0	0.003	0.0	33.375	0.0	28.071	57.785
-0.000	30.785	0.0	-25.400	11.134	5.930	0.0	4.410	3.650	-0.150
2.050	1.330	0.0	0.0	0.0	-0.000	15.614	0.0	12.714	4.714
0.264	0.0	0.0	34.185	-23.570	0.715	1.491	21.615	0.0	-22.730
0.0	0.0	-0.000	0.0	0.0					

PRIORITY 7

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.000	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	-1.000	-1.000	0.0	0.0	0.0	0.0	0.0
-1.000	0.0	-1.000	-1.000	0.0	-1.000	-1.000	-0.857	0.0	-0.000
0.0	-2.049	0.0	-0.571	-1.507	0.0	-1.507	0.0	0.714	-2.070
0.0	0.0	0.0	0.0	0.0	-1.000	0.0	-1.000	-1.000	-1.000
-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000
-1.000	0.0	0.0	-1.000	-1.000	-1.000	-1.000	-1.000	0.0	-1.000
0.0	-1.000	-0.143	0.0	0.000	0.0	2.049	0.0	0.571	1.507
0.0	1.507	0.0	-0.714	2.070	1.000	0.0	-0.143	1.000	1.000
1.000	1.000	0.0	0.0	0.0	0.0	1.935	0.0	1.935	1.935
1.935	0.0	0.0	2.507	1.143	0.530	1.891	1.590	0.0	1.143
0.0	0.0	0.0	0.0	0.0					

PRIORITY 6

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.022	0.0	-0.000
0.0	-0.604	0.0	-0.108	-0.584	0.0	-0.626	0.0	-0.136	-0.050
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.022	0.0	0.000	0.0	0.604	0.0	0.108	0.584
0.0	0.026	0.0	0.136	0.050	-0.140	0.0	-0.008	-0.188	-0.180
-0.187	-0.176	0.0	-0.236	-0.236	0.0	0.630	0.0	0.581	0.484
0.520	0.0	0.0	0.639	-0.018	0.123	0.419	0.488	0.0	0.283
0.0	0.0	0.0	0.0	0.0					

PRINT-OUT OF SIMPLEX CRITERION FOR SOLUTION ONE (CONTINUED)

PRIORITY 5

0.0	0.0	0.0	0.0	0.0	-1.000	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	-0.150	0.0	0.0	0.0	-0.021	0.0	0.000
0.0	1.097	0.0	-0.214	$\boxed{1.920}$ d_{45}^-	0.0	$\boxed{1.920}$ d_{47}^-	0.0	0.043	1.162
0.0	0.0	0.0	-1.000	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.021	0.0	-0.000	0.0	-1.097	0.0	0.214	-1.926
0.0	-1.926	0.0	-0.043	-1.162	0.0	0.0	0.171	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	-1.140	0.0	-1.140	-1.140
-1.140	0.0	0.0	-1.926	-0.021	-0.269	-0.834	-1.108	0.0	-0.021
0.0	0.0	0.0	0.0	0.0					

PRIORITY 4

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	-1.000	0.0	0.0	0.0	-1.000	0.0	0.000
0.0	-1.051	-2.000	-2.000	$\boxed{-0.051}$ d_{45}^-	-2.000	$\boxed{-0.051}$ d_{47}^-	0.0	-0.000	-0.007
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	-1.000	0.0	-0.000	0.0	-0.949	0.0	-0.000	-1.949
0.0	-1.949	-2.000	-2.000	-1.993	0.0	0.0	-0.000	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	-0.949	0.0	-0.949	-0.949
-0.949	0.0	0.0	-0.949	0.0	-0.190	-0.559	-0.369	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

PRIORITY 3

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.000	-1.000
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	-1.000	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

PRINT-OUT OF SIMPLEX CRITERION FOR SOLUTION ONE (CONTINUED)

PRIORITY 2

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

PRIORITY 1

0.0	-1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

PRINT-OUT OF SIMPLEX CRITERION FOR SOLUTION TWO

THE ZJ-CJ MATRIX

PRIORITY 9									
20.400	0.0	-1.000	63.767	0.0	42.337	0.0	-103.310	-97.380	-1.430
-101.230	-97.230	-100.230	-101.730	0.000	0.000	0.000	33.868	-7.330	0.0
-4.430	3.570	0.0	0.0	0.0	23.600	0.0	0.681	-13.786	1.503
0.0	10.185	0.0	[illegible]	0.0	-7.400	-1.330	11.976	0.0	0.0
-0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.310	-49.263
-20.400	0.0	0.0	-63.767	-42.337	103.310	97.380	1.430	101.230	97.230
100.230	101.730	-0.000	-0.000	-0.000	-33.868	7.330	0.0	4.430	-3.570
0.0	0.0	0.0	-23.600	0.0	-0.681	13.786	-1.503	0.0	-10.185
0.0	0.0	-11.975	0.0	0.0	0.001	0.0	0.0	0.0	0.0
0.0	0.0	0.0	-0.310	49.263	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	-0.000	0.0	0.0	0.0	0.0
0.0	0.0	-27.000	0.0	-11.025	0.0	0.0	0.0	0.0	0.0
-0.000	0.0	0.0	0.0	0.0					
PRIORITY 8									
-1.000	0.0	0.0	0.667	0.0	0.667	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.000	0.0	0.0
0.0	0.0	0.0	-1.000	0.0	0.0	0.0	0.0	-0.667	0.0
0.0	0.0	0.0	0.0	0.0	0.0	-0.000	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-5.000
1.000	0.0	0.0	-0.667	-0.667	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	-5.000	0.0	0.0	0.0	0.0
0.0	0.0	-1.000	0.0	-1.000	0.0	0.667	0.0	0.0	0.0
-1.000	-1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	5.000	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	1.000	0.0	1.000	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
PRIORITY 7									
0.0	0.0	0.0	-3.940	0.0	-3.490	0.0	1.858	1.718	0.438
1.906	1.904	1.905	1.894	0.0	0.236	0.236	-2.204	0.296	0.0
0.345	0.442	0.0	0.0	0.0	-0.055	0.0	0.499	0.877	0.195
0.0	-0.122	0.0	0.591	0.0	0.0	0.0	-0.183	0.0	0.0
-0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.186	2.641
0.0	0.0	0.0	3.940	3.490	-1.858	-1.718	-0.438	-1.906	-1.904
-1.963	-1.894	0.0	-0.236	-0.236	2.204	-0.296	0.0	-0.345	-0.442
0.0	0.0	0.0	0.055	0.0	-0.499	-0.877	-0.195	0.0	0.122
0.0	0.0	0.183	0.0	0.0	0.000	0.0	0.0	0.0	0.0
0.0	0.0	0.0	-0.186	-2.641	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.042	0.0	-0.179	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

PRINT-OUT OF SIMPLEX CRITERION FOR SOLUTION TWO (CONTINUED)

PRIORITY 6

0.0	0.0	0.0	[illegible]	0.0	[illegible]	0.0	8.000	8.000	0.0
[illegible]	[illegible]	[illegible]	8.000	0.0	0.0	0.0	0.206	0.0	0.0
0.0	0.0	0.0	0.0	0.0	1.000	0.0	1.200	1.867	1.000
0.0	1.000	0.0	-0.000	0.0	0.0	0.0	-2.000	0.0	0.0
0.0	-2.000	0.0	-2.000	0.0	0.0	0.0	0.0	1.000	0.750
0.0	0.0	0.0	6.667	$\boxed{9.667}$ d_6^+	-8.000	-8.000	0.0	-8.000	-8.000
[illegible]	[illegible]	0.0	0.0	0.0	-0.200	0.0	0.0	0.0	0.0
0.0	0.0	0.0	-1.000	0.0	-1.200	-1.867	-1.600	0.0	-1.000
0.0	0.0	-0.000	0.0	0.0	0.0	0.0	-2.000	0.0	-2.000
-2.000	-2.000	-2.000	-1.000	-0.750	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	-0.000	0.0	-1.000	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

PRIORITY 5

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.000	-1.000
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	1.000	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

PRIORITY 4

0.0	0.0	0.0	-1.000	0.0	-1.000	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	-1.000	$\boxed{-1.000}$ d_6^+	0.0	0.0	0.0	-1.000	-1.000
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	1.000	1.000	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

PRINT-OUT OF SIMPLX CRITERION FOR SOLUTION TWO (CONTINUED)

PRIORITY 3

0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.000	-1.000	-1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	-1.000	-1.000	-1.000
-1.000	-1.000	-1.000	0.0	0.0	-1.000	0.0	-1.000	-1.000	-1.000
-1.000	-2.000	0.0	-1.000	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

PRIORITY 2

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

PRIORITY 1

0.0	-1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

PRINT-OUT OF SIMPLEX CRITERION FOR SOLUTION THREE

THE ZJ-CJ MATRIX

PRIORITY 9

0.0	0.0	0.0	6.667	0.0	6.667	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	-1.000	-1.000	0.0	0.0	0.0	-0.667	0.0
0.0	0.0	0.0	-1.000	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	-0.667	-0.667	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	-1.000	0.0	0.667	0.0	0.0	0.0
-1.000	-1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	1.000	0.0	0.0	0.0	0.0	0.0
1.000	0.0	0.0	1.000	1.000					

PRIORITY 8

0.0	0.0	-0.002	0.517	0.0	0.498	0.0	-0.482	-0.612	0.0
0.430	0.426	-0.436	0.443	0.0	0.236	0.236	-0.141	-0.151	-0.979
-0.098	0.012	-0.436	0.0	0.0	-0.018	0.0	-0.066	-0.147	-0.195
0.0	-0.324	0.0	-0.046	0.0	0.0	0.0	0.054	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.249	-0.100
0.0	0.0	0.002	-0.517	-0.498	0.482	0.612	0.0	0.430	0.420
0.430	0.443	0.0	-0.236	-0.236	0.141	0.151	0.979	0.098	-0.012
-0.436	0.0	0.0	0.018	0.0	0.046	0.147	0.195	0.0	0.324
0.0	0.0	-0.054	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.249	0.100	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.022	0.0	0.0	0.0	0.0	0.0
-0.032	0.0	0.0	-0.020	-0.030					

PRIORITY 7

0.0	0.0	-0.000	-6.667	0.0	-9.667	0.0	8.000	8.000	0.0
8.000	8.000	8.000	8.000	0.0	0.0	0.0	0.208	0.000	0.000
0.000	0.000	0.000	0.0	0.0	1.000	0.0	1.200	1.867	1.600
0.0	1.000	0.0	0.000	0.0	0.0	0.0	-2.000	0.0	0.0
0.0	-2.000	0.0	-2.000	0.0	0.0	0.0	0.0	1.000	0.750
0.0	0.0	0.000	6.667	$\boxed{9.667}$ d_6^+	-8.000	-0.000	0.0	-8.000	-8.000
-8.000	-8.000	0.0	0.0	0.0	-0.206	-0.000	-0.000	-0.000	-0.000
-0.000	0.0	0.0	-1.000	0.0	-1.200	-1.867	-1.600	0.0	-1.000
0.0	0.0	-0.000	0.0	0.0	0.0	0.0	-2.000	0.0	-2.000
-2.000	-2.000	-2.000	-1.000	-0.750	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	-1.000	0.0	0.0	0.0	0.0	0.0
-0.000	0.0	0.0	-0.000	-0.000					

PRINT-OUT OF SIMPLEX CRITERION FOR SOLUTION THREE (CONTINUED)

PRIORITY 6									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.000	-1.000
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	-1.000	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
PRIORITY 5									
0.0	0.0	0.0	-1.000	0.0	-1.000	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.000	-1.000
0.0	0.0	0.0	-1.000	$\boxed{-1.000}$ d_6^+	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	-1.000	-1.000	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
PRIORITY 4									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.000	-1.000	-1.000
-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000
-1.000	-1.000	-1.000	0.0	0.0	-1.000	0.0	-1.000	-1.000	-1.000
-1.000	-2.000	0.0	-1.000	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

PRINT-OUT OF SIMPLEX CRITERION FOR SOLUTION THREE (CONTINUED)

PRIORITY 3

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	-1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

PRIORITY 2

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

PRIORITY 1

0.0	-1.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

THOMAS JOSEPH McGEEHAN

1941	Born July 25 in Hazleton, Pennsylvania.
1959	Graduated St. Gabriel's High School, Hazleton, Pennsylvania.
1959-63	Attended King's College, Wilkes Barre, Pennsylvania; Majored in Biology.
1963	B.S. King's College.
1963-64	Graduate Work in Library Science, Drexel University, Philadelphia, Pennsylvania.
1964	M.S. in Library Science.
1964-68	Employed by the Free Library of Philadelphia, as Adult Services Librarian to 1966 and as Assistant Head of the Library for the Blind and Physically Handicapped to 1968.
1968-72	Employed by Smith Kline and French Laboratories, Philadelphia, Pennsylvania.
1971-72	Head of Smith Kline and French Technical Information Center.
1971-77	Doctoral work at Rutgers University in Library Service.
1972-present	Employed by AUERBACH Associates, Incorporated, Philadelphia, Pennsylvania as a Senior Consultant.
1978	Ph.D. in Library Service.