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DESIGN AND DEVELOPMENT OF EQUAL EMPLOYMENT OPPORTUNITY HUMAN RESOURCES PLANNING MODELS

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The report describes the construction of a set of Navy civilian manpower management models that accomodate EEO requirements. Two types of models are presented: (1) a goal policy planning model with embedded Markoff personnel transition matrices to deal with multiple objectives involved with satisfying EEO goals over time at an aggregate or Navy-wide level and (2) a local goal-arc personnel planning model. Realistic test data are used to provide examples of both models' outputs and uses. Detailed mathematical descriptions of both

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models, including a derivation of the network or transshipment model formulation for the local model, are provided. In addition, a system of EEO goal setting accountability is addressed.

FOREWORD

This research and development was conducted in response to Navy Decision Coordinating Paper, Personnel Supply Systems (NDCP Z0107-PN) as a part of subproject PN.16, Shore Activity Manpower Planning System (SAMPS), and under the sponsorship of the Chief of Naval Operations (OP-01). The objective of the subproject is to develop an integrated system of computer-based models that can be used to minimize the differences among organizational goals, current manpower trends, and employee aspirations. The subproject was initiated to provide the necessary linkage between the Office of Civilian Personnel (OCP) manpower models conceived and developed under research (6.1) and exploratory development (6.2) phases.

The work reflected in this report describes the construction of a set of Navy civilian manpower management models that account for EEO requirements. The results of this study are intended for both headquarters level activities (e.g., NAVAIR, NAVSEA, Director of Navy Laboratories) and local activities (e.g., naval shipyards, laboratories, air rework facilities).

Other manpower modeling work done under the SAMPS aegis is described in NAVPERSRANDCEN Technical Report 79-10.

Special acknowledgment is due to Murray Rowe, NAVPERSRANDCEN, for his organization and revision of the many previously published and unpublished documents that comprise this report.

DONALD F. PARKER
Commanding Officer

A066306

SUMMARY

Problem

The Navy shore establishment is experiencing an increased need for improved civilian manpower and personnel planning as a result of growing personnel costs, retrenchments, and restrictions on work force size and composition. Activity-level managers must continually adjust personnel inventories to meet workload requirements, subject to uncertainties in the workload, acceptable levels of work force turbulence, budgetary and ceiling constraints, and EEO goals. In developing realistic manpower planning and control systems for the U.S. Navy, particularly in an EEO context, attention must be directed toward the way the Navy uses its available civilian manpower over time.

Objective

The goal of this effort was to develop two Navy civilian manpower management models that account for EEO requirements: a master goals policy planning model and a local personnel planning model. The former is intended for comprehensive policy testing at aggregate levels, while the latter determines individual assignments at the local installation.

Approach

A goal programming model with embedded Markoff transition matrices was formulated to deal with multiple objectives involved with satisfying EEO conditions over time at an aggregate or Navy-wide level. This kind of model allows decision-makers to pursue multiple manpower goals (which may be inconsistent with each other) while simultaneously accommodating other concerns including financial/budgetary limitations. It was formulated as the Flexible Equal Employment Opportunity (FEEO) model to include both upward mobility and production requirements in the same model structure.

The Coherence/Goal-Arc model was developed to determine individual assignment plans at the micro levels of local activities—such as shipyards or laboratories. It is intended to provide rapid, integer solutions, in addition to being "coherent" with the results of the overall planning model. These models were tested using hypothetical, yet realistic, Navy civilian manpower data.

Results

The FEEO model was "run" under circumstances that forced personnel flow rates to mirror those of the past, or alternatively permitted managerial flexibility in those rates. For each alternative, the model produces a suggested personnel strategy, the resultant work force after the proposed changes, and a detailed comparison to manpower requirements. In the tests that were performed, personnel trade-offs were apparent in the internal structure of the organization that, by including the flexibility options, represent feasible decision strategy alternatives. Similarly, significant trade-offs between internal transfers and outside hiring became visible by comparing the discrepancies from the EEO goals in cases with and without flexibility constraints.

The Coherence/Goal-Arc model was also tested with hypothetical Navy activity data. The model generates comparative personnel strategies for use by local

planners. The results may be used to establish training programs to effect a "bridge" between occupations to meet both EEO and production objectives. In addition, the feasibility of any of these local strategies needs to reflect the constraints imposed on the local facility's manpower system by the aggregate level of the organization. Hence, the two levels of the models are "coherently" linked to one another.

Conclusions

The EEO goals policy planning model will assist both Navy headquarters and local activity manpower planners in choosing personnel strategies that satisfy both operating needs and EEO objectives.

Recommendations

1. The Coherence/Goal-Arc model should be tested in large-scale, industrial settings, such as activities of the Naval Material Command.

2. Analysis of external labor markets applicable to major NAVSEA activities for use in improved EEO goal determination should be continued.

3. Research should be extended to improve the models' solution times and ability to handle large numbers of constraints and/or flexibility options.

4. Conversational versions of the FEEO and Coherence/Goal-Arc models should be developed for headquarters and activity-level use.

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INTRODUCTION

Problem

The U.S. Navy, along with other U.S. government organizations, is an equal employment opportunity (EEO) employer. Because of EEO law and associated pressures and incentives, however, Navy civilian manpower managers find it difficult to match qualified people to jobs, while simultaneously providing opportunities for minorities and women to achieve adequate representation across all jobs. This problem affects both the supply and demand sides of manpower planning: The supply of appropriately qualified individuals in the labor pool must be distributed in a fashion consistent with their ethnosexual (race-sex) representation in relevant populations, and the demand for individuals must be a function of employment opportunity balancing efforts, as well as production-related manpower requirements.

The problems associated with manpower planning in the U.S. Navy are, to a large extent, a function of the complexity found in large organizations. This complexity often results in conflicting evaluations of a particular policy; for example, a policy may produce very satisfactory short-range benefits but undesirable long-range effects, or it may be applicable to the organization as a whole but not for many of its divisions. Therefore, in developing realistic (systematic, automatable, and attainable) manpower planning and control systems for the Navy, particularly in an EEO context, interest must be directed toward the way the Navy uses its available civilian manpower over time. This problem is complicated by the need to balance potential effects on the system's productivity and, hence, its ability to perform its ordinary functions against the benefits that can accrue to individuals who are recruited or placed within the system to meet EEO goals.

Purpose

The objective of this effort was to construct Navy civilian manpower management models that accommodate EEO requirements in a reasonable, yet comprehensive and coordinated manner. Two types of models are required: a master goals policy planning model and a local personnel planning model. This approach allows for planning and monitoring major facets of the related recruitment, promotion, transfer, and organizational structure adjustments that need attention over pertinent time intervals.

Background

The civilian personnel planning modeling research that was originated by Charnes, Cooper, and Niehaus (1972) provided a basis for extending this research to include EEO issues. The first step, as reported by Charnes, Cooper, Lewis, and Niehaus (1976), was to include new model elements in an attempt to meet mission-related manpower goals and social responsibilities as represented by EEO goals in personnel modeling schemes. It was found, however, as discussed by Burroughs and Niehaus (1976) and Burroughs, Korn, Lewis, and Niehaus (1976), that the resulting model--called the Flexible EEO (FEEO) model--could not be used at the local level because of small cell size problems. This led to the development of an organization design model by Charnes, Cooper, Lewis, and Niehaus (1976) that employs, for local planning levels, a nonlinear goal programming model that is iteratively computed by an approximating capacitated distribution model. The state-of-the-art was further advanced by Lewis (1977), who developed prototype models with operational data, and EEO goals that considered regional labor market data. The local model was also extended into a "goal-arc network formulation" by Charnes, Cooper, Lewis, Nelson, and Niehaus (1977), which could be used in a local naval installation.

Niehaus (1978) observed that aggregate-local manpower planning decision-making linkages must be systematically coordinated either directly or through judgmental linkages so as to provide for realistic overall policies coupled with local personnel management decisions.[1] This coordination is to be accomplished by a "bottoms-up" development of EEO goals supplemented by organization design models at the local level and a policy analysis model at the overall organization level. Integral to this system is an external labor market-analysis capability developed by Atwater, Niehaus, and Sheridan (1978) to determine the available labor pools. Also required is an accountability system as proposed by Niehaus and Nitterhouse (1978) to track the goals, plans, and action process. Later versions of the latter system will probably move toward a strengthening of modeling capabilities as more knowledge becomes available through actual system operation.

The remaining sections describe the component aggregate and local models, along with the integration of a systems framework for EEO planning. Later reports will describe the area of external labor market analysis in terms of a large-scale organizational test in the Naval Sea Systems Command (NAVSEA), which covers approximately 100,000 civilian employees in 22 local labor markets.

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[1]See also Chapters III and IV of Niehaus (in press).

EEO MODEL STRUCTURES

Master Goals Policy Planning Model

A goal programming model with embedded Markoff transition matrices was formulated to deal with multiple objectives involved in satisfying EEO conditions over time at an aggregate or Navy-wide level. This kind of model allows decision-makers to pursue multiple manpower goals (which may be inconsistent with each other) while simultaneously accommodating other concerns, including financial/budgetary limitations. It was first formulated as a Flexible Equal Employment Opportunity Model (FEEO) to include both upward mobility and other concerns in the same model structure. Before describing this FEEO modeling approach, however, it should be noted that, for operational purposes, only a reduced version of the model was tested. This version was obtained by omitting the flexibility and upward mobility features. Computational support of the original model was not possible.

The FEEO model is formulated to accommodate both the short-run and longer-run considerations of an organization, so that immediate (short-run) operating needs may be satisfied while progress is being made toward longer-run targets set up to satisfy EEO objectives. The FEEO model thus tries to use a given organizational/social structure to best advantage in a way that makes contact with their present (or initial) states while explicitly indicating how that structure should be changed--in "the best possible manner"--to achieve EEO goals. In the short-run, the model considers the total number of "on-board" personnel at each job level or group of job levels (e.g., GS-9 through 12) and occupational group (e.g., technician), and assigns them in the best possible way to occupation groups judged necessary for conducting the day-to-day operations of the organization. This is done with respect to static and dynamic considerations represented by transition probabilities in Markoff matrix formats that are embedded in a wider, time-dependent goal programming model context. These transition and promotion rates prevailing from past experience are then altered, within a goal programming framework, to provide new steady-state transition and promotion probabilities that will increase the probability of more closely approaching the EEO goals in the long run.

Additional managerial controls are also provided as part of the managerial flexibility options in the FEEO model by allowing short-run specifications on the lower bound of the acceptable number of on-board personnel of a given minority status at each job category (occupational group-job level) over a single time period. These options are then merged for simultaneous consideration with other manpower planning results for their bearing on long-term issues of meeting EEO targets. The link between the long- and short-term is included in the model design via Markoff matrices, which reflect the movements of personnel from job level to job level (or occupation to occupation) over time. The managerial controls incorporated in the model, however, can be used to keep the resulting plans under management's direction at all times.

In summary, the overall objectives of the FEEO model are to minimize discrepancies between:

1. Planned on-board personnel and the organization's immediate manpower requirements.

2. The actual number of on-board personnel of a given minority or ethnosexual status at each job category and the desired number of given minority status personnel on-board at each job category at specified points in time.

The FEEO model mathematical formulation and associated definitions are provided in Figures 1 and 2 respectively.

Figure 1, line (2) gives the first set of constraints in the form of Total Manpower Goals. These constraints reflect the goals for numbers of personnel in each job category for each time period t. These are short-term constraints that deal with satisfying an organization's immediate operating needs. For a single equation in the constraint set, on-board minority personnel at a particular job category, say i, are added to non-minority personnel on-board at that position. Thus, $X_i^k(t)$ is summed over all k personnel types to produce $X_i(t)$. To this sum are added deviational terms, $\delta_i^+(t)$, $\delta_i^-(t)$, which represent the number of on-board personnel in a particular job category that either exceed—$\delta_i^+ > 0$—or fall short—$\delta_i^- > 0$—of the goal. This goal, $g_i(t)$, is a specified number that represents the staffing requirements thought necessary for each job category to maintain sufficient output of the goods or services that justify an organization's continued existence in the short run.

The deviation terms, $\delta_i^+(t)$ and $\delta_i^-(t)$, allow positive and/or negative slack in meeting total manpower goals. The values of $\delta_i^+(t)$ and $\delta_i^-(t)$, as already noted, represent deviations from the goals stated by the values prescribed for the $g_i(t)$. These deviations are then weighted by the constants $W_{ik}(t)$ and $w_i(t)$ that reflect the relative importance of each of the indicated goals as the objective function, shown on line (1) of Figure 1, pushes the solution toward meeting goals in a manner that assures that the resulting deviations are minimal.

The longer-run issue of setting and meeting target values for EEO goals is represented in the next set of constraints. Note that the variables $X_i^k(t)$ and the prescribed goals $g_i(t)$ which appear in (2) are also present in (3). Here, however, the $g_i(t)$ are multiplied by fractions $g_i^k(t)$ for the proportion of a given personnel status, say type k (e.g., a minority), who are to be represented in the total for the job category as reflected in goal $g_i(t)$. The variables $\delta_{ik}^+(t)$ and $\delta_{ik}^-(t)$, which are both constrained to be nonnegative, represent deviations from these targeted goals with these values being weighted by prescribed constants $w_{ik}(t)$ in the functional (1).

Minimize:

(1) FUNCTIONAL $$\sum_{ikt} W_{ik}(t)(\delta^+_{ik}(t)+\delta^-_{ik}(t)) + \sum_{it} W_i(t)(\delta^+_i(t)+\delta^-_i(t))$$

subject to:

(2) TOTAL MANPOWER GOAL CONSTRAINTS $$\delta^+_i(t) - \delta^-_i(t) + \sum_k X^k_i(t) = g_i(t)$$

(3) EEO PROPORTIONAL GOAL CONSTRAINTS $$\delta^+_{ik}(t) - \delta^-_{ik}(t) + X^k_i(t) = g_i(t)g^k_i(t)$$

(4) TRANSITION CONDITIONS $$-h^k_j(t) - \sum_i Z^k_{ij}(t) - \sum_i m_{ij}X^k_i(t-1) + X^k_j(t) + \sum_i Y^k_{ij}(t) = 0$$

(5) MAXIMUM ADDITIVE FLEXIBILITY $$-\sum_j Z^k_{ij}(t) + f^k_{ij}\left(\sum_{\ell} (m_{\ell i})X^k_i(t-1)\right) \geq 0$$

(6) MAXIMUM SUBTRACTIVE FLEXIBILITY $$-Y^k_{ij}(t) + m_{ij}X^k_i(t) \geq 0$$

(7) ADDITIVE-SUBTRACTIVE BALANCE CONDITIONS $$\sum_j Z^k_{ik}(t) - \sum_j Y^k_{ij}(t) = 0$$

(8) MINIMUM EEO PROPORTIONS $$X^k_i(t) - p^k_i(t)g_i(t) \geq 0$$

(9) BUDGETARY CONSTRAINTS $$-\sum_i \sum_k C^1_i(t)X^k_i(t) \geq -b^1(t)$$

$$-\sum_i \sum_j \sum_k C^2_{ij}(t)Z^k_{ij}(t-1) \geq -b^2(t)$$

$$-\sum_i \sum_k C^3_i(t)h^k_i(t) \geq -b^3(t)$$

where $\delta^+_{ik}(t)$, $\delta^-_{ik}(t)$, $\delta^+_i(t)$, $\delta^-_i(t)$, $X^k_i(t)$, $Z^k_{ij}(t)$, $Y^k_{ij}(t)$, and $X^k_{ij}(t)$ are non-negative for all i, j, k, and t.

Figure 1. FEEO model mathematical formulation.

Variable or Parameter		Definition
$X_i^k(t)$	=	Number of personnel of type k in job i in period t.
$X_i(t)$	=	$\sum_k X_i^k(t)$ = total number of personnel in job category i in period t--the sum over all personnel types k.
m_{ij}	=	Current or "historical" transition rate from job category i to job category j.
$g_i(t)$	=	Total in job category i across all k personnel types which forms the total goal prescribed for period t.
$g_i^k(t)$	=	Proportional goal in job category i for personnel type k in period t.
$\delta_i^+(t)$, $\delta_i^-(t)$	=	Deviational terms for discrepancies from the total goals in time t.
$\delta_{ik}^+(t)$, $\delta_{ik}^-(t)$	=	Deviational terms for the proportional goals in time t.
$Z_{ij}^k(t)$	=	Number of personnel type k in job category i in period (t-1) additionally transferred to category j in period t.
$h_i^k(t)$	=	Number of personnel type k "hired" from outside into category i in period t. NOTE: $h_i^k(t) < 0$ represents a RIF (Reduction in Force), and $h_i^k(t) > 0$ represents an augmentation via outside recruitment into the organization.
$f_{ij}^k(t)$	=	Policy parameters that can be used to further stipulate the nature of additional flexible transfers.
$Y_{ij}^k(t)$	=	Number of personnel type k, job category i, not transiting to job category j in period t via the expected transition rate m_{ij}.

Figure 2. FEEO model variable and parameter definitions.

Variable or Parameter		Definition
$P_i^k(t)$	=	Minimal proportions requirements of type k personnel in job category i during period t.
$C_i^1(t)$	=	Salary cost in job category i in time period t.
$C_i^2(t)$	=	Transfer costs (salary + training) for the flexible transfers from job category i to j in time t.
$C_i^3(t)$	=	Salaries + recruiting costs for new hires (or penalties associated with Reductions in Force (RIFs) when $h_i^k(t) < 0$) in period t.
$b^1(t)$, $b^2(t)$, $b^3(t)$	=	The respective budgetary limits.

Figure 2. (Continued)

The MINIMUM EEO PROPORTIONS (Figure 1, line (8)) place short-term lower bounds, $p_i^k(t)$, on the proportions of minority personnel deemed as "base-line" acceptable in each job category i. These bounds, when combined with the PROPORTIONAL EEO GOALS (line (3)), determine the fractional part of the total work force at each job category that will be of a minority status at any point in time.

Over a period of time, on-board personnel may move from one occupation or job level to another. Such movements are catalogued historically and the probabilities of their occurrence estimated to form a Markoff matrix of expected transition rates. It may be the case, however, that to best achieve multiple objectives defined by an EEO manpower program, actual movements will not equal expected transitions. More individuals may move from job i to job j than expected historically;[2] it therefore follows that, for other possible transitions from job i (over the same period), fewer individuals than historically expected will move. This concept of "flexibility" permits the model to take advantage of historical data, but does not restrict the model's solution to mirror transition situations of the past.

Special attention is drawn to the fact that these flexibility options make it possible to do more than accelerate the progress toward the EEO goals specified for <u>each</u> time interval, t. They also make it possible to demonstrate objectively the progress that is being made in the resulting affirmative actions over all of these periods. Hence, these flexibility options make it possible to achieve such affirmative action results without recourse to the rigidity associated with other alternatives such as prescribed ethnosexual quotas. Moreover, since these options are exercised in ways that apply through the whole planning time horizon, they also provide an effective way to change past transition rates to new ones that bear on future promotion and transition probabilities. In this way, the entire organization is moved toward incorporating these results into its more permanent design.

The MAXIMUM ADDITIVE FLEXIBILITY constraints (Figure 1, line (5)), reflect <u>positive</u> flexibility, the $Z_{ij}^k(t)$, in the transition rates over those historically expected, m_{ij}, for each personnel type k. The additional (positive flexibility) transfers of some particular personnel type out of a job category cannot exceed the total number of personnel of that type who were in that category at the start of the period.

Due to additional transits of some personnel type as described by positive flexibility, fewer transfers than historically expected, $Y_{ij}^k(t)$, will occur from appropriate jobs. This effect is denoted by the MAXIMUM SUBTRACTIVE FLEXIBILITY (Figure 1, line (6)). Again, an upper bound exists on the number of people who will <u>not</u> move that would otherwise be expected to move.

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[2]Transition in this model refers to movement from job i to job j where j may equal i; that is, for completeness, people who do not change jobs from one period to another are nevertheless thought of as transiting from their current job i to that same job i.

The ADDITIVE-SUBTRACTIVE BALANCE CONDITIONS (Figure 1, line (7)) are simply accounting equations that conserve the number of people undergoing flexible movements in the system. That is, the sum of all positive movements out of job i must equal the transitions out of job i that do not occur, but were expected to occur.

During a given time period, it is also necessary to consider movement into an organization from external sources by hiring, $+|h_i^k(t)|$ and from the organization by Reductions in Force (RIFs), $-|h_i^k(t)|$ for each personnel type k.

All of these movements produce TRANSITION CONDITIONS (Figure 1, line (4)). These constraints reflect equality between the respective number of personnel of each type k at each job category j at some time t, $X_j^k(t)$, with the expected number of on-board personnel who will move into the job, $\sum_i m_{ij}^k X_i(t-1)$, plus the flexibility of additional $\sum_i Z_{ij}^k(t)$, or fewer $-\sum_i Y_{ij}^k(t)$, people transiting from job j beyond those expected, plus new hires from outside $+|h_j^k(t)|$ minus RIFs, $-|h_j^k(t)|$; that is,

THOSE EXPECTED
TO TRANSIT + (± FLEXIBILITY) + HIRES - RIFs = ON-BOARD

for each personnel type k and job category i at time t.

Finally, there is a set of budget constraints (Figure 1, line (9)). The first represents a salary budget, $b^1(t)$, for all job occupants in each time period t. The second inequality in this set of budget constraints refers to transfer costs (salary plus training), $\sum_{ijk} C_{ij}^2(t)Z_{ij}^k(t-1)$, incurred during each time period for flexible transfers from the previous time period. The last group represents salaries plus recruiting costs for new hires, or penalties incurred from RIFs.[3]

The model was tested via numerical example and found to be computable, but the studies described in Burroughs, Korn, Lewis, and Niehaus (1976) and Lewis (1977) showed that a complete FEEO model for a Navy-wide application would involve some 7500 rows and 12,000 columns. This is too large and costly for implementation with current computer system and software constraints.

A variety of strategies to deal with this phenomenon was clearly needed. One strategy was directed to research that would develop computational routines

[3]Here the $C_i^3(t)$ values are the same for both new hires, $h_i^k(t) > 0$, and RIFs, $h_i^k(t) < 0$, but this may be easily altered to distinguish "new hire" and "RIF" costs if desired. See, e.g., Charnes and Cooper (6).

to exploit the special structure of the FEEO model. This work is still in progress and the new goal-arc methods described in the next section form one part of this work. In the meantime, various modifications or reductions of the FEEO model were used for a variety of other applications. This included, for example, a version without EEO ethnosexual categories in a number of civilian promotion planning applications, as in Albanese, Korn, Niehaus, and Padalino (1977) and Niehaus and Nitterhouse (1978).

As outlined in Burroughs and Niehaus (1976), at the request of the Assistant Secretary of the Navy (Manpower and Reserve Affairs), a reduced version of the model was also developed for Navy-wide use. The results obtained from this reduced model showed that the existing Navy civilian EEO goals policy needed substantial revision. The implemented version eliminated the flexibility features so that much of the existing large-scale software system already in place could be used without modification.

Using the definitions of Figure 2, this reduced model, as shown in Figure 3, can be reproduced. A comparison of Figure 3 with Figure 1 shows that the affirmative action aspects of the general FEEO model were removed. Also, the budgetary constraints were replaced by simpler manpower ceiling constraints. Rough estimates made of the EEO goals reflected in existing policy were then incorporated in the reduced model; this sufficed to show, as already noted, that these goals needed substantial revision.

Local Personnel Planning Models

The manpower planning process in the Navy (or any enterprise) involves a derivation of manpower demand forecasts in relation to "corporate" objectives. This includes provision for feedback into revision of the objectives from the results of the manpower forecasts. In addition, these forecasts must relate to other plans and parts of the organization via, for example, financial decisions supported by a common budget.

The FEEO model and its modifications are intended for comprehensive policy testing at aggregate levels in the civilian manpower planning efforts of the Navy. While final coordinating decisions are the purview of top management, there are many decisions and interactions that should be addressed at the local/regional level of decision-making on the way toward those final decisions. Thus, something further is required for determining individual or "almost individual" assignments at the micro levels of local installations--such as shipyards or laboratories--where the sparsity of jobs in some categories introduce difficulties in rounding to integer solutions. Thus, models need to be developed at the micro level that are "coherent" with the results of overall planning, but that yield integer solutions. The Coherence and Goal-Arc models described below are directed toward this problem. For the present, consistency is to be accomplished by a "bottoms-up" goal development process until testing of the local personnel planning model is completed.

Minimize:

(1) FUNCTIONAL $\sum_{ikt} W_{ik}(t)(\delta^+_{ik}(t)+\delta^-_{ik}(t)) + \sum_{it} W_i(t)(\delta^+_i(t)+\delta^-_i(t))$

subject to:

(2) TOTAL MANPOWER GOAL CONSTRAINTS $\delta^+_i(t) - \delta^-_i(t) + \sum_k X^k_i(t) = g_i(t)$

(3) EEO PROPORTIONAL GOAL CONSTRAINTS $\delta^+_{ik}(t) - \delta^-_{ik}(t) + X^k_i(t) = g_i(t)g^k_i(t)$

(4) TRANSITION CONDITIONS $-h^k_j(t) - \sum m_{ij} X^k_i(t-1) + X^k_j(t) = 0$

(5) MINIMUM EEO PROPORTIONS $X^k_i(t) - p^k_i(t)g_i(t) \geq 0$

(6) MANPOWER CEILING CONSTRAINTS $\sum_i \sum_k X^k_i(t) \leq C(t)$

Figure 3. A reduced FEEO model.

A "Coherence" Model

To illustrate the operation of the Coherence model, consider two personnel types $\alpha = 1, 2$ (e.g., females and males) and transition periods $t = 0, 1, 2$. For job categories in this example, let $i, j = 0, 1, 2, 3$, where 1 = clerical, (C), 2 = technical, (T), 3 = administrative, (A) and 0 represents natural attrition (N) and forced attrition (O), both of which are movements to "outside" of the organization.

First, let $X_{ij}^{\alpha}(t-1, t)$ represent transfers from job i to job j between two successive periods for personnel type α. These transfers are expected to occur in accordance with the organization's historical promotion-transition experience. This is represented in a Markoff matrix such as the one shown in Figure 4.

FROM \ TO	N	C	T	A
C	.26	.70	.03	.01
T	.15	.00	.80	.05
A	.13	.00	.02	.85

Figure 4. Example of a Markoff transition matrix.
(Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

In Figure 4, for instance, the first row shows that based on past experience, 26 percent of the clerical personnel are expected to leave via natural attrition; 70 percent, to remain as clerks from one period to the next; 3 percent, to move to the technical category; and 1 percent, to become administrators.

Figure 5 contains proportionality factors, p_j^{α}, which are used to derive the requirements of personnel of each personnel type α in job j for each time period from the total number of job positions that exist. Note that these are given as both actual and desired proportions, reflecting the on-board status of the personnel type and the associated "goals" for representation over the planning horizon. For example, Figure 5 illustrates management's desire to redistribute clerical jobs across male and female employees such that male representation in this job will change from 11 percent to 25 percent. The actual p_j^{α} proportions are obtained from the on-board starting population, while the desired p_j^{α} proportions represent policy statements concerning desired mixes of personnel for the future.

		C	T	A
Actual Proportions	Female	.89	.20	.40
	Male	.11	.80	.60
Desired Proportions	Female	.75	.35	.45
	Male	.25	.65	.55

Figure 5. Actual and desired proportions of male, female personnel. (Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

The total number of jobs, $a_j(t)$, obtained from the aggregate model for the indicated time periods, appears in Figure 6.

Combining these $a_j(t)$ values with the p_j^α from Figure 5 produces the amounts shown on the rims of Figure 7. For instance, 600 = .89 (675) represents the estimated number of females "on-board" in the clerical category in period t = 0, while 525 = .75 (700) represents the period 1 "goal." Note the way, then, in which the results obtained from the aggregate model in Figure 6 are combined with local (actual and desired) proportions data to produce the wanted "coherence."

j \ t	0	1	2
C	675	700	650
T	875	450	400
A	225	200	200

Figure 6. Targeted work force goals.
(Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

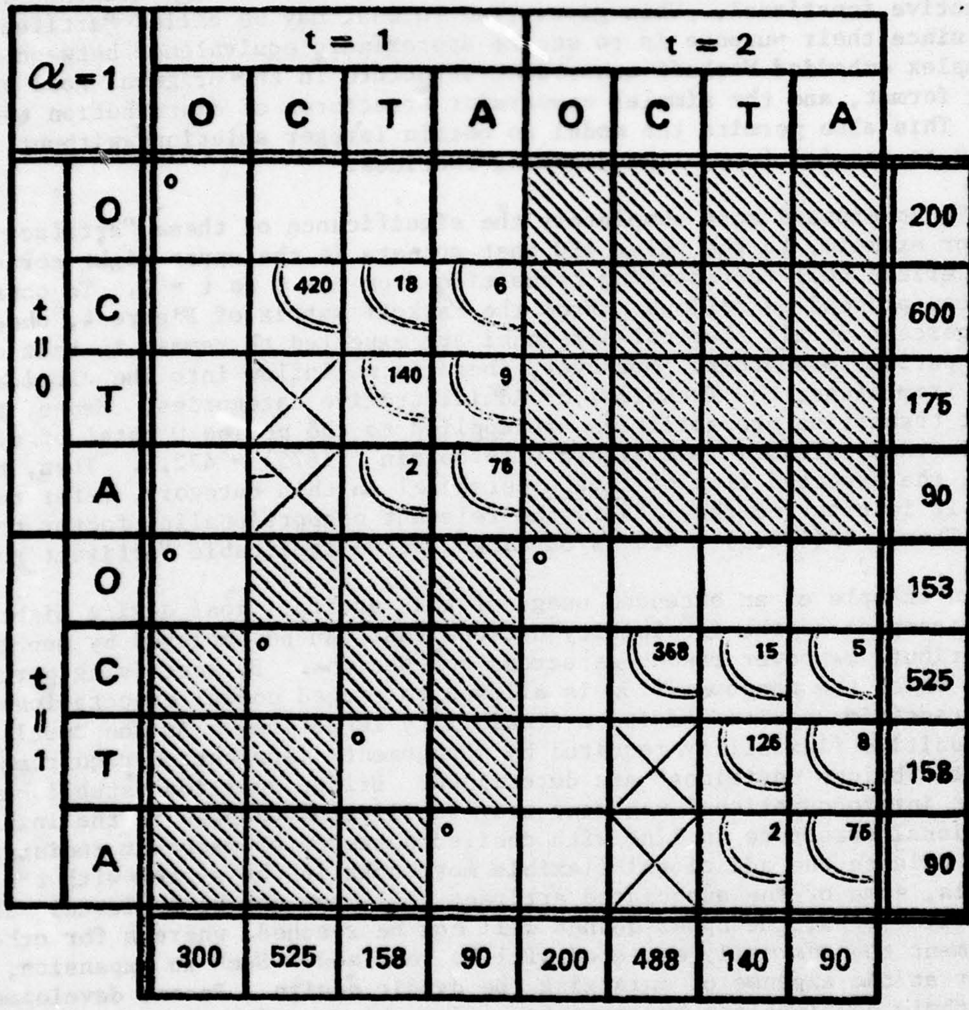

Figure 7. Dyadic format for illustration of coherence model. (Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

The location of nonlinear goal functionals is indicated in Figure 7 by the cells with numerical entries representing "goal" values enclosed in double lines in the upper right-hand corner. These nonlinear functional elements are introduced to produce a change in model format from one with a complex matrix structure to one of a "dyadic"[4] or distribution model. The original constraining relations can thereby be replaced with non-linear elements in the objective functional. This gives rise to what may be called "artifact goals," since their purpose is to secure approximate equivalence between the more complex embedded Markoff constraint structure in the original goal programming format, and the simpler constraint structures of distribution type models. This also permits the model to obtain integer solutions without resorting to special integer programming routines.

To understand more completely the significance of these "artifact goals," refer, for example, to the value 420 that appears in the upper right corner of the clerical cell representing transition from $t = 0$ to $t = 1$. To obtain this value, proceed as follows. From the Markoff matrix of Figure 4, observe that 70 percent of all clerical personnel are expected to remain in that category from one period to another. Moreover, there is no inflow into the clerical position from either the Technical or Administrative categories. Hence, the pertinent transition probabilities are applied to the period 0 total of 675 persons in this category from Figure 6 to obtain $.7(675) = 472.5$. Then, to determine the expected flow of female personnel in this category, refer to Figure 5, where it is observed that .89 is the relevant proportionality factor to employ. Thus, $.89(472.5) = 420$ is obtained as the applicable "artifact goal."

An example of an extended usage of this artifact goal device might be made with respect to the flexibility options that can be employed by management to redistribute manpower resources across occupations. By specifying particular jobs into which the manpower flow is allowed to exceed normal expectations over a given transition period, additive flexibility is defined. As the model solves for the additive flexibility required by management distribution requirements, appropriate "bridge positions" are determined. Bridge position establishment represents interoccupational movement that facilitates changes in the internal organizational structure in line with desired patterns of manpower redistribution. To balance the additional flexible movements in the system with the manpower goals, some of the associated artifact goals may not be achieved. Thus, for particular jobs, the upper bounds will not be reached, whereas for other jobs more movement than normally expected will be realized. Such an expansion, though, will occur at the expense of enlarging the dyadic design. Recent developments in algorithmic combinations and computer codes, however, make the computational costs of such elaborations relatively inexpensive.

The array of Figure 7 must be transformed in order to obtain an equivalent distribution-assignment format. This is accomplished and shown in Figure 8. (Note the use of the "N" columns in this figure to distinguish natural attrition from forced attrition, which is designated in the "O" or "outside sources" columns.) In this figure, the functional coefficients, which represent the set of relative priorities established by management for policy-making, appear as numerical values in the upper left-hand corner of the pertinent cells. For slack

[4]See Charnes and Cooper (1961).

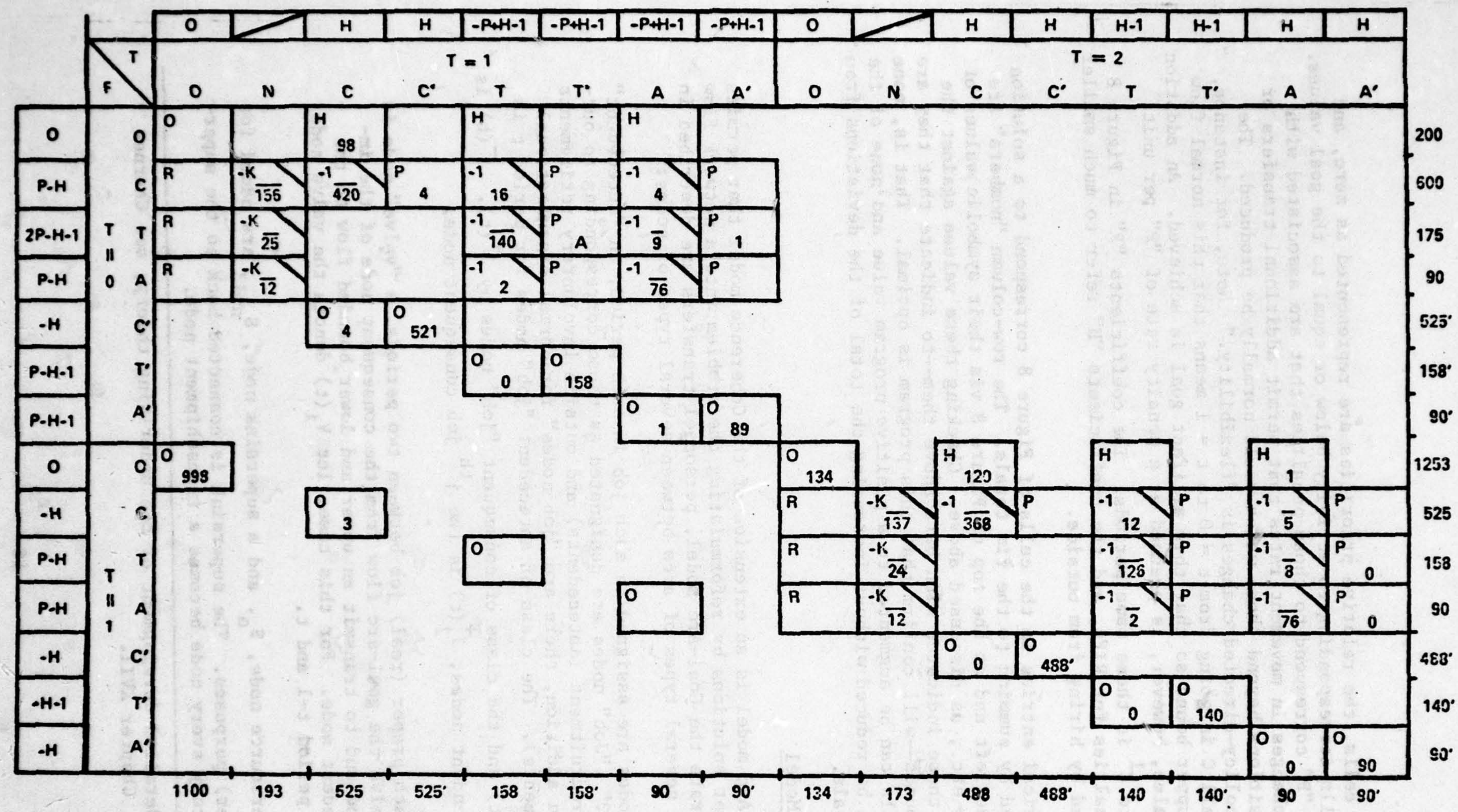

Figure 8. Expanded dyadic format for numerical illustration.
(Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

or transshipment cells, the relative priorities are represented as zero, and as -1 for the cells corresponding to activity below or equal to the goal values. The coefficients "P" correspond to those penalties that are associated with policy-directed changes in movement rates that permit additional transfers or retentions of positions beyond those which would normally be produced. The result of these policy-directed changes is "flexibility." Note, for instance, the 420 in the cell C in going from $t = 0$ to $t = 1$ means that this normal flow value is at its upper bound so that this artifact goal is achieved. An addition of four more females, however, is planned at a penalty rate of "P" per unit, via the cells C to C^1 in these same periods. The coefficients "R" in Figure 8 refer to high penalties for RIFs, and the coefficients "H" refer to much smaller penalties incurred by hiring from outside.

The numerical entries in the cells of Figure 8 correspond to a solution as may be verified by summing to the rim totals. The row-column "numbers" are represented on the left and at the top of Figure 8 via their symbolic values of 0, H, -P + H + 1, etc., as discussed above. Checking these values against the vacant cells and those indicated with bars above them—to indicate that they are at their upper bounds—will confirm that this program is optimal. That is, none of the vacant cells can be augmented to a positive program value and none of the barred values can be reduced without increasing the total of the deviations from the prescribed goals.

The Goal-Arc Model

The Goal-Arc model is an extension of the Coherence model that permits even more efficient solutions by reformulating the problem into a network flow model. To illustrate the Goal-Arc model, personnel transfers are described in terms of flows on several types of arcs between several types of nodes:[5]

1. Two nodes are assigned to each job in each period, an "antecedent" and a "consequent." "Job" nodes are designated as those corresponding to outside sources for recruitment (antecedents) and outside involuntary retirements (consequents). In addition, there are "job nodes" for normal organizational attrition (consequents). The class of antecedent "job" nodes for period t is designated as $J^-(t)$ and the class of consequent "job" nodes by $J^+(t)$. $J^-(t)$ is the i^{th} job antecendent nodes; $J_j^+(t)$ is the j^{th} job consequent node.

2. For each proper (real) job between two periods, a "valve" node is designated to receive the goal-arc flow from the consequent node of the immediate past period and to transmit an upper and lower bounded flow to the next period antecedent node. For this case, let $V_i(t)$ denote the valve node for job i between period t-1 and t.

3. A supersource node, S_o, and a supersink node, S_{n+1}, are added for PNET code (computer) purposes. The supersink is connected back to the supersource node. Thereby every node becomes a transshipment node.

[5]For further detailed development of the underlying theory, see Charnes and Cooper (1961), Chapter XVII.

The flow on every arc is unidirectional. The arcs may be "goal" arcs (with a nonlinear goal functional) involving multiple arcs between the same two nodes, or they may be simple arcs. Every simple arc (or individual arc of multiple arcs) may have an upper and a lower bound on its flow.

Let $x_{ij}^k(t)$ denote the flow from node $J_i^-(t)$ to node $J_j^+(t)$ on the k^{th} individual arc of a multiple "goal arc." The corresponding lower and upper bounds are $L_{ij}^k(t)$ and $U_{ij}^k(t)$.

Let x_{oi} denote the flow from the supersource to $J_i^-(1)$. Let $x_{i\ n+1}$ denote the flow from $J_i^+(n)$ to the supersink. Let $x_{n+1\ o}$ denote the flow from the supersink to the supersource.

Let $Y_i^k(t)$ denote the flow on arc k of the goal-arc between $J_i^+(t-1)$ and $V_i(t)$. The corresponding upper and lower bounds are $L_i^k(t)$ and $U_i^j(t)$. Let $\bar{y}_i(t)$ denote the flow of the "valve" arc between $V_i(t)$ and $J_i^-(t)$.

The network node conditions may now be written explicitly:

For supersource:

$$x_{n+1\ o} - \sum_{i \epsilon J^-(1)} x_{oi} = 0. \tag{1}$$

For $J^-(1)$:

$$x_{oi} - \sum_{j \epsilon J^+(1)} \sum_k x_{ij}^k(1) = 0. \tag{2}$$

For $J^+(1)$:

$$\sum_k \sum_{i \epsilon J^-(1)} x_{ij}^k(1) - \sum_r y_j^r = 0, \quad j \neq j_o. \tag{3}$$

Where j_o is the "outside" node,

$$x_{oj_o} + \sum_k \sum_{i \epsilon J^-(1)} x_{ij_o}^k (1) - \sum_r y_{j_o}^r (1) = 0.$$

Note that there is never flow from the "outside" node $J_{j_o}^-(1)$ to the natural attrition node $J_{i_o}^+(t)$.

For $V_i(t)$:

$$\sum_k y_i^k(t) - \bar{y}_i(t) = 0. \tag{4}$$

For $J_i^-(t)$, $t > 1$:

$$\bar{y}_i(t) - \sum_k \sum_j x_{ij}^k(t) = 0. \tag{5}$$

For $J_j^+(t)$, $t > 1$:

$$\sum_k \sum_{i \varepsilon J^-(t)} x_{ij}^k - \sum_r y_j^r(t) = 0. \tag{6}$$

For supersink S_{n+1}:

$$\sum_t y_{i_o}(t) + \sum_{i \varepsilon J^+(n)} x_{i\ n+1} - x_{n+1 o} = 0. \tag{7}$$

The Goal-Arc model is completely described as:

$$\text{Min} \left[\sum_{\substack{i,j,k,t \\ i \neq i_o}} c_{ij}^k x_{ij}^k(t) \quad \sum_{\substack{i,k,t \\ i \neq i_o, j_o}} d_i^k y_i^k(t) \right].$$

Subject to (1) - (7) above, and

$$L_{ij}^k(t) \leq x_{ij}^k \leq U_{ij}^k(t),$$

$$L_i^k(t) \leq y_i^k(t) \leq U_i^k(t),$$

where the $L_{ij}^k(t)$, $U_{ij}^k(t)$ and the $L_i^k(t)$, $U_i^k(t)$ are such that the $x_{ij}^k(t)$, $y_i^k(t)$, $\bar{y}_i(t)$ are non-negative for all i, j, k, and t.

An illustration of the Goal-Arc model is given in Figure 9 for n time periods and m + 2 job categories. S_o is the supersource node introduced on the left and S_{n+1} is the supersink node introduced on the right. In the diagram, the antecedents and the consequents of the outside node are represented by $J_{m+1}^-(t) = J_{j_o}^-(t)$, $J_{m+1}^+(t) = J_{j_o}^+(t)$, and $J_{m+2}^+(t) = J_{i_o}^+(t)$.

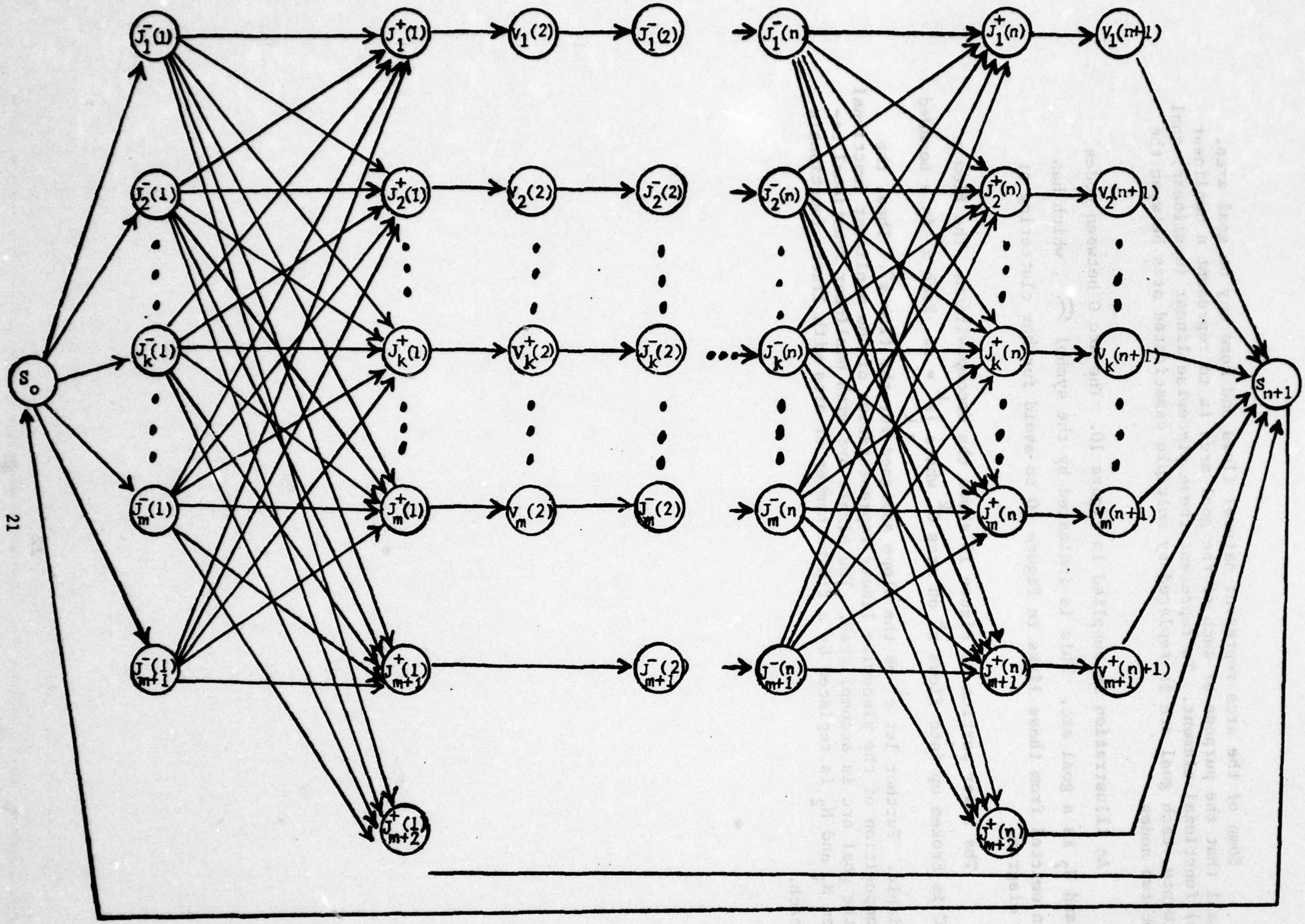

Figure 9. Goal arc network model.
(Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

Some of the arcs represent natural flows and some may be goal arcs. Recall that the purpose of each of the goal arcs is to represent a nonlinear goal functional element. To represent these piecewise linear (nonlinear) goal elements, each goal arc is replaced by multiple capacitated arcs between the same two nodes.

An illustration is supplied in Figure 10. The arc G between nodes N_1 and N_2 is a goal arc. This is indicated by the symbol , which has been omitted from these links in Figure 10 to avoid further cluttering of the diagram.

The lower portion of Figure 10 shows the decomposition. The flow z on G is broken up into flows z^k on arcs G^k where $\sum_k z^k = z$. Each z^k is a bounded variable. Further let c^k be the slope assigned for the flow z^k. Thus, the decomposition of the piecewise linear representation of the nonlinear functional on the goal arc is accomplished. The single arc with nonlinear functional between N_1 and N_2 is replaced by a finite number of arcs with linear functionals on each.

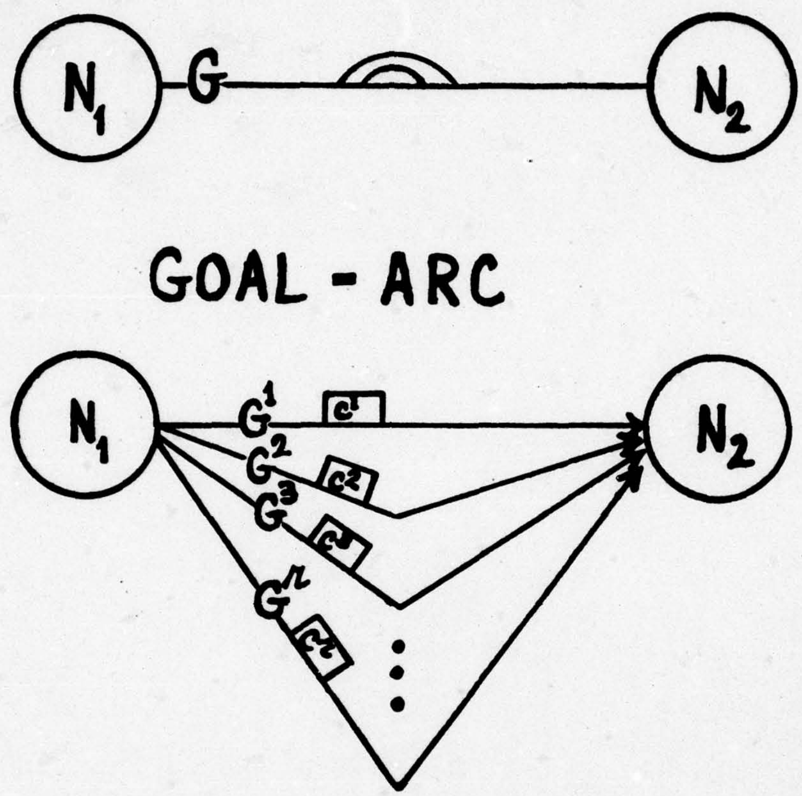

Figure 10. Decomposition of single goal-arc with nonlinear functional to multiple goal-arcs with linear functionals.
(Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977)

MODEL APPLICATIONS

FEEO Model: Navy Civilian Human Resources Planning

In this section, the FEEO model's operation will be described in the context of a numerical illustration using actual Navy data. The application will include a comparison of versions of the model with and without flexibility features (Burroughs, Korn, Lewis, & Niehaus, 1976).

Although the data are actual, they are highly aggregated and, hence, not in the form required for actual use. Yet, because the example is intended to be explanatory only, that purpose is best served by the number of variables being small. Thus, a three period model is employed here. The data represent the probable size and structure of the U.S. Navy civilian graded white collar work force in the three occupation groups of Administrative, Technical, and Clerical for the planning horizon beginning in March 1976. Within each of these three occupational groups, four job level distinctions were made (viz., GS-1--GS-4 = Level 1, GS-5--GS-8 = Level 2, GS-9--GS-12 = Level 3, GS-13--GS-15 = Level 4) for general schedule (i.e., G.S.) employment. In addition, partitioning was done on the basis of sex alone.

Figures 11 and 12, respectively, provide a description of the information needed to "run" and interpret the FEEO model. Data of the type described in Figure 11, for example, can be secured directly from Navy data sources (e.g., historical transition rates). It also lends itself to top management problems of policy-setting, such as the determination of available flexibility options. Finally, it also relates the external and internal environments via, for example, the proportional requirements.

Figure 12 describes the output or results of the FEEO model. Recall that the model stresses EEO compliance (in the long-run), while simultaneously addressing the operating needs (short-run) of the organization. This is likely to involve complex interactions; hence the pertinent details of Figure 12.

Figures 13 and 14 are the Markoff transition matrices for the male and female social groups, respectively. The diagonal cell entries indicate the proportion of personnel who remain in the job category in which they started, over one planning period. Off-diagonal elements show the transfer rates per period between any two jobs. No entry in the cell signifies an historical transfer rate close to or equal to zero. Additionally, allowable flexible movements are indicated by a "Z" in the lower right-hand corner of the appropriate cells.

Flexibility is expressed as changes to the unadjusted organizational transition matrices. This is accounted for in the model by setting up equations that permit either additions to or subtractions from the unadjusted transition rates. The extent of potential change is controlled by coefficients. In the case of additive flexibility, the coefficients are policy parameters reflecting the maximum amount by which the model is permitted to adjust the transition matrix. In the case of subtractive flexibility, the controls are set so that the number of transfers cannot exceed the number available for transfer.

VARIABLE	DESCRIPTION OF VARIABLE
Manpower Requirements	The number of individuals across social groups necessary in each job category to meet the operating needs of the organization.
Proportional Requirements	The number of minority individuals, by occupational group, desired to be on-board to match their representation in the labor force.
Minimum EEO Proportions	The proportional lower bounds allowed by job category and social group on the number of minority personnel by occupational groups.
Initial Population	The number of personnel of each social group on-board in each job category at the start of the transition period.
Historical Transition Rates	The rates of movement between specific occupational groups, based on analysis of such movement over time.
Priorities for Goal Attainment	A representation of the "penalties" associated with not meeting the total manpower goals and the proportional EEO goals.
Priorities for Hiring/Firing	A representation of the "penalties" associated with hiring personnel into jobs from outside the system, and with firing personnel.
Flexibility Policy	The degree and placement of flexibility allowed in the system as a function of organizational slack, including the priorities for internal transfer.

Figure 11. FEBO input chart.
(Source: Burroughs, Korn, Lewis, & Niehaus (1976))

VARIABLE	DESCRIPTION OF VARIABLE
On-board Personnel	The number, by social group and job category, of personnel at the end of each period . . . work force composition.
Hires/Fires	The number of personnel, by social group and job category, hired and fired (by the model) during each period.
Interoccupational Mobility	The job mobility, including that beyond historical rates, suggested to meet goals as a function of flexibility.
Goal Discrepancies	How well each goal (total and proportional) for each occupational group, is met.

Figure 12. FEEO output chart.
(Source: Burroughs, Korn, Lewis, & Niehaus (1976))

T \ F	A1	A2	A3	A4	T1	T2	T3	T4	C1	C2	C3
A1	.238	X	X	X	z	X	X	X	z	X	X
A2	.095	.556	X	X	z	$.013_z$	X	X	$.007_z$	$.031_z$	X
A3	■	.311	.874	X	■	$.016_z$	$.030_z$	X	■	$.003_z$	$.146_z$
A4	■	■	.013	.863	■	■	z	$.051_z$	■	■	$.008_z$
T1	z	X	X	X	.453	X	X	X	$.014_z$	X	X
T2	z	$.016_z$	X	X	.286	.756	X	X	$.016_z$	$.067_z$	X
T3	■	$.005_z$	$.009_z$	X	■	.107	.693	X	■	$.002_z$	$.051_z$
T4	■	■	z	$.001_z$	■	■	.001	.841	■	■	z
C1	z	X	X	X	$.018_z$	X	X	X	$.680_z$	X	X
C2	$.047_z$	$.004_z$	X	X	$.003_z$	$.003_z$	X	X	.068	.764	X
C3	■	z	z	X	■	z	z	X	■	.002	.698

Figure 13. Male Markoff transition matrix for promotions or lateral transfers, and upward mobility in the administrative, technical, and clerical occupation groups across GS-levels.

T \ F	A1	A2	A3	A4	T1	T2	T3	T4	C1	C2	C3
A1	.533	X	X	X	z	X	X	X	z	X	X
A2	.200	.634	X	X	$.004_z$	$.018_z$	X	X	$.003_z$	$.018_z$	X
A3	■	.212	.891	X	■	$.015_z$	$.096_z$	X	■	$.001_z$	$.057_z$
A4	■	■	.006	.868	■	■	$.001_z$	z	■	■	z
T1	z	X	X	X	.628	X	X	X	$.011_z$	X	X
T2	z	$.033_z$	X	X	.120	.812	X	X	$.007_z$	$.034_z$	X
T3	■	$.004_z$	$.004_z$	X	■	.024	.800	X	■	z	$.021_z$
T4	■	■	z	z	■	■	.001	1.0	■	■	z
C1	z	X	X	X	$.052_z$	X	X	X	.695	X	X
C2	z	$.014_z$	X	X	$.013_z$	$.020_z$	X	X	.084	.819	X
C3	■	z	z	X	■	z	$.002_z$	X	■	.001	.784

Figure 14. Female Markoff transition matrix for promotions or lateral transfers, and upward mobility in the administrative, technical, and clerical occupation groups across GS-levels.

Occupation Groups

A = Administrative Jobs
T = Technical Jobs
C = Clerical Jobs

Levels

1 = GS 1-4
2 = GS 5-8
3 = GS 9-12
4 = GS13-15

Key

■ = invalid transition, due to Federal System's structure
X = transition not allowed in this model...not representative of a promotion or lateral transfer
z = allowable "flexible" transition

(Source: Burroughs, Korn, Lewis, and Niehaus (1976))

Two levels of flexibility options were tested (100% and 50% of all available personnel at the start of each period). The maximum subtractive flexibilities were set to equal the transition rates given in Figures 13 and 14, so that the total movement in the system would be no greater than normally experienced.

The relative priorities or "weights" placed on deviations from the exact attainment of the workload goals were set at 15, 10, and 5 for each of the three periods respectively, and at 5, 10, and 15 for the proportional EEO goals. This was done to reflect a situation in which workload was to be considered relatively more in the short-run and EEO compliance relatively more in the long-run. Hiring weights were set at 3, and firing weights at 1000. This ensured that internal movements were preferred to hiring, and that firing was only considered in the extreme "last resort" case.

It was found by comparing model runs with and without the inclusion of flexibilities that the addition of the flexibility constraints did produce different "optimal" results. The two different levels of flexibility, however, produced identical solutions. This indicated that the number of personnel suggested for a flexible internal assignment for the optimization of the suggested goal structure was below both flexibility levels set in the tests. Thus, the allocation of slack resources to meet the demands of the additional (flexible) movements in the system suggested by the model's solutions in both cases did not exceed the available slack. The results for the example run without flexibilities are given in Figures 15, 16, and 17 for the three time periods, respectively. Analogous results for the two examples with flexibilities appear in Figures 18, 19, and 20 for the three respective transition periods. In addition, information on the suggested flexible transitions over the three periods for males and females is given in Figures 21 and 22, respectively.

In all cases studied, the total manpower goals were met exactly in the first and second periods, while positive and negative discrepancies from the third period total manpower goals were evident in both runs with and without flexibility constraints. Moreover, many of these discrepancies were the same for particular job categories despite the presence or absence of flexibility constraints. This was the case, for instance, in the level 2, 3, and 4 Technician groups, where discrepancies for all model runs were 0, +2922, and +2, respectively. However, in other categories in the third time period, very definite differences appeared to exist. One notable example occurred in the first level Technicians group, where the solution for the model without flexibilities (Figure 17) indicated no discrepancy from the total manpower goal, and the flexibility solutions (Figure 21) showed a discrepancy of -481 from the same goal. This might seem to indicate that the model with the flexibility options included provided a less desirable set of outcomes. However, a further comparison of solution results shows that, although for some occupations and levels the outcomes were worse, for others the outcomes were considerably better. This is the case for second level Administrative positions, where the discrepancy from the total manpower goal was -525 in the nonflexible solution (Figure 17), and 0 in the flexible ones (Figure 20).

PERSONNEL TYPE AND OCCUPATION GROUP/LEVEL	ABOARD	HIRES	RIF'S	PROPORTIONAL		TOTAL	
				GOAL	DISCREP.	GOAL	DISCREP.
MALE ADM LEV 1	12	9	0			35	0
FEMALE ADM LEV 1	23	102	0	23	0		
MALE ADM LEV 2	1,990	603	0			4,168	0
FEMALE ADM LEV 2	2,178	0	0	2,071	+107*		
MALE ADM LEV 3	15,835	0	0			21,290	0
FEMALE ADM LEV 3	5,455	714	0	5961	-506**		
MALE ADM LEV 4	4,858	0	0			5,627	0
FEMALE ADM LEV 4	769	405	0	844	- 75		
MALE TECH LEV 1	1,057	577	0			3,020	0
FEMALE TECH LEV 1	1,963	336	0	1,963	0		
MALE TECH LEV 2	7,210	799	0			14,294	0
FEMALE TECH LEV 2	7,084	0	0	6,561	+523		
MALE TECH LEV 3	15,826	794	0			17,604	0
FEMALE TECH LEV 3	1,778	1	0	2,641	-863		
MALE TECH LEV 4	357	31	0			391	0
FEMALE TECH LEV 4	34	0	0	27	+ 7		
MALE CLER LEV 1	6,522	3,483	0			32,609	0
FEMALE CLER LEV 1	26,087	6,404	0	26,087	0		
MALE CLER LEV 2	6,236	3,588	0			39,396	0
FEMALE CLER LEV 2	33,160	819	0	33,487	-327		
MALE CLER LEV 3	116	27	0			281	0
FEMALE CLER LEV 3	165	0	0	161	+ 4		

Figure 15. FEEO model solution, time period 1, no flexibility. (Source: Burroughs, Korn, Lewis, & Niehaus (1976))

***ABOARD - GOAL = 2178-2071 = +107 (over achievement of goal)**
****ABOARD - GOAL = 5455-5961 = -506 (under achievement of goal)**

PERSONNEL TYPE AND OCCUPATION GROUP/LEVEL	ABOARD	HIRES	RIF'S	PROPORTIONAL		TOTAL	
				GOAL	DISCREP.	GOAL	DISCREP.
MALE ADM LEV 1	14	11	0			35	0
FEMALE ADM LEV 1	21	9	0	21	0		
MALE ADM LEV 2	2,005	565	0			4,201	0
FEMALE ADM LEV 2	2,196	0	0	2.100	+ 96*		
MALE ADM LEV 3	15,085	0	0			21,457	0
FEMALE ADM LEV 3	6,372	731	0	7,081	- 709**		
MALE ADM LEV 4	4,417	0	0			5,427	0
FEMALE ADM LEV 4	1,010	308	0	1,357	- 347		
MALE TECH LEV 1	1,208	638	0			3,021	0
FEMALE TECH LEV 1	1,813	293	0	1,813	0		
MALE TECH LEV 2	6,930	623	0			14,300	0
FEMALE TECH LEV 2	7,370	0	0	7,150	+ 220		
MALE TECH LEV 3	15,075	0	0			17,611	0
FEMALE TECH LEV 3	2,536	910	0	4,403	-1,867		
MALE TECH LEV 4	321	0	0			377	0
FEMALE TECH LEV 4	56	20	0	56	0		
MALE CLER LEV 1	9,793	5,329	0			32,609	0
FEMALE CLER LEV 1	22,826	4,593	0	22,826	0		
MALE CLER LEV 2	9,849	4,608	0			39,396	0
FEMALE CLER LEV 2	29,547	0	0	29,547	0		
MALE CLER LEV 3	115	22	0			281	0
FEMALE CLER LEV 3	166	0	0	155	+ 11		

Figure 16. FEEO model solution, time period 2, no flexibility.
(Source: Burroughs, Korn, Lewis, & Niehaus (1976))

*ABOARD - GOAL = 2196-2100 = + 96 (over achievement of goal)
**ABOARD - GOAL = 6372-7081 = -709 (under achievement of goal)

PERSONNEL TYPE AND OCCUPATION GROUP/LEVEL	ABOARD	HIRES	RIF'S	PROPORTIONAL		TOTAL	
				GOAL	DISCREP.	GOAL	DISCREP.
MALE ADM LEV 1	18	15	0				
FEMALE ADM LEV 1	18	7	0	18	0	36	0
MALE ADM LEV 2	1,580	0	0				
FEMALE ADM LEV 2	2,137	0	0	2,121	+ 16*	4,242	- 525**
MALE ADM LEV 3	14,417	0	0				
FEMALE ADM LEV 3	8,668	2,132	0	8,668	0	21,671	+1,414
MALE ADM LEV 4	4,026	0	0				
FEMALE ADM LEV 4	1,550	633	0	1,550	0	5,167	+ 409
MALE TECH LEV 1	1,511	827	0				
FEMALE TECH LEV 1	1,512	122	0	1,512	0	3,023	0
MALE TECH LEV 2	6,868	435	0				
FEMALE TECH LEV 2	7,439	0	0	7,154	+285	14,307	0
MALE TECH LEV 3	14,375	0	0				
FEMALE TECH LEV 3	6,167	3,924	0	6,167	0	17,620	+2,922
MALE TECH LEV 4	289	0	0				
FEMALE TECH LEV 4	72	13	0	72	0	359	+ 2
MALE CLER LEV 1	7,195	521	0				
FEMALE CLER LEV 1	21,196	5,238	0	21,196	0	32,609	-4,218
MALE CLER LEV 2	13,078	4,855	0				
FEMALE CLER LEV 2	26,318	0	0	25,607	+711	39,396	0
MALE CLER LEV 3	116	16	0				
FEMALE CLER LEV 3	164	0	0	141	+ 24	281	0

Figure 17. FEEO model solution, time period 3, no flexibility.
(Source: Burroughs, Korn, Lewis, & Niehaus (1976))

*ABOARD - GOAL = 2137-2121 = +16 (over achievement of goal)

**ABOARD - GOAL = (1580+2137)-4242 = -525 (under achievement of goal)

PERSONNEL TYPE AND OCCUPATION GROUP/LEVEL	ABOARD	HIRES	RIF'S	PROPORTIONAL		TOTAL	
				GOAL	DISCREP.	GOAL	DISCREP.
MALE ADM LEV 1	12	8	0			35	0
FEMALE ADM LEV 1	23	5	0	23	0		
MALE ADM LEV 2	1,990	0	0			4,168	0
FEMALE ADM LEV 2	2,178	0	0	2,071	+107*		
MALE ADM LEV 3	15,835	0	0			21,290	0
FEMALE ADM LEV 3	5,455	687	0	5,961	-506**		
MALE ADM LEV 4	4,858	0	0			5,627	0
FEMALE ADM LEV 4	769	405	0	844	- 75		
MALE TECH LEV 1	1,057	313	0			3,020	0
FEMALE TECH LEV 1	1,963	85	0	1,963	0		
MALE TECH LEV 2	7,210	0	0			14,294	0
FEMALE TECH LEV 2	7,084	0	0	6,561	+523		
MALE TECH LEV 3	15,826	0	0			17,604	0
FEMALE TECH LEV 3	1,778	793	0	2,641	-863		
MALE TECH LEV 4	357	1	0			391	0
FEMALE TECH LEV 4	34	31	0	27	+ 7		
MALE CLER LEV 1	6,522	3,181	0			32,609	0
FEMALE CLER LEV 1	26,087	0	0	26,087	0		
MALE CLER LEV 2	5,909	3,255	0			39,396	0
FEMALE CLER LEV 2	33,487	1,110	0	33,487	0		
MALE CLER LEV 3	116	27	0			231	0
FEMALE CLER LEV 3	165	0	0	161	+ 4		

Figure 18. FEEO model solution, time period 1, with flexibility.
(Source: Burroughs, Korn, Lewis, & Niehaus (1976))

*ABOARD - GOAL = 2178-2071 = +107 (over achievement of goal)
**ABOARD - GOAL = 5455-5961 = -506 (under achievement of goal)

PERSONNEL TYPE AND OCCUPATION GROUP/LEVEL	ABOARD	HIRES	RIF'S	PROPORTIONAL GOAL	PROPORTIONAL DISCREP.	TOTAL GOAL	TOTAL DISCREP.
MALE ADM LEV 1	14	10	0				
FEMALE ADM LEV 1	21	4	0	21	0	35	0
MALE ADM LEV 2	1,999	0	0				
FEMALE ADM LEV 2	2,202	0	0	2,100	+ 102*	4,201	0
MALE ADM LEV 3	15,084	0	0				
FEMALE ADM LEV 3	6,373	699	0	7,081	- 708**	21,457	0
MALE ADM LEV 4	4,417	0	0				
FEMALE ADM LEV 4	1,010	308	0	1,357	- 347	5,427	0
MALE TECH LEV 1	1,208	336	0				
FEMALE TECH LEV 1	1,813	58	0	1,813	0	3,021	0
MALE TECH LEV 2	6,919	0	0				
FEMALE TECH LEV 2	7,381	0	0	7,150	+ 231	14,300	0
MALE TECH LEV 3	15,075	0	0				
FEMALE TECH LEV 3	2,536	909	0	4,403	-1,867	17,611	0
MALE TECH LEV 4	321	0	0				
FEMALE TECH LEV 4	56	20	0	56	0	377	0
MALE CLER LEV 1	9,783	4,886	0				
FEMALE CLER LEV 1	22,826	2,402	0	22,326	0	32,609	0
MALE CLER LEV 2	10,718	0	0				
FEMALE CLER LEV 2	29,678	4,545	0	29,547	- 969	39,396	0
MALE CLER LEV 3	115	22	0				
FEMALE CLER LEV 3	166	0	0	155	+ 11	281	0

Figure 19. FEEO model solution, time period 2, with flexibility.
(Source: Burroughs, Korn, Lewis, & Niehaus (1976))

*ABOARD - GOAL = 2202-2100 = +102 (over achievement of goal)
**ABOARD - GOAL = 6373-7081 = -708 (under achievement of goal)

PERSONNEL TYPE AND OCCUPATION GROUP/LEVEL	ABOARD	HIRES	RIF'S	PROPORTIONAL		TOTAL	
				GOAL	DISCREP.	GOAL	DISCREP.
MALE ADM LEV 1	18	13	0			36	0
FEMALE ADM LEV 1	18	3	0	18	0		
MALE ADM LEV 2	2,117	0	0			4,242	0
FEMALE ADM LEV 2	2,125	0	0	2,121	+ 4*		
MALE ADM LEV 3	14,417	0	0			21,671	+1,414
FEMALE ADM LEV 3	8,668	2,092	0	8,668	0		
MALE ADM LEV 4	4,026	0	0			5,167	+ 409
FEMALE ADM LEV 4	1,550	633	0	1,550	0		
MALE TECH LEV 1	1,030	0	0			3,023	- 481**
FEMALE TECH LEV 1	1,512	0	0	1,512	0		
MALE TECH LEV 2	6,889	0	0			14,307	0
FEMALE TECH LEV 2	7,418	0	0	7,154	+264		
MALE TECH LEV 3	14,375	0	0			17,620	+2,922
FEMALE TECH LEV 3	6,167	3,920	0	6,167	0		
MALE TECH LEV 4	289	0	0			359	+ 2
FEMALE TECH LEV 4	72	13	0	72	0		
MALE CLER LEV 1	11,413	4,074	0			32,609	0
FEMALE CLER LEV 1	21,196	3,320	0	21,196	0		
MALE CLER LEV 2	9,527	641	0			39,396	-4,262
FEMALE CLER LEV 2	25,607	0	0	25,607	0		
MALE CLER LEV 3	117	0	0			281	0
FEMALE CLER LEV 3	164	0	0	141	+ 23		

Figure 20. FEEO model solution, time period 3, with flexibility. (Source: Burroughs, Korn, Lewis, & Niehaus (1976))

*ABOARD - GOAL = 2125-2121 = +4 (over achievement of goal)
**ABOARD - GOAL = (1030+1512)-3023 = -481 (under achievement of goal)

1st Time Period

T \ F	A1	A2	A3	A4	T1	T2	T3	T4	C1	C2	C3
A1											
A2	-1										
A3		-603*									
A4											
T1									+302		
T2					-264					+6	
T3		+603**				-799					
T4											
C1	+1				+264						
C2						+799			-302		
C3										-6	

2nd Time Period

T \ F	A1	A2	A3	A4	T1	T2	T3	T4	C1	C2	C3
A1									+443		
A2	-1					+634					
A3		-569									
A4											
T1											
T2					-302					+12	
T3						-634					
T4											
C1	+1										
C2		+569			+302				-443		
C3										-12	

3rd Time Period

T \ F	A1	A2	A3	A4	T1	T2	T3	T4	C1	C2	C3
A1									+665		
A2	-1										
A3		-514				+406					
A4											
T1	+1										
T2					-345					+15	
T3						-406					
T4											
C1					+345						
C2									-665		
C3		+514								-15	

Figure 21. Flexible transfers for males for each of the three time periods. (Source: Burroughs, Korn, Lewis, & Niehaus (1976))

* -603 = Those who do not transit from Job A2 to A3 in the First Time Period, who were historically expected to make that move.

** +603 = Those who additionally transit from Job A2 to A3 in the First Time Period, above those who were historically expected to make that move.

KEY

A1 Administrative, Level 1
A2 Administrative, Level 2
A3 Administrative, Level 3
A4 Administrative, Level 4
T1 Technicians, Level 1
T2 Technicians, Level 2
T3 Technicians, Level 3
T4 Technicians, Level 4
C1 Clerical, Level 1
C2 Clerical, Level 2
C3 Clerical, Level 3

1st Time Period

T \ F	A1	A2	A3	A4	T1	T2	T3	T4	C1	C2	C3
A1											
A2	-5								+6,404	+36	
A3											
A4			-27*								
T1											
T2					-252						
T3											
T4							-1				
C1	+5				+252				-6,404		
C2											
C3			+27**				+1			-36	

2nd Time Period

T \ F	A1	A2	A3	A4	T1	T2	T3	T4	C1	C2	C3
A1									+2,191		
A2	-5										
A3			-2,427								
A4			- 33				+2				
T1											
T2					-236					+5,714	
T3			+2,460								
T4							-2				
C1	+5				+236						
C2									-2,191	-5,681	
C3										- 33	

3rd Time Period

T \ F	A1	A2	A3	A4	T1	T2	T3	T4	C1	C2	C3
A1											
A2	-4										
A3											+72
A4			-38				+3				
T1											
T2					-122				+1,917		
T3											
T4							-3				
C1	+4				+122						
C2									-1,917		
C3			+38								-72

Figure 22. Flexible transfers for females for each of the three time periods.

(Source: Burroughs, Korn, Lewis, & Niehaus (1976))

* -27 = Those who do not transit from Job A3 to A4 in the First Time Period, who were historically expected to make that move.

** +27 = Those who additionally transit from Job A3 to C3 in the First Time Period, above those who were historically expected to make that move.

KEY

A1 Administrative, Level 1
A2 Administrative, Level 2
A3 Administrative, Level 3
A4 Administrative, Level 4
T1 Technicians, Level 1
T2 Technicians, Level 2
T3 Technicians, Level 3
T4 Technicians, Level 4
C1 Clerical, Level 1
C2 Clerical, Level 2
C3 Clerical, Level 3

Thus, trade-offs are apparent in the internal structure of the organization and, by including the flexibility options, these trade-off possibilities represent feasible decision strategy alternatives. Similarly, significant trade-offs between internal transfers (flexible movements) and outside hiring become visible by comparing the discrepancies from the EEO goals in the cases with and without the flexibility constraints.

Local Personnel Planning Model: Navy Civilian Human Resources Planning

Two applications of the local personnel planning model are presented. The first is a test of the Coherence version of the model (Lewis, 1977). This was done using a general-purpose linear-programming package. The second application involves the Goal-Arc model. In this case, the PNET primal network code was used for solution purposes.

Coherence Model

The application of the Coherence model shows not only what the model provides when it performs its distribution-assignment tasks for the Navy civilian work force with respect to EEO and workload requirements, but also how it might relate to the workings of the aggregate FEEO model. Hence, the example employed for this application conforms to the structure of the FEEO application.

Figure 23 provides information on the actual ratios, across 11 relevant positions, of the two personnel types (male, female) currently holding these jobs at the particular installation involved. Also, it provides a goal structure for personnel representation determined appropriate for this hypothetical installation by local labor market-goal setting procedure.

The total number of jobs for all personnel types in each of the 11 categories at the aggregate level (i.e., across all activities) is presented in Figure 24. The values are similar to those that might be supplied directly by the FEEO model. When these numbers are modified by the actual personnel representation proportions at the aggregate level, the values in Figure 25 result. They represent the number of positions, across all activities within the 11 job categories involved, that are held by females.

The percentage of the total number of jobs (such as might be provided by the FEEO model) for the 11 job categories that exist at the local activity is provided in Figure 26.

When these proportions are taken times the total number of jobs in the work force, such as might be provided by the FEEO model, Figure 27 is produced.

Finally, Figure 28 shows the actual input to the run of the Coherence model for this hypothetical activity. This input is employed as row and column sums in the model's formulation and generally represent EEO staffing goals for this activity.

			A1	A2	A3	A4	T1	T2	T3	T4	C1	C2	C3
Actual	F	#1	.4	.35	.35	.2	.4	.3	.25	.2	.9	.85	.8
	M	#2	.6	.65	.65	.8	.6	.7	.75	.8	.1	.15	.2
Desired 1st PD.	F	#1	.41	.38	.38	.23	.41	.33	.26	.23	.87	.82	.79
	M	#2	.59	.62	.62	.77	.59	.67	.74	.77	.13	.18	.21
Desired 2nd PD.	F	#1	.43	.42	.42	.27	.43	.37	.28	.27	.83	.78	.77
	M	#2	.57	.58	.58	.73	.57	.63	.72	.73	.17	.22	.23
Desired 3rd PD.	F	#1	.45	.45	.45	.3	.45	.4	.3	.3	.8	.75	.75
	M	#2	.55	.55	.55	.7	.55	.6	.7	.7	.2	.25	.25

Key

A1 Administrative, Level 1
A2 Administrative, Level 2
A3 Administrative, Level 3
A4 Administrative, Level 4
T1 Technicians, Level 1
T2 Technicians, Level 2
T3 Technicians, Level 3
T4 Technicians, Level 4
C1 Clerical, Level 1
C2 Clerical, Level 2
C3 Clerical, Level 3

Figure 23. Actual and desired personnel ratios for males (M) and females (F) across job categories. (Source: Lewis (1977))

	A1	A2	A3	A4	T1	T2	T3	T4	C1	C2	C3
Starting Values	35	4149	21,195	5741	3020	14,290	17,570	399	32,609	39,396	281
1st PD	35	4168	21,290	5627	3020	14,294	17,604	391	32,609	39,396	281
2nd PD	35	4201	21,457	5427	3021	14,300	17,611	377	32,609	39,396	281
3rd PD	35	3717	23,085	5576	3023	14,307	20,542	361	28,391	39,396	280

Figure 24. Number of job i positions available—from FEEO model. (Source: Lewis (1977))

Females	A1	A2	A3	A4	T1	T2	T3	T4	C1	C2	C3
Starting Values	24	2062	4561	387	2097	6565	996	2	28,164	36,371	161
1st PD	23	2178	5455	769	1963	7084	1778	34	26,087	33,160	165
2nd PD	21	2196	6372	1010	1813	7370	2536	56	22,826	29,547	166
3rd PD	18	2137	8668	1550	1512	7439	6167	72	21,196	26,318	164

Figure 25. Number of job i positions available as determined from FEEO model, that are actually held by females. (Source: Lewis (1977))

A1	A2	A3	A4	T1	T2	T3	T4	C1	C2	C3
.05	.05	.05	.05	.1	.1	.1	.1	.03	.03	.01

Figure 26. Percentage of total number of jobs (from the FEEO model), by occupation group-job level, that exist at the local facility.
(Source: Lewis (1977))

Across all personnel types	A1	A2	A3	A4	T1	T2	T3	T4	C1	C2	C3
Starting Values	2	207	1060	287	302	1429	1757	40	978	1182	3
1st PD	2	208	1064	281	302	1429	1760	39	978	1182	3
2nd PD	2	210	1073	271	302	1430	1761	38	978	1182	3
3rd PD	2	186	1154	279	302	1431	2054	36	852	1182	3

Figure 27. Total number of jobs, $a_j(t)$, available for this local activity.
(Source: Lewis (1977))

		A1	A2	A3	A4	T1	T2	T3	T4	C1	C2	C3
Actual	#1 F	1	72	371	57	121	429	439	8	880	1005	2
Actual	#2 M	1	135	689	230	181	1000	1318	32	98	177	1
Goals PD #1	#1 F	1	79	404	65	124	472	458	9	851	969	2
Goals PD #1	#2 M	1	129	660	216	178	957	1302	30	127	213	1
Goals PD #2	#1 F	1	88	451	73	130	529	475	10	812	922	2
Goals PD #2	#2 M	1	122	622	198	172	901	1286	28	166	260	1
Goals PD #3	#1 F	1	84	519	84	136	572	616	11	682	887	2
Goals PD #3	#2 M	1	102	635	195	166	859	1438	25	170	295	1

Figure 28. Coherence model input by job category. (Source: Lewis (1977))

As in the explanatory example in the section on model structures, there are "weights" or relative priorities that define management's policy view or preference. In this example, these weights are represented as follows:

H = hiring weight = 5.
P = weight on flexible movement = 2.
-K = weight on the allowance of natural attrition = 0.
R = firing weight = 1000.
-1 = weight on expec.ˢd movement.

Since these values appear in the objective function of the Coherence model, and this objective function is to be minimized, a high weight value, such as the firing weight of 1000, tends to move the model's solution away from the inclusion of the associated variable. Thus, a weighting structure such as the one employed in this example highly discourages firing and prefers flexible movement to hiring, but at a level of preference that is much less significant than that of an historical degree of natural attrition over firing.

The same transition probabilities used in the FEEO application are also employed here. Thus, to compute the "artifact goals," appropriate transition probabilities from Figures 13 and 14 are applied to the row sums of the coherence model of Figure 28. The coherence model will meet these artifact goals before allowing flexible movements in the model's solution. This method of solution was generalized to allow positive and negative goal deviations in the Goal-Arc model.

The numerical example of the Coherence model was solved with little difficulty. The results will be discussed only briefly, since the management reporting capabilities of these local organization design models will be illustrated with the Goal-Arc model solution data. The Coherence model numerical example illustrates that the flexibility concept does in fact work. During the transition period from t = 2 to t = 3, three individuals are expected to move from the second level Administrator position to the second level Technician position. Checking Figure 14 for the probability, based on historical movements, of making this move, it is found that the pertinent transition rate is 0.33. Applying this figure to the relevant row sum (which is 102) results in the artifact goal of 0.33 (102) = 3.366 or 3 individuals. In this instance, the Coherence model filled this artifact goal and also provided for a positive flexible movement of 27 additional individuals from the second level Administrator position to the second level Technician position.

Although there is some interoccupational movement between the Clerical and Technical occupations indicated in period three, attrition and hiring practices seem to be able to effect the desired changes in representation within the Clerical occupation group. This seems inherently reasonable since the most significant changes in the personnel mix are suggested by the goal structure to occur in the Technical and Administrative groups. For the most part, these goal structures appear quite reasonable. Only in the case of the third level Technicians group (in the first and second periods) do any goal deviations occur, and these appear to be addressed in the model's solution by increased internal mobility into this position (i.e., positive flexible movement in all three periods from A3 to T3, and positive flexible movement from C3 to T3 in the third period), and direct hiring of individuals from outside the manpower system at the T3 level.

In the first transition period, as just mentioned, flexibility is indicated across the mid-level positions of the Administrative and Technical occupation groups. This same theme extends into the second and third time periods, suggesting, perhaps, the establishment of bridge positions between Administrative and Technical jobs, and supporting training programs. Some of this prescribed flexible movement provides for lateral transfers between these occupation groups. Such movement appeared as the transfer of 28 people from A2 to T2 in the first period, of 34 people from A3 to T3 in the second period, and of 2 people from T2 to A2 in the third period. It also occurred, however, that some promotions are realized during the process of this interoccupational mobility. For instance, in the first period, the transition of 11 people from T3 to A4 occurred. Therefore, it might be suggested that the training program developed to effect an organizationally effective (i.e., both in terms of EEO and production needs) bridge between these occupations should include an evaluation or testing mechanism for merit determination, as well as an appropriate competitive device to ensure equitable promotional opportunities to all trainees accepted in the program. Hence, it is such analyses that must be involved in the development of a manpower plan. A determination of the feasibility of any of the operational components of the plan needs to reflect the constraints imposed on the local facility's manpower system by the aggregate level of the organization, but also requires a consideration of the specific conditions existing at the local installation. The solution values of the model provide the fundamental framework for the local installation's plan, but it is up to management at this local level to develop strategies to support this framework. It is the combination of this strategy and the indicated numerical solution that comprises the installation's manpower plan for equal employment opportunity.

Goal-Arc Model

With the coherence results in hand, work was started to develop a small system that, of necessity, required the use of a high-speed solution methodology such as the PNET primal network code. This led to the need to generalize the method to include both upper and lower bounds in a mathematical structure that permitted ease of use of the PNET code. The Goal-Arc model was the result.

In order to make the Goal-Arc model more concrete, it is illustrated by means of a numerical example. The problem that is considered is the hypothetical problem first illustrated for the Coherence model by Charnes, Cooper, Lewis, and Niehaus (1976) and presented in the Coherence model section on page 12. The input data are repeated for the convenience of the reader.

There are two categories of personnel $\alpha = 1, 2$ (e.g., female and male) and three time periods, $t = 0, 1, 2$. The following job categories are used:

i, j	Description	Abbreviation
0	Outside Source/Natural Attrition	0
1	Clerical	C
2	Technical	T
3	Administrative	A

Figure 29 provides targeted work force goals $a_i(t)$, where $i = 1, 2, 3$ for the associated job category in each of the periods $t = 0, 1, 2$. Figure 30 provides a matrix of transition probabilities that is assumed to be applicable over these periods. Recall that N refers to natural attrition so that, for example, there is a 0.26 probability that clerical personnel will leave the organization in going from one period to another.

i \ t	0	1	2
C	675	700	650
T	875	450	400
A	225	200	200

Figure 29. Targeted work force goals, $a_i(t)$.
(Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

FROM \ TO	N	C	T	A
C	.26	.70	.03	.01
T	.15	0	.80	.05
A	.13	0	.02	.85

Figure 30. Example of a Markoff transition matrix.
(Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

In Figure 31, the actual p_i^α proportions of personnel in each job category for the initial time period and the desired p_i^α proportion of personnel in each job category for future time periods are given. The actual proportions are obtained from the "on board" starting populations. The desired proportions represent policy statements concerning the desired mix of personnel for the future.

Figure 32 provides the desired number of personnel of type $\alpha = 1$ (female) for each job category in each period. These values are obtained from Figures 29 and 31 in the following manner. Let $b_i(t) = p_i^1 a_i(t)$ where u is the smallest integer not less than u. Thus, for example, in Figure 32, 525 = .75 x 700 in the row for C where it intersects the column captioned "1."

		C	T	A
Actual Proportions	Female	.89	.20	.40
	Male	.11	.80	.60
Desired Proportions	Female	.75	.35	.45
	Male	.25	.65	.55

Figure 31. Actual and desired proportions of male, female personnel. (Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

i \ t	0	1	2
C	600	525	488
T	175	158	140
A	90	90	90
N		193	173

Figure 32. Desired number of females by job category and time period.
(Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

In Figures 33 and 34, the "artifact goals" are given for each of the two periods as indicated. The "artifact goals" are defined by $g_{ij}^{\alpha}(t) = p_i^{\alpha} a_i(t-1) M_{ij}$ where M_{ij} is the i,j^{th} element of the Markoff matrix M. In this example, attention is confined to $\alpha = 1$ and $g_{ij}^{1}(t) = g_{ij}(t)$ without ambiguity.

FROM \ TO	N	C	T	A
C	156	420	18	6
T	25		140	9
A	12		2	76

Figure 33. Artifact goals for the first period.
(Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

FROM \ TO	N	C	T	A
C	135	368	15	5
T	24		126	8
A	12		2	76

Figure 34. Artifact goals for the second period.
(Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

Similarly, let $x_{ij}(t)$ equal the number of females ($\alpha = 1$) transferred from job category i to job category j in period t and let $y_j(t)$ represent the total number of females in job category j in period t. In this model, the $y_j(t)$ and the $x_{ij}(t)$ are to conform "as close as possible" to the targeted work force goals and the "artifact goals" respectively.

This can be stated as a network problem. It is shown graphically in Figure 35. In this example, J_i^+, $J_i^-(t) = K_t^-$ and $V_i(t) = K_{(t-1)}$, where K is an abbreviation for "job category." Here, of course, K takes on the values, A, C, T, N, O. As already noted in the previous section, the symbol $\frown$ on an arc indicates that it is a "goal arc." Upper and lower bounds for the flow on

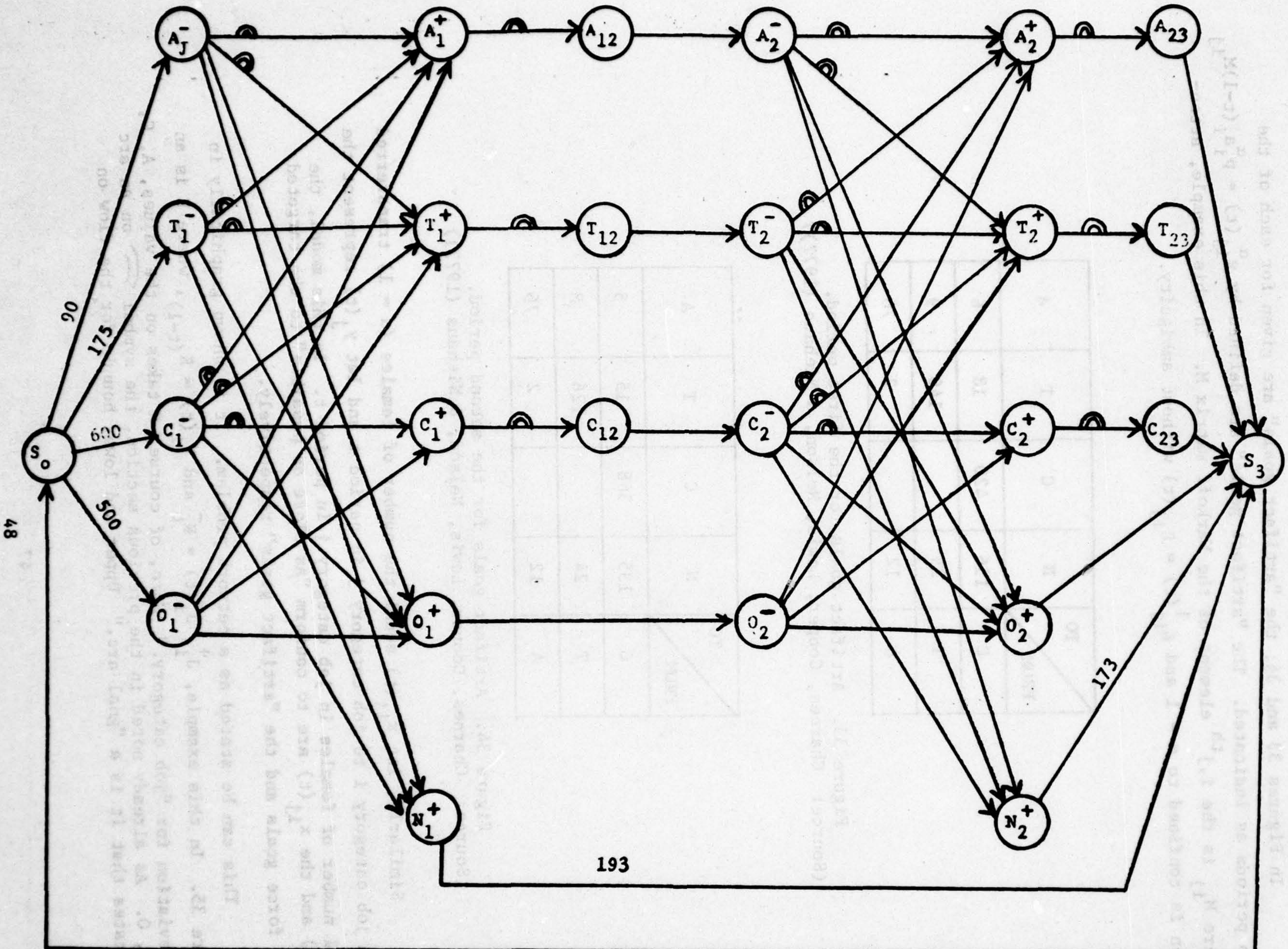

Figure 35. Goal-Arc network formulation.
(Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

the "valve" arcs are set, respectively, at the projected manpower requirements plus ten percent of the requirements and minus ten percent of the requirements.

In this example, only two pieces are employed in the piecewise linear goal functional (i.e., k = 2). Hence the decomposition on a "goal arc" is performed as described earlier with k = 2. The decomposition of "goal arcs" is examined in this example.

Consider any goal arc in Figure 35 between a K_t^- and a K_t^+. Replace this arc in Figure 36 with two arcs, say, $G_{ij}^k(t)$, where k = 1 or 2. Let $x_{ij}^k(t)$ denote the corresponding flows. These flows are bounded as follows: $0 \leq x_{ij}^1(t) \leq g_{ij}(t)$ and $0 \leq x_{ij}^2(t) < \infty$. Let c^k denote the functional coefficient on $G_{ij}^k(t)$. Assume that $c^1 < c^2$. In an optimal solution there will be no flow on $G_{ij}^2(t)$ until the flow on $G_{ij}^1(t)$ has reached $g_{ij}(t)$.

Now consider a goal arc between nodes K_t^+ and K_{t+1}. As above, replace this arc with two arcs, $G_i^1(t)$ and $G_i^2(t)$. Let $y_i^k(t)$ denote the flow on $G_i^k(t)$. The flows on the two arcs are bounded as follows: $0 \leq y_i^1(t) \leq b_i(t)$ and $0 \leq y_i^2(t) < \infty$. Let d^k denote the functional coefficient for the flow on $G_i^k(t)$. Assume that $d^1 < d^2$.

Proceeding in this manner the problem is represented as a network with the "goal arcs" decomposed as in Figure 36.

Since the objective function is to be minimized, a high positive value for the functional coefficient on an arc tends to make the resistance to flow on that arc high. In our penalty system, the following priorities are established:

1. Meeting the goal of a certain number of female personnel for each job category in each time period is given the highest priority.

2. Firing is highly discouraged.

3. Flexible movement has the second highest priority.

4. The penalty on exceeding manpower requirements is greater than any other penalty except the penalty on firing.

5. The penalty for hiring in the first period is greater than the penalty for hiring in the second period.

6. The penalty on hiring is less than the penalty on exceeding manpower but greater than the penalty on flexible movement.

7. The penalty on firing is set at an order of magnitude larger than the sum of all other weights.

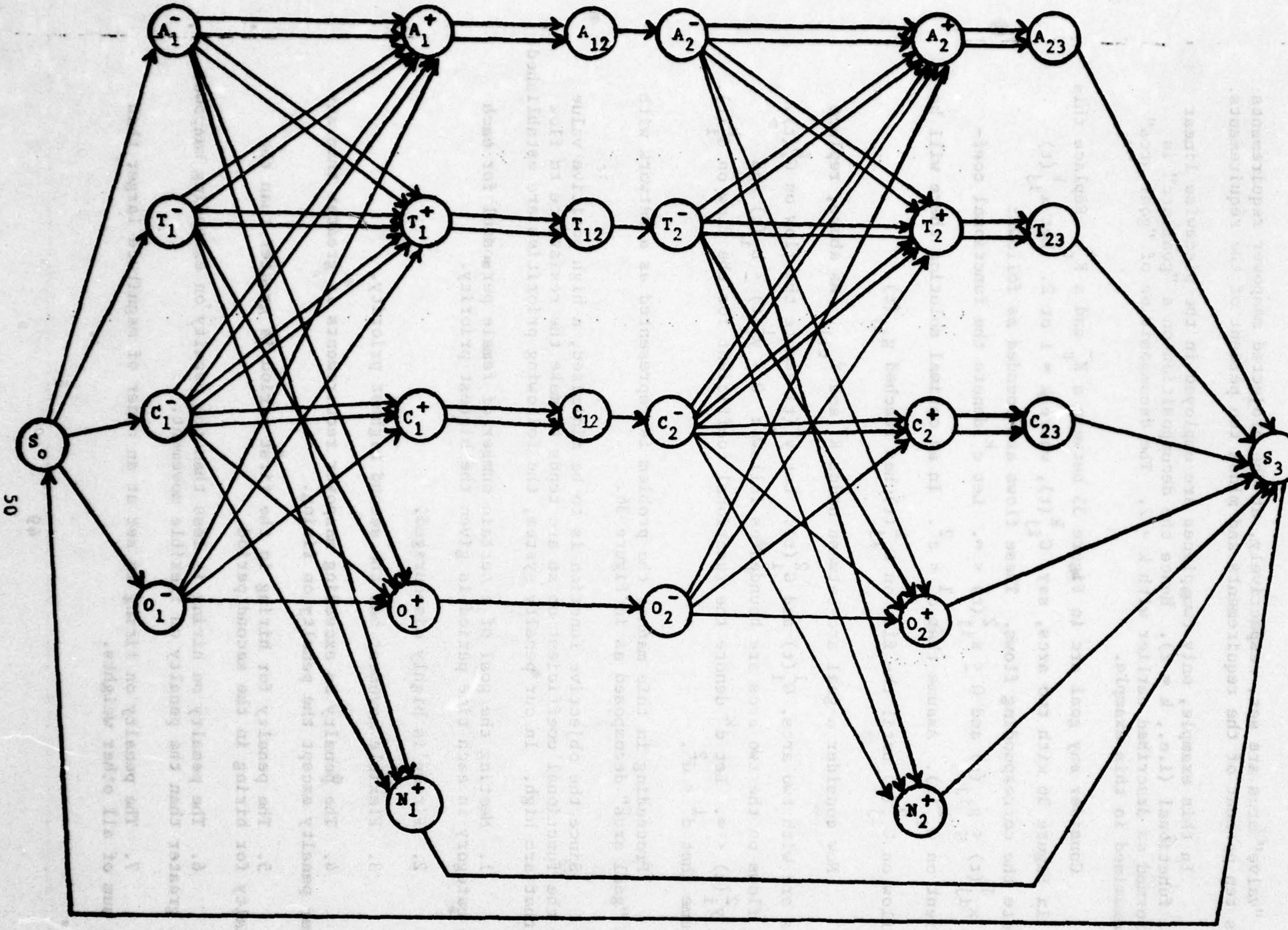

Figure 36. Network with goal-arcs decomposed.

(Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

The values for the functional coefficients on the arcs (with relevant interpretations) are given as follows:

H = hiring penalty = 5.
P = penalty on flexible movement = 2.
R = firing penalty = 1000.
G = penalty on expected movement = -1.
Q = penalty on meeting manpower requirements = -6.
F = penalty on exceeding manpower requirements = 10.

The solution is summarized in four tables as follows: The projected personnel transfers for periods 1 and 2 are given in Figures 37 and 38, respectively. The 424 under "Normal ± Flexible" in row 1 of Figure 37 represents the planned retention of females in the clerical job category in the first time period. It is composed of 420 females via normal retention plus 4 more as a part of an optimum managerial plan to alter the present composition of the organization. The total of 525 females at the bottom of this column is to be obtained by recruiting an additional 101 females from outside the organization. Figure 38 is similarly interpreted for the second time period.

Figure 39 compares work force requirements and the optimal distribution from the model—for example, targeted work force goals and optimal "on-boards." The discrepancies between the two are given in the last column of Figure 39. All discrepancies are at zero values, which means that the optimum program achieves all of the indicated targets.

Figure 40 is a summary of the personnel actions projected by the optimum plan. For example, 420 normal transfers plus 4 additional (flexible) transfers and 101 hires are projected for the clerical category in Period 1 and 368 normal transfers, 2 additional (flexible) transfers, and 118 hires in Period 2.

JOB CATEGORY	Number Aboard at Period (0)	CLERICAL		TECHNICAL		ADMINISTRATIVE		OUTSIDE LOSSES	
		Normal	Normal ± Flexible	Normal	Normal ± Flexible	Normal	Normal ± Flexible	Natural	Fires
Clerical	600	420	424	18	15	6	5	156	--
Technical	175	---	---	140	141	9	9	25	--
Administrative	90	---	---	2	2	76	76	12	--
Hires	---	---	101	---	---	--	--	--	--
Number Aboard at Period (1)	---	---	525	---	158	--	90	--	--

Figure 37. Projected personnel transfers: Female, period 1. (Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

JOB CATEGORY	Number Aboard at Period (0)	CLERICAL		TECHNICAL		ADMINISTRATIVE		OUTSIDE LOSSES	
		Normal	Normal ± Flexible	Normal	Normal ± Flexible	Normal	Normal ± Flexible	Natural	Fires
Clerical	525	368	370	15	13	5	5	137	--
Technical	158	---	---	126	126	8	8	24	--
Administrative	90	---	---	2	1	76	77	12	--
Hires	---	---	118	---	---	--	--	--	--
Number Aboard at Period (2)	---	---	488	---	140	--	90	--	--

Figure 38. Projected personnel transfers: Female, period 2. (Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

FEMALE

	On-Board Actual	Hires	Fires	Workload Requirements	Discrepancy*
PERIOD 0:					
Clerical	600				
Technical	175				
Administrative					
PERIOD 1:	Projected				
Clerical	525	101		525	
Technical	158			158	
Administrative	90			90	
PERIOD 2:					
Clerical	488	118		488	
Technical	140			140	
Administrative	90			90	

*None: All goals attained.

Figure 39. Work force requirements and model distributions. (Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

	PERIOD 1						PERIOD 2				
CATEGORY	Number Aboard at Period (0)	Normal Trans.	Flexible Trans.	Hires	Fires	Aboard End Period (1)	Normal Trans.	Flexible Trans.	Hires	Fires	Aboard End Period (2)
Clerical	600	420	4	101	--	525	368	+2	118	---	488
Technical	175	160	-2	---	--	158	143	-3	---	---	140
Admin.	90	91	-1	---	--	90	89	+1	---	---	90

Figure 40. Summary of projected personnel actions.
(Source: Charnes, Cooper, Lewis, Nelson, & Niehaus (1977))

SYSTEM DESIGN

Goal Setting and Accountability

To enable realistic EEO goals to be made, the forecast of requirements must be reconciled with other forecasts--of the supply of manpower from within the organization and from without. As Figure 41 indicates, this goal setting process requires four basic manpower planning functions:

1. Systematic analysis of manpower resources.
2. Forecast of manpower requirements.
3. Forecast of manpower supply.
4. Reconcilation with the constraints of the organizational-social structure.

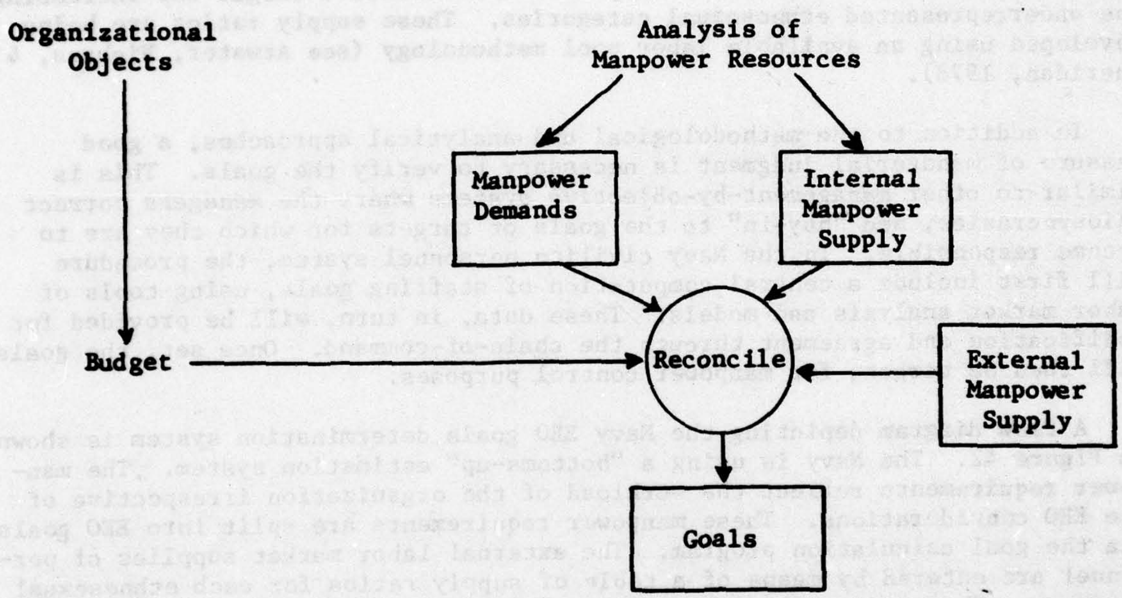

Figure 41. EEO goal setting process.
(Source: Lewis (1977))

To forecast the relationship between the workload of the production plan and the manpower required, analyses of past manpower performance and trends in productivity are needed. To be useful, the forecast must also indicate the types of manpower required--that is, it must be divided by occupational group and job level, according to such distinction as education requirements and/or GS-rating.

The supply of manpower available from within the organization, similarly divided into categories, is projected on the basis of past rates of staff retention and patterns of promotion and transfer. External supply must be examined in light of future labor market conditions. For EEO goal setting, this focuses on the social group composition of the available supply as stratified by education, occupational choice, etc. A great deal of information is therefore required for this purpose and in most cases studies will be needed to determine an accurate forecast of external labor supply (Atwater, Niehaus, & Sheridan, 1978).

Analysis of the manpower requirements and supply environment provide the goal setter with knowledge of (1) the probable outcome over the planning horizon of personnel representation across occupational categories if the exising manpower system is left unchanged by the establishment of EEO objectives, (2) the ability of the organization to effect changes in its organizational-social structure by various adaptations to meet EEO goals, and (3) the degree of imbalance of the organizational manpower system with respect to ethnosexual distributions in the labor market.

Of major concern is the setting of "reasonable" EEO goals. Considering Civil Service merit system rules and activity budgets, there are limits to which personnel policies can be adjusted to incorporate affirmative action[6] considerations. Thus, a best estimate of the supply ratios of the ethnosexual categories is required, and perhaps even increased somewhat to ensure that any error is on the side of a positive affirmative target for increasing the underrepresented ethnosexual categories. These supply ratios are being developed using an available labor pool methodology (see Atwater, Niehaus, & Sheridan, 1978).

In addition to the methodological and analytical approaches, a good measure of managerial judgment is necessary to verify the goals. This is similar to other management-by-objective systems where the managers correct idiosyncrasies, and "buy-in" to the goals or targets for which they are to become responsible. In the Navy civilian personnel system, the procedure will first include a central computation of staffing goals, using tools of labor market analysis and models. These data, in turn, will be provided for modification and agreement through the chain-of-command. Once set, the goals will then be targets for manpower control purposes.

A flow diagram depicting the Navy EEO goals determination system is shown in Figure 42. The Navy is using a "bottoms-up" estimation system. The manpower requirements reflect the workload of the organization irrespective of the EEO considerations. These manpower requirements are split into EEO goals via the goal calculation program. The external labor market supplies of personnel are entered by means of a table of supply ratios for each ethnosexual category. The supply ratios are projected for both 1 and 5 years into the future. As has been discussed, the supply ratios are a combination of national and regional statistics. Any statistical bias is on the side of the general population statistics. Thus, when there is less precise information to develop a particular supply ratio, it is on the side of population parity rather than occupation parity. In this way statistical errors tend to favor Affirmative Action.

Once the EEO goals are obtained, they are used in an accountability system. Projections are made of the EEO goals 1 and 5 years into the future. In this way, it is possible to obtain both an immediate, as well as a longer-term reading, as to the health of a particular organization's EEO program. These centrally developed goals are then evaluated locally with any differences negotiated to

[6]Affirmative action implies an active positive program to ensure that employment opportunities are available to all qualified candidates, including the use of "bridge" positions to test and improve those who may only be marginally qualified at the outset.

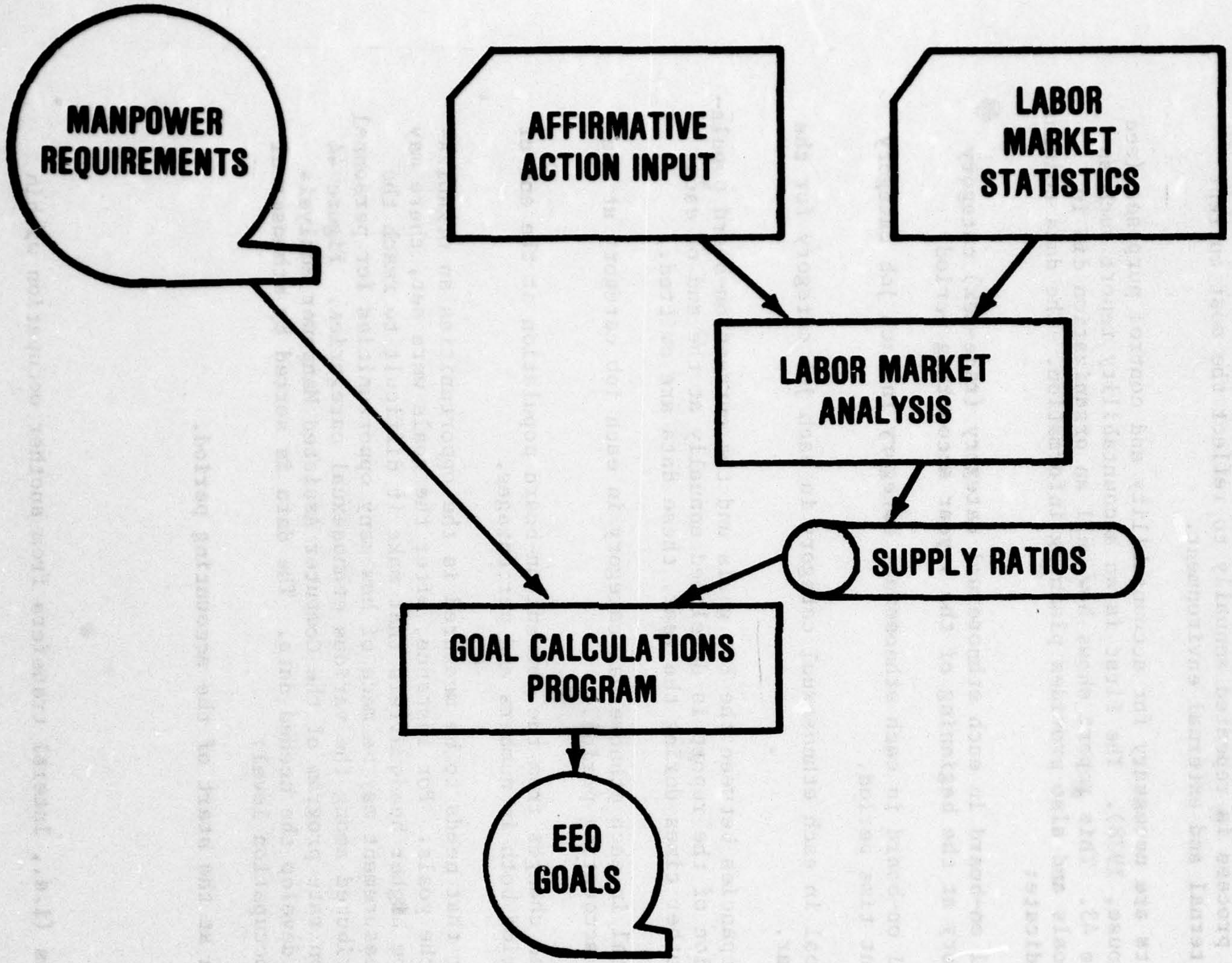

Figure 42. U. S. Navy civilian EEO goal determination system. (Source: Burroughs, Korn, Lewis, & Niehaus (1976))

correct for situations not included in the central calculations. Once agreed upon, the local organization head signs off committing the organization. At the end of the year, the goals are evaluated by higher management for possible further in-depth review. Appropriate filters are included in the computer programs to limit the data to be evaluated to significant deviations from the goals. The whole process is repeated annually to reflect the most current picture of the internal and external environment.

Several reports are necessary for accountability and control purposes (see Niehaus & Nitterhouse, 1978). The first is an accountability report such as is shown in Figure 43. This report shows how well an organization did in relation to its goals and also provides planning information. The data columns of the reports indicate:

1. The actual on-board in each ethnosexual category (race-sex) category in each job category at the beginning of the 5-year accounting period.

2. The actual on-board in each ethnosexual category in each job category at the most current time period.

3. The EEO goal in each ethnosexual category in each job category for the current fiscal year.

4. The discrepancies between the EEO goals and the current on-board population. (This version of the report is developed annually at the end of each fiscal year. At other times during the year, these data are omitted.)

5. The EEO goal in each ethnosexual category in each job category at the end of the 5-year accounting period.

6. The desired changes from the current on-board population at the end of the accounting period both in numbers and percentages.

Another factor that needs to be measured is the opportunities an organization had to meet the goals. For instance, after the goals were set, there may be constraints from higher headquarters that make it difficult to reach the goals. Also, a measurement may be made of how many opportunities for personnel actions were distributed among the various ethnosexual categories. Figure 44 uses the transition rate program of the Computer Assisted Manpower Analysis System (CAMAS) to develop the needed data. The data is sorted by ethnosexual category in each occupation level:

1. Population at the start of the accounting period.

2. Hires.

3. Promotion.

4. Other gains (i.e., lateral transfers from another occupation within the organization).

5. Opportunities for affirmative action (i.e., sum of hires, promotions, and other gains).

OCCUPATION	Level	Aboard Sep 78	Aboard Sep 77	Goal Sep 77	Discrep. Sep 77	Goal Sep 81	Desired Change By Sep 81 Diff.	Percent
SCI & ENG	GS 5-8	23	23	25	0	34	9	26.5
	GS 9-12	350	348	345	3	340	-8	-2.4
	GS 13-15	280	281	264	-3	297	36	12.1
	GS 16-18	2	2	2	0	3	1	33.3
OTH PROF	GS 5-8	23	24	25	-1	33	9	27.2
	GS 9-12	62	64	64	0	76	12	15.8
	GS 13-15	13	13	13	0	15	2	13.3
ADMIN	GS 1-4	2	2	2	0	2	0	0.0
	GS 5-8	151	174	189	-15	340	166	48.8
	GS 9-12	775	770	784	6	1187	397	34.0
	GS 13-15	113	112	112	0	114	2	1.8
	GS 16-18	1	1	1	0	1	0	0.0
TECHNICIAN	GS 1-4	145	144	144	0	144	0	0.0
	GS 5-8	845	857	851	6	898	41	4.6
	GS 9-12	697	695	694	1	687	-8	-1.2
	GS 13-15	9	4	7	-3	24	20	83.3
CLERICAL	GS 1-4	913	972	1056	-84	1638	696	40.1
	GS 5-8	553	689	653	-67	913	324	35.5
	GS 9-12	15	18	17	1	25	7	28.0
OTHER GS	GS 1-4	609	612	615	-3	634	22	3.5
	GS 5-8	442	471	463	8	497	26	5.2
	GS 9-12	5	7	8	-1	22	15	68.2
TOTAL BLACK MALE		6004	6185	6317	-152	7804	1739	22.0

Figure 43. Sample EEO accountability report, black male.
(Source: Niehaus & Nitterhouse (1978))

ADMIN GS 9-12

	Actual	Hires		Promotions		Other Gain		Tot. Opp.		Losses		Actual
	Sep 76	No.	%	No.	%	No.	%	No.	%	No.	%	Sep 77
Black Male	775	38	.030	66	.043	26	.033	130	.036	85	.029	820
Hisp Male	259	26	.020	10	.006	8	.010	44	.012	15	.005	286
Other Male	273	21	.016	8	.005	10	.012	39	.010	15	.005	297
White Male	14,994	1023	.808	778	.517	621	.797	2422	.682	2257	.785	13,159
Black Female	563	12	.009	98	.065	18	.023	128	.036	45	.015	646
Hisp Female	48	1	---	14	.009	1	.001	16	.004	7	.002	57
Other Female	49	2	.001	11	.007	1	.001	14	.003	9	.003	54
White Female	3986	142	.112	519	.345	94	.120	755	.212	439	.152	4302
Total	20,947	1265		1504		779		3548		2874		21,623

Figure 44. Sample EEO opportunities report. Navy-wide-FY77.
(Source: Niehaus & Nitterhouse (1978)

6. Losses.

7. Population at the end of the accounting period.

The percentage opportunity statistics are stated in terms of the totals for each occupation-level. A quick scan of the data can show (1) which ethnosexual groups are having personnel actions and of what kinds and (2) the percentage of the total that each ethnosexual group is having of each personnel action. The percentages alone are not enough to measure the relative changes in the ethnosexual groups. Goal information such as provided in Figure 45 is necessary to measure accountability since labor market statistics are relevant. The purpose of the opportunity report is to surface potential areas for further management attention. It can also be used to "account for" how often managers take advantage of personnel action opportunities to attain EEO objectives.

The transition data are also shown on an EEO dynamic report such as indicated by Figure 45. On this report, the data are shown sorted by occupation levels within each ethnosexual category. In this case, all the losses and gains for each ethnosexual group are shown with the internal losses in one occupation level becoming internal gains in one or more other occupation level(s).

Comparisons of current period transition rates with planned or prior period actual transition rates can be used by superiors to assess whether managers are using available personnel action opportunities to increase the rate of transition of minorities into job categories in which they are presently under-represented (as evidenced by discrepancies from goals). Appropriate rewards or punishment meted as a result of these reports should influence managers to take desired actions. Of course, normal rules of statistical inference must be applied to support statistical conclusions taken from the data.[7] However, even in the absence of "statistically significant" inferences, these reports serve as a basis for comparisons between managers and discussion of areas and methods of improvement.

<u>Use of Models for EEO</u>

The EEO models are particularly important in organizing and evaluating the competing requirements and constraints that must be considered in managing the work force. These possibilities for highly integrated solutions must be tempered with the fact that judgmentally determined factors and ease of use have to be considered. This is particularly true in the case of EEO where many of the EEO personnel and other management officials (and outside interest groups) have little training in mathematics and come from a tradition of people-oriented solutions to their problems. Recognizing these facts, the Navy is testing for implementation of a "bottoms-up" information system supplemented by models rather than a top-down modelling oriented system. Later versions will most likely move towards a strengthening of the modeling capabilities as more becomes known through the actual operation of the system.

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[7]For an in-depth discussion of statistical inference in relation to EEO, see J. Ledvinka (1975).

Occupation Category	Grade Grp	On Brd. Mar 75	Losses				Gains				On Brd. Mar 76
			Internal	%	External	%	Internal	%	External	%	
SOCIAL CATEGORY: BLACK MALE											
SCI AND ENG	GS 5-8	24	11	45.8	4	18.7	7	29.2	8	33.3	24
	GS 9-12	345	11	3.2	25	7.2	15	4.3	18	4.6	340
	GS 13-15	279	12	4.3	16	5.7	16	5.7	1	.4	288
	GS 16-18	2	—	—	1	50.0	—	—	—	—	1
OTHER PROFESSIONALS	GS 5-8	21	11	52.4	1	4.8	3	14.3	11	52.4	23
	GS 9-12	44	4	9.1	3	6.3	11	25.0	4	9.1	52
	GS 13-15	12	1	8.3	1	3.3	1	8.3	1	8.3	12
MANAGERS AND ADMIN	GS 1-4	11	5	45.5	5	45.5	—	—	—	—	1
	GS 5-8	188	80	31.9	16	8.5	35	18.6	23	12.2	170
	GS 9-12	890	29	4.2	60	8.7	108	15.7	32	4.8	741
	GS 13-15	114	4	3.5	13	11.4	12	10.5	3	2.8	112
	GS 16-18	1	—	—	—	—	—	—	—	—	1
SUB PROF AND TECH	GS 1-4	143	48	33.6	22	15.4	13	9.1	43	30.1	129
	GS 5-8	795	110	13.8	61	7.7	108	13.6	69	8.7	801
	GS 9-12	629	37	5.9	37	5.9	89	14.1	34	5.4	678
	GS 13-15	4	1	25.0	—	—	—	—	—	—	3
CLERICAL	GS 1-4	890	121	13.6	175	19.7	56	6.3	180	20.2	880
	GS 5-8	587	63	10.7	50	8.5	72	12.3	25	4.4	572
	GS 9-12	18	1	6.3	1	6.3	1	6.3	1	6.3	16
	GS 13-15	1	1	100.0	—	—	—	—	—	—	—
SERVICE	GS 1-4	595	84	16.6	116	23.0	8	1.8	217	43.0	530
	GS 5-8	373	17	4.6	33	8.8	74	19.8	12	3.2	409
	GS 9-12	3	—	—	—	—	2	66.7	1	33.3	6
Total Black Male		5677	631	11.1	640	11.3	631	11.1	682	12.0	5719

Figure 45. EEO dynamics for the period March 1975 to March 1976, all Navy (sample report). (Source: Niehaus & Nitterhouse (1978))

The initial system being tested for implementation by the Navy is shown in Figure 46. In this system, the EEO goals are developed by a simple multiplication of the manpower requirements by the labor market supply ratios for each of the local facilities. The data then flows up into a central file. The EEO goals are to be used in the accountability programs. The goals can also be used in an aggregate model without flexibilities (i.e., the reduced version of the FEEO model). This capability is to be available at the major command (such as the Naval Sea Systems Command (NAVSEA)), as well as the Navy-wide levels. This use of the model at the headquarters level permits an evaluation of possible policy changes without changing the existing policies until a better idea of the impacts are known. In this use of the model, there is generally neither the time nor the reason for adjusting all the detailed EEO goals when an analysis is made.

The flexibility features are important additions to the goal programming models for human resources. They indicated where and how promotion policy must be changed to meet both long- and short-term organizational goals, and, in turn, identify where and how many bridge positions should be established. However, their inclusion in the goal programming model structures, when partitioned not only by job level and occupational group but also by social group, results in a prohibitively large program at the aggregate level of analysis.

Since organizational analysis affecting the determination of allowable flexible movements and bridge positions takes place at the local (disaggregate) level, decisions concerning flexibility should be made there as well. This is consistent with current Navy policies and practices since individual personnel decisions concerning civilians are decentralized to the local installation.

Continued development is underway of the Goal-Arc model. Small numerical examples have been tested using PNET primal network code. The next step will be to test the model with data representative of a local naval installation. Assuming this test is successful, on-site testing will be initiated. Also, this new technology might then be able to be applied at the Navy-wide level opening up the additional possibilities of modeling "flexibilities" at the corporate level as well.

EEO planning encompasses almost all aspects of human resources planning. There is a need to integrate EEO planning with workload planning and external labor market analysis. The system depends on a reasonable estimate of the available labor pools. At the same time, the workload drives the system and issues such as upward mobility and affirmative action are important. Thus, only an integrated approach will provide the improvements in the system that are needed.

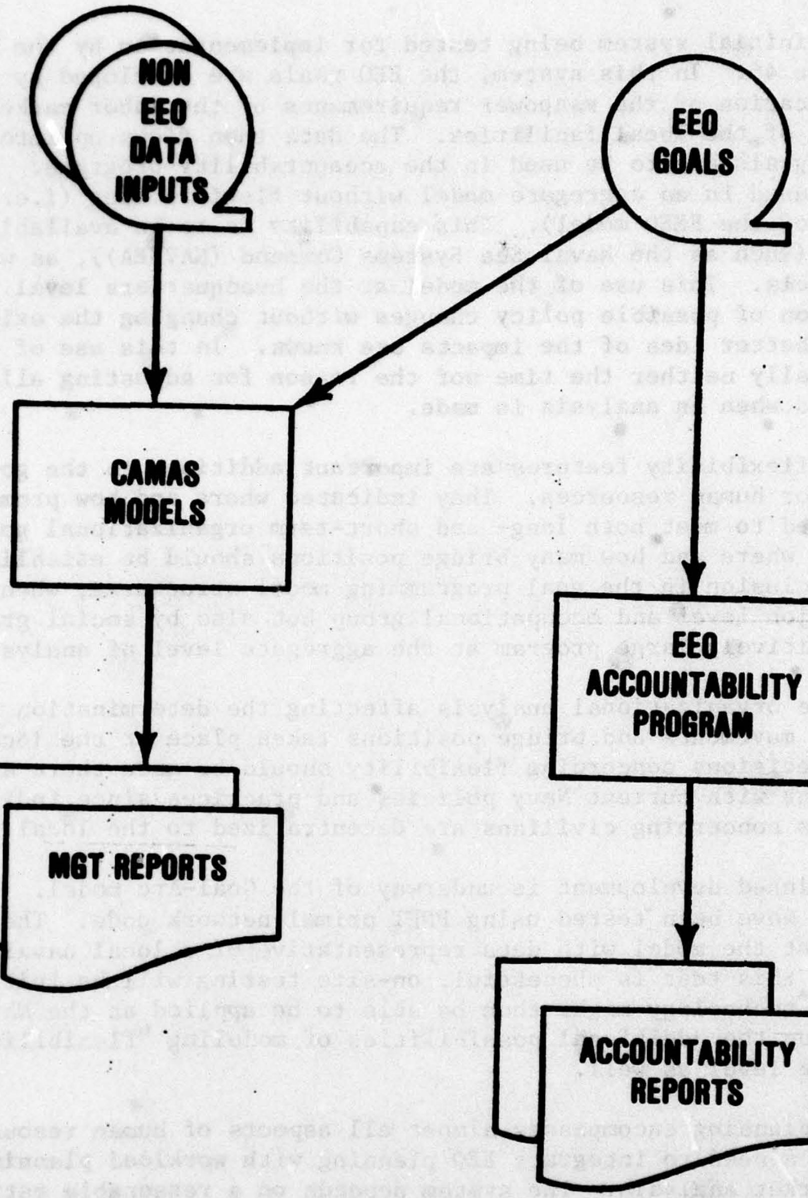

Figure 46. Navy EEO goals system.

(Source: Niehaus (in press))

CONCLUSIONS

1. The EEO goals policy planning models will assist both Navy headquarters and local activity manpower planners in choosing personnel strategies that meet operating needs while complying with EEO objectives.

In particular, the EEO models are formulated to accommodate the immediate (short-run) workload requirements while progress is also made towards longer-run targets that are set up to achieve EEO goals. The models try to use a given organizational/social structure to best advantage in a way that makes contact with their present (or initial) states while also explicitly indicating how that structure should be changed--in "the best possible manner"--to achieve EEO goals.

2. The FEEO model and its modifications are intended for comprehensive policy testing at aggregate levels in the civilian manpower planning efforts of the Navy. While final coordinating decisions are the purview of top management, there are many decisions and interactions that should be addressed at the local/regional level of decision-making on the way toward those final decisions. Thus, the Coherence/Goal-Arc models are required for determining individual or "almost individual" assignments at the micro levels of local installations (e.g., shipyards), where the sparsity of jobs in some categories introduce difficulties in rounding to integer solutions. The Coherence/Goal-Arc models are intended to be "coherent" with results of the overall planning, but yield integer solutions.

3. The EEO models are particularly important in organizing and evaluating the competing requirements and constraints that must be considered in managing the work force. Possibilities for highly integrated solutions must be tempered with the fact that many of the EEO personnel and other management officials (and outside interest groups) have little training in mathematics and come from a tradition of people-oriented solutions to their problems. Recognizing these facts, the Navy is testing for implementation of a "bottoms-up" information system supplemented by models rather than a top-down modeling oriented approach.

RECOMMENDATIONS

1. External and internal labor market analysis for use in EEO goal determination should be expanded to include all major shore activities in the Navy.

2. The EEO human resources planning models and the assoicated accountability or tracking systems should be installed at various Navy headquarters-level activities and commands (e.g., NAVAIR, NAVSEA, Director of Naval Laboratories), as well as at all major shore activities.

3. Research to improve the models' solution times and ability to handle large numbers of constraints and flexibility options should be extended.

4. Conversational versions of the FEEO and Coherence/Goal-Arc models should be developed for headquarters and activity-level managers with little or no computer programming experience.

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