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SHORE ACTIVITY MANPOWER PLANNING MODELS: DEVELOPMENT AND APPLICATION

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This report is concerned with the development of models for determining recruiting requirements based upon manpower goals and for promotion planning. These models were tested at a large industrial facility and at a large laboratory.

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FOREWORD

This research and development was conducted in response to Navy Decision Coordinating Paper, Personnel Supply Systems (NDCP-Z0107-PN) under subproject PN.16, Shore Activity Manpower Planning Systems (SAMPS) and the sponsorship of the Deputy Chief of Naval Operations (OP-01). The overall 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 in order to provide the necessary linkage between the Office of Civilian Personnel (OCP) manpower models conceived and developed under research and exploratory development phases and advanced development.

This report describes the development and testing of aggregate manpower and personnel models at large shore activities. In addition, the present status of these models, their origin, and their initial applications are discussed.

The results described in this report are intended for use by the Director of Navy Laboratory Programs; the Naval Air Systems Command; the Naval Air Rework Facility, North Island; and the Naval Underwater Systems Center, Newport.

DONALD F. PARKER
Commanding Officer

SUMMARY

Problem and Background

New management tools are needed to provide more effective human resource planning within the Navy shore establishment, at both headquarters and local activity levels, to help determine and evaluate plans for recruitment, reductions in force, and promotion to best meet current and future manpower requirements. These problems are being addressed by the development of a series of civilian manpower and personnel models for components of the Navy shore establishment. This involves the development and testing of aggregate manpower and personnel models at large shore activities.

Approach

Computer-based models were developed to provide improved civilian manpower and personnel planning within the Navy shore establishment. This included the recruiting requirements model (RRM), for use in workforce planning; the promotion planning model (PPM), a version of the RRM that provides flexibility for promotion policy testing; and the conversational use RRM (CURRM), a conversational version of RRM. These models were tested at selected naval facilities: the RRM, at the Naval Air Rework Facility, North Island (NARFNI); the PPM, at the Naval Underwater Systems Center (NUSC) and for the Director of Laboratory Programs (DLP); and the CURRM, at NUSC and in a Navy-wide professional procurement program. These tests have included a continuing program of on-site, activity-level model validation.

Results

The RRM pilot study at NARFNI has provided useful information for workload and manpower planning in an industrial setting. The model has been particularly beneficial in supporting the workload negotiation process within the Naval Air Systems Command (NAVAIR). As a result, the basic aggregate model is being extended to other NARFs and an interface is being developed with the NAVAIR-sponsored Computerized Workload Planning and Budgeting System (CWPABS).

The pilot studies at NUSC have been useful in determining junior professional engineer and scientist hiring programs. In this application, the RRM was used to explore consequences of average grade and manpower ceiling constraints, which led to application of PPM and CURRM to evaluate the effects of alternative promotion constraints and policies.

Conclusions

The pilot studies have demonstrated benefits that accrue through use of these models. Areas for additional development include expanded conversational model versions and expanded promotion planning features. Additional consumers for these models have been identified, including other NARFs, and other organizational levels, such as NAVAIR and DLP.

Recommendations

1. The Commander Naval Air Systems Command should complete development of an interface between the NARF models and CWPABS and explore application of the NARF models for workload allocation at the NAVAIR level.

2. The Director of Laboratory Programs (DLP) should evaluate the PPM for use at other laboratories, explore further use of the PPM at the DLP level, and further develop conversational forms of RRM (CURRM).

3. The Chief of Naval Operations (OP-16) should construct conversational versions of PPM, integrate work on laboratory work force goals development with the current laboratory models, and concurrently develop supporting software for the SAMPS models.

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INTRODUCTION

Problem

The Navy is facing an increased need for more effective human resource planning within the shore establishment. At both headquarters and local activity levels, new management tools are required to help develop and evaluate plans for recruitment, reductions in force, and promotion policies to best meet current and future manpower requirements. Detailed planning at the activity level must be consistent with the overall aggregate planning decisions.

Background

This problem is being addressed by development and test of a series of civilian manpower and personnel planning models for the Navy shore establishment. This effort utilizes advances in the formulation of planning models and fourth-generation computer capabilities. The Shore Activity Manpower Planning Models have been preceded by a considerable body of basic and exploratory development research. A discussion of the earlier phases of this research can be found in a report by Charnes, Cooper, and Niehaus (1972).

In the earlier modelling research, manpower models were applied to headquarters-oriented civilian manpower planning. These dynamic models use goal programming to meet a set of possibly conflicting manpower requirements "as closely as possible" for a number of periods in the future. This is done by (1) imposing various priorities and penalties for moving away from the requirements or goals, and (2) setting constraints (e.g., manpower already on-board, attrition including retirements and internal transfers between job categories, total manpower controls, and total salary budgets), on the way requirements can be met.

Objective

The objective of this effort was to develop and conduct pilot testing of aggregate manpower and personnel models at selected naval shore activities.

MODELS AND SUPPORT SYSTEMS

The test and evaluation of aggregate manpower and personnel models, and their extension to conversational forms, has been conducted at several naval activities. These tests have included a continuing effort in on-site, activity-level model validation. Parallel to this work has been the development and testing of supporting software systems.

Recruiting Requirements Model (RRM)

The aggregate recruiting requirements models (RRMs) used in these applications employ a goal programming structure, with embedded Markov transition matrices for capturing work force dynamics. An example of this kind of model follows:

Let:

$E_k^+(t)$, $E_k^-(t)$ = Positive or negative deviation, respectively, for k^{th} manpower category in time t.

$x_k(t)$ = Manpower on-board (in place) in the k^{th} manpower category in period t.

$y_k(t)$ = Hires in k^{th} manpower category in period t.

$z_k(t)$ = Fires or reductions-in-force (RIFs) in the k^{th} manpower category in period t.

M_{ik} = Transition rate between the i^{th} manpower category and the k^{th} manpower category, for one time period.

$G_k(t)$ = Manpower requirement (goal) for the k^{th} manpower category in period t.

α_{kt} = The weight applicable to a positive goal discrepancy for the k^{th} manpower category in period t.

β_{kt} = The weight applicable to a negative goal discrepancy for the k^{th} manpower category in period t.

γ_{kt} = The weight applicable to a hire in the k^{th} manpower category in period t.

δ_{kt} = The weight applicable to a firing or reduction-in-force (RIF) in the k^{th} manpower category in period t.

a_k = Initial inventory of personnel in manpower category k.

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$C(t)$ = Manpower ceiling for period t.

$s_k(t)$ = Average salary for k^{th} category in period t.

$B(t)$ = Salary budgetary ceiling for period t.

The structure of the RRM in its transformed and reduced form is as follows:

$$\text{Min} \sum_{kt}\sum [\alpha_{kt} E_k^+(t) + \beta_{kt} E_k^-(t) + \gamma_{kt} y_k(t) + \delta_{kt} z_k(t)].$$

The objective of the model is to minimize the sum of weighted deviations from gross manpower goals and weighted number of hires and fires subject to:

1. Goal Constraints:

$$G_k(t) = x_k(t) - E_k^+(t) + E_k^-(t) \qquad \text{for all k, t.}$$

2. Manpower Transition Conditions:

$$a_k = x_k(0) \qquad \text{for all k.}$$

$$0 = -\sum_i M_{ik} x_i(t-1) + x_k(t) - y_k(t) + z_k(t) \qquad \text{for all k, t.}$$

3. Manpower Ceiling Constraints:

$$\sum_k x_k(t) \leq C(t) \qquad \text{for all t.}$$

4. Salary Budget Constraints:

$$\sum_k s_k(t)\, x_k(t) \leq B(t) \qquad \text{for all t.}$$

5. Nonnegativity Constraints:

$$x_k(t),\ y_k(t),\ z_k(t),\ E_k^+(t),\ E_k^-(t) \geq 0 \qquad \text{for all k, t.}$$

The structure of the linear programming (LP) matrix[1] for this RRM is given in Table 1. Manpower requirements are specified as goals to be met. A penalty is assessed whenever the number of personnel on hand for a given category either exceeds or falls short of the manpower requirement. Penalties are also assessed for enlarging or reducing the work force. The fulfillment of the manpower requirements is restricted by a number of constraints. The first of these sets the number on board in each job category at the start equal to the current population to ensure that the base period population will

[1] See Charnes, Cooper, and Niehaus (1972) for complete development of the model mathematics and transformations to the LP matrix.

Table 1

Linear Programming Matrix for
Recruiting Requirements Models

Item	On-Board Manpower	Hires	Fires	Positive Goal Discrepancy	Negative Goal Discrepancy	Sign	Right-Hand Side (RHS)
Relative Priorities		γ	δ	α	β		
Manpower Goals	I			-I	I	=	Manpower
	I			-I	I	=	requirements
Transit Conditions	I					=	Initial population
	-M I	-I	I			=	0
	-M I	-I	I			=	0
Total Manpower Constraints	e^t e^t					$\leq$	Civilian manpower
	e^t e^t					$\leq$	available
Salary Budget Constraints	($/m)1					$\leq$	Civilian salary
	($/m)2					$\leq$	budget

be completely accounted for in the solution. This base period population is then modified by applying a matrix of movement or transition rates, which distinguishes probabilistically between those likely (1) to stay in a particular job category, (2) to move to another job category, and (3) to leave the organization. New hires and reductions during the time period are also incorporated. This process continues for the number of periods to be included in the model. In addition, constraints are set for total manpower ceilings and manpower salary budgets for each of the periods.

Promotion Planning Model (PPM)

The Promotion Planning Model (PPM) is a modification of the aggregate RRM, which has been developed for promotion policy testing (Albanese, Korn, Niehaus, & Padalino, 1977). The previous model was extended by the addition of "flexibility" features similar to those included in the Flexible EEO (FEEO) model developed by Charnes, Cooper, Lewis, and Niehaus (1975). The following new variables are added:

θ_{ikt} = The weight applicable to transfers above the historical promotion rate of personnel from category i to category k in period t.

ξ_{ikt} = The weight applicable to transfers below the historical promotion rate of personnel from category i to category k in period t.

$q_{ik}(t)$ = Number of personnel in category i who transfer to category k in period t above the historical rate.

$r_{ik}(t)$ = Number of transfers between category i and category k in period t below the historical rate.

T_{ik} = Matrix of admissible flexible transfers

= { 1, if $i \neq k$ and additional transfers (or transfer deficiencies) are allowed from category i to category k
  0, otherwise

The structure of the PPM then becomes:

$$\text{Min}\sum_{ikt}\sum\sum[\alpha_{kt}E_k^+(t) + \beta_{kt}E_k^-(t) + \gamma_{kt}y_k(t) + \delta_{kt}Z_k(t) + \theta_{ikt}q_{ij}(t) + \xi_{ikt}r_{ik}(t)].$$

The objective of the PPM model is to minimize the sum of weighted deviations from manpower goals, weighted numbers of hires and fires, and weighted numbers of promotions above/below the historical rate subject to:

1. Goal Constraints:

$$G_k(t) = x_k(t) - E_k^+(t) + E_k^-(t) \qquad \text{for all } k,\ t.$$

2. Transit Conditions:

$$a_k = x_k(0) \qquad \text{for all } k.$$

$$0 = - \sum_i M_{ik} x_i(t-1) + x_k(t) - y_k(t) + z_k(t)$$

$$- \sum_i q_{ik}(t) + \sum_i r_{ik}(t) + \sum_i q_{ki}(t) - \sum_i r_{ki}(t) \qquad \text{for all } k,\ t.$$

3. Maximum Transfer Deficiencies:

$$-M_{ik} X_i(t-1) + r_{ik}(t) \leq 0 \qquad \text{for all } k,\ t.$$

(one equation for all i,k such that $T_{ik} = 1$; note that q_{ik}, $r_{ik} \equiv 0$ for i,k such that $T_{ik} = 0$).

4. Manpower Ceiling Constraints:

$$\sum_k x_k(t) \leq C(t) \qquad \text{for all } t.$$

5. Salary Budget Constraints:

$$\sum_k s_k(t)\ x_k(t) \leq B(t) \qquad \text{for all } t.$$

6. Nonnegativity Constraints:

$$x_k(t),\ y_k(t),\ z_k(t),\ r_{ik}(t),\ q_{ik}(t),\ E_k^+(t),$$

$$E_k^-(t) \geq 0 \qquad \text{for all } k,\ t.$$

The LP matrix for the PPM is given in Table 2. This matrix differs from that for the RRM in that additional rows and columns are added to permit promotion "flexibilities." In addition to external hires and fires, internal transfers are allowed at rates that differ from those projected from historical personnel movements. These transfers are termed "excess transfers" or "transfer deficiencies" when they exist. Maximum transfer deficiency conditions limit the number of flexible transfers to the maximum possible, as indicated by the historical transition rates.

Table 2

Linear Programming Matrix for Promotion Planning Models

Item	On-board Manpower	Hires	Fires	Positive Goal Discrepancy	Negative Goal Discrepancy	Excess Transfers	Transfer Deficiency	Sign	Right-Hand Side (RHS)
Relative Priorities		γ γ	δ δ	α α	β β	θ θ	ξ ξ		
Manpower	I			−I	I			=	Manpower
Goals	I			−I	I			=	requirements
Transit	I							=	Initial population
Conditions	−M I	−I	I			$-S^a$	S^a	=	0
	−M I	−I	I			$-S^a$	S^a	=	0
Maximum Transfer	$-M_{ij}$						T_{ij}	$\leq$	0 One equation for each T_{ij} = 1 (admissable
Deficiencies	$-M_{ij}$						T_{ij}	$\leq$	0 promotion flexibility)
Total Manpower	e^T							$\leq$	Civilian manpower
Constraints	e^T							$\leq$	available
Salary Budget	($/m)1							$\leq$	Civilian salary
Constraints	($/m)2							$\leq$	budget

[a]Where the matrix S is obtained by suitable modification of T.

Conversational Use Recruiting Requirements Model (CURRM)

The development of interactive conversational versions of the aggregate manpower planning models has been stressed throughout this effort. The objective is to provide both managers and technical staff with direct access to models that reflect the dynamic behavior of their manpower resources. Interactive capabilities allow them to rapidly evaluate multiple alternative policies and assumptions, yielding a better understanding of the underlying structure and the effect of variables under management control.

These conversational versions have evolved through a number of phases. The Computer-Assisted Manpower Analysis System (CAMAS) served as the initial basis for this development (Niehaus & Sholtz, 1974). CAMAS includes all the necessary data reduction routines, use of the UNIVAC Functional Mathematical Programming System (FMPS) LP code, and output report generation for use of the RRM in the "batch" mode. It is being used to support both operational and research applications.

The first conversational version used data reduction routines from CAMAS with a separate set of programs for LP solution and cathode-ray tube (CRT) display of the problem. Changes to the display could be requested by simple commands entered through the keyboard; the computer then prompted the data necessary for such changes (Niehaus, Sholtz, & Thompson, 1973). This version was used to obtain suggested changes to the model and to provide insight into manpower analysis problems as part of various training exercises. Over 100 middle and senior level Navy managers were exposed to this system.

Extension of this system for use in testing operational problems required a considerable number of changes, four of which were substantial:

1. Computer dialogue was changed to an exception reporting system to allow greater ease of command entry.

2. FMPS LP code was included instead of an in-core solution routine.

3. Provision was made for two-character manpower category names, including translation into English names.

4. Provision was made for off-line printing of comprehensive reports.

The conversational version resulting from these changes is called the Conversational Use Recruiting Requirements Model (CURRM), which produces on-line summary and exception reports and routes complete reports to an off-line printer.

The CURRM is composed of a set of interacting programs, as shown in Figure 1. The Initialize program establishes the environment for the whole system; that is, it determines whether the on-line user is working with his model for the first time or is resuming previous work. In the former case, status information and LP solution data files are initialized, a Problem Definition file is accepted, and a run-stream is started that will automatically

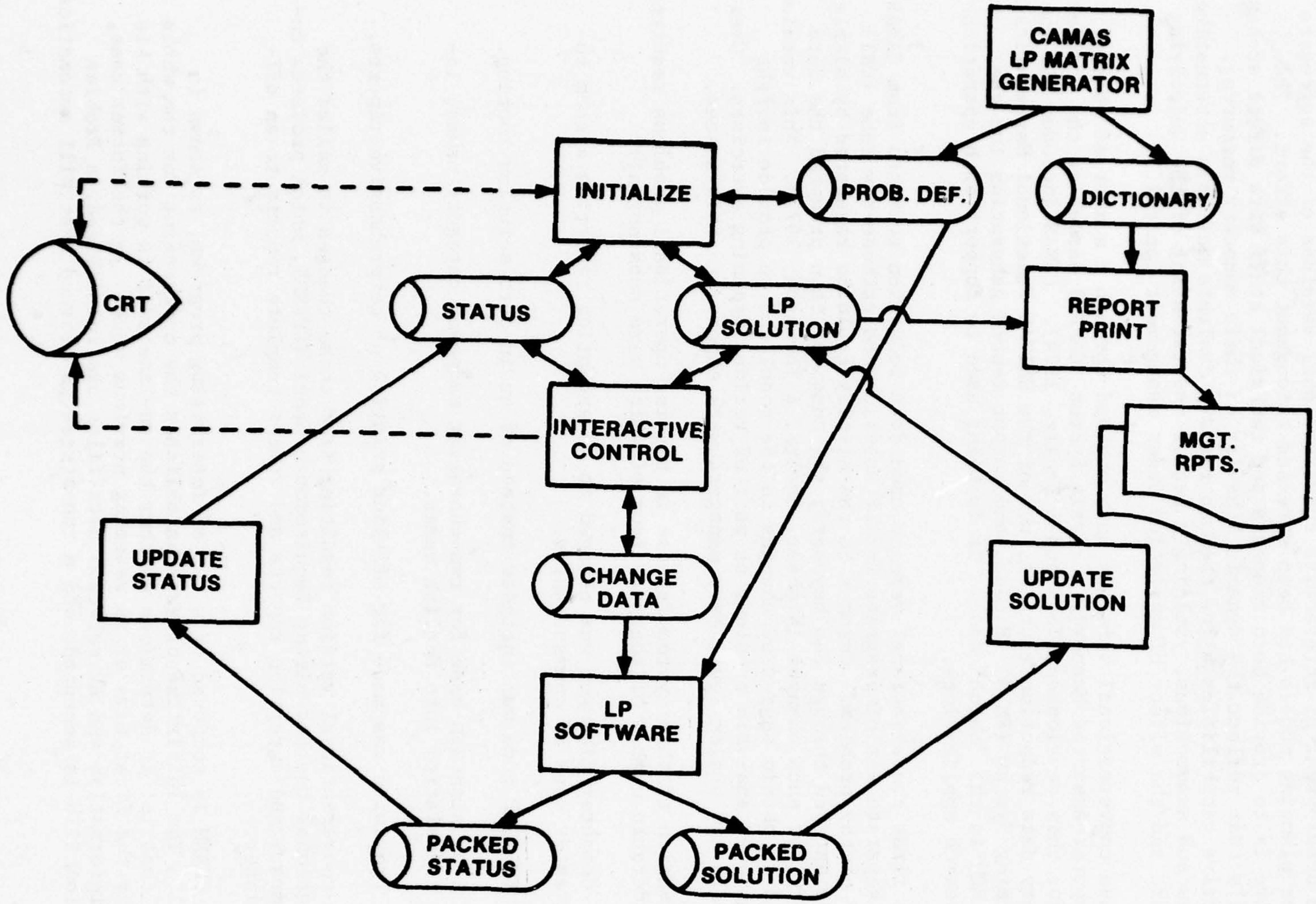

Figure 1. CURRM system flow.

call the other programs in the system to obtain an initial optimal solution. In the latter case, the program ascertains that the status and data files are present and ready, and passes control to the Interactive Control program, which does the bulk of communication with the on-line user, responding to the CURRM commands (see Figure 2). This program allows the user to inspect input data, previous solutions, status information, and current data changes. Data can be changed to correct or modify the problem, allowing exploration of alternative policies and constraints. These changes are written on the Change Data file. The Interactive Control program remains active until the user gives one of two commands--END or RUN. The END command will terminate the run; and the RUN command will close the Change Data output file, start a runstream to execute the other programs in the system through to a solution, and then return to the Interactive Control program.

The FMPS LP software (a UNIVAC-supplied LP package) is central to CURRM. This program solves the LP problem associated with the model; that is, it solves a set of simultaneous linear equations and inequalities to find the solution that minimizes the weighted sum of discrepancies, hires, and fires. For the first solution of the model, this program is called by the Initialization program, with a complete statement of the problem specified by the Problem Definition data file. For subsequent solutions, the program is called by the Interactive Control program and uses the Change Data file to update the problem statement. In either case, there are two outputs--the technical report, which is retained as the Packed Status file to provide status information, and the actual solution, which is contained in the Packed Solution file.

There are three more programs. The Update Status program scans the Packed Status file to determine whether the problem did have an optimal solution. Status and error messages found are then added to the Status file for future reference. The Update Solution program adds the solution data from the LP package to the LP Solution data file. The Report Print program is called by the user through the Interactive Control program to format the data from the solution file into two management reports that display the complete solution. The first of these reports is the summary report, which gives a single line summary for each manpower category, showing for each period the number of hires and fires necessary to implement the recommended solution and the resulting number aboard. The second is the detailed report, with a separate page for each time period, which gives, by manpower category, the number of hires and fires and the resulting number aboard, as well as the goal, discrepancy, and allowed limit on discrepancy. Thus, the user can work interactively with the model, making changes and adjustments until he has an alternative worth saving. At that point, he gives the command to have output reports produced for further reference.

Computational Refinements

Attempts have been made to improve solution times of the underlying LPs used to solve the models, using both formal mathematical approaches and an experimental approach. Charnes, Cooper, Klingman, and Niehaus (1974, 1975), employing a formal approach, developed advanced start and explicit solution techniques that apply to the general class of convex goal programming problems which includes these models. Korn (1975), who used an experimental approach,

```
WHAT CAN I DO FOR YOU?
>HELP
CURRM WILL PERFORM ANY OF THE FOLLOWING FUNCTIONS UPON ENTRY OF AN ASSOCIATED
SELECTION CODE

    CODE        CURRM FUNCTION PERFORMED UPON ENTRY OF CODE

 1  RUN         SOLVE PROBLEM AND SHOW SOLUTION
    R
 2  ??          SHOW THESE COMMENTS ON THE FUNCTIONS AND USE OF CURRM1
    HELP
 3  PI          SHOW MANPOWER AND COMPUTED MANPOWER FACTORS (REPORT-1)
 4  PA          SHOW REPORT-1 FOR ABOVE SPECIFIED AMOUNT OF MANPOWER GOAL

 5  PB          SHOW REPORT-1 FOR BELOW SPECIFIED AMOUNT OF MANPOWER GOAL

 6  PH          SHOW REPORT-1 IN EXCESS OF SPECIFIED NUMBER OF HIRES
 7  PR          SHOW REPORT-1 IN EXCESS OF SPECIFIED NUMBER OF RIFS
 8  PS          SHOW SOLUTION REPORT
 9  POC         SHOW VALID OCCUPATION CODES FOR THIS PROBLEM
10  LP1         PRINT SHORT MANPOWER REPORT
11  LP2         PRINT LONG MANPOWER REPORT
12  MON         SHOW MONITOR STATUS AND ALLOW CHANGE
13  GP          CHANGE MANPOWER LIMIT/GOALS BY %
14  SP          CHANGE SALARIES BY %
15  B           SHOW BUDGET AND ALLOW CHANGE
16  S           SHOW SALARY AND ALLOW CHANGE
17  U           SHOW UPPER MANPOWER LIMIT AND ALLOW CHANGE
18  L           SHOW LOWER MANPOWER LIMIT AND ALLOW CHANGE
19  D           SHOW MANPOWER GRADE CONSTRAINT AND ALLOW CHANGE
20  C           SHOW MANPOWER CEILING AND ALLOW CHANGE
21  P           SHOW PENALTIES/PRIORITIES AND ALLOW CHANGE
22  T           SHOW TRANSITION RATES AND ALLOW CHANGES
23  G           SHOW MANPOWER GOALS AND ALLOW CHANGES
24  E           TERMINATE CURRM SESSION
    END
    EXIT
    STOP
```

Figure 2. CURRM commands.

based his work on the assumption that the solution to most problems would be at or near the goals. Thus, the starting basis is set at the goals. He found that, for small problems of 600-800 equations, this basis reduced the solution times by 50 percent, using the Functional Mathematical Programming System (FMPS) software on a UNIVAC 1108 computer. For larger problems of 3000 equations, the solution time was reduced by a factor of 10--from several hours to 10 to 12 minutes. Using modern LP codes, this solution time was later reduced to 2 to 3 minutes for the larger problems and 8 to 15 seconds for the smaller ones. Solution times can be further reduced if the advanced start is used on the dual form. The model matrix generator used here takes advantage of this research into advanced start methodologies.

A reduced dual formulation for goal programming models can be used to reduce the size of the actual problem to be solved, thus easing computational requirements (see Charnes & Cooper, 1961; Armstrong & Hultz, 1977). The usual (primal) form of a goal programming problem may be represented as follows:

Minimize $\sum_j (a_j y_j + b_j z_j)$

Subject to: $d_j = \sum_i c_{ij} x_i - y_j + z_j \qquad j = 1,\ldots,J$

$\sum_i e_{ik} x_i \geq f_k \qquad k = 1,\ldots,K$

$x_i,\ y_j,\ z_j \geq 0$

where y_j, z_j represent deviations from goals d_j, and a_j, b_j represent the corresponding weights. The second set of conditions represent additional constraints often required in goal programming models.

The dual form for this model may be written as:

Maximize $\sum_j d_j u_j + \sum_k f_k w_k$

Subject to: $\sum_j c_{ij} u_j + \sum_k e_{ik} w_k \leq 0 \qquad i = 1,\ldots,I$

$-u_j \leq a_j \qquad j = 1,\ldots,J$

$u_j \leq b_j \qquad j = 1,\ldots,J$

$w_k \geq 0.$

Here, the u_j are free variables (i.e., they are allowed to take positive, negative, or zero values). The second and third sets of constraints can be combined as:

$$-a_j \leq u_j \leq b_j \qquad j = 1,\ldots,J.$$

These constraints can then be implemented implicitly using the upper and lower bounding features of modern LP packages, rather than as explicit rows. Thus, the dual formulation can be "collasped," or reduced in size.

The original primal formulation has (J + K + 1) rows and (I + 2J) columns. The collapsed dual formulation has (I + 1) rows and (J + K) columns. Hence, the collapsed dual formulation will have fewer rows and columns than the original primal formulation if:

$$I + 1 < J + K + 1 \text{ and } J + K < I + 2J;$$

that is, if $J > |I - K|$.

In practice, the number of rows in an LP problem affects core utilization and solution time much more significantly than the number of columns; hence, using the collapsed dual formulation may still be worthwhile even if the above condition is not satisfied, providing that:

$$I < J + K.$$

Note that the collapsed dual formulation also decreases the number of nonzero coefficients of the matrix. This fact is not of major significance, however, if the LP system being used to solve the problems exploits the super-sparsity characteristic of LP matrices, since the eliminated coefficients are all ±1.

A typical set of statistics for a Navy civilian manpower planning model is I = 2400, J = 750, K = 2415. This leads to a primal problem of 3166 rows and 3900 columns being reduced to a problem of 2401 rows and 3165 columns in the collapsed dual form. The advanced start procedures referred to previously can, of course, be utilized with the collapsed dual formulation by using the dual equivalent of the primal starting basis.

Computational advances have made it possible to solve LPs of the size expected for shore establishment problems at a reasonable cost ($10 to $15 per model alternative); thus, conversational, on-line use of these models is now feasible. The costs of using the model are more related to the staff man-hours involved than they are to the computer costs: Model generation and alternative analysis phases require intensive participation of an analyst, and initial model start-up requires greater than average staff participation.

The tests have already indicated the importance of the hardware configuration. The user must be able to see a record of the transactions in the conversational mode and to have the full output reports accessible during the interactive session. Although the demand for output printing capabilities at the conversational site does not appear to be extensive, it is strongly recommended that the minimum configuration include a teleprinter running at 1200 baud. A minicomputer with both a CRT and a printer would be even more desirable. Testing will be included as part of the SAMPS research to determine the best on-site, hardware-data communications configuration, and the amount of local disk storage required.

PILOT APPLICATION: RECRUITING REQUIREMENTS MODEL

An application of the recruiting requirements model (RRM) was conducted at the Naval Air Rework Facility, North Island (NARFNI). The work began during the summer of 1974, as a cooperative project between NARF and NAVPERSRANDCEN (see Bres & Niehaus, 1974).

NARFNI is a large industrial activity of the naval shore establishment that provides a wide range of depot-level rework and engineering services under the Naval Air Systems Command (NAVAIR). It is the largest of seven such facilities.

Workload Projection

NARF workloads are negotiated quarterly at NAVAIR workload planning conferences. These workloads, which are based upon needs of the Fleet, funding, available resources, existing workload, individual facility capabilities, and sets of previously negotiated workload norms and standard costs for each facility, are projected ahead for a maximum of five quarters. Useful data is not available beyond this horizon due to uncertainty in detailed budget and material requirements.

NARFNI had developed a workload projection system, based upon the time-phased loading of the individual shops, to evaluate the impact of various workloads and available capacity. This system, which can be used to project manpower requirements associated with workloads through a manual process, is being integrated with the emergent NAVAIR Computerized Planning and Budgeting System (CWPABS). The resultant system produces machine-readable outputs useful for manpower planning.

Model Selection and Constraints

Initial discussions between NAVPERSRANDCEN and NARFNI, as well as on-site observations, indicated that aggregate model techniques were needed:

1. To identify manpower action requirements further into the future, expanding the detailed planning horizon.

2. To identify longer term effects of proposed manpower actions.

3. To estimate excess capacity within an expanded planning horizon.

4. To identify areas where additional workload should be sought, in sufficient time for effective action to be taken.

5. To develop a capacity for rapid, detailed response to proposed workloads during negotiation conferences.

6. To develop the ability to conduct detailed evaluations of alternative workload situations.

In view of these requirements, the RRM was selected as the most applicable manpower planning model available. Since workload planning was constrained to five quarters, a five-quarter model was adopted. This quarterly-period structure fits well within attrition and transition rate estimation procedures used in the Computer-Assisted Manpower Analysis System (CAMAS), and was convenient for use with CAMAS software.

In addition to implicit structural constraints, the RRM may include explicit salary budget and manpower ceiling constraints. However, the salary budget constraints common in these models would not be useful in this application: The NARF budget is determined by applying previously negotiated man-hour norms and hourly rates to the assigned workload, which, in turn, drives both manpower requirements and budget allocation.

As of July 1974, when the study began, NARFNI employed 7123 permanent civilian employees--1666 graded Civil Service (CS) personnel in 58 major titles, and 5457 ungraded personnel in 82 series titles.[2] Of the ungraded personnel, 4401 (81.6%) were assigned to the Production Department, where rework operations are actually performed. Thus, for modelling ease and to obtain greatest initial impact on NARF operations, it was decided to limit the study to the ungraded Production Department population.

CAMAS employs a manpower classification scheme similar to (but at a more aggregated level) CS titles and grades (OCMM, 1974). The Production Department contains 29 CAMAS manpower categories. These categories, with slight modifications, were chosen for a useful level of aggregation. (Levels within categories were suppressed in the interest of model size and aggregation.)

An important use of the RRM is in assessing the effect of imposed manpower ceilings upon the manpower structure and capabilities of an organization, under a variety of policies. Such imposed ceilings have historically been a problem for NARFNI management, especially in terms of skill imbalances. Thus, total manpower ceilings for each period, within the Production Department population, were incorporated into the model.

Data Collection

Initial period on-board figures for each CAMAS manpower category were abstracted from Production Department personnel reports. Manpower goals for subsequent periods were developed from staffing requirements studies generated by the NARFNI Workload Coordination Branch. In these studies, the available workload planning data were used with mechanized and manual procedures to obtain staffing requirement estimates (including normal indirect labor and annual leave requirements) by cost center, trade, and time period.

At this point, it should be noted that cost center analysts were unable to specify requirements for some CAMAS categories because of differences in CS and CAMAS titles. In some cases, different skill levels of the same general trade were classified as separate trades even though they performed

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[2]Current force levels (1979) are somewhat less than these figures.

the same tasks. In others, the same functions were interchangeably performed by different trade groups. Finally, a few of the CAMAS categories were too aggregative, resulting in the loss of distinctions important to NARFNI. Further investigation of these problems led to redefinition of some CAMAS categories.

Several other approaches to manpower requirements projection were inspected, based upon an available eight quarters of historical data, by trade and cost center. However, because of the varying skill balances required to meet a changing workload, it appears that the best approach is using cost center analysts' projections.

Estimated attrition and intratrade transition rates for this population were generated for each quarter of FY74 by using NARFNI personnel data available in the Personnel Automated Data System (PADS). These rates were then used to estimate rates of personnel movement for parallel quarters of FY75 and the first quarter of FY76.

The use of distinct transition rates for each quarter allows modelling of seasonal effects in population movement. An investigation of NARFNI quarterly transition data, supplied by OCP for FY72, FY73, and FY74, showed possible seasonal variation. Table 3, which shows retention rates for the five largest trades over this period and some of the seasonal effects, indicates that these transition rates may not be as stable as would be desired. An important finding of an earlier study by Mannis (1973) was that population transition rates at the Naval Underwater Systems Center at Newport showed acceptable stability. More volatility would be expected at an industrial facility, such as NARFNI, which is subject to greater quarterly and yearly workload fluctuations than a research center.

Since the transition rate estimates supplied by CAMAS were based on total transition, regardless of cause, they were corrected to remove the effects of termination and reclassification of personnel for workload and ceiling adjustments. Data for these effects were obtained from the NARF Industrial Relations Office and other NARFNI sources. Although removal of these effects deletes some of the anomalous transition rates found, variability remains an issue.

Experience gained with RRMs indicates that the most critical feature in the choice of penalties or relative costs (in a general sense) associated with hiring new personnel, firing or otherwise adjusting for long-term excess personnel, and deviating from the manpower goals across one time period, is the rank order of these penalties and that outputs are insensitive to exact values used if rank order is constant. For the NARF application, two sets of penalties were used for model solution: Values of 2, 5, 5, 20 and 2, 5, 5, 10 were used for hires, positive goal discrepancies, negative goal discrepancies, and fires, respectively. Associated with the choice of penalty values is the question of maximum allowable goal deviations. Upper and lower bounds can be set individually for each trade and time period to reflect the differing importance of trades, or as a constant proportion of manpower goals. The latter approach was used here, with bounds of ±12 percent. (Subsequent experience indicates that bounds of ±7% might be more appropriate.)

Table 3

Quarterly Retention Rates for Five Largest Trades--
NARF North Island

Civil Service Series Code	Trade	Quarter	FY72	FY73	FY74
8429	Sheet Metal Mechanic	1	.956	.916	.958
		2	.981	.968	.975
		3	.975	.974	.974
		4	.979	.942	.972
8586	Aircraft Overhaul Mechanic	1	.947	.943	.967
		2	.987	.921	.986
		3	.985	.906 (.976)[a]	.954 (.977)[a]
		4	.942	.932	.957
8112	Aircraft Electrician	1	.942	.961	.946
		2	.979	.906	.979
		3	.980	.912 (.970)[a]	.853 (.980)[a]
		4	.975	.937	.947
8585	Aircraft Engine Mechanic	1	.964	.890	.981
		2	.989	.970	.981
		3	.979	.983	.963
		4	.888	.953	.978
8004	Electronics Mechanic	1	.911	.965	.952
		2	.988	.968	.972
		3	.992	.788 (.967)[b]	.943 (.954)[a]
		4	.984	.956	.918

[a]Corrected for terminations.

[b]Corrected for termination and reclassification.

The importance of ceiling constraints was discussed previously. For this application, total manpower ceilings for this population, for each period, were included. Two ceiling levels--5000 and 4300--were used for the initial model solutions. The former level exceeded manpower requirements and did not produce binding constraints, while the latter was approximately 220 below average goals for the planning periods, with binding ceiling constraints.

Model Outputs

The model described above was solved for four sets of data. Although identical manpower goals and transition rate estimates were used for all runs, two sets of penalties and ceilings were used, as shown in Table 4.

Table 4

Penalties and Constraints for NARF, North Island RRM Runs

	Penalty					Limit	
Run Number	Hiring	Positive Discrepancy	Negative Discrepancy	Firing	Manpower Ceiling	Upper (%)	Lower (%)
1	2	5	5	20	5000	+12	-12
2	2	5	5	20	4300	+12	-12
3	2	5	5	10	5000	+12	-12
4	2	5	5	10	4300	+12	-12

Summary outputs for runs 1 and 2 are displayed in Table 5. The June 1974 figures are the initial onboard strengths for the first quarter of FY75; that is, as of 1 July 1974. The "aboard" figures for each subsequent quarter are the estimated onboard strengths at the beginning of the quarter following the month given. These figures include personnel remaining onboard from the beginning of the quarter, plus the "hires" and minus the "RIFs" listed from the current quarter. Hires are, more generally, recommendations for additional personnel in the given trades, which can be filled by new hires or by transfer of excess personnel from other trades. RIFs are personnel retrained and transferred to trades with unmet needs or terminated. Normally, internal adjustments are favored over hires and terminations, to assure the stability, productivity, and morale of the work force. Of course, the exact actions taken would be decided by management. The hires and RIFs give the optimum manpower action plan for meeting manpower goals, subject to penalties and constraints, and aboard figures represent the estimated strengths resulting from these actions and expected movements within the population.

Table 5

Summary Results of Runs 1 and 2—
North Island Model

Code	Category	Jun 74 Aboard	Sep 74 Aboard	Sep 74 Hires	Sep 74 RIFs	Dec 74 Aboard	Dec 74 Hires	Dec 74 RIFs	Mar 75 Aboard	Mar 75 Hires	Mar 75 RIFs	Jun 75 Aboard	Jun 75 Hires	Jun 75 RIFs	Sep 75 Aboard	Sep 75 Hires	Sep 75 RIFs
								Run 1									
1011	IN MECH ELEC	46	49	3	—	49	1	—	48	1	—	47	8	—	47	—	—
1021	ELEC MECH	280	304	37	—	303	5	—	296	6	—	297	18	—	297	14	—
1031	ELEC IN RPMN	57	55	—	1	53	—	—	52	1	—	53	3	—	53	2	—
1041	ELEC MCH NEC	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1051	ELECTRICIANS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1061	AIRCRAFT ELC	670	654	18	—	641	—	—	635	7	—	654	47	—	654	33	—
1071	MACHINISTS	239	236	—	1	231	—	4	228	—	—	223	—	—	221	—	—
1081	TOOLMAKER	16	16	—	2	16	—	—	16	—	1	16	—	—	18	—	—
1091	MACH TOOL OP	145	143	2	—	140	—	—	137	6	—	134	6	—	134	4	—
1101	WELDERS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1111	ELECTROPLTRS	47	54	7	—	53	—	—	53	—	—	53	—	—	53	—	—
1121	MOLDERS	2	2	—	—	2	—	—	2	—	—	2	—	—	2	—	—
1131	MTL PROC WRK	107	126	19	—	125	—	—	121	—	4	113	—	—	113	—	—
1141	SHT MTL MECH	924	960	72	—	937	—	—	926	9	—	955	43	—	955	37	—
1151	MTL WRKS NEC	7	7	—	—	7	—	1	7	—	—	7	2	—	7	—	—
1161	FLD SYS WRKS	10	11	—	—	10	—	—	10	1	—	9	—	—	10	—	—
1171	ACRT PPL MCS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1181	ACRT ENG MCH	374	376	1	—	373	—	—	348	—	18	307	—	39	310	—	—
1191	ACT OVHL MCH	781	818	51	—	823	—	—	820	13	—	857	66	—	857	17	—
1201	PIPEFITTERS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1211	WOOD CRFTSMN	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1221	CARPENTERS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1231	WOODMKRS NEC	20	18	—	3	18	—	—	18	—	—	18	—	—	19	—	—
1241	SHIPFITTERS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1251	FAB LTHR WKR	19	22	3	—	22	—	—	22	1	—	22	—	—	22	—	—
1261	INSTR RPRMEN	192	182	—	5	183	—	—	177	2	—	179	7	—	179	5	—
1271	PAINTERS	146	161	17	—	160	—	—	159	—	—	166	10	—	166	2	—
1281	PLASTICS WKS	19	26	7	—	26	—	—	26	1	—	26	1	—	26	—	—
1291	PRINTING WKS	13	13	—	—	13	—	—	13	1	—	13	1	—	13	—	—
1301	TIRE-RBR WKS	23	22	—	1	21	—	—	21	2	—	21	1	—	21	—	—
1311	FAC MANT WKS	3	3	1	—	3	—	—	3	—	—	3	—	—	1	3	—
1321	IDR EFQMT WK	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1331	FXD EQ RPMN	1	1	—	—	1	—	—	1	—	—	1	—	—	—	1	—
1341	FXD EQ OPRTS	57	52	1	—	52	—	—	49	2	—	46	5	—	46	4	—
1351	MBL EQ OPRTS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1361	HVY DTY EQMT	53	52	—	—	52	1	—	52	1	—	52	—	—	52	1	—
1371	AMM-EXPL WKS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1381	WPNS MCS+RPM	62	66	4	—	65	—	—	65	2	—	68	4	—	68	—	—
1391	PROD EXPDTRS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1401	WAREHS WKS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1411	PKG+PROC WKS	87	96	12	—	95	2	—	95	3	—	96	8	—	96	4	—
1421	MISC UNG NEC	1	1	—	1	1	—	—	1	—	—	1	1	—	1	—	1
1431	GARDNRS-LBRS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total		4401	4526	255	14	4475	9	5	4401	59	23	4439	231	40	4444	123	1

Table 5 (Continued)

Code	Category	Jun 74 Aboard	Sep 74 Aboard	Sep 74 Hires	Sep 74 RIFs	Dec 74 Aboard	Dec 74 Hires	Dec 74 RIFs	Mar 75 Aboard	Mar 75 Hires	Mar 75 RIFs	Jun 75 Aboard	Jun 75 Hires	Jun 75 RIFs	Sep 75 Aboard	Sep 75 Hires	Sep 75 RIFs
									Run 2								
1011	IN MECH ELEC	46	49	3	—	48	—	—	46	—	—	47	9	—	47	—	—
1021	ELEC MECH	280	268	1	—	267	4	—	260	5	—	261	16	—	261	12	—
1031	ELEC IN RPMN	57	53	—	2	51	—	—	49	—	—	53	6	—	51	—	—
1041	ELEC MCH NEC	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1051	ELECTRICIANS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1061	AIRCRAFT ELC	670	636	—	—	624	—	—	611	—	—	584	—	—	613	58	—
1071	MACHINISTS	239	236	—	1	231	—	4	224	—	4	219	—	—	221	3	—
1081	TOOLMAKER	16	16	—	2	16	—	—	16	—	1	16	—	—	18	—	—
1091	MACH TOOL OP	145	141	—	—	138	—	—	137	8	—	134	6	—	134	4	—
1101	WELDERS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1111	ELECTROPLTRS	47	48	1	—	52	5	—	52	—	—	53	1	—	53	—	—
1121	MOLDERS	2	2	1	—	2	—	—	2	—	—	2	—	—	2	—	—
1131	MTL PROC WRK	107	112	5	—	117	6	—	117	—	—	113	4	—	113	—	—
1141	SHT MTL MECH	924	888	—	—	906	40	—	926	39	—	955	44	—	918	—	—
1151	MTL WRKS NEC	7	7	—	—	7	—	1	7	—	—	7	2	—	7	—	—
1161	FLD SYS WRKS	10	10	—	1	9	—	—	9	1	—	9	1	—	10	—	—
1171	ACRT PPL MCS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1181	ACRT ENG MCH	374	375	—	—	372	—	—	348	—	17	307	—	38	309	—	—
1191	ACT OVHL MCH	781	767	—	—	772	—	—	816	59	—	847	59	—	831	—	—
1201	PIPEFITTERS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1211	WOOD CRFTSMN	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1221	CARPENTERS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1231	WOODMKRS NEC	20	18	—	3	18	—	—	18	—	—	18	—	—	19	—	—
1241	SHIPFITTERS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1251	FAB LTHR WKR	19	19	—	—	19	—	—	22	4	—	22	—	—	22	—	—
1261	INSTR RPRMEN	192	182	—	5	182	—	1	177	3	—	179	7	—	179	5	—
1271	PAINTERS	146	158	14	—	157	—	—	156	—	—	166	13	—	166	2	—
1281	PLASTICS WKS	19	26	7	—	26	—	—	25	—	—	26	2	—	26	—	—
1291	PRINTING WKS	13	13	—	—	13	—	—	12	—	—	13	2	—	13	—	—
1301	TIRE-RBR WKS	23	21	—	2	20	—	—	18	—	—	18	1	—	21	2	—
1311	FAC MANT WKS	3	3	—	—	3	—	—	3	—	—	3	—	1	3	1	—
1321	IDR EFQMT WK	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1331	FXD EQ RPMN	1	1	—	—	1	—	—	1	—	—	1	—	—	1	—	—
1341	FXD EQ OPRTS	57	51	—	—	51	—	—	46	—	—	40	1	—	46	9	—
1351	MBL EQ OPRTS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1361	HVT DTY EQMT	53	52	—	—	52	1	—	52	1	—	52	1	—	51	—	—
1371	AMM-EXPL WKS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1381	WPNS MCS+RPM	62	62	—	—	61	—	—	65	6	—	68	4	—	68	—	—
1391	PROD EXPDTRS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1401	WAREHS WKS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1411	PKG+PROC WKS	87	84	—	—	84	2	—	84	3	—	84	7	—	96	14	—
1421	MISC UNG NEC	1	1	—	1	1	—	—	1	—	—	1	1	—	1	—	1
Total		4401	4299	31	17	4300	58	6	4300	129	22	4298	187	39	4300	110	1

Analysis of Model Results

Table 5 shows that, in the first run, the heaviest hiring patterns occur in September 1974 (for the second quarter of FY75) and in June 1975 (for the first quarter of FY76). The only significant RIFs are in the Aircraft Engine Mechanic trade (Code 1181) for March and June 1975. These patterns reflect program levels set at the May 1974 workload planning conference.

Results for the first run also show that the aircraft program significantly increases going into the first and second quarters of FY75. Initial onboard figures (June 1974) do not include the increased personnel necessary to meet this workload; however, they are reflected in the hires for the second quarter (September 1974) (i.e., for Sheet Metal Mechanics (Code 1141), Aircraft Overhaul Mechanics (Code 1191), and other trades).

The detailed report for the second quarter of FY75 (September 1974) is given in Table 6, which provides manpower goals, discrepancies from these goals, and the allowed upper and lower limits for each trade in addition to aboard, hires, and fires figures. As shown, the goals for Aircraft Electricians (1061), Sheet Metal Mechanics (1141), and Aircraft Overhaul Mechanics (1191) have not been met, even with substantial hires. This is because the requirements peak in the second quarter. Hiring up to goals during this period would have created excess personnel in subsequent periods, which would have, in turn, incurred those concurred for the earlier goal deviations. Onboard figures are well within allowed limits.

Returning to Table 5, we find that third quarter FY75 figures (December 1974) for the first run are not exceptional with goals closely followed. However, fourth quarter FY75 figures (March 1975) show more activity: Hires have increased, even though attrition losses bring the total strength lower than for the previous quarter. Hires are primarily replacements for attrition losses. The excessive RIFs in the Aircraft Engine Mechanics (1181) category arise from decreases in the engine program scheduled for the third and fourth quarters of FY75. RIFs are recommended to bring the trade level down to goal, since attrition losses will not be sufficient to remove the excesses. Since needs do not increase again within the planning horizon, consideration of termination or transfer is recommended. These figures might also be used as an indication of excess capacity, to spur a more aggressive search for aircraft engine work. Onboard figures for this quarter are well within allowed limits.

The significant hiring increases for the first quarter of FY76 (June 1975) reflect another increase in the aircraft program and slightly higher fourth quarter attrition rates. The engine program continues to decrease, reducing requirements for Aircraft Engine Mechanics (1181). Again, RIFs bring trade strength level down to the goal, allowing goals to be closely met. In the second quarter of FY76 (September 1975), goals specified are the same as those in the previous quarter. Hires are replacements for trade losses, and goals are met.

Table 6

Detailed Manpower Report for September 1974 (Run 1)--
NARF North Island Model

Code	Category	Aboard	Hires	RIFs	Goal	Discrepancy	Limits	
							Lower	Upper
1011	IN MECH ELEC	49	3	--	49	--	43	55
1021	ELEC MECH	304	37	--	304	--	268	340
1031	ELEC IN RPMN	55	--	1	53	2	47	59
1041	ELEC MCH NEC	0	--	--	--	--	0	0
1051	ELECTRICIANS	0	--	--	--	--	0	0
1061	AIRCRAFT ELC	654	18	--	667	-13	587	747
1071	MACHINISTS	236	--	1	236	--	208	264
1081	TOOLMAKER	16	--	2	16	--	14	18
1091	MACH TOOL OP	143	2	--	143	--	126	160
1101	WELDERS	0	--	--	--	--	0	0
1111	ELECTROPLTRS	54	7	--	55	-1	48	62
1121	MOLDERS	2	--	--	2	--	2	2
1131	MTL PROC WRKS	126	19	--	126	--	111	141
1141	SHT MTL MECH	960	72	--	981	-21	863	1099
1151	MTL WRKS NEC	7	--	--	7	--	6	8
1161	FLD SYS WRKS	11	--	--	10	1	9	11
1171	ACRT PPL MCS	0	--	--	--	--	0	0
1181	ACRT ENG MCH	376	1	--	376	--	331	421
1191	ACT OVHL MCH	818	51	--	871	-53	766	976
1201	PIPEFITTERS	0	--	--	--	--	0	0
1211	WOOD CRFTSMN	0	--	--	--	--	0	0
1221	CARPENTERS	0	--	--	--	--	0	0
1231	WOODMKRS NEC	18	--	3	18	--	16	20
1241	SHIPFITTERS	0	--	--	--	--	0	0
1251	FAB LTHR WKR	22	3	--	22	--	19	25
1261	INSTR RPRMEN	182	--	5	182	--	160	204
1271	PAINTERS	161	17	--	163	-2	143	183
1281	PLASTICS WKS	26	7	--	26	--	23	29
1291	PRINTING WKS	13	--	--	13	--	11	15
1301	TIRE-RBR WKS	22	--	1	21	1	18	24
1311	FAC MANT WKS	3	1	--	3	--	3	3
1321	IDR EFQMT WKS	0	--	--	--	--	0	0
1331	FXD EQ RPMN	1	--	--	1	--	1	1
1341	FXD EQ OPRTS	52	1	--	53	-1	47	59
1351	MBL EQ OPRTS	0	--	--	--	--	0	0
1361	HVY DTY EQMT	52	--	--	52	--	46	58
1371	AMM-EXPL WKS	0	--	--	--	--	0	0
1381	WPNS MCS+RPM	66	4	--	68	-2	60	76
1391	PROD EXPDTRS	0	--	--	--	--	0	0
1401	WAREHS WKS	0	--	--	--	--	0	0
1411	PKG+PROC WKS	96	12	--	96	--	84	108
1421	MISC UNG NEC	1	--	1	1	--	1	1
1431	GARNRS-LBRS	0	--	--	--	--	0	0
User Totals		4526	255	14	4615			
Time Period Totals		4526	255	14	4615			

When results obtained for runs 1 and 3, where ceilings were not binding, were compared, there was no change in model solution when RIF penalties were reduced from 20 to 10. However, when results of runs 2 and 4, where ceilings were binding, were compared, the solution for one trade differed by two RIFs for the last time period. Thus, it appears that results are not sensitive to the size of RIF penalties in this range.

Comparisons were then made between runs 1 and 2, and between results of runs 3 and 4 to determine the effects of imposing a binding ceiling. Table 6 shows that the 4300 ceiling is closely met in all quarters for run 2. These ceilings were met through attrition, which is impacted more heavily in high attrition trades, and created serious imbalances. The total RIFs and their distribution are very similar to those in run 1.

Table 7 provides the detailed report for the second quarter of FY75 (September 1974) from run 2. As shown, striking skill imbalances result from imposing a binding ceiling: Electronics Mechanics (Code 1021), Electroplaters (Code 1111), Fabric and Leather Workers (Code 1251), and Packaging and Processing Workers (Code 1411) trades are at the lower bound allowed. The important Aircraft Overhaul Mechanic (Code 1191) and the Metal Processing Worker (Code 1131) trades are one away from their lower bounds, and several other trades are close to their limits. Although these trades can be forced closer to goals by increasing the lower bounds, especially for critical trades, the total of the lower bounds must not exceed the ceiling, for obvious reasons.

Finally, Table 5 (run 1) shows that hiring patterns, driven by program increases, are delayed and attenuated when a ceiling is imposed. New hires required to handle the increased aircraft program cannot be hired until attrition has reduced other trades and until the engine program has decreased, allowing termination of existing employees.

Further Developments

The results of the first phase of the NARFNI recruiting requirements study were favorably received by NARFNI management. Work has continued since that time, concentrated in several areas:

1. Continued parallel tests of the model with existing planning methods, allowing refinement of the basic model, evaluation of prototype support systems, and development of NARF expertise in the use of such models.

2. Development of a capability for on-site model solution and/or direct access to models over a telecommunications network.

3. Development of NARFNI workload planning models and subsequent integration with the RRM.

4. Development of multiple activity center models for NARF manpower planning.

Table 7

Detailed Manpower Report for September 1974 (Run 2)--
NARF North Island Model

Code	Category	Aboard	Hires	RIFs	Goal	Discrepancy	Limits Lower	Limits Upper
1011	IN MECH ELEC	49	3	--	49	--	43	55
1021	ELEC MECH	268	1	--	304	-36	268	340
1031	ELEC IN RPMN	53	--	2	53	--	47	59
1041	ELEC MCH NEC	0	--	--	--	--	0	0
1051	ELECTRICIANS	0	--	--	--	--	0	0
1061	AIRCRAFT ELC	636	--	--	667	-31	587	747
1071	MACHINISTS	236	--	1	236	--	208	264
1081	TOOLMAKER	16	--	2	16	--	14	18
1091	MACH TOOL OP	141	--	--	143	-2	126	160
1101	WELDERS	0	--	--	--	--	0	0
1111	ELECTROPLTRS	48	1	--	55	-7	48	62
1121	MOLDERS	2	--	--	2	--	2	2
1131	MTL PROC WRKS	112	5	--	126	-14	111	141
1141	SHT MTL MECH	888	--	--	981	-93	863	1099
1151	MTL WRKS NEC	7	--	--	7	--	6	8
1161	FLD SYS WRKS	10	--	1	10	--	9	11
1171	ACRT PPL MCS	0	--	--	--	--	0	0
1181	ACRT ENG MCH	375	--	--	376	-1	331	421
1191	ACT OVHL MCH	767	--	--	871	-104	766	976
1201	PIPEFITTERS	0	--	--	--	--	0	0
1211	WOOD CRFTSMN	0	--	--	--	--	0	0
1221	CARPENTERS	0	--	--	--	--	0	0
1231	WOODMKRS NEC	18	--	3	18	--	16	20
1241	SHIPFITTERS	0	--	--	--	--	0	0
1251	FAB LTHR WKR	19	--	--	22	-3	19	25
1261	INSTR RPRMEN	182	--	5	182	--	160	204
1271	PAINTERS	158	14	--	163	-5	143	183
1281	PLASTICS WKS	26	7	--	26	--	23	29
1291	PRINTING WKS	13	--	--	13	--	11	15
1301	TIRE-RBR WKS	21	--	2	21	--	18	24
1311	FAC MANT WKS	3	--	--	3	--	3	3
1321	IDR EFQMT WKS	0	--	--	--	--	0	0
1331	FXD EQ RPMN	1	--	--	1	--	1	1
1341	FXD EQ OPRTS	51	--	--	53	-2	47	59
1351	MBL EQ OPRTS	0	--	--	--	--	0	0
1361	HVY DTY EQMT	52	--	--	52	--	46	58
1371	AMM-EXPL WKS	0	--	--	--	--	0	0
1381	WPNS MCS+RPM	62	--	--	68	-6	60	76
1391	PROD EXPDTRS	0	--	--	--	--	0	0
1401	WAREHS WKS	0	--	--	--	--	0	0
1411	PKG+PROC WKS	84	--	--	96	-12	84	108
1421	MISC UNG NEC	1	--	1	1	--	1	1
1431	GARDNRS-LBRS	0	--	--	--	--	0	0
User Totals		4299	31	17	4615			
Time Period Totals		4299	31	17	4615			

As a result of parallel tests (1 above), manpower categories have been modified to more accurately meet NARFNI planning needs. The cost center analysts responsible for developing gross manpower requirements required as input to this model have accepted the requirement for multiperiod planning. They are now producing longer-term estimates on a regular basis using common procedures. The workload planning section at NARFNI has gained a better understanding of work force dynamics through use of this planning model.

When the study commenced, considerable effort had to be expended so that NARFNI personnel could run the model on a Navy UNIVAC 1110 in the San Diego area on an independent basis. This arrangement was not satisfactory. The 1110 Center, which supports an engineering and scientific laboratory, did not supply the type of support required by NARF workload planners at the industrial NARFNI facility. Coordination and logistical problems between the NARFNI, the 1110 Center, and the Washington, D. C. based CAMAS support slowed development considerably.

As a result of the problems encountered in installing the model on a remote system, it was decided to install the CAMAS software required, modified for limited interactive use by skilled computer specialists, on a time-sharing network. Also output report formats were altered to allow printing on 80-column terminals available to NARFNI planners. This support system was maintained by headquarters personnel familiar with the CAMAS system.

Experience with computer support systems for the NARFNI model has provided valuable insight into support system requirements for model use at an industrial facility. This experience has been an important consideration in development of the SAMPS system design.

NARFNI has continued to develop improved planning systems for workload and budget planning, and has taken the lead in the development of CWPABS, which is being installed on a telecommunications network for use by all NARFs. Work is underway to provide an interface between outputs of this system and the NARFNI RRM. The integrated result of this effort would be available to all the NARFs, although details of the manpower planning model will differ for each facility.

NARFNI has expressed interest in developing a more detailed model that would consider the Production Department divisions separately and include flows between divisions. A preliminary prototype of this multidivision linked model was run successfully. However, since this capability is not available in the computer support system, the model has not been introduced to the NARFNI planning department. It would also be useful to include Production Controllers and Expediters, as well as GS-graded Electronic Technicians employed in the avionics repair area, in the model. This development, however, remains a task for the future.

Finally, the NARF model is providing data that are timely enough for use in parallel with the present planning practices in a retrenchment environment requiring substantial changes in both the number of personnel and the types of skills required. These types of data are not available in the manual system, extend farther into the future than those provided by the manual system, and can be generated in a more expeditious manner.

PILOT APPLICATIONS: PROMOTION PLANNING MODEL

Because of the control of high grade level positions within the Navy civilian personnel population, there has been a large increase in the number of midlevel positions--General Schedule grades GS-9 through GS-12. Since this concentration has been especially marked at the GS-12 level, the need to focus upon this level is a major concern within the Navy. A suggested remedy to this problem has been to control promotions of employees at all levels, thus avoiding a build-up at any particular grade. These controls would be implemented as part of a large revision, which would include more thorough position management and position classification systems.

The Promotion Planning Model (PPM) was formulated to gain a better understanding of the impact of such promotion controls. It is an extension of the basic Recruiting Requirements Model (RRM) to allow promotions and other population movements that differ from normal historical movement rates.[3] The initial uses of the PPM involved two applications: The first concerned the graded personnel at the Naval Underwater Systems Center (NUSC), Newport; and the second, the graded personnel under control of the Director of Laboratory Programs (DLP), encompassing all Navy RDT&E,N Laboratories commanded by the Chief of Naval Material.

The PPM is designed to provide estimates of the numbers of people that should be hired, fired, or promoted to meet given manpower requirements as closely as possible, subject to constraints on that manpower system. Its objective is to minimize the weighted sum of (1) deviations above and below the manpower requirements, (2) numbers of hires and fires, and (3) numbers of transfers above or below historical promotion/demotion rates, subject to a number of constraints. First, the number at the start in each job category is set equal to the initial (base) population. The base population is then multiplied by a matrix of historial movement or transition rates to predict the number of people (1) staying in a particular job category, (2) being promoted at the historical rate, and (3) leaving the organization. The resultant numbers for each job category, plus the hires and flexible transfers and minus the fires and flexible transfers out, provides the number in each job category at the next time period. This process is repeated for each of the time periods in the model. Constraints have been added to the model to ensure that the number of flexible (differing from the historical rate) transfers out of a job category for promotion or demotion is less than or equal to the number in each job category estimated by historical retention rates. This ensures that these additional transfers are possible. Constraints are also set for each time period for the total manpower limitation or ceiling. The sum of the numbers in each job category in a given period must be less than or equal to the total manpower limitation for that period.

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[3]See Albanese, Korn, Niehaus, and Padalino (1977). This model is an a adaptation of the "flexibility" EEO model discussed by Charnes, Cooper, Lewis, and Niehaus (1976).

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Both PPM applications used 30 September 1976 data for initial populations. In all but one case, three planning periods were used, each of one year-length. Overall manpower ceilings were set equal to the sum of the goals for the corresponding time period. The same weight was used for exceeding a given goal as for falling short of that goal; similarly, the weights for deviations from the historical promotion rates did not depend on the direction of the deviations.

NUSC Application

The manpower categories used for the NUSC PPM application were GS grades 1 through 17 for non-junior professionals (NJPs) and grades 5, 7, and 9 for junior professional (JPs). JPs who are promoted advance two grades; and NJPs, one grade. Both groups retain their respective identities when promoted--up to the GS-11 level. The historical promotion and separation rates, initial populations (aboard), and manpower goals were developed by NUSC. The transition rates appear in Table 8, while the initial aboard and goals are contained in each run. The first eight runs varied in differences in the penalties assigned to various types of action, as shown in Table 9. This first set of runs used goals only for the last period, to allow maximum flexibility.

In the first three runs (1-3), the highest penalty was assigned to fires; and the lowest, to hires. Since goals were only given for the last time period, all hiring and firing occurred in that period; because of the nonzero separation rates, hiring and firing in the last time period are the most effective way to meet goals in that time period. Since hires have a lower penalty than deficiencies (i.e., below goal), none of the latter occurred; similarly, excesses (above goal) were retained to avoid firing. The only excess occurred at the GS-12 level. Some hiring and promotion deviations occurred during the last period.

The first three runs indicated a situation where the goals cannot all be met without resorting to firing, if the current promotion rates are retained. Run 4 was designed to study a policy in which the current promotion rates are retained, the goals are met, and a minimum number of people are fired. To do this, goal and promotion discrepancies were assigned the highest penality; fires, an intermediate penalty; and hires, the lowest penalty. This policy resulted in a relatively large number of people being fired in some of the middle grades. In periods 1 and 2, there were net gains in some of the categories, even though no hiring occurred until the last period. The reason for this was that the number of people promoted into some of the grades exceeded the number leaving the respective grades due to promotions and separations. Increasing the number of periods to five (Run 5) did not alleviate this problem; in fact, the number of excesses in some grades actually increased. Run 6 was similar to Run 4, except that fires were assigned a higher weight than goal discrepancies. In this case, the excess personnel were retained rather than fired.

Table 8

Promotion and Separation Rates--NUSC
PPM Application

Grade	Promotion Rate	Separation Rate
Non-Junior Professional:		
1	1.000	.000
2	.333	.333
3	.429	.122
4	.149	.051
5	.191	.10
6	.167	.083
7	.312	.043
8	.376	.025
9	.130	.041
10	.294	.071
11	.141	.024
12	.028	.027
13	.039	.036
14	.021	.048
15	.000	.067
16	.000	.125
17	.000	.000
Junior Professional:		
5	.833	.056
7	.529	.082
9	.630	.054

Table 9

Penalties Assigned--NUSC PPM Application

Nature of Action	Alternative Run 1	2	3	4	5	6	7	8
Hires	1	2	2	1	1	1	1	10
Fires	7	7	7	10	10	100	1000	1000
Positive Goal Discrepancy	3	3	4	100	100	10	100	100
Negative Goal Discrepancy	3	3	4	100	100	10	100	100
Positive Promotion Discrepancy	2	4	4	100	100	100	10	1
Negative Promotion Discrepancy	2	4	4	100	100	100	10	1

In Run 7, the penalty for promotion discrepancies was lower than that for fires and goal discrepancies, but still above that of hires. In this case, fires and goal deviations were eliminated. The price paid was that promotions were drastically reduced in the middle grades; in fact, they were frozen in grades 11 and 12 for the last period. Run 8 is similar to Run 7, except that promotion discrepancies incurred less penalties than hires; this resulted in a slight reduction in the total number of hires, but still further cutbacks in promotions.

To bring the issues into sharper focus, an extensive number of runs was tested with goals for all three periods. Results of several runs made to evaluate the inclusion of average grade constraints into the model showed that, including such a device, in addition to the other constraints being imposed, was of questionable value. Since ceilings were much more of a constraining factor, average grade constraints were relaxed in subsequent runs, so as not to affect the solutions.

A final set of runs was made to examine the possibilities of maintaining junior professional hiring and promotions. For these runs, it was assumed that firing would be done only as a last resort. The action penalties assigned for these runs are given in Table 10. The results of Run W show that promotions were cut considerably with grade imbalances projected in low grades (GS-2-3) and in the GS-12s in Period 1. Also, there was little hiring of any personnel at all in Period 1 and little hiring of JPs until Period 3.

Table 10

Penalties--NUSC PPM Application

Nature of Action	Alternative Run W	X	Y	Z
Hires	10	10	10	10
Fires	1000	1000	1000	1000
Positive Goal Discrepancy				
For Grades 13-17	100	100	100	2000
For Other Grades	100	100	100	100
Negative Goal Discrepancy	100	100	100	100
Positive Promotion Discrepancy				
NJPs Below Grade 13	1	1	1	1
JPs	1	200	200	200
Grades 13 and above	1	1	500	1
Negative Promotion Discrepancy				
NJPs	1	1	1	1
JPs	1	200	200	200

In Run X the policy was further shaped by putting relatively large penalties on promotion discrepancies for JPs. The results of this run showed that the GS-12 grade imbalance moved up to the higher grades, with the low grade imbalances making the difference. Since these results were unacceptable, additional penalties were put on positive promotion discrepancies for GS-13s and above in Run Y. This also turned out to be unacceptable as the penalties should have been placed down to the GS-12 level if the GS-13 and above goals were of particular concern.

Using Runs W, X, and Y as trial runs, a final alternative was constructed to see if all the conditions and constraints could lead to an implementable promotion policy. In Run Z, the high penalties on the positive promotion discrepancies for GS-13s and above were replaced with high penalties on positive goal discrepancies for GS-13s and above, thus more accurately reflecting the desired control. The penalties on the JP promotion discrepancies continued to give a high priority on keeping the promotions at the historical rates. As shown in Table 11, this increased the goal imbalances at GS-12 and at GS-2 and GS-3. Hiring of JPs was restricted in Period 1 but indicated at good levels in Periods 2 and 3.

The last series of runs showed that the GS population was so highly overconstrained that almost any policy results in undesirable side effects. The model appears to work well in reflecting the effects of policy decisions. These policy decisions may then be made external to the model. Since these decisions currently are being discussed, no further comments will be made on the model runs at NUSC.

Table 11

Detailed Manpower Report from Run Z--NUSC PPM Application

Grade	Aboard--Begin	Hires	Fires	Promotions from Category: Expected	Promotions from Category: Additional	Promotions from Category: Actual	Other Losses	Aboard--End	Goal	Goal Discrepancy
Period 1--Sep 76 to Sep 77 (Sep 77 ceiling = 2663; average grade = 10.32; target grade = 11.00)										
NJP:										
1	1	0	0	1	-1	0	0	1	1	0
2	3	0	0	1	1	2	1	0	3	-3
3	48	0	0	21	0	21	6	24	48	-24
4	195	0	0	28	-13	16	10	190	190	0
5	136	0	0	26	-16	10	15	127	132	-6
6	60	0	0	10	-3	7	5	58	58	0
7	93	0	0	29	-23	6	4	90	90	0
8	79	0	0	29	-23	6	2	77	77	0
9	123	0	0	16	-12	4	5	120	120	0
10	85	0	0	25	-25	0	6	83	83	0
11	490	0	0	69	-10	59	12	476	476	0
12	710	0	0	20	4	24	19	726	690	36
13	360	0	0	14	-3	11	13	360	360	0
14	146	0	0	3	1	4	7	146	146	0
15	45	0	0	0	1	1	3	45	45	0
16	8	0	0	0	0	0	1	8	8	0
17	1	0	0	0	0	0	0	1	1	0
JP:										
5	18	6	0	15	0	15	1	8	12	-4
7	85	0	0	45	-11	34	7	59	59	0
9	92	0	0	58	-1	57	5	64	64	0
Total	2779	6	0	411	-134	277	122	2663	2663	0
Period 2--Sep 77 to Sep 78 (Sep 78 ceiling = 2621; average grade = 10.34; target grade = 11.0)										
NJP:										
1	1	0	0	1	-1	0	0	1	1	0
2	0	0	0	0	0	0	0	0	3	-3
3	24	6	0	10	0	10	3	17	47	-30
4	190	23	0	28	-1	27	10	186	186	0
5	127	0	0	24	-13	11	14	129	129	0
6	58	0	0	10	-2	8	5	57	57	0
7	90	0	0	28	-22	6	4	88	88	0
8	77	0	0	28	-22	6	2	75	75	0
9	120	0	0	16	-12	4	5	117	117	0
10	83	0	0	24	-24	0	6	81	81	0
11	476	0	0	67	-41	26	11	466	466	0
12	726	0	0	20	4	24	20	709	676	33
13	360	0	0	14	-3	11	13	360	360	0
14	146	0	0	3	1	4	7	146	146	0
15	45	0	0	0	1	1	3	45	45	0
16	8	0	0	0	0	0	1	8	8	0
17	1	0	0	0	0	0	0	1	1	0
JP:										
5	8	11	0	6	0	6	0	12	12	0
7	59	30	0	31	0	31	5	59	59	0
9	64	0	0	40	-13	27	3	64	64	0
Total	2663	70	0	350	-148	202	112	2621	2621	0
Period 3--Sep 78 to Sep 79 (Sep 79 ceiling = 2621; average grade = 10.25; target grade = 11.)										
NJP:										
1	1	1	0	1	0	1	0	1	1	0
2	0	2	0	0	0	0	0	1	1	0
3	17	39	0	7	0	7	2	47	47	0
4	186	30	0	28	0	28	9	186	186	0
5	129	1	0	25	-10	15	14	129	129	0
6	57	0	0	10	0	10	5	57	57	0
7	88	0	0	27	-15	12	4	82	88	-6
8	75	0	0	28	-17	11	2	75	75	0
9	117	0	0	15	-9	6	5	117	117	0
10	81	0	0	24	-24	0	6	81	81	0
11	466	0	0	66	-37	29	11	466	466	0
12	709	0	0	20	4	24	19	685	676	0
13	360	0	0	14	-3	11	13	360	360	0
14	146	0	0	3	1	4	7	146	146	0
15	45	0	0	0	1	1	3	45	45	0
16	8	0	0	0	0	0	1	8	8	0
17	1	0	0	0	0	0	0	1	1	0
JP:										
5	12	11	0	10	0	10	1	12	12	0
7	59	26	0	31	0	31	5	59	59	0
9	64	0	0	40	0	40	3	51	64	-13
Total	2621	110	0	349	-109	240	110	2621	2621	0

DLP Application

Having gained experience with the PPM at NUSC, a similar model was constructed for the work force of the Navy labs as a whole. With this larger population, a more detailed manpower categorization becomes practicable.

The manpower categories for the Director of Laboratory Programs (DLP) application are specified by (1) GS grade and (2) CAMAS occupation categories corresponding to those grades (OCMM, 1974). The following six categories were used: scientists and engineers, other professionals, administrative, technicians, clerical and other GS. The model was run at the occupation-grade level of detail, and the results were then aggregated to reports by grade alone for overall evaluation.

The initial onboard figures and historical transition rates were based upon data from the Personnel Automated Data System (PADS). The manpower goals were obtained by multiplying the initial aboard for the corresponding categories by proportionality factors determined from the Five Year Defense Plan (FYDP) figures for the appropriate years. Those levels having fewer than three people initially aboard (e.g., GS-10 scientists and engineers) were not included in the tests in an attempt to eliminate invalid levels and to increase numerical stability. (This accounts for the absence of the Grade 17 category from the DLP reports.)

The action penalties used in these tests are shown in Table 12. In Run A, the goal and promotion discrepancies were forced to zero by assigning them a high penalty; hires and fires were allowed to occur as needed. This resulted in a significant amount of firing in the middle grades, particularly in Grade 12. In Run B, excess personnel were retained rather than fired. In this case, the manpower ceiling constraint caused deficiencies in the lower grades to counterbalance the excesses in the middle grades. In Run C, the manpower goals were all met without firing, provided that the promotion rates were allowed to vary. In this case, however, the number of promotions were substantially reduced, particularly in Grade 11. Tables 13 and 14 provide Run C summary data for the scientists and engineers and for all GS grades respectively.

Table 12

Penalties Assigned--DLP PPM Application

Nature of Action	Alternative Run A	Alternative Run B	Alternative Run C
Hires	1	1	1
Fires	10	100	1000
Positive Goal Discrepancy	100	10	100
Negative Goal Discrepancy	100	10	100
Positive Promotion Discrepancy	100	100	10
Negative Promotion Discrepancy	100	100	10

Table 13

Summary Report for Scientists and Engineers (Run C)—DLP PPM Application

Grade	Aboard—Begin	Hires	Fires	Promotions from Grade: Expected	Additional	Actual	Aboard—End	Goal	Goal Discrepancy
Period 1—Sep 76 to Sep 77									
5	32	19	0	22	0	22	30	30	0
7	310	127	0	172	0	172	291	291	0
9	568	115	0	295	-4	291	533	533	0
11	1166	27	0	318	-315	3	1094	1094	0
12	3263	0	0	82	-42	40	3063	3063	0
13	2604	0	0	102	-83	19	2444	2444	0
14	1060	0	0	19	0	19	995	955	0
15	386	0	0	1	0	1	362	362	0
16	34	5	0	0	0	0	32	32	0
Total	9423	293	0	1011	-444	567	8844	8844	0
Period 2--Sep 77 to Sep 78									
5	30	20	0	21	0	21	30	30	0
7	291	133	0	162	0	162	287	287	0
9	533	133	0	277	0	277	525	525	0
11	1094	77	0	299	-155	144	1078	1078	0
12	3063	0	0	77	0	77	3016	3016	0
13	2444	73	0	95	-32	63	2407	2407	0
14	995	0	0	18	0	18	980	980	0
15	362	17	0	1	0	1	357	357	0
16	32	5	0	0	0	0	31	31	0
Total	8844	458	0	950	-187	763	8711	8711	0
Period 3—Sep 78 to Sep 79									
5	30	21	0	21	0	21	31	31	0
7	287	147	0	159	0	159	299	299	0
9	525	161	0	272	0	272	548	548	0
11	1078	139	0	294	0	294	1125	1125	0
12	3016	26	0	75	0	75	3149	3149	0
13	2407	215	0	94	0	94	2513	2513	0
14	980	25	0	18	0	18	1023	1023	0
15	357	38	0	1	0	1	373	373	0
16	31	8	0	0	0	0	33	33	0
Total	8711	780	0	934	0	934	9094	9094	0

Table 14

Summary Report for Total GS Grades
(Run C)--DLP PPM Application

Grade	Aboard--Begin	Hires	Fires	Promotions from Grade: Expected	Promotions from Grade: Additional	Promotions from Grade: Actual	Aboard--End	Goal	Goal Discrepancy
Period 1--Sep 76 to Sep 77 (Sep 77 ceiling = 17515)									
1	5	3	0	2	0	2	5	5	0
2	159	113	0	76	0	76	150	150	0
3	511	233	0	212	0	212	479	479	0
4	1367	298	0	326	-2	324	1282	1282	0
5	1471	91	0	297	-50	247	1381	1381	0
6	666	4	0	120	-6	114	625	625	0
7	985	157	0	339	-6	333	924	924	0
8	311	2	0	85	0	85	292	292	0
9	1346	156	0	471	-37	434	1264	1264	0
10	412	2	0	78	-17	61	387	387	0
11	2597	27	0	442	-410	32	2433	2433	0
12	4415	0	0	102	-42	60	4144	4144	0
13	2862	13	0	115	-87	28	2687	2687	0
14	1125	0	0	20	0	20	1057	1057	0
15	398	1	0	1	0	1	373	373	0
16	34	5	0	0	0	0	32	32	0
Total	18659	1107	0	2686	-657	2029	17515	17515	0
Period 2--Sep 77 to Sep 78 (Sep 78 ceiling = 17252)									
1	5	3	0	2	0	2	5	5	0
2	150	114	0	72	0	72	147	147	0
3	479	242	0	199	0	199	474	473	0
4	1282	342	0	35	-2	303	1264	1264	0
5	1381	151	0	279	-27	252	1361	1361	0
6	625	12	0	113	-2	111	616	616	0
7	924	190	0	319	-1	218	911	911	0
8	292	8	0	80	0	80	287	287	0
9	1264	206	0	442	-2	440	1245	1245	0
10	387	6	0	73	0	73	381	381	0
11	2433	105	0	416	-196	220	2397	2397	0
12	4144	0	0	95	0	95	4080	4080	0
13	2687	95	0	107	-33	74	2646	2646	0
14	1057	0	0	19	0	19	1040	1040	0
15	373	19	0	1	0	1	368	368	0
16	32	5	0	0	0	0	31	31	0
Total	17515	1498	0	2522	-263	2259	17252	17252	0
Period 3--Sep 78 to Sep 79 (Sep 79 ceiling = 18009)									
1	5	3	0	2	0	2	5	5	0
2	147	122	0	71	0	71	153	153	0
3	473	265	0	197	0	197	493	493	0
4	1264	410	0	302	0	302	1320	1320	0
5	1361	228	0	275	-7	268	1420	1420	0
6	616	27	0	110	0	110	642	642	0
7	911	238	0	314	-1	313	951	951	0
8	287	24	0	79	0	79	299	299	0
9	1245	273	0	434	0	434	1299	1299	0
10	381	28	0	72	0	72	398	398	0
11	2397	242	0	409	-5	404	2502	2502	0
12	4080	56	0	93	0	93	4261	4261	0
13	2646	251	0	106	0	106	2762	2762	0
14	1040	28	0	19	0	19	1086	1086	0
15	368	41	0	1	0	1	385	385	0
16	31	8	0	0	0	0	33	33	0
Total	17252	2244	0	2484	-13	2471	18009	18009	0

PILOT APPLICATIONS: CONVERSATIONAL USE RECRUITING REQUIREMENTS MODEL

Two distinct manpower planning problems were selected to test the Conversational Use Recruiting Model (CURRM). One was concerned with determining the needs for junior professional hiring at the Naval Underwater Systems Center (NUSC), Newport over the next 3 years in light of ceiling and high-grade constraints. The other concerned determining Navy-wide intake requirements over the next 5 years for the Navy's procurement career program.

NUSC Application

NUSC Newport had been involved since 1972 in application studies with manpower planning techniques (see Charnes, Cooper, Niehaus, & Padalino, 1973). Studies that were supported as part of the Shore Activity Manpower Planning System (SAMPS) project include the testing of CURRM (reported here) and the production planning model (PPM) (reported in the previous section).

Manpower Planning

With the current climate within the Navy, top management at NUSC is concerned with those manpower policies that impact on ceilings, budget, and average grade of the work force. Typical manpower planning problems that need to be addressed include:

1. The number of junior professionals that should be hired under different conditions involving budgets, ceiling, salary, and average grade constraints.

2. The proper distribution of the work force under various manpower ceilings over different time periods, given alternative occupational and grade level goals.

3. Alternative promotion policy strategies that can be employed at each occupation and grade level, given different separation rates and average grade restrictions.

4. Meeting end-year strength ceilings if the separation rate decreases and determining how such decreases will affect hires and promotions.

5. Attainment of EEO goals (as defined in the Affirmative Action Plan) under current conditions at NUSC, and determining what jobs should be designated as upward mobility positions.

NUSC has addressed these problems of manpower planning by using:

1. The Automated Personnel Data System, which consists of both historical and current transactions files. This system allows NUSC to use historical data, to see current trends, and to develop manpower profiles for the Center at any period in time.

2. Statistical Data and Reports affecting management needs gathered from the personnel system.

3. Integrated Financial and Personnel Files, which are used to bring together manpower, budgeting, and program information. By using the current year financial data along with the program summary data, the technical program and manpower requirements for a 3-year planning period can be examined.

4. Long-Range Staffing Plans (i.e., allocation of "billets" among all Center organizations) developed by top management.

5. Manpower Planning Models, including both a NUSC-developed probabilistic retirement forecasting model and the conversational use recruiting requirements model (CURRM).

CURRM Installation

The installation of the CURRM computer software at NUSC originated in staffing studies for Center programs over a 2-year time period (two 6-month planning intervals followed by a 1-year planning period), using the Computer-Assisted Manpower Analysis System (CAMAS) (Charnes, Cooper, Niehaus, & Padalino, 1973). Although CAMAS could handle massive amounts of relevant data accurately and quickly, its use was curtailed since only computer professionals were knowledgable enough to feed in the data, to operate the systems, and to interpret the outputs. This situation led to the installation of CURRM, which made the manpower planning models conversational; that is, the user could engage in dialogues with the computer, which would guide him by asking questions and eliciting responses. With CURRM, the models could be used directly by the managers or subject-matter specialists. NUSC was chosen as the test site for CURRM because of prior successful experience with CAMAS.

Installation of CURRM involved three separate phases. Phase I was completed in August 1974 and involved transferring NUSC data to the Office of Civilian Personnel (OCP). The data base was then used to test CURRM on the UNIVAC 1108 computer at the Naval Command System Support Activity (NAVCOSSACT). During Phase II, which was conducted at NUSC in January 1975, the CURRM package was tested on NUSC's UNIVAC 1108 to determine operational and compatibility problems. During Phase III, which was completed in March 1975, NUSC and NAVCOSSACT personnel worked to overcome difficulties imposed by differences in the computer operational environments.

In addition, the existing systems features of CURRM were reviewed and several changes were suggested by NUSC personnel. After 2 months of debugging and testing, managerial tests were conducted that introduced CURRM to several members of top management at NUSC.

These managerial tests proved to be quite successful, both in determining the usefulness of CURRM and in providing insights into the study to be conducted with the model. Although a variety of changes were suggested (e.g., in managerial support procedures, software, and hardware configurations), CURRM, in its present form, represents a vast improvement over previous support systems. The managers and their noncomputer-trained staff analysts appeared considerably more comfortable with this version than with previous forms of the model. The ability to exercise direct control over model processing was of major importance to the acceptance of these models for decision-making support. The results of these initial tests were reported by Niehaus, Sholtz, and Thompson (1973).

Based upon the encouraging results of these tests, a review was made to identify additional features that would make CURRM completely responsive to NUSC requirements. An agreement was reached among NUSC, OCP, and NAVCOSSACT to implement the required changes, which included the transfer of additional computer programs from OCP to NUSC. These programs were successfully installed in September 1975 and are fully operational. NUSC is now able to use CURRM independently, without requiring outside assistance.

It costs approximately $55 to use CURRM for a 35-minute session, which includes starting a new problem, solving the problem two times, making four changes, and printing two reports on a high-speed printer. NUSC is currently using a terminal that prints at 30 cps; the printing speed of 10 cps terminals was found to be inadequate because the text in CURRM is quite lengthy and some of the minireports provided by CURRM can average about 20 lines each. Testing is also underway at OCP in the use of a CRT and printer combination at 120 cps.

CURRM Operational Studies

NUSC has a continuing need for highly trained engineers and scientists to perform research, design, development, analysis, tests, evaluation, and in-service engineering work in underwater weapon systems. Because of the specialized nature of its mission and functions, NUSC must recruit talent from colleges and universities for entry level positions, developing the special skills required through experience and training on the job. Because of this requirement, along with the need to maintain the proper occupational mix of all employees, NUSC must analyze the recruitment, promotion, and attrition processes and their interrelationship within the organization to assure that sound personnel policy decisions are made.

Since NUSC is a research laboratory rather than a production-oriented facility, it finds the CURRM system useful mainly for establishing general trends rather than for developing specific hiring and firing plans for each occupational and grade groups. Since estimating manpower goals for every occupational and grade group is extremely difficult in a research environment, NUSC planners generally take the initial population and adjust it proportionately to meet total ceiling restrictions for future time periods. These numbers then become the manpower goals for the specified future time period, required as inputs to the CURRM model.

The basic problem is to determine the number of excesses and deficiencies existing in each occupational and grade grouping during the planning period FY76 through FY79, under a variety of manpower ceilings and goals. Special emphasis is given to the effect of hires of junior professional (JP) engineers and scientists at the GS-5 and GS-7 levels. In resolving this problem, NUSC management defined seven approaches that they felt were realistic manpower strategies during the planning years. These approaches, which reflect a series of possible ceiling restrictions for FY76 through FY79, are listed in Table 15. Approach A specifies that manpower goals must be met by FY76; and Approach B, by FY78. Approaches C and D include the

Table 15

Alternate Manpower Planning Approaches
to be Analyzed by CURRM

Approach	Constraints
A	• Separation rate set equal to 5.5% for planning years. • Manpower ceilings remain unchanged for FY76 to FY78 (2902 FTP). • Lower bound of Engineer/Scientist GS-5 through GS-7 manpower goals set to zero for each year. • Reductions taken proportionately across each occupational and grade grouping except GS-13 through GS-15. • Goals for GS-13 through GS-15 set at 554 for each planning year. • Promotions into GS-13 through GS-15 set equal to losses from the grade levels. All other grade groupings had normal promotion rate.
B	Same as A except manpower ceilings are as follows: June 76 3075 June 77 2989 June 78 2902
C	Same as A except 36 service jobs (guards and firefighters) are eliminated and their billets are distributed among Engineers/Scientists as follows: 33 to GS-9 through GS-12 Engineers/Scientists 3 to GS-5 through GS-7 Engineers/Scientists — 36
D	Same as C except manpower ceilings are as follows: June 76 3075 June 77 2989 June 78 2902
E	Same as C except: • Separation rate is set equal to 5.0% for planning years. • The manpower ceilings are as follows: June 76 3015 Sept 76 3030 Sept 77 2882 Sept 78 2882
F	Same as A except that: • Separation rate is set equal to 5.0% for planning years. • The manpower ceilings are as follows: Sept 76 3030 Sept 77 2926 Sept 78 2882 Sept 79 2882
G	Same as F except that in FY77 through FY79, 34 service jobs (guards and firefighters) are eliminated and their billets are distributed among Engineers/Scientists as follows: 31 to GS-9 through GS-12 3 to GS-5 through GS-7 — 34

added restriction of contracting out the firefighter and guard work force and distributing their billets among the Engineering/Scientist population, thus alleviating the pressure of the cutbacks on this group. These four approaches were set up at the end of FY75 in response to preliminary ceiling allocations for FY76 through FY78.

Approach E is the same as C except that the separation rate is reduced from 5.5 to 5.0 percent and the ceilings are changed to reflect additional ceiling information provided when the fiscal year was converted from June 1976 to September 1976. Approach F is the same as A except for changes to the separation rate and adjustment of the manpower ceilings. Finally, Approach G is the same as F except that, in FY77 through FY79, 34 service jobs (guards and firefighters) are eliminated and their billets are distributed among Engineers/Scientists. Approaches F and G were set up when NUSC received preliminary manpower ceilings for the planning period from FY77 through FY79.

In all approaches, GS-13 through GS-15 group goals were set at 554 for FY76 through FY78. For all groups, the upper and lower bounds were set at 10 percent over and under the goal, with two exceptions. First, for the Engineer/Scientist GS-5s through GS-7s (the junior professionals (JPs)), the lower bound was set at zero; and the upper bound, at 10 percent over the goal. This lets the model freely select the best hiring policy for JPs, allowing significant changes to the college recruiting program. Second, for the GS-13 through GS-15 groups, the upper and lower bounds were set equal to the grade losses, which forces the model to have precisely the required number for each period. To set the promotions in the GS-13 through GS-15 groups equal to the grade losses, the free flow promotion rates were set to zero, with promotions being expressed as "hires" in the model output. The penalties used in all the runs were 1 for hires, 5 for hires, 3 for positive discrepancies, and 2 for negative discrepancies.

Table 16 is a summary of the hires that would be allowed under the constraints of the various approaches. As shown, the critical period in Approaches A, C, and E was FY76, which required RIFs—ranging from 31 to 113 employees, depending on the approach--to meet the manpower ceilings imposed by the end of that fiscal year. Information on these RIFs was fed back to the Chief of Naval material, who is responsible for the central management of the nine Navy R&D centers, and was influential on CNM's decision to stretch the ceiling cuts over a 3-year period--to FY78.

As shown in Table 16, constraints under Approaches A through D did not allow for the hiring of JPs in FY76. However, a decision was made to go ahead with the college recruiting program--without making formal committments--pending final receipt of the FY ceilings. As FY76 progressed, it became evident that the ceilings would not be as tight as originally expected, and that they would be revised. In converting to the new fiscal year, ceilings were revised and Approach E was formulated, which suggested that 22 JPs could be hired if the RIF was effected. NUSC wanted to hire the JPs but not at the expense of the other employees. In February 1975, the ceilings were revised upward by about 30. Based on the new ceilings, NUSC decided that the recruiting goal for FY76 would include between 20 and 25 JPs; accordingly, 21 were hired.

Table 16

Hires Allowed Under Alternative Approaches

	FY76		FY77		FY78		FY79	
Approach	JP	Total	JP	Total	JP	Total	JP	Total
A	0	-113 (RIFs)	13	116	16	169	--	--
B	0	43	0	102	0	113	--	--
C	0	-113 (RIFs)	15	168	17	170	--	--
D	0	44	0	103	21	103	--	--
E	22	- 31 (RIFs)	7	38	32	32	--	--
F	--	--	25	39	25	88	26	126
G	--	--	26	39	27	86	27	123

Note. Total includes JPs.

As indicated previously, Approaches F and G reflect the latest ceiling levels; thus, they are being used as a basis for (1) establishing a plan for the allocation of billets and (2) recruiting JPs. Although NUSC management was concerned about the impact of these levels on recruiting, Table 16 shows that at least limited hiring would be permitted during all three planning years, with FY77 being the most restricted. As a result of the solutions shown in this table, NUSC planned to include about 25 JPs in the total of 39 hires anticipated for FY77. FY78 and FY79 will allow additional hires; further, NUSC plans to convert temporary employees to permanent status as vacancies occur during these years.

The NUSC has found CURRM useful in analyzing manpower policies on a strategic level. Changes in manpower goals can be easily reflected in the model, and changes can be made to the transition rates when it is found that separation rates are trending either up or down. The model is also useful in indicating approximately how many of the high grade positions (GS-13 through GS-15) will be vacated during the planning periods, which allows NUSC to plan for promotions to these levels on a systematic basis. This is especially true in light of current ceilings for high grade positions.

NUSC has been under both average grade and high-grade constraints from higher headquarters (Chief of Naval Material) at various times over the last 3 years. Since these two problems are somewhat related, the model has been useful in allowing management to anticipate the consequences of any actions before they occur. Since NUSC is required to stay within the constraints upon high-grade positions, promotions at these particular grade levels are important.

NUSC has set up a promotion review board that receives promotions and sets up priorities for them. The model has been useful in estimating the number of vacancies expected over various time periods so that management knows well in advance the number of promotions that can be effected. This has helped NUSC to take a more organized approach to solving the problem of allocating these resources and has allowed the positions to be filled on a more timely basis, thus helping in a small way to maintain morale.

Navy-wide Procurement Career Program Application

The second CURRM application concerned determining Navy-wide intake requirements over the next 5 years for the Navy's procurement career program. This involved the study of four procurement occupations, using five grade groupings (i.e., GS-1-4, 5-8, 9-12, 13-15, and 16-18). Table 17, which is an example of the model output, gives an idea of the data involved.

While Navy Department Headquarters officials were interested in the approach, they felt that the Navy-wide data were of little use beyond reporting aggregate needs to the Office of the Secretary of Defense. It was found that the important decisions, such as the level of intake, were made one echelon down, at the command level. Based upon this knowledge, input to the model was reformulated for the largest command employing civilians--the Naval Sea Systems Command--which is responsible for the procurement and maintenance of ships and ordnance. A conversational session was then held with those concerned in OCP, the Naval Material Command, and NAVSEA Headquarters. This study is being continued to satisfy input planning requirements.

Table 17

Procurement Career Model Output

Code	Category	1974 Aboard	1975 Aboard	1975 Hires	1975 RIFs	1976 Aboard	1976 Hires	1976 RIFs	1977 Aboard	1977 Hires	1977 RIFs	1978 Aboard	1978 Hires	1978 RIFs	1979 Aboard	1979 Hires	1979 RIFs
1011	GEN BUS-INDS	2	2	1	—	2	1	—	2	1	—	2	1	—	2	1	—
1012	GEN BUS-INDS	135	136	43	—	137	44	—	139	45	—	140	44	—	141	45	—
1013	GEN BUS-INDS	245	245	35	—	249	39	—	252	38	—	254	38	—	255	37	—
1014	GEN BUS-INDS	92	92	2	—	94	4	—	95	3	—	96	3	—	96	2	—
1015	GEN BUS-INDS	1	1	—	—	1	—	—	1	—	—	1	—	—	1	—	—
1021	CONT + PROCU	4	4	—	—	4	—	—	4	—	—	4	—	—	4	—	—
1022	CONT + PROCU	401	402	163	—	408	168	—	414	171	—	417	170	—	418	169	—
1023	CONT + PROCU	1331	1334	115	—	1352	130	—	1372	134	—	1382	125	—	1385	119	—
1024	CONT + PROCU	624	626	34	—	634	40	—	643	42	—	648	38	—	650	35	—
1025	CONT + PROCU	11	11	2	—	11	2	—	11	2	—	11	2	—	11	2	—
1031	IND PROP MGT	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1032	IND PROP MGT	27	27	12	—	28	13	—	28	12	—	28	12	—	28	12	—
1033	IND PROP MGT	92	92	9	—	94	11	—	95	10	—	96	10	—	96	9	—
1034	IND PROP MGT	2	2	—	1	2	—	1	2	—	1	2	—	1	2	—	1
1035	IND PROP MGT	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1041	INDSTRL SPEC	1	1	1	—	1	1	—	1	1	—	1	1	—	1	1	—
1042	INDSTRL SPEC	28	28	17	—	29	18	—	29	17	—	29	17	—	29	17	—
1043	INDSTRL SPEC	415	416	89	—	421	93	—	427	95	—	430	93	—	431	92	—
1044	INDSTRL SPEC	175	175	14	—	178	17	—	180	17	—	182	17	—	182	15	—
1045	INDSTRL SPEC	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total		3586	3594	537	1	3645	581	1	3695	588	1	3723	571	1	3732	556	1

DISCUSSION AND CONCLUSIONS

Recruiting Requirements Model

The recruiting requirements model (RRM) being used at the Naval Air Rework Facility (NARF), North Island, has demonstrated its usefulness and is being extended to the other NARFs under agreement with NAVAIR. The model that was used at the Navy Underwater Systems Center has led to the proposed use of RRMs at other laboratory facilities.

The industrial and laboratory studies have emphasized different uses of the same basic model structure. In industrial applications, the most important manpower planning consideration is the detailed workload scheduled for the near future. In this situation, the RRM is used to determine how a facility should adjust its work force to meet manpower goals through hires, force reductions, and cross-utilization of personnel, and to evaluate capabilities for proposed and existing work forces. The RRM used in the workload negotiation process by NARF North Island to evaluate proposed workload schedules, given existing or attainable work-force composition and size, allows identification of excess capacity, so that suitable workload can be sought to maintain facility utilization.

Some means of coordination with the local workload planning process is required for the effective use of the RRM at an industrial facility. The purpose of this coordination is the conversion of the detailed work-load schedule into detailed manpower requirements. In the case of the NARFs, an interface is being developed between the RRM and the NAVAIR-sponsored Computerized Workload Planning and Budgeting System being installed at each of the NARFs. Similar efforts would be required at other industrial facilities.

The emphasis in a laboratory use of the RRM centers on the determination of recruitment policies and plans required to maintain a viable laboratory work force. In laboratory applications, the work force is less volatile than in industrial settings, and detailed manpower requirements are not as well defined. Here the manpower requirements are specified by laboratory management, in response to the research programs being supported, the funding, and ceiling constraints. In this case, the interface with the workload planning process for manpower requirement specification is an interface with the laboratory manager.

Promotion Planning Model

An important development in the laboratory applications has been the promotion planning model (PPM), an extension of the RRM to allow flexibility. Promotion planning and grade limitations have become significant issues within the Navy Laboratory System. The PPM allows laboratory management to evaluate promotion policies and grade limitations while considering the dynamic nature of the work force and the hiring and force reductions needed to achieve manpower goals. The PPM may also be used to determine promotion policies and hiring patterns that are consistent with grade structure requirements. Applications of the PPM at NUSC and for the Director of Laboratory Programs have allowed management to quantify the results of imposing conflicting policies on hiring, firing, grade limits, and promotion controls. These results can then be used as a basis for further policy decisions at higher levels.

Given the assumptions and data used in the PPM NUSC and DLP applications, it is apparent that the manpower goals, as given, cannot be met without firing the personnel who are in excess of requirements, or reducing promotion rates. One reason for this situation is that, because of reduced requirements, the initial populations exceed the stated manpower goals and ceilings. A second, structural reason is that promotion rates are higher in middle grades, resulting in an accumulation of personnel, especially at the GS-11 and GS-12 levels, for the professional occupational series.

If the choice is between reducing the number of promotions and firing, employees affected would certainly prefer the former. Both courses of action, or even the threat of them, will tend to motivate people to leave the organization on their own, which, in turn, reduces or even eliminates the need to actually carry out these adverse actions. The problem with this tactic is that the most competent people, who have the best prospect of finding jobs elsewhere, will be the most likely to leave. Selective promotion of the most qualified people may overcome this difficulty. Such a promotion system would require that a promotion board concentrate on the grade levels that constitute the long-term cadres of personnel. In any case, it seems clear that the PPM offers a useful way to evaluate the effects, over time, of promotion and grade control policies within an organization.

Conversational Use Recruiting Requirements Model

The preliminary managerial tests with the conversational use RRMs (CURRMs) were very productive as a learning device for both the managers and the researchers. In addition, they were an important transitional phase in the acceptance and implementation of the models. A primary objective of the tests was to determine managerial acceptance of the usefulness of the models. This objective was met fully, with both CURRM applications currently being refined and extended to provide the needed support to decision making on a recurring basis.

It was clear from both applications that the conversational environment should be designed to support staff analysts in conjunction with managers rather than managers alone. There are a large number of variables to be considered in a given model alternative. In a specific application, there may be five to ten alternatives. This information needs to be analyzed and the more distinct alternatives presented to the decision maker (or policy committee). Further refinements or additional alternatives can then be tested during or after the decision-making session. The conversational models can be fitted to the style of management that evolves from their use, with the amount of staff analyst support determined by the decision maker(s).

It is expected that some form of three-stage process will evolve from the use of the conversational capability. The first stage involves data reduction and processing the first model alternative; the second, an analysis of the alternatives jointly selected by the managers and the staff analysts; and the third, a decision-making session where additional conversational use may be included as part of the process.

The CURRM applications revealed a need for additional software capabilities. Some of these are minor changes to make the dialogue more understandable. Others involve extensions requiring major modifications. Between these extremes fall a number of desirable changes requiring some software development beyond the initial design. Most desired were modifications to permit inputting classes of changes rather than one change at a time. These changes were subsequently made and proved to be valuable.

The professional operations research analyst with knowledge of computer operating systems could still beat the conversational input procedures by using a text editor on an interactive terminal when large scale changes were desired. Even without the software changes, however, the conversational model in its present form is a vast improvement over previous model support procedures. The users without a computer or operations research background felt they had control over the use of the models, which was extremely difficult for them previously.

The NUSC tests provided further insight into the interrelationships of the model variables. Alternate optimum plans for the last time period in the model were noticed in a number of cases, indicating different ways of treating the horizon conditions. Results were stabilized by adding another time period beyond the required planning horizon. An alternate approach taken was to increase the difference between penalties for hires and fires. Results at another facility (Bres & Niehaus, 1974) were insensitive to the magnitude of these weights. This difference is probably due to the presence of tight constraints in the NUSC examples, and would only be required in such cases.

These applications also indicated the importance of hardware configurations. It is necessary to examine a number of output reports during conversational use of the model, including the results of previous alternatives. Minimum requirements are for a 132-character line teleprinter for printing standard outputs. A minicomputer configuration containing an intelligent CRT terminal with roll-back capabilities, some disk storage (4.8M bytes), and a line printer would be much more desirable. Higher speed lines (300 to 1200 baud) are necessary in view of data transmission requirements. The demand for output printing in conversational use does not appear to be excessive, as summary reports are one page, and detailed reports, only five pages.

Computer Support Software

The supporting software development for these models has been proceeding in parallel with applications. The installation of aggregate models on a time-sharing computer network has been tested and found to be effective in widening access to these models. Conversational enhancements have been formulated but implementation has not been completed. The advanced computational features have reduced solution times for the basic models by two orders of magnitude, a significant achievement that expands potential application of these models.

RECOMMENDATIONS

This project has included several pilot studies that have been of major importance for the development and useful application of civilian manpower and personnel models. In view of the success in these pilot studies, the application of these models should now be extended to other similar shore activity facilities using operational support. Specifically:

1. The Commander, Naval Air Systems Command should complete development of the interface between the NARF versions of the RRM and the NAVAIR CWPABS system and explore applications of the RRM for workload allocation at the NAVAIR level.

2. The Director of Laboratory Programs (DLP) should evaluate the PPM for use at other laboratories, explore further use of PPM at the DLP level, and further develop conversational versions of the RRM (CURRM).

3. The Chief of Naval Operations (OP-16) should construct conversational versions of the PPM, integrate work on laboratory work force goals development with the current laboratory models, and concurrently develop supporting software for the RRM and PPM models.

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