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NAVAL UNDERWATER SYSTEMS CENTER
Newport, Rhode Island 02840

Technical Memorandum

APPLICATION OF THE NAVY AVERAGE GRADE MODEL TO THE NAVAL UNDERWATER SYSTEMS CENTER

Date: 6 March 1973

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Manpower Utilization Department

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Forecasts for manpower requirements by NUSC for fiscal year 1973 and fiscal year 1974 were made using a linear regression model of the goal programming variety. An application of one of the Charnes, Cooper, Niehaus career management models for manpower planning was then made to evaluate the consequences of the policy of reducing average GS grade to 9.35 while attempting to meet these forecasted requirements.

Estimation of model parameters and evaluation of subsequent output indicated the following:

- Imposition of the 9.35 average GS grade requirements will seriously affect planned policies relating to NUSC's staffing structure.
- A most significant result of this study is that the structure of the Markoff decision model, relating to a population that is smaller than usual, results in apparent statistical validity. It should provide a useful tool for many manpower studies at NUSC in the future.

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INTRODUCTION

This report summarizes an application of one of the Charnes, Cooper, Niehaus career management models for manpower planning at the Naval Underwater Systems Center (NUSC), Newport, Rhode Island. As this career management model is well described in the literature (for example, see references 1-3), the details of the model will be omitted at this point and brought in as required in the description that follows.

A study of operations and the gathering of data were done in Newport from June to August, 1972. This included the analysis of data developed by the Office of Civilian Manpower Management (OCMM) by means of their Computer-Assisted Manpower Analyses System (CAMAS). Preliminary analysis was also done during this time to increase confidence in a successful conclusion. The final analysis was done at the University of Texas at Austin in order to utilize the computation equipment and computer codes available there.

DEFINITION OF MANPOWER CATEGORIES

In defining useful manpower or occupational categories a trade-off must be made between narrowly defined categories for detailed planning and aggregated categories to gain the statistical advantages associated with larger populations. These categories must also allow projection of future needs or goals.

This initial problem was attacked in the following manner. Statistics on the staffing levels in each of approximately 105 occupational series at the end of the calendar years 1968 through 1971 were examined. With the help of an Operations Research Analyst of the NUSC Manpower Resources Directorate and later, the OCMM Computer Sciences Group, categories of different combinations of occupational series were defined on the basis of (1) similar job requirements for meaningful planning and (2) large enough aggregate numbers for derivation and application of transition rates. A matrix showing sample correlation coefficients of staffing levels for each of these categories (over the 4 years) with every other category and with total General Schedule and total work force was calculated and examined. Results for the categories agreed upon to date show that categories containing 75% of the population of the entire General Schedule (salaried) work force have a sample correlation coefficient of .85 or greater when compared with the total General Schedule work force population for the 4 years. These categories include a higher proportion of the population of primary interest. The population of a portion of the remaining categories with lower correlation coefficients appears predictable. Unfortunately, the correlation coefficients are more a guide than a statistically meaningful indicator because of the very low number of observations (four). The categories decided on are listed in table 1.

TABLE 1

OCCUPATIONAL CATEGORIES

Identification Number	Type	Occupational Series Codes Included
601	Personnel Professionals	201, 212, 221, 230, 235
602	Computer Specialists	334
603	General Clerical & Administrative	301
604	Management and Program Analysts	341, 343, 345
605	Budget, Finance, Accounting	501, 504, 505, 510, 560
606	General Engineers	801
607	Miscellaneous Engineers	803, 806, 808, 810, 871, 893, 896
608	Mechanical Engineers	830
609	Electronic and Electrical Engineers	850, 855, 899
611	Procurement, Supply, Transportation Professionals	1101, 1102, 1654, 2001, 2003, 2030, 2101, 2130
612	Physicists	1310, 1399
613	Physical Scientists	1301, 1320, 1321, 1360
614	Mathematicians	1515, 1520, 1529, 1530, 1599
616	Electronics Technicians	856
617	Engineering Technicians	802
618	Equipment Specialists	1670
619	300 Series Clerks (Typists, Stenographers, Secretarys, Miscellaneous Office Workers)	302, 304, 305, 312, 318, 322, 324, 332, 335, 342, 344, 350, 356, 359, 382, 394

TABLE 1 (Continued)

Identification Number	Type	Occupational Series Codes Included
620	500 Series Clerks (Financial Types)	520, 525, 540, 544
621	All other series not in other groups	
622	Technical Writing and Editing	1083

CAREER MANAGEMENT GRADE GROUPINGS

10	GS 1-4
20	GS 5-8
30	GS 9-12
40	GS 13-15
50	GS 16-18

PROJECTING MANPOWER NEEDS

The projection of manpower needs ideally would be made by relating work force requirements to tasks and forecasting the future task loads and hence the manpower requirements. An attempt to accomplish this is currently in progress by the Manpower Forecasting Division at NUSC. As an interim method, it was decided to forecast by regressing the categories with high correlation coefficients on total General Schedule work force and then making separate estimates for the other categories.

Regression analysis is generally performed by using the method of least squares. This technique fits a straight line to the data and thus minimizes the sum of the squared deviations of the observations from the line. This method has various statistical properties which make testing of hypotheses about the phenomenon under study quite straightforward. These statistical properties are, however, obtained under statistical assumptions that may not be fulfilled (and often are not) in practice. For example, these may be a priori known constraints on the regression parameters being estimated. In our situation, the sum of several individually forecasted variables must be equal to a total known in advance, i.e., a manpower ceiling, which invalidates the least-square procedure. One method that allows us to guarantee the total is that of constrained regressions (introduced by Charnes and Cooper[4,5]), which, incidentally, was also the progenitor of goal programming. One of its most useful forms for us here involves minimizing the sum of the absolute deviations from the fitted straight line under the constraint that the sum of the projected totals is equal to the specified quantity. This forecasting model was set up and run on the University of Texas College of Business Administration's CDC 3100 computer using the CDC Regina linear programming code.

The first run used penalties of 1.0 for deviations from the fitted line for each datum and penalties of 50.0 for each unit of deviation for the known totals for the 4 years past (December of 1968, 1969, 1970, and 1971) and for the year being forecast. This run resulted in a forecast total that was 81 below the calculated ceiling for the categories under consideration. (This ceiling was calculated by subtracting the estimates for the other categories and wage grade employees from the ceiling specified in the NUSC internal staffing plan.)

The second run penalized the deviations from the ceiling for the year being forecast by 50 for each unit deviated. Thus, the total came out as desired but the individual forecasts for certain categories were considered too large. In order to alleviate this condition, upper bounds were imposed on all categories. These were assigned according to the growth of the category population with respect to total General Schedule work force growth over the 3-year period. Three types of category growth were differentiated: Those with noticeably lower growth, those with approximately equal growth, and those with more rapid growth. The bounds were set in correspondence with the three sets of growth rates at different multiples of the December 1971 figures. The model was run again and the solution indicated that the bounds were set too low. They were further increased based on the July 1972 onboard figures. The final run was accepted for use in the career management model with slight changes to categories 608 (mechanical engineers) and 604 (management and program analysts) to reflect a large increase in the latter, evident in the July 1972 figures.

To reiterate a point made above, this forecasting model is at best an interim device and should be replaced as soon as possible with a more accurate method. Regression analysis using historical data as a forecasting device involves the implicit assumption that there is a relationship between the variables in the analysis which will continue unchanged. In this case, this assumption is known to be false as there is a changing relationship among the various elements of the work force. However as with the other parameters of the career management model, these forecasted goals may be changed to reflect the beliefs of the user, e.g., the Manpower Utilization Department, or others. Table 2 summarizes the onboard figures used in the forecasting model and the forecasts made. An inspection of the line designated "All General Schedule" indicates a part of the forecasting problem. It is seen that over a 3-year period, this quantity increased by 286 employees, whereas from December 1971 to December 1972 it is expected to increase by an additional 376, a large jump.

Having obtained forecasts by occupational group, the next requirement is to divide these into the proper GS occupational categories. An occupational group, however, may be spread among several NUSC Directorates in a project organization, and hence the grade structure is not managed by occupation as such. There is, then, no ideal grade structure that is close at hand for the various occupations. To overcome this problem it was decided that the economists' hypothesis of "revealed preference" would be useful. This principle is often used to determine a consumer's utility or preference function which he himself may not be able to directly specify. The utility function is "revealed" by the actions of the consumer who is assumed to exhibit actual preferences in his buying habits. Applying this to the case at hand, it is assumed that NUSC has revealed the grade structure that is desired by establishing the structure they have had over the past several years.

Table 3 shows that the grade structure (using career management grade groupings: GS 1-4, 5-8, 9-12, 13-15, 16-18) has been reasonably constant

TABLE 2

ONBOARD MANPOWER AND FORECASTS

Group		Forecast Method	Dec. 1968	Dec. 1969	Dec. 1970	Dec. 1971	Jul. 1972	Model Upper Bounds	FY'73,74 Forecast	
Personnel	601	Est.	25	26	28	23	22		25	
Computer Specialist	602	Model	16	18	19	21	18	26	26	
General Clerical/Admin.	603	Model	45	47	47	51	56	65	65	
Management & Program Anal.	604	Model	13	12	15	22	29	35	25	(32 Adjustment)
Budget, Finance, Acctg.	605	Est.	27	31	29	27	28		30	
General Engineer	606	Est.	65	66	70	65	84		90	
Miscellaneous Engineers	607	Est.	17	18	20	20	20		20	
Mechanical Engineers	608	Model	213	224	233	245	244	281	281	(273 Adjustment)
Electron. & Electrical Engr.	609	Model	541	567	609	682	730	852	801	
Proc./Supply/Trans.	611	Est.	15	15	14	15	16		17	
Physicists	612	Model	124	127	126	129	128	142	142	
Physical Scientists	613	Est.	37	38	35	33	26		33	
Mathematicians	614	Model	98	101	106	118	134	145	135	
Electronics Technicians	616	Model	302	318	336	330	394	412	407	
Engineering Technicians	617	Est.	164	168	173	169	167		170	

TM No.
MA11-4138-73

TABLE 2 (Continued)

ONBOARD MANPOWER AND FORECASTS

Group		Forecast Method	Dec. 1968	Dec. 1969	Dec. 1970	Dec. 1971	Jul. 1972	Model Upper Bounds	FY'73,74 Forecast
Equipment Specialists	618	Est.	64	56	46	46	44		46
Clerks, Typists, Stenos, etc	619	Est.	285	312	270	305	319		325
Clerks, Financial Types	620	Est.	29	35	35	37	32		39
All other groups	621	Model	214	220	218	230	249	260	260
Technical Writing & Editing	622	Model	25	33	33	36	36	45	45
All General Schedule		(Actual or Ceiling)	2319	2432	2463	2605	2776		2981
Wage Board		(Staffing Plan)	435	363	353	359	320		
TOTAL ONBOARD			2754	2795	2816	2964	3096		3340

NOTE: The figures in the July 1972 column were superseded with others broken down by GS series that were slightly different. The latter were used for the career management model initial population.

TABLE 3

DETERMINATION OF GRADE STRUCTURE FOR GOALS

Occupation Group	ACTUAL 10 GS 1 - 4				ACTUAL 20 GS 5 - 8				ACTUAL 30 GS 9 - 12				ACTUAL 40 GS 13 - 15				ACTUAL 50 GS 16 - 18				PROJECTED 1972 - 73				
	6/68	6/69	6/70	6/71	6/68	6/69	6/70	6/71	6/68	6/69	6/70	6/71	6/68	6/69	6/70	6/71	6/68	6/69	6/70	6/71	10	20	30	40	50
601					.16	.12	.04	.08	.64	.62	.68	.67	.20	.27	.29	.25						.05	.67	.27	
602					.33	.22	.06	.09	.67	.78	.94	.91										.10	.90		
603	.69	.72	.70	.73	.27	.21	.26	.16	.05	.06	.04	.05				.05					.71	.19	.05	.05	
604					.08	.07	.08	.07	.92	.93	.85	.73			.08	.20						.07	.73	.20	
605	.04	.04	.03	.11	.40	.38	.38	.37	.40	.42	.45	.37	.16	.15	.14	.15					.06	.38	.41	.15	
606									.31	.32	.35	.36	.66	.63	.59	.53	.03	.04	.06	.06			.36	.58	.06
607							.06		.72	.71	.63	.55	.28	.29	.31	.45							.50	.50	
608					.08	.06	.08	.07	.74	.76	.73	.70	.18	.18	.20	.23						.07	.68	.25	
609	.01	.02	.02	<	.11	.06	.09	.11	.61	.63	.59	.57	.27	.28	.30	.31	.01	.01	.01	.01	.01	.12	.54	.32	.01
611					.69	.65	.57	.50	.21	.35	.36	.38			.07	.12						.48	.40	.12	
612					.18	.12	.07	.02	.58	.59	.61	.59	.23	.29	.31	.39			.01	.01		.02	.59	.38	.01
613					.03		.03	.08	.44	.53	.50	.51	.50	.44	.45	.38	.03	.03	.03	.03		.08	.51	.38	.03
614	.02	.02	.02		.26	.19	.14	.09	.55	.60	.62	.65	.16	.19	.23	.26						.07	.67	.26	
616			.04	.02	.24	.26	.26	.20	.76	.74	.69	.77	<	<	.01	.01					.02	.22	.75	.01	
617	.02		.11	.06	.17	.20	.17	.16	.81	.80	.72	.78									.05	.17	.78		
618					.28	.11	.20	.24	.72	.89	.80	.76										.28	.72		
619	.80	.78	.77	.75	.19	.21	.22	.23	.01	.01	.01	.02									.74	.24	.02		
620	.44	.27	.18	.17	.56	.70	.79	.79		.03	.03	.03									.18	.79	.03		
621	.30	.31	.33	.36	.45	.42	.42	.38	.24	.24	.22	.25	.01	.02	.02	.02					.38	.36	.24	.02	
622					.03	.07	.07	.03	.97	.93	.93	.97										.03	.97		

(< Means Less Than .01)

over a 3-year period yielding four observation points. The following procedure was used to determine projected grade structure for each occupation:

•Take GS ranges that are fairly stable and use the average, then go to the other ranges.

•If trend is definite, follow it.

•Use judgment on others, including data on promotion rates to help make the decision.

In quite a few categories the absolute numbers were small, and thus slight shifts in the proportions chosen have little or no effect on the number eventually forecast. The values for the actual proportions were taken from the transition rates provided by Dr. Niehaus of OCMM. The application of these projected proportions to the gross totals forecast for the categories is actually done within the career management model.

THE CAREER MANAGEMENT MODEL FOR NUSC

LINEAR PROGRAMMING MATRIX

The linear programming matrix (table 4) is essentially that presented in published papers on the OCMM models with some slight modifications. The first, as mentioned above, is to include the calculation of the goals within the model for the various GS series after specifying the manpower forecasts for the overall occupational group. This was done to allow changing the forecasts more easily. One negative result that arose when running the model (on the CDC6600 computer at the University of Texas) was that additional core storage and longer run times were required. In retrospect, this modification is considered unwise. However, this as well as other run time problems are expected to be alleviated by University of Texas-OCMM developments providing accelerated starts, etc. The other change was the replacement of the salary budget and manpower available constraints (which could not be well estimated) with a maximum average grade constraint and upper and lower bounds on the onboard manpower variables for the 2 years for which the model was set up. Such additional constraints are described in the OCMM papers. The G matrix shown in table 4 represents the grade structure proportions described previously.

MANPOWER ATTRITION

The initial population figures are taken from an actual onboard count for July 1972 at the start of FY 1973. Transition rates for the attrition equations were provided by Dr. Niehaus, Assistant for Computer Sciences at OCMM.

TM No.
MA11-4138-73

TABLE 4

NUSC LINEAR PROGRAMMING MATRIX

No. of Equations	Constraint	Group Goal Variables		Series Goal Variables		On Board Manpower			New Hire Manpower		Reduction In Force Manpower (RIF)		Positive Goal Discrepancies		Negative Goal Discrepancies		SIGN	Right Hand Side
						Initial	FY'73	FY'74	FY'73	FY'74	FY'73	FY'74	FY'73	FY'74	FY'73	FY'74		
		1-20	21-40	41-104	105-168	169-232	233-296	297-360	361-424	425-488	489-552	553-616	617-680	681-744	745-808	809-872		
20	Group Manpower Required	I															=	Forecast FY'73
20	(From Forecast Model)		I														=	Forecast FY'74
64	Series Manpower Goals Calculations	G		-I													=	0
64			G		-I												=	0
64	Manpower Attrition					I											=	Initial Pop.
64						-M	I		-I		I						=	0
64							-M	I		-I		I					=	0
2	Manpower Ceilings						11111									+X873	=	FY'73 Ceiling
								11111								+X874	=	FY'74 Ceiling
64	Manpower Goals Discrepancies			-I			I						-I		I		=	0
64					-I			I						-I		I	=	0
2	Average Grade						←Ai→									+AG3·X873	≤	AG3 . MC3
								←Ai→								+AG4·X874	≤	AG4 . MC4
64	Upper Bounds			1.1I			-I										>	0
					1.1I			-I									>	0
64	Lower Bounds			-.9I			I										>	0
					-.9I			I									>	0
1	Objective (to be minimized)								β_1	β_1	β_2	β_2	α	α	α	α		

These rates were laid out in matrix form on large charts to enable easier comparison of personnel movement from year to year. Examination of these graphic layouts showed that most transitions were on the diagonal (no movement), one step to the right (promotion to the next GS series class), or a separation. The transfers to other occupational groups, while not rare, proved to be erratic in all but a few cases. For this reason, the projected rates used for the model were for the most part static (remained in occupational group and GS series class) or a simple promotion within the occupational goup. The percentage involved in erratic transfers was included in the static class. When analyzing the results of a computer run of the model, the user will be aware when it is possible to transfer within NUSC rather than hiring from outside. The few transfers that were included involved only a few personnel for the year. For the most part the transition rates had acceptable stability and determining the rates to use from the historical rates followed the procedure explained for determining the grade structure proportions.

It seems that in conducting research of almost any type, certain observations are made or results obtained that while not specifically sought are nevertheless quite interesting and occasionally valuable. This serendipity came about here while trying to establish greater confidence in the estimation of transition rates for the small populations in the study.

A technique used by a University of Texas at Austin research group investigating the prediction of automobile accidents and injuries was attempted for transition rates. Briefly, this technique is based on the assumption that if one can compare favorably a number of attributes for populations X and Y, then certain other known attributes of population Y related to the comparable ones can be used as surrogates for the unknown attributes of X. In our case we lack faith in parameters derived from small subpopulations at NUSC. There are, however, larger subpopulations of these occupational groupings within the Navy. If the categories containing large numbers (electrical engineers, mechanical engineers, etc.) at NUSC have transition rates comparing favorably to some larger Navy population, then we may be able to use this larger population to generate transition rates for NUSC's smaller categories.

The larger Navy population used for the comparison was that of Navy Laboratories. The transition rates were again provided by Dr. Niehrus. The occupational groups chosen for comparison were the larger engineering and scientific groups: mechanical engineers (608), electrical and electronics engineers (609), physicists (612), and mathematicians (614). Table 5 shows these rates for the Navy Laboratory groups as well as all NUSC groups. Unfortunately, the rates were not comparable. However, a situation that appears to reflect favorably on NUSC's work environment was observed. In most of these categories, NUSC has lower separation rates even though it has lower promotion rates.

TABLE 5

TRANSITION MATRIX DETERMINATION

OCCUPATION		STATIC			PROMOTED WITHIN GROUP			SEPARATED			TRANSFER WITHIN NUSC			PROJECTED TRANSITION RATES			
		FY			FY			FY			FY			FY 72, 73			
Group	Series	69	70	71	69	70	71	69	70	71	69	70	71	Static	Prom.	Sep.	Trans.
601	20	.5	.33	1.0	.5	.67	-							.67	.33		
	30	.88	.88	.84	.12	.06	-	-	.06	.16				.84	.03	.13	
	40	1.0	1.0	.75				-	-	.125	-	-	.125	.88		.12	
602	20	.8	.25	[illegible]	.2	.75	-							.70	.30		
	30	.9	.86	.94				-	-	.06	.1	.14	-	.94		.06	
603	10	.89	.59	.63	.04	.03	-	-	.24	.22	.07	.14	.15	.66	.02	.23	.09
	20	.70	.60	.5	.10	-	-	-	-	.25	.20	.40	.25	1.0			
	30	.5	.67	.5	-	-	-	-	.33	.-	.5	-	.5	1.0			
	40													1.0			
604	20	-	1.0	1.0	1.0	-	-							1.0			
	30	.92	.77	.73	-	.08	.09	-	.08	.09	.08	.08	.09	.82	.09	.09	
	40	-	-	1.0										1.0			
605	10	-	-	1.0	-	1.0	-	1.0	-	-				.50	.50		
	20	.90	.80	.82	-	-	.09	.10	.20	-	-	-	.09	.80	.10	.10	
	30	1.0	1.0	.69	-	-	.08	-	-	[illegible]	-	-	.15	1.0			
	40	1.0	1.0	.75							-	-	.25	1.0			
606	30	1.0	.86	.92	-	-	.08	-	.05	-	-	.09	-	.96	.04		
	40	.97	.91	.88	.03	.02	-	-	.05	.10	-	.02	.02	.90		.10	
	50	1.0	1.0	1.0										1.0			
607	30	.77	.90	.70	.	.10	.20	.23	-	.10				.80	.10	.10	
	40	.80	1.0	1.0				.20	-	-				1.0			
608 NUSC	20	.29	.33	.29	.41	.58	.41	.29	.08	.29				.3	.4	.3	
LABS		.21	.21	.17	.57	.61	.60	.19	.10	.16	.03	.08	.07				
NUSC	30	.94	.92	.91	.01	.03	.07	.03	.04	.01	.02	.01	.01	.91	.06	.02	.01
LABS		.88	.86	.86	.03	.06	.06	.05	.06	.05	.04	.02	.03				
NUSC	40	.90	.97	1.0	.03	-	-	[illegible]	.03	-				1.0			
LABS		.88	.91	.92				.03	.05	.04	.09	.04	.04				
609 NUSC	10	.80	.17	-	-	.33	-	.20	.50	1.0						1.0	
LABS		.32	.25	.20	.17	.18	.29	.51	.55	.48	-	.02	.03				
NUSC	20	.47	.10	.32	.31	.87	.32	.22	.03	.32	-	-	.04	.37	.38	.25	
LABS		.36	.17	.29	.40	.57	.42	.19	.25	.25	.05	.01	.04				

TABLE 5 (cont'd)

TRANSITION MATRIX DETERMINATION

OCCUPATION		STATIC			PROMOTED WITHIN GROUP			SEPARATED			TRANSFER WITHIN NUSC			PROJECTED TRANSITION RATES			
Group	GS Series	FY 69	70	71	FY 69	70	71	FY 69	70	71	FY 69	70	71	FY 72, 73 Static	Prom.	Sep.	Tran
609 NUSC	[illegible]0	.95	.89	.88	.03	.08	.07	.02	.03	.03	.01	.01	.02	.90	.07	.03	-
LABS		.88	.84	.87	.05	.08	.06	.05	.07	.05	.02	.01	.02				
NUSC	40	.96	.99	.98	.01	-	-	.02	.01	.02	.01	-	-	.98	.02		
LABS		.95	.92	.93				.02	.05	.05	.03	.03	.02				
NUSC	50	1.0	1.0	1.0										1.0			
LABS		.80	1.0	.75				-	-	.08	.20	-	.17				
611	20	.91	.73	1.0	.09	-	-	-	.09	-	-	.18	-	1.0			
	30	1.0	.83	1.0				-	.17	-				1.0			
	40	-	-	1.0										1.0			
612 NUSC	20	.27	-	.11	.32	.60	.33	.32	.07	.33	.09	.33	.22	.33	.34	.33	-
LABS		.31	.15	.14	.41	.44	.51	.20	.19	.22	.08	.22	.14				
NUSC	30	.83	.84	.82	.09	.03	.08	.04	.05	.03	.04	.08	.08	.84	.07	.04	.05
LABS		.80	.73	.81	.07	.05	.06	.08	.07	.06	.05	.15	.07				
NUSC	40	1.0	1.0	1.0										1.0			
LABS		.92	.93	.95				.03	.05	.04	.05	.02	.02				
NUSC	50	-	-	1.0										1.0			
LABS		1.0	1.0	.93									.07				
613	20	-	-	1.0	1.0	-	-							.67	.33	-	-
	30	.93	.95	.95	-	.05	-	.07			-	-	.05	1.0			
	40	.88	.94	.82				.12	.06	.06	-	-	.12	.94	-	.06	-
	50	1.0	1.0	1.0										1.0			
614 NUSC	20	.46	.11	.27	.42	.67	.40	.13	.22	.33				.30	.40	.30	
LABS		.20	.15	.2[illegible]	.59	.63	.42	.18	.21	.29	.03	.01	-				
NUSC	30	.92	.88	.91	.06	.07	.03	.02	.05	.03	-	-	.03	.92	.05	.03	
LABS		.81	.81	.84	.07	.05	.05	.10	.11	.08	.02	.03	.03				
NUSC	40	1.0	1.0	.96				-	-	.04				1.0			
LABS		.94	.93	.92				.04	.05	.05	.02	.02	.03				
616	10	-	-	.23				-	-	.69	-	-	.08	.30		.70	
	20	.74	.89	.74	.17	.11	.24	.01	-	-	.09	-	.02	.83	.17		
	30	.98	.95	.96	-	.01	-	.01	.03	.03	.01	.01	.01	.97		.03	

TABLE 5 (cont'd)

TRANSITION MATRIX DETERMINATION

OCCUPATION		STATIC			PROMOTED WITHIN GROUP			SEPARATED			TRANSFER WITHIN NUSC			PROJECTED TRANSITION RATES			
		FY			FY			FY			FY			FY 72, 73			
Group	Series	69	70	71	69	70	71	69	70	71	69	70	71	Stat.	Prom.	Sep.	Tran.
616	40	1.0	1.0	1.0										1.0			
617	10	-	-	.24				.67	-	.76	.33	-	-	.24		.76	
	20	.74	.74	.64	.15	.13	.18	-	-	.12	.11	.09	.06	.78	.18	.04	
	30	.97	.92	.89				.01	.06	.07	.02	.02	.04	.91		.06	.03
618	20	.35	.86	1.0	.53	-	-				.12	.14	-	1.0			
	30	.84	.63	.89				.07	.04	.05	.09	.33	.05	.95		.05	
619	10	.77	.65	.60	.04	.02	.04	.14	.22	.27	.06	.11	.10	.56	.04	.30	.10
	20	.88	.88	.87			.03	.02	.07	.05	.10	.05	.05	.89	.02	.05	.04
	30	.67	1.0	1.0				.33	-	-				1.0			
620	10	.50	.56	.67	.29	.22	.17	-	.22	.17	.21	-	-	.66	.17	.17	
	20	.94	.87	.63	.06	-	-	-	.09	.04	-	.04	.33	.96		.04	
	30	-	1.0	1.0										1.0			
621	10	.85	.67	.73	.05	.06	.04	.05	.09	.11	.06	.19	.11	.76	.05	.13	.06
	20	.86	.88	.77	.02	-	.07	.07	.04	.09	.05	.08	.07	.86	.03	.07	.04
	30	.90	.96	.93				.08	.02	.06	.02	.02	.02	.95		.05	
	40	1.0	.80	1.0				-	.20	-				1.0			
622	20	1.0	1.0	.33	-	-	.33	-	-	.33				1.0			
	30	.80	.96	.74				-	.04	.05	.20	-	.21	.95		.05	

NOTE: All figures refer to NUSC only unless indicated as being for all Navy Labs.

A brief inspection of a few other Navy occupational groups of reasonable size showed that NUSC also had lower separation and lower promotion rates in these occupations.

MANPOWER CEILINGS

The ceilings used were those estimated for a Center Staffing Plan for FY 1973 and FY 1974, which are equal and include 2981 plus the 359 wage board employees forecast for a total ceiling of 3340.

AVERAGE GRADE CONSTRAINTS

Such constraints require the sum (over all subgroups) of a papulation multiplied by its average grade to be less than or equal to the average grade required multiplied by the total work force size. The average grade to use for each group was determined from December 1971 work force composition studies done by the NUSC Manpower Forecasting Division. The overall work force is divided into five career classes: engineer/scientist, professional/administrative, technicians, administrative support, and clerical. For each career management grade grouping (GS 1-4, 5-8, etc.) within these classes the average grade was calculated. These averages were then used as weights for the appropriate occupational groups in the average grade constraints (table 6).

TABLE 6

Average Grade Weights

Career Grade Group	Eng/Sci	Prof/Admin	Tech	Admin Support	Clerical
10 GS 1-4					3.50
20 GS 5-8	6.94	6.67	7.04	6.88	5.31
30 GS 9-12	11.30	10.50	10.30	10.30	9.00
40 GS 13-15	13.70	13.50	13.00	13.00	
50 GS 16-18	16.00	16.00			

(NOTE: 3.50 was used for all occupations in the GS 1-4 class although there were no figures available for these groups.)

UPPER AND LOWER BOUNDS

The solution is restricted by these bounds to allow no more than a 10% deviation from the goal in onboard manpower in each career grade grouping. This was found acceptable for use by Dr. Niehaus in the running of other OCMM models for NUSC.

OBJECTIVE FUNCTION WEIGHTS

The objective function weights or penalties are those used in the average grade model referred to above. These are shown in table 7.

TABLE 7

Objective Function Penalties

	GS 1-4	5-8	9-12	13-15	16-18
New Hires	8	8	8	8	8
RIFs	33	38	41	44	1000
Discrepancies from Goals	13	18	21	24	26

MODEL SIZE

The model as coded required 748 constraint rows and one for the objective function. There are 874 structural variables and 258 slack variables for a total of 1132 columns. The density of the matrix (persentage of nonzero coefficients) is estimated as approximately 0.3 percent.

NUSC-CM-USE

The career management model, as set up for NUSC, is ideal for the evaluation of policy prescription. For the test example, it was decided to evaluate the impact of an average grade restriction of 9.35 on the center for FY 73 and FY 74. This figure represents the target assigned for FY 73. Toward this end, the program was run first with an average grade constraint of 12.0 so that this would be nonbinding and then with an average grade of 9.35 to see how the solutions differed.

The LP6600 code used solves the problem by a two-phase method. In phase I, the computer obtains a basic feasible solution, and in phase II the optimal solution is found. If there is no feasible solution, the code never gets out of phase I and prints out the message that no feasible solution exists. This happened on both runs initially. For the nonbinding average grade run, it was found necessary to increase the upper bound for group 1344 (physical scientists, GS 13-15, FY74) by two to get out of phase I. Considering the approximations used, this was not considered a drastic change. The problem encountered when the average grade constraint of 9.35 was put in is a bit more interesting. It turned out that in order to get a feasible starting solution for phase II, it was necessary to raise the average grade constraint to 9.36. The implications of the results will be discussed after presenting selected results for comparison. See table 8.

The large number of iterations in phase I relative to phase II indicates that most of the computer time is used up trying to find an initial feasible solution. This can be reduced by (1) specifying an initial basis for the solution and (2) employing the following device to remove zero entries on the right-hand side. One adds an additional equation, say X875 = 1; then adds multiples of this equation to the constraints having zero right sides.

The relative values of the objective function at optimality, 20382 in case 1 versus 36232 in case 2, show the heavy penalty exacted by the imposition of the average grade constraint. This is further demonstrated by the evidence from the slack variables for the bounds. The values of these variables show how far away the onboard manpower for each career management grade group is from an upper or lower bound. Without the imposition of the average grade constraint, very few variables are against either upper or lower bounds in either fiscal year. Imposing the constraint of 9.36 pushes almost all the values against these constraints. As might be anticipated, the GS 1-4 and 5-8 groups are at the upper bounds and the GS 13-15 and 16-18 groups at the lower bounds. The solution consistently RIFs (reductions-in-force) GS 16s at a penalty of 1000 each to do this. The General Schedule work force is also kept from attaining the ceiling under the 9.36 value. The solution space under this constraint is vastly reduced and thus greatly limits the options of the Center.

Table 9 summarizes certain optimal values of the variables for the larger engineering and scientific groups and also for the 300 series clerical occupations. This demonstrates the effect described above—packing the lower GS levels to the upper bound and reducing the higher GS levels to the lower bound under the imposition of a 9.36 average grade. The number of RIFs might possibly be reduced by cutting back on promotions from a class to the one above.

TABLE 8

SELECTED COMPARATIVE RESULTS

	CASE 1 No Average Grade Constraint	CASE 2 Average Grade Constraint of 9.36
Number of Iterations - Phase I	844	935
Number of Iterations - Phase II	147	68
Value of Objective Function		
at Start of Phase II	36960	39963
at Optimality	20382	36232
Average Grade FY73	9.62	9.36
Average Grade FY74	9.76	9.36
CPU time required (seconds)	443	523
Number of nonzero slack variables (out of 64 possible in each category)		
Upper Bounds FY73	63	40
Upper Bounds FY74	58	36
Lower Bounds FY73	61	37
Lower Bounds FY74	59	30
Number of onboard manpower classes (of 64 possible) not against either upper or lower bounds of 10%		
FY73	60	13
FY74	55	2
No. of Personnel Below Ceiling		
FY73	8	91
FY74	0	151

TABLE 9

SELECTED RESULTS FROM THE NUSC MODEL

MAJOR MANAGEMENT GRADE GROUPS		GS	INITIAL ONBOARD	FY'73,74 GOALS	CASE 1: NO GRADE CONSTRAINT ONBOARD FY'73	ONBOARD FY'74	RIF (-) OR HIRE (+) FY'73	RIF (-) OR HIRE (+) FY'74	CASE 2: AVERAGE GRADE 9.36 ONBOARD FY'73	ONBOARD FY'74	RIF (-) OR HIRE (+) FY'73	RIF (-) OR HIRE (+) FY'74
Mechanical Engrs.	60820	5-8	13	19	19	19	+15	+13	21	21	+17	+15
	30	9-12	170	186	186	186	+26	+ 9	167	167	+ 7	+ 7
	40	13-15	61	68	68	75	- 3	- 6	61	61	-10	-10
Electrical Engrs.	60910	1-4	18	8	8	8	+ 8	+ 8	9	9	+ 9	+ 9
	20	5-8	96	96	96	96	+61	+61	106	106	+70	+67
	30	9-12	372	433	433	433	+58	+ 3	389	389	+14	- 5
	40	13-15	238	256	256	281	- 3		231	231	-29	-23
	50	16-18	5	8	8	9	- 2	- 4	7	8	- 3	- 4
Physicists	61220	5-8	4	3	3	3	+ 2	+ 2	3	3	+ 2	+ 2
	30	9-12	75	84	84	84	+19	+12	75	75	+11	+11
	40	13-15	37	54	49	54	+ 6		49	49	+ 6	- 5
	50	16-18	1	1	1	1			1	1		
Mathematicians	61420	5-8	14	9	9	9	+ 5	+ 7	10	10	+ 6	+ 7
	30	9-12	80	90	90	90	+11	+ 3	81	81	+ 2	+ 2
	40	13-15	41	35	35	39	-10	- 1	32	32	-13	- 4
Clerical	61910	1-4	250	241	241	216	+92	+72	265	265	+116	+105
	20	5-8	65	78	72	78	+ 9		86	86	+ 18	- 1
	30	9-12	6	7	7	7	- 1	- 1	7	7	- 1	- 1

Thus, the use of the model for evaluating a policy prescription of reducing average grade to 9.36 shows that the impact on both grade structure and promotion policy is quite significant. The benefits of grade reduction to this level would have to be balanced against the disadvantages of instituting the requisite changes in promotion policy and grade structure. Although some of the quantitative values used in the model are open to question, the solution is extreme enough to merit confidence in its qualitative aspects for the policy being tested. Various other policy prescriptions could of course be checked—changes in promotion policy, upper and lower bounds, grade strucrure within each career management grade grouping, and so forth.

FOLLOW-ON RESEARCH POSSIBILITIES FOR NUSC

This study showed that it is worthwhile to develop a version of the OCMM Career Management Model for NUSC use. However, care must be taken in the selection of the model parameters because of the size of the manpower population. The study pointed to the need for including program data in the models. A software support system is needed which allows local flexibility but still takes advantage of the CAMAS software already in being at OCMM. In conclusion, some of the follow-on research possibilities for NUSC include:

1. Better forecasting of needs.

2. Incorporation of separating those close to retirement eligibility from rest of work force. (This is already operational in the CAMAS software.)

3. Behavioral problems with model implementation.

4. Models of OCMM multilevel type for support among Directorates.

5. Establish software system to allow advanced start and file storage of solutions with interactive terminal for parameter changes.

6. Estimation of the value of preserving project teams.

7. Formal incorporation of manpower variables in bidding strategies for new projects.

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Laurence S. Mannis
Manpower Utilization
Manpower Forecasting Division
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