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ATTRITION-SEVERITY INDEX (ASI) FOR SELECTED NAVY RATINGS: DEVELOPMENT

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AND
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The purpose of this research was to develop an application of multiattribute utility theory to the person-job match problem. An index of attrition severity was developed using five factors: retention rate, personnel replacement cost, rating size, rating requirements, and rating priority. Multiplicative and additive forms of attrition-severity functions were developed and compared. Sensitivity analysis was conducted to assess utility functions and factor weights.

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FOREWORD

This research was conducted in advanced development subproject Z1167-PN.02 (Computer-Assisted Testing, Counseling, and Assignment of Recruits). The objective of the project was to develop an index that yields a reasonably robust rank-ordering of selected Navy ratings on a measure of attrition severity. This analysis is a part of a larger effort by the Navy Personnel Research and Development Center to develop a computerized system for Navy personnel assignment, called Classification and Assignment within PRIDE (Personalized Recruitment for Immediate and Delayed Enlistment) (CLASP) (see Kroeker & Rafacz, 1983). The index developed in this research has been incorporated into the attrition component of the operational CLASP system (Kroeker & Folchi, 1984). The contracting officer's technical representative was Dr. Leonard P. Kroeker.

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SUMMARY

Problem

When assigning first-term enlisted personnel to ratings, the Navy attempts to maximize productivity and job satisfaction. To assist the Navy Recruiting Command in accomplishing these goals, Navy Personnel Research and Development Center has developed a computerized assignment system called Classification and Assignment within PRIDE (Personalized Recruitment for Immediate and Delayed Enlistment) (CLASP), which incorporates information on prospective enlistees and ratings to improve the match of enlistees with "A" school training. Using CLASP, Navy classifiers place first-term enlistees in ratings appropriate to their ability levels, individual preferences, and Navy objectives and priorities.

After training, which often takes months, most recruits work in highly technical jobs crucial to the fleet combat readiness. It is important for the Navy to select and assign recruits who are well matched to occupations and who will remain in the Navy throughout their enlistment. Furthermore, the need for CLASP will expand as the Navy moves toward a strength of 600 deployable ships and 15 battle groups.

The information collected by CLASP includes (a) school success predictions, which are based on the applicants' performance on the Armed Services Vocational Aptitude Battery (ASVAB), (b) the required technical aptitude and the job complexity of ratings, (c) Navy priorities and individual preferences, (d) minority fill rate, and (e) fraction fill rate. A sixth component based on applicants' potential for remaining in the Navy throughout their initial enlistment would increase CLASP's effectiveness. However, before the component could be defined, it was necessary to have an index of the severity of attrition from ratings.

Purpose

The purpose of the research reported here was to develop an index of the severity of attrition in selected Navy ratings.

Method

Demand for personnel was measured using rating size (number of persons in the rating), rating requirement (Navy's need for personnel), and rating priority (relative importance to the Navy), using the multiattribute functions of retention rates, replacement costs, and Navy demand for personnel. Alternatives to determining (a) the form that the multiattribute functions should take and (b) the weights to assign each function were investigated and the most appropriate single measure and weight identified. Retention rates were determined by analyzing data for 85 technical ratings open to first-term junior personnel. These data were obtained from the Navy enlisted master file for 1980. Replacement costs were calculated following the Navy enlisted billet cost model; rating size was determined from inventory data reported by the Naval Military Personnel Command; rating requirements were determined by comparing rating inventories with the Navy's requirements for personnel for the rating; and rating priority was determined using the method developed by Kroeker and Rafacz (1983). The weight to be assigned each factor was determined by applying additive and multiplicative methods to each of the factors. Neither method proved to be preferred. The multiplicative form was selected because it was more easily interpreted.

Results and Conclusions

An index of 85 technical, first-term personnel ratings was developed that yields a rank ordering of ratings on a measure of attrition severity. The functional form of the index allows other factors to be added to the attrition-severity index if they are required.

Recommendations

1. The attrition-severity index developed in this research should be used in determining assignment utility within the CLASP model.

2. Personnel researchers should investigate the use of multiattribute utility functions as a means to analyze other personnel decisions, such as retention.

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Problem and Background

When assigning first-term enlisted personnel to ratings, the Navy attempts to maximize productivity and job satisfaction. To assist the Navy Recruiting Command in accomplishing these goals, Navy Personnel Research and Development Center has developed a computerized assignment system called Classification and Assignment within PRIDE (Personalized Recruitment for Immediate and Delayed Enlistment) (CLASP), which incorporates information on prospective enlistees and ratings to improve the match of enlistees with "A" school training. Using CLASP, Navy classifiers place first-term enlistees in ratings appropriate to their ability levels, individual preferences, and Navy objectives and priorities (Kroeker & Rafacz, 1983).

After training, which often takes months, most recruits work in highly technical jobs crucial to the fleet combat readiness. It is important for the Navy to select and assign recruits who are well matched to occupations and who will remain in the Navy throughout their enlistment. Furthermore, the need for CLASP will expand as the Navy moves toward a strength of 600 deployable ships and 15 battle groups. It has been estimated that 100,000 new accessions will be needed each year for the next several years (Office of the Assistant Secretary of Defense, 1983).

The information collected by CLASP includes (a) school success predictions, which are based on the applicants' performance on the Armed Services Vocational Aptitude Battery (ASVAB), (b) the required technical aptitude and the job complexity of ratings, (c) Navy priorities and individual preferences, (d) minority fill rate, and (e) fraction fill rate. A sixth component based on applicants' potential for remaining in the Navy throughout their initial enlistment would increase CLASP's effectiveness. However, before the component could be defined, it was necessary to have an index of the severity of attrition from ratings.

In assigning first-term enlistees to ratings, factors such as the rating retention rates, the cost of replacing enlistees leaving the Navy, and the Navy's demand for trained personnel should be considered. However, no definitive method is available that prescribes the use of specific models considering multiple attributes.

Over 10 years ago, Turban and Metersky (1971) lamented the lack of empirical foundations for multiattribute utility theory. Since then, many field studies and empirical comparisions of alternative approaches to multiattribute models have been conducted, although there has been no consensus on preferred methodology. Huber (1974) reviewed published research studies that used multiattribute utility models. He concluded, using the the ability of the model to predict actual decisions as a choice criterion, that simple additive models did as well as more complex additive models or conjunctive multiplicative models. Cook and Stewart (1975) compared seven methods for obtaining subjective descriptions of judgmental policy.

Newman (1977) showed that weighting was unimportant for linear models when no attributes were negatively correlated and all were put on standardized scales. He empirically demonstrated that differential weighting affected results when the negative correlation of some attributes could not be removed by appropriate scaling. Schoemaker and Waid (1982) compared five conceptually different approaches in terms of their predictive ability and their weights. Their findings indicated that the methods generally differed systematically concerning the weights given to the various attributes, as well as the variances of the resulting predictions. On average, however, the methods predicted about equally well, except for unit weighting, which was clearly inferior. Furthermore, nonlinear models were found to be inferior to linear ones.

Keeny and Raiffa (1977) posited elegant techniques for capturing the utility function of individual decision makers. Edwards (1977) proposed a 10-step technique for multiattribute utility measurement. Saaty (1977) designed a scaling procedure for measuring priorities in hierarchical goal structures.

Purpose

The purpose of the research reported here was to develop an index of the severity of attrition in selected Navy ratings.

METHOD

Demand for personnel was measured using rating size (number of persons in the rating), rating requirement (Navy's need for personnel), and rating priority (relative importance to the Navy), using the multiattribute functions of retention rates, replacement costs, and Navy demand for personnel. Important issues addressed in developing the multiattribute attrition-severity index were (a) how to determine the form of the multiattribute functions for retention rates, replacement costs, and the Navy's demand for trained personnel, and (b) how to assign weights to each function. Results of applications to these issues were evaluated.

Multiattribute Functions

The subjects and procedures used in developing the measures of the attributes in the attrition-severity index differed for retention rates, replacement costs, and the Navy's demand for trained personnel.

Retention Rates

The methods used to determine retention rates required (a) measuring retention in Navy ratings, (b) establishing the data base, and (c) formulating retention functions for selected Navy ratings.

Measuring Retention. No up-to-date, multiple-year, occupation-specific retention curves for the Navy were found in the literature, although Bartholomew and Forbes (1979), Grinold and Marshall (1978), and Lurie (1979) discussed the difficulties in measuring transitional loss rates. The present research derived a single measure for selected Navy ratings. Retention rates can be thought of as compliments of attrition rates (i.e., retention rate = 100 - attrition rate).

Let

S_i^j = number of enlistees in the jth Navy rating at the beginning of the ith year of service

where

i = 1, 2, 3 . . . n;

j = ABE, ABF, ABH . . . YN (selected Navy ratings);

and let

$S^j_{i,k}$ = number of enlistees in the jth Navy rating at the beginning of the kth year of service who were in the same rating at the beginning of the ith year of service

for

i = 1, 2, 3 . . . n;
$k \geq i$;

and

j = ABE, ABF, ABH . . . YN.

It follows that

$$W^j_{i,k} = \left(S^j_i - S^j_{i,k}\right)/S^j_i;$$

where

i = 1, 2, 3 . . . n;
j = ABE, ABF, ABH . . . YN;

and $W^j_{i,k}$ is the k - i year loss rate for persons who were present in the jth Navy rating at the beginning of the ith year of service. If all persons who leave a rating also leave the Navy, then $W^j_{i,i+1}$ is the ith year attrition rate.

It would be preferable to be able to directly estimate yearly first-term attrition rates, $W^j_{i,k}$ for

$k = 2, 3, 4, 5$

for all Navy ratings. However, such estimations would involve tracing an entry cohort for a full 4 years. Alternatively, it is possible to use a cross-sectional, compositional method for estimating first-term loss rates, as follows:

By looking at 1 year's data for each rating, a set of 1-year transitional loss rates, $W^j_{i,i+1}$ for

$i = 1, 2, 3, 4$

for first term enlistees can be estimated. The term $1 - W^j_{i,i+1}$ can be interpreted as the probability that a person in the j rating at the beginning of one year will continue in the jth Navy rating to the beginning of the next year.

Therefore, it follows that

$$P^j_{i,k} = \prod_{m=i}^{k-1} \left(1 - W^j_{m,m+1}\right)$$

where

i = 1, 2, 3 . . . n;
j = ABE, ABF, ABH . . . YN;
$k \geq i$

where $P^j_{i,k}$ is the probability someone in the jth Navy rating at the beginning of year i will continue to be in the jth rating at the beginning of year k ($k \geq i$). Because the interest here is in first-term attrition,

let

$$P^j_k = P^j_{1,k}$$

and

$$P^j_1 = 1.00, \text{ by definition.}$$

The primary weakness of using the transitional loss rate as the retention measure was its failure to account for recruits entering and leaving during an accounting period. Because these recruits were not recognized as leaving or as having belonged to the system, they were not accounted for when the transitional loss rate was estimated.

Rating-specific transitional loss rates create artificially high attrition rates because enlistees who moved laterally into another rating were considered to have left the service. A partial remedy for this problem was to consider enlistees who transferred to other ratings as losses only if they were not in the Navy at the end of a period. Because this method of accounting for losses provided a more accurate estimate of attrition rates, it was used in calculating retention rates.

Another inaccuracy was introduced in the model with the assumption that S represents the number of persons, or stock, in a specific rating on the first day of their service in the Navy. In reality, first-term enlistment personnel are not assigned to specific skill ratings immediately; rather, they are assigned to a number of apprenticeship ratings until they qualify for a specific skill rating inventory. The length of time necessary to qualify for initial entry in a specific skill rating inventory varies across ratings and depends on the training pipeline for the technical rating.

In general, two distinct training pipelines that lead to skilled rating designation are open to first-term enlisted personnel. The first pipeline is primarily through formal "A" school training. Approximately 70 percent of recruit training graduates immediately enter an "A" school designed to provide training for a specific skill rating (Resource Consultants, Inc., 1980). Enlistees enter the technical rating inventory that they were trained for when they graduated from "A" school. The length of time required to enter a specific rating inventory is contingent on graduation and depends primarily on the length of "A" school training. Because "A" school course lengths vary among ratings and individual students, the time required to enter technical rating inventories through "A" school also varies among ratings and students.

The second method of entering a technical rating inventory is through on-the-job training. After completing recruit training, approximately 30 percent of the graduates enter formal apprenticeship training. These apprenticeship schools provide new recruits with basic skills in their designated apprenticeship areas. When enlistees graduate from apprenticeship training, they enter the fleet for on-the-job training. To be assigned to a technical rating inventory, enlistees must pass the Navy-wide examination for E-4. The length of time required to enter a technical rating inventory depends primarily on the time it takes to qualify and pass the E-4 examination. Passing rates for Navy-wide advancement examinations vary among ratings.

Because the majority of first-term personnel initially enter a rating inventory through the formal "A" school pipeline, the majority of annual accessions enter a rating inventory within a relatively short time. Huck and Midlam (1977), using a 1976 data base, provided evidence that approximately 60 percent of new accessions had attained a skilled rating status 6 months after enlistment.

When retention rates were estimated for specific-skill ratings, the attrition that occurs before rating designation or while personnel are in general apprenticeship ratings, was not considered, even though Lurie (1979) provided evidence that substantial attrition occurred among nondesignated personnel in the first few months of service, particularly among general detail personnel or those from the on-the-job training pipeline. Therefore, these nondesignated personnel, who were usually members of large apprenticeship ratings, could not be uniquely identified with specific skill ratings. Thus, the effect of attrition behavior among first-term personnel was not accurately captured by the model. Any rating-specific retention rates estimated using the model were based on the retention of enlistees after reaching designated rating status.

Establishing the Data Base. The data base used to estimate rating-specific retention functions was the Navy enlisted master file, which contains information on all active duty enlisted personnel. The 1-year, cross-sectional data used to estimate rating-specific retention functions included the Navy enlisted population (E-1 to E-4) between 30 September 1979 and 30 September 1980.

For this research, initial enlistments of 4 years were considered the norm, even though the guarantees of formal training contained in initial enlistment contracts produce some initial enlistments of 5 or 6 years. However, because the number of 4-year enlistees greatly exceeded the number of 6-year enlistees, the typical first-term enlistee was considered to be serving in the Navy on an initial 4-year enlistment obligation. Retention functions were estimated exclusively from data obtained on 4-year enlistees.

Including the apprenticeship ratings, 118 ratings were identified in the data base. Two groups of ratings were deleted from the preliminary group: (a) senior ratings, which are not open to first-term junior (E-1 through E-4) personnel due to the proficiency level of the jobs, and (b) apprenticeship ratings, the majority of which could not be uniquely associated with specific technical ratings. The exceptions were the medical apprenticeship ratings. Hospitalman recruit, hospitalman apprentice, and hospitalman ratings excusively feed to the hospital corpsman rating. Dental recruit, dentalman apprentice, and dentalman ratings exclusively feed to the dental technician rating. These specific medical apprenticeship ratings were combined with the appropriate technical medical ratings to derive the total number for the computation of retention rates. The final data base included 85 ratings.

Retention Functions. The yearly retention rates represent retention in specific years. The cumulative retention functions are the products of two or more yearly retention rates. The retention functions resulting from the estimation procedure are presented in Table 1. The retention functions estimated for Year 4 are biased by reenlistment behavior. Additionally, the rating-specific retention estimates contain an acknowledged bias, because such measures represent retention only after enlistees reach the designated rating. The results of correlations calculated among yearly retention rates and selected cumulative retention functions are presented in Table 2.

As expected, due to reenlistments, retention estimates in Year 4 provided only moderately positive correlation coefficients. Among years in which retention rates were based on loss attributed solely to attrition, the Year 2 estimate appeared to be the least correlated with other years. The cumulative retention functions provided by far the highest correlations, with the Year 3 estimate providing the best single-year results. Hence, the Year 3 retention rate was selected as the single measure of retention. This selection was somewhat arbitrary. However, the choice of other alternative measures of retention would not affect the prototypical procedure for developing an attrition-severity index.

Navy ratings were ranked according to their Year 3 retention rate. A ranking of 1 indicates the highest Year 3 retention rate and a ranking of 85 indicates the lowest Year 3 retention rate (see Table 1, last column).

The Year 3 figure represents the probability that a person in a given rating will complete Year 3 in the Navy after attaining that rating. The five ratings that were found to have the lowest Year 3 probabilities of retention were illustrator draftsman (DM) (.60), opticalman (OM) (.67), mess management specialist (MS) (.70), ship's serviceman (SH) (.70), and ocean system technician (OT) (.71). The five ratings with the highest probabilities of retention were communications technical (interpretive) (CTI) (.95), missile technician (MT) (.94), patternmaker (PM) (.92), aviation electrician's mate (AE) (.92), and data systems technician (DS) (.92).

Replacement Costs

A process was designed to identify the costs associated with replacing first-term enlisted personnel who leave the Navy before the end of their initial enlistment. Available cost data that could be used to construct rating-specific costs were reviewed and a measure of the total first-term replacement costs calculated. For the purpose of analyzing the effect of personnel cost on attrition severity, first-term replacement costs (RCs) were defined as the total cost to the Navy to train an enlistee in a particular rating for a specified time.

The Navy enlisted billet cost model (BCM) was the only well-developed cost model that provided the needed cost data (Eskew, Berterman, Smith, Noah, & Breaux, 1978; Butler & Simpson, 1980). BCM was developed approximately 15 years ago, primarily as a means of addressing costs associated with force structure and personnel planning, and to provide the Navy with a means of computing reasonably accurate personnel resource costs. The model recognizes that the Navy procures personnel resources and, through training and experience, develops those resources into the skill levels required to perform many and varied jobs. For enlisted personnel, these skills and skill levels are represented by ratings and pay grades. The Navy identifies its enlisted personnel requirements in terms of billets, which are unique combinations of ratings and pay grades, such as an E-4 boiler technical billet. The BCM computes the annual costs of filling authorized billets with personnel possessing requisite skills. Currently, the BCM provides cost data for 8 pay grades, E-2 through E-9, of 94 ratings.

Table 1

Retention Functions and Ranking for 85
Navy Enlisted Ratings
FY 1980

Rating Acronym	Rating Name	Retention Function by Year of Service[a] 1	2	3	4[b]	Ranking by Year 3 Retention Rate[c]
ABE	Aviation boatswain's mate (launching and recovery)	.95	.91	.85	.17	32
ABF	Aviation boatswain's mate (fuels)	.94	.90	.84	.26	36
ABH	Aviation boatswain's mate (aircraft handling)	.93	.86	.82	.26	33
AC	Air traffic controller	.97	.93	.90	.39	12
AD	Aviation machinist's mate	.95	.91	.87	.25	18
AE	Aviation electrician's mate	.99	.95	.92	.26	6
AG	Aerographer's mate	.94	.89	.84	.30	35
AK	Aviation storekeeper	.90	.82	.76	.32	72
AME	Aviation structural mechanic (safety equipment)	.96	.91	.87	.28	17
AMH	Aviation structural mechanic (hydraulics)	.96	.90	.85	.28	29
AMS	Aviation structural mechanic (structures)	.97	.92	.88	.25	15
AO	Aviation ordinanceman	.94	.89	.83	.27	42
AQ	Aviation fire control technician	.92	.90	.84	.53	33
ASE	Aviation support equipment technician (electrical)	.95	.90	.85	.37	30
ASH	Aviation support equipment technician (hydraulics and structures)	.88	.84	.79	.31	65
ASM	Aviation support equipment technician (mechanical)	.91	.85	.79	.23	62
AT	Aviation electronics technician	.94	.91	.88	.56	16
AW	Aviation antisubmarine warfare operator	.93	.90	.87	.39	22
AX	Aviation antisubmarine warfare technician	1.00	.98	.92	.66	7
AZ	Aviation maintenance administrationman	.91	.82	.75	.28	76
BM	Boatswain's mate	1.00	.95	.88	.21	13
BT	Boiler technician	.91	.82	.76	.22	73
BU	Builder	.95	.91	.87	.67	20
CE	Construction electrician	.98	.91	.86	.73	27
CM	Construction mechanic	.97	.91	.86	.67	26
CTA	Communications technician (administrative)	.95	.86	.75	.39	75
CTI	Communications technician (interpretive)	1.00	1.00	.95	.35	2
CTM	Communications technician (maintenance)	.97	.93	.91	.86	8
CTC	Communications technician (communications)	.93	.87	.84	.33	37
CTR	Communications technician (collection)	.88	.84	.79	.33	64
CTT	Communications technician (technical)	.97	.93	.86	.37	24
DK	Disbursing clerk	.92	.87	.81	.37	51
DM	Illustrator draftsman	.67	.63	.60	.38	85
DP	Data processing technician	.95	.90	.84	.58	38
DS	Data systems technician	1.00	.97	.92	.82	5
DT	Dental technician	.93	.87	.80	.63	60

[a]Calculated as 1.0 attrition rate for that year, rounded to nearest hundredth. Some year-of-service cells consisted of fewer than 20 individuals.

[b]Survival estimations based on rating-specific losses resulting from attrition as well as failure to reenlist.

[c]1 = highest Year 3 retention rate; 85 = lowest Year 3 retention rate.

Table 1 (Continued)

Rating Acronym	Rating Name	Retention Function by Year of Service[a] 1	2	3	4[b]	Ranking by Year 3 Retention Rate[c]
EA	Engineering aid	.89	.87	.81	.35	56
EM	Electrician's mate	.93	.87	.83	.37	40
EN	Engineman	.92	.86	.80	.19	59
EO	Equipment operator	.95	.88	.81	.64	55
ET	Electronics technician	.94	.89	.84	.65	39
EW	Electronics warfare technician	.95	.94	.91	.69	9
FTB	Fire control technician (ballistic missile fire control)	1.00	.91	.85	.79	28
FTG	Fire control technician (gun fire control)	.94	.90	.87	.42	21
FTM	Fire control technician (surface missile fire control)	.93	.89	.82	.55	47
GMG	Gunner's mate (guns)	.92	.86	.80	.23	61
GMM	Gunner's mate (missiles)	.97	.91	.83	.22	44
GMT	Gunner's mate (technician) (electrical)	.94	.90	.86	.36	23
GSE	Gas turbine system technician (electrical)	1.0	1.00	1.00	.74	1
GSM	Gas turbine system technician (mechanical)	1.00	.96	.91	.67	11
HM	Hospital corpsman	.93	.86	.81	.31	52
HT	Hull maintenance technician	.94	.87	.81	.22	54
IC	Interior communications electrician	.95	.90	.84	.39	34
IM	Instrumentman	.94	.86	.83	.23	43
IS	Intelligence specialist	.94	.88	.85	.42	31
JO	Journalist	.91	.83	.76	.46	71
LI	Lithographer	1.00	.91	.86	.35	25
ML	Molder	.83	.83	.75	.11	77
MM	Machinist's mate	.91	.84	.78	.35	68
MN	Mineman	.92	.87	.83	.45	41
MR	Machinery repairman	.98	.91	.87	.21	19
MS	Mess management specialist	.87	.77	.69	.25	83
MT	Missile technician	1.00	.98	.94	.89	3
MU	Musician	1.00	.96	.91	.41	10
OM	Opticalman	1.00	.93	.67	.33	84
OS	Operations specialist	.92	.86	.80	.20	58
OT	Ocean systems technician	.85	.77	.71	.29	81
PC	Postal clerk	.93	.81	.74	.20	78
PH	Photographer's mate	.97	.93	.88	.69	14
PM	Patternmaker	1.00	.92	.92	.05	4
PN	Personnelman	.87	.79	.73	.34	79
PR	Aircrew survival equipmentman	.87	.82	.79	.24	63
QM	Quartermaster	.92	.85	.80	.23	57
RM	Radioman	.90	.83	.78	.33	67
RP	Religious program specialist	.94	.79	.76	.53	74
SH	Ship's serviceman	.90	.76	.70	.20	82
SK	Storekeeper	.93	.86	.81	.30	53
SM	Signalman	.89	.79	.72	.18	80
STG	Sonar technician (surface)	.95	.88	.83	.58	46
STS	Sonar technician (submarine)	.92	.87	.82	.70	48
SW	Steelworker	.96	.92	.82	.66	45
TD	Trademan	.84	.79	.77	.30	70
TM	Torpedoman's mate	.91	.83	.77	.31	69
UT	Utilitiesman	.90	.86	.82	.64	49
YN	Yeoman	.90	.83	.79	.34	66

[a]Calculated as 1.0 attrition rate for that year, rounded to nearest hundredth. Some year-of-service cells consisted of fewer than 20 individuals.

[b]Survival estimations based on rating-specific losses resulting from attrition as well as failure to reenlist.

[c]1 = highest Year 3 retention rate; 85 = lowest Year 3 retention rate.

Table 2

Correlations Between Yearly Retention Rates
and Cumulative Retention Functions
in 85 Navy Ratings

Years in Service	Years in Service 1	2	3	4	Cumulative Years 2 & 3
Year 2	.20	--	--	--	--
Year 3	.84	.30	--	--	--
Year 4	.22	.28	.22	--	--
Years 2 & 3	.89	.62	.81	.39	--
Years 1, 2, & 3	.89	.50	.95	.29	.95

Note. Coefficients are Pearson product-moment correlations.

The BCM was designed to accommodate grade-specific costs, length-of-service costs, and overhead costs. The model provides rating-specific costs as a function of either length of service or pay grade. The length-of-service method is more useful for estimating first-term RCs than is the pay grade method.

A variety of cost-conversion and allocation procedures are incorporated in the BCM. To convert costs by rating and length of service to costs by rating and pay grade, the rating-specific median length of service data are typically used. The conversion of rating- and pay-grade-specific costs to rating- and length-of-service specific costs is more complex. Rating-specific mean times are applied to advancement. If, for example, the mean time to advancement to E-5 in a given rating is 4.3 years, the cost for Year 5 is computed as .3 (rating cost for E-4) + .7 (rating cost for E-5). Then, if the mean time to advancement to E-6 in the same rating is 10.6 years, Years 6 through 10 are exclusively identified with pay grade E-5. Annual per-capita costs are computed and transferred directly to length-of-service cells or distributed proportionally to pay grades on the basis of the size of the pay grade inventory. Overhead costs that cannot be readily identified with a specific pay grade, length-of-service cell, or rating are typically distributed equally across ratings. Although these examples oversimplify the costing methods used in the BCM, they generally describe the type of conversion and allocation techniques incorporated in the model.

Ten basic cost elements are used in the BCM:

1. Base pay
2. Hazard pay
3. Federal Insurance Contributions Act (FICA)
4. All-Navy cost by grade
5. All-Navy cost by year
6. Constant cost by grade
7. Constant cost by year
8. Retirement costs

9. School costs
10. Downtime costs

These items and their applicability to a replacement cost model are discussed separately in the appendix.

Replacement Cost Computation. As a result of the review of each cost element, six basic cost elements were selected to estimate rating-specific, first-term RCs (see Table 3). Element costs were obtained from a March 1981 computerized analysis of the BCM. Rating-specific costs computed by length of service were used exclusively in the development of RCs.

Table 3

Navy Enlisted Billet Cost Model (BCM) Elements Used in Estimating Replacement Costs

Cost Element	Components
Base pay	Base pay
Hazard pay	Flight crew pay Submarine crew pay
FICA	Employer social security taxes
All-Navy cost by grade	Sea and foreign duty pay Family separation allowance Overseas station allowance Quarters allowance in cash Quarters allowance in kind Unemployment insurance Commissary Medical and CHAMPUS[a] PCS[a]
All-Navy cost by year	Accession clothing Recruitment Messing and subsistence Command and administration Dependent school Death gratuity Prisoner apprehension Disability
School costs	School costs

[a]Defined in the appendix.

Because the design of the BCM specifically guards against the double counting of costs, simple summations were applied in developing RCs. The typical first-term enlistee is considered to be serving in the Navy on an initial 4-year enlistment obligation. If such an assumption is made, the estimated RC can be defined as the magnitude of the nth replacement cost element in the ith year of service for the jth Navy rating. It follows that

$$RC_i^j = \sum_{n=1}^{6} ERC_{n,i}^j$$

where

$i = 1, 2, 3, 4;$
$j =$ ABE, ABF, ABH . . . YN;
$n = 1, 2, 3 \ldots 6;$

and RC_i^j is the RC for the jth Navy rating during the ith year of service. It then follows that

$$CRC_k^j = \sum_{n=1}^{k} RC_{n,i}^j$$

where

$k \geq i;$
$j =$ ABE, ABF, ABH . . . YN;
$i = 1, 2, 3, 4;$

and where CRC can be interpreted as the cumulative replacement cost for a Navy member in the jth rating attriting in the kth year of service.

Estimated Replacement Costs. Table 4 presents the estimated cumulative RC for 85 specific technical ratings and the uniquely associated apprenticeship ratings open to first-term junior personnel (E-1 through E-4). As with retention rates, the goal was to select a single measure of attrition cost for the attrition-severity index. The RC data were carefully analyzed to select a single measure of rating-specific replacement cost. Table 5 presents the correlations among yearly and cumulative RCs.

Table 4

Cumulative Replacement Costs (RCs) for 85 Navy Ratings
FY 1980

Rating[a]	Cumulative RCs by Year of Service 1	2	3	4	Ranking by Year 3 RC[b]
ABE	15,100	27,600	41,400	55,800	36
ABF	12,200	24,000	37,900	52,200	82
ABH	14,200	26,600	39,800	54,000	57
AC	14,500	27,100	41,500	56,800	31
AD	16,000	28,600	42,500	56,900	24
AE	15,100	28,900	42,700	57,300	21
AG	15,400	28,000	41,500	56,700	32
AK	14,500	27,100	40,400	54,700	45
AME	17,000	29,000	43,000	52,200	20
AMH	15,800	28,000	41,600	55,800	30
AMS	15,500	28,000	41,400	55,700	34
AO	15,300	27,700	41,400	55,700	37
AQ	22,600	39,200	54,200	69,000	5
ASE	15,500	28,100	41,900	56,800	28
ASH	14,700	27,300	40,800	55,100	39
ASM	15,600	28,300	42,200	57,200	25
AT	18,000	32,600	47,300	62,400	11
AW	16,300	29,500	44,000	59,700	15
AX	20,200	35,500	49,900	65,500	9
AZ	13,900	26,200	39,700	53,900	58
BM	13,200	25,500	38,500	52,700	76
BT	13,300	25,500	38,800	52,900	70
BU	12,200	24,400	37,900	53,100	81
CE	12,200	24,600	38,100	53,100	78
CM	12,300	24,500	38,000	52,900	79
CTA	14,400	26,700	40,200	55,100	50
CTI	13,200	25,500	39,000	53,200	65
CTM	18,600	35,500	50,000	66,400	8
CTO	14,400	26,800	40,400	54,900	48
CTR	14,900	27,200	40,700	54,400	41
CTT	15,800	28,200	41,800	56,700	29
DK	13,300	25,600	39,200	53,400	63
DM	14,200	26,700	40,000	54,900	56
DP	13,500	25,900	39,400	54,000	59
DS	13,600	26,300	40,600	55,900	44
DT	35,800	62,100	79,500	97,800	1
EA	12,400	25,200	40,400	55,200	46
EM	14,900	31,700	45,600	60,500	14
EN	12,400	25,000	38,500	52,800	75
EO	12,200	24,500	37,800	52,400	83
ET	18,400	37,900	53,700	69,600	6
EW	18,500	38,600	52,700	68,200	7

[a]Rating acronyms are defined in Table 1.

[b]1 = highest RC rank; 85 = lowest RC.

Table 4 (Continued)

Rating[a]	Cumulative RCs by Year of Service 1	2	3	4	Ranking by Year 3 RC[b]
FTB	29,400	46,300	63,200	81,600	2
FTG	16,600	33,000	47,100	62,100	12
FTM	13,700	28,200	42,200	57,400	26
GMG	13,300	25,700	38,900	53,600	67
GMM	15,900	28,500	41,900	57,000	27
GMT	16,600	29,400	43,200	57,900	18
GSE	14,600	28,600	43,600	58,800	17
GSM	14,900	28,100	42,600	58,600	23
HM	12,600	25,100	38,700	52,900	71
HT	13,400	25,800	39,400	54,300	60
IC	13,500	28,300	42,700	58,300	22
IM	14,600	27,000	40,300	54,900	49
IS	14,100	26,800	40,400	56,200	47
JO	13,800	26,300	40,100	55,200	54
LI	13,700	26,000	39,200	53,500	62
ML	12,300	24,500	37,700	52,000	85
MM	16,400	32,500	46,300	62,000	13
MN	13,800	26,600	40,200	56,300	52
MR	12,400	24,600	37,900	52,900	80
MS	14,500	26,800	40,100	54,400	53
MT	23,600	41,200	57,500	75,400	3
MU	13,100	25,400	39,000	53,100	66
OM	14,000	27,300	43,700	57,800	16
OS	14,400	26,900	40,200	54,600	51
OT	14,200	27,000	40,800	54,900	40
PC	12,300	25,200	38,600	52,900	74
PH	15,000	27,500	41,200	56,500	38
PM	12,600	24,800	38,700	52,700	73
PN	13,900	26,400	40,000	55,000	55
PR	17,000	29,600	43,100	57,400	19
QM	13,500	25,800	39,300	54,200	61
RM	15,000	27,800	41,400	55,900	35
RP	14,400	27,000	40,700	54,800	42
SH	13,300	25,600	38,700	52,900	72
SK	13,300	25,600	38,900	53,100	68
SM	13,500	25,800	39,000	53,200	64
STG	16,400	30,000	48,600	65,900	10
STS	17,900	34,300	54,400	74,400	4
SW	12,300	24,600	38,100	53,400	77
TD	14,600	27,300	40,700	54,900	43
TM	14,700	27,300	41,600	56,800	33
UT	12,300	24,600	37,800	52,200	84
YN	13,200	25,500	38,900	53,100	69

[a]Rating acronyms are defined in Table 1.

[b]1 = highest RC rank; 85 = lowest RC.

The results reveal very high positive correlations among the cost estimates considered. The third-year cumulative RCs were selected for use because the correlations were .92 and above, and the measure corresponds to the third-year cumulative retention functions. There is a degree of arbitrariness in this choice. The choice of other measures from Table 5, or even combinations not present in Table 5, would not affect the development of an attrition-severity index, although it could affect the rankings.

Table 5

Correlations Between Yearly and Cumulative RCs in 85 Navy Ratings

Year	Years of Service					
	1	2	3	4	1 & 2[a]	1, 2, & 3[b]
Year 2	.86	--	--	--	--	--
Year 3	.96	.89	--	--	--	--
Year 4	.83	.95	.92	--	--	--
Years 1 & 2	.98	.95	.97	.91	--	--
Years 1, 2, & 3	.98	.93	.99	.92	.99	--
Years 1, 2, 3, & 4[c]	.95	.95	.99	.96	.99	.99

Note. Coefficients are Pearson product-moment correlations.

[a]The sum of the replacement costs for Years 1 and 2.

[b]The sum of the replacement costs for Years 1, 2, and 3.

[c]The sum of the replacement costs for Years 1,2, 3, and 4.

Using a Year 3 criterion, the five ratings having the highest RCs were found to be dental technical (DT) ($79,500), fire control technician (Ballistic missile fire control) (FTB) ($63,200), missile technician (MT) ($57,500), sonar technician (submarine) (STS) ($54,000), and aviation fire control technical (AQ) ($54,200). The ratings exhibiting the lowest RCs were molder (ML) ($37,700), utilitiesman (UT) ($37,800), equipment operator (EO) ($37,800), aviation boatswain's mate (ABF) (fuels) ($37,900), and builder (BU) ($37,900).

Demand for Personnel

Estimates of the Navy's demand for personnel for each of 85 Navy ratings included three factors: (a) rating size (number of personnel in the rating), (b) requirements (need for trained personnel), and (c) priority (relative importance of the rating) to the Navy. It was assumed that the loss of personnel will affect the personnel system more significantly for ratings with smaller sizes than ratings with larger sizes; for ratings with shortages than ratings with an excess; and for ratings with higher priorities than ratings with lower priorities.

Rating Size. Rating size was measured from rating inventory data contained in Fourth Quarter FY-80 Navy Military Personnel Statistics (Navy Military Personnel Command (NMPC) 1980). The rating-specific inventories for pay grades E-1 through E-4 were summed to derive estimates of first-term size for the 85 ratings presented in Table 6. The machinist's mate (MM) (12,296), hospital corpsman (HM) (12,386), boiler technician (BT) (7,741), radioman (RM) (7,449), and electronics technician (ET) (6,749) ratings had the largest rating sizes of first-term personnel. Patternmaker (PM) (61), molder (ML) (115), opticalman (OM) (118), religious program specialist (RP) (147), and engineering aid (EA) (153) ratings had the smallest rating sizes.

Rating Requirements for Personnel. The need for enlisted personnel can be determined by comparing rating inventories with rating personnel requirements. If the requirements exceed the inventory, then a shortage exists. Conversely, if the inventory exceeds the requirements, an excess exists. Need can be expressed as a proportion of requirements, where a positive percentage indicates a shortage of trained personnel for the rating and a negative percentage indicates an excess.

Using data provided in Fourth Quarter FY-80 Navy Military Personnel Statistics (NMPC, 1980), rating-specific measures of personnel needs were estimated. The results are presented as proportions in Table 6. The measures were computed from inventory and requirements data for pay grades E-3 through E-9, rather than just for E-1 and E-2, pay grades that typically contain first-term personnel. Because requirements for E-1 and E-2 personnel are not formally established within the Navy's billet structure, these pay grades could not be used in the computations. Pay grades E-3 through E-9 were chosen to capture the full effect of attrition on specific ratings, in recognition of the Navy's policy of developing personnel through training and experience to a skilled work force. The loss of first-term personnel through attrition not only affects the Navy's ability to meet requirements typically filled by first-term personnel, it also affects the Navy's ability to maintain adequate personnel to develop and advance to the more skilled positions in the higher pay grades. If severe needs already exist in higher pay grades in a particular rating, the effect of first-term in that rating attrition is more serious than otherwise.

As shown in Table 6, the five ratings exhibiting the greatest need for personnel were: musician (MU) (.42), operations specialist (OS) (.38), instrumentman (IM) (.28), aviation fire control technician (AQ) (.28), and electronics warfare technician (EW) (.24) ratings. Conversely, the five ratings that exhibited the greatest excess of personnel were gas turbine system technician (electronics GSE) (-.31), illustrator draftsman (DM) (-.19), sonar technician (submarine) (STS) (-.06), aviation support equipment technician (mechanical) (ASM) (-.04), and construction mechanic (CM) (-.02).

Priority of Ratings. Any measure of rating priority or the importance of a particular rating to the Navy in carrying out its mission must be subjective. Establishing such a rating priority requires qualified or knowledgeable raters. Because subjective judgments are necessary, measures of this kind vary to some extent among different groups of raters.

This research used a measure of the relative importance of Navy ratings that was developed for CLASP (Kroeker & Rafacz, 1983). With a distribution characterized by a mean of 50 and a standard deviation of 10, a numerical value of 80 on this measure indicates extremely high priority and 20 indicates very low priority. Machinist's mate (MM) (69), signalman (SM) (69), fire control technician (ballistic missile fire control) (FTB) (66), gunner's mate (guns) (GMG) (66), and gunner's mate (missiles) (GMM) (66) ratings received the highest priorities. Musician (MU) (29), religious program specialist (RP) (31),

Table 6

Demand for First-Term Personnel in Selected Navy Ratings

Rating[a]	Size	Need[b]	Priority	Rating	Size	Need	Priority
ABE	1,252	.16	47	FTB	382	-.01	66
ABF	1,126	.05	47	FTG	1,229	.12	66
ABH	1,933	.03	47	FTM	1,556	.14	66
AC	979	.01	45	GMG	1,714	.12	66
AD	6,613	00	51	GMM	708	.15	66
AE	3,264	.15	54	GMT	944	.11	58
AG	911	.03	41	GSE	163	-.31	59
AK	2,982	.13	38	GSM	346	.04	59
AME	1,487	.07	52	HM	12,386	.18	59
AMH	2,913	.05	52	HT	6,410	.07	55
AMS	4,254	.08	52	IC	2,549	.15	59
AO	3,096	.17	49	IM	174	.28	36
AQ	892	.28	57	IS	420	.09	45
ASE	342	.16	41	JO	339	.11	32
ASH	392	.02	41	LI	202	.05	32
ASM	583	-.04	41	ML	115	.03	35
AT	3,612	.14	59	MM	12,296	.08	69
AW	1,208	.11	59	MN	584	.09	50
AX	734	.08	60	MR	1,235	.11	45
AZ	1,538	.13	37	MS	890	.08	49
BM	3,544	.17	45	MU	254	.42	29
BT	7,741	.08	65	OM	118	.18	34
BU	1,368	.15	44	OS	4,116	.38	65
CE	520	.13	42	OT	624	.16	56
CM	841	-.02	35	PC	651	.16	56
CTA	362	.07	49	PH	1,114	.13	43
CTI	204	.20	57	PM	61	.00	35
CTM	592	.06	50	PN	2,622	.08	49
CTO	720	.16	54	PR	977	.12	53
CTR	840	.03	60	QM	2,004	.12	54
CTT	609	.18	56	RM	7,449	.16	62
DK	853	.13	49	RP	147	.09	31
DM	170	-.19	32	SH	2,424	.17	56
DP	1,757	.11	42	SK	3,950	.06	51
DS	831	.02	53	SM	1,680	.23	69
DT	2,226	.19	47	STG	2,343	.02	53
EA	153	.09	38	STS	1,380	-.06	62
EM	5,839	.06	57	SW	636	.06	39
EN	4,880	.03	49	TD	725	.12	50
EO	1,099	.09	45	TM	1,596	.16	59
ET	6,749	.05	53	UT	670	.11	42
EW	762	.24	59				

[a]Rating acronyms are defined in Table 1.

[b]Need = (Personnel requirements - inventory) divided by requirements, for E-3 to E-9.

patternmaker (PM) (35), journalist (JO) (32), and lithographer (LI) (32) ratings received the lowest priorities.

Summary of Factors

First-term attrition-severity factors are presented for 85 ratings in Table 7. The mean, standard deviation, range, kurtosis, and skewness for the five factors in the multiattribute index are presented in Table 8.

As shown in Table 7, when the rating-specific measures for RC, requirements for personnel, and rating priority increase in value, the severity of attrition also increases. However, as rating size and retention rates increase, the severity of attrition decreases. When the factors were ranked across the 85 ratings, they had diverse effects on the severity of attrition. For example, the aviation antisubmarine warfare technician (AX) rating was ranked very low for retention (7), moderately for size (55) and personnel requirements (36), and very high for replacement cost (77) and priority (73). For any factor under consideration, a ranking of 1 indicates a low effect on attrition severity and a ranking of 85 indicates a high effect on attrition severity.

Table 9 presents the Pearson correlation coefficients for factors affecting the severity of first-term attrition. As shown, a moderately negative correlation exists between rating size and rating priority (-.37), and a moderately positive correlation between RCs and rating priority (.31). The correlations, which vary in sign and are low between the other pairs of factors, tend to verify that no subset of measures can be used to capture the effect on all five factors on attrition.

The diversity of the effect of each of the factors on specific occupations reinforces the need to apply a multiattribute model that will collapse the information on all five factors and, thus, assist job assigners to make a rational determination of rating-specific attrition severity.

Assignment of Weights

Two different methods of combining the measures of retention rates, RCs, and the Navy's demand for personnel into an overall first-term attrition-severity index were developed. One method uses an additive model and the other method uses a multiplicative model. The effects of equal and differential weighting procedures were considered for both kinds of models.

The data were transformed with a standardization of attributes to scales with means of 50 and standard deviations of 10. The direction of the standardization was such that a value of 75 indicated a very high effect on the severity of attrition and a transformed value of 25 indicated a very low effect on attrition severity.

Let

$X_{i,j}$ = the $\underline{i}$th factor value for the $\underline{j}$th rating

where

$i = 1 \ldots 5,$

and

$j = 1 \ldots 85.$

Table 7

Ranking of First-Term Attrition-Severity Factors for Selected Navy Ratings

Rating[a]	Retention Rate	Replacement Cost	Rating Demand for Personnel		
			Size	Need	Priority
ABE	32	50	37	69	33
ABF	36	4	41	22	32
ABH	50	29	27	16	31
AC	12	55	44	12	30
AD	18	62	7	11	45
AE	6	65	17	62	56
AG	35	54	47	19	17
AK	72	41	25	55	12
AME	17	66	34	30	49
AMH	29	56	19	24	47
AMS	15	52	11	32	48
AO	42	49	18	72	37
AQ	33	81	48	82	61
ASE	30	58	73	70	15
ASH	65	47	69	15	18
ASM	62	61	66	6	16
AT	16	75	15	57	65
AW	22	71	40	43	22
AX	7	77	55	36	73
AZ	76	28	33	53	11
BM	13	10	16	71	26
BT	73	16	4	33	77
BU	20	5	36	59	24
CE	27	8	67	56	19
CM	26	7	51	8	8
CTA	75	36	71	29	39
CTI	2	21	76	79	62
CTM	8	78	64	28	43
CTO	37	38	57	66	55
CTR	64	45	52	18	72
CTT	24	57	63	76	60
DK	51	23	50	54	40
DM	85	30	79	2	4
DP	38	27	28	47	21
DS	5	42	53	13	53
DT	60	85	24	78	34
EA	56	40	81	40	13
EM	40	72	9	25	63
EN	59	11	10	17	41
EO	55	3	43	37	29
ET	39	80	6	23	51
EW	9	79	54	81	66

Note. 1 = lowest attrition effect; 85 = highest attrition effect.

[a]Rating acronyms defined in Table 1.

Table 7 (Continued)

Rating[a]	Retention Rate	Replacement Cost	Rating Demand for Personnel: Size	Need	Priority
FTB	28	84	70	9	83
FTG	21	74	39	51	79
FTM	47	60	32	58	78
GMG	61	19	29	48	80
GMM	44	59	58	60	81
GMT	23	68	46	44	64
GSE	1	69	80	1	71
GSM	11	63	72	20	70
HM	52	15	1	74	67
HT	54	26	8	31	57
IC	34	64	21	61	68
IM	43	37	78	83	10
IS	31	39	68	38	28
JO	71	32	74	42	3
LI	25	24	77	21	5
ML	77	1	84	7	9
MM	68	73	2	34	85
MN	41	34	65	39	44
MR	19	6	38	45	27
MS	83	33	3	64	35
MT	3	83	49	4	82
MU	10	20	75	85	1
OM	84	70	83	77	4
OS	58	35	13	84	76
OT	81	46	62	68	59
PC	78	12	60	67	25
PH	14	48	42	3	23
PM	4	13	85	10	7
PN	79	31	20	35	38
PR	63	67	45	52	50
QM	57	25	26	49	54
RM	67	51	5	65	74
RP	74	44	82	41	2
SH	82	14	22	73	58
SK	53	18	14	26	46
SM	80	22	30	80	84
STG	46	76	23	14	52
STS	48	82	35	5	75
SW	45	9	61	27	14
TD	70	43	56	50	42
TM	69	53	31	63	69
UT	49	2	59	46	20
YN	66	17	12	75	36

Note. 1 = lowest attrition effect; 85 = highest attrition effect.

[a]Rating acronyms defined in Table 1.

Table 8

Distributional Characteristics of First-Term Attrition-Severity Factors in 85 Navy Ratings

Statistical Analysis	Attrition	RC	Demand for Personnel Size	Need	Priority
Mean	.175	42,500	2,050	.097	50
Standard deviation	.067	6,250	2,500	.10	10
Range	.40	41,900	12,300	0.73	50
Kurtosis	0.98	15.3	5.84	3.57	-0.74
Skewness	0.41	3.4	2.3	-0.47	-0.10

Table 9

Correlations Between First-Term Attrition-Severity Factors in 85 Navy Ratings

Severity Factor	Retention Rate	RC	Size	Need
Retention	--	--	--	--
Replacement costs	-.19	--	--	--
Size	-.15	-.01	--	--
Need	.12	-.05	-.10	--
Priority	-.16	.31	-.37	.07

Note. Coefficients are Pearson product-moment correlations.

Also,

W_i = the weighting for the ith factor,

$i = 1 \ldots 5,$

$W_i > 0$ for all i,

and

$$\sum_{i=1}^{5} W_i = 1.0$$

Then an additive attrition-severity index (AASI) for occupation j can be defined as

$$AASI_j = \sum_{i=1}^{5} W_i X_{i,j}$$

The AASI should be centered on a mean of 50 and be more compact about its mean than are the underlying attribute distributions.

A multiplicative attrition-severity index (MASI) for occupation j can be defined as

$$MASI_j = \left[\frac{\prod_{i=1}^{5} X_{i,j}^{b_i}}{\max_j \prod_{i=1}^{5} X_{i,j}^{b_i}} \right] \times 100,$$

where

b_i = the weighting for the ith factor,

$i = 1 \ldots 5,$

and

$b_i > 0$ for all i.

The MASI is a nonnegative number ranging up to 100 for the rating with the most severe attrition. The MASI is directly interpretable for each occupation as the proportional value of the index for that occupation compared to the index for the occupation with the most severe attrition.

To assist the Navy in assessing the consequence of using equal weights, a sensitivity analysis of alternative weights was conducted for both the additive and and multiplicative form of an attrition-severity index.

Equal Weights

Equal weighting for the AASI occurs when each of the five W_i are set equal to 0.2. Similarly, equal weighting for the MASI occurs when each b_i = 1.0. Table 10 presents the correlations among the five attrition factors and the associated equally weighted AASIs and MASIs.

Table 10

Correlations Between Attrition Factors and
Equally Weighted Additive and Multiplicative Attrition-Severity
Indices in 85 Navy Ratings

	Retention	RC	Size	Need	Priority	AASI
RC	-.19	--	--	--	--	--
Size	.15	-.01	--	--	--	--
Need	.12	-.05	-.10	--	--	--
Priority	-.16	.31	-.37	.07	--	--
AASI[a]	.31	.53	.19	.52	.43	--
MASI[b]	.24	.19	.27	.49	.40	.97

Note. Coefficients are Pearson product-moment correlations.

[a]Additive attrition severity index.

[b]Multiplicative attrition severity index.

With the exception of cost, a similar pattern of correlations exists for each factor for both AASI and MASI. Costs seem to be more directly related to the AASI than to the MASI. The correlation of MASI with AASI (.97) reinforces the tentative conclusion of Huber (1974) as to the similarity in results with the additive and multiplicative models.

Unequal Weights

To determine the effect of alternative factor weights on the indices, calculations were made using three different sets of weights and the correlated results. Table 11 provides the results of the procedure when factors were doubled. Each factor was separately weighted by 1/3 with the weights of the remaining four factors weighted by 1/6. AASI 1 and MASI 1 were the equally weighted AASIs and MASIs. A2ASI 1 was the AASI with Factor 1 weighted twice the other factors. Making one factor twice as important as the other factors leaves the resultant attrition-severity ranking of the occupations relatively unchanged.

Table 11

Correlations Between AASIs With One Factor Weighted Twice as Much as the Other Factors

	AASI 1	A2ASI 1	A2ASI 2	A2ASI 3	A2ASI 4	A2ASI 5
A2ASI 1	.92	--	--	--	--	--
A2ASI 2	.95	.82	--	--	--	--
A2ASI 3	.91	.81	.85	--	--	--
A2ASI 4	.95	.87	.85	.83	--	--
A2ASI 5	.94	.82	.90	.78	.87	--
MASI 1	.97	.87	.91	.92	.91	.90

Note. MASI 1 is the equally weighted multiplicative index. A2ASI 1 indicates an additive index with Factor 1 weighted twice as much as the other individual factors. Coefficients are Pearson product-moment correlations.

Table 12 provides the results from doubling the importance of one factor while leaving the other factors at equal importance for the MASI. Each factor was separately weighted by a power of 2, while the other four factors were weighted with a power of 1. M2ASI 1 is the multiplicative index with Factor 1 weighted twice the other factors. As for the AASI, doubling the importance of one factor leaves the resultant occupational ranking by attrition-severity relatively invariant.

Table 12

Correlations Between MASIs With One Factor Weighted Twice as Much as the Other Factors

	MASI 1	M2ASI 1	M2ASI 2	M2ASI 3	M2ASI 4	M2ASI 5
M2ASI 1	.93	--	--	--	--	--
M2ASI 2	.88	.76	--	--	--	--
M2ASI 3	.96	.88	.84	--	--	--
M2ASI 4	.96	.89	.81	.90	--	--
M2ASI 5	.95	.84	.80	.89	.89	--
AASI 1	.97	.90	.86	.92	.92	.92

Note. MASI 1 and AASI 1 are the equally weighted multiplicative and additive attrition-severity indices (AASI and MASI), respectively. M2ASI 2 indicates a multiplicative index with Factor 2 weighted twice as much as the other individual factors. Coefficients are Pearson product-moment correlations.

Tables 13 and 14 present the results of weighting each factor five times as important as others for the AASIs and MASIs respectively. Variation now begins to occur in the resultant rankings. For the additive model (Table 13), the correlation of the equally weighted index with the five quintuple weighted indices varies from a low of .56 to a high of .77. For the multiplicative model (Table 14), the same correlation ranges from a low of .53 to a high of .79. The results indicate both a fairly strong (.53 or greater) correlation within models (additive or multiplicative indices) and a fairly strong positive (.51 or greater) correlation between models (between additive and multiplicative indices), when attribute weights are changed by a factor of 5.

Table 13

Correlations Between AASIs with One Factor Weighted Five Times as Much as the Other Factors

	AASI 1	A5ASI 1	A5ASI 2	A5ASI 3	A5ASI 4	A5ASI 5
A5ASI 1	.65	--	--	--	--	--
A5ASI 2	.77	.29	--	--	--	--
A5ASI 3	.56	.23	.38	--	--	--
A5ASI 4	.77	.47	.40	.31	--	--
A5ASI 5	.71	.28	.60	.11	.46	--
MASI 1	.97	.58	.74	.62	.73	.68

Note: A5ASI 4 indicates an additive index with Factor 4 weighted five times as much as any one of the other individual factors. (AASI 1 and MASI 1 are the equally weighted additive and multiplicative attrition-severity indices, respectively.) Coefficients are Pearson product-moment correlations.

Table 14

Correlations Between MASIs with One Factor Weighted Five Times as Much as the Other Factors

	MASI 1	M5ASI 1	M5ASI 2	M5ASI 3	M5ASI 4	M5ASI 5
M5ASI 1	.57	--	--	--	--	--
M5ASI 2	.53	.18	--	--	--	--
M5ASI 3	.79	.43	.33	--	--	--
M5ASI 4	.71	.39	.31	.47	--	--
M5ASI 5	.75	.34	.20	.51	.53	--
AASI 1	.97	.59	.51	.76	.69	.74

Note: M5ASI 2 indicates a multiplicative index with Factor 2 weighted five times as much as any one of the other individual factors. (AASI 1 and MASI 1 are the equally weighted additive and multiplicative attrition-severity indices, respectively.) Coefficients are Pearson product-moment correlations.

The extremely high positive correlation between the indices calculated using equal factor weights and the indices derived when the individual factors were separately weighted double indicates that such a weighting would have little effect on how the index values ordered the ratings. The decreasing positive correlations, realized when the factors were separately weighted by powers of 5, indicate that a weight of at least 3 or more must be applied to make any one factor a substantially more significant determinant of the first-term attrition-severity index.

RESULTS

First-term attrition-severity index values for the 85 ratings based on the index values when the factors were equally weighted are presented in Table 15. As shown, in most cases the results provided by the index correspond with anticipated outcomes. Groups that have been considered critical to the Navy in terms of personnel, such as the operations specialist (OS), signalman (SM), and fire control technicians (ballistic missile and aviation fire control) (FTB) ratings, received higher index values. Likewise, those ratings that have not been considered critical, such as the photographer's mate (PH), lithographer (LI), and patternmaker (PM) ratings, received lower index values. However, in some cases the results deviated substantially from those expected. The dental technician (DT) rating received the highest attrition-severity index value, and gas turbine system technician (electrical) (GSE) received the lowest index value.

In some instances, deviations from prior expectations may be the result of the manner in which the attributes or factors were developed. In other cases they may merely be the result of wrong impressions. There may be a problem with the gas turbine system technician (electrical) (GSE) rating, which was created to staff a new class of gas-turbine-driven ships. The rating-specific measures developed for GSE indicate that the its size is small, it has an extremely high retention rate, and it is overstaffed. The requirements factor was developed on the basis of current requirements and current inventory. No consideration was given to the fact that the Navy is training and developing excess gas turbine system technicians in anticipation of adding new gas-turbine-driven ships to the fleet in the next several years.

Although the first-term attrition-severity index developed may not provide an entirely satisfying estimate of attrition-severity for gas turbine system technicians, the extremely high attrition-severity value assigned to the dental technician rating may be an accurate representation of attrition-severity for the rating. The Navy traditionally has relied heavily on the priority or importance factor in determining which ratings require attention. The dental technical rating was assigned a moderately low priority value, but its value for the cost factor was 5 standard deviations above the cost factor average. Such a situation emphasizes the need to consider several factors in determining the severity of personnel losses from specific ratings, and provides evidence of the usefulness of a multiattribute model in determining attrition-severity.

Table 15

First-Term Attrition-Severity Index Values
and Ranking for 85 Navy Ratings

Ranking	Rating[a]	ASI	Ranking	Rating[a]	ASI
1	DT	100	44	RM	34
2	AQ	85	45	IS	34
3	SM	81	46	AW	34
4	FTB	71	47	EO	33
5	OT	69	48	EA	33
6	OS	64	49	ASH	33
7	EW	64	50	UT	32
8	GMM	61	51	JO	32
9	TM	60	52	RP	31
10	SH	59	53	EM	31
11	FTM	58	54	ET	31
12	FTG	57	55	AMH	31
13	OM	54	56	CE	30
14	GMG	53	57	ABH	30
15	PR	53	58	AE	30
16	STS	50	59	DP	30
17	TD	49	60	MS	29
18	CTT	49	61	BU	29
19	PC	49	62	ABF	29
20	CTO	47	63	SK	29
21	CTR	46	64	ASM	29
22	CTA	46	65	BT	28
23	IC	46	66	MR	28
24	GMT	45	67	AG	28
25	AX	44	68	MU	28
26	AT	42	69	SW	27
27	QM	42	70	AMS	26
28	STG	41	71	DS	26
29	PN	41	72	BM	25
30	DK	41	73	HT	25
31	IM	40	74	ML	25
32	ABE	39	75	AC	24
33	MN	39	76	EN	24
34	AO	38	77	LI	21
35	CTM	37	78	DM	20
36	ASE	37	79	CM	18
37	YN	36	80	AD	17
38	AZ	36	81	PH	16
39	GSM	35	82	PM	16
40	AK	35	83	MM	12
41	MT	35	84	HM	8
42	AME	35	85	GSE	6
43	CTI	35			

Note: Rankings are from highest to lowest severity of attrition.

[a]Rating acronyms defined in Table 1.

CONCLUSIONS

There appears to be little empirical justification for selecting the additive model (AASI) rather than the multiplicative model (MASI). Because there was some direct interpretation to the numbers attached to occupations by the MASI (the MASI for each occupation can be interpreted as the proportion of the index for the occupation with the most severe attrition), it was selected as the preferred method.

The analysis of the effect of varying factor weights indicates the appropriateness of using equal factor weights. Ranking of occupations by attrition-severity seems to be relatively stable under substantially different factor weights. This research has shown that it is possible to develop an index that yields a reasonably robust rank ordering of ratings on a measure of attrition-severity.

If the Navy uses the attrition-severity index, data sources and procedures will be needed to keep the factors in the attrition-severity index current. The functional form of this index allows other factors to be added to the attrition-severity index when research indicates they are needed.

RECOMMENDATIONS

1. The attrition-severity index developed in this research should be used in determining assignment utility within the CLASP model.

2. Personnel researchers should investigate the use of multiattribute utility functions as a means to analyze other personnel decisions, such as retention.

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APPENDIX

COST ELEMENTS AND DISCUSSION

COST ELEMENTS AND DISCUSSION

Cost Elements

Base Pay

The base pay cost element reflects an enlisted member's annual base pay or basic salary. The computed base pay costs are based on a statutory table of monthly base pay by pay grade and length of service.

Hazard Pay

Hazard pay consists of flight crew and submarine crew pay. As with base pay, hazard pay is calculated from statutory tables; however, hazard pay is calculated as a function of the probability of receiving hazard pay within specific ratings.

FICA

The FICA cost element recognizes the Navy's responsibility as an employer to contribute to Social Security. The FICA costs borne by the Navy and transferred to the Treasury are computed by multiplying an appropriate FICA rate by base pay and cannot exceed statutory ceilings placed on such contributions.

All-Navy Costs by Grade

The all-Navy costs-by-grade element includes those costs that are considered by the model not to be rating specific, but rather are defined and allocated by pay grade. This basic cost element consists of nine individual components or subelements: (1) sea and foreign duty pay; (2) family separation allowance; (3) overseas station allowance, including cost of living, housing, and temporary lodging payments; (4) quarters allowance in cash, or the cash amount provided to an enlisted member for housing when government quarters cannot be furnished; (5) quarters allowance in kind, or the cost of providing an enlisted member with government quarters; (6) unemployment insurance, which reflects the Department of Labor's allocation of such costs to the Navy; (7) commissary; (8) medical and CHAMPUS (civilian health and medical program for the uniform services) costs; and (9) PCS, which includes accession, training, operational, rotational, separation, and organization travel costs. Most of the cost estimates of the individual components are developed outside of the model, principally from current-year budget data, and are provided as inputs to the model as pay-grade-specific totals. For subelements, such as commissary, overseas station allowance, and unemployment insurance, where the input data are provided as lump sums and are not grade-specific, costs are allocated to pay grades as per-capita costs.

All-Navy Cost by Year of Service

This element is similar to all-Navy costs by grade by virtue of the fact that the costs that comprise the element are not rating specific and are drawn primarily from budget data, but differs in the fact that the costs are identified as varying by length of service. The all-Navy, cost-by-year element is composed of nine individual components: (1) accession clothing, reflecting the cost of the initial issue of uniforms to new recruits; (2) recruitment, including advertising and other explicit budget expenses associated with recruiting; (3) mess and subsistence, consisting of cash disbursements for food computed from a daily subsistency rate gleaned from budget data and multiplied by a 360-day year; (4) command and administration, composed of a variety of personnel-related costs derived from budget data; (5) dependent schools, consisting of the costs associated with the operation of dependent schools in overseas locations; (6) E-7 clothing, recognizing the initial uniform allowance provided to newly selected chief petty officers; (7) death gratuity, including the costs associated with the death of active duty members; (8) prisoner apprehension, including the costs associated with the apprehension of deserters; and (9) disability provision, consisting of costs incurred when members are disabled on active duty. The costs associated with each component of the element are allocated to length-of-service cells based on the type of component in question. The costs associated with some components, such as accession clothing, recruitment, and E-7 clothing, can be uniquely associated with a specific length-of-service cell. For example, accession clothing and recruitment costs are allocated entirely to the first year of service, while the E-7 clothing cost is allocated entirely to the length-of-service cell that corresponds to an E-7's mean time to advancement within a rating. Other component costs that cannot be uniquely identified with a specific length-of-service cell are allocated equally to all cells as annual per-capita costs.

Constant Cost by Grade

This element was designed to include all grade-specific premium pays other than hazard pay. Currently, input data for this element are not available for use by the BCM; however, inputs from the joint unified military pay system are anticipated in the future.

Constant Cost by Year

Currently, this element consists solely of selected reenlistment bonus costs, or those costs associated with incentive bonuses paid to reenlisting first and second term personnel. Selected reenlistment bonus costs are computed on the basis of rating specific bonus eligibility and are distributed to length-of-service cells 5 through 20.

Retirement Costs

A required retirement fund size is computed for every possible pay grade and length-of-service retirement "window." For each such window a probability is also calculated that an individual will retire in that window rather than some other. The products of these fund sizes and the probabilities are then discounted to present value, and summed to yield current retirement liability. This allocation method treats retirement as an accrued liability and distributes retirement costs over length-of-service cells to form a sinking fund based upon the probability of reaching vesting points in each length-of-service cell.

School Costs

School costs by course and location are provided by Chief of Naval Education and Training course costing branch. Student attendance data are derived from the Navy integrated training resource and administrative system, which has three files. The student transaction history file is the only one used. The attendance records are matched to the Navy's enlisted master file to determine rating and length-of-service data on attendees. Student records are matched to the cost records; the total number of matches is considered the total course attendance. Total number of student records is divided into course cost to determine cost per graduate. The student attendance record with appended cost is distributed to a rating matrix and then allocated forward in time on the basis of the number of years the trained cohort is expected to serve in the Navy.

Downtime Costs

An individual filling a billet spends time during the course of a full billet year in nonproductive activities, such as training. In order to staff a billet full time, another individual possessing a comparable level of skill and experience must be available to fill the billet during nonproductive periods. Thus, an upward adjustment of the preliminary total cost must be made to reflect the additional amount of cost required to fill a billet for a full work year. The BCM makes this adjustment by multiplying the sum of the previous nine elements by an estimated proportion of time during a year that persons in a rating spend as prisoners, patients, students, or in a transient status.

Discussion

The content and computation of each BCM cost element were carefully reviewed to determine whether the cost estimates could be appropriately included in the development of replacement costs. Because the constant cost-by-grade element did not contain cost data and the constant cost-by-year element contained only selected reenlistment bonus costs, which are incurred only after the first term of enlistment, these elements were removed from consideration in constructing replacement costs. The portion of all-Navy cost-by-year elements containing E-7 clothing costs also was considered to be inappropriate for the estimation of first-term replacement costs and was not considered in the computations. Additionally, the treatment of school costs, retirement costs, and downtime costs in the BCM required additional consideration.

As defined in this study, a first-term replacement cost is the total cost to the Navy to develop an individual in a particular rating to replace one who leaves the Navy during a specified year of service prior to the completion of the first-term enlistment. The allocation scheme used to distribute training costs over the number of years a trained enlisted member is expected to serve in the Navy was incompatible with the definition of a first-term replacement cost. If the BCM's allocation of school costs to length-of-service cells was used in computing replacement cost estimations, the portion of the replacement costs which could be attributed to school costs would be seriously understated. For example, if someone left the Navy at the end of the first year of service, under the BCM's allocation scheme the training costs associated with the first year of service would only represent a fraction of the true cost of replacing the person. Thus, for the purpose of measuring replacement costs, rating-specific school costs estimated within the BCM were applied to the year of their occurrence.

The treatment of retirement as an accrued liability presented another problem. Although the retirement cost element is appropriately included in the BCM, it has little relevance to first-term replacement costs. If a recruit leaves before completing his or her initial enlistment, a certain amount of money must be invested to bring another recruit up to the point where the first left. If the recruit has not left the Navy, the additional cost is not incurred. Because no additional retirement cost is incurred by the Navy from attrition among first-term recruits, the cost element containing retirement costs was deleted from replacement-cost computations.

The inclusion of downtime costs in replacement-cost computations was also subject to question. Downtime costs represent the additional cost incurred in filling a billet for a full work year and are computed as a function of the amount of time a person filling a billet or destined to fill a billet spends in nonproductive activities outside of it. Because the interest here is in replacement costs and not billet costs, downtime costs were deleted from replacement cost computations.

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