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THE FEASIBILITY OF DERIVING A COST/EFFECTIVENESS FORMULA FOR MAN/MACHINE FUNCTION ALLOCATION

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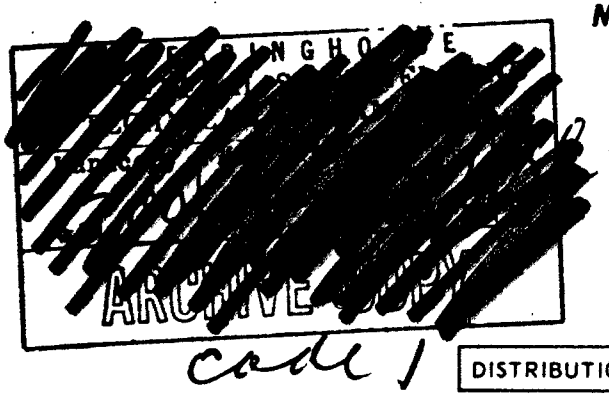

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AN ACTIVITY OF THE BUREAU OF NAVAL PERSONNEL

THE FEASIBILITY OF DERIVING A COST/EFFECTIVENESS FORMULA FOR MAN/MACHINE FUNCTION ALLOCATION

by

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BRIEF

In order to investigate the feasibility of developing a cost/effectiveness formula for man/machine function allocation, a preliminary cost/effectiveness formula was constructed and evaluated. Measures of cost and effectiveness, sources of data, and availability of data were investigated.

Using the preliminary formula and methodology as a basis for the analysis, it was concluded that adequate measures of cost are available but that adequate measures of variable effectiveness have not yet been developed. Due to the complexity of the cost/effectiveness formula and methodology and to the lack of accessibility of input data, a large amount of time and money will be required to perform function allocation analyses. It was determined that the derivation of a cost/effectiveness formula for man/machine function allocation is feasible. At this time cost/effectiveness analysis seems applicable to most cases of function allocation and appears to offer a reliable method for the allocation of functions between men and machines.

On the basis of this research it was recommended that the structure and contents of a personnel cost data bank be delineated and that such a bank be established as soon as possible. Research should be conducted for the purpose of developing adequate variable effectiveness measures. An empirical test of the cost/effectiveness method of function allocation should be conducted in order to refine the formula and methodology and to demonstrate feasibility. Research should be conducted into other personnel research applications of cost/effectiveness.

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I. INTRODUCTION

A. Cost/Effectiveness

Cost/effectiveness analysis, a technique for the evaluation of alternative proposals, has become a useful tool for military planning and procurement. The cost/effectiveness approach is relevant to a large class of system analysis problems in which costs incurred and benefits derived cannot be measured in the same units.

Cost/effectiveness analyses have proved useful because: (a) they suggest an examination of alternative ways of attaining a given objective or goal; (b) they limit attention to appropriate objectives and relevant variables; (c) they require identification and quantification of these factors; and (d) they define the way in which the cost and effectiveness elements are assumed to interact. Properly used, they bring into focus not only costs, but the effects of cost changes, on mission effectiveness.

Cost/effectiveness analysis cannot replace judgement. Judgement is necessary in developing the quantitative values assigned to each element in the analysis, in determining which elements shall enter the analysis, and in how they shall enter. Cost/effectiveness analysis supplements judgement by inductive and numerical reasoning and insures that fully documented alternatives are compared to one another in a logical and consistent manner.

The identification, quantification, and systemization of cost/effectiveness analysis can add to the likelihood that the judgement decision is a good one. While the apparent precision of cost/effectiveness analysis sometimes leads to the danger of unwarranted confidence in the results (unwarranted because of inaccurate or incomplete inputs or because of erroneous analyses), it must be pointed out that this same danger, plus others, exist in all approaches.

The use of cost/effectiveness methodology involves two roles: that of the analyst, and that of the decision maker. In actual practice, these roles may be fulfilled by one person or by a team of individuals. The function of the analyst is to provide the decision maker with feasible alternatives and the information concerning the cost and effectiveness of each.

An effective analysis is a combination of theory, procedures, and data. Essential to effective analysis is an understanding of the physical characteristics of the system, the equipment within the system, the support equipment, the maintenance plan, the interactions between men and machines within the system, and the effects of enemy action and technology. Cost elements must be identified and definitions standardized. Effectiveness elements must be identified from operational considerations and quantified. The method of cost/effectiveness analysis must present the decision maker with data clearly descriptive of the true relationships between cost and effectiveness within each proposal and between alternative proposals.

Frequently the decision maker is presented with a cost/effectiveness ratio. This approach may lead to a distortion of the true situation since ratio criteria tend to ignore the absolute magnitude of the numerator and denominator. For instance, the cost/effectiveness ratio is the same if the cost is $5,000 and the effectiveness .3 or if the cost is $15,000 and the effectiveness .9. The cost/effectiveness ratio will not necessarily result in selecting the "correct" alternative unless the level of either cost or effectiveness is held fixed and the level of cost or effectiveness is the same for each alternative being compared. If the cost for all alternatives is identical, it is just as simple to designate the proposal with the highest effectiveness as best. Conversely, if the effectiveness values are identical the proposal with the lowest cost is best. While cost/effectiveness ratios should not be used as criteria, presenting ratios as part of data analysis may assist the decision maker. Several types of ratios may be useful; the ratio of total cost to total effectiveness within each system, or incremental cost/effectiveness ratios within each system. In any case, all absolute values should be presented along with the ratios.

Often the analyst has either a fixed budget constraint or a fixed effectiveness requirement. In either case the selection of a schedule of acceptable alternatives is greatly simplified. When a fixed cost requirement is imposed, the analyst selects those alternatives which cost less than the budgeted amount. With fixed effectiveness the analyst selects those alternatives which exceed a minimum amount of effectiveness.

In other cases the analyst must assume a range of levels of cost and effectiveness which might be acceptable to the decision maker. By selecting those proposals that fall within the "joint set" of acceptable cost and acceptable effectiveness, the analyst determines which alternatives should be considered.

There are several ways in which cost/effectiveness analysis may be applied to personnel research and human engineering. Personnel planners may eventually use cost/effectiveness analysis to reach manning decisions, to determine the most effective use of incentives for personnel retention, and to select the most effective and the least costly training methods. The cost/effectiveness method may also be applied to the allocation of functions in complex man/machine systems and it is to this last application that this research is primarily directed.

B. Purpose

This study was conducted in an attempt to meet the Navy's need for improved methods of assigning functions to men, machines, or man/machine combinations in new systems under development. The specific purpose was to determine the feasibility of developing a cost/effectiveness formula and methodology for the allocation of functions at an early point in the system development cycle.

C. Scope of Report

This report presents a series of research conclusions and recommendations which relate to the feasibility of developing and employing a cost/effectiveness method for reaching more rational function allocation decisions.

The preliminary formulae and methodology presented here were constructed for the evaluation of feasibility and will require refinement before they may be used in actual application.

The conclusions and recommendations in this report are intended to advise system designers of the possibility of using cost/effectiveness methods for function allocation and to delineate the need for the further development of this method as a tool for personnel research and engineering design.

D. Research Approach

This research began with a review of cost, effectiveness, and function allocation literature. Numerous workers in the areas of cost/effectiveness, human factors, personnel research, and equipment design were interviewed to discern the relevant variables in the application of cost/effectiveness techniques to man/machine function allocation. A preliminary formula and

methodology were constructed for the purpose of determining the feasibility of refining and utilizing such a method. The feasibility of deriving a cost/effectiveness formula was evaluated with respect to the following criteria:

1. Will the technique result in reliable function allocation decisions?

2. Is the technique applicable in most cases?

3. Will the formula be easily computed?

4. Is the necessary data readily available?

5. Will the time required to employ this technique be burdensome to the user?

6. Are adequate measures of both cost and effectiveness available at this time or must they be developed?

7. Is the use of a cost/effectiveness method for function allocation itself justified from a cost/effectiveness standpoint?

E. Background

1. Function Allocation

Function allocation is the process by which work is assigned to men or machines or combinations of men and machines. A function in a system is defined as any human or automated process, or combination of the two, that contributes to the satisfaction of a system's performance requirements. When functions are being evaluated by an allocation decision maker, any level of task or job may be considered.

An early approach to the problem of function allocation assumed that men and machines were comparable and, in general, that men are flexible but cannot be depended upon to perform in a consistent manner, whereas machines can be depended upon to perform consistently but they have no flexibility whatsoever. This method was established by P. M. Fitts (37) and utilized a list of the ways in which man is superior to machine and vice versa. From the information contained in a list of this type either a man or a machine is assigned to a given function. Unfortunately, assigning functions in this way is cumbersome, does not contribute to present methods of system design and evaluation, and the lists are quickly outdated by new technological developments.

Recently researchers have begun to look for complementary uses of men and machines in systems. The designer must know if the available components meet the system's requirements, how much they cost, weigh, and how long they last. The central issue in choosing components (including man) to do a job in a complex system is usually not so much which component will do a better job, as which component will do an adequate job for less money, less weight, less power, or with a smaller probability of failure and with less maintenance required. The object of the careful allocation of functions is to improve the overall performance of the system and to minimize cost.

There is an urgent need for improved methods of assigning functions which will be compatible with modern engineering decision making. Present methods of equipment design require that any decision making method be quantified, easily employed, and consistently reliable. The alternative proposal which is selected must be as effective as possible for as low a cost as possible.

2. The Concept of Using Cost/Effectiveness for Function Allocation

The answers to some of the problems of function assignment lie in the development of new methods through research and empirical testing. The concept of using a cost/effectiveness method seemed to have the potential of meeting the needs of equipment designers. This method can quantify the function allocation problem with respect to both cost and effectiveness and provide a consistent method of decision making. It has the potential of providing system designers with a method which will be easily employed and which will result in reliable, quantifiable decisions. In addition to meeting system designers' requirements, this method calls attention to personnel constraints at an early stage of system development which could eliminate many of the personnel problems often designed into a system and could lead to more efficient use of personnel in man/machine systems.

II. PROCEDURE

In order to evaluate the feasibility of developing a cost/effectiveness formula for function allocation, a preliminary formula and methodology were constructed. These were used to identify the important cost/effectiveness variables and their availability to the user as well as to validate the general applicability of the technique.

In the general description of cost/effectiveness given earlier in this report, the disadvantages of cost/effectiveness ratios were discussed. If a single general ratio formula were presented for cost/effectiveness evaluations, the user could draw the mistaken conclusion that the use of a ratio evaluation is recommended. Due to the disadvantages of the ratio approach, independent formulae will be presented for cost and effectiveness. The following formula and methodology are recommended for use when functions are being costed. In order to facilitate visualization of the formula as it is derived, a fold-out diagram has been provided in Appendix A. The completely derived cost formula is presented in Appendix B.

A. Cost

The following guidelines are strongly recommended to ensure a uniform costing procedure. Equipment and personnel costs should be carefully separated and costed by the procedures outlined below:

1. Costing should be performed for the predicted lifetime of the system. The lifetime of the system should be predicted as accurately as possible before the cost analysis is undertaken.

2. Only those cost elements which contribute significantly to the total cost of either equipment or personnel should be incorporated in the costing procedures.

3. Analysts should ensure consistency and comparability of cost elements when function allocation alternatives are being costed.

4. Costs invested prior to the inception of a program or those invested primarily in relation to another project, sunk costs, should be carefully separated from current costs related directly to the project.

5. Care should be taken to include only those costs which are pertinent to the particular function allocation cost/effectiveness trade off.

6. Fixed costs should be differentiated from recurring costs in order to avoid duplication.

7. Costing procedures should be well documented and reviewed before final decisions are confirmed.

8. Areas of uncertainty, where assumptions and estimates have been made in the costing procedure, should be delineated.

9. Cost analyses should remain dynamic, reflecting changes in the system design as these changes occur, throughout the development of the system.

10. Since the overall reliability of total cost is derived from the reliability of input costs, the analyst must evaluate the sources and methods of computation of input data for the guidance of the decision maker.

The user of the preliminary cost formula presented here should note that this model is limited to the most function-related costs. Certain costs, such as those attributable to G. I. Bill benefits, though important in long range and large scale planning, have been deliberately excluded since sources of data may not be available or the cost may not be significant at the function level. Certain support and logistic elements of overall costs are also excluded since they cannot be isolated at the function level.

The general formula for the cost of a given function is:

$$C_{EQ} + C_{PERS} = C_{FUNCTION}$$

Where:

C_{EQ} = Total equipment cost

C_{PERS} = Total personnel cost

$C_{FUNCTION}$ = Total function cost

1. Equipment Costs

The Cost and Economic Information System (CEIS), now being developed within the Department of Defense, will upgrade the

capability of analyzing actual and estimated costs in the acquisition of current and future weapons systems. It will encompass all Navy Department effort that relates to cost and economic information. Unfortunately, CEIS includes only the costs which relate to equipment. Further, costs included are often gross estimates designed for the costing of military operations and therefore not sufficiently detailed for utilization at the function level.

In the costing of any function, certain problems arise which are specific to that function. In these cases special costing technques may be required or additional variables may require consideration. For these reasons neither detailed equipment costing procedures nor equipment cost elements are presented within this report. It is recommended that the users of this function allocation methodology acquire the services of a qualified cost analyst who can compute the equipment costs involved in fulfilling the function under consideration. In any case, however, it is essential that all costing be performed in accordance with the general guidelines outlined in this section (pages 7 and 8).

2. Personnel Costs

Personnel costs are calculated with respect to several assumptions: All personnel involved in completing the function are included in the costing. The cost is prorated with respect to the personnel time devoted to the performance of the function under consideration. Personnel cost is calculated from the beginning of service through the point in the man's career when duty with the function is completed. Personnel researchers should conduct the personnel cost analysis since a detailed knowledge of personnel factors is often required.

The question, "How should the total cost of a man's services be divided among the systems of which he is a component during his Naval career?" remains a problem in assigning the appropriate cost of a man to a particular function. This problem has not been approached in this study, but must be resolved through further research before personnel costs attributed to any function are meaningful.

The total personnel cost may be derived as follows for any function:

$$C_{PERS} = \sum_{i=1}^{N} M_i$$

Where:

C_{PERS} = The total personnel cost for the lifetime of the system.

M = The cost of one man in the function by his rate/rating.

$$M = (I_{PR})(T_{\%})(R)$$

$$I_{PR} = \frac{L_S}{D}$$

Where:

I_{PR} = Index of personnel replacement

L_S = Lifetime of the system in years

D = Duty time with the function in years

$T_{\%}$ = The percentage of the man's working time required by the function

R = The cost of a particular rate/rating through the end of duty time with the function

Duty time with a particular function may be calculated from sea and shore duty times for the rating involved. Depending upon the probable physical location of the job (sea or shore), the appropriate duty time for the rating is taken directly from the length of duty tables. The percentage of working time of a particular rate/rating which is spent performing, or supporting the performance of a given function (such as maintenance time) should be determined by personnel researchers, as should the rates to be assigned.

The cost of a particular rate/rating may be calculated by the following formulae. The costing methods employed in the formulae have been derived from those used in previous personnel cost studies (5, 63).

The major elements involved in rate/rating (R) costs are presented below. "R" is a percapita cost when calculated by the following method:

$$R = P + T' + A + T'' + G$$

Where:

R = The cost of using a particular rate/rating

P = Total procurement cost per man

T' = Training cost through the end of duty time with the function per man

A = Pay and allowances through the end of duty time with the function per man

T" = Transportation cost through the end of duty time with the function per man

G = General support cost per man

a. Procurement. Procurement cost represents all cost elements that are paid by the Navy from the first contact with a prospective enlistee until the oath of enlistment is administered to him at the recruiting station.

$$P = p + r + v$$

$$r = \frac{r_t}{N_e}$$

$$v = \frac{(N_V)(V_{AR})}{N_e}$$

Where:

p = Basic per capita procurement cost

r = Per capita rental cost of buildings used in procurement

r_t = Total cost of rentals used in procurement

N_e = Number of enlistments

v = Per capita vehicle amortization cost due to procurement

N_v = Number of vehicles used in recruiting

V_{AR} = Vehicle amortization rate in dollars per vehicle

b. Training (T'). The accurate calculation of training costs is basic to total personnel cost accuracy. Training cost is the major element in personnel cost and is the source of most of the variation in costs between ratings. The official training requirements for a new system are established in a training plans conference (TPC). The TPC decisions are usually supported by personnel and training recommendations, developed through predictive personnel research.

Occasionally the same training is offered at several locations. Weighted averages should be used when determining the cost of any training program where two or more schools give the same training, since the schools may differ in costs and in student output.

The training costs used in these calculations should be computed from data which excludes student pay and allowances since these are included in another part of the formula. The only exceptions to this rule are the aviation ratings for which student pay and allowances are included in training costs.

Presently, training costs are reported through two separate systems. Aviation training cost reports are controlled by the Chief of Naval Operations (OPNAV) and include training cost plus building and equipment depreciation and student pay and allowances. Training costs for all other ratings exclude pay and allowances, building depreciation, and equipment depreciation. The latter training costs are reported by the Bureau of Naval Personnel (BUPERS).

Due to the different reporting systems, calculations are facilitated if pay and allowances are calculated from entry into service to end of duty with the function for all ratings except the aviation ratings. For all aviation ratings, pay and allowances should be calculated for the time not spent in aviation training from entry into service through the end of duty with the function. For example, pay and allowances should be calculated for the time spend in recruit training since this is reported by BUPERS and does not include student pay and allowances.

Equipment depreciation cost is currently included in OPNAV costs but not in BUPERS costs. In his training Equipment and Building Amortization Study (45), Burton J. Goodyear shows that equipment depreciation costs are highly variable between schools, ranging from 0.6% to 68.0% of the total per capita training cost. Therefore, equipment cost must be considered an important and significant variable, and must be included in any meaningful cost estimate. In order to obtain more complete BUPERS training cost estimates, equipment depreciation costs should be included with those costs presently compiled by BUPERS.

In Goodyear's study (45, page 8) building depreciation costs were also examined. Most building depreciation costs were too insignificant to warrant inclusion in training costs. Therefore, it would prove highly uneconomical for BUPERS to attempt to include building depreciation in training costs. For the purposes of function allocation, building costs may be accounted as "sunk" costs which cannot be charged to an individual rating or system.

It is therefore recommended that aviation training costs be taken directly from the Naval Air Technical Training Command's Cost Per Student Report (66). As has been noted, building depreciation costs are now included in aviation training costs but not in BUPERS training costs. Building depreciation costs are statistically not significant, and therefore their inclusion in or exclusion from the cost of training should not affect training cost computations significantly. Furthermore, should building depreciation cost data be included in BUPERS training costs, no modification of the cost model will be required.

An important unlisted difference between ratings is the cost of on-the-job training (OJT). It is not yet possible to quantify the costs involved in OJT. However, since more OJT is required for the more complicated jobs the cost varies greatly between ratings.

Per capita training cost may be calculated from the following formula:

$$T' = \sum_{i=1}^{N} C_{Si}$$

Where:

T' = The total cost/student of all training

C_S = The cost/student of a specific school attended

$$C_S = N_W C_{SW} + C_{Eq}$$

$$C_{SW} = \frac{C_T}{N_{SW}}$$

$$C_{Eq} = (E_{SW})(N_W)$$

$$E_{SW} = \frac{C_{AE}}{N_{SW}}$$

$$C_{AE} = \frac{E_T}{L_{TEq}}$$

Where:

N_W = The catalogue length of course in weeks

or

The weighted average length of course in weeks, when the same course is offered in two or more locations and the length of course differs between the locations.

C_{SW} = The cost/student week

or

The weighted average cost/student week, when the same course is offered in two or more locations and the cost/student week differs between the locations.

C_T = The total annual cost of a specific school, less student pay and allowances.

N_{SW} = Number of student weeks per year reported for the specific school

C_{Eq} = The per capita cost of equipment for a specific school

E_{SW} = Equipment cost/student week

C_{AE} = Annual equipment cost

E_T = Total school equipment cost

L_{TEq} = Estimated lifetime of training equipment

When several schools offer the same course, weighted averages of the length of training and the cost/student week become necessary. In order to calculate weighted averages for training formula inputs, the following formulae may be used. The inputs to these formulae are defined immediately above.

$$N_W = \frac{N_{W1}N_{SW1} + N_{W_2}N_{SW_2}}{N_{SW_1} + N_{SW_2}}$$

$$C_{SW} = \frac{C_{SW_1}N_{SW_1} + C_{SW_2}N_{SW_2}}{N_{SW_1} + N_{SW_2}}$$

Often personnel researchers recommend that a new course be constructed. In order to estimate the per capita cost of such a course, the following formula is proposed:

$$C_{ES} = N_{EW}C_{ESW} + C_{EEq}$$

Where:

C_{ES} = Estimated per capita cost of a recommended course

N_{EW} = Recommended number of weeks in the proposed course

C_{ESW} = Average cost/student week of similar school already established, without equipment depreciation costs.

C_{EEq} = The estimated per capita cost of training equipment

$$C_{EEq} = \frac{E_{ET}}{O_T}$$

$$E_{ET} = (E)(N_{Eq})$$

$$O_T = (N_S)(N_M)(I_{PRS})$$

$$I_{PRS} = \frac{L_{SU}}{D}$$

Where:

E_{ET} = The estimated total cost of training equipment

O_T = Total student output of a course during the time the system is in use

E = The estimated cost of one piece of training equipment

N_{Eq} = The number of pieces of training equipment required during the time the system is in use

N_S = The number of systems required by the Navy during the time the system is in use

N_M = The number of men per system who will take the course

I_{PRS} = Index of student personnel replacement for schools

L_{SU} = Estimated time the system will be in use

D = Duty time with the system

c. Pay and Allowances (A). The amount of pay and allowances received by any enlisted man is based upon pay grade, duty location (sea or shore), and type of duty. In order to calculate the pay and allowances for a given rate/rating, one must know the average time in grade for the rating being considered and the pay and allowance regulations which are applicable in the particular case. Pay and allowances should be costed through the end of duty with the function.

$$A = \sum_{i=1}^{N} (N_{yr} r_{CA}) + I + P_{SF} + P_H + P_P + B_T$$

Where:

A = The total pay and allowance cost of a man through the point of his replacement in the function

N_{yr} = The average number of years in a pay grade for the rating being costed

r_C = The monthly military compensation including basic pay, quarters, subsistence, maintenance clothing allowance, and Federal Insurance Contributions Act (FICA)

r_{CA} = The annual military compensation including basic pay, quarters, subsistence, maintenance clothing allowance, and Federal Insurance Contributions Act (FICA)

I = Initial clothing allowance

P_{SF} = Total sea and foreign duty pay

P_H = Total hazardous duty pay

P_P = Total proficiency pay

B_T = Total re-enlistment bonus

$$P_{SF} = \sum_{i=1}^{N} (r_{SF} N_m) i$$

Where:

N_m = The number of months qualifying while holding a particular pay grade

r_{SF} = The rate of sea or foreign duty pay for a particular pay grade

$$P_H = \sum_{i=1}^{N} (r_H N_m) i$$

Where:

N_m = The number of months qualifying while holding a particular pay grade

r_H = The rate of hazardous duty pay for individual pay grade

$$P_P = \sum_{i=1}^{N} (r_{PP} N_m) i$$

Where:

N_m = The number of months in which the man qualifies for proficiency pay

r_{PP} = The rate of proficiency pay for the individual rating or NEC

$$B = \sum_{i=1}^{N} (N_y B_{\%} r_p) i$$

$$B_V = (N_y B_{\%} r_p)(m)$$

$$B_T = B + B_V$$

Where:

N_y = Number of years for which a man reenlists at any particular time. Not to include any years beyond the end of duty with the function.

$B_{\%}$ = Percentage of pay given as a bonus for the specific reenlistment.

r_p = The monthly amount of pay at time of reenlistment

B_V = The Variable Reenlistment Bonus (VRB) (applies to certain ratings only and may be applied only to the first reenlistment)

B_T = The total amount of reenlistment bonus paid to any single man

m = The VRB multiple which applies to a given rating

d. Transportation (T"). The Navy's cost of transporting a man may be calculated by the following formula.

$$T'' = \frac{t_a + t_d + t_o + t_r + t_s + t_{ou}}{N_{aes}}$$

Where:

T" = Total transportation costs through the end of duty with the function

t_a = Accession travel (Recruiting Station to Recruit Training Center)

t_d = Travel from training center to first duty station

t_o = Operational move, within the United States

t_r = Rotational move, outside the United States

t_s = Separation travel

t_{ou} = Travel of organized units

N_{aes} = Average enlisted strength (as estimated by Pers-H111)

e. General (G). General support cost includes separation costs, medical costs, retirement allocation, and other personnel costs.

$$G = S' + M_d + R_{RA} + O_{PC}$$

$$N_{tt} = N_{tu} + N_{ts} + N_{tg}$$

$$S' = \frac{(u)(N_{tu}) + (s)(N_{ts}) + (g)(N_{tg})}{N_{tt}}$$

$$C_R = (A_P)(P_N)$$

$$R_{\%} = \frac{N_{RtR}}{N_{Rt}}$$

$$C_{RR} = (C_R)(R_{\%})$$

$$R_{RA} = \frac{C_{RR}}{N_R}$$

$$O_{PC} = o_a + o_i + o_d + o_l$$

Where:

G = General costs

S' = Estimated separation cost per man

u = Rate of lump sum terminal leave (unused leave)

s = Rate of severance pay (disability)

g = Rate of authorized donations (discharge gratuities)

N_{tt} = Total number terminating

N_{tu} = Number terminating with lump sum terminal leave

N_{ts} = Number terminating with severance pay

N_{tg} = Number terminating with discharge gratuities

M_d = Total medical cost

C_R = The cost of the Navy's retirement system

A_P = Actuarial percentage for retirement system cost

P_N = Total Navy pay

$R_{\%}$ = The percentage of those retiring who are from a given rating

N_{RtR} = Number retiring from the rating (annually)

N_{Rt} = Total number retiring from the Navy

C_{RR} = Cost of retirement for a given rating

N_R = Number in the rating

R_{RA} = Per capita rating retirement allocation

O_{PC} = Other military personnel costs

o_a = Cost of apprehension of military deserters, absentees, and escaped military prisoners

o_i = Cost of interest on enlisted personnel deposits

o_d = Cost of death gratuities

o_l = Cost of servicemen's group life insurance

3. Utilizing the Cost Formula

The formulae presented in Section II were derived for the purpose of assessing the availability of cost input data and evaluating the problems associated with a general cost/effectiveness formula. In order to assess the availability of input data for the elements in the formulae, the Personnel Cost Element Source Table, Appendix E, was developed.

All of the elements in the personnel cost formula are listed in Appendix E. For each element the following information is given:

SOURCE: The document in which the value of the element is found, or the operations which are required to attain the value of the element (estimation or computation).

FORM OF INPUT DATA: The form of the data which is used to compute or to estimate the value of the element.

USABILITY OF INPUT DATA: The processing required by the input data before it may be used to compute the value of the element.

AVAILABILITY OF DOCUMENTS AND DATA: The availability of reference documents in which the values of cost elements are listed.

INPUTS UPDATED: The frequency of revision of cost reference documents.

ELEMENT AVAILABILITY: The general availability of the element, the feasibility of computing the value of the element as determined by the available data and the requirements of the formula.

COMMENTS: Additional facts about the element.

An analysis of the data in Appendix E reveals several characteristics concerning the availability of cost formula elements. These are summarized below in Table 1. For example, Table 1 shows that all elements except three may be computed with presently available data.

Feasibility of the development and use of a personnel cost formula is indicated from the information in Appendix E and Table 1. Preliminary personnel cost formula, a general costing methodology and cost data are available.

The formula presented is a preliminary model, which will require further development, testing, and evaluation before application as a decision making methodology.

From the information condensed in Table 1, it quickly becomes apparent that the data inputs to this formula are difficult to acquire and to compute. The use of the formula is time-consuming and its use by individuals working independently of one another would result in a vast duplication of effort. Parts of the cost data become obsolete quickly and items are updated at differing rates. Therefore, derived overall personnel cost figures quickly become "dated". However, if the data were stored in a personnel cost data bank and storage and retrieval methods were well structured, these problems could be alleviated. Desired costs for many types of personnel problems could then be readily retrieved. A greater variety of costs would also be available, from one official source of cost information. Efforts of individual researchers would not be wasted in repetitious data gathering and computation, and the cost estimate used in cost/effectiveness evaluations would be correct, valid, timely and easy to obtain. Finally, the cost/effectiveness evaluations would be less costly if an automated costing system were instituted.

B. Effectiveness

When the feasibility of deriving a general effectiveness formula for use in function allocation cost/effectiveness trade offs was investigated, a lack of adequate effectiveness measures, effectiveness criteria, and human effectiveness data was discovered. This dearth of information made a variable effectiveness model infeasible at this time. A "fixed effectiveness" model was then considered. The fixed effectiveness model provided a practical approach to the problem of effectiveness measurement in personnel cost/effectiveness trade offs which may be used at the present time. Instead of determining effectiveness by a set of predetermined interrelated

TABLE 1

A Summary of the Availability of the Inputs to the Preliminary Personnel Cost Formula

Classification of Element	Number in Each Class
Source:	
Reference document	36
Computation	36
Estimation	12
Office source	10
No source	1
Availability of documents and data:	
N/A	46
Personal contact required	24
Distribution list	13
Personal contact required initially	6
Restricted or classified	2
Personal contact and need to know required	2
Professional judgement and knowledge	1
Not available at the present time since these data are not centrally recorded	1
Form of input data:	
Tabled value	36
Other elements	28
Stated value	11
Professional evaluation and/or information	7
Other elements and additional personnel information	7
Other elements and additional data	3
Personnel data required	1
Additional data	1
N/A	1
Usability of input data:	
May be used directly	55
Computation required	26
N/A	13
Judgements required	1
Inputs updated:	
N/A	50
Annually	33
As necessary	8
Triannually	2
Semiannually	2
Element availability:	
May be acquired	45
May be computed	32
May be estimated	12
May not be computed	3
May not be computed as required by the formula	2
May not be acquired	1
Comments:	
Comment made	9
N/A	86

effectiveness measures, the user defines effectiveness in relation to the particular problem being considered and establishes effectiveness criteria on the basis of his needs. For instance, the level of fixed effectiveness may be defined as "the ability to perform a given function to a minimum degree of satisfaction". This does not take into account any variations in effectiveness beyond the minimum requirement of being able to perform the functions. Alternatives of approximately equivalent effectiveness or alternatives which supersede a fixed effectiveness criterion may be traded off on the basis of cost, using a refined model of the costing methodology derived in Section II. A. of this report.

This method of criterion establishment gives the effectiveness methodology more flexibility and permits its application to other personnel research and human factors problems. Since the effectiveness measure is freely defined, it may be related to personnel retention, performance of a task, or the completeness and applicability of training. Thus the researcher can use a cost/effectiveness methodology in solving problems where alternative options for system manning, incentives for personnel retention, or training methods, are traded off, as well as applying the methodology to the original problem of function allocation. However, since the cost model in this report is adapted to function allocation, it is not directly applicable to all possible personnel cost/effectiveness trade offs. The model must be specifically refined and adapted to use with each type of problem.

In the future, variable effectiveness models should be utilized as they are developed. These models may soon be possible for manning, training, and personnel retention trade offs. However, a variable effectiveness model for function allocation will be more difficult to derive, since an overall effectiveness model for man/machine systems must take into account many more complex variables than those involved in personnel effectiveness or in equipment effectiveness. Even under the most favorable conditions where human effectiveness data or equipment effectiveness data may be available, there is, at present, no known way to combine the information into a meaningful effectiveness measure. Investigation of the feasibility of developing adequate effectiveness measures is presently underway at the U. S. Naval Personnel Research Activity in San Diego. The results of this study may eventually be applied in a cost/effectiveness model for man/machine function allocation.

III. CONCLUSIONS AND RECOMMENDATIONS

It is concluded that:

1. Cost/effectiveness analysis seems to offer a reliable method for most cases of allocating functions between men and machines.

2. The cost/effectiveness technique might be applicable to the solution of many personnel research problems.

3. Adequate cost measures and cost data are available although some elements are difficult to acquire.

4. A personnel cost data bank is needed immediately in order to facilitate the computation of personnel costs.

5. Variable effectiveness measures which might be used in a cost/effectiveness function allocation trade off are not available at this time. The cost/effectiveness method of function allocation may be employed if fixed effectiveness measures are used, and effectiveness criteria are specified by the user.

6. It is feasible to derive a cost/effectiveness formula for man/machine function allocation.

On the basis of this research, the following recommendations are made:

1. An empirical test of the cost/effectiveness method of function allocation should be conducted.

2. Research should be conducted to develop the structure and content requirements for a personnel cost data bank, which should be established as soon as possible.

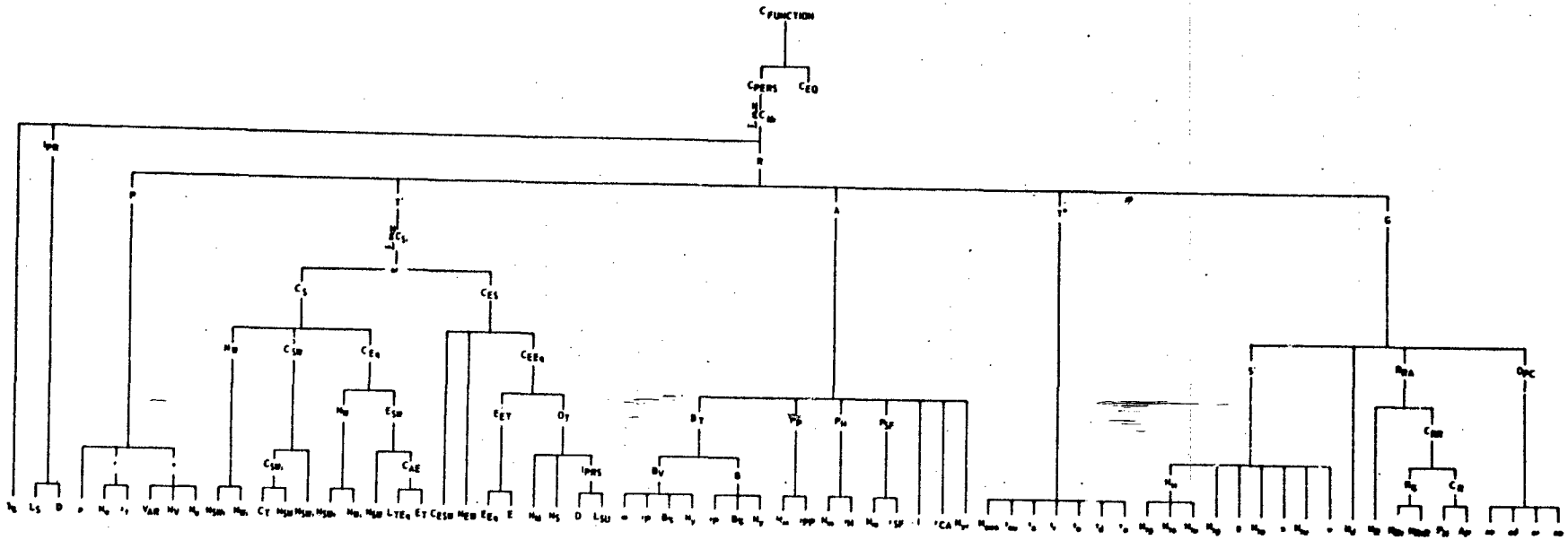
3. Research should be conducted for the purpose of developing adequate variable effectiveness measures.

4. The cost/effectiveness method of function allocation should not be generally implemented until its feasibility has been established by empirical testing of the method and the formulae and methodology presented here have been refined.

5. The feasibility of utilizing cost/effectiveness as a basis for manning decisions, evaluating incentives for personnel retention and for evaluating alternative training programs should be investigated.

APPENDIX A

BRANCHING MODEL OF THE COST FORMULA



APPENDIX A - BRANCHING MODEL OF THE COST FORMULA

APPENDIX B

DERIVATION OF COST FORMULA FOR COST/EFFECTIVENESS FUNCTION ALLOCATION DECISIONS

APPENDIX B

DERIVATION OF COST FORMULA FOR COST/EFFECTIVENESS FUNCTION ALLOCATION DECISIONS

$$C_{FUNCTION} = C_{EQ} + C_{PERS}$$

$$C_{PERS} = \sum_{i=1}^{N} M_i$$

$$M = (I_{PR})(T_{\%})(R)$$

$$I_{PR} = \frac{L_S}{D}$$

$$R = P + T' + A + T'' + G$$

$$P = p + r + v$$

$$r = \frac{r_t}{N_e}$$

$$v = \frac{(N_V)(V_{AR})}{N_e}$$

$$T' = \sum_{i=1}^{N} C_{Si}$$

$$C_S = N_W C_{SW} + C_{Eq}$$

$$C_{SW} = \frac{C_T}{N_{SW}}$$

$$C_{Eq} = (E_{SW})(N_W)$$

$$E_{SW} = \frac{C_{AE}}{N_{SW}}$$

$$C_{AE} = \frac{E_T}{L_{TEq}}$$

$$N_W = \frac{N_{W_1} N_{SW_1} + N_{W_2} N_{SW_2}}{N_{SW_1} + N_{SW_2}}$$

$$C_{SW} = \frac{C_{SW_1} N_{SW_1} + C_{SW_2} N_{SW_2}}{N_{SW_1} + N_{SW_2}}$$

$$C_{ES} = N_{EW} C_{ESW} + C_{EEq}$$

$$C_{EEq} = \frac{E_{ET}}{O_T}$$

$$E_{ET} = (E)(N_{Eq})$$

$$O_T = (N_S)(N_M)(I_{PRS})$$

$$I_{PRS} = \frac{L_{SU}}{D}$$

$$A = \sum_{i=1}^{N} (N_{yr} r_{CA})_i + I + P_{SF} + P_H + P_P + B_T$$

$$P_{SF} = \sum_{i=1}^{N} (r_{SF} N_m)i$$

$$P_H = \sum_{i=1}^{N} (r_H N_m)i$$

$$P_P = \sum_{i=1}^{N} (r_{PP} N_m)i$$

$$B = \sum_{i=1}^{N} (N_y B_{\%} r_p)i$$

$$B_V = (N_y B_{\%} r_p)(m)$$

$$B_T = B + B_V$$

$$T'' = \frac{t_a + t_d + t_o + t_r + t_s + t_{ou}}{N_{aes}}$$

$$G = S' + M_d + R_{RA} + O_{PC}$$

$$N_{tt} = N_{tu} + N_{ts} + N_{tg}$$

$$S' = \frac{(u)(N_{tu}) + (s)(N_{ts}) +)g)(N_{tg})}{N_{tt}}$$

$$C_R = (A_p)(P_N)$$

$$R_{\%} = \frac{N_{RtR}}{N_{Rt}}$$

$$C_{RR} = (C_R)(R_{\%})$$

$$R_{RA} = \frac{C_{RR}}{N_R}$$

$$O_{PC} = o_a + o_i + o_d + o_l$$

APPENDIX C

INDEX OF SYMBOLS
(DERIVED ORDER)

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APPENDIX C

INDEX OF SYMBOLS
(DERIVED ORDER)

$C_{FUNCTION}$	Total Function Cost
C_{EQ}	Total Equipment Cost
C_{PERS}	Total Personnel Cost for the lifetime of the system
M	The cost of one man in the function by his rate/rating
I_{PR}	Index of personnel replacement
L_S	Lifetime of the system in years
D	Duty time with the function in years
$T_{\%}$	The percentage of the man's working time required by the function
R	The cost of a particular rate/rating through the end of duty time with the function
P	Total Procurement Cost
T'	Training cost through the end of duty time with the function
A	Pay and Allowances through the end of duty time with the function
T''	Transportation cost through the end of duty time with the function
G	General support cost
p	Basic per capita procurement cost
r	Per capita rental cost of buildings used in procurement

r_t	Total cost of rentals used in procurement
N_e	Number of enlistments
v	Per capita vehicle amortization cost due to procurement
N_V	Number of vehicles used in recruiting
V_{AR}	Vehicle amortization rate in dollars per vehicle
C_S	The cost/student of a specific school attended
N_W	The catalogue length of course in weeks, or the weighted average length of course in weeks, when the same course is offered in two or more locations and the length of course differs between the locations
C_{SW}	The cost/student week or the weighted average cost/student week, when the same course is offered in two or more locations and the cost/student week differs between the locations
C_T	The total annual cost of a specific school, less student pay and allowances
N_{SW}	Number of student weeks per year reported for the specific school
C_{Eq}	The per capita cost of equipment for a specific school
E_{SW}	Equipment cost/student week
C_{AE}	Annual equipment cost
E_T	Total school equipment cost
L_{TEq}	Estimated lifetime of training equipment

C_{ES}	Estimated per capita cost of a recommended course
N_{EW}	Recommended number of weeks in the proposed course
C_{ESW}	Average cost/student week of similar schools already established, less equipment depreciation costs
C_{EEq}	The estimated per capita cost of training equipment
E_{ET}	The estimated total cost of training equipment
O_T	Total student output of a course during the time the system is in use
E	The estimated cost of one piece of training equipment
N_{Eq}	The number of pieces of training equipment required during the time the system is in use
N_S	The number of systems required by the Navy during the time the system is in use
N_M	The number of men per system who will take the course
I_{PRS}	Index of personnel replacement for schools
L_{SU}	Estimated time the system will be in use
N_{yr}	The average number of years in a pay grade for the rating being costed
N_m	The number of months a man qualifies for a type of pay
r_C	The monthly military compensation including basic pay, quarters, subsistence, maintenance clothing allowance, and Federal Insurance Contributions Act (FICA)

r_{CA}	The annual military compensation including basic pay, quarters, subsistence, maintenance clothing allowance, and Federal Insurance Contributions Act (FICA)
I	Initial Clothing Allowance
N	The Nth case
i	Each individual case
P_{SF}	Total sea and foreign duty pay
P_H	Total hazardous duty pay
P_P	Total proficiency pay
r_{SF}	The rate of sea or foreign duty pay for a particular pay grade
r_H	The rate of hazardous duty pay for the individual pay rate
r_{PP}	The rate of proficiency pay for the individual rating or NEC
r_P	The monthly amount of pay at time of reenlistment
B	Sum of regular reenlistment bonus (this amount may not exceed $2,000)
B_V	The Variable Reenlistment Bonus (applies to certain ratings only and may be applied only to the first reenlistment)
B_T	The total amount of reenlistment bonus paid to a single man
m	The Variable Reenlistment Bonus multiple which applies to a given rating

N_y	Number of years for which a man reenlists at any particular time. Not to include any years beyond the end of duty with the function.
$B_{\%}$	The percentage of pay given as a bonus for the specific reenlistment
t_a	Accession travel (Recruiting Station to Recruit Training Center)
t_d	Travel from training center to first duty station
t_o	Operational move, within the United States
t_r	Rotational move, outside the United States
t_s	Separation travel
t_{ou}	Travel of organized units
N_{aes}	Average enlisted strength as estimated by Pers-H111
S'	Estimated separation cost per man
s	Rate of severance pay - disability
u	Rate of lump sum terminal leave ---- unused leave
g	Rate of authorized donations discharge gratuities
N_{tt}	Total number terminating
N_{tu}	Number terminating with lump sum terminal leave
N_{ts}	Number terminating with severance pay
N_{tg}	Number terminating with discharge gratuities
M_d	Total medical cost

C_R	The cost of the Navy's retirement system
A_P	Actuarial percentage for retirement system cost
P_N	Total Navy Pay
$R_{\%}$	The percentage of those retiring who are from a given rating
N_{RtR}	Number retiring from the rating (annually)
N_{Rt}	Total number retiring from the Navy
C_{RR}	Cost of retirement for a given rating
N_R	Number in the rating
R_{RA}	Per capita rating retirement allocation
O_{PC}	Other military personnel costs
o_a	Cost of apprehension of military deserters, absentees, and escaped military prisoners
o_i	Cost of interest on enlisted personnel deposits
o_d	Cost of death gratuities
o_l	Cost of servicemen's group life insurance

APPENDIX D

INDEX OF SYMBOLS
(ALPHABETICAL ORDER)

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APPENDIX D

INDEX OF SYMBOLS
(ALPHABETICAL ORDER)

A	Pay and allowances through the end of duty time with the function
A_P	Actuarial percentage for retirement system cost
B	Sum of regular reenlistment bonus (this amount may not exceed $2,000)
B_T	The total amount of reenlistment bonus paid to any single man
B_V	The Variable Reenlistment Bonus (applies to certain ratings only and may be applied only to the first reenlistment)
$B_\%$	The percentage of pay given as a bonus for the specific reenlistment
C_{AE}	Annual equipment cost
C_{EEq}	The estimated per capita cost of training equipment
C_{EQ}	Total equipment cost
C_{Eq}	The per capita cost of equipment for a specific school
C_{ES}	Estimated per capita cost of recommended course
C_{ESW}	Average cost/student week of similar schools already established, less equipment depreciation costs
$C_{FUNCTION}$	Total function cost
C_{PERS}	Total personnel cost
C_R	The cost of the Navy's retirement system

C_{RR}	Cost of retirement for a given rating
C_S	The cost/student of a specific school attended
C_{SW}	The cost/student week, or the weighted average cost/student week
C_T	The total annual cost of a specific school, less student pay and allowances
D	Duty time with the function or system in years
E	The estimated cost of one (1) piece of training equipment
E_{ET}	The estimated total cost of training equipment
E_{SW}	Equipment cost/student week
E_T	Total school equipment cost
G	General support cost
g	Rate of authorized donations discharge gratuities
I	Initial clothing allowance
i	Each individual case
I_{PR}	Index of personnel replacement
I_{PRS}	Index of personnel replacement for schools
L_S	Lifetime of the system in years
L_{SU}	Estimated time the system will be in use
L_{TEq}	Estimated lifetime of training equipment
M	The cost of one man in the function by his rate/rating

M_d	Total medical cost
m	The Variable Reenlistment Bonus multiple which applies to a given rating
N	The Nth case
N_{aes}	Average enlisted strength as estimated by Pers-H111
N_{Eq}	The number of pieces of training equipment required during the time the system is in use
N_{EW}	Recommended number of weeks in the proposed course
N_e	Number of enlistments
N_M	The number of men per system who will take the course
N_m	The average number of months in the pay grade for the rating being costed, or the number of months a man qualifies for a type of pay
N_R	Number in the rating
N_{Rt}	Total number retiring from the Navy
N_{RtR}	Number retiring from the rating (annually)
N_S	The number of systems required by the Navy during the time the system is in use
N_{SW}	Number of student weeks per year reported for the specific school
N_{tg}	Number terminating with discharge gratuities
N_{ts}	Number terminating with severance pay
N_{tt}	Total number terminating

N_{tu}	Number terminating with lump sum terminal leave
N_V	Number of vehicles used in recruiting
N_W	The catalogue length of course in weeks, or the weighted average length of course in weeks
N_y	Number of years of reenlistment at this particular time
N_{yr}	The average number of years in a pay grade for the rating being costed
O_{PC}	Other military personnel costs
O_T	Total student output of a course during the time the system is in use
o_a	Cost of apprehension of military deserters, absentees, and escaped military prisoners
o_d	Cost of death gratuities
o_i	Cost of interest on enlisted personnel deposits
o_l	Cost of servicemen's group life insurance
P	Total procurement cost
P_H	Total hazardous duty pay
P_N	Total Navy pay
P_P	Total proficiency pay
P_{SF}	Total sea and foreign duty pay
p	Basic per capita procurement cost

R	The cost of a particular rate/rating
R_{RA}	Per capita rating retirement allocation
$R_{\%}$	The percentage of those retiring who are from a given rating
r	Per capita rental cost of buildings used in procurement
r_C	The monthly military compensation rate
r_{CA}	The annual military compensation including basic pay, quarters, subsistence, maintenance clothing allowance, and Federal Insurance Contributions Act (FICA)
r_H	The rate of hazardous duty pay for the individual pay grade
r_P	The monthly rate of pay at the time of reenlistment
r_{PP}	The rate of proficiency pay for the individual pay grade
r_{SF}	The rate of sea or foreign duty pay for a particular pay grade
r_t	Total cost of rentals used in procurement
S'	Estimated separation cost per man
s	Rate of severance pay - disability
T'	Training cost through the end of duty time with the function
T''	Transportation cost through the end of duty time with the function
$T_{\%}$	The percentage of the man's working time required by the function

t_a	Accession travl (Recruiting station to Recruit training center)
t_d	Travel from training center to first duty station
t_o	Operational move, within the United States
t_{ou}	Travel of organized units
t_r	Rotational move, outside the United States
t_s	Separation travel
u	Rate of lump sum terminal leave ---- unused leave
V_{AR}	Vehicle amortization rate in dollars per vehicle
v	Per capita vehicle amortization cost due to procurement

APPENDIX E

PERSONNEL COST ELEMENT SOURCE TABLE

APPENDIX E

PERSONNEL COST ELEMENT SOURCE TABLE

ELEMENT	SOURCE OF ELEMENTS	AVAILABILITY OF DOCUMENTS AND DATA	FORM OF INPUT DATA	USABILITY OF INPUT DATA	INPUTS UPDATED	ELEMENT AVAILABILITY	COMMENTS
$C_{FUNCTION}$	Computation	N/A	Other cost elements. Additional data.	Computation required	N/A	May be computed	N/A
C_{EQ}	Computation	Restricted and/or classified	Other cost elements. Additional data.	Computation required	N/A	May be computed	To be computed by system cost analysts
C_{PERS}	Computation	N/A	Other cost elements. Additional personnel data.	Computation required	N/A	May be computed	N/A
M	Computation	N/A	Other cost elements. Additional personnel data.	Computation Required	N/A	May be computed	N/A
I_{PR}	Computation	N/A	Other elements	Judgments required	N/A	May be computed	N/A
L_S	Estimation by system engineers	Restricted data and professional knowledge	Additional data	N/A	N/A	May be estimated	N/A
D	Sea Duty: BUPERS NOTE 1306 Series	Distribution list	Tabled value	May be used directly	Triannually	May be acquired	N/A
	Shore Duty: The enlisted transfer manual NAVPERS 15909A, Memorandum correction #9, Chapter VII, Article 7.22	Distribution list	Tabled value	May be used directly	Semiannually	May be acquired	N/A
$T_{\%}$	Estimation by personnel researchers	N/A	Professional knowledge and additional data	N/A	N/A	May be estimated	N/A
R	Computation	N/A	Other cost elements. Additional data.	Computation required	N/A	May be computed	N/A
P	Computation	N/A	Other cost elements	Computation required	N/A	May be computed	N/A

APPENDIX E (continued)

ELEMENT	SOURCE OF ELEMENTS	AVAILABILITY OF DOCUMENTS AND DATA	FORM OF INPUT DATA	USABILITY OF INPUT DATA	INPUTS UPDATED	ELEMENT AVAILABILITY	COMMENTS
T'	Computation	N/A	Other cost elements	Computation required	N/A	May be computed without training equipment costs. May not be computed with training equipment costs.	Training equipment element not available
A	Computation	N/A	Other cost elements. Personnel data, additional information.	Computation required	N/A	May be computed	N/A
T"	Computation	N/A	Other cost elements. Additional personnel data.	Computation required	N/A	May be computed	N/A
G	Computation	N/A	Other cost elements. Additional personnel data.	Computation required	N/A	May be computed	N/A
p	DD Form 804 Enlisted Personnel Procurement and Processing Report	N/A	Tabled value	May be used directly	Annually	May be acquired	N/A
r	Computation	N/A	Other elements	May be used directly	N/A	May be computed	N/A
r_t	BUPERS, Pers-B61, Recruiting Administration Branch	Personal contact required	Stated value	May be used directly	Annually	May be acquired	N/A
N_e	BUPERS, Pers-B61, Recruiting Administration Branch	Personal contact required	Stated value	May be used directly	Annually	May be acquired	N/A
v	Computation	N/A	Other elements	May be used directly	N/A	May be computed	N/A
N_v	NAVFACENGCOM Transportation Management Division	Personal contact required	Stated value	May be used directly	Annually	May be acquired	N/A

APPENDIX E (continued)

ELEMENT	SOURCE OF ELEMENTS	AVAILABILITY OF DOCUMENTS AND DATA	FORM OF INPUT DATA	USABILITY OF INPUT DATA	INPUTS UPDATED	ELEMENT AVAILABILITY	COMMENTS
V_{AR}	NAVFACENGCOM Transportation Management Division	Personal contact required	Stated value	May be used directly	Annually	May be acquired	N/A
C_S	Computation	N/A	Other cost elements. Additional personnel data.	Computation required	N/A	May be computed without training equipment cost. May not be computed with training equipment cost.	Training equipment element is not available.
N_W	Navy Formal Schools Catalog, NAVPERS 1500	Personal contact required, may be difficult to obtain	Tabled value	May be used directly	As necessary	May be acquired	N/A
		Distribution list	Tabled value	May be used directly	As necessary	May be acquired	N/A
C_{SW}	Computation	N/A	Other elements	May be used directly	N/A	May be computed	N/A
C_T	Summary sheet of the BUPERS Report 1500, tabulated by BUPERS, Pers-Cb11	Personal contact and need to know required	Tabled value	May be used directly	Annually	May be acquired	N/A
N_{SW}	Summary sheet of the BUPERS Report 1500, tabulated by BUPERS, Pers-Cb11	Personal contact and need to know required	Tabled value	May be used directly	Annually	May be acquired	N/A
C_{Eq}	Computation	N/A	Other elements	Computation required	N/A	May not be computed	See E_T
E_{SW}	Computation	N/A	Other cost elements	Computation required	N/A	May not be computed	See E_T
C_{AE}	Computation	N/A	Other cost elements	May be used directly	N/A	May not be computed	See E_T

APPENDIX E (continued)

ELEMENT	SOURCE OF ELEMENTS	AVAILABILITY OF DOCUMENTS AND DATA	FORM OF INPUT DATA	USABILITY OF INPUT DATA	INPUTS UPDATED	ELEMENT AVAILABILITY	COMMENTS
E_T	None at the present time	Not available at the present time since these data are not centrally recorded	N/A	N/A	N/A	May not be acquired	Data not available. The lack of this element prevents the computation of several other elements.
L_{TEq}	Estimation by training personnel and system designers	N/A	Other cost elements. Additional personnel and engineering data.	N/A	N/A	May be estimated	N/A
C_{ES}	Computation	N/A	Other cost elements	Computation required	N/A	May be computed	N/A
N_{EW}	Estimation	N/A	Professional evaluation and training estimates	N/A	N/A	May be estimated	N/A
C_{ESW}	Estimation	N/A	Professional evaluation of similar training facilities	N/A	N/A	May be estimated	N/A
C_{EEq}	Computation	N/A	Other elements	Computation required	N/A	May be computed	N/A
E_{ET}	Computation	N/A	Other elements	May be used directly	N/A	May be computed	N/A
O_T	Computation	N/A	Other elements	Computation required	N/A	May be computed	N/A
E	Estimation by system engineers and cost analysts	N/A	Professional information and system cost data	N/A	N/A	May be estimated	N/A
N_{Eq}	Estimation by personnel researchers and training personnel	N/A	Professional information and training data	N/A	N/A	May be estimated	N/A
N_S	Estimation by system engineers and operations analysts	Restricted data and classified information	Professional information and Naval planning information	N/A	N/A	May be estimated	N/A
N_M	Estimation	N/A	Personnel data and personnel research recommendations	N/A	N/A	May be estimated	N/A
I_{PRS}	Computation	N/A	Other elements	May be used directly	N/A	May be computed	N/A

ELEMENT	SOURCE OF ELEMENTS	AVAILABILITY OF DOCUMENTS AND DATA	FORM OF INPUT DATA	USABILITY OF INPUT DATA	INPUTS UPDATED	ELEMENT AVAILABILITY	COMMENTS
L_{SU}	Estimation by system engineers and operations analysts	N/A	Estimation by system engineers, engineering data required	N/A	N/A	May be estimated	N/A
D	Sea Duty: BUPERS NOTE 1306 Series	Distribution list	Tabled value	May be used directly	Triannually	May be acquired	N/A
	Shore Duty: The enlisted transfer manual NAVPERS 15909A, Memorandum Correction #9, Chapter VII, Article 7.22	Distribution list	Tabled value	May be used directly	Semiannually	May be acquired	N/A
N_{yr}	Length of Service Summary, Series 70 based on the U. S. Naval Examining Center statistical compilations, available at the Enlisted Advancement Plans Section (Pers-A122) of the Bureau of Naval Personnel.	Personal contact required initially	Tabled value	May be used directly	As necessary	May be acquired	N/A
N_m	Computation from N_{yr}	N/A	Tabled value	May be used directly	N/A	May be computed	N/A
r_C	Navy Comptroller Manual, NAVEXOS P-1000, Volume III	Distribution list	Tabled value	May be used directly	Annually	May be acquired	N/A
r_{CA}	Navy Comptroller Manual, NAVEXOS P-1000, Volume III	Distribution list	Tabled value	May be used directly	Annually	May be acquired	N/A
I	Navy Comptroller Manual NAVEXOS P-1000, Volume IV, Chapter 4.	Distribution list	Tabled value	May be used directly	Annually	May be acquired	N/A
P_{SF}	Computation	N/A	Other elements	Computation required	N/A	May be computed	N/A
P_H	Computation	N/A	Other elements	Computation required	N/A	May be computed	N/A

APPENDIX E (continued)

ELEMENT	SOURCE OF ELEMENTS	AVAILABILITY OF DOCUMENTS AND DATA	FORM OF INPUT DATA	USABILITY OF INPUT DATA	INPUTS UPDATED	ELEMENT AVAILABILITY	COMMENTS
P_P	Computation	N/A	Other elements	Computation required	N/A	May be computed	N/A
B	Computation	N/A	Other elements	Computation required	N/A	May be computed	N/A
r_{SF}	Navy Comptroller Manual, NAVEXOS P-1000, Volume IV, Chapter 4, Article 044060	Distribution list	Tabled value	May be used directly	Annually	May be acquired	N/A
r_H	Navy Comptroller Manual, NAVEXOS P-1000, Volume IV, Chapter 4, Article 044080	Distribution list	Tabled value	May be used directly	Annually	May be acquired	N/A
r_{PP}	BUPERS Instruction 1430.12 Series	Distribution list	Tabled value	May be used directly	As necessary	May be acquired	N/A
B_V	Computation	N/A	Other elements	Computation required	N/A	May be computed	N/A
B_T	Computation	N/A	Other elements	Computation required	N/A	May be computed	N/A
m	BUPERS Instruction 1133.18 Series	Distribution list	Tabled value	May be used directly	As necessary	May be acquired	N/A
N_y	Estimation	N/A	Personnel facts, other information	N/A	N/A	May be estimated	N/A
$B_{\frac{y}{p}}$	Navy Comptroller Manual NAVEXOS P-1000, Volume IV, Chapter 4, Article 044070	Distribution list	Tabled value	May be used directly	Annually	May be acquired	N/A
r_p	Estimation	N/A	Other elements	N/A	N/A	May be estimated	N/A
N_{aes}	Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967, pp. 1-7. Average enlisted strength.	Personal contact required	Tabled value	May be used directly	Annually	May be acquired	N/A

APPENDIX E (continued)

ELEMENT	SOURCE OF ELEMENTS	AVAILABILITY OF DOCUMENTS AND DATA	FORM OF INPUT DATA	USABILITY OF INPUT DATA	INPUTS UPDATED	ELEMENT AVAILABILITY	COMMENTS
t_a	Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967, pp. 1-57 to 1-89.	Personal contact required	Tabled value	May be used directly	Annually	May be acquired	N/A
t_d	Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967, pp. 1-57 to 1-89.	Personal contact required	Tabled value	May be used directly	Annually	May be acquired	N/A
t_o	Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967, pp. 1-57 to 1-89.	Personal contact required	Tabled value	May be used directly	Annually	May be acquired	N/A
t_r	Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967, pp. 1-57 to -189.	Personel contact required	Tabled value	May be used directly	Annually	May be acquired	N/A
t_s	Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967, pp. 1-57 to 1-89.	Personal contact required	Tabled value	May be used directly	Annually	May be acquired	N/A
t_{ou}	Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967, pp. 1-57 to 1-89.	Personal contact required	Tabled value	May be used directly	Annually	May be acquiredq	N/A
S'	Computation	N/A	Other elements	Computation required	N/A	May be computed	N/A
u	Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967 Appropriation: Military Personnel, Navy, P 1-43, Separation payments, lump sum terminal leave	Personal contact	Tabled value	May be used	Annually	May be acquired	N/A

APPENDIX E (continued)

ELEMENT	SOURCE OF ELEMENTS	AVAILABILITY OF DOCUMENTS AND DATA	FORM OF INPUT DATA	USABILITY OF INPUT DATA	INPUTS UPDATED	ELEMENT AVAILABILITY	COMMENTS
s	Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967 Appropriation: Military Personnel, Navy, P. 1-43, Severance pay - disability	Personal contact required	Tabled value	May be used directly	Annually	May be acquired	N/A
$\bar{s}$	Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967 Appropriation: Military Personnel, Navy, P. 1-43, Discharge gratuities	Personal contact required	Tabled value	May be used directly	Annually	May be acquired	N/A
N_{tt}	Summation of items from Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967 Appropriation: Military Personnel, Navy, P. 1-43, Sum of numbers of those receiving separation pay	Personal contact required	Tabled value	Computation required	Annually	May be acquired	N/A
N_{ts}	Bureau of Naval Personnel, Pers-H111, Justification of estimates for FY 1967 Appropriation: Military Personnel, Navy, P. 1-43, those receiving severance pay	Personal contact required	Tabled value	May be used directly	Annually	May be acquired	N/A
N_{tu}	Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967 Appropriation: Military Personnel, Navy, P. 1-43, Number receiving lump sum terminal leave	Personal contact required	Tabled value	May be used directly	Annually	May be acquired	N/A

APPENDIX E (continued)

ELEMENT	SOURCE OF ELEMENTS	AVAILABILITY OF DOCUMENTS AND DATA	FORM OF INPUT DATA	USABILITY OF INPUT DATA	INPUTS UPDATED	ELEMENT AVAILABILITY	COMMENTS
N_{tg}	Bureau of Naval Personnel, Pers-Hill, Justification of Estimates for FY 1967 Appropriation: Military Personnel, Navy, P. 1-43, Number receiving discharge gratuities	Personal contact required	Stated value	May be used directly	Annually	May be acquired	N/A
M_d	Bureau of Medicine and Surgery, Comptroller's Office	Personal contact required	Stated value given in itemized budgetary form	May be used directly	Annually	May be acquired	This is a budgetary figure
C_R	Computation	N/A	Other elements	May be used directly	N/A	May be computed	N/A
A_p	DOD Actuarian's Office, OASD (Manpower)	Personal contact required initially	Stated value from statistical computations	May be used directly	Annually	May be acquired	N/A
P_N	DOD Actuarian's Office, OASD (Manpower)	Personal contact required initially	Stated value from statistical computations	May be used directly	N/A	May be computed	N/A
R_{ℓ}	Computation	N/A	Other elements	May be used directly	N/A	May be computed	N/A
N_{RtR}	BUPERS Strength and Statistics Branch Pers-A23	Personal contact required intially	Stated value	May be used directly	As necessary	May be acquired	A special computer program will be written by Pers-A23 to retrieve these data
N_{Rt}	BUPERS Strength and Statistics Branch Pers-A23	Personal contact and special arrangements required	Stated value	May be used directly	As necessary	May be acquired	N/A
C_{RR}	Computation	N/A	Other elements	Computation required	N/A	May be computed	N/A

APPENDIX E (continued)

ELEMENT	SOURCE OF ELEMENTS	AVAILABILITY OF DOCUMENTS AND DATA	FORM OF INPUT DATA	USABILITY OF INPUT DATA	INPUTS UPDATED	ELEMENT AVAILABILITY	COMMENTS
N_R	BUPERS Strength and Statistics Branch Pers-A23	Personal contact and special arrangements required	Stated value	May be used directly	As necessary	May be acquired	N/A
R_{RA}	Computation	N/A	Other elements	Computation required	N/A	May be computed	N/A
O_{PC}	Computation	N/A	Other elements	May be used directly	N/A	May be computed computed	N/A
O_a	Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967 Appropriation: Military Personnel, Navy, P. 1-93	Personal contact required	Tabled value	May be used directly	Annually	May be acquired	N/A
O_1	Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967 Appropriation: Military Personnel, Navy, P. 1-93	Personal contact required	Tabled value	May be used directly	Annually	May be acquired	N/A
O_d	Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967 Appropriation: Military Personnel, Navy, P. 1-93	Personal contact required	Tabled value	May be used directly	Annually	May be acquired	N/A
O_1	Bureau of Naval Personnel, Pers-H111, Justification of Estimates for FY 1967 Appropriation: Military Personnel, Navy, P. 1-93	Personal contact required	Tabled value	May be used directly	Annually	May be acquired	N/A

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ABSTRACT

This report presents a summary of progress made in a continuing investigation into the feasibility of deriving a cost/effectiveness formula for man/machine function allocation. A preliminary cost/effectiveness formula is presented with an evaluation of the sources and availability of the data inputs required by the formula.

Using the preliminary formula and methodology as a basis for the analysis, it was concluded that adequate measures of cost are available but that adequate measures of variable effectiveness have not yet been developed. Due to the complexity of the cost/effectiveness formula and methodology and to the lack of accessibility of input data, a large amount of time and money will be required to perform function allocation analyses. It was determined that the derivation of a cost/effectiveness formula for man/machine function allocation is feasible. At this time cost/effectiveness analysis seems applicable to most cases of function allocation and appears to offer a reliable method for the allocation of functions between men and machines.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Cost/Effectiveness						
Man/Machine Function Allocation						
Function Allocation						
Training						
Trade Offs						
Manning						
Human Effectiveness						
Cost						
Effectiveness						