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REVIEW OF NAVY CONTRACT ADMINISTRATION FIELD ACTIVITIES

Logistics Management Institute

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13. ABSTRACT

The primary purpose of this report was to develop quantitative staffing criteria for Navy SUPSHIP and NAVPRO offices. A secondary purpose was to attempt to develop a planning tool for internal Navy management use. The method used was a statistical analysis of empirical data on staffing requirements for the time period January 1967 through December 1971. Equations were developed which can be used to estimate total contract administration personnel requirements in field offices. The relationships can also be used as the bases for staffing criteria as required in OMB Circular A-11. The methodology, techniques and relationships can be helpful in the area of productivity measurement.

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SUMMARY

With the sponsorship of the Deputy Chief of Naval Material (Procurement and Production) and the Commander, Naval Ship Systems Command, the Logistics Management Institute was requested by the Assistant Secretary of Defense (Installations and Logistics) to undertake a task for the review of offices of Supervisors of Shipbuilding, Conversion and Repair, USN and Naval Plant Representatives. The task included a review and analysis of the organization, functional responsibilities, interface relationships, workload trends, and staffing criteria for those offices.

An interim report was issued to the Deputy Chief of Naval Material (Procurement and Production) in October 1971 presenting our conclusions and recommendations on organization, functional responsibilities, and interface relationships.

This is our final report and covers the second phase of our review. The primary purpose of the second phase was to develop quantitative staffing criteria for certain Navy contract administration field personnel requirements. A secondary purpose was to attempt to develop a planning tool for internal Navy management use. The method used was a statistical analysis of empirical data on staffing requirements for the time period January 1967 through December 1971.

We have had only limited success in accomplishing those purposes. We conclude that statistical review of historical data is not an appropriate technique for determination of an optimum staffing level for a specific office or for divisions

within an office. Assuming, however, that the Navy continues to manage its field contract administration services offices in a manner similar to that used in the 1967-1971 time frame, we developed equations which can be used, on a Systems Command basis, to estimate future total contract administration personnel requirements.

In addition, the relationships presented in this study can be used as the statistical bases for staffing criteria in satisfaction of the requirements of OMB Circular A-11. We believe that the methodology, analytical techniques, and, at least, some of the relationships can be used in the area of productivity measurement. We recommend that the Systems Commands have the flexibility to level out peak and slack work periods by allowing them to operate within a reasonable range of the computed staffing level and that the relationships presented in this report be periodically updated.

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ABBREVIATIONS

Throughout this report, a number of acronyms and abbreviations have been used. The following list is supplied to help the reader with those terms with which he is not familiar.

ASPR	Armed Services Procurement Regulation
CAS	Contract administration services
CI	Confidence interval
CV	Coefficient of variation
LMI	Logistics Management Institute
MAT	Naval Material Command Headquarters
NAVAIR	Naval Air Systems Command
NAVAIRINST	Naval Air Systems Command Instruction
NAVMAT	Naval Material Command
NAVORD	Naval Ordnance Systems Command
NAVORDINST	Naval Ordnance Systems Command Instruction
NAVPR	the Naval Plant Representative
NAVPRO	Naval Plant Representative Office
NAVSHIPS	Naval Ship Systems Command
OCMM	Office of Civilian Manpower Management-Navy
OMB	Office of Management and Budget
OPNAV	Office of the Chief of Naval Operations
OPNAVINST	Instruction issued by the Office of the Chief of Naval Operations
R^2	Coefficient of determination
SACAM	Ship Acquisition Contract Administration Manual
SE	Standard error
SUPSHIP	Supervisor of Shipbuilding, Conversion and Repair, USN
SYSCOM	Naval Systems Command

I. INTRODUCTION

In December 1970, the Logistics Management Institute (LMI) undertook the task of reviewing the organization, functional assignments, workload, and staffing criteria of Navy CAS activities at the initiative of the Deputy Chief of Naval Material (Procurement and Production). Only those offices designated as a Supervisor of Shipbuilding, Conversion and Repair (SUPSHIP) or Naval Plant Representative (NAVPRO) were included. Other Navy offices designated as CAS components (Inspectors of Naval Material-Petroleum, Navy Fuel Supply Offices, Naval Regional Procurement Offices, Branch Offices of the Office of Naval Research, and Offices of Naval Research Resident Representative) were excluded from the study.

In March 1971, the task was amended to include the attempted development of staffing criteria for Navy field CAS offices. The Commander, Naval Ship Systems Command requested the amendment in order to assist that Command in meeting the requirement for staffing criteria specified in Bureau of the Budget (now the Office of Management and Budget) Circular A-11, Section 13.3. (Appendix A).

The original intent of the amended task was the development of staffing criteria for SUPSHIP offices for inclusion in OPNAV Instruction 5310.5A, "U. S. Navy Staffing Criteria Manual for Activities Ashore." (SUPSHIPS are not presently included in that Instruction.) MAT 02 amended the NAVSHIPS request to include a reevaluation and possible redevelopment of the NAVPRO criteria shown in Section 71 of OPNAVINST 5310.5A.

The project was conducted in two phases. From March through October 1971, emphasis was placed on the organizational and functional aspects of the task. The Commands and offices specified in Section 1.B.1. of the task order were visited and each CAS supervisor was interviewed. In the field offices, each department or division director was also interviewed. In addition, visits were made to the appropriate offices in the Office of the Assistant Secretary of Defense (Installations and Logistics), the Directorate for Contract Administration Services of the Defense Supply Agency, the Air Force Systems Command, and the Air Force Contract Management Division.

On the basis of those interviews, a review of the organization and functional assignments for CAS offices was made and submitted to MAT 02 in an interim report issued in October, 1971.

This final report presents the results of the staffing criteria phase of the study. The major portion of the field work indicated in Appendix B was performed in this phase. In spite of the complete and thorough cooperation we received from all our study contacts, it should be recognized that any attempt to identify significant empirical relationships in the area of human activity will probably yield a larger margin of error than an analysis of physical or natural phenomena. The data used in the study were heavily impacted by such qualitative considerations as individual motivation, personalities of supervisors and subordinates, orders from higher supervisory echelons, etc. The subject of the significance of the data and results is discussed more fully later in the report.

Prior to starting the second phase, the technique to be used to develop staffing criteria was carefully reviewed with

the Navy. It was generally agreed that the most reliable determination of the number of personnel which <u>should</u> be in a CAS office required the use of industrial engineering techniques. Because of practical manpower constraints, it was decided that the next best alternative would be a statistical review of empirical data over a specified time period. In addition to criteria for the total number of personnel in a field CAS office, we were also to attempt to develop guidelines for the number of people in the various divisions/departments usually found in a NAVPRO/SUPSHIP. Chapters III and IV and Appendices C through G detail the methodology, results, and recommendations of that review.

The report assumes some reader familiarity with contract administration services functions and basic statistical concepts. A list of abbreviations is provided for those less familiar with the acronyms used in the report while the chapter on methodology includes some background information on statistics.

II. ASSUMPTIONS AND LIMITATIONS

The use of statistical techniques on empirical data to develop a planning tool imposes certain restrictions and implies specific assumptions. It is necessary to realize the limitations of the analyses in order to place the results in their proper perspective.

1. Comprehensiveness of Variables

The specific variables chosen for study were determined by asking each SUPSHIP/NAVPR and each department/division director visited during the first part of the study to identify measurable actions or indicators which he believed had an impact on the work performed in his office. This list was added to and modified through discussions with CAS personnel at the headquarters level and through subjective analyses made within LMI.

The variables for which we obtained data were, therefore, considered to be a reasonably complete list of significant, quantifiable events and actions which indicate an office's workload. Some data were not included in the study, such as:

a. quantifiable variables, common to all CAS offices, which were considered insufficiently significant to warrant their inclusion in the final descriptive equation.

b. quantifiable variables which were unique to one or a few offices and could not be applied to the larger groups of offices for which relationships were developed.

c. qualitative variables which were excluded from this study but which exert a significant impact on workload or the way in which the workload is handled.

Another significant assumption was that a linear or log-linear model adequately describes the empirical data.

2. Causative vs. Associative Effects

In using regression analysis, one tries to examine the effect that some variable exerts on others and to find a functional relationship among the variables expressed as a mathematical equation. A distinction is made between independent and dependent variables. The variable being "explained" is the dependent variable. Independent variables are those that are found to exert an influence on the dependent variable.

The relationship between the dependent and independent variable may be either causative or associative. For the most part, the variables we used are associative in nature rather than causative. For instance, "value shipped," one of the independent variables studied, appeared to have a strong correlation with the number of personnel needed to man an office. However, this is an associative variable. The fact that some goods of definite value were produced by a contractor does not, in itself, cause work in the government office. Rather, the contract terms, the requirements of ASPR, and various procurement rules and regulations define the amount of inspection to be performed, the forms to be filled out, the reviews and approvals to be made, etc. The value of the goods produced is merely a convenient measure of the cumulative effects of all the legal requirements which are the true causes of the workload.

An assumption in this study is that the variables measured, though they may be associative, are reasonable measures of the work required to be performed by an office.

3. Representative Sampling

In the Continental United States, there are 16 SUPSHIP offices, 9 NAVAIR NAVPROs, and 6 NAVORD NAVPROs. Of these, we visited 10 SUPSHIPS, 7 NAVAIR NAVPROs and 5 NAVORD NAVPROs. Although the sample represents well over 50% of each population, there is still some question whether each office should be considered as a part of a homogeneous organization or whether it is sufficiently unique to warrant individual consideration. Various offices will differ because of the existence of branch offices, bailed aircraft, floating drydocks, unique products, special contractor relationships, etc.

We acknowledge the unique characteristics of the various SUPSHIP/NAVPRO offices. We endeavored, however, to include most extremes within our range of observations. For instance, we included large and small offices, repair and new construction, conventional airframe, helicopter, and electronics manufacturers, research and hardware-oriented offices, etc. We, therefore, believe our sample to be representative of the many types of offices found in the SUPSHIP/NAVPRO organizations.

4. Sample Size

The limited number of offices in each SYSCOM population is too small to warrant the assumption of a normal distribution for any sample of the offices.

We attempted to overcome the problem of sample size by collecting data for ten points in time for each of the

selected offices. The initial regression equations were computed from those data. We then recognized that a specific time-observation is not completely independent of preceding or subsequent observations. For that reason we then limited our sample size for analysis to three or four time periods which are farther apart from each other in time and would allow us to look at observations which did not have a direct relationship with one another. In this manner, we used a minimum of twenty sample observations per SYSCOM from which new regression equations were computed. Since these equations did not vary significantly from those using ten time points and since we are not ignorant of the population parameters which the equations describe, we are confident that the sample size is adequate for describing the desired relationships even though it may fall short of the requisite size for normalcy.

5. Data Accuracy

A significant limitation is the expected accuracy of the data used in the analyses. We endeavored to check, edit, and verify all collected data to a reasonable extent. Some obvious errors were corrected when found, and unofficial records were used when they appeared to be more reliable or were the only sources available. Errors were especially prevalent for the 1967-1968 time frame. It must be recognized, however, that some data might be erroneous because of misunderstanding of definitions, incomplete or inaccurate records, or human error. In addition, we believe that there was enough inconsistency in the way records were maintained and reports generated that an LMI recommendation on improved data retrieval is appropriate although peripheral to the subject of this study.

In order to conduct the analysis with the chosen techniques, a proxy was required in those few instances where no data were available on a variable for an observation. A mean was inserted in those instances, as may be seen in Appendix D.

6. Mission Consistency

A possible limitation which we encountered and one which should be carefully considered in any future updating of the data base is the consistency of mission definition among similar offices. We found that some offices are responsible for other than CAS functions. The dependent variables (personnel) would, therefore, be inflated with respect to the independent variables. In this study, we adjusted the dependent variable (when possible) to account for those added functions.

A related limitation occurs when an office is not performing all of the CAS functions. In those cases, there was no good way to adjust the independent variable, since none of them was thought to be solely or exclusively related to one department. This is a source of error in this study, and management judgment should be used to modify the results as they would appear to apply to such offices. This source of error is not significant, however, when viewing total SYSCOM staffing needs, so long as the SYSCOM is not required to perform additional functions with the resources indicated by the equations in this study.

III. RESULTS AND RECOMMENDATIONS

The primary results of this study are the equations, noted below, which describe the staffing relationships for CAS offices. The equations were derived from data describing individual office staff relationships. However, when the equations were used to compute the staffing levels of individual offices, a wide variance between the computed and actual levels was noted (Tables 1 through 3).

Because of these wide variances, it was believed that the equations would yield better results (reduced variances) if they were used only to describe the aggregate staff levels of an entire Systems Command. A limited test of the equations which aggregated the individual office results to the Systems Command level (Tables 4 through 6) verifies that reduced variances are realized when the computed staff levels are aggregated at that level.

The following equations should be considered in the context that they provide an acceptable description of staffing requirements only at the Systems Command level.

A. SUPSHIP STAFFING CRITERIA

SUPSHIP offices are not covered by formal staffing criteria in OPNAVINST 5310.5A. This does not imply, however, that NAVSHIPS has not applied some informal criteria as a guide in allocating billets. This LMI study indicates that a reasonable correlation existed from 1967 through 1971 between progress payments, changes processed, and staff levels. These relationships are shown on Figures 1A and 1B. It should be noted that

a more rigorous presentation would show the confidence level envelope on Figure 1A with hyperbolic rather than linear bounds. The 68% confidence level at the mean would equal the standard error. We have shown an envelope with constant boundaries equal to the standard error for the sake of simplicity. Figure 1A also plots the raw data corrected for the changes processed. Table 1 lists the observed values, calculated values and variances for the original observations.

The algebraic expression for these relationships is:

$$\sum_{i=1}^{n} Y_i = \sum_{i=1}^{n} (170.8 \ (\log X_1) + 0.013X_2 - 620)_i$$

where

Y_i = Total computed personnel estimate (military and civilian) for the ith SUPSHIP office for the projected time frame.

X_1 = Annual rate, for the projected time frame, of progress payments and other payments (in thousands of dollars) to contractors representing work accomplished.

X_2 = Annual processing rate, for the projected time frame of changes, change orders, cost/price proposals, contract or job modifications and other contract changes requiring SUPSHIP effort or review.

n = Number of SUPSHIP offices being estimated.

This equation has a coefficient of determination (R^2) of 0.75.[1]

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[1]The data on SUPSHIP 3 and SUPSHIP 4 were not used in calculating the relationship since those offices fall far outside the range of observations.

Figure 1A

STAFFING CRITERIA FOR
OFFICES OF SUPERVISOR OF SHIPBUILDING, CONVERSION AND REPAIR, USN
See Figure 1B for Adjusting Variable

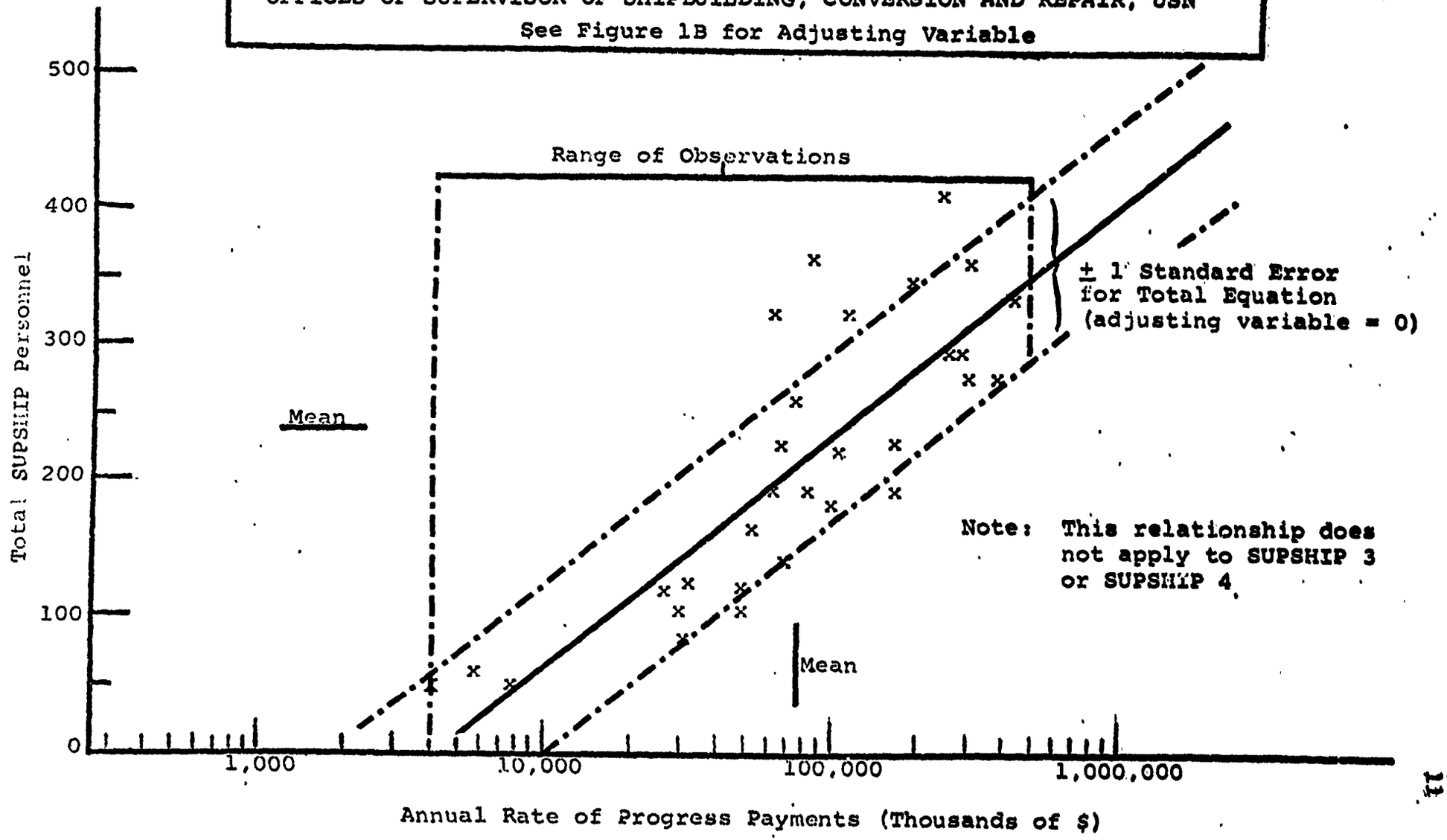
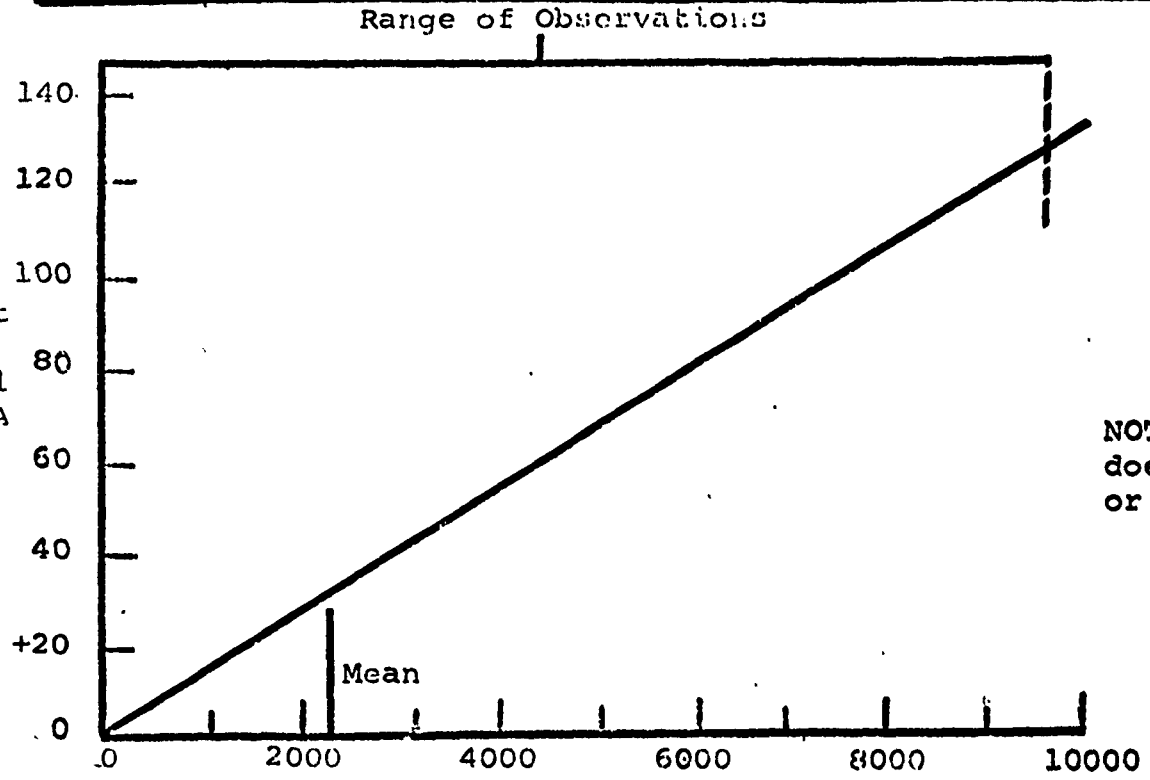


Figure 1B

STAFFING CRITERIA FOR OFFICE OF SUPERVISOR OF SHIPBUILDING, CONVERSION AND REPAIR, USN

Adjustment to Figure 1A



NOTE: This relationship does not apply to SUPSHIP 3 or SUPSHIP 4

Table 1

SUMMARY OF DATA AND VARIANCES—SUPSHIPS

Data Point[1]	No. of Personnel Computed	Actual	Variance	% Variance
13-2	124	105	-19	-18
13-6	155	127	-28	-22
13-9	149	109	-40	-36
14-2	65	63	-2	-3
14-6	27	56	29	52
14-9	-7	50	57	114
15-2	377	364	-13	-4
15-6	376	360	-16	-4
15-9	427	383	-44	-11
16-2	307	415	108	26
16-6	326	366	40	11
16-9	345	390	45	12
17-2	224	201	-23	-11
17-6	283	257	-26	-10
17-9	260	195	-65	-33
18-2	201	139	-62	-45
18-6	259	182	-77	-42
18-9	319	259	-60	-23
19-2	188	179	-9	-5
19-6	222	204	-18	-9
19-9	244	222	22	10
20-2	176	112	-64	-57
20-6	171	95	-76	-80
20-9	130	69	-61	-88
21-2	270	409	139	34
21-6	269	342	73	21
21-9	342	295	-47	-16
22-2	300	364	64	18
22-6	199	322	123	38
22-9	206	253	47	19

NOTE:

(1) Data point designations refer to underlined observations listed in Appendix D.

B. NAVAIR NAVPRO STAFFING CRITERIA

The major difference between NAVPRO offices (both for NAVAIR and NAVORD) and SUPSHIP offices is that the amount of variation in the staffing levels which is "explained" by the regression equation (R^2) is much greater for the NAVPROs. (For NAVAIR NAVPROs, R^2 equals 0.91.) We believe this improved variation to be, in part, attributable to the fact that NAVPROs have been following a staffing pattern based upon the criteria promulgated in OPNAV Instruction 5310.5A (Section 71).

That Instruction provides for government personnel as a function of "number of contractors' technical personnel," "number of contractors' direct personnel," "number of contractors' quality assurance personnel," etc. At the start of our analysis, we found a high correlation between "value shipped" and those variables noted above (we also collected data on the same variables). The methodology that we used and summarized in Section IV.B., indicated that "value shipped" provided a closer relationship to government personnel than those other variables. We, therefore, used the one variable as a descriptor.

Figure 2 shows the graph of the equation for NAVAIR NAVPROs, the data points used in calculating the relationship, and the 68% confidence interval.[1] Table 2 lists the observed data, the calculated values and the variances for each observation. The equation described in Figure 2 is:

$$\sum_{i=1}^{n} Y_1 = \sum_{i=1}^{n} (39 + 0.00024X_1)_i$$

[1] Note the comment on page 10 concerning the shape of the confidence limit boundaries.

where

Y_i = Total computed personnel estimate (military and civilian) for the ith NAVAIR NAVPRO office for the projected time frame.

X_1 = Annual rate (in thousands of dollars), for the projected time frame, of the value of material and goods shipped to the government from the contractor's plant.

n = Number of NAVAIR NAVPRO offices being estimated.

C. NAVORD NAVPRO STAFFING CRITERIA

As in the case of NAVAIR, staffing criteria for NAVORD NAVPROs are also provided in OPNAVINST 5310.5A. The equation describing their historical staffing relationships gives the best "fit" (R^2 = .92) of the three SYSCOMS. That can be deceiving, however, in light of the coefficient of variation (CV) of 25%. Figure 3 shows the plot of the original data, the resulting equation and the limits set by one standard error.[1] Table 3 lists the observed data, the calculated values and the variances for each observation. The equation is:

$$\sum_{i=1}^{n} Y_1 = \sum_{i=1}^{n} (0.00081X_1 - 15)_i$$

where

Y_i = Total computed personnel estimate (military and civilian) for the ith NAVORD NAVPRO office for the projected time frame.

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[1] Note the comment on page 10 concerning the shape of the confidence limit boundaries.

Figure 2

STAFFING CRITERIA FOR
NAVAL PLANT REPRESENTATIVE OFFICES
NAVAL AIR SYSTEMS COMMAND

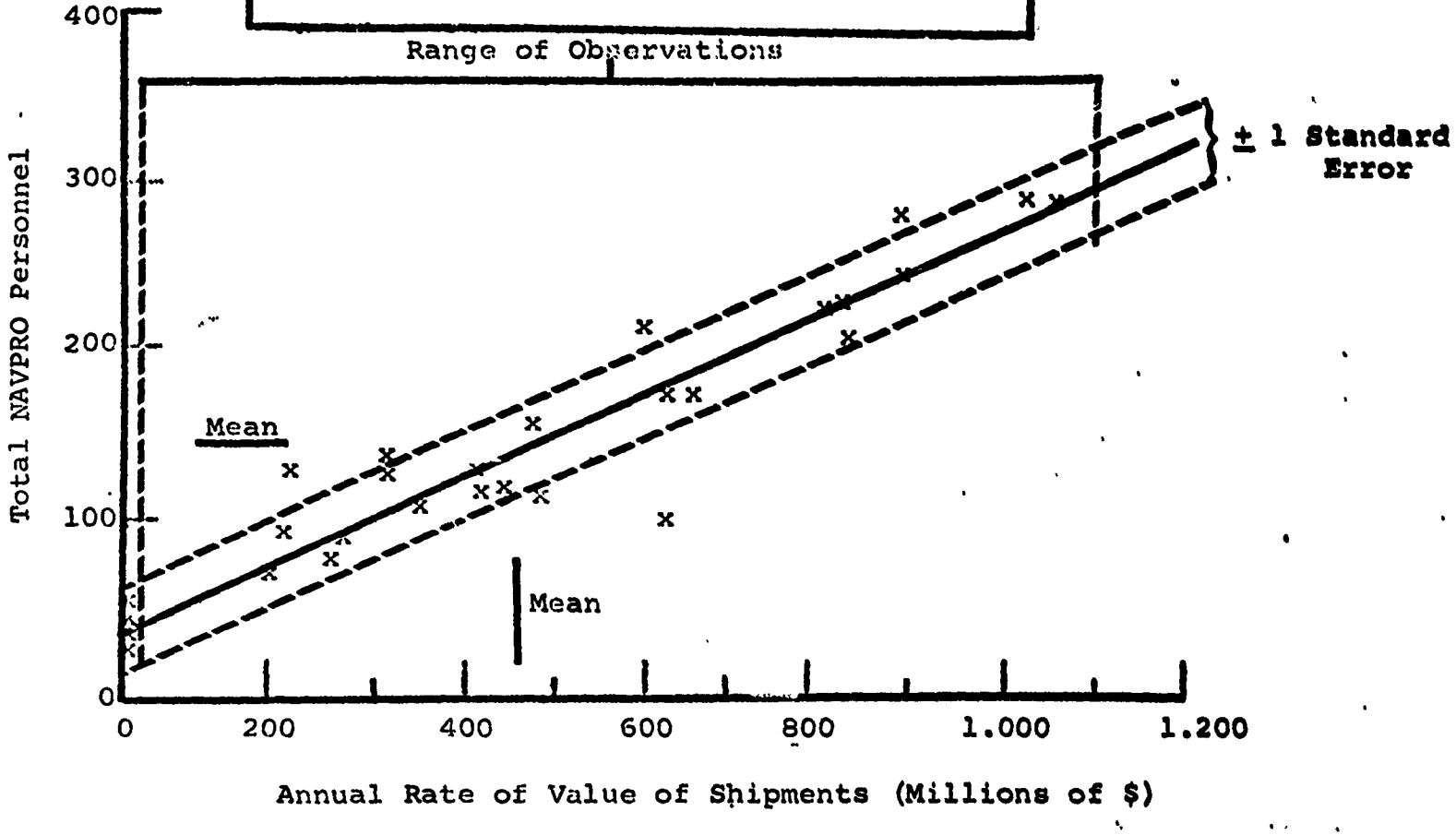

Table 2

SUMMARY OF DATA AND VARIANCES—NAVAIR NAVPROs

Data Point (1)	No. of Personnel		Variance	% Variance
	Computed	Actual		
6-2	228	229	1	0
6-5	248	247	-1	0
6-7	181	222	41	18
6-9	224	223	-1	0
7-2	101	93	-8	-9
7-5	84	95	-11	-12
7-7	98	78	-20	-26
7-9	81	76	-5	-7
8-2	291	292	1	0
8-5	283	296	13	4
8-7	248	285	37	13
8-9	234	214	-20	-9
9-2	86	133	47	35
9-5	111	128	17	13
9-7	187	111	-76	-68
9-9	122	111	-11	-10
10-2	40	45	5	11
10-5	40	39	-6	-15
10-7	40	38	-2	-5
10-9	42	37	-5	-14
11-2	130	127	-3	-2
11-5	186	183	-3	-2
11-7	195	178	-17	-10
11-9	151	163	12	7
12-2	111	135	24	18
12-5	130	125	-5	-4
12-7	138	120	-18	-15
12-9	154	119	-35	-29

NOTE:

(1) Data point designations refer to underlined observations listed in Appendix D.

X_1 = Annual rate (in thousands of dollars), for the projected time frame, of the value of material and goods shipped to the government from the contractor's plant.

n = Number of NAVORD NAVPRO offices being estimated.

D. CONCLUSIONS AND RECOMMENDATIONS

From the tests shown in Chapter IV, we conclude that the equations developed for a group of offices are valid within the established confidence limits and over the range of values for which observations were made. Assuming that the Naval Systems Commands make a conscious decision to continue their past management practices for field CAS offices, we recommend that:

1) The relationships determined by the regression equations in this report can be used by the Naval Systems Commands as a management tool for projecting personnel staffing requirements.

2) The relationships of this study could be established as the statistical bases for staffing criteria in satisfaction of the requirements of OMB Circular A-11.

3) The relationships set forth in this report should be updated annually.

4) The Systems Commands should have flexibility to level out peak and slack work periods by allowing them to operate within a reasonable range of the computed staffing level. That range should consider operational circumstances as well as the fact that the equations describe "average" offices.

Figure 3

STAFFING CRITERIA FOR
NAVAL PLANT REPRESENTATIVE OFFICES
NAVAL ORDNANCE SYSTEMS COMMAND

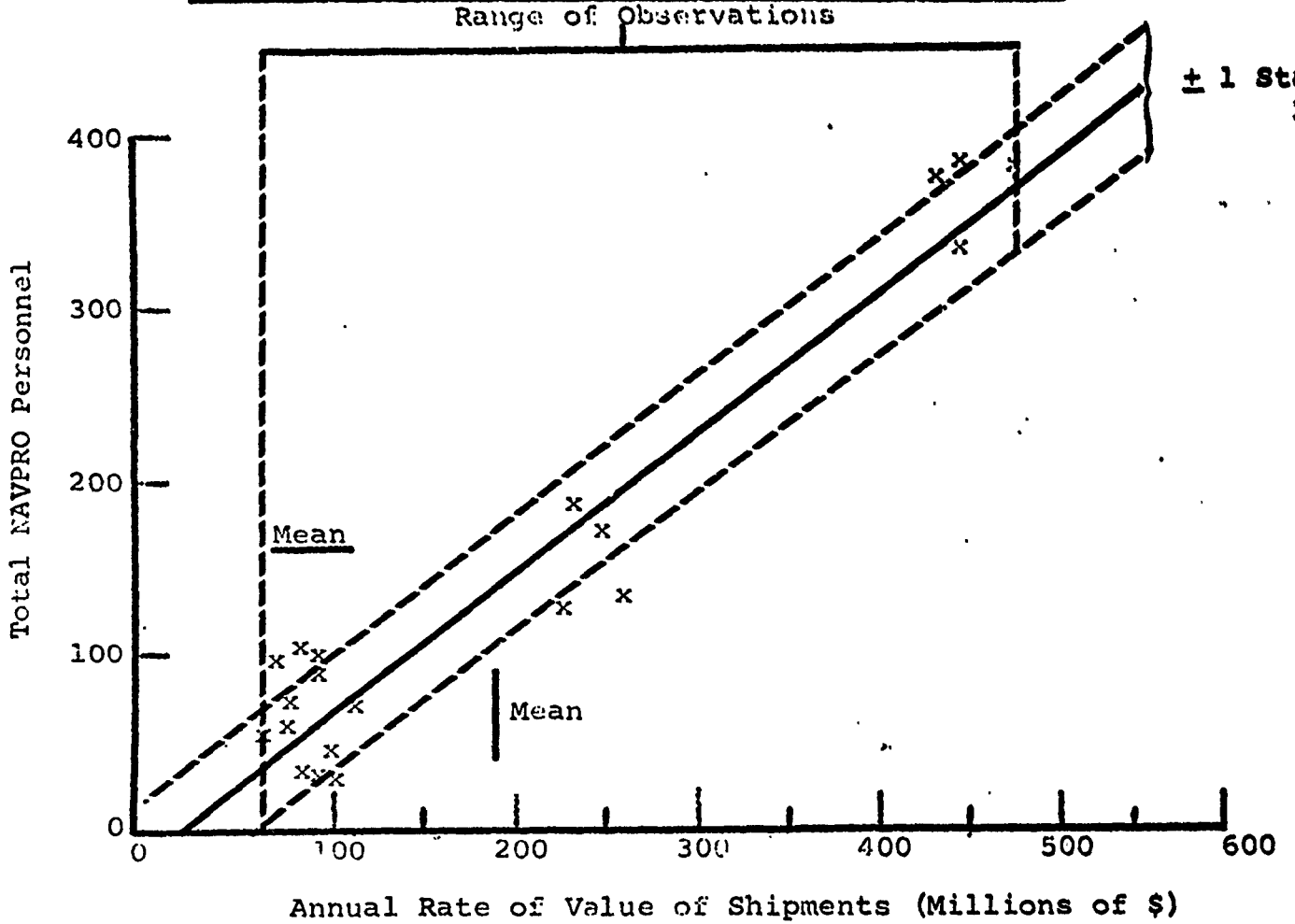

Table 3

SUMMARY OF DATA AND VARIANCES---NAVORD NAVPROs

Data Point (1)	No. of Personnel		Variance	% Variance
	Computed	Actual		
1-2	180	187	7	4
1-5	192	171	-21	-12
1-7	203	134	-69	-51
1-9	173	128	-45	-35
2-2	68	32	-36	-113
2-5	61	32	-29	-91
2-7	71	29	-42	-145
2-9	73	41	-32	-78
3-2	350	334	-16	-5
3-5	350	386	36	9
3-7	376	381	5	1
3-9	341	379	38	10
4-2	58	88	30	34
4-5	59	101	42	42
4-7	61	98	37	38
4-9	48	98	50	51
5-2	85	73	12	16
5-5	51	74	23	31
5-7	46	60	14	23
5-9	43	54	11	20

NOTE:

(1) Data point designations refer to underlined observations listed in Appendix D.

5) NAVMAT should critically review and standardize the information gathering and reporting processes from the field offices.

The last recommendation is peripheral to the major concerns of the study but we believe it to be appropriate. The need for improved procedures was apparent to LMI during the data gathering phase of the study. Improved and standardized reporting procedures could provide a better understanding of CAS office staffing relationships.

We have not attempted to develop criteria on a detailed position basis, as set forth in OPNAVINST 5310.5A. However, relationships similar to those developed for an entire office were determined for departments/divisions within an office and are shown in Appendix F. Those relationships are subject to the assumptions and limitations discussed in Chapter II, as well as the other cautionary notes of this report. However, as a starting point for future work by the Navy in establishing staffing criteria for individual offices, it is suggested that the staffing criteria in OPNAVINST 5310.5A be reviewed for consistency with the relationships set forth in this report.

A recent report of the Joint Economic Committee of the U.S. Congress[1] discusses workload measurement and productivity in the Federal sector. We believe that the methodology, statistical techniques, and, at least, some of the relationships developed and presented in this report can be used by the Navy in meeting the recommendations of that report.

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[1] "Measuring and Enhancing Productivity in the Federal Sector:" A Study Prepared for the Use of the Joint Economic Committee of the Congress of the United States by Representatives of the Civil Service Commission, General Accounting Office and Office of Management and Budget, August 4, 1972.

E. USE OF RESULTS

The equations presented in this report produce unmeaningful results when they are used to predict the staffing level for a specific office under current management criteria. The reason for this is that the equations describe the average relationships for offices when, in fact, there are no "average" offices. By definition, some offices must fall above the mean and some below it. Hence we do not recommend the use of the equations for predicting the staff levels of a specific office without concurrent changes in management controls and practices.

We can, and do, recommend that the equations be used for estimating the total CAS office staff requirements for a SYSCOM, since individual office variances from the mean tend to cancel each other out when they are aggregated. Limiting the application of the equations to the SYSCOM level recognizes the fact that the SYSCOM is in a better position to estimate the total independent variable than are the individual offices. (For example, consider the case of two CAS offices estimating the impact of the same anticipated procurement—which will be awarded to only one contractor.)

The potential use of these equations could change, however, if the Navy were to alter its management practices. One alternative could be that CAS managers may accept these, or similar, equations as standards for all offices, permitting deviations only by explicit permission. We do not presume to specify or recommend such a specific policy standard since we believe that to be a prerogative of the Systems Command manager and should charge from one manager to another depending on his specific objectives and interests.

Chapter IV gives the results of testing the equations for both individual and total CAS office staff predictions under existing management practices. It shows the considerable improvement in variance achieved through aggregating the individual office results. Even so, there are still some differences between the computed and actual aggregate staff levels. The differences should not be disturbing since the regression equation only provides a point estimate of staffing levels given a point estimate for the independent variable. But the independent variable estimate may change from time to time in the course of a year. If followed to the letter, this would require CAS management to hire new staff or lay off people periodically throughout the year to meet the dictates of each new estimate. In practice, leveling of the workload is allowed by use of overtime, temporary help, and training programs. We agree with this policy and recommend that the SYSCOMS present any point estimate in the context of a range in which it proposes to manage. Hence, even though a SYSCOM might compute a specific overall personnel requirement, it is reasonable that they should expect to manage to within, say, 5 or 10 percent of that estimate—given the same conditions and requirements which existed in the prior five year period on which the equation is based. The concepts of the standard error and confidence interval, discussed in the next chapter, may be helpful in establishing a reasonable management range.

IV. SUMMARY OF METHODOLOGY

This Chapter summarizes the methods and techniques used in data collection, analysis, and testing. Detailed definitions of the statistical terms used in this Chapter are provided in Appendix E.

Prior to presenting the methodology, it may be helpful to discuss and understand the concepts of standard error and confidence limits. The equations shown in this report represent an average in an apparent relationship between a dependent and one or more independent variables. Since they are averages, one should expect to find approximately one-half of the data observations higher than calculated from the equation and one-half lower.

In addition, since we observed only a sample of the total population, it should be expected that the equations would have changed, even though slightly, had we sampled different offices or different time periods.

It is those valid changes in the equations for which the standard error and confidence limits provide boundaries. Figure 4 provides a pictorial presentation of these concepts.

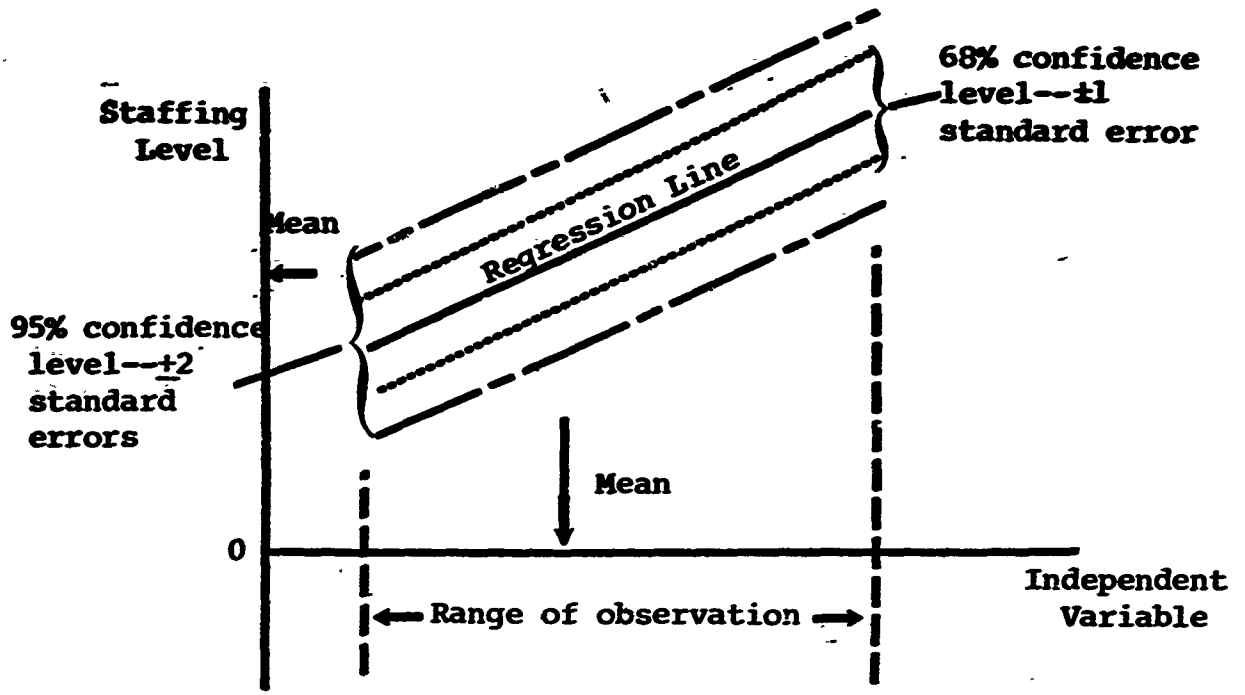

Fig. 4 Standard Error, Confidence Level, and Range of Observation

The standard error establishes a range in which the mean relationship might fall if other sets of data had been taken. One standard error (plus or minus) establishes the boundaries in which approximately two-thirds (68%) of relationships based on samples of the population would fall. Approximately two standard errors establishes the boundaries for 95% of the mean relationships. (Note the comment on the shape of the confidence limit boundaries in Section III. A.)

For example, if we were to repeat our data sampling procedures 20 times and develop 20 relationships from the sampled data, then 19 out of the 20 relationships would be within two standard errors of our present results and 13 of the 20 relationships would be within one standard error.

A convenient way of measuring the relative importance of a standard error (SE) is through the coefficient of variation

(CV) which is defined as the standard error divided by the mean of the dependent variable. In the area of staffing criteria, a standard error of 50 with a mean observed staffing level of 200 would provide a CV of 0.25 (or 25%).

The reader should also note that the range of observation is given for each set of results. While it is simply the range of the collected data, it defines the boundaries between which the results are statistically valid. Although, in practice, it is reasonable to extend the relationships a small distance beyond these boundaries, such an extension should be made conservatively and with appropriate care.

A. DATA COLLECTION

Having determined the variables to be investigated for significance as specified in Section II.1., we first attempted to collect the information at the headquarters level. It became quickly apparent that most of the information was unavailable, unverifiable, or unreliable. It was, therefore, decided that visits to selected field offices would be needed.

Field offices to be visited were selected on the basis of broad coverage of office size, type of contractor work performed (new construction, repair, spares production), and equipment produced. We attempted to be as consistent as possible concerning definitions and data sources. In many instances, however, data had to be developed from individual contract files, internal office records or personal files (especially for data in the 1967-1968 time frame). Definitions were not consistent and some data had to be subjectively modified in an attempt to achieve consistency. Some data were simply not available at either headquarters or field level.

B. ANALYSIS

Prior to the application of any statistical analysis, a method of handling blanks (missing data) in the data matrix and some general hypotheses on the homogeneity of the population had to be developed.

The problem of missing data points was resolved by the insertion of means. The approach enabled us to use available computer programs to analyze the data that were available for a time-observation for those variables where the data were missing. Using subjective judgment of the specific variable and the amount of missing data, the inserted means were computed from preceding and subsequent observations, the office for the entire time period studied, or the entire population for the total time period.

Preliminary regressions and determinations of the standard deviation were made on all the data to check on the homogeneity of the population. The dispersion of the data led to further testing resulting in a decision to consider the CAS offices under each SYSCOM as separate populations. All results are shown on that basis.

Three approaches were used on the data after modification as noted above. They were: linear regression analysis; curvilinear regression analysis (linear analysis of logarithmic transformations of the variables); and a method best described as a graphical approximation to multi-variable non-linear relationships.[1] From an analysis of the residuals (the

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[1]The first two methods are adequately treated in any standard text on statistical inference such as Applied Regression Analysis, by N. R. Draper and H. Smith, John Wiley and Sons, Inc., New York, 1966. A complete exposition of the graphical approximation method can be found in Methods of Correlation and Regression Analysis, 3rd Edition, by M. J. B. Ezekiel and K. A. Fox, John Wiley and Sons, Inc., New York, 1959.

difference between the actual and computed values of the dependent variable), the graphical approximation method did not appear to be as useful as a combination of the first two methods. Therefore, we dropped consideration of the graphical method in subsequent analyses and concentrated on the development of various linear and curvilinear relationships.

The preliminary regression analyses indicated that relatively few of the variables studied provided any significant historical relationship to actual staffing. The remaining analyses were directed toward providing a maximum coefficient of determination (R^2) and a minimum standard error (SE). To achieve these goals, many subjective trade-offs had to be made.

We also applied the Durbin-Watson statistic as a test for serial correlation of the data and found a strong implication of serialization. In other words, the value of a variable was influenced by its value in the previous time period as well as by its relationship with another variable. We were able to minimize the effect of serialization by using three or four time periods rather than all ten. This resulted in very minor changes in the equations and the smaller sample size was accepted as being definitive for the relationship.

The implication of this adjustment for future updating of the equations is that time periods should be chosen so that there are intervening time periods which are not considered. For instance, an annual update could use data from any one quarter only. Those data would be multiplied by four to annualize them prior to applying the equations in this report.

In summary, the analysis involved:

1. studying the scatter diagrams showing the raw plots of the total personnel in an office versus different independent variables to get an impression of the types of relationships involved.

2. analyzing the correlation matrix to see which independent variables were correlated with the dependent variables, and also which independent variables were auto-correlated, i.e., were related to one another. It is preferable to deal with independent variables that are not related to one another as more information can be extracted from the results of the regression equations.

3. running the step-wise regression program to determine the most significant variables to enter the regression equation.

4. using the t-test to test the coefficients for significant difference from zero to determine whether specific variables should be retained in the equation.

5. studying the analyses of variance table, F ratio and R^2 to determine the significance of the contribution of an independent variable to the coefficient of determination.

6. examining the standard error of the estimate of the regression equation and placing 68% and 95% confidence limits on the results.

7. application of the Durbin-Watson statistic to test for serial correlation.

C. TESTING

A primary concern of the study was the development of staffing criteria which could be used to estimate or predict future staffing levels for all offices--not only those sampled.

We obtained staffing data on a total office basis from the Office of Civilian Manpower Management-Navy (OCMM) for June 1972 as well as for the entire period of the study. These data were used to test the results for prediction purposes (Tables 4 through 6).

As the test results indicate, the regression equations give unsatisfactory estimates of staffing needs on a specific office basis. Therefore, we do not recommend their use for that purpose under current management practices. It is also noted that at least two offices were outside the range of observation when test data were used. We have identified them separately to show how the equation would have predicted their levels were it used outside its relevant range. In general, the further from the range of observation, the less reliable are the results. We would, therefore, suggest that the data base be updated to incorporate these extreme observations before the equations derived from it are used in describing the work relationships of offices displaying such extreme data points.

Table 4

TEST OF SUPSHIP STAFFING CRITERIA

Dependent Variable: Total SUPSHIP Personnel
Equation: Total Personnel = $170.8 (\log X_1) + 0.013X_2 - 620$

X_1 = Annual rate of progress payments (thous. of $)

X_2 = Annual number of changes processed

Sampled Offices	December 1971 Computed	Actual	Diff.	%	June 1972 (1) (2) Computed	Actual	Diff.	%
1	146	107	-39	-36	150	102	-48	-47
2	344	397	53	13	484	426	-58	-14
3	334	322	-12	- 4	380	353	-27	- 8
4	349	388	39	10	322	396	74	19
5	60	50	-10	-20	96	51	-45	-88
6	118	188	70	37	150	(3)	--	--
7	165	219	54	25	207	210	3	1
8	90	54	-36	-67	61	(3)	--	--
9	221	290	69	24	205	317	112	35
10	142	225	83	37	149	187	38	20
Sub-Totals		2240	271	12%		2042	49	2%
Other Offices (1) (2)								
11	- 3	126	129	(4)	71	118	47	40
12	-196	15	211	(4)		no reports available		
13	43	55	12	22	11	49	38	78
14	159	142	-17	-12	142	118	-24	-20
15	192	99	-93	-94	172	101	-71	-70
Sub-totals		296	-98	-33%		386	-10	- 3%
Totals		2536	173	7%		2428	39	2%

NOTES:

(1) Military personnel estimates added to OCMM report (actual based on sample military to civilian ratio)

(2) Data for changes were not available and a proxy was substituted in the calculation.

Estimated changes =

$$\frac{\text{(Sample mean of changes)}}{\text{(Sample mean of progress payments)}} \times \text{observed progress payments}$$

(3) Not listed in OCMM report.

(4) Independent variable outside of range of observation--not used in computing %.

Table 5

TEST OF NAVAIR NAVPRO STAFFING CRITERIA

Dependent Variable: Total NAVPRO Personnel
Equation: Total Personnel = $39 + 0.00024X_1$

X_1 = Annual rate of value of shipments (thous. of $)

Sampled Offices	December 1971				June 1972 (1)			
	Computed	Actual	Diff.	%	Computed	Actual	Diff.	%
1	112	219	107	49	197	239	42	18
2	80	77	- 3	- 4	72	85	13	15
3	266	220	-46	-21	217	231	14	6
4	116	108	- 8	- 7	108	111	3	3
5	41	35	- 6	-17	42	37	- 5	-14
6	219	168	-51	-30	141	169	28	17
7	159	121	-38	-31	145	(2)	--	--
Sub-Total		948	-45	- 5%		872	105	12%
Other Offices (1)								
8	66	(2)	--	--	(2)	--	--	--
9	68	64	- 4	- 6	64	67	3	4
10	80	(2)	--	--	(2)	--	--	--
Sub-total		64	- 4	- 6%		67	3	4%
Total		1012	-53	- 5%		939	108	12%

NOTES:

(1) Military personnel estimates added to OCMM report as noted on Table 4.

(2) Not listed in OCMM report.

Table 6

TEST OF NAVORD NAVPRO STAFFING CRITERIA

Dependent Variable: Total NAVPRO Personnel
Equation: Total Personnel = $0.00081X_1 - 15$

X_1 = Annual rate of value of shipments (thous. of $)

Sampled Offices	December 1971 Computed	Actual	Diff.	%	June 1972 (1) Computed	Actual	Diff.	%
1	108	126	18	14	103	123	20	16
2	68	46	-22	-48	83	45	-38	-84
3	315	363	48	13	363	(2)	--	--
4	43	98	55	56	72	(2)	--	--
5	38	53	15	28	43	50	7	14
Sub-total		686	114	16%		218	-11	- 5%
Other Offices (1)								
6	85	137	52	38	67	132	65	49
Total		823	166	20%		350	54	15%

NOTES:

(1) Military personnel estimates added to OCMM report as noted on Table 4.

(2) Not listed in OCMM report.

D. OTHER STATISTICAL FINDINGS

In addition to the equations and graphs given in the previous Chapter, other statistical information may be useful to the reader in understanding the applicability of the results. This is especially true when applying the equation to an existing situation. Attention should be given to the coefficient of variance and the confidence limits so that the appropriate management judgment may be given during a review of a SYSCOM's needs.

1. For SUPSHIP offices:

Equation:

$Y = 170.8 (\log X_1) = 0.013X_2 - 620$ (defined on page 10).

$R^2 = 0.75$

SE = 63

CV = 27%

Means:

$\bar{Y} = 230$

$\overline{\log X_1} = 4.79$

$\bar{X}_2 = 2352$

Confidence limits:

68% = ± 63

95% = ± 122

Range of observations:

X_1 (thous. of \$) = \$3,408 to \$360,364

X_2 = 34 to 9648

2. For NAVAIR offices:

Equation:

$Y = 39 + 0.00024X_1$ (defined on page 15).

$R^2 = 0.91$

SE = 24

CV = 16%

Means:

$\bar{Y} = 148$

$\bar{X}_1$ (thous. of $) = $458,293

Confidence limits:

68% = ± 24

95% = ± 47

Range of observations:

X_1 (thous. of $) = $5,822 to $1,195,946

3. For NAVORD offices:

Equation.

$Y = 0.00081X_1 - 15$ (defined on page 15)

$R^2 = 0.92$

SE = 36

CV = 25%

Means:

$\bar{Y} = 144$

$\bar{X}_1$ (thous. of $) = $197,094

Confidence limits:

68% = ± 36

95% = ± 70

Range of observations:

X_1 (thous. of $) = $78,012 to $479,600

Appendix A

ASSISTANT SECRETARY OF DEFENSE
Washington, D. C.

Installations and Logistics **DATE: 30 Mar 1971**

TASK ORDER SD-271-147
(Task 71-8 Rev.)

1. Pursuant to Articles I and III of the Department of Defense Contract No. SD-271 with the Logistics Management Institute, the Institute is requested to undertake the following task:

A. TITLE: Review of Navy Contract Administration Field Activities

B. SCOPE OF WORK: This task entails a review and analysis of the organization, functional responsibilities, interface relationships workload trends and staffing criteria of selected headquarters and field Contract Administration Services (CAS) activities under the command of the Chief of Naval Material. It is anticipated that some field activities may be assigned additional important responsibilities over the next several months. It is appropriate at this time to evaluate the organization, responsibilities, and personnel resources of these activities against current and projected contract administration requirements.

In performing this task, LMI will:

1) Review and analyze the organization, functional responsibilities, interface relationships, and workload trends of headquarters and field CAS activities which will include but need not be limited to:

a) Headquarters:

(1) Naval Material Command
(2) Naval Air Systems Command
(3) Naval Ordnance Systems Command
(4) Naval Ship Systems Command

b) Field:

(1) Naval Air Systems Command Representative-Atlantic

(2) Naval Air Systems Command Representative-Pacific

(3) Naval Plant Representative Offices:

(a) Bethpage
(b) Burbank
(c) Dallas
(d) East Hartford
(e) Pomona

(4) Supervisors of Shipbuilding, Conversion, and Repair, USN:

(a) Groton
(b) Newport News
(c) Pascagoula

2) Identify and evaluate variations in organization, functional statements, and operations in the activities in 1) above.

3) Examine the interface relationships of activities in 1) above with buying and program offices, with Defense contractors, and with other DoD personnel resident in the contractors' plants.

4) Attempt to develop staffing criteria for field CAS activities. It is expected that contacts, in addition to those in 1) above, will be made to obtain meaningful data and information on correlation techniques and applicability of proposed criteria.

5) Develop findings, conclusions, and recommendations and incorporate them in a report, with supporting information and rationale.

2. SCHEDULE: The final report will be submitted by 1 December 1972.

/s/ Glenn V. Gibson

ACCEPTED /s/ Wm. F. Finan

DATE 30 March 1971

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[1] As extended from 31 March 1972.

DEPARTMENT OF THE NAVY
NAVAL SHIP SYSTEMS COMMAND
Washington, D.C. 20360

01P2:GND:llo
Ser 68-01P2
15 Mar 1971

From: Commander, Naval Ship Systems Command
To: Assistant Secretary of Defense (Installations and Logistics)

Subj: Logistics Management Institute review of Navy Contract Administration Organizations

Ref: (a) ASD (I&L) task order to LMI number SD-271-147, task 71-8 of 1 December 1970
(b) Bureau of the Budget Circular A-11 dtd June 15, 1970

1. Reference (a) tasked the Logistics Management Institute (LMI) to review and analyze the organization, functional responsibilities, interface relationships, and workload trends of various Headquarters and field Contract Administration Service (CAS) activities, including several of the Supervisors of Shipbuilding, Conversion, and Repair, and Naval Ship Systems Command (NAVSHIPS) Headquarters.

2. It is requested that reference (a) be amended to include the requirement for identifying workload indicators for the functions under study which LMI determines would form valid bases for the development of the staffing criteria in section 13.3 of reference (b). This information would assist NAVSHIPS in further improving workload/workforce balance in these areas.

3. For further information or assistance, Mr. George Deihl (NAVSHIPS) 01P2, OX2-8190 or OX2-8191) is the NAVSHIPS point-of-contact on staffing criteria, and will be available on request.

/s/ N. Sonenshein

Excerpt from
BUREAU OF THE BUDGET
Circular A-11
June 15, 1970

Section 13.3 (underlining added)

13.3 Estimates relating to numbers of personnel.

Estimates for the budget year should reflect the most efficient utilization of manpower (see Bureau of the Budget Circular No. A-64, as amended by Transmittal Memorandum No. 1). To the maximum extent possible, the estimates are to represent agency plans covering both manpower inputs and work outputs required for implementing program objectives and exercising appropriate managerial control.

Estimates of manpower requirements for measurable workloads should be based on forecasts of workload and manpower productivity wherever feasible (see section 24.4). Statistical standards may be used in the development of productivity trends and to express the relationship between workload indicators and manpower requirements.

The estimates for staffing requirements will assume that improvements in skills, organization, procedures, and supervision will steadily increase employee productivity and at the same time maintain adequate quality. Where automatic data processing equipment is installed, special gains in employee productivity will ordinarily be budgeted after the first year.

Personnel currently authorized will be utilized to the maximum extent in staffing new programs and expansions in existing programs, and a reduced number of personnel should generally be planned where the workload is stable. Estimates of staffing requirements for on-going as well as new programs will be based upon quantitative forecasts of workload for each program, together with adequate substantive data for converting workload to required personnel. Increases in staffing will be approved only when it is demonstrated that essential functions cannot be performed with existing employees.

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Appendix B

OFFICES CONTACTED AND VISITED

During Both Phases of the Study

Department of Agriculture

- Economic Research Service
- Statistical Reporting Service

Department of Defense

- Directorate for Contract Administration Services, Office of the Assistant Secretary of Defense (Installation & Logistics)
- Defense Supply Agency, Contract Administration Services
  - Office of Plans and Management
  - Executive Directorate for Contract Administration
  - Executive Directorate for Quality Assurance
  - Executive Directorate for Production

Department of the Air Force

- Deputy Chief of Staff for Systems and Logistics, Directorate of Procurement Policy
- Air Force Systems Command
  - Directorate of Procurement Support
  - Air Force Contract Management Division

Department of the Navy

- Assistant Vice Chief of Naval Operations
  - Director of Naval Administration, History (Naval) Division
- Office of Civilian Manpower Management
  - Manpower Information Division
- Deputy Chief of Naval Material(Procurement and Production)
  - Acquisition Management Review Division
  - Contract Administration Division
  - Procurement Management Division
- Naval Air Systems Command Headquarters
  - Organization and Manpower Management Office
  - Material Acquisition Directorate, Contract Administration Service and Quality Assurance Branch

Naval Ordnance Systems Command Headquarters
Product Assurance Division, Contract Administration Services Branch

Naval Air Systems Command Representative—Atlantic
Naval Air Systems Command Representative
Contract Support Department
Quality Assurance and Engineering Department

Naval Air Systems Command Representative—Pacific
Contract Support Department

Naval Plant Representative Offices
Akron, Ohio
Baltimore, Md.
Bethpage, N. Y.
Burbank, Calif.
Dallas, Texas
Dothan, Ala.
East Hartford, Conn.
Great Neck, N. Y.
Pittsfield, Mass.
Pomona, Calif.
Silver Spring, Md.
Stratford, Conn.
Sunnyvale, Calif.

Supervisor of Shipbuilding, Conversion and Repair Offices
Bath, Maine
Bay City, Mich. (Resident Office)
Boston, Mass.
Groton, Conn.
New Orleans, La.
Newport News, Va.
Pascagoula, Miss.
Portsmouth, Va.
San Deigo, Calif.
Seattle, Wash.
Sturgeon Bay, Wisc.

Appendix C

DEFINITIONS OF VARIABLES USED

The results of this study are expressed as equations with one or more independent variables used to determine the number of personnel utilized historically to perform the work of an office or division within an office. Because of differences among SYSCOMs, the variables must be defined to insure consistent data.

The field phase of the study included the gathering of data on 25 independent and 9 dependent variables. For various reasons, these were reduced to 22 independent and 6 dependent variables for NAVPROs and 17 independent variables for SUPSHIPS. As a result of our analyses, a total of 8 independent variables have been chosen to provide relationships to the 6 dependent variables.

The definitions of the 14 variables finally used are given below. The definitions of the 20 initial variables which were eventually dropped are available at LMI.

Dependent Variables:

All dependent variables concern the number of personnel (both civilian and military) in an office or department/division of an office. Thus variable "total SUPSHIP/NAVPRO personnel" refers to all government employees, military and civilian, clerical, professional, and supervision, who are assigned to a SUPSHIP or NAVPRO office for the purpose of performing CAS functions. If an unusual, non-CAS oriented function is assigned to the office for administrative purposes, its personnel should

not be included in the total.

The organizational sub-divisions refer to the usual divisions or departments specified in NAVSHIPS 0900-000-3010 (the SACAM), NAVAIRINST 5000.6, and NAVORDINST 5000.2.

Note that separate equations are not given for the function of command or command staff--those individuals not assigned to a specific functional division but who act in a staff or advisory capacity to the Commander. They are included in the equations for total office personnel.

Within the divisions, the variable "personnel" includes all government employees, military and civilian, including the division chief.

Independent Variables:

1. Value of Shipments/Progress Payments.

The purpose of this variable is to serve as a description of the work performed by the contractor under contracts administered by the CAS office. The data may be in the form of progress payments, invoices paid, or value of goods accepted by the government. Progress payments are generally encountered in single unit, high value items (i.e., new ship construction). Value of goods accepted is generally encountered in multiple-unit, long term contracts such as air frames, engines, and electronics. Invoices paid are usually descriptive of short term efforts such as repair work or purchases of spares.

In all cases, we attempted to use that measure which provided the most accurate value description of the contractor's work.

The forms used as data sources were NAVSHIPS 4350/4, NAVAIR 5220 and NAVORD 4330-14.

2. Changes.

During the life of any contractual document, changes and modifications are made that must be evaluated in some way by the CAS office. These changes are designated by many terms in the various commands and offices. We attempted to insure that all significant work-producers were counted and, therefore, were unable to use the same term in all offices.

Basically, however, we requested information on cost/price proposals in NAVPROs and changes and job order modification in SUPSHIPs.

We found a very poor availability of data on changes and relied heavily on personal and local files. Because of this, we believe that the raw data on changes to be the least reliable of the variables used in the final equations.

3. Number of Firm Fixed Price (FFP) Contracts.

This variable covered only major contracts and excluded all other contractual documents such as purchase orders, job orders, letter contracts, etc. In SUPSHIPs, the only office where this variable showed as significant, we obtained data on FFP new contraction and overhaul contracts and Master Ship Repair contracts.

4. Terminations and Closeouts.

This variable was significant only for SUPSHIPs. For NAVPROs, the term includes only terminations for cause or convenience and completions or closeouts of contracts excluding purchase orders, job orders, etc. For SUPSHIPs, however, the term also includes the completion or closeout of job orders under Master Ship Repair contracts in addition to new construction and major overhaul contracts.

5. Value of Government Property.

This variable includes the value of land, buildings, industrial plant equipment, special tooling and special test equipment held by the contractor. The variable excludes material and other special categories such as bailed aircraft, floating drydocks, military equipment, etc.

6. Contracts over 90% Completed.

This variable was used for NAVAIR NAVPROs only. It refers only to prime contracts on which over 90% of the hardware has been delivered and the contract is still open.

7. Contractor Personnel - Technical and Production.

The final equations included contractors' production personnel for SUPSHIPs and contractors' technical personnel for NAVPROs. In both cases the data include only the contractor personnel involved in government work under the cognizance of the local CAS office.

For SUPSHIPS, the data were available from NAVSHIPS form 4350-2. For NAVPROs, the data were obtained directly from the contractor on the basis of consistency with OMB 22-R-261.

Variables for which data were collected but not used

1. Dependent variables
   a) SUPSHIP/NAVPRO operating budget
   b) SUPSHIP/NAVPRO total civilian hours paid
   c) SUPSHIP/NAVPRO personnel on Command staff

2. Independent variables
   a) Number of contractors serviced
   b) Number of plants serviced
   c) Average distance to plants serviced
   d) Type of contractor facility
   e) Number of items of government property held by contractor
   f) Undelivered balance of production and R and D contracts administered by SUPSHIP/NAVPRO
   g) Number of contract documents (active and inactive) being administered by SUPSHIP/NAVPRO
   h) Number of cost-type prime contracts being administered by SUPSHIP/NAVPRO
   i) Number of fixed-price-incentive prime contracts being administered by SUPSHIP/NAVPRO
   j) Number of government agencies with contracts administered by SUPSHIP/NAVPRO

k) Number of contractor's purchase orders submitted for SUPSHIP/NAVPRO approval

l) Value of contractor's purchase orders submitted for SUPSHIP/NAVPRO approval

m) Number of forms DD 250 processed

n) Number of Quality Assurance personnel employed by contractor on government work

o) Number of clerical personnel employed by contractor on government work

p) Number of managerial personnel employed by contractor on government work

q) Total contractor employees on government work

Appendix D

INPUT DATA TO ANALYSIS

The following is a table of the data upon which our analysis was based. Values are shown only for those variables which are represented in a regression equation. Data collected for variables which were later found to be insignificant are omitted. It should be noted that only the time periods underlined were actually utilized in computing the equations. Where a better fit was found by transforming the variable to logarithmic form, the transformation was made but the data on the table reflect the raw values. In some cases when values of variables were missing, the mean for that office was substituted in its place. The sub-totals for each department do not add up to the total for an office because the personnel on the Command staff were not included.

See Appendix C for precise definition of variables.

		DEPENDENT VARIABLES						INDEPENDENT VARIABLES			
		PERSONNEL ON BOARD						GOVT PROP		CHANGES, CHANGE	CONTR TECHN.
OFFICE	TIME	ADMIN	CNTRS	ENGR	QA	MAT/IND	TOTAL	HELD	VALUE SHIPPED	ORDERS	PERS.
1	1	29*	49*	16*	58*	38*	197*	85000	145127	1510	1752
	2	28	48	14	55	35	187	85000	120508	1228	1695
	3	27	45	13	50	34	176	85000	121900	2208	1619
	4	26	45	14	46	35	173	81000	131759	851	1577
	5	26	44	14	46	34	171	102000	127716	959	2082
	6	22	41	14	45	37	168	101000	115928	1166	2163
	7	15	37	10	35	28	134	79000	134877	2025	1937
	8	13	37	7	34	27	127	78000	114129	896	1773
	9	14	36	8	34	27	128	95000	116263	1009	1679
	10	14	35	8	34	27	126	87000	111006	1206	1742
2	1	6*	10*	16*	0	0	35	53222	51477*	22*	1076
	2	5	9	15	0	0	32	53541	51477*	22*	1090
	3	5*	9*	15*	0	0	32	52065	51478*	21	1058
	4	5	10	15	0	0	33	49606	51478*	24	1093
	5	5	10	12	2	0	32	59896	46852	38	1121
	6	5	10	10	2	0	30	61706	49678	23	1158
	7	5	10	8	2	0	29	62599	53211	26	1136
	8	5	11	9	3	8	38	65193	53716	20	1065
	9	6	9	8	3	12	41	67582	54317	18	1024
	10	6	8	8	5	14	46	70064	51091	7	1075
3	1	48	36	82	100	39	315	112722	225365*	322*	3472
	2	51	36	83	110	44	334	124004	225365*	255	3476
	3	53	36	79	108	41	327	142434	225365*	268	3071
	4	52	37	80	109	43	331	146763	225365*	339	2910
	5	55	44	83	143	51	386	152289	225365*	395	2936
	6	52	43	80	142	50	377	200521	213246	289	3274
	7	51	44	79	143	52	381	203795	241197	354	2910
	8	49	43	75	153	51	383	199016	237373	302	2788
	9	46	42	73	157	49	379	201452	220112	300	2776
	10	41	37	73	152	48	363	197416	214897	395	2588

		DEPENDENT VARIABLES						INDEPENDENT VARIABLES				
		PERSONNEL ON BOARD										
OFFICE	TIME	ADMIN	CNTRS	ENGR	QA	MAT/IND	TOTAL	GOVT PROP HELD	VALUE SHIPPED	CHANGES, CHANGE ORDERS	CONTR. TECHN. PERS.	CONTR. 90% COMPL.
4	1	4	11	25	27	19	92	36376	40159	507	1851	
	2	4	11	25	25	19	88	35825	44998	358	1905	
	3	5	12	26	32	20	100	36568	46477	464	2065	
	4	5	12	25	32	20	99	38421	41993	398	2094	
	5	5	13	25	32	20	101	37949	45741	542	2116	
	6	4	14	24	32	18	96	36311	39895	337	2000	
	7	4	14	25	31	19	98	36724	47051	445	1808	
	8	4	14	25	31	20	98	36625	43209	470	1689	
	9	4	14	25	31	20	98	36685	39006	481	1605	
	10	4	14	26	31	19	98	38882	40311	501	1472	
5	1	12	9	5	28	11	70	43219	58811	118	1308	
	2	12	11	5	29	11	73	44995	61874	71	1322	
	3	13	10	5	29	11	73	40625	53144	104	1231	
	4	13	11	5	29	11	73	36325	51572	76	1160	
	5	13	10	5	28	13	74	43783	40941	65	1148	
	6	12	10	5	28	12	72	52242	48097	89	1094	
	7	9	7	3	25	11	60	49232	38061	64	1043	
	8	7	7	3	23	10	54	43558	37766	62	982	
	9	7	8	3	22	10	54	39188	36000	86	948	
	10	7	8	3	22	10	53	34847	32000	57	896	
6	1	13*	16*	10*	147	20*	226	63079	455968		4232*	35
	2	14	17	10	146	21	229	87444	393881		5006	31
	3	13*	24*	13*	139	26*	240	99682	343845		4761	38
	4	13	24	13	139	27	241	116877	354473		4821	23
	5	14*	25*	14*	139	28*	247	139513	434779		5155	30
	6	11	23	12	134	26	230	153106	350497		5316	33
	7	11	23	12	120	26	222	169202	296055		3928	31
	8	12	21	12	116	24	222	156170	298830		3663	73
	9	12	20	11	112	24	223	144870	386396		2821	119
	10	12	18	11	112	23	219	138761	152558		2624	123

		DEPENDENT VARIABLES						INDEPENDENT VARIABLES			
		PERSONNEL ON BOARD									
OFFICE	TIME	ADMIN	CNTRS	ENGR	QA	MAT/IND	TOTAL	GOVT PROP HELD	VALUE SHIPPED	CONTR. TECHN. PERS.	CONTR. 90% COMPL.
7	1	10	17	11	28	14	86	79109	108159	1222	15
	2	10	17	11	32	17	93	86366	129402	1196	19
	3	11	17	12	32	17	94	106272	119750	1221	22
	4	11	16	13	32	20	98	98335	118647	1336	25
	5	11	13	13	32	20	95	91377	94159	1196	30
	6	10	12	12	31	19	89	90303	136419	1069	21
	7	8	11	12	25	17	78	35430	123578	1018	24
	8	8	12	11	24	18	78	81902	133201	856	25
	9	8	12	9	24	18	76	75180	88470	597	25
	10	9	12	9	24	18	77	68458	84069	591	27
8	1	28	43	23	143	36	290	404800	464266	9519	134
	2	25	41	22	151	37	292	415600	524960	10399	190
	3	23	41	22	150	37	287	408800	552973	10650	114
	4	26	38	20	160	36	294	402000	517840	9907	211
	5	20	40	19	161	41	296	395300	508667	11298	96
	6	21	39	23	155	43	295	491700	444699	10675	230
	7	22	38	24	150	41	285	664500	435754	9229	215
	8	21	36	23	148	40	280	678100	511919	8137	56
	9	23	35	23	78	43	214	765600	406876	7990	149
	10	20	33	23	89	42	220	954900	473433	7309	478
9	1	12	20	12	45	24	124	27850*	82927	5434	49*
	2	11	24	13	49	25	133	27850*	99440	5800	49*
	3	12	24	13	49	26	134	19100	120611	5274	49*
	4	11	24	12	47	25	127	27850*	103308	5398	49*
	5	10	24	13	45	25	128	29300	151249	5652	49*
	6	8	23	11	45	21	119	27850*	103369	5622	49*
	7	9	22	10	37	23	111	34100	308199	5730	49*
	8	9	22	10	37	25	112	27850*	320103	5136	49*
	9	9	22	10	37	23	111	28900	174355	4856	49*
	10	8	22	11	37	22	108	27850*	161337	4485	49*

		DEPENDENT VARIABLES						INDEPENDENT VARIABLES			
		PERSONNEL ON BOARD						GOVT PROP	VALUE	CONTR. TECHN.	CONTR. 90%
OFFICE	TIME	ADMIN	CNTRS	ENGR	QA	MAT/IND	TOTAL	HELD	SHIPPED	PERS.	COMPL.
10	1	11*	10*	1*	19*	9*	55*	3148	6938	134	5
	2	9	7	1	16	7	45	4147*	3166	70	2
	3	7	7	1	13	7	38	5994	3617	58	2
	4	7	7	1	14	7	40	4147*	4535	52	3
	5	6	7	1	14	7	39	5556	3599	64	3
	6	7	6	1	15	7	40	4147*	2911	58	4
	7	5	5	1	15	7	38	3335	2186	71	5
	8	4	6	1	15	7	38	4147*	2011	52	2
	9	4	5	1	15	7	37	2701	7703	63	6
	10	3	5	1	15	7	35	4147*	4125	60	6
11	1	10	23	13	52	19	125	105664	137873	2840	40
	2	11	23	13	52	20	127	108800	189768	3196	48
	3	14	26	15	58	22	141	121705	221593	3645	61
	4	16	27	19	65	24	157	123087	270227	3948	63
	5	21	31	21	70	28	183	135081	306532	3859	61
	6	18	30	21	68	26	171	140528	353810	3302	72
	7	17	35	19	69	30	178	146015	325458	3119	68
	8	17	32	20	67	30	174	143754	298588	2552	81
	9	15	31	20	64	27	163	142296	234162	2346	88
	10	13	32	23	66	26	168	138566	224593	2457	96
12	1	20	27	11	51	26	146	36002	109100	3094	29
	2	15	23	10	50	25	135	36002	150823	3085	26
	3	18	24	11	51	24	139	36002	179601	3488	20
	4	13	23	9	50	24	130	40073	148817	4129	24
	5	13	23	9	46	22	125	38118	189707	2606	30
	6	13	22	9	39	22	119	44676	131212	2778	36
	7	12	22	11	37	23	120	50907	206959	1705	27
	8	13	21	12	37	23	119	52589	232300	1665	28
	9	14	19	13	37	22	119	45173	239819	1440	27
	10	13	20	13	35	19	121	45893	250128	1569	28

		DEPENDENT VARIABLES							INDEPENDENT VARIABLES			
		PERSONNEL ON BOARD										
OFFICE	TIME	ADMIN	CNTRS	ENGR	QA	MAT/IND	TOTAL	VALUE SHIPPED	TERMS.	FFPC	CHANGES, CHANGE ORDERS	CONTR. PROD. PERS.
13	1	7	12	38	26	19	108	19502	1	8	234	2236*
	2	7	10	35	28	19	105	10712	0	9	167	2232
	3	8	12	39	29	25	119	12711	0	10	523	2582
	4	8	12	38	33	28	125	13084	1	9	368	2587
	5	8	12	34	30	27	123	14141	0	9	378	2487
	6	8	18	31	30	28	127	13059	0	9	792	2627
	7	10	17	30	31	26	126	11548	2	7	929	1776
	8	10	17	25	19	22	108	15556	1	6	932	1907
	9	13	15	26	17	25	109	11812	1	5	827	1811
	10	11	13	26	20	23	107	11124	0	5	906	2071
14	1	10	11	42	0	0	66	3519*	46	15	885	602
	2	9	9	42	0	0	63	3519*	57	15	1054	279
	3	7	8	42	0	0	60	3606	46	14	701	449
	4	4	11	40	0	0	58	4660	58	14	196	364
	5	8	10	39	0	0	60	5677	36	17	217	333
	6	8	7	37	11	0	56	2486	59	17	613	198
	7	7	6	35	11	0	52	3811	36	16	194	178
	8	7	6	34	11	0	51	1704	59	16	450	200
	9	11	3	32	11	0	50	1649	82	15	445	132
	10	12	3	32	11	0	50	4560	59	15	167	213
15	1	31	57	153	121	0	364	117845	0	15	3191*	6376*
	2	31	57	153	121	0	364	107018	2	15	3291	4806
	3	32	59	153	118	0	364	115406	3	15	4006	7527
	4	30	33	126	119	52	362	98961	5	15	2439	6947
	5	30	33	131	121	54	371	113129	2	15	2884	7048
	6	28	40	117	120	53	360	113295	7	15	3102	7103
	7	30	40	121	117	53	363	114196	8	15	3108	6529
	8	30	39	125	123	53	374	133915	3	15	3039	5886
	9	33	37	133	124	53	383	123510	1	10	4824	5838
	10	34	40	184	79	46	388	115997	2	28	2026	5700

		DEPENDENT VARIABLES						INDEPENDENT VARIABLES				
		PERSONNEL ON BOARD										
OFFICE	TIME	ADMIN	CNTRS	ENGR	QA	MAT/IND	TOTAL	VALUE SHIPPED	TERMS.	FFPC	CHANGE, CHANGE ORDERS	CONTR. PROD. PERS.
16	1	41	20	112	134	52	376	124241	0*	3*	849*	15225
	2	51	22	119	145	61	415	98330	1*	3*	849*	16075
	3	39	18	104	124	52	353	99397	0*	4*	849*	16050
	4	44	18	103	125	49	356	75754	1*	9	849*	15850
	5	45	22	102	124	51	362	78311	0	6	849*	14150
	6	52	23	107	116	51	366	128492	0	6	849*	15800
	7	48	20	96	120	52	370	146209	0	1	849*	14800
	8	53	24	106	123	51	395	131852	1	1	849*	12517
	9	52	22	110	120	51	390	164789	1	0	849*	13139
	10	57	24	111	120	49	397	165069	2	0	849*	17250
17	1	10	24	77	47	15	174	16836	220*	47*	1996*	3099
	2	10	28	96	50	16	201	21570	103	57	1996*	3646
	3	18	31	111	52	25	239	17471	227	78	2186	3241
	4	18	29	111	53	25	239	38893	259	58	3003	3304
	5	17	32	116	57	27	252	29068	222	58	2141	3360
	6	17	33	120	57	27	257	32869	231	38	3084	3419
	7	18	30	110	57	27	245	12033	232	56	2526	2852
	8	15	25	103	54	24	224	13285	220	29	918	1796
	9	12	24	95	45	17	195	42636	245	36	1287	986
	10	12	24	88	45	17	188	7940	243	16	826	1093
18	1	14	15	28	31	34	143	29991	2	3	393	7155
	2	13	14	28	31	31	139	28168	2	4	393	7743
	3	13	14	30	32	34	145	36115	0	5	280	7555
	4	14	14	29	32	31	143	31942	1	3	280	8524
	5	14	13	39	33	33	157	47164	0	5	162	6625
	6	17	20	50	46	34	182	66565	0	4	162	6553
	7	17	21	51	48	34	192	98959	0	2	181	5710
	8	23	28	57	50	40	244	198509	0	3	182	6597
	9	28	33	57	52	41	259	147020	0	2	188	9281
	10	39	41	73	58	42	322	180182	0	2	188	9154

		DEPENDENT VARIABLES						INDEPENDENT VARIABLES				
		PERSONNEL ON BOARD										
OFFICE	TIME	ADMIN	CNTRS	ENGR	QA	MAT/IND	TOTAL	VALUE SHIPPED	TERMS.	FFPC	CHANGES, CHANGE ORDERS	CONTR. PROD. PERS.
19	1	14	15	64	24	26	155	19854	25	36	57	5452*
	2	16	15	65	26	36	179	26774	26	41	13	5730
	3	15	15	65	30	38	183	44952	28	41	28	6834
	4	17	15	63	35	40	192	51730	30	36	212	6278
	5	16	16	66	43	40	204	53432	17	32	382	7289
	6	16	15	63	48	39	204	42548	11	30	17	7861
	7	16	15	63	49	39	205	36116	19	44	53	6793
	8	16	15	63	55	39	211	44704	30	31	723	2842
	9	16	17	50	84	37	222	26792	35	33	450	2534
	10	16	17	52	81	36	219	15138	24	24	250	2909
20	1	9*	18*	23*	40*	25*	126	17950	5	22	285	1741*
	2	9	15	20	36	21	112	20650	7	28	314	3069
	3	9	15	19	35	21	110	21306	14	28	287	2695
	4	9	14	18	35	21	107	18442	15	24	313	1820
	5	7	14	20	33	18	99	21550	6	26	289	2059
	6	7	14	19	32	15	95	19480	13	23	268	1065
	7	6	12	18	27	13	83	16915	5	23	165	1421
	8	5	10	17	24	13	76	12835	3	20	129	1577
	9	5	10	15	20	12	69	11850	4	19	129	1369
	10	4	8	14	16	8	54	6976	3	18	110	595
21	1	33	36	200	87	25	417	47263	356	23	2367*	2900*
	2	27	39	202	76	30	409	34827	97	56	2366*	1753
	3	18	40	167	67	35	380	46983	261	52	2366*	2861
	4	20	40	163	86	37	401	68336	219	45	2367*	3275
	5	23	39	145	79	39	393	54436	243	54	2445	3408
	6	28	46	123	68	33	342	47281	130	28	1454	4022
	7	29	48	101	53	33	312	47800	131	45	3947	3847
	8	26	47	98	50	30	297	33910	136	26	1476	2609
	9	27	44	104	44	30	295	68085	163	37	3239	2596
	10	25	46	102	44	30	290	23717	196	40	1640	1732

		DEPENDENT VARIABLES						INDEPENDENT VARIABLES				
		PERSONNEL ON BOARD										
OFFICE	TIME	ADMIN	CNTRS	ENGR	QA	MAT/IND	TOTAL	VALUE SHIPPED	TERMS.	FFPC	CHANGES, CHANGE ORDERS	CONTR. PROD. PERS.
22	1	44	46		80	57	362	48760*	45*	50*	826*	4364*
	2	43	50	111	78	58	364	76409	54	53	1292	5266
	3	43	50	111	77	56	361	90245	55	52	1135	5106
	4	43	52	108	78	55	357	74997	19	53	1013	5634
	5	43	49	101	75	54	341	60359	21	43	952	5011
	6	43	49	94	68	49	322	25309	44	47	581	4978
	7	34	46	86	54	39	286	34927	50	50*	757	4924
	8	31	42	83	52	37	274	38187	43	44	570	4087
	9	24	36	81	45	37	253	29761	54	54	381	2733
	10	23	40	76	34	30	225	8649	61	52	554	1539

NOTES:

1) *Mean value used; actual value missing or not reported. While all 10 time periods are shown, only periods 2, 6, 9 or 2, 5, 7, 9 were used in formulating the regression equations.

2) Data for "Value Shipped," "Terminations," and "Changes" are for the six months prior to the point of observation. To use these data on the same basis as the equations in this report, they must be multiplied by 2.

3) Time periods:

1	June 1967
2	Dec 1967
3	June 1968
4	Dec 1968
5	June 1969
6	Dec 1969
7	June 1970
8	Dec 1970
9	June 1971
10	Dec 1971

Appendix E

STATISTICAL EQUATIONS

The computer program used to run the regression analysis was the Stepwise Regression (BMDO2R) of the Biomedical statistical package. Stepwise computes a sequence of regression equations, at each step adding to the equation that variable which makes the greatest reduction in the error sum of the squares. It is the variable with the highest partial correlation with the dependent variable after accounting for the variables already added.

The BMD source is written in FORTRAN and is generally available. We used a CDC 6600 series computer. The BMD reference manual clearly states the input format of the control cards to be used. The input data were punched into cards and the appropriate fields transformed to logarithmic form.

The statistical definitions and formulae referenced in the text of this report were the standard mathematical equations developed in most books but will be described below for the reader's convenience.

1. Mean or average

$$\bar{X} = \sum_{i=1}^{n} X_i,$$

where X_i is the ith observation

2. Range of observation of X equals

$$X_{max} - X_{min}$$

where X_{max} and X_{min} are the maximum and minimum values of X respectively.

3. Variance of X = σ^2

$$\sigma^2 = \frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{n}$$

4. Standard deviation of X = σ

$$\sigma = \sqrt{\sigma^2}$$

5. Coefficient of variation CV

$$CV = \frac{\sigma}{\bar{X}}$$

where $\bar{X}$ is the mean of X

6. Coefficient of correlation $= \sqrt{x.y}$

$$\sqrt{x.y} = \frac{\sum_{i=1}^{n} (X_i - \bar{X}) \quad (Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n} (X_i - \bar{X})^2 \sum_{i=1}^{n} (Y_i - \bar{Y})^2}}$$

7. Coefficient of determination = R^2

$$R^2 = \frac{\text{explained sum of squares}}{\text{total sum of squares}}$$

$$= \frac{\sum_{i=1}^{n} (\hat{Y}_i - \bar{Y})^2}{\sum_{i=1}^{n} (Y_i - \bar{Y})^2}$$

where $\hat{Y}_i = b_o + b_1 X_i$ (computed value of Y_i at X_i)

Y_i = actual value of Y at X_i

8. F ratio

$$F = \frac{\text{variance explained by regression equation}}{\text{residual variance}}$$

$$= \frac{\sum_{i=1}^{n} (\hat{Y}_i - \bar{Y})^2 / k}{\sum_{i=1}^{n} (Y_i - \hat{Y})^2 / (n-k)}$$

where k is the number of degrees of freedom associated with regression equation and n is the number of observations.

9. Confidence interval on Y evaluated at X_1 equals

$$\hat{Y}_i \pm t\left(v, 1-\frac{\alpha}{2}\right) \cdot \sigma_{y.x}$$

where $t\left(v, 1-\frac{\alpha}{2}\right)$ is the t statistic corresponding to v degrees of freedom and a two-tailed $1-\alpha$ confidence interval.

10. Residual e_i

$$e_i = Y_i - b_o - b_1 X_i$$

represents the difference between the computed and actual values of Y at X_i

Appendix F

REGRESSION EQUATIONS FOR DEPARTMENTS/DIVISIONS

In addition to finding a regression equation relating total personnel on board with its explanatory variables, the department/divisions for the offices were also investigated. By the very nature of a statistical approach to problem solving, a range of values rather than a point estimate is to be inferred from the equations. This range is given below for 68% and 95% confidence intervals respectively about the mean of $\hat{Y}_i$, where $\hat{Y}_i = b_o + b_1 X_i$.

In theory the range about the mean is the minimum so we must consider this the best possible case. The range of variance for personnel is large when predicting a subset of the total office. The equations represent relationships found to be true in the past and cannot be sensitive to changes in organization policy or shifts of emphasis that may occur in the future. We do not, therefore, recommend that the equations be used for predictive purposes without appropriate management action. The departments studied were:

1. Administration
2. Contracts
3. Engineering/Planning
4. Quality Assurance
5. Materials/Industrial

The equations and corresponding statistics are given below for each of the Commands. (See Appendix C for a more detailed definition of the independent variables).

SUMMARY OF STATISTICAL FINDINGS
REGRESSION EQUATIONS FOR DEPARTMENTS
SUPSHIPS

Regression Equation for Personnel in:	R^2	S.E.*	C.V.	C.I.68%**	C.I.95%**
ADMIN = $0.105X_1 - 2$ X_1 = number of total personnel in CAS office	.77	7.0	.32	15-29	8-36
CONTRACTS = $14.8(\log X_1) + 0.311X_2 + 0.0022X_3 - 58$ X_1 = progress payments (thous.$), annual rate X_2 = Firm fixed price contracts on hand X_3 = number of changes, proposals, change orders processed per year	.71	8.3	.33	17-34	10-42
PLAN = $41.6(\log X_1) + 0.077X_2 + 0.0085X_3 - 149$ X_1 = progress payments (thous.$), annual rate X_2 = number of terminations processed per year X_3 = number of changes, proposals, change orders processed per year	.66	28.7	.37	50-106	22-134
QA = $54.4(\log X_1) + .0037X_2 - 211$ X_1 = progress payments (thous.$), annual rate X_2 = number of changes, proposals, change orders processed per year	.67	23	.39	35-81	13-103
MAT = $27.7(\log X_1) - 66$ X_1 = number of contractor personnel in government production	.64	10.9	.36	19-41	9-51

*Standard error of the estimate
**Confidence intervals at $\bar{Y}$ (mean of dependent variable)

SUMMARY OF STATISTICAL FINDINGS
REGRESSION EQUATIONS FOR DIVISIONS
NAVORD NAVPROs

Regression Equation for Personnel in:	R^2	S.E*	C.V.	C.I.68%**	C.I.95%**
ADMIN = $0.141X_1 - 2$ X_1 = number of total personnel in CAS office	.94	4.7	.26	14-23	9-27
CONTRACTS = $40.1(\log X_1) + 8.4(\log X_2) - 207$ X_1 = value shipped (thous.$), annual rate X_2 = number of changes processed per year	.94	4.2	.18	19-27	15-31
ENGR = $139.7(\log X_1) - 424$ X_1 = number of contractor technical personnel on government work	.73	15.1	.58	11-41	0-55
QA = $0.00031X_1 - 13$ X_1 = value shipped (thous.$), annual rate	.85	19.5	.41	28-67	10-86
IND = $64.7(\log X_1) + 24.2(\log X_2) - 302$ X_1 = number of contractor technical personnel on government work X_2 = value of government property on hand (thous.$)	.89	6.0	.26	17-29	11-35

*Standard error of the estimate
**Confidence intervals at $\bar{Y}$ (mean of dependent variable)

SUMMARY OF STATISTICAL FINDINGS
REGRESSION EQUATIONS FOR DIVISIONS
NAVAIR NAVPROs

Regression equation for Personnel in:	R^2	S.E.*	C.V.	C.I.68%**	C.I.95%**
ADMIN = $0.058X_1 + 4$ X_1 = number of total personnel in CAS office	.69	3.1	.24	10-16	7-19
CONTRACTS = $0.00001X_1 + 13.3(\log X_2) - 4$ X_1 = Value shipped (thous.$), annual rate X_2 = number of contracts over 90% completed on hand	.81	4.6	.21	17-27	13-31
ENGR = $7.78(\log X_1) - 13$ X_1 = number of contractor technical personnel on government work	.70	3.9	.31	8-16	4-20
QA = $0.00014X_1 + 2$ X_1 = value shipped (thous.$), annual rate	.81	21	.32	34-86	16-30
IND = $5.99(\log X_1) + 8.36(\log X_2) - 36$ X_1 = number of contractor technical personnel on government work X_2 = value of government property on hand (thous.$)	.87	3.7	.16	19-27	101-195

*Standard error of the estimate
**Confidence intervals at $\bar{Y}$ (mean of dependent variable)

Appendix G

ADJUSTMENT FOR SERIALIZATION

When measuring observations for the same data over time in one office, there is danger that serialization may have taken place. In other words, the value of an observation is partially affected by preceding and subsequent values of the same data in addition to the effect of another variable. If serialization exists in a data set, the method of least squares may not give the best estimate of the relationships.

To test for serialization, we applied the Durbin-Watson statistic, d,[1] as defined by the equation

$$d = \frac{\sum_{i=2}^{n} \left[(Y_i - \hat{Y}_i) - (Y_{i-1} - \hat{Y}_{i-1}) \right]^2}{\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2}$$

The data sets for ten consecutive points in time showed a positive result in serial correlation.

To overcome this potential defect in the regression equations, we arbitrarily chose time points 2, 6, and 9 for SUPSHIPS and 2, 5, 7, and 9 for NAVPROs as the bases for the regression equations. In most cases, the test for serialization then proved negative. Since the equations were very similar, we chose those equations based on the smaller number of time points. The following tables present the equations developed together with the Durbin-Watson statistic for each and a table of the relevant ranges for the statistic, d.

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1) For a description and discussion of the Durbin-Watson statistic, see Statistics-An Introductory Analysis, 2nd Edition, T. Yamane, Harper and Row, New York, 1967, pp. 809-813.

TEST LIMITS FOR SERIALIZATION

The d Statistic

Significance points of d_L and d_U: 5%

Number of variables	1		2		3	
Number of observations	d_L	d_U	d_L	d_U	d_L	d_U
20	1.20	1.41	1.10	1.54	1.00	1.68
28	1.33	1.48	1.26	1.56	1.18	1.65
30	1.35	1.49	1.28	1.57	1.21	1.65
50	1.50	1.59	1.46	1.63	1.42	1.67
70	1.58	1.64	1.55	1.67	1.52	1.70
100	1.65	1.69	1.63	1.72	1.61	1.74

If

$d < d_L$ positive serial correlation exists

$d > d_U$ there is no positive serial correlation

$d_L < d < d_U$ the test is inconclusive

SERIAL CORRELATION TEST ON SUPSHIP DATA

Number of Observations	100		30	
Organization	Equation	d	Equation	d
ADMIN	$Y=0.102X_1-2$	0.3838	$Y=0.105X_1-2$	1.159
CONTRACTS	$Y=13.5(\log X_1)+0.28X_2+0.00025X_3-52$	0.9505	$Y=14.8(\log X_1)+0.311X_2+0.0022X_3-58$	1.200
PLANNING	$Y=45.8(\log X_1)+0.092X_2+0.0085X_3-171$	0.9574	$Y=41.6(\log X_1)+0.077X_2+0.0085X_3-149$	1.647**
QA	$Y=54.5(\log X_1)+0.0045X_2-213$	0.8339	$Y=54.4(\log X_1)+0.0037X_2-211$	1.101
MATERIAL	$Y=28.4(\log X_1)-69$	0.6739	$Y=27.7(\log X_1)-66$	1.931*
TOTAL PERSONNEL	$Y=170.1(\log X_1)+0.0175X_2-624$	0.7510	$Y=170.8(\log X_1)+0.013X_2-620$	1.287**

*Test shows there is no positive serial correlation

**Test is inconclusive

SERIAL CORRELATION TEST ON NAVAIR NAVPRO DATA

Number of Observations	70		28	
Organization	Equation	d	Equation	d
ADMIN	$Y = 0.057X_1 + 4$	0.7521	$Y = 0.058X_1 + 4$	2.144*
CONTRACTS	$Y = 0.00001X_1 + 11.7(\log X_2) - 2$	0.7740	$Y = 0.00001X_1 + 13.3(\log X_2) - 4$	1.548**
ENGR	$Y = 7.73(\log X_1) - 13$	0.4197	$Y = 7.78(\log X_1) - 13$	2.590*
QA	$Y = 0.00014X_1 + 7$	0.8556	$Y = 0.00014X_1 + 2$	2.543*
INDUSTRIAL	$Y = 6.58(\log X_1) + 7.34(\log X_2) - 34$	0.7546	$Y = 5.99(\log X_1) + 8.36(\log X_2) - 36$	2.000*
TOTAL PERSONNEL	$Y = 0.00023X_1 + 48$	1.255	$Y = 0.00024X_1 + 39$	2.485*

*Test shows there is no positive serial correlation
**Test is inconclusive

SERIAL CORRELATION TEST ON NAVORD NAVPRO DATA

Number of Observations	50		20	
Organization	Equation	d	Equation	d
ADMIN	$Y = 0.143X_1 - 2$	0.3009	$Y = 0.141X_1 - 2$	0.9518
CONTRACTS	$Y = 42.5(\log X_1) + 6.7(\log X_2) - 215$	1.139	$Y = 40.1(\log X_1) + 8.4(\log X_2) - 207$	2.210*
ENGR	$Y = 137.3(\log X_1) - 415$	1.072	$Y = 139.7(\log X_1) - 424$	2.377*
QA	$Y = 0.00030X_1 - 11$	1.115	$Y = 0.00031X_1 - 13$	2.707*
INDUSTRIAL	$Y = 58.7(\log X_1) + 25.4(\log X_2) - 288$	0.4057	$Y = 64.7(\log X_1) + 24.2(\log X_2) - 302$	2.283*
TOTAL PERSONNEL	$Y = 0.00079X_1 - 12$	1.504**	$Y = 0.00081X_1 - 15$	2.448*

*Test shows there is no positive serial correlation

**Test is inconclusive