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THE DETERMINANTS OF BASE OPERATING SUPPORT COSTS

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CNA

CENTER FOR NAVAL ANALYSES

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The study analyzes spending on base operating support (BOS) activities at 144 domestic naval installations. Statistical regression techniques are used to derive a cost-estimating relationship (CER) that relates BOS spending to such base characteristics as the number of military personnel and the total building area. The CER is then applied to several issues concerning the management of the naval shore establishment: whether there are economies of

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20 scale in BOS spending that could be captured through base consolidation; how a given total BOS budget should be allocated across bases that differ in characteristics; and whether statistically-derived cost estimating relationships are better tools for analysis of BOS spending than simple ratios, such as BOS cost per mission person, that are favored by OSD.

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THE DETERMINANTS OF BASE OPERATING SUPPORT COSTS

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Institute of Naval Studies

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1. The Base Operating Support Study set out to develop algorithms to estimate base operating support (BOS), costs, utilizing an existing historical data base and statistical regression analysis, as a function of the characteristics of individual installations.

2. The study analyzed data from the Domestic Base Factors Report (1979) describing 144 domestic naval installations in CONUS, Hawaii, and Alaska, categorized by primary mission (e.g., naval air stations). The BOS cost estimating relationships (CERs) that finally evolved from the statistical regression analysis included five explanatory variables: number of active military personnel, number of civilian personnel, building area, land area, and energy consumption. For the CER derived, the standard statistical measure for goodness of fit, coefficient of correlation, was 0.90. This favorably contrasts with the 0.11 coefficient of correlation for BOS cost as a linear function of number of mission persons on the base, a CER currently used in some DOD offices.

3. Because of the goodness of fit of this CER, it will be worthwhile to examine more closely those bases whose costs depart significantly from the predictions. The Shore Activities Planning and Programming Division (OP-44) has begun a detailed evaluation of these base outliers to the regression line to determine in each case whether special circumstances explain the BOS cost deviation from the CER prediction.

4. Based on a statistical regression analysis of the Domestic Base Factors Report (1979), this study indicates that, for analytical purposes, the CERs derived herein are better estimators of BOS cost than the simple, one variable equations in common use.

5. Enclosure (1) is forwarded.

M. S. Holcomb

M. S. HOLCOMB
Vice Admiral, U.S. Navy
Director, Navy Program Planning

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EXECUTIVE SUMMARY

A naval shore base requires many resources that are not specific to the particular missions supported by the base. Such Base Operating Support (BOS) resources include: maintainance and repair of real property; financial, legal and other administrative services; specific services such as base transportation and security; and community support functions such as medical clinics and commissary. These activities account for about $2 billion annually in the Department of Navy budget.

The Navy needs a model of BOS costs to help manage the shore establishment. This study develops such a model -- a cost estimating relationship, or CER -- and applies it to the policy questions of whether consolidating bases would save on BOS cost, and whether BOS funds are being wisely allocated across installations during the yearly budget process. The CER is derived from data in the FY 1979 Domestic Base Factors Report (DBFR), and verified using data in the FY 1980 DBFR. Statistical regression techniques are used to relate BOS spending to such variables as the number of military and civilian personnel at the base, the size of the base as measured by total acreage and building area, and the base's energy consumption.

The CER implies that the Navy could save about 15 percent in annual BOS cost by halving the number and doubling the size of its bases. This finding does not mean that consolidation would save on total cost. Consolidation could require spending for new land, new construction and re-settlement (fixed costs). Consolidation might also affect direct, mission-related operating costs and operational readiness. By ignoring these factors, we can make no overall judgments about the desirability of consolidation.

To help in the yearly budget process, the CER is used to estimate an "expected" level of BOS funds for each base in the sample. Those bases spending more than "expected" are offered as candidates for more detailed analysis by the Navy. We are not claiming that these bases are inefficient; their higher spending could be for activities not captured by our aggregate data. The higher spending, moreover, could be contributing significantly to mission readiness and personnel retention -- benefits of BOS spending that are not measured in this analysis of cost.

Other findings of the study are: 1) BOS decisions should not be based on simple performance ratios such as BOS cost per mission person that are favored by OSD, and 2) the DBFR is a unique source of BOS data, but it could be reduced in size to

ease the reporting burden and still provide enough data for statistical analysis of BOS cost.

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INTRODUCTION

The resources to maintain a Naval shore installation are of two types. Some resources directly support the missions carried out by the base. At a naval air station, for example, the direct costs pay for the military personnel who maintain and fly the squadron aircraft, the fuel to operate these aircraft, and the civilians employed at a Naval Air Rework Facility (NARF) that may be located at the base.

This study is concerned, however, with the indirect costs of operating bases. Such Base Operating Support (BOS) costs are not specific to missions, but would be required to maintain any shore installation, whether it is a naval air station, a naval station, a naval supply center, a laboratory, a hospital, or another type of installation. Maintaining and repairing the buildings is one example. How much you have to do does not usually depend on what missions the buildings support. Transportation and security maintained by the host of the base are also BOS functions, as are legal, medical, and administrative services performed by the base. Table 1 shows the four functional categories into which BOS resources are often grouped.

A major reason for studying BOS cost is that large expenditures are involved: the Navy spends about two billion dollars annually on these resources. A more immediate reason is the recent Congressional interest in BOS. Using data supplied by OSD, the Senate Appropriations Committee in 1977 compared BOS spending by 18 installations. The Committee took direct budget action based on these findings: Bases with high BOS cost per mission person received cuts in BOS funds. (Some of the cuts were subsequently removed through re-programming.)

For use in future budget reviews, the Senate Appropriations Committee also asked OSD to develop and submit a yearly reporting system for BOS cost and its determinants. The resulting Domestic Base Factors Report (DBFR) is a unique source of data, and its analysis is the subject of this study. We will present, in turn, the policy issues to be addressed, the method of analysis, a description of the data, the numerical results, and the implications of these results for the policy issues.

TABLE 1

EXAMPLES OF BOS RESOURCES

Facility Services

- Maintenance and repair of all real property
- Minor construction
- Utilities
- Custodial and janitorial services

Administrative Services

- Base administration
- Base comptroller
- Base legal services

Specific Services

- Base transportation
- Base security, fire and police
- Base communications

Community Support Services

- Medical and dental clinics
- Commissary
- Recreation

ISSUES FOR ANALYSIS

This study derives a statistical Cost Estimating Relationship (CER) that relates BOS spending at a naval base to the characteristics of the base. This CER provides insight into five issues concerning management of the Naval shore establishment. The first is economies of scale. The Navy's domestic shore establishment is somewhat spread out across the country, and this raises the question of whether consolidating small bases into larger ones would save money. This analysis measures the economies of scale in BOS spending. BOS cost is only <u>one</u> part of the picture, however. Consolidation can also affect direct operating costs and operational efficiency. Any savings in yearly costs would have to be balanced against possible fixed costs for new land, new military construction, and re-settlement. These fixed costs would depend, in turn, on how much excess capacity we have at existing bases and how much of our original investment we could recoup by selling off unneeded land. Our analysis of BOS cost thus provides only one input to the consolidation decision.

The second application of the cost estimating relationship (CER) concerns the Navy's yearly allocation of the BOS budget across bases. Here, too, a CER can provide some help but not the complete answer. The CER presents a picture of what bases with various characteristics <u>have been</u> spending for BOS. It thus estimates what a particular base <u>would</u> spend if it fits the general pattern. If that base is <u>spending</u> much more than this, that suggests a closer, more detailed look is in order. We have used the CER to construct a list of candidate bases for detailed study by the Navy.

The next issue focuses specifically on the methods for allocating BOS. As described above, this study derives a CER from statistical analysis of the data. Lacking anything better, the Navy has for years been allocating BOS by giving a base what it got last year, plus some allowance for inflation, plus some additional funds if the base appeared to have special problems. In the interest of finding a more systematic approach, OSD has recently suggested using simple ratios such as BOS cost per mission person. If one naval air station has much higher BOS cost per mission person than the average for all naval air stations, that base is a potential candidate for a budget cut. The third issue thus considers whether a statistically-derived CER is really better than the OSD method for budget determination.

The fourth issue concerns the cost estimates for ships and aircraft that are listed in the Navy Program Factors Manual. The method for deriving CER's in this study can be used to update the BOS components of these costs.

A major limitation underlies the analysis of these questions. We lack a measure of the benefits of BOS. Consider BOS expenditures for maintenance, for example. Unless the Navy maintains and repairs real property, sooner or later the buildings will crumble and the base will be unable to carry out its missions. But there is no current measure of the relationship between expenditures on maintenance and the level of readiness. The connection is diffuse, and attempts to construct the relationship would take us too far afield.

Other BOS activities provide community services to improve the quality of life and help make the Navy an attractive career. Analyzing the relationship between BOS and retention would also be a study in itself. Re-enlistment depends on the community services at <u>all</u> the shore installations to which a sailor has been assigned during his recent service, and assembling this time-series data for individuals would not be a simple task.

Lacking numerical measures of output, we cannot make ultimate judgments about the "optimal" size of the Navy's BOS budget or its allocation across bases. Consider two naval air stations that are alike in all major respects, but that spend different amounts for BOS. The lower cost base might be spending the ultimately correct amount for BOS, given the benefits of readiness and retention. The more expensive air station would then be regarded as inefficient.

On the other hand, it might be the more expensive base that was spending the ultimately correct amount for BOS. In this case, the cheaper base would be inefficient, even though it was operating on a more parsimonious level with regard to BOS spending.

These considerations will affect how we interpret the results of the quantitative analysis.

METHODOLOGY

This section describes the method of analysis and shows how the numerical results can be applied to the policy issues.

The goal is to explain BOS cost at 144 of the domestic naval installations included in the DBFR.[1] For purposes of this study, to "explain" BOS cost means to relate it to base characteristics that are assumed to determine its value. Statistical regression, or "curve-fitting" techniques are used for this purpose, and the result is an equation that looks as follows (for illustration):

$$\text{BOS cost} = a_o \, (\text{MIL})^{a_1} \, (\text{CIV})^{a_2} \, (\text{AREA})^{a_3}$$

where

- MIL = the number of active military personnel at the base
- CIV = the number of civilian personnel
- AREA = total building area in thousands of square feet

The coefficients of the equation (a_0 through a_3) will be estimated by fitting the equation to the data.

This is mainly a cross-section study: the statistical analysis is across bases at a fixed point in time (1979). The resulting CER was checked, however, against data in the 1980 DBFR. The statistical fit proved almost as good as for the 1979 data. This gives some confidence in using the CER for future prediction provided the estimated BOS costs are adjusted for inflation.

Various features of the regression equation will provide information on the issues mentioned above. The sum of the exponents will measure the economies of scale, and show how much BOS cost can be saved through consolidation. If $a_1+a_2+a_3 = 0.5$, for example, doubling the size of a typical base (doubling the explanatory variables) would multiply BOS cost by a factor of only 1.4 ($2^{0.5}$). Consolidation would thus

[1] Twelve other installations were omitted because data were incomplete (e.g., for the new Trident bases) or because the bases appeared unique (e.g., the Washington Navy Yard.)

lower BOS expenditure (but not necessarily total expenditure). Second, the difference between the "observed" BOS cost given by the data and the "predicted" BOS cost given by the regression equation will evaluate the base's spending against the standard of all the bases in the sample as a whole (after adjusting for MIL, CIV, AREA and the other variations at the base in question). Finally, with respect to planning, each exponent will estimate a marginal cost: how much BOS cost will rise, for example, with increases in the number of military personnel.

DATA

The validity of our findings hinges on our ability to obtain a regression equation that meets statistical and common-sense criteria. This depends, in turn, on our having enough good data on the installations of interest. This section of the report describes the variables we have obtained, and comments on their reliability.

The sample of bases consists of 144 domestic naval installations in CONUS, Hawaii, and Alaska. All large naval installations in the continental U.S. are included, along with major bases located in Hawaii and Alaska. The installations are all hosts -- commands that have responsibility for providing BOS services to the tenants that reside on the base. Table 2 describes the sample further.

Each base is categorized by its primary mission: e.g., naval air stations. The classification is not clean: A host naval air station has aircraft squadrons in its list of tenants, but it may also have other tenants whose missions have nothing to do with air operations. This lack of homogeneity does not prove much of a problem: Our findings confirm that BOS cost as defined by the Navy does not depend on the type of mission at a base. The costs of maintenance and repair of real property, for example, depends on the area of the buildings, and little on what those buildings are used for.

Table 3 defines the variables gathered for each base in the sample. Except where noted, the source of the data is the FY 1979 Domestic Base Factors Report (DBFR). (Data from the FY 1980 DBFR became available toward the end of the study. These data were used only as a check on the numerical analysis of the 1979 data.) The DBFR data were "scrubbed" by OP-44 (Shore Activities Planning and Programming Division) in extensive conversations with the bases designed to achieve reporting consistency. Data from the previous two DBFRs (FY 1977 and FY 1978) were not scrubbed. They show major inconsistencies as a result, and were therefore not used in the analysis.

There is a point in listing all the explanatory variables that were assembled, even though only <u>five</u> proved necessary in obtaining a good aggregate predictive model for BOS cost. The point is that most of the variables that are reported by the DBFR because they appear related to BOS cost are <u>not</u> necessary for such a model, and collecting many of these data may add more to the "paperwork burden" than to useful knowledge.

TABLE 2

NAVAL INSTALLATIONS ANALYZED

30	Naval air stations
10	Naval bases, defined in this study to mean either a naval station, amphibious base, or submarine base[1]
6	Public works centers
16	Regional medical centers plus the National Naval Medical Center at Bethesda, Maryland
16	Training centers and schools
6	Naval support activities
8	Naval shipyards
15	Supply and storage facilities including Naval supply centers, weapons stations and ordnance stations
13	Research and development sites
5	Test and evaluation sites
13	Communications stations and security activities
6	Naval facilities, which are used in coastal anti-submarine warfare
144	TOTAL

[1] The term "naval base" is often used to mean a complex involving one or more naval stations, amphibious bases or submarine bases located together in one area.

TABLE 3

DEFINITIONS OF VARIABLES

Dependent Variable

BOS COST

Total spending by each installation during FY 79 on base operating support resources (in millions of FY 79 dollars).

Physical Plant Variables

AREA

Total floor area of buildings in square feet.

ACRE

Total acreage of land on base.

CPV

Estimates of the current plant value of the real property on the base. The Naval Facilities Engineering Command (NavFac) made these estimates by taking the original acquisition cost of each building and inflating it to current FY 79 dollars using a construction cost index. Subsequent improvements were assumed to be made at the time of original acquisition because the dates of the improvements have not been kept until recently. The estimated values of CPV are therefore biased upward, and the bias is larger for the older installations.

AGE

The average age of all buildings on the base calculated from data supplied by NavFac. The age of each building was weighted by its size in square feet.

TABLE 3 (continued)

Personnel Variables

MIL

The number of active military personnel, officers plus enlisted, at the base. BOS and mission personnel are both included. The variable refers to the average number of men physically present at the base during the year, not the number authorized. Average transient load is thus included. In addition, OP-44 instructed bases to include the number of men assigned to ships serviced by the base, whether the ships were homeported there or not. The number of men assigned to ships was multiplied by 60 percent to account for the time these ships spent out of port.

CIV

The number of civilian personnel, those assigned to BOS as well as to mission tasks.

RES

The average number of reserve personnel physically on the base during the year.

RET

The number of retired military personnel in the vicinity of the base.

DEP

The number of dependents excluding the sponsor. The number living both on and off the base were regarded as separate variables.

SF

The number of staff and faculty assigned to installations engaged, at least partly, in training.

STUD

The average daily student load at training installations.

TABLE 3 (continued)

BASE

The number of active military personnel at naval bases (naval stations, amphibious bases, and submarine bases) with shore-side assignments.

BOS

The number of military plus civilian personnel assigned to BOS functions.

Operational Variables

PLANES

The average number of aircraft normally stationed at the base. Those aircraft assigned to the base but deployed elsewhere during the year are not counted.

NARF

The number of civilian personnel at naval air stations assigned to a NARF (Naval Air Rework Facility). The Force Distribution Report (FDR) maintained by NavFac is the source for this variable.

DISP

The total displacement (full) of ships assigned to the base. The list of ships assigned was obtained from the FDR, and the displacement of each type was obtained from the Naval Ships Register.

ELEC

The total electrical generating capacity of the ships assigned to the base. See the definition of DISP for the sources of the data.

COMP

The total complement of personnel on ships assigned to the base. See DISP for the sources.

SHP

The total shaft horsepower of ships assigned to the base. See DISP for the sources.

BED

The number of beds at regional medical centers (plus the National Naval Medical Center at Bethesda). OP-96 provided the data. The authorized and capacity number of beds were treated as separate variables.

Climate[1]

TEMP

The average daily temperature, calculated over the past 20 years.

COOLDAYS

The number of cooling-degree-days per year, averaged over the past 20 years. A temperature of 85 degrees Fahrenheit is used as the standard. If the average daily temperature on August 20 is 95 degrees, for example, this constitutes 10 cooling-degree days. Daily figures are added to give yearly totals.

HEATDAYS

The reverse of COOLDAYS. If the average daily temperature on December 20 is 45 degrees, for example, this constitutes 40 heating-degree-days.

PRECIP

The average yearly inches of precipitation for the base, averaged over the past 20 years.

SNOW

The yearly inches of snowfall during the year, averaged over the past 20 years.

[1]The source for all these variables is Alva L. Wallis, Jr., Comparative Climatic Data Through 1976, National Climatic Center, Asheville, N.C., April 1977.

TABLE 3 (continued)

Other Variables

BTU

The total BTUs of energy consumed by the base during the year. Included are the use of electricity, coal and natural gas. One exception: fuel for aircraft is not included.

WAGE

An estimate of the average wage of civilian DoD employees hired by DoD in the locale. Regional wage scales by step and grade were furnished by the DOD Wage Fixing Authority. We selected the wage corresponding to the average grade of civilian workers at the base (from Office of Civilian Manpower Management), assuming he was at step 4, the Navy-wide average.

Type of Base

The set of "dummy" variables shown below were used. (NAS, for example, is a dummy variable that takes on the value 1 at each of the 30 naval air stations, and the value 0 at each of the 114 other installations.) By using dummy variables, all regressions can be run on the total sample of 144 installations, but with the flexibility to estimate different coefficients at different classes of bases. The dependence of BOS cost on the number of military personnel, for example, will prove higher at naval stations than at other bases.

TABLE 3 (continued)

Dummy Variable	Bases where value = 1
NAS	Naval air stations
NARF	Naval air stations with NARFs
NB	Naval bases, defined in this study to be a naval station, amphibious base, or submarine base
PWC	Public works centers
MED	Regional medical centers plus the National Naval Medical Center at Bethesda, Maryland
TRSCH	Training centers and schools
NSA	Naval support activities
SY	Naval shipyards
SS	Supply and storage facilities, defined in this study to include naval supply centers and naval weapon centers
RD	Research and development sites such as the Naval Research Lab
TE	Test and evaluation sites such as the one at China Lake, California
COMS	Communications stations and security activities
FAC	Naval facilities such as the one at Cape Hatteras, North Carolina, which are used for strategic ASW.

REGRESSION ANALYSIS

Regression analysis is a way to estimate the coefficients of a statistical relationship after the explanatory (independent) variables are chosen and the functional form of the equation (linear, log, etc.) has been selected. Ideally, the selection of explanatory variables should be based on prior knowledge of what factors most affect the dependent variable; and the form of the equation should be chosen according to knowledge about how the explanatory variables interact.

CHOICE OF EXPLANATORY VARIABLES

There is too little understanding of BOS resource use at naval installations, however, to carry out this procedure in ideal form. We were not sure beforehand which variables are most important; many of those listed in table 3 appear closely related to BOS spending. We therefore used statistical criteria to help choose among them. Regressions were run with different combinations of variables, in hopes of finding a combination that met these criteria: (1) The sign of the coefficients should be the ones expected on intuitive grounds (e.g., more personnel means higher BOS cost); and (2) the coefficients of each explanatory variable should be statistically significant at the 10% level (high t-statistics in statistical terms). Meeting the latter criterion accomplishes two things. First, it tends to produce a "parsimonious" model in which a relatively small number of explanatory variables are able to account for a relatively high percentage of the variability in BOS cost (a high value of R^2, in statistical terms). Second, it ensures that the regression will estimate the independent effect of each explanatory variable, even if the data for these variables are correlated.[1] (See appendix table A-4 for the correlation coefficients.)

These are the explanatory variables that best met the tests of intuitive plausibility and statistical fit. First are two personnel measures. Bases with larger numbers of military personnel (MIL) must provide more legal and medical services, more bachelor housing and commissary, and more support services for dependents. Large numbers of civilians (CIV) are employed by the NARFs and by the research laboratories, and there is lots of equipment to be maintained and repaired.

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[1]Measuring independent effects requires only that the data show some independent movement of the variables. When the variables become too correlated to separate out their effects on the dependent variable, one or more t-statistics will fall. High t-statistics thus mean that the independent contributions have been estimated.

About half of all BOS cost is for maintenance and repair of real property, and building area (AREA) is a general indicator of the amount of real property that must be maintained and repaired. The total acreage (ACRE) at an installation is an indicator of physical size. Bases with larger amounts of land must spend more for base transportation and security and for maintenance of roads and grounds.

The final variable (BTU) measures the amount of power consumed by the utilities at the base. Energy consumption is a general measure of the tempo of operations at an installation.

Note that these five explanatory variables are measures of resources. BOS cost can also be related to operational variables such as the number of aircraft, and we will discuss this in the section on Marginal Cost of Base Expansion.

CHOICE OF FUNCTIONAL FORM

There is no firm intuition about whether the relationship between these explanatory variables would be linear, exponential, or some other form. The exponential functional form was selected on a statistical basis: among various simple mathematical forms, it gave the best fit with the data.

RESULTS

The estimated relation is shown in table 4. The equation is an extension of simple curve-fitting where you take a two-dimensional scatter diagram and fit a straight line to get an idea of how y relates to x. The equation in table 4 involves 5 x's instead of one, and an exponential relationship instead of a linear one. The equation says that if you have a base with so many military personnel, so many civilian personnel, and so on, and if you insert these figures into the equation, you get a predicted value of BOS cost that tracks with the actual BOS cost in a statistical sense.

In fact, the equation fits the data to a remarkable degree. In addition to possessing intuitive appeal, the coefficients are all positive (more resources yield higher cost), the coefficients (exponents) of the explanatory variables all have high statistical significance, and the equation as a whole explains 90 percent of the variability in BOS cost.

The five explanatory variables proved best among the 70 we tested. We tried personnel variables like the numbers of dependents, retirees, and reserves. We distinguished between the civilians assigned to NARFs and to research laboratories. We tried operational variables like the number of aircraft at

TABLE 4

MAJOR REGRESSION[a]

$$\text{BOS COST} = 0.0405(\text{MIL})^{.034}(\text{CIV})^{.248}(\text{AREA})^{.249}(\text{ACRE})^{.061}(\text{BTU})^{.155}$$

where

MIL = number of active military personnel
CIV = number of civilian personnel
AREA = building area (thousand square feet)
ACRE = land area (acres)
BTU = energy consumption

R^2	.90[b]
t-statistics (level of statistical significance)[c]	
MIL	1.76 (8%)
CIV	7.29 (.01%)
AREA	4.58 (.01%)
ACRE	3.54 (.05%)
BTU	3.94 (.01%)
Scale elasticity	.75[d]

---

[a]For all installations, excluding naval bases, communications stations, and security activities.

[b]The regression was actually estimated in the logarithmic form (ln stands for natural logarithm):

$$\ln \text{BOS COST} = \ln 0.0405 + .034 \times \ln \text{MIL} + .248 \times \ln \text{CIV} + \ldots$$

The R^2 of .90 means that the regression explains 90% of the variability in ln BOS COST. This is equivalent to explaining about 80% of the variability in BOS COST itself.

[c]The 10 percent level is often used as a minimum criterion in empirical analysis.

[d]This is the sum of the exponents of the explanatory variables. A scale elasticity of .75 implies that a 1 percent increase in all explanatory variables leads to a .75 percent increase in BOS COST. The interpretation is somewhat different for large changes: doubling all explanatory variables multiplies BOS COST by only $(2)^{.75} = 1.7$, which indicates positive economies of scale.

air stations, the total displacement of ships homeported at naval stations, the number of faculty at training installations, and the number of beds at hospitals. None of these yielded a more intuitive and statistically sound CER. (Note, however, that the operational variables are necessary in order to make estimates of marginal cost for use in force level studies, as described later.)

That it is possible to explain cost with so few variables means that these represent, in the aggregate, many of the more detailed determinants. Building area and acreage represent the overall size of the base including roads, fences, etc. The effect of the explanatory variables must therefore be interpreted in a particular way: the measured effect of increasing an included variable is actually the effect of increasing, as well, the broader set of determinants it represents.

This reinforces the point that BOS are general, non-mission related activities. And it also implies that having to construct the full DBFR of about 100 variables may add more to the Navy's reporting burden than to useful knowledge.

The exponential form of equation yields a single estimate of elasticity[1] independent of base size. The exponent of MIL, for example, implies that a one percent increase in the number of military personnel leads to a .034 percent rise in BOS cost.

The coefficient for civilian personnel is much greater than for military personnel, possibly because civilians carry out BOS functions. AREA has a high coefficient because much BOS activity is devoted to the upkeep of buildings (Real Property Maintenance Activities, or RPMA).

The exponential form of equation has the property that the returns to scale (the scale elasticity) is the same regardless of base size. The elasticity of .75 means that doubling the size of a base would increase BOS COST by only 70 percent (see footnote d of table 4). Other functional forms that were rejected by the statistical criterion mentioned earlier do not have this property. The constant scale elasticity is thus a finding, not an assumption.

The major regression equation in table 4 does not distinguish among different types of base. In the process of estimating this equation, we checked to see if the regression

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[1]The elasticity of y with respect to x is defined as the percentage change in y that results from a 1% change in x.

coefficients would be different for different types of bases.[1] It turned out that the coefficients had to be modified for only 23 installations: the 10 naval bases (a naval base was defined earlier to be a naval station, amphibious base or submarine base) and the 13 communications and security facilities. Table 5 shows the new estimated coefficients.

The elasticity associated with the number of active military personnel nearly doubles in value at the naval bases (but still remains lower than the coefficient on civilian personnel). The increase may be related to the fact that many military personnel associated with naval bases are stationed on ships and submarines serviced by the base. The piers and other shore-side facilities for these ships require maintenance, repair, and other support that may not be "picked up" by AREA, ACRE, and the other explanatory variables. (It is interesting, however, that none of the ship-related variables shown in table 3 increased the explanatory power of the regression.)

At the 13 communications stations and security group activities, the elasticity associated with military personnel also increases sharply. The coefficient of area almost disappears. Despite the large coefficient changes for Naval Bases and communications and security facilities, the scale elasticity remains close to the estimate of .75 found for the other kinds of bases.

It is remarkable that with so few exceptions, a single equation with only five variables is able to predict so well the BOS cost of a wide variety of naval installations: naval air stations, supply centers, weapons stations, research laboratories, weapons test ranges, shipyards, schools and so on. The explanation is the general nature of BOS resources mentioned above. If such highly aggregate variables as total personnel and area can explain BOS cost across different naval air stations, for example, it is plausible that bases with different missions would follow that same pattern. "A building is a building."

A later section will discuss the "robustness" of our findings: whether the findings are sensitive to the choices of explanatory variables, the functional form, and the use of 1980 data.

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[1]This was done by including dummy variables (shown in table 3) to indicate each type of base. The dummy variables were included linearly and also multiplied by the other variables. In all cases but those described in the text, the dummy variables lacked statistical significance at the 10% level.

TABLE 5

OTHER REGRESSIONS

10 Naval Bases

$$\text{BOS COST} = 0.0405(\text{MIL})^{.066}(\text{CIV})^{.248}(\text{AREA})^{.249}(\text{ACRE})^{.061}(\text{BTU})^{.155}$$

t-statistic	
MIL	3.6
Scale elasticity	.78

13 Communications Stations and Security Activities

$$\text{BOS COST} = .0405(\text{MIL})^{.234}(\text{CIV})^{.248}(\text{AREA})^{.0014}(\text{ACRE})^{.061}(\text{BTU})^{.155}$$

t-statistic	
MIL	2.3
AREA	.02
Scale elasticity	.70

NOTE: See table 4 for the value of R^2, and for the t-statistics of those coefficients that did not change from the major regression. For comparison, the coefficient of MIL was .034 in the major regression, and the coefficient of AREA was .249.

POLICY IMPLICATIONS

ECONOMIES OF SCALE

Can the Navy save BOS funds through consolidation? The scale elasticities shown in tables 4 and 5 suggest modest savings. Doubling all the resources at the base increases BOS cost by only 70 percent. (The scale elasticity is about .75, and 2 raised to this power is about 1.7).

Consider, for example, the case of naval air stations, whose BOS cost averages about $35 million annually. If two "average" stations were combined into one, the total BOS cost would be only about $60 million (1.7 x $35 million). This is an annual saving of about $10 million, or 15 percent from the $70 million cost of operating the stations separately.

As we pointed out in the introduction, however, a saving in BOS cost is not a sufficient reason for consolidation. Consolidation might require spending for new land, new construction and re-settlement. Such fixed costs could outweigh the yearly savings in BOS cost (appropriately discounted to the present for comparison with the fixed costs). Readiness could also be affected: The largest organizations are not necessarily the smoothest-running. These effects must all be analyzed before judging the full consequences of consolidation. The scale economies for BOS cost could prove a minor factor.

EFFICIENCY OF INDIVIDUAL BASES

Are some naval bases currently spending too much on BOS? As discussed earlier, a complete answer to this question requires knowing how BOS spending at a base contributes to readiness and retention.

It is possible, for example, that BOS spending is too low at <u>all</u> bases, in the sense that increased spending would bring high returns in improved readiness and retention. Whether this is the case cannot be determined without relating BOS to readiness and retention -- a difficult analytical task. But, whatever total spending level the Navy chooses, there is something to be said for allocating it appropriately across installations. If some bases are spending disproportionately, their expenditures may be reasonable targets for closer study.

The regression equation is a way to determine what is "disproportionate" spending. The equation estimates the average BOS expenditures of bases, adjusted for their specific characteristics. For any given base, the "adjusted average", or "predicted" level of BOS cost is simply found by substituting the base's characteristics (AREA, ACRE, etc.) into the regression equation.

Subtracting the "predicted" value of BOS from the "observed" value given by the actual data yields the "residual". As a final step, we express the residual as a percentage of the predicted value of BOS cost. A base with a "relative residual" of 10 percent is one that is spending 10 percent more than what the CER predicts for that base. A relative measure seems closer to the intuitive notion of efficiency: a large base with a large residual is no more or less efficient than a small base with a proportionally small residual.

Consider, for example, the Naval Support Activity at New Orleans. Table 6 lists the explanatory variables for this base, and shows the result of substituting these variables into the regression equation. The resulting value of $24.30 million is the activity's predicted BOS cost, based on the BOS cost of the entire population of bases. Subtracting the actual value of BOS cost at NSA New Orleans yields a residual of -$16.13 million. This base is spending 66 percent less than predicted.

Unusually large and small residuals are shown in the following tables. Those bases whose relative residual is large and positive are listed in table 7. Those with large negative values are shown in table 8.

It is especially important to be clear about the implications of this kind of analysis. It is not certain that the Bethesda Medical Center, for example, is wasting money or that NSC Oakland is letting its physical plant decay. There could be good and sufficient reasons for these disparities -- reasons other than simple misallocation of resources. There might be reporting errors in the data. A base that is spending less than predicted might be receiving some unreimbursed BOS services from another base. A base that is spending more than predicted could be carrying out missions that are not fully captured by our explanatory variables. No statistical relationship is perfect.

Another important caveat is that as we pointed out earlier, we lack measures of the output of BOS spending: readiness to perform missions, and retention of personnel. This means that even aside from the above factors, we cannot make judgment about the "efficiency" of resource allocation at bases.

Our analysis, therefore, only suggests that the Navy should take a more detailed look at such bases. Only where no

TABLE 6

SAMPLE RESIDUAL ANALYSIS: NSA NEW ORLEANS

Characteristics

MIL = 2139
CIV = 1894
AREA = 2579 (Thousand square feet)
ACRE = 225
BTU = 349,520

BOS Cost predicted

$24.30 million[a]

BOS Cost actual

$ 8.17 million

Residual

-$16.13 million

Relative residual

-66%[b]

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[a] $0.0405(MIL)^{.034}(CIV)^{.248}(AREA)^{.249}(ACRE)^{.061}(BTU)^{.155}$

[b] $\frac{\text{Residual}}{\text{BOS Cost predicted}} \times 100$

TABLE 7

BASES WITH BOS SPENDING MORE THAN 50% ABOVE PREDICTED

UIC	Base	Relative Residual
00168	National Naval Medical Center, Bethesda MD	183%
00158	NAS, Willow Grove, Horsham, PA	96
62688	Naval Station, Norfolk, Norfolk, VA	83
00389	Naval Station, Roosevelt Roads, Ceiba, PR	77
60191	NAS, Oceana, Virginia Beach, Virginia	75
60036	Naval Weapons Station, Concord, Concord, CA	67
00314	Naval Submarine Base, Pearl Harbor, Honolulu, HI	63
00197	Naval Ordnance Station, Louisville, Louisville, KY	57
63042	NAS, Lemoore, Lemoore, CA	57
00188	NAS, Norfolk, Norfolk, VA	54
00247	Naval Training Center, San Diego, San Diego, CA	52
62813	Naval Station, Pearl Harbor, Honolulu, HI	51

TABLE 8

BASES WITH BOS SPENDING MORE THAN 50% BELOW PREDICTED

UIC	Base	Relative Residuals
00228	Naval Supply Center, Oakland, Oakland, CA	-51%
00406	Naval Supply Center, Puget Sound, Bremerton, WA	-52
5340A	Nav Pac Missile Range Facility, Kekaha, HI	-52
62741	Naval Supply Corps School Athens, GA	-53
63401	Fleet ASW Training Center Lant, Norfolk, VA	-56
00124	Naval War College, Newport, RI	-58
62271	Naval Postgraduate School Monterey, CA	-60
61414	Naval Amphibious Base Little Creek, Norfolk, VA	-64
00205	Naval Support Activity, New Orelans, New Orleans, LA	-66
61665	Fleet Combat Training Center, PAC, San Diego, CA	-68
00849	Naval Security Group Activity, Skaggs Island, Sonoma, CA	-72
62603	Fleet and Mine Warfare Training Center, Charleston, SC	-76
70240	Naval Communication Station, San Diego, CA	-84

"special cases" are found to exist should the Navy consider shifting BOS funds from "overspenders" to "underspenders."

This examination has already begun, and borne fruit. Working from an earlier version of this report, OP-44 discovered that the Bethesda Medical Center had been including all spending by its medical school under BOS, and the Naval Air Station at Norfolk had been including all spending by the NARF, the Safety Center, and some other tenants. Improvements in the quality of data are thus one of the consequences of cost studies such as this one.

BEST TECHNIQUE FOR COMPARING BOS SPENDING AMONG BASES

This section concerns techniques for analyzing BOS spending -- in particular, for estimating what a base "should" spend for BOS. Lacking measures of output, we have used regression analysis to explain actual spending. The regression equation, or CER relates BOS cost to a variety of explanatory variables acting together. Our CER assumes that bases with more military and civilian personnel, building area, land acreage and energy use have higher expected, or predicted BOS cost.

It is this predicted level that serves as the measure of what a base "should" spend. Bases that spend much more than this (i.e., that have high absolute or relative residuals) are the likely candidates for budget cuts (subject, of course, to the necessary detailed examination).

The OSD analysis of BOS spending, on the other hand, focuses on the simple ratio of BOS spending per mission person (military plus civilian) as an indicator of what a base should spend. Here, it is the bases with higher than average BOS cost per mission person that are the likely candidates for budget cuts.

We recommend the regression approach. It offers three advantages over simple ratios. First, it recognizes that BOS cost might depend on more than one explanatory variable. Using "BOS cost per mission person" as the criterion for "allowed" spending implicitly assumes that the number of mission personnel is the only causative factor. The problem is not avoided by using a variety of simple ratios. Adding "BOS cost per square foot of building area" to the list does provide some information, but not in a form that adds in an obvious way to the understanding obtained from examining BOS cost per mission person: BOS cost per square foot assumes that only building area is the determining factor. We need a way of measuring the combined effect of several explanatory variables, and that is what the regression does: The number of military personnel explains part of BOS cost, building area explains another part, and so on. No single explanatory variable is forced to account for the effects of all.

Second, the regression technique recognizes that the relationship between BOS cost and an explanatory variable need not be a proportional one. Using BOS cost per mission person as the criterion for allowed spending implicitly assumes that a one percent increase in mission personnel should lead to a one percent (strictly proportional) increase in BOS cost. The regression approach is not limited to proportional relationships.

Finally, regression offers a systematic way of making the selection of explanatory variables and functional form: It allows one to test various choices to see which ones provide the best fit with the data. The ratio of BOS cost per mission person can be subjected to statistical tests of fit, but OSD has not offered such tests as justification for using the simple ratio. And the test results are, in fact, disappointing. We tried a regression equation with mission personnel alone and found an exponential coefficient of .275 (the OSD ratio assumes 1.0) and an R^2 of only .26; moreover, a regression that forces a proportional relationship has an R^2 of only .11 (table 9).

TABLE 9

STATISTICAL TESTS OF BOS COST PER MISSION PERSON

$$\text{BOS COST} = 2.32\ \text{MISPERS}^{.275}$$

R^2	.26
t-statistic[a]	

$$\text{BOS COST} = .0037\ \text{MISPERS}$$

R^2	.11

---

[a]The point of this regression is that the exponent of MISPERS is not 1.0, which would indicate a proportional relationship with BOS cost. A statistical test shows that, with high confidence, the exponent is indeed different from 1.0 (t-statistic of 18.6, which implies statistical significance at better than the .01 percent level).

In summary, statistical regression techniques offer the advantages of flexibility in trying combinations of explanatory variables and functional forms, and testing them for goodness of fit at every step. BOS cost per mission person states the model by assertion. Some BOS activities are provided directly to personnel, but there's no a priori reason why the relationship should be a strictly proportional one, or why BOS cost should be related to military personnel alone. Our own CER analysis shows that BOS cost is definitely not proportional to <u>total</u> personnel -- mission plus BOS -- and that other variables also contribute significantly to explanation.

Note that the simple ratio of BOS cost per mission person is not even a good proxy for the regression approach. The two approaches give completely different results (figures 1 and 2): Many bases with high BOS cost per mission person have low absolute or relative residual, and many with low BOS cost per mission person have high absolute or relative residual. Over the 30 naval air stations, the correlation coefficient between the two measures is an entirely negligible .02 (the value for perfect correlation is 1.00).

MARGINAL COST OF BASE EXPANSION

So far, two features of the CER have been applied to resource allocation problems: the scale elasticity revealed the economies of scale in BOS spending, and the residuals indicated which installations spent more or less than predicted (and which therefore deserved a closer look).

The individual coefficients of the CER also have an application. Just as the scale elasticity gives the percentage increase in BOS cost due to a 1 percent increase in all the explanatory variables moving together, each coefficient (exponent) gives the percentage increase in BOS cost due to a 1 percent increase in that variable alone. The coefficient for MIL in the major regression, for example, indicates that a 1 percent increase in the number of military personnel yields a .034 percent increase in BOS cost (holding the other explanatory variables constant).

This relationship can be used to estimate the marginal BOS cost associated with an increase in military personnel at a particular base. Take NAS Alameda, for example. The 1980 DBFR lists 4882 for the number of military personnel and $42.2 million for BOS cost. A 1 percent increase in military personnel (49 men) should lead to a .034 percent increase in BOS cost ($14,348). The marginal cost is therefore $293 per man.

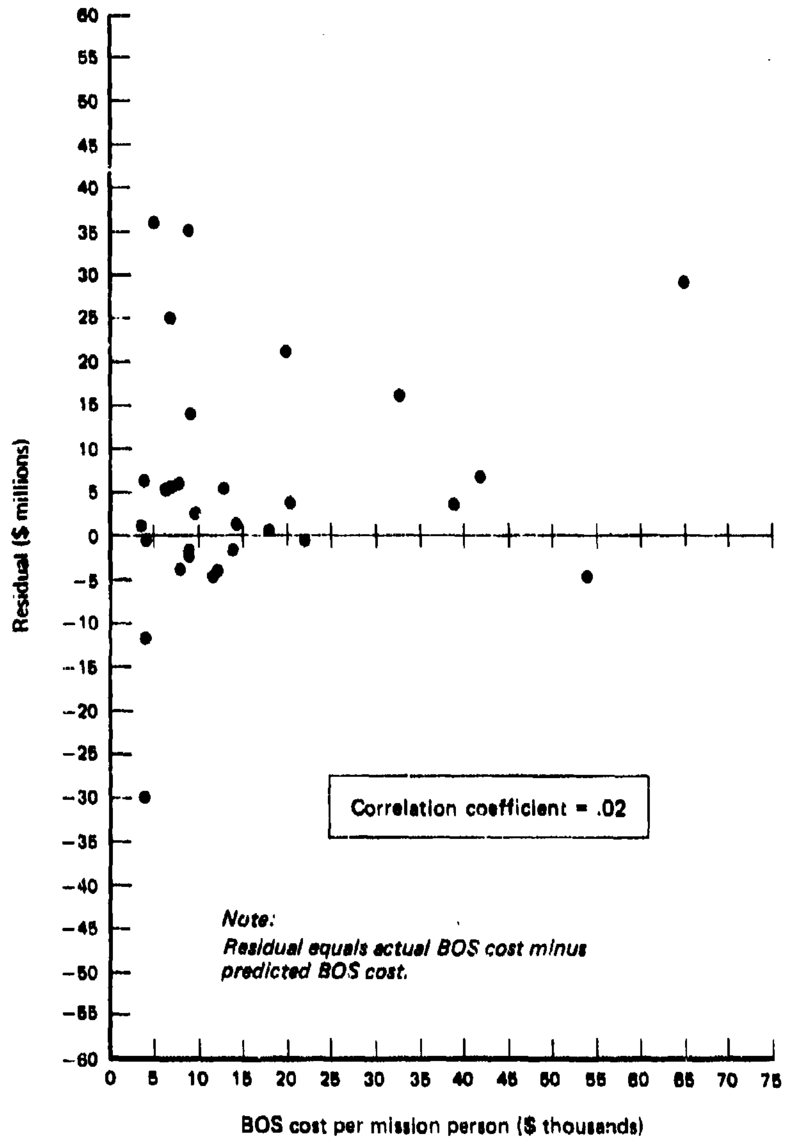

FIG. 1: RESIDUAL vs. RATIO MEASURE OF BOS SPENDING (30 NAVAL AIR STATIONS)

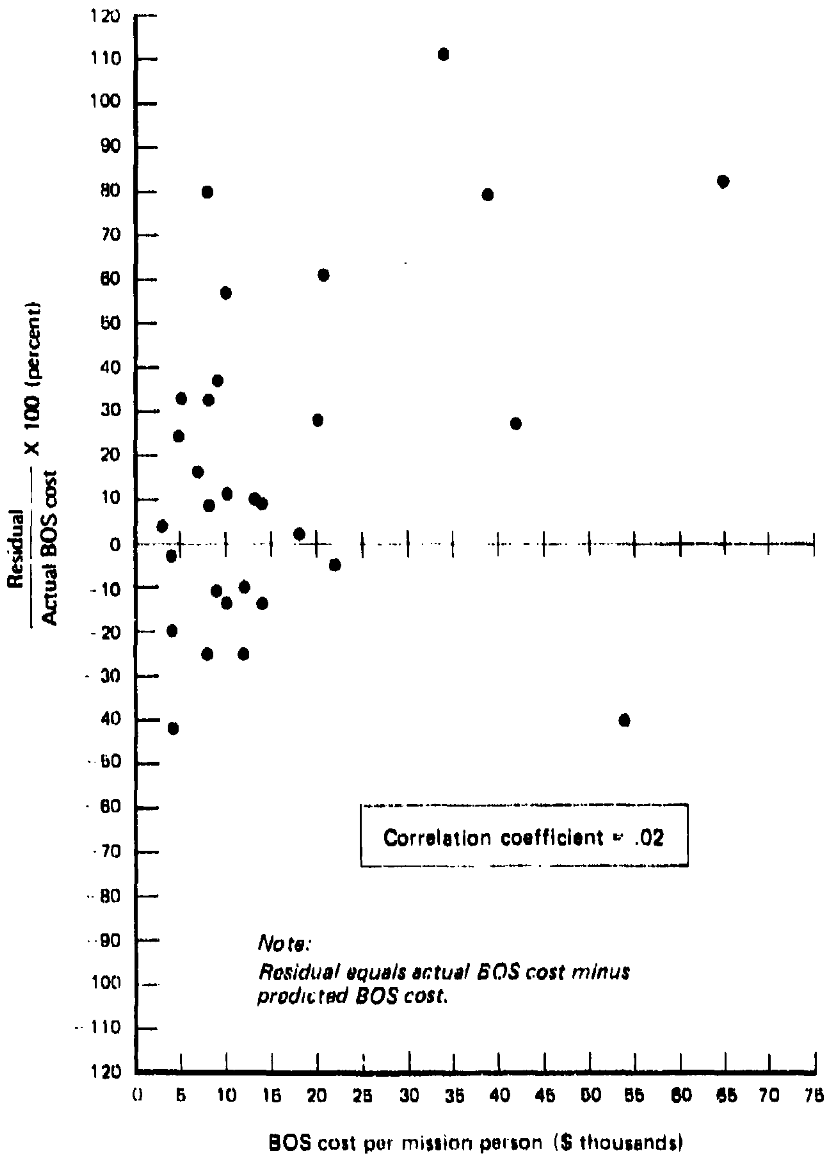

FIG. 2: RELATIVE RESIDUAL vs. RATIO MEASURE OF BOS SPENDING (30 NAVAL AIR STATIONS)

Marginal costs associated with the other explanatory variables can be derived in the same way. These factors might be useful in planning changes to the Navy shore structure -- provided, of course, that these changes are expressed in terms of the resource variables that appear in the CER. (A change will typically involve more than one explanatory variable; the marginal cost calculation will account for all.)

Suppose, however, that an anticipated change in the Navy base structure is not expressed in terms of these resource variables. The Navy might be planning to expand a NARF, for example, and may want a more refined estimate of the marginal cost of additional area of this sort, rather than relying on a general estimate based on a composite for all types of structures (i.e., the AREA variable used in this analysis). To estimate this marginal cost, one could simply construct a new list of explanatory variables that includes the new one and any others that appeared useful as control variables. (The coefficient of an explanatory variables measures the effect of that variable on the dependent variable holding all other explanatory variables constant.)

As another application, the explanatory variables need not be limited to resources such as people and area, but could be operational variables such as the ships and aircraft that create the ultimate demand for resources at naval bases and air stations. (The number of students is the operational variable that generates the need for resources at training installations, the number of beds generates the need for resources at hospitals, etc.). Force level studies typically require estimates of the total marginal cost of ships and aircraft, and one component of these total marginal costs is the BOS cost that bases spend in supporting those ships and aircraft. These marginal costs can be estimated using the above techniques. The analyst first selects some characteristics of ships and aircraft that appear related to BOS cost: the empty weight, thrust, or spotting factor of aircraft, and the displacement and shaft horsepower of ships. One could also include the size of crew. Control variables would then be selected and the resulting regression would be estimated. The coefficients of the equation (CER) would yield the cost per ton of ship displacement or per shipboard person, and the cost per pound of aircraft weight or per aircraft crewman. The marginal cost associated with a given ship or aircraft can then be determined by noting the displacement, empty weight, crew size, etc., for the ship or aircraft being considered.

Some estimates of this sort were carried out and compared with the estimates given in the Navy Program Factors Manual. In general, the regression, or CER approach gave much higher cost estimates for aircraft and somewhat lower estimates for ships. Work on this "offshoot" of the study is still continuing, and the results will be reported separately.

REPORTING SYSTEMS

The next issue concerns the efficiency of our reporting systems. Does the DBFR add anything to the information already available in Washington? Could the number of variables be reduced to ease the reporting burden on the Navy without lowering the quality of decision making?

Uniqueness of the DBFR

Our analysis suggests that the DBFR is, indeed, unique. The high "goodness of fit" achieved by the CER appears directly related to the comprehensiveness and comparability of the DBFR data. In reporting BOS cost, host commands were asked by the OSD instructions to include not only their own spending, but also BOS spending by all the tenant commands at the base. OP-44 (Shore Activities Planning and Programming Division) deserves the credit for ensuring that the Navy's bases followed this guidance.

Different Navy tenants at a given base can receive BOS funds through different claimants. Some tenants belong to different Services, and their BOS funds are thus not listed in Navy budget accounts. The DBFR is the only system we are aware of that reports total BOS cost on a functional basis -- by installation.

The DBFR also takes a comprehensive view in reporting the manpower and physical predictors of BOS cost. OP-44 ensures that bases report total military personnel, for all Services. Navy personnel assigned to ships and aircraft are included because the base must provide BOS services when the ships and aircraft are physically at the base. Moreover, ships and aircraft (and their personnel) are reported at the bases that actually provide the BOS services. Other reporting systems, such as the Force Distribution Report, list ships by homeport, even if the ships are regularly assigned to tie up elsewhere when in port. For example, two CVs homeported at Naval Station, San Diego normally tie up at Naval Air Station, North Island.

The DBFR thus keeps more complete track of resources, and a more comparable track of BOS cost and its personnel and physical determinants. The proof of the pudding is that we obtained poorer statistical results when we used variables reported by the FDR, rather than by the DBFR.

Level of Detail

The DBFR thus appears to be a worthwhile system for BOS reporting. But it is "overkill." It asks for roughly 100 separate pieces of data, far more than the five variables (number of military personnel, area, etc.) needed for a good aggregate model of BOS cost. As mentioned above, these five variables are able to account for the effect on BOS cost of detailed personnel variables like the numbers of military dependents, retirees, and reserves, and the number of civilians assigned to NARFs and to research laboratories. We also did not need operational variables like the number of aircraft at air stations, the total displacement of ships homeported at naval stations, the number of faculty at training installations, and the number of beds at hospitals. These operational variables are necessary, however, in order to make estimates of marginal cost for use in force level studies, as described earlier.

Our analysis is not definitive enough to suggest collecting the five resource variables plus the operational variables and no others. Different kinds of analysis require different variables. Our analysis does suggest, however that the full DBFR imposes a reporting burden that exceeds the value obtained.

ROBUSTNESS OF THE STUDY FINDINGS

The findings of this study are no more valid than the regression equation on which they are based. This section examines the stability of the regression results to changes in explanatory variables, functional form, and year of the data.

Tables 10 and 11 show the pattern of relative residuals caused by changes in explanatory variables and functional forms. (The relative residuals are an important output of the study, and one that is especially sensitive to these changes: residuals could easily change even if the scale elasticity did not.)

In both tables, regression I is the one derived earlier and shown in tables 4 and 5[1]. In regression II, the dependent and explanatory variables are entered in the linear form. Equations III and IV use a somewhat different set of explanatory variables - those that yielded the best fit on purely statistical grounds. (Resource and operational variables are mixed in this "best set," and this creates problems of interpretation.) Regression III uses the exponential form (just like regression I) and IV the linear form (just like regression II).

Tables 10 and 11 show that bases with large relative residuals (positive and negative) using regression I also have large relative residuals (positive and negative) using the alternate regressions. In other words, the pattern of residuals is stable and we thus have more confidence that our findings are not accidents of analytical technique.

Another check on the regression equation is to see if it yields stable predictions over time. If it does, we can have greater confidence in the scale elasticity shown in table 4, and in using the equation for residual analysis in the future. Data from the 1980 DBFR became available toward the end of the study, and we used it to re-estimate the regression equation (table 12). (The same explanatory variables and functional form were used, but the coefficients were re-calculated with the later data.) Several of the coefficients changed somewhat, and the level of statistical significance for the number of military personnel fell substantially. However, the other levels of statistical significance and the value of R^2 remained high. The scale elasticity changed little in practical terms: Combining two naval air stations would save 20 percent on BOS cost (1980 data) rather than 15 percent (1979

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[1]The three equations for the three categories of bases come from a single regression that includes dummy variables.

TABLE 10

STABILITY OF RELATIVE RESIDUALS:
BASES SPENDING MORE THAN 50% ABOVE PREDICTED

UIC	Base	Relative Residuals for Regressions: I	II	III	IV
00168	National Naval Medical Center, Bethesda MD	183%	198%	150%	84%
00158	NAS, Willow Grove, Horsham, PA	96	103	70	68
62688	Naval Station, Norfolk, Norfolk, VA	83	39	85	37
00389	Naval Station, Roosevelt Roads, Ceiba, PR	77	108	74	130
60191	NAS, Oceana, Virginia Beach, Virginia	75	40	49	10
60036	Naval Weapons Station, Concord, Concord, CA	67	86	104	158
00314	Naval Submarine Base, Pearl Harbor, Honolulu, HI	63	52	61	63
00197	Naval Ordnance Station, Louisville, Louisville, KY	57	40	46	46
63042	NAS, Lemoore, Lemoore, CA	57	79	39	45
00188	NAS, Norfolk, Norfolk, VA	54	54	27	52
00247	Naval Training Center, San Diego, San Diego, CA	52	54	75	82
62813	Naval Station, Pearl Harbor, Honolulu, HI	51	63	46	57

TABLE 11

STABILITY OF RELATIVE RESIDUALS:
BASES SPENDING MORE THAN 50% BELOW PREDICTED

UIC	Base	Relative Residuals for Regressions: I	II	III	IV
00228	Naval Supply Center, Oakland, Oakland, CA	-51%	-48%	-48%	-52%
00406	Naval Supply Center, Puget Sound, Bremerton, WA	-52%	-56%	-50%	-52%
5340A	Nav Pac Missile Range Facility, Kekaha, HI	-52%	-61%	-46%	-53%
62741	Naval Supply Corps School Athens, GA	-53%	-77%	-48%	-71%
63401	Fleet ASW Training Center Lant, Norfolk, VA	-56%	-91%	-47%	-88%
00124	Naval War College, Newport, RI	-58%	-75%	-55%	-69%
62271	Naval Postgraduate School Monterey, CA	-60%	-57%	-53%	-46%
61414	Naval Amphibious Base Little Creek, Norfolk, VA	-64%	-44%	-62%	-45%
00205	Naval Suport Activity, New Orleans, New Orleans, LA	-66%	-67%	-62%	-58%
61665	Fleet Combat Training Center, PAC, San Diego, CA	-68%	-81%	-63%	-75%
00849	Naval Security Group Activity, Skaggs Island, Sonoma, CA	-72%	-83%	-71%	-80%
62603	Fleet and Mine Warfare Training Center, Charleston, SC	-76%	-96%	-73%	-94%
70240	Naval Communication Station, San Diego, CA	-84%	-95%	-83%	-94%

TABLE 12

COMPARISON OF REGRESSIONS USING 1979 AND 1980 DBFR DATA

	1979 Data[a]	1980 Data
Coefficient (Level of Statistical Significance)		
MIL	.036 (6.9%)	.030 (24%)
CIV	.247 (.02%)	.272 (.01%)
AREA	.253 (.01%)	.205 (.10%)
ACRE	.061 (.05%)	.070 (.10%)
BTU	.156 (.01%)	.116 (.31%)
Scale Elasticity	.75	.69
R^2	.90	.85

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[a]These coefficients are slightly different from those shown in table 4 because two bases had to be deleted from the 1979 list in order to compare results with 1980 (one 1979 base was closed, and one was made a tenant of another.)

data). More importantly, the list of bases with especially high and especially low relative residuals shows considerable stability from one year to the other (see page A-1, second paragraph).

APPENDIX A

INPUTS AND SELECTED OUTPUTS OF REGRESSION ANALYSIS

APPENDIX A

INPUTS AND SELECTED OUTPUTS OF REGRESSION ANALYSIS

Tables A-1 and A-2 define and list the data used to derive the regression equation discussed in the text. Table A-2 also presents some statistics generated by the regression. Except where noted, the data are from the 1979 DBFR (the listing is a computer printout that gives more digits than needed.) There is no value of "relative residual (1980)" for two bases, UICs 70024 and 00743. One was closed in 1980, and one was made a tenant of another host.

An impression of the stability of the results can be obtained from table A-3. In this table, the observations are ordered by the value of the relative residual in 1979. The first page of the table shows that those bases with large positive relative residuals in 1979 also tend to have large positive relative residuals in 1980. The third page of the table illustrates a similar point for negative relative residuals.

Table A-4 lists the correlations among the variables used in the central regression.

TABLE A-1

DESCRIPTIONS OF VARIABLES

Abbreviation	Description
UIC	Uniform Installation Code
MIL	The number of active military personnel
CIV	The number of civilian personnel
AREA	Building area in square feet
ACRE	Total land area in acres
BTU	Energy consumption in BTUs
BOS COST ACTUAL	BOS Cost actually spent, in millions of 1979 dollars
BOS COST PREDICTED	BOS cost predicted from regression equation, in millions of 1979 dollars

ABSOLUTE RESIDUAL = (BOS COST ACTUAL) - (BOS COST PREDICTED)

$$\text{RELATIVE RESIDUAL} = \frac{\text{ABSOLUTE RESIDUAL}}{\text{BOS COST PREDICTED}}$$

RELATIVE RESIDUAL (1980) = Same as relative residual, but using 1980 data

TABLE A-2

DATA

NAVAL AIR STATIONS

	UIC	BOS.COST	MIL	CIV	AREA	ACRE	BTU
00188 VA NAS, NORFOLK	188	96.895	7260	5837	7522	3200	1330830.6
00207 FL NAS, JACKSONVILLE	207	46.399	8550	4558	7012	4814	1275519.6
00213 FL NAS, KEY WEST	213	32.197	1547	659	5742	5247	290600.8
00236 CA NAS, ALAMEDA	236	42.191	4862	7051	8645	2697	2525348.2
00246 CA NAS, NORTH ISLAND	246	141.740	22770	9310	41086	46031	362351.4
00296 CA NAS, MOFFETT FIELD	296	38.422	5110	2437	3321	3909	397968.8
00334 HI NAS, BARBERS POINT *	334	23.541	3270	504	2363	32779	84977.8
00389 PR NAVAL STATION, ROOSEVELT ROADS,	389	64.372	3123	1285	6249	36861	277079.0
00620 WA NAS, WHIDBEY ISLAND	620	51.139	6577	989	4353	71042	695751.6
60087 ME NAS, BRUNSWICK	60087	24.575	3213	510	2476	7259	539699.2
60191 VA NAS, OCEANA	60191	56.294	9026	926	3924	8872	631460.4
60200 FL NAS, CECIL FIELD	60200	32.714	7709	727	2930	20048	387191.0
60259 CA NAS, MIRAMAR	60259	33.402	10256	1041	3692	22972	471401.8
60462 AK NAVAL STATION, ADAK *	60462	19.638	1655	164	2643	53448	696102.6
60495 NV NAS, FALLON	60495	16.796	1119	276	1270	152304	66702.6
63042 CA NAS, LEMOORE	63042	56.275	4550	904	4679	39173	649732.6
[illegible] CA NAVAL AIR FACILITY, EL CENTRO	[illegible]	7.562	377	198	1220	621711	68071.2
00101 MA NAS, SOUTH WEYMOUTH	101	10.590	2667	248	996	2320	174444.8
00158 PA NAS, WILLOW GROVE	158	29.713	875	980	851	853	208815.6
00196 GA NAS, ATLANTA	196	7.917	555	141	387	163	45671.4
00206 LA NAS, NEW ORLEANS	206	12.758	1010	486	1275	4924	125454.6
00215 TX NAS, DALLAS	215	12.519	1058	529	917	795	141124.2
00275 IL NAS, GLENVIEW	275	11.241	977	293	1283	1285	382651.2
00204 FL NAS, PENSACOLA	204	62.564	5020	6076	5864	2869	1315619.8
00216 TX NAS, CORPUS CHRISTI	216	57.644	2229	4354	5954	4373	1249840.0
00639 TN NAS, MEMPHIS	639	35.206	3126	1278	6121	3498	1411224.6
60241 TX NAS, KINGSVILLE	60241	13.566	1648	492	1564	5582	162257.8
60376 TX NAS, CHASE FIELD	60376	14.049	1542	528	1601	9633	170593.4
60508 FL WHITING FIELD	60508	14.713	2080	496	2079	11029	338383.0
63043 MS NAS, MERIDIAN	63043	13.683	1444	448	2092	13495	268953.2

TABLE A-2 (Cont'd)

NAVAL AIR STATIONS

	BOS COST ACTUAL (1979)	BOS COST PREDICTED (1979	ABSOLUTE RESIDUAL (1979)	RELATIVE RESIDUAL (1979)	RELATIVE RESIDUAL (1980)
00188 VA NAS, NORFOLK	96.895	63.018596	33.8764042	0.55343036	0.77150242
00207 FL NAS, JACKSONVILLE	46.399	59.571587	-13.1725866	-0.20433544	0.00928845
00213 FL NAS, KEY WEST	32.199	26.215548	5.9834517	0.26638587	0.32208142
00236 CA NAS, ALAMEDA	42.191	73.675114	-31.4841136	-0.41376405	-0.39596919
00246 CA NAS, NORTH ISLAND	141.740	108.118444	33.6215559	0.32021878	-0.22095583
00296 CA NAS, MOFFETT FIELD	38.422	34.306131	4.1158687	0.14912403	-0.04320078
00334 HI NAS, BARBERS POINT	23.541	18.704914	4.8360862	0.31200818	0.21824360
00389 PR NAVAL STATION, ROOSEVELT ROADS	64.372	36.320608	28.0513924	0.79985976	0.79694819
00620 WA NAS, WHIDBEY ISLAND	51.139	38.211876	12.9271242	0.36447109	0.72361257
60087 ME NAS, BRUNSWICK	24.575	22.955695	1.6193049	0.11416262	0.14486487
60191 VA NAS, OCEANA	56.294	32.147316	24.1466840	0.78223277	0.64894111
60200 FL NAS, CECIL FIELD	32.714	27.283376	5.4306237	0.23569751	0.29938018
60259 CA NAS, MIRAMAR	33.402	33.204343	0.1976566	0.03666927	0.18738021
60462 AK NAVAL STATION, ADAK	19.638	20.075398	-0.4373980	0.02802445	0.21127777
60495 NV NAS, FALLON	16.796	14.049853	2.7461471	0.26663248	2.05672961
63042 CA NAS, LEMOORE	56.275	35.827723	20.4472775	0.59862241	0.80298536
60296 CA NAVAL AIR FACILITY, EL CENTRO	7.562	13.461978	-5.8999776	-0.36398646	-0.53144686
00101 MA NAS, SOUTH WEYMOUTH	10.590	11.916175	-1.3261752	-0.02737247	0.08609745
00158 PA NAS, WILLOW GROVE	29.713	15.126823	14.5861774	1.03036691	0.43089862
00196 GA NAS, ATLANTA	7.917	5.377991	2.5390088	0.65805403	1.00817547
00206 LA NAS, NEW [illegible]	12.758	14.460359	-1.7023587	-0.04857132	-0.14945340
00215 TX NAS, DALLAS	12.519	12.434770	0.0842298	0.03719339	0.65185696
00275 IL NAS, GLENVIEW	11.241	13.903280	-2.6622803	-0.11956030	-0.27797112
00204 FL NAS, PENSACOLA	62.564	58.627548	3.9364525	0.08420022	-0.03216295
00216 TX NAS, CORPUS CHRISTI	57.644	53.518132	4.1258678	0.09577815	-0.28739297
00639 TN NAS, MEMPHIS	35.206	40.109093	-4.9030934	-0.09731193	0.70876771
60241 TX NAS, KINGSVILLE	13.566	16.258641	-2.6926411	-0.10410717	-0.20720732
60376 TX NAS, CHASE FIELD	14.049	17.303225	-3.2542250	-0.13027774	-0.18986859
60508 FL WHITING FIELD	14.713	20.544239	-5.8312391	-0.23516272	-0.15339958
63043 MS NAS, MERIDIAN	13.683	19.353701	-5.6707014	-0.24133375	-0.34057294

TABLE A-2 (Cont'd)

NAVAL STATIONS

	UIC	BOS COST	MIL	CIV	AREA	ACRE	BTU
00129 CT NAVAL SUB BASE, NEW LONDON	129	31.923	11524	1081	5536	1136	1868402.6
00245 CA NAVAL STATION, SAN DIEGO	245	88.704	44155	2756	4298	1164	7779981.4
00314 HI NAVAL SUB BASE, PEARL HARBOR	314	19.554	2503	285	1071	103	80762.8
60201 FL NAVAL STATION, MAYPORT	60201	31.184	12895	742	1880	3515	712107.6
61165 SC NAVAL STATION, CHARLESTON	61165	51.710	20911	11782	2847	1155	223598.0
61414 VA NAVAL AMPHIB BASE, LITTLE CREEK	61414	17.762	6903	856	1245	11813	1327612.4
62021 CA NAVAL AMPHIB BASE, CORONADO	62021	18.030	2990	398	1694	4044	155694.6
62688 VA NAVAL STATION, NORFOLK	62638	91.241	38508	1787	3635	1450	674912.8
62813 HI NAVAL STATION, PEARL HARBOR	62813	54.917	11829	1537	4162	838	181443.0
63406 CA NAV SUB SUPPORT FAC, SAN DIEGO	63406	6.613	5882	115	431	289	49955.2

PUBLIC WORK CENTERS

	UIC	BOS COST	MIL	CIV	AREA	ACRE	BTU
00187 VA NAV PUBLIC WKS CTR, NORFOLK	187	24.389	17	1843	4094	474	474906.4
62755 HI NAV PUB WKS CTR, PEARL HARBOR	62755	40.306	13	1558	10999	2116	349005.0
63387 CA NAV PUBLIC WKS CTR, SAN DIEGO	63387	27.886	3	675	8068	1518	609148.0
65113 IL NAV PUB WKS CTR, G. LAKES	65113	14.240	11	666	3501	540	469888.0
65114 FL NAV PUBLIC WKS CTR, PENSACOLA	65114	14.918	9	797	1556	297	3568283.2
68378 CA NAV PUBLIC WKS CTR, S FRAN	68378	33.721	13	1117	10165	696	651476.0

TABLE A-2 (Cont'd)

NAVAL STATIONS

	BOS COST ACTUAL (1979)	BOS COST PREDICTED (1979)	ABSOLUTE RESIDUAL (1979)	RELATIVE RESIDUAL (1979)	RELATIVE RESIDUAL (1980)
00129 CT NAVAL [illegible] , NEW LONDON	31.923	51.675346	-19.7523457	-0.36288767	-0.01617858
00245 CA NAVAL STATION, SAN DIEGO	88.704	83.910247	4.7937533	0.06904763	0.40924509
00314 HI NAVAL SUB BASE, PEARL HARBOR	19.354	11.872943	7.4810573	0.71431806	0.60896296
60201 FL NAVAL STATION, MAYPORT	31.184	33.516129	-2.3321292	-0.03974591	-0.14944556
61165 SC NAVAL STATION, CHARLESTON	51.710	60.647917	-8.9379167	-0.13088523	-0.36172474
61414 VA NAVAL AMPHIB BASE, LITTLE CREEK	17.762	49.070538	-31.3085383	-0.61765245	-0.29174909
62021 CA NAVAL AMPHIB BASE, CORONADO	18.030	20.093587	-2.0635870	-0.05293167	-0.40088431
62688 VA NAVAL STATION, NORFOLK	91.241	49.837112	41.4038879	0.85084962	0.43407582
62813 HI NAVAL STATION, PEARL HARBOR	54.917	36.269150	18.6478503	0.54172349	0.52162342
63406 CA NAV SUB SUPPORT FAC, SAN DIEGO	6.613	7.897426	-1.2844263	-0.03601507	-0.27249758

PUBLIC WORK CENTERS

	BOS COST ACTUAL (1979)	BOS COST PREDICTED (1979)	ABSOLUTE RESIDUAL (1979)	RELATIVE RESIDUAL (1979)	RELATIVE RESIDUAL (1980)
00187 VA NAV PUBLIC WKS CTR, NORFOLK	24.389	25.031045	-0.6420446	0.01430046	0.15516682
62755 HI NAV PUB WKS CTR, PEARL HARBOR	40.306	31.691580	8.6144201	0.30337459	-0.33439408
63387 CA NAV PUBLIC WKS CTR, SAN DIEGO	27.886	24.260638	3.6253621	0.19065295	2.87141763
65113 IL NAV PUB WKS CTR, G. LAKES	14.240	18.450464	-4.2104642	-0.17400452	-0.19704267
65114 FL NAV PUBLIC WKS CTR, PENSACOLA	14.918	20.663800	-5.7458005	-0.22966736	0.40853482
68378 CA NAV PUBLIC WKS CTR, S FRAN	33.721	29.345061	4.3559393	0.18239156	0.79396639

TABLE A-2 (Cont'd)

MEDICAL CENTERS

	UIC	BOS COST	MIL	CIV	AREA	ACRE	BTU
00168 MD NATIONAL NAVAL MED CTR	168	88.729	2391	2133	4356	243	635870.0
00203 FL NAV AERO & REG MED CTR, PENSACOLA	203	4.722	453	251	325	42	106233.2
00285 TX NAV REG MED CTR, CORP CHRISTI	285	2.376	224	89	263	32	35835.2
60002 TN NAV REG MED CTR, MEMPHIS	60002	2.752	478	119	247	39	85778.4
66818 VA NAV REG MED CTR, PORTSMOUTH	66818	12.519	2119	1064	1196	111	308625.0
68056 CA NAV REG MED CTR, SAN DIEGO	68056	14.327	2033	943	1416	85	133820.0
68084 NC NAV REG MED CTR, CHARLESTON	68084	5.085	626	272	478	24	90072.4
68085 FL NAV REG MED CTR, JACKSONVILLE	68085	7.702	654	292	339	75	152642.8
68086 RI NAV REG MED CTR, NEWPORT	68086	3.894	275	173	371	41	58342.8
68090 CA NAV REG MED CTR, LONG BEACH	68090	6.947	473	428	603	65	118285.0
68092 IL NAV REG MED CTR, G. LAKES	68092	9.698	803	237	1149	85	267128.0
68093 NC NAV REG MED CTR, CAMP LEJEUNE	68093	6.192	561	289	569	127	90118.0
68094 CA NAV REG MED CTR, C. PENDLETON	68094	9.772	661	400	586	339	120605.0
68095 WA NAV REG MED CTR, BREMERTON	68095	3.921	309	198	283	24	61433.2
68097 CA NAV REG MED CTR, OAKLAND	68097	10.098	1247	609	896	207	214191.8
68101 PA NAV REG MED CTR, PHILADELPHIA	68101	9.924	575	361	798	48	472063.0

TRAINING CENTERS

	UIC	BOS COST	MIL	CIV	AREA	ACRE	BTU
00210 IL NAVAL TNG CTR, N. CHICAGO	210	53.360	3022	1353	7730	1026	1557053.4
00247 CA NAVAL TRAINING CTR, SAN DIEGO	247	36.864	2187	705	4638	608	486933.8
00281 VA FLEET COMBAT TRNG CTR, LANT	281	10.254	3228	800	1486	1038	531744.2
00948 CA FLEET ASW TRNG CTR, PAC	948	5.516	952	128	435	27	42350.8
61665 CA FLEET COMBAT TRAINING CTR, PAC	61665	2.040	630	620	207	91	38880.0
62603 SC FLEET AND MINE WARFARE TRNG CTR	62603	0.330	175	10	149	10	8108.8
62661 RI NAV EDUCATION & TRAINING CTR	62661	28.911	2641	1507	8559	2298	1498868.0
63082 FL NAVAL TECH TRNG CTR, CORRY STA	63082	7.040	2478	180	1018	473	198258.2
63322 SC FBM SUBMARINE TRNG CTR	63322	1.159	259	19	164	8	41731.0
63401 VA FLEET ASW TRNG CTR, LANT	63401	0.683	236	8	114	5	41961.2
65928 FL NAVAL TRAINING CENTER, ORLANDO	65928	28.984	2385	1977	6557	2068	625438.0
00124 RI NAVAL WAR COLLEGE	124	2.311	216	206	595	22	39994.2
00161 MD US NAVAL ACADEMY	161	32.155	844	1909	5312	1747	801605.2
62271 CA NAVAL POST GRADUATE SCHOOL	62271	8.194	1657	792	2545	620	341985.0
62741 GA NAVY SUPPLY CORPS SCHOOL	62741	1.864	85	62	393	58	55036.0
64356 VA ARMED FORCES STAFF COLLEGE	64356	2.382	445	92	288	30	47740.0

TABLE A-2 (Cont'd)

MEDICAL CENTERS

	BOS COST ACTUAL (1979)	BOS COST PREDICTED (1979)	ABSOLUTE RESIDUAL (1979)	RELATIVE RESIDUAL (1979)	RELATIVE RESIDUAL (1980)
00168 MD NATIONAL NAVAL MED CTR	88.729	31.341429	57.3875706	1.86295174	3.69659680
00203 FL NAV AERO & REG MED CTR, PENSACOLA	4.722	6.209134	-1.4871338	-0.07845439	0.44141093
00205 TX NAV REG MED CTR, CORP CHRISTI	2.376	3.689862	-1.3138623	-0.08506070	-0.07700747
60002 TN NAV REG MED CTR, MEMPHIS	2.752	4.639249	-1.8872485	-0.19124833	-0.30543765
66018 VA NAV REG MED CTR, PORTSMOUTH	12.519	16.243119	-3.7241190	-0.16770911	-0.19205068
68054 CA NAV REG MED CTR, SAN DIEGO	14.327	14.200775	0.1262245	0.07930725	0.03315432
68084 NC NAV REG MED CTR, CHARLESTON	5.086	6.646466	-1.5604660	-0.08432542	0.03646077
68085 FL NAV REG MED CTR, JACKSONVILLE	7.702	7.224137	0.4778110	0.20456427	0.06972589
68086 RI NAV REG MED CTR, NEWPORT	3.894	5.228355	-1.3343545	-0.06395024	-0.05924133
68090 CA NAV REG MED CTR, LONG BEACH	6.947	8.648278	-1.7012778	-0.08108872	0.22694211
68092 IL NAV REG MED CTR, G. LAKES	9.698	10.225562	-0.5275621	0.04620165	0.04269439
68093 NC NAV REG MED CTR, CAMP LEJEUNE	6.192	7.752477	-1.5604770	-0.07229651	-0.14561140
68094 CA NAV REG MED CTR, C. PENDLETON	9.772	10.065390	-0.2933899	0.07020196	-0.25304628
68095 WA NAV REG MED CTR, BREMERTON	3.921	4.963339	-1.0423392	-0.00853039	0.89218011
68097 CA NAV REG MED CTR, OAKLAND	10.098	12.658655	-2.5606549	-0.12328758	-0.03519938
68101 PA NAV REG MED CTR, PHILADELPHIA	9.924	10.840626	-0.9166258	0.00769090	0.08854336

TRAINING CENTERS

	BOS COST ACTUAL (1979)	BOS COST PREDICTED (1979)	ABSOLUTE RESIDUAL (1979)	RELATIVE RESIDUAL (1979)	RELATIVE RESIDUAL (1980)
00210 IL NAVAL TNG CTR, N. CHICAGO	53.360	40.563647	12.7963532	0.34011619	0.38328257
00247 CA NAVAL TRAINING CTR, SAN DIEGO	36.864	24.304308	12.5596920	0.55791311	0.63679504
00281 VA FLEET COMBAT TRNG CTR, LANT	10.254	20.122186	-9.8681861	-0.44071689	-0.27614284
00[illegible] T ASW TRNG CTR, PAC	5.516	4.884418	0.6315816	0.33403805	0.28939258
61445 CA FLEET COMBAT TRAINING CTR, PAC	2.040	6.352265	-4.3122652	-0.52143056	-0.46648041
62403 SC FLEET AND MINE WARFARE TRNG CTR	0.330	1.389378	-1.0[illegible]93776	-0.04273685	-0.53679610
62661 RI NAV EDUCATION & TRAINING CTR	28.911	44.432319	-15.5213194	-0.32681885	-0.05574623
63082 FL NAVAL TECH TRNG CTR, CORRY STA	7.040	10.200697	-3.1606972	-0.21181858	-0.14485218
63322 SC FTM SUBMARINE TRNG CTR	1.159	2.130082	-0.9710816	0.01357618	-0.08143535
63401 VA FLEET ASW TRNG CTR, LANT	0.683	1.547983	-0.8649834	0.08722093	-0.08999468
65928 FL NAVAL TRAINING CENTER, ORLANDO	28.984	38.622675	-9.6386748	-0.22366848	-0.19042527
00124 RI NAVAL WAR COLLEGE	2.311	5.538830	-3.2278301	-0.40222034	-0.23755761
00161 MD US NAVAL ACADEMY	32.155	36.053927	-3.8989266	-0.08040529	-0.10389104
62271 CA NAVAL POST GRADUATE SCHOOL	8.194	20.307638	-12.1136378	-0.54726394	-0.39525915
62741 GA NAVY SUPPLY CORPS SCHOOL	1.864	3.980114	-2.1161140	-0.28042261	-0.33433649
64356 VA ARMED FORCES STAFF COLLEGE	2.382	4.054477	-1.6724772	-0.16586039	0.19927020

TABLE A-2 (Cont'd)

NAVAL SUPPLY STATIONS

	UIC	BOS COST	MIL	CIV	AREA	ACRE	BTU
00109 VA NAVAL WEAPONS STA, YORKTOWN	109	40.143	1103	1886	3120	10638	461315.9
00164 IN NAV WEAPONS SUPPORT CTR, CRANE	164	23.675	57	3390	5235	62509	664466.6
00174 MD NAV ORDNANCE STA, INDIAN HEAD	174	31.274	282	2242	2365	3381	1554659.8
00189 VA NAVAL SUPPLY CTR, NORFOLK	189	29.146	485	3732	10596	2672	451380.0
00193 SC NAVAL WEAPONS STA, CHARLESTON	193	34.892	4088	1286	4221	16589	587477.4
00197 KY NAV ORDNANCE STA, LOUISVILLE	197	26.796	8	2431	1369	129	279416.2
00228 CA NAVAL SUPPLY CTR, OAKLAND	228	20.463	955	3094	10199	1053	386636.6
00244 CA NAVAL SUPPLY CTR, SAN DIEGO	244	18.641	374	1199	1422	20	185213.0
00406 WA NAVAL SUPPLY CTR, PUGET SOUND	406	4.733	61	493	1092	256	77610.6
00604 HI NAVAL SUPPLY CTR, PEARL HARBOR	604	8.028	70	724	3712	838	41803.6
00612 SC NAVAL SUPPLY CTR, CHARLESTON	612	9.286	125	1073	1465	195	45736.2
60036 CA NAVAL WEAPONS STA, CONCORD	60036	33.116	1727	1121	1193	13756	162916.6
60478 NJ NAVAL WEAPONS STA, EARLE	60478	13.988	725	674	1103	11165	258232.2
60701 CA NAVAL WEAPONS STA, SEAL BEACH	60701	20.646	377	2117	3299	13975	148450.2
68297 HI NAVAL MAGAZINE, LUALUALEI	68297	6.169	247	169	1510	12604	42216.6

SHIPYARDS

	UIC	BOS COST	MIL	CIV	AREA	ACRE	BTU
00102 NH PORTSMOUTH NAVAL SHIPYARD	102	25.713	996	7859	3529	286	1696548.0
00151 PA PHILADELPHIA NAVAL SHIPYARD	151	60.741	286	8913	7067	904	3741350.8
00181 VA NORFOLK NAVAL SHIPYARD	181	54.367	784	12382	8659	1309	2711290.2
00191 SC CHARLESTON NAVAL SHIPYARD	191	64.135	110	7861	2905	1906	1885877.2
00221 CA MARE ISLAND SHIPYARD	221	105.156	2300	9850	10451	5895	1657554.6
00251 WA PUGET SOUND NAVAL SHIPYARD	251	76.972	917	10812	5652	2020	1926911.8
00311 HI PEARL HARBOR NAVAL SHIPYARD	311	39.570	345	6470	3421	155	190335.4
60258 CA LONG BEACH NAVAL SHIPYARD	60258	49.573	51	7382	2211	350	1216356.6

TABLE A-2 (Cont'd)

NAVAL SUPPLY STATIONS

	BOS COST ACTUAL (1979)	BOS COST PREDICTED (1979)	ABSOLUTE RESIDUAL (1979)	RELATIVE RESIDUAL (1979)	RELATIVE RESIDUAL (1980)
00109 VA NAVAL WEAPONS STA. YORKTOWN	40.143	32.638530	7.5044700	0.26056535	0.16299693
00164 IN NAV WEAPONS SUPPORT CTR. CRANE	28.675	45.766449	-17.0914495	-0.35159925	-0.39705472
00174 MD NAV ORDNANCE STA. INDIAN HEAD	31.274	35.788248	-4.5142479	-0.09819559	-0.26913136
00189 VA NAVAL SUPPLY CTR. NORFOLK	29.148	46.744349	-17.5963495	-0.35504504	-0.37895107
00193 SC NAVAL WEAPONS STA. CHARLESTON	34.892	35.573546	-0.6815460	0.00895199	-0.03296503
00197 KY NAV ORDNANCE STA. LOUISVILLE	26.796	17.064152	9.7318483	0.62891191	0.00387894
00228 CA NAVAL SUPPLY CTR. OAKLAND	20.463	41.702716	-21.2397161	-0.48533328	-0.55321396
00244 CA NAVAL SUPPLY CTR. SAN DIEGO	18.641	13.750934	4.8900655	0.42833929	0.41673447
00406 WA NAVAL SUPPLY CTR. PUGET SOUND	4.733	9.852261	-5.1192605	-0.41810309	-0.52692135
00604 HI NAVAL SUPPLY CTR. PEARL HARBOR	8.028	14.421690	-6.3936904	-0.37399849	-0.35253198
00612 SC NAVAL SUPPLY CTR. CHARLESTON	9.286	11.998507	-2.7125075	-0.14272671	-0.23908074
60034 CA NAVAL WEAPONS STA. CONCORD	33.116	19.853405	13.2625954	0.71839545	0.68118603
60478 NJ NAVAL WEAPONS STA. EARLE	13.988	17.594797	-3.6067968	-0.14815726	-0.43103779
60701 CA NAVAL WEAPONS STA. SEAL BEACH	20.646	28.078520	-7.4325197	-0.22909041	-0.22427445
68277 HI NAVAL MAGAZINE. LUALUALEI	6.169	9.821190	-3.6521895	-0.27004769	-0.36494693

SHIPYARDS

	BOS COST ACTUAL (1979)	BOS COST PREDICTED (1979)	ABSOLUTE RESIDUAL (1979)	RELATIVE RESIDUAL (1979)	RELATIVE RESIDUAL (1980)
00102 NH PORTSMOUTH NAVAL SHIPYARD	25.713	47.214665	-21.5016652	-0.43422240	-0.30737758
00151 PA PHILADELPHIA NAVAL SHIPYARD	60.741	67.069314	-6.3283141	-0.07944489	-0.08188281
00181 VA NORFOLK NAVAL SHIPYARD	54.367	77.273181	-22.9061815	-0.28349009	-0.36080733
00191 SC CHARLESTON NAVAL SHIPYARD	64.135	47.594109	16.5408906	0.36855171	0.42537280
00221 CA MARE ISLAND SHIPYARD	105.156	80.543049	24.6129506	0.31800324	0.19595670
00251 WA PUGET SOUND NAVAL SHIPYARD	76.972	65.845577	11.1264233	0.18416458	0.42750113
00311 HI PEARL HARBOR NAVAL SHIPYARD	39.570	29.654264	9.9157361	0.36810005	0.56634539
60258 CA LONG BEACH NAVAL SHIPYARD	49.573	35.993499	13.5795005	0.40505927	0.21030695

TABLE A-2 (Cont'd)

NAVAL SUPPORT ACTIVITIES

	UIC	BOS COST	MIL	CIV	AREA	ACRE	BTU
00205 LA NAVAL SUPPORT ACT, NEW ORLEANS	205	8.168	2139	1894	2579	225	349522.8
00255 WA NAVAL SUPPORT ACT, SEATTLE	255	5.570	1830	738	2021	271	228271.6
60028 CA NAVAL SUPPORT ACT, TREASURE IS	60028	26.824	1214	606	2985	1087	516057.8
61174 NY NAVAL SUPPORT ACT, BROOKLYN	61174	18.382	2296	482	2018	133	310836.0
61189 PA NAV SUPPORT ACT, PHILADELPHIA	61189	12.152	4795	1277	3393	522	228480.8
68311 CA NAV SUPPORT ACT, LOS ANGELES	68311	24.361	1442	457	3640	1154	296047.4

RESEARCH & TESTING CENTERS

	UIC	BOS COST	MIL	CIV	AREA	ACRE	BTU
00163 IN NAVAL AVIONICS CENTER	163	15.938	8	2258	857	167	201319.8
00167 MD D W TAYLOR NAV SHIP R&D CTR	167	18.331	22	1600	1459	211	218095.8
00173 DC NAVAL RESEARCH LABORATORY	173	39.561	39	3481	2985	862	893954.6
00178 VA NAVAL SURFACE WEAPONS CTR	178	24.707	121	2681	1361	4321	196545.2
00253 WA NAV UNDERSEA WARFARE ENGR STA	253	15.835	301	2856	2030	4078	281783.8
60921 MD NAV SURFACE WEAPONS CTR, WH OAK	60921	23.763	50	2136	1717	1059	318293.0
61331 FL NAV COASTAL SYSTEMS LABORATORY	61331	10.011	254	840	631	665	54709.8
61533 MD NAVAL SHIP R&D CENTER, ANNAPOLIS	61533	11.158	5	894	576	112	148062.4
66001 CA NAVAL OCEAN SYSTEMS CTR	66001	33.031	315	3385	1533	3843	183923.0
66604 RI NAVAL UNDERWATER SYST CTR	66604	19.828	89	2665	1250	215	307482.2
00421 MD NAVAL AIR TEST CTR, PAX RIVER	421	66.895	3335	4573	4816	6638	903691.2
0534A HI NAV PAC MISSILE RANGE FACILITY	1009	3.599	127	416	312	2399	46568.8
60530 CA NAVAL WEAPONS CTR, CHINA LAKE	60530	63.080	932	4470	6529	1127015	1094192.6
62269 PA NAVAL AIR DEVELOPMENT CENTER	62269	25.551	317	2499	1778	921	307382.2
62376 NJ NAVAL AIR PROPULSION CENTER	62376	7.916	8	587	570	73	345963.8
63126 CA PACIFIC MISSILE TEST CENTER	63126	53.928	1036	1662	4825	27084	582879.6
68335 NJ NAV AIR ENG CTR, LAKEHURST	68335	29.468	865	2046	2862	7399	586503.0
70024 CT NAV UNDERWATER SYS DEV CTR, N.L.	70024	14.832	40	1415	637	152	132898.0

TABLE A-2 (Cont'd)

NAVAL SUPPORT ACTIVITIES

	BOS COST ACTUAL (1979)	BOS COST PREDICTED (1979)	ABSOLUTE RESIDUAL (1979)	RELATIVE RESIDUAL (1979)	RELATIVE RESIDUAL (1980)
00205 LA NAVAL SUPPORT ACT, NEW ORLEANS	8.168	24.182361	-16.0143609	-0.62088069	-0.58420752
00255 WA NAVAL SUPPORT ACT, SEATTLE	5.570	16.889285	-11.3192850	-0.61099597	-0.55239770
60028 CA NAVAL SUPPORT ACT, TREASURE IS	26.824	21.435935	5.3880652	0.29800731	-0.29601693
61174 NY NAVAL SUPPORT ACT, BROOKLYN	18.382	15.332716	3.0492839	0.26409436	-0.43376257
61189 PA NAV SUPPORT ACT, PHILADELPHIA	12.152	23.730727	-11.5787272	-0.44578184	-0.27327965
68311 CA NAV SUPPORT ACT, LOS ANGELES	24.361	19.479761	4.8812386	0.30191533	-0.16195347

RESEARCH & TESTING CENTERS

	BOS COST ACTUAL (1979)	BOS COST PREDICTED (1979)	ABSOLUTE RESIDUAL (1979)	RELATIVE RESIDUAL (1979)	RELATIVE RESIDUAL (1980)
00163 IN NAVAL AVIONICS CENTER	15.988	14.416734	1.5712664	0.17835291	0.16034362
00167 MD D W TAYLOR NAV SHIP R&D CTR	18.331	15.965364	2.3656361	0.21080060	0.26994376
00173 DC NAVAL RESEARCH LABORATORY	39.561	31.963993	7.5970066	0.26895909	0.36301675
00178 VA NAVAL SURFACE WEAPONS CTR	24.707	22.412309	2.2946911	0.14700365	0.10107559
00253 WA NAV UNDERSEA WARFARE ENGR STA	15.835	27.300267	-11.4652670	-0.38333936	-0.41634148
60921 MD NAV SURFACE WEAPONS CTR, WH OAK	23.763	21.480747	2.2822529	0.15279976	0.09526448
61331 FL NAV COASTAL SYSTEMS LABORATORY	10.011	10.394897	-0.3838966	0.05926980	0.00935709
61533 MD NAVAL SHIP R&D CENTER, ANNAPOLIS	11.158	9.486997	1.6710031	0.28154359	0.23951368
66001 CA NAVAL OCEAN SYSTEMS CTR	33.031	24.871274	8.1597258	0.36828534	0.29838964
66604 RI NAVAL UNDERWATER SYST CTR	19.828	19.351186	0.4768136	0.07631644	0.30997097
00421 MD NAVAL AIR TEST CTR, PAX RIVER	66.895	50.903689	15.9913113	0.33379332	0.30636480
0574A HI NAV PAC MISSILE RANGE FACILITY	3.599	7.533012	-3.9340118	-0.38948722	-0.52927625
60530 CA NAVAL WEAPONS CTR, CHINA LAKE	63.080	73.475034	-10.3950340	-0.12786702	-0.12904188
62269 PA NAVAL AIR DEVELOPMENT CENTER	25.551	23.685346	1.8656539	0.12098348	0.14098679
60376 NJ NAVAL AIR PRODUCTION CENTER	7.916	9.567414	-1.6514135	-0.06508669	0.03843350
63126 CA PACIFIC MISSILE TEST CENTER	53.928	38.520729	15.4072713	0.42593356	0.30533279
68335 NJ NAV AIR ENG CTR, LAKEHURST	29.488	32.825434	-3.3374344	-0.07120803	-0.09864459
70024 CT NAV UNDERWATER SYS DEV CTR, N.L.	14.832	11.699157	3.1328427	0.35325987	

TABLE A-2 (Cont'd)

NAVAL COMMUNICATION STATIONS

	UIC BOS	COST	MIL	CIV	AREA	ACRE	BTU
00702 ME NAV SECURITY GP ACT, WINTER HA	702	3.295	341	68	320	583	62758.6
00743 PR NAVAL COMM STA, PUERTO RICO	743	3.523	368	199	592	2580	78407.2
00788 MD NAVAL COMM UNIT, WASHINGTON	788	2.940	191	176	297	210	72620.0
00849 CA NAV SECURITY GP ACT, SKAGGS IS	849	0.952	292	45	173	3309	48841.0
00886 CA NAVAL COMM STA. STOCKTON	886	5.068	392	373	6244	2769	60474.2
00950 HI NAV COMM AREA MASTER STA, EPAC	950	8.414	1130	201	580	2430	193035.8
62892 FL NAVAL SECURITY GROUP, HOMESTEAD	62892	2.400	395	45	85	815	13314.4
63038 ME NAVAL COMM UNIT, CUTLER	63038	3.238	115	103	290	2999	298201.8
63886 AK NAVAL SECURITY GROUP, ADAK	63886	4.423	550	53	309	7553	108957.5
66754 PR NAV SECURITY GRP, SABANA SECA	66754	3.709	273	63	428	2251	44894.0
70092 DC NAVAL SECURITY STA. WASHINGTON	70092	5.539	580	614	569	38	51139.2
70240 CA NAVAL COMM STA, SAN DIEGO	70240	0.280	246	10	94	622	15122.6
70272 VA NAVCOMM AREA MASTER STA, LANT	70272	2.705	190	75	476	1471	155135.0

NAVAL FACILITIES

	UIC BOS	COST	MIL	CIV	AREA	ACRE	BTU
57040 DE NAVAL FACILITY, LEWES	57040	1.420	104	18	100	364	20587.8
57041 NC NAVAL FACILITY, CAPE HATTERAS	57041	0.904	140	2	110	58	33526.2
57053 CA NAVAL FAC, CENTERVILLE BEACH	57053	2.236	223	20	145	48	47635.0
57054 CA NAVAL FACILITY, PT SPUR	57054	1.185	97	17	93	48	56230.0
57055 OR NAVAL FACILITY, COOS HEAD	57055	0.949	118	14	95	178	11963.0
57056 WA NAVAL FACILITY, PACIFIC BEACH	57056	1.202	127	16	121	53	19668.2

TABLE A-2 (Cont'd)

NAVAL COMMUNICATION STATIONS

	BOS COST ACTUAL (1979)	BOS COST PREDICTED (1979)	ABSOLUTE RESIDUAL (1979)	RELATIVE RESIDUAL (1979)	RELATIVE RESIDUAL (1980)
00702 ME NAV SECURITY GP ACT, WINTER HA	3.295	3.671196	-0.3761963	0.16991337	0.20135176
00743 PR NAVAL COMM STA, PUERTO RICO	3.523	5.242169	-1.7191694	-0.13718927	
00700 MD NAVAL COMM UNIT, WASHINGTON	2.940	3.386510	-0.4465098	0.16343971	0.15580336
00849 CA NAV SECURITY GP ACT, SKAGGS IS	0.952	3.413685	-2.4616853	-0.42818396	-0.47917979
00884 CA NAVAL COMM STA, STOCKTON	5.008	6.402835	-1.3948347	-0.06166561	-0.24738373
00950 HI NAV COMM AREA MASTER STA, EPAC	8.414	8.255378	0.1586220	0.14034754	0.04368080
62992 FL NAVAL SECURITY GROUP, HOMESTEAD	2.400	2.753224	-0.3532239	0.23491591	-0.15084760
63038 ME NAVAL COMM UNIT, CUTLER	3.238	4.444860	-1.2068595	-0.04653905	0.31241392
63004 AK NAVAL SECURITY GROUP, ADAK	4.423	4.898195	-0.4751947	0.10714261	0.63443627
66754 PR NAV SECURITY GRP, SABANA SECA	3.709	3.529913	0.1790870	0.33402723	0.43354465
70092 DC NAVAL SECURITY STA, WASHINGTON	5.539	5.960123	-0.4211232	0.09712497	-0.05040288
70240 CA NAVAL COMM STA, SAN DIEGO	0.280	1.719914	-1.4399137	-0.25577659	-0.11353825
70272 VA NAVCOMM AREA MASTER STA, LANT	2.705	3.995301	-1.2903006	-0.07266051	-0.19693942

NAVAL FACILITIES

	BOS COST ACTUAL (1979)	BOS COST PREDICTED (1979)	ABSOLUTE RESIDUAL (1979)	RELATIVE RESIDUAL (1979)	RELATIVE RESIDUAL (1980)
57040 DE NAVAL FACILITY, LEWES	1.420	2.030497	-0.6104969	0.19182648	0.14101701
57041 NC NAVAL FACILITY, CAPE HATTERAS	0.904	1.265581	-0.3615814	0.50444687	0.34712103
57053 CA NAVAL FAC, CENTERVILLE BEACH	2.236	2.355280	-0.1192798	0.37393441	0.03640669
57054 CA NAVAL FACILITY, PT SUR	1.185	2.025556	-0.8405564	0.07871593	-0.03088770
57055 OR NAVAL FACILITY, COOS HEAD	0.949	1.671238	-0.7222382	0.16620124	0.05073949
57056 WA NAVAL FACILITY, PACIFIC BEACH	1.202	1.840536	-0.6385364	0.19639033	0.02718955

TABLE A-3

COMPARISON OF RELATIVE RESIDUALS USING 1979 AND 1980 DATA

UIC	RELATIVE RESIDUAL(1979)	RELATIVE RESIDUAL(1980)
168	1.85924249	3.69659680
158	1.04936157	0.41089862
62688	0.82474326	0.43407588
349	0.79323254	0.73594819
60191	0.76970263	0.64894111
60036	0.73344545	0.68118603
314	0.70078628	0.60998296
196	0.66645140	1.00817547
197	0.65609147	0.00387894
63042	0.58707741	0.80298536
188	0.55293276	0.77150242
247	0.54441064	0.63679504
62813	0.52438487	0.52182342
57041	0.48589311	0.34712103
244	0.43883077	0.41673447
60258	0.42660647	0.21030695
63126	0.42446580	0.30533279
65001	0.39097598	0.29838964
311	0.30785846	0.56634539
191	0.38534660	0.42537280
57053	0.37157120	0.03640869
620	0.35581121	0.72361257
421	0.33821715	0.30838480
948	0.33742109	0.23939258
210	0.32524080	0.38322257
221	0.32082697	0.19595670
66794	0.31391107	0.41354465
246	0.31328932	-0.22095583
334	0.31155699	0.21824360
61533	0.30421398	0.23951368
62755	0.30134976	-0.33439408
68511	0.29152385	-0.16195547
60028	0.29010485	-0.23601693
173	0.28082559	0.30301675
60495	0.26923310	2.05672961
109	0.26469259	0.16299693
61174	0.25789595	-0.43378257
213	0.25627907	0.32208142
62892	0.23743363	-0.15084760
60200	0.22969331	0.29938018
167	0.22643473	0.28994378
68085	0.21334228	0.06972599
163	0.20257472	0.16034362
57056	0.19796863	0.02718955
57040	0.19684388	0.14101701
251	0.19294535	0.42750115
63387	0.18365564	2.87141763
68378	0.17565233	0.79395639
57055	0.17093765	0.05073949
60921	0.16706296	0.08596448

TABLE A-3 (Cont'd)

UTC	RELATIVE RESIDUAL(1979)	RELATIVE RESIDUAL(1980)
178	0.16609361	0.10107659
788	0.15671632	0.15580336
702	0.15456906	0.20135176
296	0.15262692	-0.04310078
62269	0.13353757	0.14098675
950	0.12370395	0.04368080
60087	0.10673464	0.14486487
216	0.09667655	-0.28739297
70092	0.09318669	-0.05040288
215	0.09202560	0.65185696
66604	0.09264348	0.30997097
63086	0.08956169	0.63443627
204	0.08653001	-0.03216295
63056	0.03477079	0.03315432
63401	0.07994481	-0.08999468
57094	0.07945438	-0.03088770
68094	0.07637412	-0.25304628
61331	0.07597650	0.00935709
245	0.04759329	0.40924509
68092	0.04131594	0.04265439
60259	0.03119768	0.18738021
187	0.01925999	0.15516682
60462	0.01295202	0.21127777
63322	0.01025122	-0.09143535
68101	0.00714124	0.09854336
193	0.00514157	-0.03298503
68095	0.00032691	0.89210011
101	-0.02966206	0.08609745
63406	-0.04396160	-0.27749758
62603	-0.04425920	-0.53679610
206	-0.04546359	-0.1[illegible]945340
60201	-0.05275341	-0.1[illegible]44558
62376	-0.05746794	0.0[illegible]43350
68086	-0.05786613	-0.05[illegible]24133
63038	-0.05874935	0.31241392
62021	-0.06233727	-0.40088431
68093	-0.06716963	-0.14561140
68335	-0.06756602	-0.09864459
203	-0.07126973	0.44141093
68090	-0.07448467	0.27694211
151	-0.07622797	-0.03139281
68084	-0.07918011	0.03646077
285	-0.07950204	-0.07700747
161	-0.08253706	-0.10389104
70272	-0.08980411	-0.19693942
886	-0.06993304	-0.24738373
174	-0.09578322	-0.26913136
60241	-0.10355100	-0.20720732
639	-0.10564668	0.70876771
68097	-0.11936023	-0.03519938
275	-0.12332564	-0.27797112

TABLE A-3 (Cont'd)

UTC	RELATIVE RESIDUAL (1979)	RELATIVE RESIDUAL (1980)
60530	-0.12466891	-0.12904188
61165	-0.12565825	-0.30172474
60376	-0.12932950	-0.18786859
612	-0.13192234	-0.23908074
60478	-0.14373255	-0.43103779
64356	-0.16289501	0.19927020
66818	-0.16383098	-0.19205048
63113	-0.17483617	-0.19704267
60002	-0.18740194	-0.30543765
207	-0.20559560	0.00928845
63082	-0.21630193	-0.14485218
60701	-0.22251855	-0.22427445
65928	-0.22672443	-0.17042527
63116	-0.22974295	0.40853482
60508	-0.23788248	-0.15339958
63043	-0.24373665	-0.34057294
70240	-0.26308394	-0.11353825
68297	-0.27040534	-0.36494693
62741	-0.28026983	-0.33433649
181	-0.28031789	-0.36030733
125	-0.29752490	-0.01617858
62667	-0.33386864	-0.03574623
18[illegible]	-0.34710409	-0.39705472
189	-0.35483431	-0.37995107
60296	-0.36298083	-0.33144686
60[illegible]	-0.37114451	-0.35253158
25[illegible]	-0.37588415	-0.41634148
100[illegible]	-0.37896104	-0.52927625
12[illegible]	-0.39881452	-0.23765761
406	-0.41333504	-0.32692135
23[illegible]	-0.41459372	-0.39596919
102	-0.42970716	-0.30737758
849	-0.43303606	-0.47917979
28	-0.44091448	-0.27614284
61189	-0.44623642	-0.27327965
228	-0.48606978	-0.55321398
61665	-0.51152946	-0.45648041
62271	-0.54828139	-0.39525915
255	-0.61132978	-0.55239770
205	-0.61957195	-0.38420752
61414	-0.62483197	-0.29174909

TABLE A-4

CORRELATION MATRIX

	BOS	MIL	CIV	AREA	ACRE	BTU	NB x MIL	CS x MIL
BOS	1							
MIL	.39	1						
AREA	.89	.35	.83	1				
ACRE	.55	.36	.39	.56	1			
BTU	.83	.29	.77	.80	.41	1		
NB x MIL	.21	.43	.09	.11	.03	.15	1	
CS x MIL	-.38	-.10	-.34	-.33	.03	-.30	-.09	1
CS x AREA	-.37	-.11	-.32	-.29	.03	-.28	-.08	.98

Note: Except for NB and CS, all variables are in logarithmic form, the form they have in the regression. NB is a dummy variable with value 1 for Naval bases, and 0 otherwise. Recall that our definition of Naval bases includes Naval stations, amphibious bases and submarines bases. CS is a dummy variable for communications stations and security activities.