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Estimating Area Cost Factors for Military Construction Projects: A Computerized Approach

Robert E. Chapman
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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

PREFACE

The computerized procedure presented in this report was developed under the sponsorship of the Department of Defense by the Applied Economics Group of the Center for Building Technology, National Engineering Laboratory, National Bureau of Standards. This procedure is an outgrowth of a cooperative project between the Center for Building Technology and Michigan State University to develop an economically sound method for estimating area cost factors for military construction projects. Accurate estimates of area cost factors are of crucial importance to the military since these factors are used as deflators to adjust for regional cost differentials among planned projects. Past efforts in this area have focused on the use of cost indices based primarily on private market construction activities. Since the type and nature of construction projects carried out in the private sector often deviates from those carried out by the military, the use of cost indices based on private sector activities may complicate the process of planning and implementing a workable budget for future military construction projects.

ABSTRACT

This report describes a computerized procedure for estimating area cost factors
for military construction projects. The empirical basis for this procedure
rests upon the results of an econometric analysis of over 500 military con-
struction projects. Technical and empirical evidence from a wide variety of
published sources were also used to provide supplemental information on wage
rates, material prices and the level of construction activities in the locali-
ties where the projects were undertaken. This report is intended to serve as a
user manual for military personnel concerned with the problem of periodically
updating the area cost factors for each service's installations. A series of
technical appendices are also included which describe the theoretical underpin-
nings of the econometric models which constitute the core of the computerized
procedure as well as provide samples of computer output and a complete listing
of the computer program.

Key words: Applied economics; construction; cost; estimation; location factors;
            model building; statistical analysis.

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Most Common SI Units and their
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QUANTITY	INTERNAITONAL (SI) UNIT	U.S. CUSTOMARY UNIT	APPROXIMATE CONVERSION
LENGTH	meter (m)	foot (ft)	1 m = 3.2808 ft
	millimeter (mm)	inch (in)	1 mm = 0.0394 in
AREA	square meter (m^2)	square yard (yd^2)	1 m^2 = 1.1960 yd^2
		square foot (ft^2)	1 m^2 = 10.764 ft^2
	square millimeter (mm^2)	square inch (in^2)	1 mm^2 = 1.5500 x $10^{-3}in^2$
VOLUME	cubic meter (m^2)	cubic yard (yd^3)	1 m^3 = 1.3080 yd^3
		cubic foot (ft^3)	1 m^3 = 25.315 ft^3
	cubic millimeter (mm^3)	cubic inch (in^3)	1 mm^3 = 61.024 x $10^{-6}in^3$
CAPACITY	liter (L)	gallon (gal)	1 L = 0.2642 gal
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VELOCITY, SPEED	meter per second (m/s)	foot per second (ft/s or f.p.s.)	1 m/s = 3.2808 ft/s
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ACCELERATION	meter per second squared (m/s^2)	foot per second squared (ft/s^2)	1 m/s^2 = 3.2808 ft/s^2
MASS	metric ton (t) [1000 kg]	short ton [2000 lb]	1 t = 1.1023 ton
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DENSITY	metric ton per cubic meter (t/m^3)	ton per cubic yard (ton/yd^3)	1 t/m^3 = 0.8428 ton/yd^3
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FORCE	kilonewton (kN)	ton-force (tonf)	1 kN = 0.1124 tonf
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ANSI Z210 .1-1976, "American National Standard for Metric Practice;" also issued as
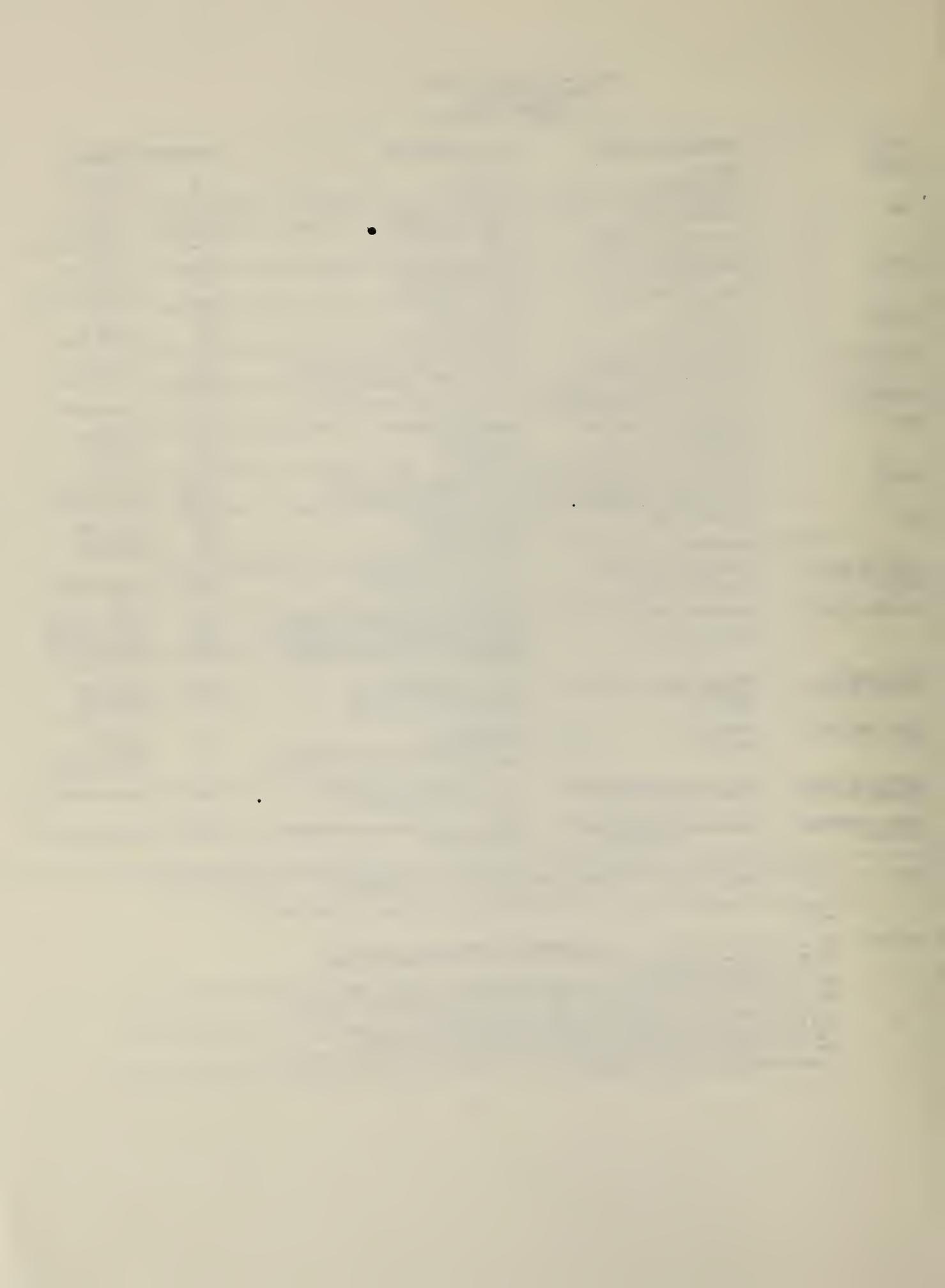ASTM E380-76[c], or IEEE Std. 268-1976.

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1.0 INTRODUCTION

Past experience with military construction projects has indicated that large discrepancies can arise between the amount authorized for a particular project and the actual cost of the project. Such discrepancies interfere with the budgeting process in situations of both overestimation and underestimation. In circumstances where the actual costs are overestimated, the "surplus" amount is not available for alternative uses. In circumstances where the actual costs are underestimated, either additional funds must be sought, or cost saving design changes must be implemented.

The current cost estimating procedures used by the Department of Defense involve first estimating the cost of a particular project in a given locale, and then adjusting the estimated cost through the use of two multiplicative factors. These factors adjust: (1) the size of the particular project visa-vis the size of a "standard" project; and (2) the construction costs in the location of the proposed project relative to construction costs in a "standard" or "base" location. (The standard location or "base city" used in this report is Washington, D.C.). Errors in the estimation for either of these adjustment factors can result in considerable error in the cost estimate used to facilitate comparisons among proposed military construction projects prior to the actual allocation of funds. From a more pragmatic point of view, these errors introduce considerable uncertainty into the budgeting process for proposed military construction projects. Given that the size of construction projects, in terms of square footage, is changing less rapidly than the fluctuations in the market place, relatively more uncertainty is generated by regional cost differentials than by factors affecting size.

Since the Department of Defense submits proposed projects for annual appropriations, it would thus be desirable if estimates of area cost factors[1] could be updated on an annual basis just prior to Congressional Hearings. Currently, area cost factors are reviewed annually using limited data and often not in the time period most likely to facilitate budget planning. The accuracy of area cost factors is extremely important since Congressional statute limitations on funds available for construction projects are quite stringent and assume that all area cost factors used have been accurately estimated.

1.1 PURPOSE

The purpose of this report is to describe a computerized procedure for estimating area cost factors for military construction projects, identify its data requirements, show how to run the procedure in a batch mode, and provide guidelines for interpreting its output. The procedure described in this report is based on the results of an econometric analysis of over 500 military

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[1] The term area cost factor is defined as a multiplicative factor used to reflect relative geographical cost differentials. They are used in the development of military construction program projects and/or alternative basing studies. They are not used, however, to develop construction cost growth forecasts.

construction projects.[1] The end result of this econometric analysis was a procedure which explicitly takes into consideration variations in the prices for labor and materials. This report is intended to serve as a user's manual for military personnel concerned with the problem of periodically updating the area cost factors for each service's installations.

1.2 SCOPE AND APPROACH

The general plan of this report is to briefly describe the computer program, state the requirements of the program, and show how the computer program may be accessed. Specifically, this user's manual is organized as follows.

Section 2.1 describes the economic theory of cost functions which permitted an economically sound method for estimating area cost factors to be derived from empirical data on military construction projects. Section 2.2 includes a discussion of the computer algorithm; illustrating how a user would actually apply the program. Step-by-step instructions are then given to: (1) identify the necessary inputs; (2) facilitate the preparation of the input deck; and (3) interpret the program's output.

This report also contains three technical appendices.

Appendix A shows how, given an underlying set of technical relationships, a function suitable for estimating area cost factors may be derived.

Appendix B provides examples of what the actual input and output statements from the computer should look like. A sample computer run is given to show how data from major metropolitan areas could be used to estimate area cost factors if information from individual military installations were not available.

Appendix C consists of a listing of the computer program. The program is written in FORTRAN.[2]

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[1] Details of the econometric analysis are given in James M. Johannes, Paul D. Koch and Robert H. Rasche, An Investigation of Factors Affecting Geographical Cost Differentials on Military Construction Projects, National Bureau of Standards, NBS-GCR-80-197, 1980.

[2] The guide used in preparing this computer program was Fortran V Level 1 Reference Manual, Interdata Inc., Oceanport, N.J., November 1975.

2.0 DESCRIPTION OF THE COMPUTER PROGRAM

2.1 METHOD OF APPROACH

Past efforts at estimating area cost factors have made use of cost indices contained within construction cost estimating guidebooks or other published sources. Most guidebooks also contain detailed cost adjustment indices which differ not only by region but by labor categories as well. They are usually applied to average cost figures in order to attain figures which are more appropriate to local construction market conditions. Although cost indices serve to control for systematic differences in the structure of construction costs, they may promote a false sense of security.[1] This stems from two factors: (1) the construction project mix; and (2) Federal regulatory requirements.

Cost indices are really little more than a market basket of construction labor, materials, and sometimes equipment. The weights used in computing the index are based on specific types of construction. Consequently, should the type of construction being put in place for a particular region differ from that used to compute the weights for the index, it is quite likely that the index would introduce a bias into any cost to which it was applied. Unfortunately, there is no a priori information which can be used to identify the direction and size of such a bias.

It is almost certain that programs such as the Small Business Set-Aside Program, Affirmative Action Compliance Program, Davis-Bacon Act, Buy America Act, and others increase Federal contract construction costs. In particular, the proliferation of competition-limiting programs may have a significant cost impact. Federal regulatory requirements may thus introduce biases which will render meaningless the weights used in a construction cost index based on private sector activity.

The purpose of this section is to show how the requirements of having a sound cost engineering approach can be integrated with economic theory. Combining both aspects of the problem results in a cost estimating procedure which is sensitive to the technical considerations of the construction process as well as to local market conditions.

The approach taken in this study is highly desirable due to the explicit relationship between construction costs and the production process.[2] Stated another way, once a particular building design is established and a contractor

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[1] Lawrence Jaquith, "The Cost Index: Working Tool or Trap," Architectural Record, February 1969.

[2] The presentation in this section aims at providing a non-technical discussion of the engineering economic techniques used in developing the relationship between costs and production technology. Those readers who wish a more technical discussion which states this relationship explicitly are referred to appendix A.

is selected to construct the building, the contractor must decide on how to best combine the various inputs (labor, equipment, materials) to erect the building. In making such decisions the firm is constrained by the existing construction technology. Through the economic concept of the production function, however, an explicit mathematical statement of the construction technology can be made. The general form of the production function is given as:

$$Q = f(L,E,M)$$

where   Q = the output (square feet of floor area);
        L = the labor input into the construction process;
        E = the equipment input into the construction process;
        M = the materials input into the construction process; and
        f = the explicit functional relationship.

It is important to point out that the production function is a technical relationship which represents the current "state-of-the-art" method of combining the construction inputs to erect the building. It is also a constraint on how the contractor can substitute among inputs in putting up the building. Given the productive constraints under which the firm must operate, it becomes possible to overlay the cost structure faced by the contractor in erecting the building. This structure is based on the rationale that firms attempt to minimize the costs of producing a given output. (Cost minimization is a prerequisite for profit maximization, a concept which has had long standing acceptance in the field of economics.) Given the constraints of the construction process and the goal of cost minimization by the contactor, the cost structure faced by the firm can then be expressed through the use of the economic tool known as the cost function. A general statement of the cost function may be taken as

$$C\text{*} = g(T,S,P_L,P_E,P_M)$$

where C* = the minimum total cost of erecting the building;
       T = a representation of the relevant technical issues;
       S = a measure of the size or scale of the project;
     P_L = the price per unit of labor;
     P_E = the price per unit of equipment;
     P_M = the price per unit of building materials; and
       g = the explicit functional relationship.

Depending on the functional form of the production function, the cost function, C*, can take on various representations. In this study the cost functions are based on the assumption that the production function underlying the construction

process is Cobb-Douglas.[1] This assumption is made both because it is consistent with previous studies of the construction industry[2] and for ease of exposition.

The cost function associated with the Cobb-Douglas production function is particularly attractive since it can be expressed as a product of three factors. These factors are: (1) a technology factor; (2) a size factor; and (3) a market factor. The technology factor, TF, is defined by the underlying construction process. That is, certain basic construction techniques (technologies) interact with the structure type in defining an approach which is feasible in the engineering sense. The size factor, SF, may be derived from the size adjustment chart, where a factor line is used to define a cost relationship factor from a size relationship factor (see figure 2.1). The market factor, MF, reflects the influence that supply and demand conditions in the local construction market for key labor, material and equipment inputs have on the overall cost of the job. The cost function, C*, may thus be written as:

$$C* = (TF)x(SF)x(MF) \qquad\qquad 2.2$$

The concept of an area cost factor may now be introduced through reference to equation 2.2. Suppose a subscript which ties each cost function evaluation to a given locale is introduced. For example, the Washington, D.C. locale may be denoted by a "w" subscript. The "base city" cost function is thus given by C_w^*. It is then possible to construct an area cost factor for that city by regionally factoring the two cost functions. In the actual process of regional factoring, the Washington, D.C. cost function is used as a deflator. That is, C_w^* is the denominator of the equation defining the area cost factor. The area cost factor for a particular city, say Chicago, ACF_c, may thus be defined as

$$ACF_c = C_c^*/C_w^* \; .$$

In general, for any arbitrary city, j, the area cost factor is defined as:

$$ACF_j = C_j^*/C_w^*. \qquad\qquad 2.3$$

Expanding equation 2.3 through reference to equation 2.2 reveals that

$$ACF_j = [(TF_j)\,(SF_j)\,(MF_j)]/[(TF_w)\,(SF_w)\,(MF_w)] \qquad\qquad 2.4$$

---

[1] The general form of the Cobb-Douglas production function is given as:

$$Q = A \; L^{\alpha 1}E^{\alpha 2}M^{\alpha 3}$$

where L, E and M are as defined earlier and A, $\alpha 1$, and $\alpha 2$, and $\alpha 3$ are positive constants relating the inputs to the output Q. A is frequently referred to as an efficiency parameter and $\alpha 1$, $\alpha 2$, and $\alpha 3$ are referred to as output elasticities.

[2] For an authoritative source on this subject see John S. McConnaughey, <u>Production Functions in Contract Construction for the United States, 1972</u> (unpublished), Ph.D. dissertation, Michigan State University, 1976.

Figure 2.1 Size/Unit Cost Adjustment Chart

typical size

Cost adjustment curve

COST RELATIONSHIP

AREA RELATIONSHIP
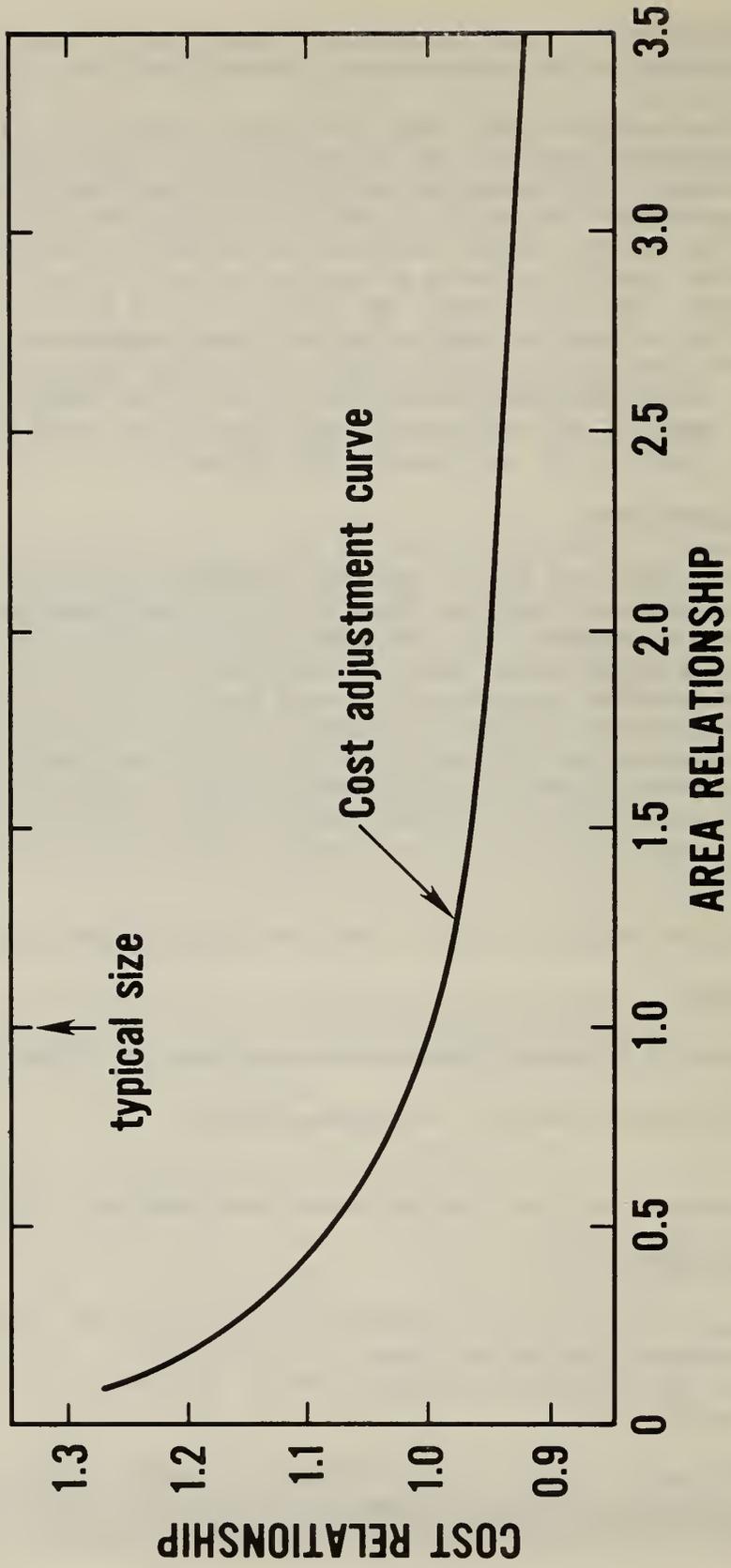
Since area cost factors reflect the relative cost differentials of erecting an identical structure in a different locale, the TF_j and TF_w terms in equation 2.4 cancel.[1] By the same token, holding design constant would imply that the size factor for Washington, D.C., SF_w would cancel the size factor for Chicago, SF_c, or for any other city. Thus the area cost factor for each city, j, may be defined as

$$ACF_j = MF_j/MF_w \qquad\qquad 2.5$$

Equation 2.5, based on empirical estimates of equation 2.2, is the formula actually used in the computer program described in the next section.

2.2   DESCRIPTION OF COMPUTER ALOGORITHM

The computer program discussed in this section is written is FORTRAN. Although the program is written in FORTRAN it is not necessary for the user to know how to use FORTRAN in order to run the program. The program is designed to provide a maximum amount of flexibility to the user and includes several check mechanisms which significantly reduce the chance of a user error. This section begins with a discussion of the data required to run the program. Guidelines are also given as to how these required data can be collected. Section 2.2.2 makes use of a flowchart to provide a description of the computer algorithm. Several examples are also used to illustrate some of the safeguards built into the program and to facilitate the interpretation of the output.[2]

2.2.1   Data Requirements

In order to calculate area cost factors for each installation, information on 10 labor skills and four building materials are required.[3] Each of the 10 labor skills are identified in table 2.1. These skills are: (1) common building laborer; (2) bricklayer; (3) carpenter; (4) cement mason; (5) electrician; (6) operating engineer; (7) painter; (8) plumber; (9) sheet metal worker; and (10) structural steel worker. These skills represent the bulk of the labor

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[1] Technology factors may change over time. However, unless one were interested in comparing the area cost factor in one location at one point in time to the area cost factor for some other location at some different point in time, it would not be necessary to include the TF_j and TF_w terms in the cost function. The cost functions which were actually estimated did include these terms so that future comparisons among locales could be made. The computer program discussed in the following sections, however, does not include a technology factor.

[2] Those readers wishing a more detailed example are referred to appendix B, where a sample runstream is presented, and appendix C, where a complete listing of the computer program is given.

[3] In the event that data from each installation can not be obtained, cost information from major cities can be used. Installations can then be paired off with a major city. See appendix B for an example of such an approach.

involved in the construction projects used to estimate the cost functions discussed earlier. Note that the indicated figure for each skill includes the contractor's overhead and profit. The figures required for the computer program include additions to the bases due to worker's compensation and employer's liability, U.S. and state unemployment, Social Security, builder's risk and public liability, and overhead and profit. Since overhead and profit will vary as a function of the type of job, the size of the job, the location of the job and prevailing economic conditions at the locale, some care should also be taken to insure that it is adequately reflected in the wage data reported. Each of the four building materials are identified in table 2.2. These four materials are: (1) common brick; (2) lumber, 2" x 4"; (3) ready mix concrete; and (4) structural steel (light). Additional qualifying information is also given in table 2.2. For example, the delivered price per cubic yard of concrete assumes a regular weight mix with a strength of 3000 psi.

It is important to point out that the four building materials listed above do not affect equally the calculations of the area cost factor. In particular, for some category codes, one or more of the materials may not be included as a key cost factor. This is because the empirical analysis of that category code revealed that material to be of minor importance. Furthermore, even if a material is used across all category codes, there may be a difference in the cost impact associated with a change in the price of that material. The preceding statement can be best explained by noting that the coefficients of the cost functions described earlier are a type of weight reflecting the relative importance of that building material. Through the use of econometric methods, these weights were estimated so as to obtain the best possible fit or measure of the importance of that key cost factor.

Thus far no mention has been made about how to obtain the data listed in tables 2.1 and 2.2. Two alternative approaches will be pursued in addressing this topic. These approaches are: (1) obtain all fourteen pieces of data from each installation; and (2) obtain all data from a single source. As will be shown in the paragraphs which follow, there are substantial advantages in obtaining all data from a single source.

Obtaining data from each source is time consuming, and it is likely that different agents will report different types of information. Unless consistency checks can be devised to screen these data, some area cost factors may not accurately represent the premium placed on a particular installation's location. One crude consistency check is to require each installation to provide the same set of data for the nearest major city. Since this type of data is often published periodically, it would, at least in theory, be possible to "check" the figures provided by the installation against published results. Should one decide to pursue this approach, it is recommended that past records be reviewed to determine if any meaningful cost figures are included in documents submitted for progress payments. In the event that recent records are unavailable, it should be possible to contact local contractors and suppliers to obtain the information outlined in tables 2.1 and 2.2.

The second approach, whereby all data are obtained from a single source, is highly desirable since it saves time both in the field and at the central

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Table 2.1   Labor Skills for Which Wage Rates are Required and Weights Applicable to Each Labor Skill[a]

Labor Skill	Weight
Common Building Laborer	.05
Bricklayer	.08
Carpenter	.23
Cement Mason	.07
Electrician	.14
Operating Engineer	.05
Painter	.04
Plumber	.20
Sheet Metal Worker	.04
Structural Steel Worker	.10

[a] Labor skills and weights are based on historical data made available by the Army Corps of Enginers.

Table 2.2   Material Price Specifications Required for Each Installation

Building Material	Unit	Additional Information
Common Brick	Delivered Price Per 1000	
Lumber 2" x 4"	Delivered Price Per 1000 Board Feet	#2 Grade Carload Lot Surface 4 Sides
Ready Mix Concrete	Delivered Price Per Cubic Yard	Regular Weight 3000 P.S.I.
Structural Steel (Light)	Delivered Price Per Ton	Delivered Price Includes: (1) Base Price at Mill; (2) Extras and Delivery to Shops; (3) Drafting; (4) Shop Fabricating and Warehouse Handling; (5) Shop Coat Paint; and (6) Trucking to Job Site

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facility where the area cost factors are being calculated.[1] Furthermore, if all data are obtained from a single source there is less likelihood that different types of data (i.e., non-systematic biases) will be presented for different installations. The likelihood of systematic biases across the entire data set being introduced is, however, higher in this mode of operation. Although both types of biases do pose complications in interpreting the area cost factors which result from the program, relatively less danger is associated with any systematic biases which may be introduced in this case. This claim may be supported by noting: (1) these biases are likely to be small; and (2) the regional factoring process may tend to cause some cancelling of errors.

Of the various ways of obtaining the data for each installation, perhaps the fastest and simplest is to purchase the data directly from a nationally known cost engineering firm. Many of these firms keep extensive data bases which are in some cases tabulated at the zip code level. Such geographic detail is more than sufficient for estimating a set of area cost factors. In such an event, each installation would be located by zip code and each of the 14 pieces of information recorded. If such detailed cost information cannot be easily obtained, it is still satisfactory to use data from contiguous areas. In these cases, however, it may be necessary for some engineering judgment to be exercised to determine if any adjustments are called for.[2] Although these guidelines are rather simple and straight forward, it is believed that following them will permit the data required to exercise the computerized procedure to be obtained with a minimal amount of effort on the part of the central facility engineering staff.

2.2.2 Applying the Computerized Procedure

The computerized procedure discussed earlier is programmed to determine regional cost differentials, i.e., area cost factors for either a group of military installations or cities. The computerized procedure for determining these area cost factors is outlined in figure 2.2. Figure 2.2 is a flow chart showing the sequence through which the area cost factors are calculated. For purposes of

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[1] Potential sources of data for this approach include standard cost manuals such as McGraw-Hill's Dodge Manual for Building Construction, Pricing and Scheduling, and R.S. Means, Building Construction Cost Data.

[2] Although the results of the computerized procedure for estimating area cost factors are based on information which can be readily measured or checked, it is important to point out that some judgmental decisions are inevitable. There is no substitute for professional experience. The use of this procedure is not intended to do away with the input from experienced individuals but to complement it. However, the use of this procedure does reduce to a minimum the reliance on decisions which are purely judgmental and hence can neither be confirmed nor denied. Thus, a real strength of this procedure is being able to identify quickly any discrepancies should they result, determine how serious they are, and take them into consideration in any future any future calculations.

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explanation, the flow chart is divided into six sections beginning with the 100s and ending with the 600s. The designation of each section refers to the numbers of the statements included within it. For example, in the first section (100s) the cost data are read, tested for errors, and reproduced. This section contains statements numbered 100, 110, 120, 130, and 140, and is included within the section of the program having statements numbered in the 100s. The same procedure holds for the remaining five sections.

The 100s section of the program (line number 1 through 57 in the listing which appears in appendix C) begins with a dimension statement. Variables whose values are to be stored must first be dimensioned. Table 2.3 lists and defines the variables used in the computer program. The dimensioned variables are each alloted 250 rows by one column of storage space. The only exception to this array size is the ACF variable which is given 250 rows by three columns of storage space.[1] These columns represent storage space and room for calculation of the area cost factors. It should be noted that the number of rows indicated in the dimension statement (250) is a somewhat arbitrary upper limit of the number of military installations or cities for which an area cost factor may be required as opposed to the actual number for which data are being input. The actual number of installations or cities for which cost data are being input is indicated by the value in integer variable I. (See line number 22 of the computer listing given in appendix C.) Consequently, the dimensions given on each variable in table 2.3 are I x 1, I x 3, or I rather than 250 x 1, 250 x 3 or 250. If data on more than 250 locations is to be input, the number or rows of storage space indicated for the variables in the dimension statement should be changed to reflect the actual number of locations for which data are provided. For the example presented in appendix B, the variable I is set equal to 145, the number of cities for which data will be input. In order to provide a ready reference, the remainder of the discussion will proceed on the assumption that the example presented in appendix B is the case for which estimates of area cost factors are desired.

Within the program's first DO loop, ten wage rates, four material costs and two identification codes are input. The wage and material factors are read through a floating point format. The identifiers CITY(J) and ICODE(J) are read through an integer format.[2] The last statement number under the control of this DO loop is 100. Hereafter, the DO loops in this program will be referenced according to

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[1] For those readers referring to the listing of the computer program given in appendix C, it is important to point out that a 'C' in column 6 of the data card refers to a continuation of the information contained on the previous card. It does not change the name of the variable. A 'C' in column 1 of the data card indicates an information statement or "comment line." This comment line serves solely to describe or identify the procedure which follows it.

[2] It should be noted that a slash (/) within the format statement indicates the termination of data reading on the first card applicable to a particular city or installation and the beginning of data reading on the second card of that city or installation (see line number 27 of the computer listing given in appendix C).

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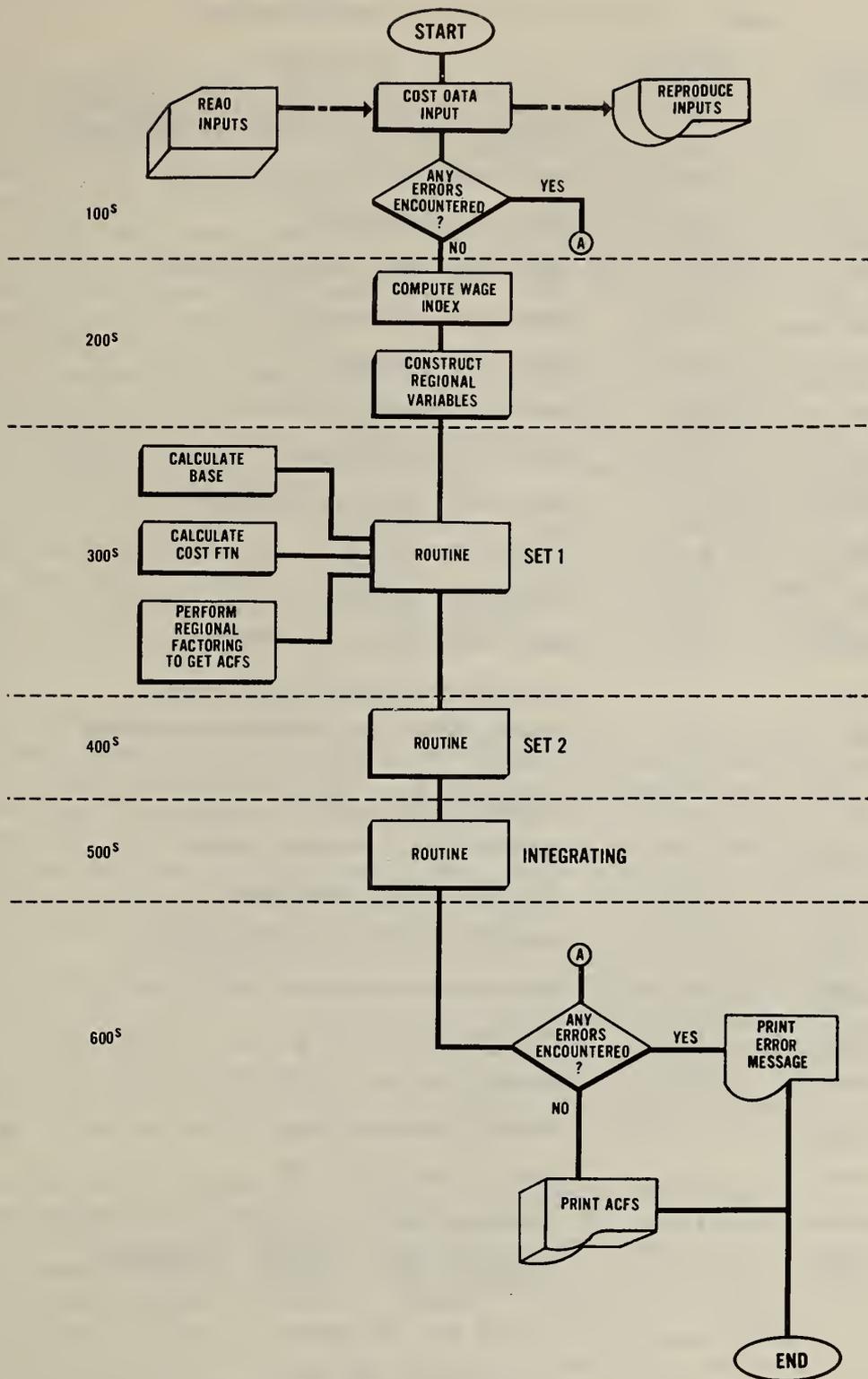
Figure 2.2   Flowchart for Area Cost Factor Computer Program

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Table 2.3 Variables Used in the Computer Program

VARIABLE	DIMENSION	DESCRIPTION
I	1 x 1	Number of military installations (or major cities) for which cost data are being input.
J	1 x 1	Installation (or major city) number.
ACF	I x 3	Area cost factor matrix
WCL	I x 1	Wage rate: common building laborer
WBR	I x 1	Wage rate: bricklayer
WCA	I x 1	Wage rate: carpenter
WCM	I x 1	Wage rate: cement mason
WEL	I x 1	Wage rate: electrician
WOE	I x 1	Wage rate: operating engineer
WPA	I x 1	Wage rate: painter
WPL	I x 1	Wage rate: plumber
WSM	I x 1	Wage rate: sheet metal worker
WSW	I x 1	Wage rate: structural steel worker
AWR	I x 1	Wage index for each installation (or major city)
WP	I x 1	Material price: lumber
SSP	I x 1	Material price: structure steel
CBP	I x 1	Material price: common brick
RMCP	I x 1	Material price: ready mix concrete
STAWR	I x 1	Natural logarithm of AWR
STWP	I x 1	Natural logarithm of WP
STCP	I x 1	Natural logarithm of RMC
STSSP	I x 1	Natural logarithm of SSP
STCBP	I x 1	Natural logarithm of CBP
CITY	I x 1	Installation ID
ICODE	I x 1	Identifier Code 1 = Alaska; 2 = Hawaii; 0 = Otherwise
J1	1 x 1	Leading line space flag
J2	1 x 1	Lagging line space flag
J3	1 x 1	Error flag
X1-X5	1 x 1	Working space
C1-C10	1 x 1	Constants used in computing area cost factors for SET 1.
D1-D12	1 x 1	Constants used in computing area cost factors for SET 2.
CONE	1 x 1	Cost function for SET 1.
CTWO	1 x 1	Cost function for SET 2.

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to the last statement number under their control (e.g., loop 100, loop 200, etc.). J is the index of loop 100 and of all other DO loops found in the program. Each loop proceeds from an initial index value of one (1) to a final index value of I (in this example, I = 145). Each city/installation for which an area cost factor is to be calculated has two data cards. The first data card includes the ten wage rates applicable to a particular city/installation. The second data card includes the four material costs and the ICODE(J) identifier which corresponds to each city/installation. The final entry on both data cards is the identification code CITY(J) which is used as a means of keeping track of the city or installation to which a particular set of cost factors apply. The cities/installations are given numbers from 1 through I. City 1 is the base city (Washington, D.C.). The cities/installations are assigned the remaining numbers (2 through I), in order, alphabetically by the state in which they are located and alphabetically within each state. A complete listing of the 145 cities and their corresponding identification codes used in the illustrative example is provided in table B.2. The other identifier, ICODE(J), is used in determining which locations require special coefficients in the calculation of their area cost factor. More succinctly, a value of ICODE(J) equal to 1 implies that the city/installation is in Alaska, a value of 2 implies that the city/installation is in Hawaii. In all other cases the value of ICODE(J) is equal to 0.

Several IF statements are included to check for errors in the input data. These statements test whether the wage rates or material prices entered into the program are less than or equal to zero. If a value is negative or equal to zero, an error has been encountered.[1] The program will highlight this error by double spacing above and below the lines of the city/installaiton containing the incorrect figure when the data are printed. The double spacing is achieved through the use of the carriage control mechanisms in the variables J1 and J2. In addition, an error in the input data will change the value of the error flag, J3, from 0 to 1. Following the completion of loop 100, if an error has been encountered, this flag triggers a printed message, ERROR IN INPUT DATA. Compilation is then terminated. The input data are reproduced to facilitate verification of input values. Table 2.4 illustrates an example where the price of common brick for CITY 83 was entered as .00 instead of 95.00. Double spacing appears above and below the lines containing the incorrect figure. In the event that no error is encountered, the program proceeds to the 200s section.

The 200s section of the computer program (line number 58 through 83 in the listing which appears in appendix C) begins with a DO loop (loop 200) designed to calculate the wage index, AWR(J), for each city/installation. Wage rates for ten skills--common building laborer, bricklayer, carpenter, cement mason, electrician, operating engineer, painter, plumber, sheetmetal worker, and structural steel worker--are weighted and added to get the total wage, TWAGE(J). The TWAGE(J) figure for each city is then divided by TWAGE(1), the base city (Washington, D.C.) total wage rate, and multiplied by 100. The resulting wage indices are the AWR(J) for each city.

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[1] Non positive values for wage and material prices are not permitted on technical grounds because the natural logarithm of zero or a negative number is not defined.

Regional variables are computed in the second part of the 200s section. In loop 250, the log values of the AWR(J) and four material prices are calculated for each city. The four material price variables are WP(J) (lumber price), SSP(J) (structural steel price), CBP(J) (common brick price), and RMCP(J) (ready mix concrete price). The log values of AWR(J), WP(J), SSP(J), CBP(J) and RMCP(J) are transferred (via X1, X2, X3, X4 and X5) to the variables STAWR(J), STWP(J), STSSP(J), STCBP(J) and STCP(J), respectively, where they are stored.

In the 300s section (line number 84 through 109 in the listing which appears in appendix C), the "SET 1 Structures Routine," the base city cost function for set 1 category codes[1] and set 1 category code structures' cost function for each location are calculated and factored to determine the area cost factors corresponding to these category codes. (The base city function city function is used as a deflator.) The coefficients of the cost functions, C1, C2, and C3 are multiplied by the log values in STAWR(J), STSSP(J) and STCP(J), respectively. The sum of the products is then exponentiated. When the log values associated with CITY(1) are used, the resulting value is the base city cost function for set 1 category (C7). In addition, there is an adjustment factor for Alaska (C5) and a coefficient corresponding to a dummy variable for Hawaii (C6). These values estimate the unusual costs of building set 1 category code structures in such areas; costs which are not captured in the measured input prices. Loop 300 begins by multiplying C1 through C3 by the log values corresponding to each city/installation in the same manner outlined for the base city. The sum of the products is set equal to C8. Two IF statements follow immediately. These statements refer to the ICODE(J) column read previously from the data cards.[2] A '1' in the ICODE(J) column indicates a city location in Alaska. A '2' in the column denotes a Hawaii location. A '0' appears in the ICODE(J) column for any other city location. If ICODE(J) is equal to 1 it is referred to a statement which takes the exponential of C8 and assigns that value to C9. To determine the cost function for set 1 category code structures (CONE) for cities or installations in Alaska, C9 is multiplied by the Alaska adjustment factor (C5). The IF statement for ICODE(J) equal to 2 transfers the applicable data to an equation which adds the Hawaii coefficient (C6) to C8. The resultant value is put into C10. The exponential of this value is set equal to CONE. The other city locations (ICODE(J) = 0) use the standard procedure. That is, C1, C2 and C3 are multiplied by STWAG(J), STSSP(J) and STCP(J), respectively, and summed. The result (C8) is then exponentiated, the value of which is set equal to CONE. In each case after computing the cost function, the program proceeds to the calculation of the area cost factors for set 1 category codes, ACF(J,1). This is accomplished by dividing each city's cost function by that of the base city (i.e., CONE/C7).

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[1] Category codes 74023, 21105, 51010, 4410, 7211, and 72411 compose the "Set 1 Structures." All other category codes are grouped under "Set 2 Structures."

[2] The ICODE(J) is the next to last column on the right of the second data line (card) for each city/installation (see the sample output shown in table 2.4).

Table 2.4   Illustration of Error in Input Data

15.00	19.25	19.45	19.05	22.65	24.35	17.25	22.80	22.75	28.45	80
340.00	700.00	130.00	44.15	0	80					
15.00	18.95	19.35	18.75	24.70	24.35	18.30	23.35	22.45	25.95	81
420.00	675.00	100.00	34.50	0	81					
14.00	19.60	19.70	18.45	22.20	24.35	17.25	22.35	21.55	24.35	82
420.00	675.00	100.00	34.50	0	82					
12.85	17.90	19.30	15.60	20.25	16.70	14.90	21.55	21.40	22.00	83
345.00	815.00	.00	39.85	0	83					
16.45	18.30	17.60	18.15	20.80	20.00	16.25	20.20	20.50	20.70	84
340.00	700.00	130.00	44.15	0	84					
14.25	16.20	15.20	16.05	19.80	16.75	14.05	17.40	21.30	20.35	85
340.00	700.00	130.00	44.15	0	85					
18.10	21.95	21.65	21.20	24.20	22.20	19.05	22.25	22.75	24.35	86
350.00	705.00	160.00	39.55	0	86					

The 400s section of the program (line number 110 through 136 in the listing which appears in appendix C), the "SET 2 Structure Routine," follows a plan very similar to the one used for set 1 structures. The coefficients D1 through D5 are multiplied by STAWR(1), STWP(1), STSSP(1), STCBP(1) and STCP(1), respectively. The sum of the products with regard to the base city is then put into D6. The exponential of D6 is set equal to D9, the base city cost function. The variables D7 and D8 represent the set 2 category codes structures' coefficient for Alaska and Hawaii, respectively. In loop 400, the variable D10 is defined as the summation of the D coefficients multiplied by the values of the transformed variables for each city. The cost function (CTWO) is derived by taking the exponential of D10. As in the set 1 structure routine, IF statements are used to reroute data for installations in either Alaska or Hawaii to a special cost function equation. Both the Alaska and Hawaii sequences begin by adding the appropriate coefficient (D7 or D8) to D10. The exponential of the result, D11 for Alaska and D12 for Hawaii, determines the cost function, CTWO. The area cost factors for set 2 structures are then calculated by dividing CTWO, the cost function for each city, by D9, the Washington, D.C.(base city) cost function. Set 2 category code area cost factors are stored in column 2 of the ACF array (i.e., ACF (J,2)).

In the 500s section (line number 137 through 143 in the listing which appear in appendix C), the "Integrating Routine," a project weighted average area cost factor is generated for each installation. The unweighted area cost factors for set 1 category codes (ACF(J,1)) and set 2 category codes (ACF(J, 2)) are multiplied by 0.26 and 0.74, respectively, to reflect the relative frequency with which structures within these two sets of category codes occur.

The final portion of the program, the 600s section (line number 144 through 161 in the listing which appears in appendix C), is devoted to the output format for for the printing of the area cost factors or an error message. Loop 600 begins with an IF statement which applies to the 1st, 51st, 101st, 151st and 201st lines of area cost factor data output by the computer. A format statement permits these lines to appear at the top of a new page of the computer printout under headings ('CITY,' 'ACF,' which describe the city/installation which the area cost factors apply. The area cost factors are printed fifty to a page through a floating point format. As noted earlier, the message 'ERROR IN INPUT DATA' indicates that one or more of the values input in the 100s section was found to be less than or equal to zero. Compilation is terminated following this printed message.

Preparing an Input Deck and Interpreting the Results of the Program: A Simplified Example

The purpose of this section is to provide a step-by-step example which will illustrate how the procedure would be applied in practice. In order to keep the example simple, data inputs and outputs on a sample of only 10 cities will be used. Since these cities are a part of the detailed example illustrated in appendix B, the reader can use the exposition presented in this section as an overview to test his/her understanding of the procedure prior to turning to the detailed example in the appendix.

The first step in applying the computerized procedure is to specify the number of cities/installations for which data will be input. This step is accomplished at line number 22 of the program (See appendix C) where the <u>integer</u> variable I is read. (Note that I must be an integer, i.e., 100 is acceptable whereas 100.0 is not.) For the example presented in this section I is set equal to 10, i.e., the statement I=10 is inserted at line number 22. It is important to point out that this step is a programming change rather than an input per se. This is because the integer variable I specifies the count on all DO loops referenced within the program.

The second step in applying the computerized procedure is to prepare the data cards. The program is arranged so that wage rate data is entered on the first card applicable to a particular city/installation, and material price data and the ICODE(J) identifier are entered on the second card of that city/installation. In order to minimize the likelihood of input error and to facilitate debugging, the CITY(J) identifier appears as the last number on the right on all data cards. It is extremely important to note the order in which the data are entered on the cards. For example, interchanging two material prices by accident can cause a completely meaningless estimate of the desired area cost factor to be printed. As a means of avoiding this problem, reference should be made to table 2.5 prior to the preparation of the data cards. Table 2.5 shows the order in which the data <u>must</u> be entered on the cards, the variable name as it is referenced within the program, the format through which the variable will be read and a brief description of what the variable is.

Returning once more to the example, the 10 cities for which data are to be input are identified in table 2.6. Table 2.7 shows the actual data input for the 10 cities. Note that column 5 on line (card) 2 of city 6 (Anchorage, Alaska) contains a 1 to distinguish it from all non Alaska locations. The first city on the list, regardless of the number of cities, is always the base city.

The base city may or may not be Washington, D.C. However, in this report the base city is always assumed to be Washington, D.C. The data, once read by the program, are manipulated according to the flowchart (figure 2.2) and the discussion presented earlier so as to arrive at an estimate of the area cost factors for each city.

The estimates of the area cost factors associated with the data input in table 2.7 are shown in table 2.8. Columns 1 and 2 of table 2.8 are exactly as they would be output from the program. Column 3 of table 2.8 provides a cross tabulation between the city number and city name; it is provided for convenience only and would <u>not</u> be a part of the standard computer output. Referring to table 2.8, it can be seen that the area cost factor for Washington, D.C., is 1.00. This result stems from the fact that Washington, D.C., is the base city and consequently dividing the Washington, D.C. cost function for each structure type by the base city cost function will always produce a value of 1.00.

The estimated area cost factors presented in table 2.8 may then be used as a part of the budget process through which the adjusted cost per unit for the primary facility, $ACPU_p$, is calculated. The adjusted cost per unit is defined as

Table 2.5 Assembling the Input Deck: Data Card Format

ORDER OF INPUT	VARIABLE NAME	FORMAT FOR VARIABLE	DESCRIPTION
Card One			
1	WCL(J)	F6.2	Wage rate in the Jth city/installation: Common Laborer
2	WBR(J)	F6.2	Wage rate in the Jth city/installation: Bricklayer
3	WCA(J)	F6.2	Wage rate in the Jth city/installation: Carpenter
4	WCM(J)	F6.2	Wage rate in the Jth city/installation: Cement Mason
5	WEL(J)	F6.2	Wage rate in the Jth city/installation: Electrician
6	WOE(J)	F6.2	Wage rate in the Jth city/installation: Operating Engineer
7	WPA(J)	F6.2	Wage rate in the Jth city/installation: Painter
8	WPL(J)	F6.2	Wage rate in the Jth city/installation: Plumber
9	WSM(J)	F6.2	Wage rate in the Jth city/installation: Sheetmetal Worker
10	WSS(J)	F6.2	Wage rate in the Jth city/installation: Structural Steel Worker
11	CITY(J)	I5	Installation ID for the Jth city/installation
Card Two			
1	WP(J)	F7.2	Material price in the Jth city/installation: Lumber
2	SSP(J)	F7.2	Material price in the Jth city/installation: Structural Steel
3	CBP(J)	F7.2	Material price in the Jth city/installation: Common Brick
4	RMCP(J)	F6.2	Material price in the Jth city/installation: Ready Mix Concrete
5	ICODE(J)	I3	Identifier code for the Jth city/installation
6	CITY(J)	I6	Installation ID for the Jth city/installation

Table 2.6 Sample Cities Used in the Example

City Number	City Name
1	Washington, D.C.
2	Birmingham, Alabama
3	Huntsville, Alabama
4	Mobile, Alabama
5	Montgomery, Alabama
6	Anchorage, Alaska
7	Phoenix, Arizona
8	Tucson, Arizona
9	Little Rock, Arkansas
10	Anaheim, California

Table 2.7 Assembling the Input Deck: Sample Input Stream

```
 14.45    20.15    17.70    17.75    20.70    17.65   18.95   21.20   20.85   21.25    1
400.00   800.00   130.00    30.00        0        1
 11.40    17.00    15.75    14.20    19.40    15.65   16.00   20.55   19.45   20.45    2
288.00   700.00    91.00    34.75        0        2
  9.15    15.25    14.00    14.05    19.10    16.60   14.95   18.15   19.45   18.80    3
325.00   875.00   100.00    35.00        0        3
 10.40    16.45    15.15    14.70    20.65    15.00   15.80   19.00   18.55   17.65    4
300.00   750.00   120.00    43.00        0        4
  9.20    15.95    15.60    14.85    16.40    15.65   11.90   18.85   19.45   20.45    5
288.00   700.00    91.00    34.75        0        5
 26.85    30.10    28.70    27.70    36.20    29.25   31.25   32.50   32.40   36.75    6
380.00   700.00   168.00    39.90        1        6
 15.75    20.20    18.90    18.55    26.70    20.80   17.75   23.80   25.10   27.00    7
325.00   700.00   110.00    39.00        0        7
 15.75    20.20    18.90    18.55    24.30    20.80   16.25   23.80   19.90   27.00    8
325.00   700.00   110.00    39.00        0        8
 11.00    15.60    15.15    14.30    18.20    15.10   13.10   19.25   19.10   18.80    9
320.00   700.00    97.00    35.00        0        9
 19.50    24.15    22.85    22.55    26.90    24.90   23.50   27.55   27.20   29.15   10
300.00   790.00   108.00    40.10        0       10
```

Table 2.8 Estimate of Area Cost Factors for Sample Cities

(1) CITY	(2) ACF	(3) City Name
1	1.00	Washington, D.C.
2	0.90	Birmingham, Alabama
3	0.93	Huntsville, Alabama
4	0.97	Mobile, Alabama
5	0.89	Montgomery, Alabama
6	1.84	Anchorage, Alaska
7	1.00	Phoenix, Arizona
8	1.00	Tucson, Arizona
9	0.90	Little Rock, Arkansas
10	1.05	Anaheim, California

$$\text{ACPU}_p = \frac{\text{PFC}}{\text{SIZE}} \times \frac{1}{\text{ACF}} \times \text{SF} \times \frac{\text{SIOH} \ \& \ \text{CONT}}{} \times \frac{2175}{\text{ENR}}. \qquad 2.9$$

where PFC = the total cost of the primary portion of the facility at award
(primary facility cost);
ACF = the area cost factor;
SF = the size factor (see figure 2.1);

SIOH & CONT = SIOH and contingency (1.1017);

ENR = Engineering News Record Index at award; and

2175 = Engineering News Record Index projected to 31 March/April 1982;

An average cost per unit can also be calculated for the support facility cost, ACPU_s, by replacing the primary facility cost, PFC, with the support facility cost, SFC, in equation 2.9. Support facility costs are separated from primary facility costs since non-market factors such as climate may have a profound influence on the type of support services needed (e.g., the special HVAC requirements associated with a base in Alaska).

The ACPU_p figure is particularly important because some categories of primary facilities are subject to statutory limits. Even if the particular category of structure being considered is not subject to a statutory limit, a wide divergence from the service wide average will reduce the likelihood of approval.

3.0 SUMMARY

A computerized procedure has been used to calculate estimated area cost factors for military construction projects. The computerized procedure is based on the results of a detailed econometric analysis of over 500 military construction projects located throughout the nation. Variations in the prices of labor and materials are considered, so that the area cost factors produced are applicable to a particular city or military installation.

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APPENDIX A

THEORETICAL AND EMPIRICAL ISSUES IN THE FORMULATION
OF AN AREA COST FACTOR MODEL

The purpose of this appendix is to show how the requirements of having a
sound cost engineering approach can be integrated with the economic theory
of cost functions. Combining both aspects of the problem results in a cost
estimating procedure which is sensitive to the technical considerations of
the construction process as well as to local market conditions.

The cost function approach is highly desirable due to the duality
relationship between the cost function and the production function associated
with the physical process. (Recall that the term production function as used
in this study refers to an explicit relationship between a set of inputs
(i.e., labor, materials, and capital) and technological factors which taken
together produce a given output, e.g., square floor area provided.) The
duality relationship stems from the fact that the contractor attempts to
minimize costs subject to the technical constraints imposed by the production
function. A simple analytical technique through which this constrained mini-
mization problem can be solved is known as the method of Lagrange multipliers.
The essence of the Lagrange-multiplier method is to convert a constrained-
minimization problem into a form such that the necessary conditions for an
unconstrained minimization can still be applied. If we assume the constraint
$Q = f(L,E,M)$ is exactly met (where Q = the output; L = the labor input into
the construction process; E = the equipment input into the construction
process; M = the materials input into the construction process; and f defines
the functional relationship between Q, L, E and M), then $Q - f(L,E,M)$ is
equal to zero and may be incorporated into the cost function to form an aug-
mented function with the same value. This function is known as the Lagrangian.
That is, by incorporating the constraint into the Lagrangian function and by
treating the Lagrangian multiplier as an extra variable, it is possible to
solve the constrained minimization problem, C^*, by identifying the optimal
values of L, E and M, of the unconstrained minimum. An additional point
worth noting is that the solution value of the Lagrange multiplier provides a
measure of the impact of a change in the level of output, Q, on the optimal
value of the cost function.[1]

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[1] For a detailed discussion of production functions, cost functions, duality,
and Lagrangian multipliers, the interested reader is referred to Walter
Nicholson, Microeconomic Theory: Basic Principles and Extensions, The Dryden
Press, Inc., Hinsdale, Illinois, 1972.

The duality relationship has been documented in numerous economic and engineering economics articles.[1,2] Through reference to the duality relationship it is possible to assert that the cost function tells us the least-cost way of providing Q square feet of floor area. In an actual empirical study, the cost function associated with the underlying process would first be theoretically derived from the production function by solving a constrained optimization problem. The theoretical parameters of the cost function would then be empirically estimated using econometric techniques until a "best fit" model was uncovered.

The derivation of the cost functions used in this study proceeds on the assumption that the production function underlying the construction process is Cobb-Douglas. This assumption is made both because it is consistent with previous studies of the construction industry[3] and for ease of exposition. In the mathematical discussion which follows, it is assumed that the prices of all inputs are independent. Under this assumption, the quantity of output, Q, the square feet of floor area provided, and the cost of output, C, may be expressed as:

$$Q = \tau_t \tau_s \left(\prod_{j=1}^{n} X^{\alpha}_j \right) \qquad\qquad\qquad A.1$$

$$C = \sum_{j=1}^{n} X_j P_j \qquad\qquad\qquad A.2$$

where

Q = total square feet of floor area to be provided;

τ_t = basic construction technology factor;

τ_s = basic construction scale factor;

X_j = quantity of the jth input (materials, labor, equipment) required to perform the job;

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[1] Eugene Silberberg, The Structure of Economics: A Mathematical Analysis, McGraw-Hill Publishing Company, New York, 1978.

[2] Gerald L. Musgrave and Robert H. Rasche, "Estimation of Cost Functions," The Engineering Economist, Vol. 22, No. 3, 1973.

[3] For an authoritative source on this subject see John S. McConnaughey, Production Functions in Contract Construction in the United States, 1972 (unpublished), Ph.D. dissertation, Michigan State University, 1976.

α_j = the percentage change in output associated with a one percent change in the utilization of the jth input;

C = the total cost (expected bid price) of the job; and

P_j = the unit cost of the jth input.

Note also that the summation sign, Σ, and the product sign, Π, are used in equations A.1 and A.2. They are defined as:

$$\sum_{j=1}^{n} X_j P_j = X_1 P_1 + X_2 P_2 + \ldots + X_n P_n$$

and

$$\prod_{j=1}^{n} X_j^{\alpha_j} = (X_1^{\alpha_1}) \ldots (X_n^{\alpha_n})$$

The constrained optimization problem may then be solved through application of the method of Lagrange multipliers.

Based on the constrained optimization problem referenced above, it is possible to assert that the cost minimizing demand curve for each input reduces to:

$$X_\ell^* = (Q^{1/R}) (\tau t \cdot \tau s)^{-1/R} \left(\prod_{\substack{j=1 \\ j \neq \ell}}^{n} (\alpha j / \alpha_\ell)^{-\alpha_j/R} (P_\ell / P_j)^{-\alpha_j/R} \right) \qquad \text{A.3}$$

where $R = \sum_{j=1}^{n} \alpha_j$; and

$\ell = 1, \ldots, n.$

The minimum cost solution for providing Q square feet of floor area is then determined by substituting equation A.3 into equation A.2. This substitution yields:

$$C^* = \sum_{j=1}^{n} X_j^* P_j$$

or equivalently:

$$C^* = (Q^{1/R}) (\tau t \cdot \tau s)^{-1/R} \left(\prod_{j=1}^{n} (P_j)^{-\alpha_j/R} \right)(R) \left(\prod_{j=1}^{n} (\alpha_j)^{-\alpha_j/R} \right) \qquad \text{A.4}$$

A closer examination of equation A.4 would reveal that it consists of three distinct factors. These factors are: (1) a technology factor; (2) a size factor; and (3) a market factor. The technology factor, TF, is defined by the underlying construction process. That is, certain basic construction techniques (technologies) interact with the structure type in defining an approach which is feasible in the engineering sense. The size factor, SF, may be derived from the size adjustment chart, where a factor line is used to define a cost relationship factor from a size relationship factor (see figure 2.1). The market factor reflects the influence that supply and demand conditions in the local construction market for key labor, material and equipment inputs have on the overall cost of the job. The market factor, MF, in equation A.4 is given as:

$$MF = (\prod_{j=1}^{n} (P_j)^{-\alpha_j/R}) (R) (\prod_{j=1}^{n} (\alpha_j)^{-\alpha_j/R})$$

Equation A.4 may thus be written as:

$$C^* = (TF) \times (SF) \times (MF) \qquad\qquad A.5$$

The concept of regional factoring may now be introduced through reference to equation A.5. Suppose a subscript which ties each cost function evaluation to a given locale is introduced. For example, the Washington, D.C. locale may be denoted by a "w" subscript. The "base city" cost function is thus given by C_w^*. It is then possible to construct an area cost factor for that city by regionally factoring the two cost functions. In the actual process of regional factoring, the Washington, D.C. cost function is used as a deflator. More succinctly, C_w^* is the denominator of the equation defining the area cost factor. The area cost factor for Chicago, ACF_c, may thus be defined as

$$ACF_c = C_c^*/C_w^*.$$

In general, for any arbitrary city, j, the area cost factor is defined as:

$$ACF_j = C_j^*/C_w^* . \qquad\qquad A.6$$

Expanding equation A.6 reveals that

$$ACF_j = [(TF_j) (SF_j) (MF_j)]/[(TF_w) (SF_w) (MF_w)]. \qquad\qquad A.7$$

Since area cost factors reflect the relative cost differential of erecting an identical structure in a different locale, the TF_j and TF_w terms of equation A.7 cancel. By the same token, holding design constant would imply that the size factor for Washington, D.C., SF_w, would cancel the size factor for Chicago, SF_c, or for any other city. Thus the area cost factor for each city, j, may be defined as:

$$ACF_j = MF_j/MF_w \qquad\qquad A.8$$

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Equation A.8 based on empirical estimates of A.4 (presented next) is the formula actually used in the computer program.

It is important to point out that the theoretical minimum cost curve (equation A.4) will not normally be observed in its entirety. The previous statement is based on the concepts of technical and allocative inefficiency. These two types of inefficiencies cause the contractor's costs to be above the envelope curve which defines the minimum construction cost subject to the technology constraints. This one-sided error process could cause serious empirical problems where it not for a second error process associated with random shocks both positive and negative (e.g., weather conditions, labor relations, material and equipment contracts, etc.) which overlays and dominates it. Since the discussion of productive efficiency serves to highlight some of the empirical issues, it will be developed in some detail. Those readers wishing a more comprehensive treatment of the theoretical and empirical issues associated with productive efficiency are referred to the articles by Farrell[1] and Aigner, Lovell and Schmidt.[2]

In order to make use of a graphical representation to illustrate the two types of productive inefficiency, a two factor constant returns to scale production function[3] will be utilized. Now if the production function for the "perfectly efficient firm" is known, by virtue of our constant returns to scale assumption we can make use of a single isoquant[4] (or equal output curve) to illustrate both types of inefficiency. The single isoquant in this case is I_1 and is shown on figure A.1 as a downward sloping curve. The two axes of figure A.1 reflect the total inputs of X_1 and X_2 divided by the total output Q. In figure A.1 the perfectly efficient firm faced with a given set of factor prices P_1 and P_2 would produce at point B where the cost curve is tangent to the isoquant I_1. Point B is therefore the minimum cost solution. Technical inefficiency (i.e., producing using the wrong quantities of inputs but with the right portions) is

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[1] M. J. Farrell, "The Measurement of Productive Efficiency," _Journal of the Royal Statistical Society_, Series A, Vol. 120, Part III, 1957.

[2] D. J. Aigner, C. A. K. Lovell and P. J. Schmidt, "Formulation and Estimation of Stochastic Frontier Production Function Models," _Journal of Econometrics_, Vol. 6, No. 4, 1977.

[3] A constant returns to scale production function is one in which if all outputs are increased/decreased proportionally the output is increased/decreased by the same proportion. For example, doubling all inputs would double the output.

[4] An isoquant is a curve giving all the technically feasible ways of providing a given level of output. For a constant returns to scale production function all isoquants are just radial blow ups of the unit isoquant. More precisely, since $Q = f(X_1, X_2)$ is the production function, for a given output Q we can write the unit isoquant as

$$1 = f(X_1/Q, X_2/Q).$$

Figure A.1. Graphical Representation of Technical and Allocative
Inefficiency in Producing a Given Level of Output

X₂
Q

X₁ /Q
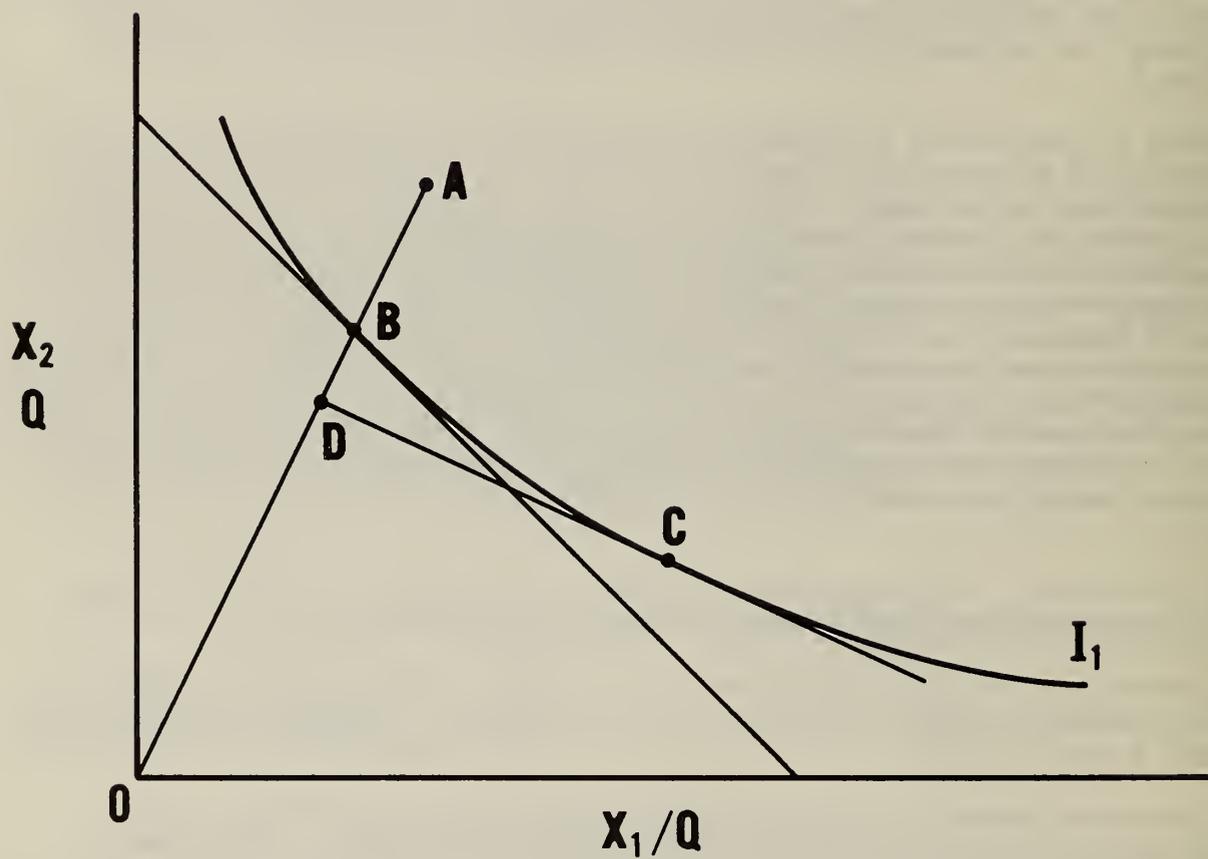
Source: J. M. Farrell, op. cit., p. 254.

measured by the difference between one and the ratio of the inputs required to those actually used. An example of technical ineffiicnecy would be a firm producing a total output of Q at point A.[1] In this case the technical efficiency is defined as OB/OA; thus the measure of technical inefficiency is 1-OB/OA. The measurement of allocative inefficiency (i.e., producing using inputs in the wrong proportions but using quantities that are technically correct) is less straight forward. An example of allocative inefficiency would be a firm producing at C when the factor prices would indicate that production at B was most efficient. If one constructs a tangent from point C to the ray OB and denotes the point of intersection as D, then allocative inefficiency is given as 1-OD/OB. Total inefficiency may then be defined either as the sum of technical and allocative inefficiency or, as Farrel does it, by 1-OD/OA. Regardless of which definition is adopted, the total cost of production is higher due to inefficiency. Since firms may not be flexible enough to always use the right quantities (technical efficiency) or right proportions (allocative efficiency) observed cost will lie above the envelope curve defined by the theoretical minimum cost curve.

As pointed out earlier, this argument does not address the issue of random shocks which act as a countervailing mechanism. Thus one can explicitly recognize the constraints placed on the estimation of the relevant cost functions but safely assert that these "theoretical" constraints are subsumed in a second random process. This permits the estimation of the relevant cost functions to be carried out in a straight-forward manner using ordinary least squares. Several introductory econometrics texts contain excellent descriptions of the technique and its properties[2,3] for the reader who wishes greater detail. In applying the technique to the data analyzed in this study, it was necessary to impose two restrictions in order to obtain consistent estimates. First, the theoretical formulations of the cost functions had to be superimposed as constraints on the empirical formulations actually estimated. Second, to insure that all data were internally consistent, some data used in the estimation had to be scaled to avoid any problems with dimensionality.

Two cost functions are actually used in the program, one for category codes 74023, 21105, 51010, 44110, 72111, and 72411, and one for all other category codes. The first cost function is referred to as the "SET 1" category code cost function. This cost function is given as:

$$\ln C_1(J) = 0.36754*STAWR(J) + 0.211603*STSSP(J) + 0.239606*STCP(J) \qquad \text{A.9}$$

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[1] Note that point A lies on the ray from the origin passing through point B. This is why it was claimed that the firm used the right proportions, since any point of the ray represents the same proportions of X_1 and X_2 as at point B.

[2] J. Johnston, Econometric Methods, McGraw-Hill Publishing Company, New York, 1972.

[3] A. Kontsoyiannis, Theory of Econometrics: An Introductory Exposition of Econometric Methods, Barnes and Noble, New York, 1977.

where $\ln C_1(J)$ = the natural logarithm of the minimum total cost solution for the jth city;

STAWR(J) = the natural logairthm of the average wage rate index;

STSSP(J) = the natural logarithm of the cost per ton of structural steel;

STCP(J) = the natural logarithm of the cost per cubic yard of ready mix concrete.

The second cost function is referred to as the "SET 2" category code cost function. This cost function is given as:

$$\ln C_2(J) = 0.212421*STAWR(J) + 0.0522205*STWP(J) + 0.0861036*STSSP(J)$$
$$+ 0.238871*STCBP(J) + 0.0383134*STCP(J) \qquad\qquad A.10$$

where $\ln C_2(J)$ = the natural logarith of the minimum total cost solution;

STWP(J) = the natural logarithm of the cost of lumber; and

STCBP(J) = the natural logarithm of the cost per thousand common brick.

An unweighted area cost factor is then computed for each set, where

$$ACF_1(J) = C_1(J)/C_1(1)$$

and

$$ACF_2(J) = C_2(J)/C_2(1)$$

The project weighted area cost factor, ACF(J), is then computed to reflect the relative frequency with which structures within the two sets of category codes occur. The project weighted area cost factor is given as

$$ACF(J) = 0.26ACF_1(J) + 0.74ACF_2(J). \qquad\qquad A.11$$

SAMPLE COMPUTER RUN

In section 2.2, background information was given that identified the inputs required to use the computerized procedure and provided an example of what a typical output would look like. The purpose of this appendix is to expand on that example and illustrate, in some detail, how the procedure would be applied in practice. More specifically, this appendix includes a sample computer run designed to show how data from major metropolitan areas can be used to estimate area cost factors if information from individual military installations were not available. This example is based on the set of military construction projects examined in the econometric analysis used to estimate cost functions for this study.

The first step in this or in any future exercise in actually assigning input prices to each of the installations/projects is to construct a list of cities for which at least some information is available. The R.S. Means Building Construction Cost Data guide reports material price indices for 30 cities.[1] This list of cities is displayed in table B.1 along with the identification number (CITY(J)) for each city. Table B.2 provides a listing of 145 cities for which input data are available. It is important to point out that for future projects, cost data from additional cities might be available.

The second step is to assign one of the cities listed in table B.1 to each of the cities listed in table B.2, the complete list of cities for which area cost factors are sought. This is necessary because the R.S. Means guide reports material price figures for only 30 cities. Those cities without direct material price data are assigned the data of the nearest city (geographically) listed in table B.1. The identification number (CITY(J)) of the city from which material price figures are taken appears in parentheses following the city name in table B.2.

The third step is to assign one of the cities in table B.2 to each of the installations/projects. Such a procedure guarantees that the assignment of input prices will be the best possible for material prices, at least for some time period, and will be as geographically accurate as possible. In assigning cities to installations/projects, two rules should be followed. First, if an installation/project is in a city given in table B.2 that city should be assigned to the installation/project. Second, if an installation/project is in a city not given in table B.2, the city geographically closest to the installation/project should be assigned to it. In the rare case where two or more cities in table B.2 are equidistant from an installation/project, the city in or nearest the state in which the installation/project is located should be assigned to it. The actual city assignments for the installations from the

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[1] Building Construction Cost Data: 1980, R.S. Means Company, Inc., Kingston, Mass., 1979. Another widely used guide that can be recommended for this exercise is McGraw-Hill's 1980 Dodge Manual for Building Construction Pricing and Scheduling, McGraw-Hill Information Systems, Inc., New York, 1979.

military construction projects analyzed in the econometric study are given in table B.3.

The remainder of this appendix will make use of data from the R.S. Means guide in putting together a sample input deck to calculate the desired area cost factors. It is important to point out that the read and format statements given in table 2.5 and defined on lines 24 through 27 of the computer program (see appendix C), must be carefully followed. If the format given in table 2.5 is used, the data from the 145 cities listed in table B.2 would appear (both on punched cards and as a data input printback) as shown in exhibit B.1. Recall from Chapter 2 that exhibit B.1 is a printback of all the data input. The purpose of this printback is to assist users in finding any obvious errors, such as negative costs,[1] as well as those which are less easily checked when the user verifies the punched cards.

As discussed in Chapter 2, the program computes a wage index for each installation/project. These indices are in turn used in the cost function for that installation/project as a surrogate for labor costs. Since the data actually input are wage rates[2], it was felt advisable to printout the calculated values of the wage index. In this way, the user can compare the wage indices with each other to determine if they appear to be in the right "ball park." A sample set of wage indices, based on the data shown in exhibit B.1, are given in exhibit B.2. Note that these indices include wide swings, as much as 100 percent in some cases, so that some care should be exercised in verification.

The final set of outputs are the area cost factors. These estimates are given in exhibit B.3. Column 1 of exhibit B.3 contains the installation/project ID number. It is important to point out that the base city always appears on the first line of output. In this case, the base city is Washington, D.C. The numbers in column 1 may then be cross referenced to table B.2 to determine the identity of the city. The installation(s)/project(s) assigned to that city may then be cross tabulated through reference to table B.3. A sample cross tabulation for each installation identified in table B.3 is shown in table B.4. The estimated area cost factor for each installation is also shown in table B.4.

As discussed in section 2.2.2, the area cost factor estimates presented in exhibit B.3, once paired with the installation/project, are ready for use in determining the adjusted cost per unit for the primary facility (see equation 2.9 in section 2.2.2) and/or the adjusted cost per unit for the support facility.

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[1] In the event that a non-positive wage rate or material cost is inadvertently entered on a data card, the printback is designed to double space before and after that line to highlight the mistake. A non-positive wage rate on material price will also cause the program to terminate immediately after the input data have been reproduced. An example in which this safeguard is used is shown in table 2.4 of section 2.2.2.

[2] As indicated in table 2.1, the wage rates are in the form of billing rate per hour for 10 labor skills. Direct billing rate per hour figures applicable to cities/installations for which the reader requires area cost factors may not be readily available. The billing rates listed in exhibit B.1 are approximations based on calculations done on data taken from two publications of the R.S. Means Company: 1980 Labor Rates for the Construction Industry and Building Construction Cost Data: 1980. The total wage rate (base wage rate plus fringe benefit package) for each of the ten labor skills is taken from Means' Labor Rates. The total hourly wage for a particular skill added to total subcontractor overhead and profit (expressed as a percentage of the total hourly wage) equals the billing rate for that labor skill. Subcontractors' average percentage mark-ups are listed in Means' Cost Data. The average overhead and profit percentages applicable to the 10 labor skills are: 40.7 percent for common building laborers, 38.6 percent for bricklayers, 38.6 percent for carpenters, 37.3 percent for cement masons (finishers), 40.6 percent for electricians, 43.7 percent for operating engineers (light equipment operators), 38.5 percent for painters (ordinary) 41.3 percent for plumbers, 42.6 percent for sheet metal workers, and 55.8 percent for structural steel workers. The average percentage for a particular skill is multiplied by the corresponding total wage rate for a given city. The resulting product is then added to the total wage rate. This sum is rounded to the nearest five cents to arrive at the approximate billing rate applicable to a particular skill and city.

Table B.1

Thirty Cities for Which Material Price Data are Reported and Their
Corresponding CITY Numbers

1	Washington, D.C.
7	Phoenix
13	Los Angeles
17	San Diego
18	San Francisco
22	Denver
32	Atlanta
38	Chicago
45	Indianapolis
53	New Orleans
56	Baltimore
57	Boston
62	Detroit
69	Minneapolis
71	Kansas City
72	St. Louis
86	Buffalo
87	New York City
98	Cincinnati
99	Cleveland
100	Columbus
111	Philadelphia
112	Pittsburgh
122	Memphis
123	Nashville
128	Dallas
131	Houston
132	San Antonio
138	Seattle
144	Milwaukee

Major Cities and Their Corresponding CITY Numbers

District of Columbia

1   Washington (1)[1]

Alabama

2   Birmingham (32)
3   Huntsville (123)
4   Mobile (53)
5   Montgomery (32)

Alaska

6   Anchorage (138)

Arizona

7   Phoenix (7)
8   Tucson (7)

Arkansas

9   Little Rock (122)

California

10   Anaheim (13)
11   Bakersfield (13)
12   Fresno (18)
13   Los Angeles (13)
14   Oxnard (13)
15   Riverside (13)
16   Sacramento (18)
17   San Diego (17)
18   San Francisco (18)
19   Santa Barbara (13)
20   Stockton (18)
21   Vallejo (18)

Colorado

22   Denver (220

Connecticut

23   Bridgeport (87)
24   Hartford (57)
25   New Haven (87)

Delaware

26   Wilmington (111)

Florida

27   Ft. Lauderdale (32)
28   Jacksonville (32)
29   Miami (32)
30   Orlando (32)
31   Tampa (32)

Georgia

32   Atlanta (32)
33   Columbus (32)
34   Macon (32)
35   Savannah (32)

Hawaii

36   Honolulu (13)

Idaho

37   Boise (138)

Illinois

38   Chicago (38)
39   Peoria (38)
40   Rockford (38)
41   Springfield (72)

Indiana

42   Evansville (45)
43   Ft. Wayne (45)
44   Gary/Hammond (38)
45   Indianapolis (45)
46   South Bend (38)

Iowa

47   Des Moines (71)

Kansas

48   Topeka (71)
49   Wichita (71)

Kentucky

50   Lexington (98)
51   Louisville (98)

Louisiana

52   Baton Rouge (53)
53   New Orleans (53)
54   Shreveport (128)

Maine

55   Portland (57)

Maryland

56   Baltimore (56)

Massachusetts

57   Boston (57)
58   Lawrence (57)
59   Springfield (57)
60   Worcester (57)

Michigan

61   Ann Arbor (62)
62   Detroit (62)
63   Flint (62)
64   Grand Rapids (62)
65   Kalamazoo (62)
66   Lansing (62)
67   Saginaw (62)

Minnesota

68   Duluth (69)
69   Minneapolis (69)

Mississippi

70   Jackson (53)

Missouri

71   Kansas City (71)
72   St. Louis (72)

Montana

73   Billings (22)

Nebraska

74   Omaha (71)

Nevada

75   Las Vegas (13)
76   Reno (18)

New Hampshire

77   Manchester (57)

New Jersey

78   Camden (111)
79   Jersey City (87)
80   Newark (87)
81   Paterson (87)
82   Trenton (111)

New Mexico

83   Albuquerque (22)

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[1] The number in parentheses indicates the identification number (CITY(J)) of the nearest city for which material price data are reported. Cities are assigned material price data from one of the thirty cities reporting such information (see table A.1).

New York

84 Albany (87)
85 Binghampton (87)
86 Buffalo (86)
87 New York (87)
88 Rochester (86)
89 Syracuse (86)
90 Utica (87)
91 Yonkers (870

North Carolina

92 Charlotte (32)
93 Greensboro (1)
94 Raleigh (1)

North Dakota

95 Bismarck (69)

Ohio

96 Akron (99)
97 Canton (99)
98 Cincinnati (98)
99 Cleveland (99)
100 Columbus (100)
101 Dayton (98)
102 Lorain (99)
103 Toledo (62)
104 Youngstown (99)

Oklahoma

105 Oklahoma City (128)
106 Tulsa (71)

Oregon

107 Portland (138)

Pennsylvania

108 Allentown (111)
109 Erie (86)
110 Harrisburg (56)
111 Philadelphia (11)
112 Pittsburgh (112)
113 Reading (111)
114 Scranton (111)

Rhode Island

115 Providence (57)

South Carolina

116 Charleston (32)
117 Columbia (32)

South Dakota

118 Rapid City (22)
119 Sioux Falls (69)

Tennessee

120 Chattanooga (32)
121 Knoxville (123)
122 Memphis (122)
123 Nashville (123)

Texas

124 Amarillo (128)
125 Austin (132)
126 Beaumont (131)
127 Corpus Christi (132)
128 Dallas (128)
129 El Paso (7)
130 Ft. Worth (128)
131 Houston (131)
132 San Antonio (132)

Utah

133 Salt Lake City (22)

Vermont

134 Burlington (57)

Virginia

135 Newport News (1)
136 Norfolk (1)
137 Richmond (1)

Washington

138 Seattle (138)
139 Spokane (138)
140 Tacoma (138)

West Virginia

141 Charleston (100)
142 Huntington (100)

Wisconsin

143 Madison (144)
144 Milwaukee (144)

Wyoming

145 Cheyenne (22)

Assignment of Military Bases to Cities

State/Base	City Assignment
Alabama	
Craig AFB Selma	5 - Montgomery
Ft. McClellan	2 - Birmingham
Ft. Rucker	5 - Montgomery
Jasper	2 - Birmingham
Maxwell AFB	5 - Montgomery
Alaska	
Adak	6 - Anchorage
Eielson AFB	6 - Anchorage
Elmendorf AFB	6 - Anchorage
Ft. Wainwright	6 - Anchorage
Kokiak Tracking Station	6 - Anchorage
Shemya AFB	6 - Anchorage
Arizona	
Ft. Huachucha	8 - Tucson
Luke AFB	7 - Phoenix
Williams AFB	7 - Phoenix
Yuma Proving Ground	7 - Phoenix
Arkansas	
Blytheville AFB	122 - Memphis
Jonesboro	122 - Memphis
Pine Bluff Arsenal	9 - Little Rock
USARC Little Rock	9 - Little Rock
California	
March AFB	15 - Riverside
Beale AFB	16 - Sacramento
Camp Pendleton (MCR)	17 - San Diego
Coronado	17 - San Diego
Edwards AFB	12 - Fresno
El Toro (MCAS Santa Ana)	10 - Anaheim
Ft. Ord	18 - San Francisco
Fresno	12 - Fresno
George AFB	10 - Anaheim
Hunter-Liggett Military Res	12 - Fresno
Letterman GH San Francisco	18 - San Francisco
Mather AFB	16 - Sacramento
McClellan AFB	16 - Sacramento
MCSC Barstow	11 - Bakersfield
Miramar San Diego	17 - San Diego
NAS Elcentro	17 - San Diego
NAS Imperial Beach	17 - San Diego
NAS Lemoore	12 - Fresno
NAS Moffett Field	18 - San Francisco
NAS North Is. San Diego	17 - San Diego
Nav Hosp Oakland	18 - San Francisco
Navschcmd Mare Is. Vallejo	21 - Vallejo
NMC Res Ctr San Bruno	18 - San Francisco

Table B.3 (continued)

State/Base	City Assignment
California (continued)	
NS Long Beach	13 – Los Angeles
Norton AFB	15 – Riverside
NS San Diego	17 – San Diego
NWC China Lake	11 – Bakersfield
NWS Seal Beach	10 – Anaheim
Oakland Ca. Army Base	18 – San Francisco
Presidio of Monterey	18 – San Francisco
San Diego	17 – San Diego
San Onofre (Camp Pendleton)	17 – San Diego
Seal Beach	13 – Los Angeles
Sierra Army Depot	16 – Sacremento
Vandenburg AFB	19 – Santa Barbara
Colorado	
Air Force Academy	22 – Denver
Air National Guard Denver	22 – Denver
Buckley ANG Base Denver	22 – Denver
Ft. Carson Colorado Springs	22 – Denver
Lowry AFB	22 – Denver
NORAD Colorado Springs	22 – Denver
Peterson Field AFB	22 – Denver
Connecticut	
NSMC New London Groton	24 – Hartford
Delaware	
Dover AFB	26 – Wilmington
District of Columbia	
Walter Reed Hospital	1 – Washington
Florida	
Cape Canaveral	30 – Orlando
Corry Field Pensacola	4 – Mobile
Elgin AFB Ft Walton Beach	4 – Mobile
Elgin AFB Valparaiso	4 – Mobile
Homestead AFB	29 – Miami
Mayport	28 – Jacksonville
MacDill AFB	31 – Tampa
NAS Jacksonville	28 – Jacksonville
NAS Pensacola	4 – Mobile
NAS Whiting Field	4 – Mobile
NRMA Jacksonville	28 – Jacksonville
NS Mayfort	28 – Jacksonville
NTC Orlando	30 – Orlando
Orlando	30 – Orlando
Panama City	4 – Mobile
Patrick AFB Melbourne	30 – Orlando
Tyndall AFB Panama City	4 – Mobile

Table B.3 (continued)

State/Base	City Assignment
Georgia	
Atlanta Army Depot	32 – Atlanta
Dobbins AFB	32 – Atlanta
Ft. Benning	33 – Columbus
Ft. Gordon	34 – Macon
Ft. Stewart	35 – Savannah
Glynco	28 – Jacksonville
McCollum Kennesaw	32 – Atlanta
Moody AFB	35 – Savannah
NAS Marietta	32 – Atlanta
Robins AFB	34 – Macon
Hawaii	
Barbers Pt Oahu (NAS)	36 – Honolulu
Barking Sands	36 – Honolulu
Hickam AFB Oahu	36 – Honolulu
Kaneohe Bay Oahu	36 – Honolulu
Pearl Harbor	36 – Honolulu
Schofield Barracks	36 – Honolulu
Idaho	
Coeur D Alene	139 – Spokane
Mountain Home AFB	37 – Boise
Illinois	
Capital Map ANG Springfield	41 – Springfield
Chanute AFB	39 – Peoria
Glenview	38 – Chicago
Scott AFB Belleville	72 – St. Louis
Indiana	
Ft. Ben Harrison Indianapolis	45 – Indianapolis
Kansas	
Ft. Riley Junction City	48 – Topeka
McConnell AFB	49 – Wichita
Kentucky	
Ft. Campbell Clarksville	123 – Nashville
Ft. Knox	51 – Louisville
Lexington	50 – Lexington
Louisiana	
Barksdale AFB	54 – Shreveport
England AFB	54 – Shreveport
Ft. Polk	54 – Shreveport
NAS New Orleans	53 – New Orleans
New Orleans	53 – New Orleans
USARC Monroe	54 – Shreveport

State/Base	City Assignment
Maryland	
Bethesda	1 - Washington
Ft. George Meade	56 - Baltimore
Massachusetts	
Ft. Devens Ayer	60 - Worcester
Westover AFB Chicofee Falls	59 - Springfield
Michigan	
Kincheloe AFB	62 - Detroit
Mississippi	
Columbus AFB	2 - Birmingham
Gulfport	4 - Mobile
Keesler AFB Biloxi	4 - Mobile
Meridian	70 - Jackson
Missouri	
Ft. Leonard Wood	72 - St. Louis
Lambert Fld St. Louis	72 - St. Louis
Whiteman AFB	71 - Kansas City
Montana	
Malmstrom AFB	73 - Billings
Nebraska	
Offutt AFB Omaha	74 - Omaha
Nevada	
Nellis AFB	75 - Las Vegas
New Hampshire	
Pease AFB	77 - Manchester
New Jersey	
Ft. Dix	82 - Trenton
Ft. Monmouth	82 - Trenton
McGuire AFB Wrightstown	82 - Trenton
New Mexico	
Cannon AFB	83 - Albuquerque
Holloman AFB	83 - Albuquerque
Kirtland AFB	83 - Albuquerque
New York	
USMA West Point	87 - New York

State/Base	City Assignment
North Carolina	
Auxiliary Landing Field	94 – Raleigh
Cherry Point	94 – Raleigh
Ft. Bragg	94 – Raleigh
MCB Camp Lejeune	94 – Raleigh
New River	94 – Raleigh
Pope AFB (Ft Bragg)	94 – Raleigh
Seymour Johnson AFB	94 – Raleigh
Winston-Salem	93 – Greensboro
North Dakota	
Hector Fld ANGB Fargo	68 – Duluth
Minot AFB	68 – Duluth
Ohio	
Wright Patterson AFB	101 – Dayton
Oklahoma	
AFRC Okla City	105 – Oklahoma City
Attus AFB	105 – Oklahoma City
Ft. Sill	105 – Oklahoma City
Tinker AFB	105 – Oklahoma City
Vance AFB Enid	105 – Oklahoma City
Oregon	
NMC Portland	107 – Portland
Pennsylvania	
Pittsburgh Int Aprt	112 – Pittsburgh
South Carolina	
Charleston AFB	116 – Charleston
Ft. Jackson	117 – Columbia
MCAS Beaufort	116 – Charleston
MCRD Parris Island	116 – Charleston
Shaw AFB	117 – Columbia
South Dakota	
Ellsworth Rapid City	118 – Rapid City
Tennessee	
Army Res Ctr Chattanooga	120 – Chattanooga
NAS Memphis Millington	122 – Memphis
Nav Hosp Memphis	122 – Memphis
Texas	
Bergstrom AFB Austin	125 – Austin
Brooks AFB San Antonio	132 – San Antonio
Corpus Christi (NAS)	127 – Corpus Christi

State/Base	City Assignment
Texas (continued)	
Dallas (NAS)	128 – Dallas
Ellington AFB Houston	131 – Houston
Ft. Bliss El Paso	129 – El Paso
Ft. Hood	125 – Austin
Ft. Sam Houston	132 – San Antonio
Goodfellow AFB	125 – Austin
Kelly AFB	132 – San Antonio
Lackland AFB San Antonio	132 – San Antonio
Laredo AFB	127 – Corpus Christi
Laughlin AFB Del Rio	132 – San Antonio
NAS Kingsville	127 – Corpus Christi
Perrin AFB Sherman	128 – Dallas
Randolph AFB San Antonio	132 – San Antonio
Reese AFB Lubbock	124 – Amarillo
Sheppard AFB Wichita Falls	128 – Dallas
Webb AFB Big Spring	132 – San Antonio
Utah	
Hill AFB	133 – Salt Lake City
NMCC Salt Lake City	133 – Salt Lake City
Virginia	
Air Nat Guard Henrico	137 – Richmond
Amphib Base Little Creek	136 – Norfolk
Ft. Belvoir	1 – Washington
Ft. Eustis	135 – Newport News
Ft. Lee	137 – Richmond
Ft. Myer	1 – Washington
Langley AFB Hampton	135 – Newport News
NMCRTC Richmond	137 – Richmond
Norfolk	136 – Norfolk
NS Norfolk	136 – Norfolk
NS Portsmouth	136 – Norfolk
NW Chesapeake	136 – Norfolk
NWS Yorktown	135 – Newport News
Roanoke	93 – Greensboro
Washington	
Ft. Lewis	140 – Tacoma
McChord AFB	140 – Tacoma
NAS Whidbey	138 – Seattle
NTS Bangor Annex	138 – Seattle
Trentwood	139 – Spokane
Yakima	140 – Tacoma

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<center>Table B.3 (continued)</center>

State/Base	City Assignment
Wisconsin	
Mitchell Field Milwaukee	144 - Milwaukee
Wyoming	
Warren AFB Cheyenne	145 - Cheyenne

Table B.4 Estimates of Area Cost Factors for Selected Military Bases

State/Base	AREA COST FACTOR
Alabama	
Craig AFB Selma	.89
Ft. McClellan	.90
Ft. Rucker	.89
Jasper	.90
Maxwell AFB	.89
Alaska	
Adak	1.84
Eielson AFB	1.84
Elmendorf AFB	1.84
Ft. Wainwright	1.84
Kodiak Tracking Station	1.84
Shemya AFB	1.84
Arizona	
Ft. Huachucha	1.00
Luke AFB	1.00
Williams AFB	1.00
Yuma Proving Ground	1.00
Arkansas	
Blytheville AFB	.92
Jonesboro	.92
Pine Bluff Arsenal	.90
USARC Little Rock	.90
California	
March AFB	1.05
Beale AFB	1.17
Camp Pendleton (MCR)	1.07
Coronado	1.07
Edwards AFB	1.16
El Toro (MCAS Santa Ana)	1.05
Ft. Ord	1.18
Fresno	1.16
George AFB	1.05
Hunter-Liggett Military Res	1.16
Letterman GH San Francisco	1.18
Mather AFB	1.17
McClellan AFB	1.17
MCSC Barstow	1.05
Miramar San Diego	1.07
NAS Elcentro	1.07
NAS Imperial Beach	1.07
NAS Lemoore	1.16
NAS Moffett Field	1.18
NAS North Is. San Diego	1.07
Nav Hosp Oakland	1.18
Navschcmd Mare Is. Vallejo	1.17
NMC Res Ctr San Bruno	1.18

State/Base	AREA COST FACTOR
California (continued)	
NS Long Beach	1.05
Norton AFB	1.05
NS San Diego	1.07
NWC China Lake	1.05
NWS Seal Beach	1.05
Oakland Ca. Army Base	1.18
Presidio of Monterey	1.18
San Diego	1.07
San Onofre (Camp Pendleton)	1.07
Seal Beach	1.05
Sierra Army Depot	1.17
Vandenburg AFB	1.05
Colorado	
Air Force Academy	0.97
Air National Guard Denver	0.97
Buckley ANG Base Denver	0.97
Ft. Carson Colorado Springs	0.97
Lowry AFB	0.97
NORAD Colorado Springs	0.97
Peterson Field AFB	0.97
Connecticut	
NSMC New London Groton	1.06
Delaware	
Dover AFB	.96
District of Columbia	
Walter Reed Hospital	1.00
Florida	
Cape Canaveral	.89
Corry Field Pensacola	.97
Elgin AFB Ft. Walton Beach	.97
Elgin AFB Valparaiso	.97
Homestead AFB	.90
Mayport	.88
MacDill AFB	.90
NAS Jacksonville	.88
NAS Pensacola	.97
NAS Whiting Field	.97
NRMA Jacksonville	.88
NS Mayfort	.88
NTC Orlando	.89
Orlando	.89
Panama City	.97
Patrick AFB Melbourne	.89
Tyndall AFB Panama City	.97

State/Base	AREA COST FACTOR
Georgia	
Atlanta Army Depot	.90
Dobbins AFB	.90
Ft. Benning	.86
Ft. Gordon	.86
Ft. Stewart	.87
Glynco	.88
McCollum Kennesaw	.90
Moody AFB	.87
NAS Marietta	.90
Robins AFB	.86
Hawaii	
Barbers Pt Oahu (NAS)	1.52
Barking Sands	1.52
Hickam AFB Oahu	1.52
Kaneohe Bay Oahu	1.52
Pearl Harbor	1.52
Schofield Barracks	1.52
Idaho	
Coeur D Alene	1.09
Mountain Home AFB	1.06
Illinois	
Capital Map ANG Springfield	.96
Chanute AFB	1.06
Glenview	1.08
Scott AFB Belleville	.97
Indiana	
Ft. Ben Harrison Indianapolis	.98
Kansas	
Ft. Riley Junction City	1.03
McConnell AFB	1.01
Kentucky	
Ft. Campbell Clarksville	.93
Ft. Knox	.98
Lexington	.97
Louisiana	
Barksdale AFB	.98
England AFB	.98
Ft. Polk	.98
NAS New Orleans	.98
New Orleans	.98
USARC Monroe	.98

Table B.4 (continued)

State/Base	AREA COST FACTOR
Maryland	
Bethesda	1.00
Ft. George Meade	.93
Massachusetts	
Ft. Devens Ayer	1.06
Westover AFB Chicofee Falls	1.05
Michigan	
Kincheloe AFB	1.14
Mississippi	
Columbus AFB	.90
Gulfport	.97
Keesler AFB Biloxi	.97
Meridian	.95
Missouri	
Ft. Leonard Wood	.97
Lambert Fld St. Louis	.97
Whiteman AFB	1.06
Montana	
Malmstron AFB	.96
Nebraska	
Offutt AFB Omaha	1.04
Nevada	
Nellis AFB	1.03
New Hampshire	
Pease AFB	1.02
New Jersey	
Ft. Dix	.97
Ft. Monmouth	.97
McGuire AFB Wrightstown	.97
New Mexico	
Cannon AFB	.97
Holloman AFB	.97
Kirtland AFB	.97
New York	
USMA West Point	1.07

State/Base	AREA COST FACTOR
North Carolina	
Auxiliary Landing Field	.93
Cherry Point	.93
Ft. Bragg	.93
MCB Camp Lejeune	.93
New River	.93
Pope AFB (Ft. Bragg)	.93
Seymour Johnson AFB	.93
Winston-Salem	.93
North Dakota	
Hector Fld ANGB Fargo	.99
Minot AFB	.99
Ohio	
Wright Patterson AFB	.99
Oklahoma	
AFRC Okla City	.99
Attus AFB	.99
Ft. Sill	.99
Tinker AFB	.99
Vance AFB Enid	.99
Oregon	
NMC Portland	1.11
Pennsylvania	
Pittsburgh Int Aprt	1.02
South Carolina	
Charleston AFB	.84
Ft. Jackson	.85
MCAS Beaufort	.84
MCRD Parris Island	.84
Shaw AFB	.85
South Dakota	
Ellsworth Rapid City	.93
Tennessee	
Army Res Ctr Chattanooga	.89
NAS Memphis Millington	.92
Nav Hosp Memphis	.92
Texas	
Bergstrom AFB Austin	.91
Brooks AFB San Antonio	.91
Corpus Christi (NAS)	.88

State/Base	AREA COST FACTOR
Texas (continued)	
Dallas (NAS)	.98
Ellington AFB Houston	.97
Ft. Bliss El Paso	.90
Ft. Hood	.91
Ft. Sam Houston	.91
Goodfellow AFB	.91
Kelly AFB	.91
Lackland AFB San Antonio	.91
Laredo AFB	.88
Laughlin AFB Del Rio	.91
NAS Kingsville	.88
Perrin AFB Sherman	.98
Randolph AFB San Antonio	.91
Reese AFB Lubbock	.97
Sheppard AFB Wichita Falls	.98
Webb AFB Big Spring	.91
Utah	
Hill AFB	.97
NMCC Salt Lake City	.97
Virginia	
Air Nat Guard Henrico	.95
Amphib Base Little Creek	.94
Ft. Belvoir	1.00
Ft. Eustis	.94
Ft. Lee	.95
Ft. Myer	1.00
Langley AFB Hampton	.94
NMCRTC Richmond	.95
Norfolk	.94
NS Norfolk	.94
NS Portsmouth	.94
NW Chesapeake	.94
NWS Yorktown	.94
Roanoke	.93
Washington	
Ft. Lewis	1.10
McChord AFB	1.10
NAS Whidbey	1.11
NTS Bangor Annex	1.11
Trentwood	1.09
Yakima	1.10

State/Base	AREA COST FACTOR
Wisconsin	
Mitchell Field Milwaukee	1.03
Wyoming	
Warren AFB Cheyenne	.96

Exhibit B.1

Input Stream for the Sample
Computer Run

```
 14.45  20.15  17.70  17.75  20.70  17.65  18.95  21.20  20.85  21.25      1
400.00 800.00 130.00  30.00   0       1
 11.40  17.00  15.75  14.20  19.40  15.65  16.00  20.55  19.45  20.45      2
288.00 700.00  91.00  34.75   0       2
  9.15  15.25  14.00  14.05  19.10  16.60  14.95  18.15  19.45  18.80      3
325.00 875.00 100.00  35.00   0       3
 10.40  16.45  15.15  14.70  20.65  15.00  15.80  19.00  18.55  17.65      4
300.00 750.00 120.00  43.00   0       4
  9.20  15.95  15.60  14.85  16.40  15.65  11.90  18.85  19.45  20.45      5
288.00 700.00  91.00  34.75   0       5
 26.85  30.10  28.70  27.70  36.20  29.25  31.25  32.50  32.40  36.75      6
380.00 700.00 168.00  39.90   1       6
 15.75  20.20  18.90  18.55  26.70  20.80  17.75  23.80  25.10  27.00      7
325.00 700.00 110.00  39.00   0       7
 15.75  20.20  18.90  18.55  24.30  20.80  16.25  23.80  19.90  27.00      8
325.00 700.00 110.00  39.00   0       8
 11.00  15.60  15.15  14.30  18.20  15.10  13.10  19.25  19.10  18.80      9
320.00 700.00  97.00  35.00   0       9
 19.50  24.15  22.85  22.55  26.90  24.90  23.50  27.55  27.20  29.15     10
300.00 790.00 108.00  40.10   0      10
 19.50  25.60  22.85  22.55  27.00  24.90  18.65  26.85  25.15  29.15     11
300.00 790.00 108.00  40.10   0      11
 21.00  23.90  25.50  23.60  24.90  26.85  19.65  27.20  23.85  29.15     12
310.00 735.00 180.00  46.30   0      12
 19.50  23.45  22.85  22.40  27.45  24.90  22.10  27.55  26.45  29.15     13
300.00 790.00 108.00  40.10   0      13
 19.50  23.75  22.85  22.55  27.55  24.90  23.05  27.55  25.75  29.15     14
300.00 790.00 108.00  40.10   0      14
 19.50  23.15  22.85  22.55  26.75  24.90  22.30  27.55  24.15  29.15     15
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300.00 790.00 108.00 40.10   0    15
 21.00 25.35 25.50 23.60 29.30 26.85 25.35 28.50 27.40 29.15   16
310.00 735.00 180.00 46.30   0    16
 19.50 23.35 21.90 21.40 25.95 25.00 22.30 27.55 26.00 29.15   17
310.00 715.00 130.00 41.00   0    17
 21.00 25.80 25.55 23.60 30.90 26.85 22.65 33.20 27.25 29.15   18
310.00 735.00 180.00 46.30   0    18
 19.50 23.65 22.85 22.55 27.75 24.90 21.85 27.55 27.75 29.15   19
300.00 790.00 108.00 40.10   0    19
 21.00 23.90 25.50 23.60 28.10 26.85 23.10 27.20 25.20 29.15   20
310.00 735.00 180.00 46.30   0    20
 21.00 25.80 25.50 23.60 28.15 26.85 25.35 29.40 26.35 29.15   21
310.00 735.00 180.00 46.30   0    21
 13.50 18.90 18.60 18.20 21.80 17.80 19.50 21.55 21.95 21.65   22
345.00 815.00  95.00 39.85   0    22
 14.05 17.10 17.00 16.95 20.30 19.15 15.25 18.65 22.40 24.10   23
340.00 700.00 130.00 44.15   0    23
 14.05 17.65 17.20 16.60 22.15 19.15 17.95 22.40 19.60 24.10   24
265.00 750.00 181.00 38.25   0    24
 14.05 17.40 17.10 17.25 19.95 19.10 15.05 20.15 19.60 24.10   25
340.00 700.00 130.00 44.15   0    25
 14.75 17.95 18.85 16.80 21.10 18.60 16.40 22.75 19.55 23.80   26
420.00 675.00 100.00 34.50   0    26
 12.70 17.50 15.90 16.35 18.40 14.60 15.30 18.15 20.00 21.95   27
288.00 700.00  91.00 34.75   0    27
  8.90 14.95 14.25 12.80 17.70 14.35 14.45 19.45 17.95 17.50   28
288.00 700.00  91.00 34.75   0    28
 12.60 17.55 15.90 17.35 20.30 15.50 15.30 18.05 20.00 20.40   29
288.00 700.00  91.00 34.75   0    29
 10.40 14.40 15.20 14.30 17.45 14.35 12.60 19.45 19.05 19.60   30
288.00 700.00  91.00 34.75   0    30
 11.35 16.35 15.30 15.35 19.90 15.05 15.20 19.85 17.15 20.30   31
288.00 700.00  91.00 34.75   0    31
 10.95 16.95 15.95 15.85 20.60 13.15 16.20 19.35 18.35 19.60   32
288.00 700.00  91.00 34.75   0    32
  8.60 11.10 13.80 10.50 15.10 13.15 11.95 15.95 15.60 19.60   33
288.00 700.00  91.00 34.75   0    33
  8.25 12.25 13.30 11.20 16.10 13.15 14.25 17.30 14.35 19.60   34
288.00 700.00  91.00 34.75   0    34
  9.20 15.10 14.70 11.00 16.90 13.70 12.60 18.25 15.80 18.60   35
288.00 700.00  91.00 34.75   0    35
 16.05 20.15 21.15 19.55 26.45 22.50 21.25 24.05 26.15 22.85   36
300.00 790.00 108.00 40.10   2    36
 15.95 19.40 18.15 17.60 20.60 19.30 15.95 22.00 20.75 22.05   37
380.00 700.00 168.00 39.90   0    37
 16.70 20.95 20.70 20.60 23.65 19.60 16.85 22.15 21.60 26.55   38
322.00 730.00 150.00 46.00   0    38
 17.85 19.80 19.85 19.15 20.90 19.90 18.15 21.55 21.30 22.55   39
322.00 730.00 150.00 46.00   0    39
 16.80 19.05 18.90 18.35 20.15 19.60 15.95 21.75 20.95 26.80   40
322.00 730.00 150.00 46.00   0    40
 17.40 17.90 18.30 18.15 21.10 17.95 16.70 21.10 20.75 21.55   41
344.00 725.00 105.00 36.00   0    41
 14.95 18.80 18.05 17.60 21.00 18.15 16.40 22.65 21.90 23.60   42
390.00 700.00 110.00 36.25   0    42
 14.00 18.25 17.65 17.10 20.65 16.45 15.95 21.70 21.15 23.50   43
390.00 700.00 110.00 36.25   0    43
 15.80 21.10 21.00 20.70 21.95 19.25 19.50 22.80 22.75 25.40   44
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322.00 730.00 150.00 46.00   0     44
  14.50 19.80 20.60 17.50 21.65 15.75  17.30 21.65 21.50 23.60   45
390.00 700.00 110.00 36.25   0     45
  14.75 19.75 18.55 17.80 20.40 18.75  15.00 21.50 20.65 23.40   46
322.00 730.00 150.00 46.00   0     46
  16.10 19.40 17.55 17.05 21.40 17.05  17.15 21.40 20.55 20.80   47
380.00 795.00 148.00 36.50   0     47
  12.85 16.85 15.40 15.70 21.65 19.40  16.30 20.55 20.20 23.15   48
380.00 795.00 148.00 36.50   0     48
  12.15 17.00 15.10 15.85 19.10 19.40  15.50 19.30 20.25 19.10   49
380.00 795.00 148.00 36.50   0     49
  13.00 17.95 17.00 16.75 20.15 14.65  14.20 20.55 23.10 23.25   50
380.00 700.00 110.00 40.95   0     50
  13.05 17.25 16.50 15.95 22.55 14.65  14.40 22.70 23.10 23.25   51
380.00 700.00 110.00 40.95   0     51
  11.65 19.15 17.70 14.70 22.10 15.20  14.05 19.35 20.05 20.15   52
300.00 750.00 120.00 43.00   0     52
  12.60 17.35 16.90 16.30 19.85 15.65  16.30 18.70 19.55 19.75   53
300.00 750.00 120.00 43.00   0     53
  10.70 16.40 15.80 14.10 20.55 15.55  15.25 19.75 18.60 20.55   54
295.00 640.00 140.00 43.80   0     54
  12.05 14.05 14.20 13.95 18.70 18.65  10.10 17.40 16.95 20.20   55
265.00 750.00 181.00 38.25   0     55
  12.50 17.35 17.15 17.00 19.40 17.05  15.70 18.75 17.25 21.25   56
410.00 700.00 100.00 33.40   0     56
  15.25 18.75 18.95 18.70 22.50 18.65  19.55 22.45 22.05 23.90   57
265.00 750.00 181.00 38.25   0     57
  15.25 18.70 19.45 18.55 19.75 18.65  19.55 19.90 22.05 23.90   58
265.00 750.00 181.00 38.25   0     58
  15.25 18.05 17.25 17.90 19.40 17.95  15.80 19.35 19.70 23.90   59
265.00 750.00 181.00 38.25   0     59
  15.25 18.30 19.10 18.15 19.85 18.65  19.40 19.20 19.00 23.90   60
265.00 750.00 181.00 38.25   0     60
  17.20 23.55 19.90 23.20 22.80 25.20  17.95 23.30 25.40 28.80   61
288.00 945.00 175.00 36.80   0     61
  18.55 23.55 23.10 21.45 25.15 25.20  21.60 25.10 25.40 29.80   62
288.00 945.00 175.00 36.80   0     62
  15.45 20.25 18.60 19.10 22.15 22.00  16.75 22.35 21.05 29.80   63
288.00 945.00 175.00 36.80   0     63
  13.10 16.55 16.90 15.45 21.65 22.00  12.35 21.85 19.70 23.05   64
288.00 945.00 175.00 36.80   0     64
  14.00 17.75 17.70 16.60 21.65 22.00  15.85 21.85 21.45 23.05   65
288.00 945.00 175.00 36.80   0     65
  16.80 18.45 19.90 17.30 21.65 22.00  18.00 21.85 21.45 29.80   66
288.00 945.00 175.00 36.80   0     66
  14.80 18.75 18.60 17.55 21.95 22.00  16.20 22.10 21.75 29.80   67
288.00 945.00 175.00 36.80   0     67
  15.00 18.10 17.05 16.95 20.25 18.30  17.25 20.45 20.05 21.60   68
370.00 685.00 135.00 36.00   0     68
  15.25 18.45 17.85 17.60 21.40 18.30  17.25 20.30 20.75 21.65   69
370.00 685.00 135.00 36.00   0     69
   9.25 14.60 14.05 12.40 18.05 14.05  11.90 18.25 17.85 18.85   70
300.00 750.00 120.00 43.00   0     70
  15.75 19.40 19.05 17.80 23.05 21.00  17.85 22.75 21.40 23.15   71
380.00 795.00 148.00 36.50   0     71
  17.30 19.95 18.95 19.45 22.50 18.30  18.40 22.00 21.10 21.45   72
344.00 725.00 105.00 36.00   0     72
  14.40 18.45 16.60 17.30 19.90 19.35  14.70 21.60 19.70 22.30   73
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345.00 815.00   95.00 39.85   0     73
 14.65 19.35 18.75 17.15 22.70 16.40 18.15 21.70 19.70 19.85   74
380.00 795.00 148.00 36.50   0     74
 16.20 20.45 22.10 19.30 25.85 24.90 21.20 26.05 25.75 29.15   75
300.00 790.00 108.00 40.10   0     75
 16.25 21.60 22.35 20.75 27.45 27.65 23.15 26.15 24.15 29.15   76
310.00 735.00 180.00 46.30   0     76
 13.10 15.05 14.85 14.90 17.80 18.65 12.05 18.60 18.20 20.40   77
265.00 750.00 181.00 38.25   0     77
 14.40 20.45 19.40 19.45 25.10 24.35 16.90 22.90 22.05 28.45   78
340.00 700.00 130.00 44.15   0     78
 15.05 20.85 20.35 19.70 23.40 24.35 21.75 23.10 22.35 28.45   79
340.00 700.00 130.00 44.15   0     79
 15.00 19.25 19.45 19.05 22.65 24.35 17.25 22.80 22.75 28.45   80
340.00 700.00 130.00 44.15   0     80
 15.00 18.95 19.35 18.75 24.70 24.35 18.30 23.35 22.45 25.95   81
420.00 675.00 100.00 34.50   0     81
 14.05 19.60 19.70 18.45 22.20 24.35 17.25 22.35 21.55 24.35   82
420.00 675.00 100.00 34.50   0     82
 12.85 17.90 19.30 15.60 20.25 16.70 14.90 21.55 21.40 22.00   83
345.00 815.00   95.00 39.85   0     83
 16.45 18.30 17.60 18.15 20.80 20.00 16.25 20.20 20.50 20.70   84
340.00 700.00 130.00 44.15   0     84
 14.25 16.20 15.20 16.05 19.80 16.75 14.05 17.40 21.30 20.35   85
340.00 700.00 130.00 44.15   0     85
 18.10 21.95 21.65 21.20 24.20 22.20 19.05 22.25 22.75 24.35   86
350.00 705.00 160.00 39.55   0     86
 17.25 23.70 23.80 23.20 23.50 21.85 18.75 26.70 25.95 30.30   87
340.00 700.00 130.00 44.15   0     87
 16.80 20.00 19.45 19.80 22.35 18.45 17.40 24.30 21.60 22.35   88
350.00 705.00 160.00 39.55   0     88
 15.60 18.15 18.25 17.70 22.15 20.30 17.05 20.55 23.10 22.30   89
350.00 705.00 160.00 39.55   0     89
 14.35 17.20 15.65 16.05 20.65 20.30 14.35 20.85 23.10 20.40   90
340.00 700.00 130.00 44.15   0     90
 16.05 22.45 20.40 22.25 24.15 25.70 16.25 23.40 23.05 30.30   91
340.00 700.00 130.00 44.15   0     91
  7.75 11.40 14.15 10.10 16.10 12.80 11.75 17.30 14.15 17.70   92
288.00 700.00   91.00 34.75   0     92
  7.75 11.25 14.15 10.10 16.10 12.80 11.75 17.30 14.15 18.15   93
400.00 800.00 130.00 30.00   0     93
  7.75 11.40 14.15 10.10 16.10 12.80 11.75 17.30 14.15 18.15   94
400.00 800.00 130.00 30.00   0     94
 11.10 15.65 14.70 15.10 18.25 15.25 12.90 20.60 18.70 20.90   95
370.00 685.00 135.00 36.00   0     95
 17.85 20.35 20.15 18.95 22.00 20.60 18.25 21.85 20.15 25.35   96
394.00 375.00 144.00 39.50   0     96
 15.85 19.40 18.35 18.95 19.70 20.60 18.10 20.30 20.15 22.30   97
394.00 875.00 144.00 39.50   0     97
 18.15 20.65 20.65 20.90 22.25 20.15 19.45 22.95 22.65 24.30   98
380.00 700.00 110.00 40.95   0     98
 20.50 22.55 22.60 21.80 23.40 21.00 21.00 22.95 23.15 25.35   99
394.00 875.00 144.00 39.50   0     99
 15.10 19.80 18.25 17.35 22.05 20.10 17.65 22.25 20.95 23.95  100
385.00 950.00 155.00 38.00   0    100
 15.75 18.95 19.20 17.45 22.00 20.15 18.65 21.50 21.55 23.50  101
380.00 700.00 110.00 40.95   0    101
 16.50 20.00 22.05 19.80 23.05 21.00 21.00 21.95 23.15 25.35  102
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394.00 875.00 144.00 39.50  C    102
 18.55 21.85 21.85 21.60 23.50 20.55 19.85 23.65 22.90 25.10   103
288.00 945.00 175.00 36.80  0    103
 17.50 20.00 19.85 18.90 21.45 20.05 19.65 20.90 21.30  3.45   104
394.00 875.00 144.00 39.50  0    104
 12.40 18.75 16.20 17.65 19.70 17.10 15.30 19.80 19.45 19.95   105
295.00 640.00 140.00 43.80  0    105
 12.40 17.80 16.20 16.70 19.40 17.10 16.15 19.55 19.30 19.95   106
380.00 795.00 148.00 36.50  0    106
 17.35 23.40 20.25 20.05 28.80 22.65 19.85 27.35 25.05 25.05   107
380.00 700.00 168.00 39.90  0    107
 13.25 18.15 17.75 17.90 19.20 18.70 16.15 21.50 20.55 24.55   108
420.00 675.00 100.00 34.50  0    108
 16.30 20.05 18.70 18.40 23.40 20.00 15.90 21.05 22.15 25.05   109
350.00 705.00 160.00 39.55  0    109
 12.95 16.40 16.95 16.55 18.15 18.70 14.30 19.60 20.55 23.60   110
410.00 700.00 100.00 33.40  0    110
 15.65 19.55 20.45 20.40 22.25 20.25 18.65 22.05 22.05 24.65   111
420.00 675.00 100.00 34.50  0    111
 17.00 21.45 20.35 20.70 21.95 18.95 18.70 21.95 22.15 24.10   112
360.00 750.00 120.00 39.35  0    112
 12.65 16.90 16.65 16.55 19.05 18.70 15.80 21.50 20.55 23.35   113
420.00 675.00 100.00 34.50  0    113
 15.35 18.45 17.20 17.30 19.60 18.70 14.95 19.95 19.40 24.25   114
420.00 675.00 100.00 34.50  0    114
 15.10 18.80 18.45 17.55 19.90 19.75 16.90 20.30 22.05 22.95   115
285.00 750.00 181.00 38.25  0    115
  7.05 11.00 12.45 10.65 15.25 12.55 11.75 15.40 14.95 17.00   116
288.00 700.00  91.00 34.75  0    116
  7.05 15.40 12.45 14.30 13.70 12.05 11.75 15.70 14.95 17.00   117
288.00 700.00  91.00 34.75  0    117
 11.10 15.40 15.80 14.30 18.25 15.30 12.45 18.35 17.95 20.15   118
345.00 815.00  95.00 39.85  0    118
 11.25 18.15 15.55 17.05 18.30 15.30 12.45 17.30 16.90 20.15   119
370.00 685.00 135.00 36.00  0    119
 10.80 17.20 15.75 14.05 18.60 13.55 13.65 18.35 18.00 18.45   120
288.00 700.00  91.00 34.75  0    120
  9.70 15.75 14.05 12.20 17.00 13.55 13.95 17.65 18.00 16.70   121
325.00 875.00 100.00 35.00  0    121
 11.55 18.15 16.25 16.25 20.00 16.00 15.95 20.40 20.30 19.60   122
320.00 700.00  97.00 35.00  0    122
 11.05 15.75 15.45 12.45 18.00 14.55 13.90 17.70 17.00 19.35   123
325.00 875.00 100.00 35.00  0    123
  9.80 16.40 15.90 13.45 18.55 16.90 14.45 17.70 18.35 19.80   124
295.00 640.00 140.00 43.80  0    124
 10.35 16.85 16.60 15.15 19.10 14.90 13.35 18.70 19.15 19.25   125
285.00 700.00 109.00 28.00  0    125
 12.40 20.20 17.70 16.30 21.80 15.55 16.70 19.40 21.50 20.55   126
285.00 705.00 110.00 38.00  0    126
  9.00 14.90 13.50 13.25 17.50 13.70 14.00 16.20 15.75 16.80   127
285.00 700.00 109.00 28.00  0    127
 10.65 17.50 17.00 16.55 19.05 16.90 15.90 17.95 18.15 19.15   128
295.00 640.00 140.00 43.80  0    128
  9.60 12.95 13.20 11.90 15.50 15.20 11.65 15.40 17.30 18.40   129
325.00 700.00 110.00 39.00  0    129
 10.65 17.40 17.00 16.55 19.25 16.90 16.00 17.95 18.15 19.15   130
295.00 640.00 140.00 43.80  0    130
 13.85 19.35 18.75 17.80 21.95 17.10 18.50 21.10 21.50 21.75   131
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285.00 705.00 110.00 38.00   0    131
 10.20 16.50 15.90 15.60 18.45 15.25 14.00 19.80 19.15 18.45   132
285.00 700.00 109.00 28.00   0    132
 13.25 19.40 17.30 16.75 21.60 22.75 16.00 20.70 20.30 22.05   133
345.00 815.00  95.00 39.85   0    133
 13.00 14.85 14.85 14.70 15.45 17.95 12.05 15.65 15.20 20.90   134
265.00 750.00 181.00 38.25   0    134
  9.30 13.85 14.60 12.35 16.85 10.95 11.90 16.65 16.10 18.10   135
400.00 800.00 130.00 30.00   0    135
  9.30 14.05 14.60 12.35 17.15 10.95 12.10 16.90 15.75 18.10   136
400.00 800.00 130.00 30.00   0    136
  9.30 16.75 14.60 12.35 18.10 10.95 12.55 17.85 17.35 18.85   137
4C0.00 800.00 130.00 30.00   0    137
 18.80 22.30 20.30 20.80 27.05 21.35 19.65 27.70 26.00 25.05   138
380.00 700.00 168.00 39.90   0    138
 17.00 19.55 19.65 18.70 24.50 20.30 18.60 24.95 25.20 25.05   139
380.00 700.00 168.00 39.90   0    139
 18.80 21.35 19.80 19.90 26.85 21.35 19.65 24.95 25.80 25.05   140
380.00 700.00 168.00 39.90   0    140
 14.60 19.55 19.40 18.25 21.35 18.70 15.40 20.45 20.30 23.05   141
385.00 950.00 155.00 38.00   0    141
 14.70 19.60 18.50 18.45 21.90 18.70 16.00 21.90 20.95 23.35   142
385.00 950.00 155.00 38.00   0    142
 15.40 17.40 17.00 16.25 20.05 20.15 16.55 20.85 20.45 21.20   143
350.00 755.00 140.00 32.60   0    143
 18.40 21.35 20.25 19.45 22.55 20.15 18.85 22.30 22.45 25.00   144
350.00 755.00 140.00 32.60   0    144
 13.85 19.40 17.90 16.20 19.40 20.40 19.50 19.50 19.25 22.35   145
345.00 815.00  95.00 39.85   0    145
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1	100.00	30	84.83
2	90.88	31	89.25
3	83.93	32	89.94
4	87.33	33	73.51
5	85.17	34	75.89
6	162.71	35	80.04
7	113.49	36	115.89
8	110.38	37	101.51
9	85.65	38	111.57
10	130.02	39	105.47
11	128.54	40	104.73
12	131.04	41	100.62
13	129.63	42	102.68
14	129.93	43	99.58
15	128.62	44	111.33
16	138.06	45	104.89
17	126.99	46	101.57
18	143.73	47	99.58
19	130.20	48	95.52
20	134.34	49	89.73
21	138.13	50	96.20
22	102.21	51	99.04
23	96.01	52	94.49
24	101.53	53	91.60
25	97.03	54	90.18
26	102.84	55	83.06
27	89.65	56	92.38
28	82.26	57	106.04
29	90.71	58	101.94
		59	96.57
		60	99.91
		61	116.95
		62	125.28
		63	109.21
		64	98.19
		65	101.37
		66	109.17
		67	107.49
		68	96.97
		69	99.21
		70	80.91
		71	106.67
		72	105.08
		73	97.52
		74	101.26
		75	122.50
		76	125.85
		77	86.21
		78	112.94
		79	114.53
		80	110.86
		81	111.42
		82	107.69
		83	99.24
		84	98.51
		85	88.55
		86	114.41
		87	125.85

88	105.36
89	101.78
90	95.07
91	117.59
92	74.39
93	74.56
94	74.62
95	87.88
96	108.50
97	100.59
98	111.42
99	117.46
100	104.37
101	104.65
102	112.72
103	115.97
104	95.60
105	93.06
106	91.99
107	122.44
108	99.54
109	105.86
110	93.71
111	108.89
112	109.10
113	96.28
114	97.31
115	100.17
116	69.39
117	71.59
118	85.85
119	86.46
120	85.55
121	79.27
122	92.82
123	83.55
124	86.02
125	88.35
126	96.67
127	76.96
128	89.65
129	74.25
130	89.78
131	101.74
132	87.98
133	99.69
134	80.75
135	77.18
136	77.71
137	81.30
138	121.61
139	113.15
140	117.28
141	102.04
142	103.39
143	96.95
144	110.51
145	97.58

Estimated Area Cost Factors
Based on the Sample Input
Stream

CITY	ACF
1	1.00
2	.90
3	.93
4	.97
5	.89
6	1.34
7	1.00
8	1.00
9	.90
10	1.05
11	1.05
12	1.16
13	1.05
14	1.05
15	1.05
16	1.17
17	1.07
18	1.18
19	1.05
20	1.16
21	1.17
22	.97
23	1.00
24	1.06
25	1.01
26	.96
27	.90
28	.88
29	.90
30	.89
31	.90
32	.90
33	.86
34	.86
35	.87
36	1.52
37	1.06
38	1.08
39	1.06
40	1.06
41	.96
42	.98
43	.97
44	1.08
45	.98
46	1.05
47	1.04
48	1.03
49	1.01
50	.97

CITY	ACF
51	.98
52	.99
53	.98
54	.98
55	1.01
56	.93
57	1.07
58	1.06
59	1.05
60	1.06
61	1.13
62	1.14
63	1.11
64	1.08
65	1.09
66	1.11
67	1.10
68	.99
69	1.00
70	.95
71	1.06
72	.97
73	.96
74	1.04
75	1.03
76	1.14
77	1.02
78	1.05
79	1.05
80	1.04
81	.98
82	.97
83	.97
84	1.01
85	.98
86	1.08
87	1.07
88	1.06
89	1.05
90	1.00
91	1.06
92	.86
93	.93
94	.93
95	.97
96	1.08
97	1.06
98	1.01
99	1.10
100	1.09

CITY	ACF
101	.99
102	1.09
103	1.12
104	1.04
105	.99
106	1.02
107	1.11
108	.95
109	1.06
110	.93
111	.97
112	1.02
113	.94
114	.94
115	1.06
116	.84
117	.85
118	.93
119	.97
120	.89
121	.92
122	.92
123	.93
124	.97
125	.91
126	.96
127	.88
128	.98
129	.90
130	.98
131	.97
132	.91
133	.97
134	1.00
135	.94
136	.94
137	.95
138	1.11
139	1.09
140	1.10
141	1.08
142	1.08
143	1.00
144	1.03
145	.96

APPENDIX C

LISTING OF THE COMPUTER PROGRAM

```
1*    C
2*    C     THE PURPOSE OF THIS PROGRAM IS TO COMPUTE AN AREA COST FACTOR FOR A
3*    C     GIVEN SET OF INSTALLATIONS
4*    C
5*    C     INITIALIZATION FOR THE TOTAL NUMBER OF INSTALLATIONS FOR WHICH AREA
6*    C     COST FACTORS ARE TO BE COMPUTED
7*    C
8*          DIMENSION ACF(250,3),AWR(250),WP(250),SSP(250),CEP(250),RMCP(250),
9*         CCITY(250),STAWR(250),STWP(250),STSSP(250),STCBP(250),STCP(250),
10*        CWCL(250),WBR(250),WCA(250),WCM(250),WEL(250),WOE(250),WPA(250),
11*        CWPL(250),WSM(250),WSS(250),ICODE(250),TWAGE(250)
12*   C
13*   C     ERROR FLAG
14*   C
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```
15*              J3=0
16*      C
17*      C         INPUT ROUTINE FOR KEY FACTORS
18*      C
19*      C         INPUT NUMBER OF INSTALLATIONS FOR WHICH AREA COST FACTORS ARE TO BE
20*      C         COMPUTED
21*      C
22*              I=145
23*              DO 100 J=1,I
24*              READ(5,110)WCL(J),WBR(J),WCA(J),WCM(J),WEL(J),WOE(J),WPA(J),
25*             CWPL(J),WSM(J),WSS(J),CITY(J),WP(J),SSP(J),CBP(J),RMCP(J),
26*             CICODE(J),CITY(J)
27*      110 FORMAT(10F6.2,I5/3F7.2,F6.2,I3,I6)
28*              J1=' '
29*              J2=' '
30*              IF(WCL(J).LE.0) GO TO 120
31*              IF(WBR(J).LE.0) GO TO 120
32*              IF(WCA(J).LE.0) GO TO 120
33*              IF(WCM(J).LE.0) GO TO 120
34*              IF(WEL(J).LE.0) GO TO 120
35*              IF(WOE(J).LE.0) GO TO 120
36*              IF(WPA(J).LE.0) GO TO 120
37*              IF(WPL(J).LE.0) GO TO 120
38*              IF(WSM(J).LE.0) GO TO 120
39*              IF(WSS(J).LE.0) GO TO 120
40*              IF(WP(J).LE.0) GO TO 120
41*              IF(SSP(J).LE.0) GO TO 120
42*              IF(CBP(J).LE.0) GO TO 120
43*              IF(RMCP(J).LE.0) GO TO 120
44*              GO TO 150
45*      120 J1='0'
46*              J2='/'
47*              J3=1
48*      130 WRITE(6,140)J1,WCL(J),WBR(J),WCA(J),WCM(J),WEL(J),WCE(J),WPA(J),
49*             CWPL(J),WSM(J),WSS(J),CITY(J),WP(J),SSP(J),CBP(J),RMCP(J),ICODE(J),
50*             CCITY(J),J2
51*      140 FORMAT(A1,10X,10F6.2,I5/10X,3F7.2,F6.2,I3,I6/A1)
52*              GO TO 100
53*      150 WRITE(6,160)J1,WCL(J),WBR(J),WCA(J),WCM(J),WEL(J),WOE(J),WPA(J),
54*             CWPL(J),WSM(J),WSS(J),CITY(J),WP(J),SSP(J),CBP(J),RMCP(J),ICODE(J),
55*             CCITY(J),J2
56*      160 FORMAT(A1,10X,10F6.2,I5/10X,3F7.2,F6.2,I3,I6,A1)
57*      100 CONTINUE
58*              IF(J3.EG.1) GO TO 660
59*      C
60*      C         CALCULATION OF WAGE INDEX
61*      C
62*              DO 200 J=1,I
63*              TWAGE(J)=WCL(J)*0.05+WBR(J)*0.08+WCA(J)*0.23+WCM(J)*0.07+WEL(J)*
64*             CO.14+WOE(J)*0.05+WPA(J)*0.04+WPL(J)*0.20+WSM(J)*0.04+WSS(J)*0.10
65*              AWR(J)=(TWAGE(J)/TWAGE(1))*100
66*              WRITE(6,210)J,AWR(J)
67*      210 FORMAT(20X,I10,F10.2)
68*      200 CONTINUE
69*      C
70*      C         INITIALIZATION OF CITY FACTORS FOR COMPUTING AREA COST FACTORS
71*      C
72*              DO 250 J=1,I
```

```
73*              X1=ALOG(AWR(J))
74*              X2=ALOG(WP(J))
75*              X3=ALOG(SSP(J))
76*              X4=ALOG(CBP(J))
77*              X5=ALOG(RMCP(J))
78*              STAWR(J)=X1
79*              STWP(J)=X2
80*              STSSP(J)=X3
81*              STCBP(J)=X4
82*              STCP(J)=X5
83*          250 CONTINUE
84*      C
85*      C       CONSTANTS USED IN COMPUTING SET 1 AREA COST FACTORS
86*      C
87*              C1=.367540
88*              C2=.211603
89*              C3=.239606
90*              C4=C1*STAWR(1)+C2*STSSP(1)+C3*STCP(1)
91*              C5=1.46
92*              C6= .426809
93*              C7=EXP(C4)
94*      C
95*      C       ROUTINE FOR COMPUTING SET 1 AREA COST FACTORS
96*      C
97*              DO 300 J=1,I
98*              C8=C1*STAWR(J)+C2*STSSP(J)+C3*STCP(J)
99*              IF(ICODE(J).EQ.1) GO TO 310
100*             IF(ICODE(J).EQ.2) GO TO 320
101*             CONE=EXP(C8)
102*             GO TO 330
103*         310 C9=EXP(C8)
104*             CONE=C9*C5
105*             GO TO 330
106*         320 C10=C8+C6
107*             CONE=EXP(C10)
108*         330 ACF(J,1)=CONE/C7
109*         300 CONTINUE
110*     C
111*     C       CONSTANTS USED IN COMPUTING SET 2 AREA COST FACTORS
112*     C
113*             D1=.212421
114*             D2=.0522205
115*             D3=.0861036
116*             D4=.238671
117*             D5=.0383134
118*             D6=D1*STAWR(1)+D2*STWP(1)+D3*STSSP(1)+D4*STCBP(1)+D5*STCP(1)
119*             D8=.388239
120*             D9=EXP(D6)
121*     C
122*     C       ROUTINE FOR COMPUTING SET 2 AREA COST FACTORS
123*     C
124*             DO 400 J=1,I
125*             D10=D1*STAWR(J)+D2*STWP(J)+D3*STSSP(J)+D4*STCBP(J)+D5*STCP(J)
126*             IF(ICODE(J).EQ.1) GO TO 410
127*             IF(ICODE(J).EQ.2) GO TO 420
128*             CTWO=EXP(D10)
129*             GO TO 430
130*         410 D11=D10+D7
```

66

```
131*        CTWO=EXF(D11)
132*        GO TC 430
133*   420  C12=D10+D8
134*        CTWO=EXP(D12)
135*   430  ACF(J,2)=CTWO/D9
136*   400  CCNTINUE
137*  C
138*  C     INTEGRATING ROUTINE
139*        C7=.455858
140*  C
141*        DO 500 J=1,I
142*        ACF(J,3)=ACF(J,1)*0.26+ACF(J,2)*0.74
143*   500  CCNTINUE
144*  C
145*  C     OUTPUT FORMAT
146*  C
147*        DO 600 J=1,I
148*        IF(J.EQ.1.OR.J.EQ.51.OR.J.EQ.101.OR.J.EQ.151.OR.J.EQ.201)GO TO 610
149*        WRITE(6,620)J,ACF(J,3)
150*   620  FORMAT(10X,I10,F10.2)
151*        GO TO 600
152*   610  WRITE(6,630)
153*   630  FORMAT(1H1,16X,'CITY',6X,'ACF')
154*        WRITE(6,640)J,ACF(J,3)
155*   640  FORMAT(10X,I10,F10.2)
156*   600  CCNTINUE
157*        IF(J3.NE.1) GO TO 650
158*        WRITE(6,670)              .
159*   670  FORMAT(10X,'ERROR IN INPUT DATA')
160*   650  J3=0
161*        END
```

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FEDERAL INFORMATION PROCESSING STANDARD SOFTWARE SUMMARY

01. Summary date	02. Summary prepared by (Name and Phone)	03. Summary action

01. Summary date

Yr.	Mo.	Day
8 1	0 1	1 2

02. Summary prepared by (Name and Phone)
Robert E. Chapman   301/921-3855

05. Software title
Area Cost Factor Estimation Procedure

03. Summary action

New ☒   Replacement ☐   Deletion ☐

Previous Internal Software ID

04. Software date

Yr.	Mo.	Day
8 1	0 1	1 2

06. Short title   NA

07. Internal Software ID
NA

08. Software type

☐ Automated Data System
☒ Computer Program
☐ Subroutine/Module

09. Processing mode

☐ Interactive
☒ Batch
☐ Combination

10. Application area

General

☐ Computer Systems Support/Utility
☒ Scientific/Engineering
☐ Bibliographic/Textual

☐ Management/Business
☐ Process Control
☐ Other

Specific

military construction projects

11. Submitting organization and address
Operations Research Division
Center for Applied Mathematics
National Bureau of Standards
Washington, D. C.   20234

12. Technical contact(s) and phone

Robert E. Chapman
301/921-3855

13. Narrative

Program will estimate a geographical cost index, area cost factor, for each military installation and/or major city in the United States for which data are input. Two sets of area cost factors, one for each major set of military category codes, are estimated and then weighted to reflect the relative frequency with which structures within each set have occurred historically.

14. Keywords

15. Computer manuf'r and model	16. Computer operating system	17. Programing language(s)	18. Number of source program statements
UNIVAC 1108A	NBS Computer Services Division	FORTRAN V	

19. Computer memory requirements	20. Tape drives	21. Disk/Drum units	22. Terminals
	None	None	None

23. Other operational requirements

24. Software availability

Available ☒   Limited ☐   In-house only ☐

Operations Research Division
Center for Applied Mathematics
National Bureau of Standards
Washington, D. C.   20234

25. Documentation availability

Available ☒   Inadequate ☐   In-house only ☐

Operations Research Division
Center for Applied Mathematics
National Bureau of Standards
Washington, D. C.   20234

26. FOR SUBMITTING ORGANIZATION USE
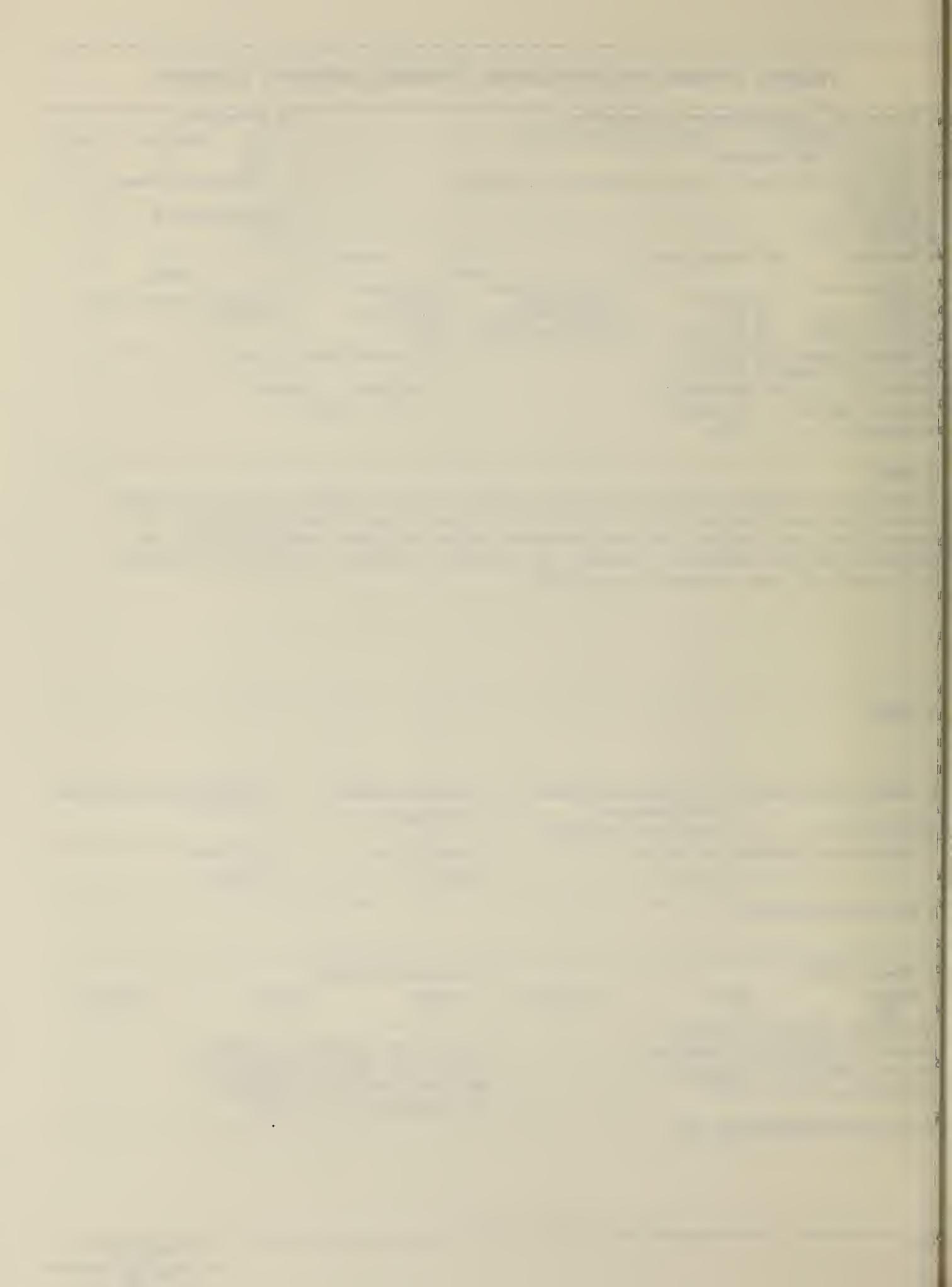
INSTRUCTIONS

01. **Summary Date.** Enter date summary prepared. Use Year, Month, Day format: YYMMDD.

02. **Summary Prepared By.** Enter name and phone number (including area code) of individual who prepared this summary.

03. **Summary Action.** Mark the appropriate box for new summary, replacement summary or deletion of summary. If this software summary is a replacement, enter under "Previous Internal Software ID" the internal software identification as reported in item 07 of the original summary, and enter the new internal software identification in item 07 of this form; complete all other items as for a new summary. If a software summary is to be deleted, enter under "Previous Internal Software ID" the internal software identification as reported in item 07 of the original summary; complete only items 01, 02, 03 and 11 on this form.

04. **Software Date.** Enter date software was completed or last updated. Use Year, Month, Day format: YYMMDD.

05. **Software Title.** Make title as descriptive as possible.

06. **Short Title.** (Optional) Enter commonly used abbreviation or acronym which identifies the software.

07. **Internal Software ID.** Enter a unique identification number or code.

08. **Software Type.** Mark the appropriate box for an Automated Data System (set of computer programs), Computer Program, or Subroutine/Module, whichever best describes the software.

09. **Processing Mode.** Mark the appropriate box for an Interactive, Batch, or Combination mode, whichever best describes the software.

10. **Application Area.**
    General: Mark the appropriate box which best describes the general area of application from among:

    Computer Systems Support/Utility   Process Control
    Management/Business   Bibliographic/Textual
    Scientific/Engineering   Other

    Specific: Specify the sub-area of application; e.g.: "COBOL optimizer" if the general area is "Computer Systems Support/Utility"; "Payroll" if the general area is "Management/Business"; etc. Elaborate here if the general area is "Other."

11. **Submitting Organization and Address.** Identify the organization responsible for the software as completely as possible, to the Branch or Division level, but including Agency, Department (Bureau/Administration), Service, Corporation, Commission, or Council. Fill in complete mailing address, including mail code, street address, city, state, and ZIP code.

12. **Technical Contact(s) and Phone:** Enter person(s) or office(s) to be contacted for technical information on subject matter and/or operational aspects of software. Include telephone area code. Provide organization name and mailing address, if different from that in item 11.

13. **Narrative.** Describe concisely the problem addressed and methods of solution. Include significant factors such as special operating system modifications, security concerns, relationships to other software, input and output media, virtual memory requirements, and unique hardware features. Cite references, if appropriate.

14. **Keywords.** List significant words or phrases which reflect the functions, applications and features of the software. Separate entries with semicolons.

15. **Computer Manufacturer and Model.** Identify mainframe computer(s) on which software is operational.

16. **Computer Operating System.** Enter name, number, and release under which software is operating. Identify enhancements in the Narrative (item 13).

17. **Programing Language(s).** Identify the language(s) in which the software is written, including version; e.g., ANSI COBOL, FORTRAN V, SIMSCRIPT II.5, SLEUTH II.

18. **Number of Source Program Statements.** Include statements in this software, separate macros, called subroutines, etc.

19. **Computer Memory Requirements.** Enter minimum internal memory necessary to execute software, exclusive of memory required for the operating system. Specify words, bytes, characters, etc., and number of bits per unit. Identify virtual memory requirements in the Narrative (item 13).

20. **Tape Drives.** Identify number needed to operate software. Specify, if critical, manufacturer, model, tracks, recording density, etc.

21. **Disk/Drum Units.** Identify number and size (in same units as "Memory"—item 19) needed to operate software. Specify, if critical, manufacturer, model, etc.

22. **Terminals.** Identify number of terminals required. Specify, if critical, type, speed, character set, screen/line size, etc.

23. **Other Operational Requirements.** Identify peripheral devices, support software, or related equipment not indicated above, e.g., optical character devices, facsimile, computer-output microfilm, graphic plotters.

24. **Software Availability.** Mark the appropriate box which best describes the software availability from among: **Available to the Public, Limited Availability** (e.g.: for government use only), and **For-In-house Use Only.** If the software is "Available", include a mail or phone contact point, as well as the price and form in which the software is available, if possible.

25. **Documentation Availability.** Mark the appropriate box which best describes the documentation availability from among: **Available to the Public, Inadequate for Distribution,** and **For In-house Use Only.** If documentation is "Available", include a mail or phone contact point, as well as the price and form in which the documentation is available, if possible. If documentation is presently "Inadequate", show the expected availability date.

26. **For Submitting Organization Use.** This area is provided for the use of the organization submitting this summary. It may contain any information deemed useful for internal operation.

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4. TITLE AND SUBTITLE

Estimating Area Cost Factors for Military Construction Projects: A Computerized Approach

5. AUTHOR(S)

Robert E. Chapman and Bruce E. Thompson

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)* **NATIONAL BUREAU OF STANDARDS** **DEPARTMENT OF COMMERCE** **WASHINGTON, D.C. 20234**	7. Contract/Grant No.
	8. Type of Report & Period Covered

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Directorate of Engineering and Services   Naval Facilities Engineering Command
Department of the Air Force   Department of the Navy
Washington, D. C. 20330   Washington, D. C. 20390

10. SUPPLEMENTARY NOTES

Office of Chief of Engineers
U. S. Army
Washington, D. C. 20314

[X] Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

This report describes a computerized procedure for estimating area cost factors for military construction projects. The empirical basis for this procedure rests upon the results of an econometric analysis of over 500 military construction projects. Technical and empirical evidence from a wide variety of published sources were also used to provide supplemental information on wage rates, material prices, and the level of construction activities in the localities where the projects were undertaken. This report is intended to serve as a user manual for military personnel concerned with the problem of periodically updating the area cost factors for each service's installations. A series of technical appendices are also included which describe the theoretical underpinnings of the econometric models which constitute the core of the computerized procedure as well as provide samples of computer output and a complete listing of the computer program.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

Applied economics; construction; cost; estimation; location factors; model building; statistical analysis.

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