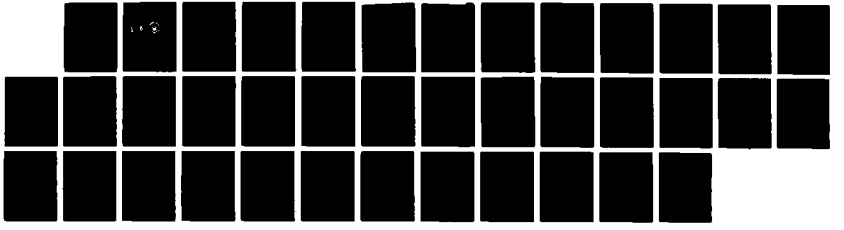
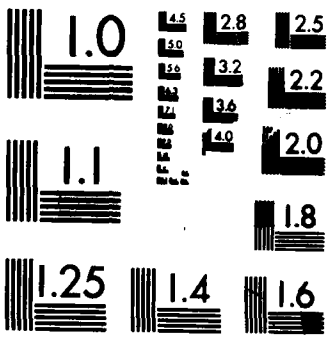
AD-A183 075 ON THE FEASIBILITY OF CREATING A COMPARABLE DATABASE FOR NONRECURRING COS..(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA D C BOGER ET AL. MAY 87 NPS-54-87-004 1/1

UNCLASSIFIED F/G 5/3 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(2)

NPS-54-87-004

DTIC FILE COPY

NAVAL POSTGRADUATE SCHOOL

Monterey, California

AD-A183 075

DTIC
ELECTE
AUG 1 2 1987
S D
C D

ON THE FEASIBILITY OF CREATING A COMPARABLE DATABASE FOR NONRECURRING COST ANALYSIS UNDER DUAL SOURCE COMPETITION

Dan C. Boger

and

Shu S. Liao

May 1987

Approved for public release; distribution unlimited.

Prepared for: Naval Air Systems Command
Cost Analysis Division
Washington, D. C. 20361

NAVAL POSTGRADUATE SCHOOL
Monterey, California

RADM. R. C. Austin
Superintendent

David A. Schrady
Provost

The research summarized herein was sponsored by the Naval Air Systems Command, Cost Analysis Division under work order N0001986WR6347W.

Reproduction of all or part of this report is authorized.

This report was prepared by:

Dan C. Boger, Associate Professor

Shu S. Liao, Professor

Department of Administrative Sciences

Reviewed by:

Willis R. Greer, Jr., Chairman
Department of Administrative Sciences

Released by:

Kneale T. Marshall
Dean of Information and Policy Science

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION Unclassified	1b RESTRICTIVE MARKINGS A183075
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S) NPS-54-87-004	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION Naval Postgraduate School 6b OFFICE SYMBOL (If applicable)	7a NAME OF MONITORING ORGANIZATION Naval Air Systems Command Cost Analysis Division
6c ADDRESS (City, State, and ZIP Code) Monterey, CA 93943	7b ADDRESS (City, State, and ZIP Code) Washington, D.C. 20361
8a NAME OF FUNDING/SPONSORING ORGANIZATION Naval Air Systems Command Cost Analysis Division 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N0001986WR6347W
8c ADDRESS (City, State, and ZIP Code) Washington, D.C. 20631	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO / PROJECT NO / TASK NO / WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification) (UNCLASSIFIED)
On the Feasibility of Creating a Comparable Database for Nonrecurring Cost Analysis Under Dual Source Competition

12 PERSONAL AUTHOR(S)
Dan C. Boger and Shu S. Liao

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Final report	FROM _____ TO _____	January 1986 to Sept. 1986	33 pp.

16 SUPPLEMENTARY NOTATION

17 COSATI CODES		
FIELD	GROUP	SUB-GROUP

18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Dual source commetition, nonrecurring costs, cost drivers, cost estimation relationships

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

This study examines the nature of nonrecurring cost items and develops systematic procedures for the government and contractors to follow in order to generate a database of nonrecurring costs which is both consistent and comparable. The objective was to develop a method for generating an analyzable set of data for parametric estimation of nonrecurring costs. Cost elements were analyzed and their cost drives were identified.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT	21 ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	
22a NAME OF RESPONSIBLE INDIVIDUAL	22b TELEPHONE (Include Area Code) / 22c OFFICE SYMBOL

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

ON THE FEASIBILITY OF CREATING A COMPARABLE DATABASE FOR NONRECURRING COST ANALYSIS UNDER DUAL SOURCE COMPETITION

by

Dan C. Boger

and

Shu S. Liao

Department of Administrative Sciences

Naval Postgraduate School

Monterey, California 93943

May 1987

Accession For
NTIS CRA&I
DTIC TAB
Unannounced
Justification
By
Distribution /
Availability Codes
Dist | Avail and/or special
A-1

DTIC COPY INSPECTED

EXECUTIVE SUMMARY

In dual sourcing decisions, it is necessary that the nature and extent of nonrecurring costs be fully analyzed. Nonrecurring costs are important since they represent those investment costs which must be incurred before the second source produces any output. Therefore, good measurement and models of nonrecurring investment costs are required in order to determine whether dual sourcing can save costs.

A major task in cost estimation is to determine the cost behavior of a cost element so that the amount of the cost element may be estimated when the factors driving the cost change. This report examines the cost behavior of major nonrecurring cost elements and explores the feasibility of creating a comparable data base for parametric analysis of nonrecurring costs when a second supplier is to be established for competitive procurement.

To estimate nonrecurring costs associated with establishing a second source, both analogy and parametric CER methods have been used. However, our examination of contractors' cost estimation methods indicates that government cost analysts face several difficulties under current cost data reporting systems. These are discussed in detail in chapter 2.

Since nonrecurring costs consist of several categories of cost items, a parametric cost estimating model with a small number of available observations and a large number of potential explanatory variables would be unreliable, even if possible. A feasible solution is to disaggregate the nonrecurring costs into relatively

homogeneous groups of cost items for data accumulation purposes. With a consistent data base and relatively homogeneous cost items, a parametric model for each group may be constructed with a relatively small number of observations, a typical constraint in major weapon system cost estimation.

Our research effort focused on identifying the components of nonrecurring second source start-up costs, their cost behavior, and cost drivers. Our findings can be summarized below.

First, it is necessary to separate nonrecurring material costs from labor and overhead costs for estimating purpose. The main reason is that the cost drivers for each are not always the same. Lumping material and labor costs together would require adding more explanatory variables to the CER model.

Second, parametric CER models for labor cost must be based on labor hours, not on labor dollars as some cost analysts do now.

Third, the most important explanatory variable that needs to be operationalized is the complexity of the weapon system. Most of the manpower needed is variable and is driven, according to contractors, by the amount of labor hours. In fact, some contractors have used certain surrogate measures for the level of complexity. Standardizing the measure of system complexity is necessary if a parametric CER is to be developed.

Our recommendation is that material and labor costs should be separately reported for each category defined in the main body of the report and that defining the complexity level of a system holds the key to developing viable parametric CER models for nonrecurring costs.

CHAPTER 1

INTRODUCTION

Competition has been hailed by virtually every corner of the public and private sectors as a vehicle for reducing the cost of acquiring weapon systems. However, in order to introduce competition in major weapon system procurement, a second source of supply must be created. The cost to establish a competitive second supply source can be high and difficult to estimate. This report examines the feasibility of creating a comparable data base for parametric analysis of nonrecurring costs when a second supplier is to be established for competitive procurement.

BACKGROUND

In dual sourcing decisions, it is necessary that the nature and extent of nonrecurring costs be fully analyzed. Nonrecurring costs are important since they represent those investment costs which must be incurred before the second source produces any output. It should be noted that the only way dual sourcing will produce overall cost savings for the Government is for the present value of the eventual recurring cost savings to offset the nonrecurring investment costs. Therefore, good measurement and models of nonrecurring investment costs are required in order to determine whether dual sourcing can save costs.

A major task in cost estimation is to determine the cost behavior of a cost element so that the amount of the cost element

may be estimated when the factors driving the cost change. Our earlier research has identified several difficulties with the current state of the estimation of nonrecurring costs of dual sourcing.[1] First among these difficulties is that there is an inconsistent treatment of nonrecurring cost elements with their being predefined as either fixed or variable. The second difficulty is that different methods were used to aggregate costs into the cost elements used for analysis. These difficulties result in the data of nonrecurring costs compiled by specific sources being noncomparable with data compiled by other sources, thus rendering the data unusable for analytical purposes. The lack of acceptable nonrecurring cost models can be partially attributed to these difficulties.

To address this problem, it is necessary to develop systematic procedures for the government and contractors to follow in order to generate a database of nonrecurring costs which is both consistent and comparable. These procedures should provide specific and particular guidelines for all parties to a contract to follow in order to produce a consistent and comparable database of nonrecurring costs for parametric analysis.

OBJECTIVE OF THE PROJECT

The objective of the project is to examine the nature of

---

[1] Dan C. Boger and Shu S. Liao, "An Analysis of Quantity-Split and Nonrecurring Costs Under a Competitive Procurement Environment (Vol. I)," Technical Report NPS54-85-08, Naval Postgraduate School, Monterey, CA, September 1985.

nonrecurring cost items and develop systematic procedures for the government and contractors to follow in order to generate a database of nonrecurring costs which is both consistent and comparable. Potential changes to RFP's and RFQ's will be analyzed with recommendations made as to how such changes could result in the provision of an analyzable set of data from each government contractor and how these sets may be aggregated to provide weapons-system peculiar databases for future analysis. The key element in such a system will be the provision of consistent and comparable databases.

RESEARCH METHODOLOGY

Due to the paucity of prior research on nonrecurring costs under dual source environments, the study relies heavily on first-hand data gathering. Five missile system contractors were visited by the research team jointly or separately. One of the five defense contractors is a prime contractor for a sole-source missile program. The intention was to see the differences and similarities between a sole sourced program and a dual sourced program. The remaining four are either the original source or the second source of dual-sourced missile programs. Individuals interviewed included cost-estimating specialists, financial managers, program managers, contract managers, and engineering/technical division managers.

The interview focused on the following three questions:

1. the criteria for classifying nonrecurring costs in setting up production facility,

2. the classification of nonrecurring cost items as variable or fixed costs.
3. the method of tracking and accounting start-up nonrecurring costs to segregate from follow-on production efforts.

SCOPE AND LIMITATIONS OF THE STUDY

As mentioned earlier, this study relied heavily on first-hand data gathering from defense contractors' files due to the paucity of prior research. Some contractors, however, were reluctant to discuss even their procedures, because of their perceptions of the "competition-sensitive" nature of this information. In addition to this problem of cooperation, the conduct of this study was further hampered by two built-in difficulties related to the maturity of the programs studied. The second supplier was either established several years ago or had only recently been announced. For the former, some of the techniques used to estimate the startup costs were often lost to corporate memory. For the latter, either the methods to be used for cost estimation had not been decided on or the information was considered to be competition sensitive. As a result, information disclosed tends to be of a general nature. However, the researchers were able to partially reconstruct the picture from supplemental documents accompanying proposals submitted to the Government procurement office. Therefore, the results of the research provide the reader with a comprehensive but incomplete overview of cost elements and costing methods used by the defense aerospace industry in the treatment of nonrecurring investment costs in a reprocurement environment.

CHAPTER 2

DATABASE AND PARAMETRIC COST ESTIMATION

Cost estimation is a projection into the future from a database compiled from past experiences. Accuracy of the projection depends on many things, not the least of which is the validity of the database. The need for a comparable and consistent database has long been recognized in the cost estimation community. This chapter discusses various cost estimation techniques, their database requirements, and related current Government regulations.

COST ESTIMATING METHODS

In subsequent chapters reference will be made to the different methods of cost estimation used by defense aerospace contractors. This section discusses the three basic methods most widely used.

Analogy Method

The method of analogy is based on direct comparisons with historical information on like components of existing systems.[2] There is intuitive and logical appeal to the popularity of this method. For example, the use of new structural material for aircraft often requires the development of special cutting and forming techniques with manufacturing labor requirements that differ significantly from those based on a sample of primarily aluminum airframes.

---

[2] C. A. Batchelder, et al., An Introduction to Equipment Cost Estimating, Memorandum RM-6103-SA, The Rand Corporation, Santa Monica, CA, December 1969, pp. 2, 6-8.

Faced with this problem when titanium was first considered for use in airframe manufacture, airframe companies developed standard-hour values for titanium fabrication on the basis of shop experience in fabricating test parts and sections. Although the experience of fabricating test parts is not identical to the effort necessary to build the entire airframe, an estimate can be made by considering the similarities and extrapolating.3

Most often it works as follows. The item(s) to be produced is first compared with a recent project to determine if there are any common elements. If it is found that a significant portion of the new system is similar to the former one, the hours of effort and material expended to produced the previous item are used as a base estimate. Differences in the design and performance of the two systems are then considered. Estimates are made for these and added to the base.

The strength of the analogy method is that it can provide sufficient accuracy for the least cost in the shortest time.4 The key requirement is to ascertain the similarity of items to be compared. Therefore, the database requirement is mainly concerned with establishing an objective basis to characterize an item for analogy. This requirement is best examplified by recent Air Force

---

3 Batchelder, pp. 7-8; Joseph W. Lemire, Jr., "Cost Estimating Methods Utilized by the Defense Aerospace Industry in the Production of Technical Data, Masters' Thesis, Naval Postgraduate School, Monterey, CA, June 1985, p. 21.

4 Lemire, pp. 35-36.

attempts to establish a cost estimating model for tools.[5]

Engineering Method

The industrial engineering approach involves breaking down the system into separate segments of work. These segments are then examined in detail and estimates are made for each segment. The detailed estimates are then consolidated into a total estimate for the overall system. This method is normally used when a thorough, detailed analysis is required for all the processes involved.

The system must be relatively well-defined before this method can be used. It is often applied using a work breakdown structure (WBS) in which the system is organized in levels and each of the levels is comprised of a number of elements. A cost is estimated for each component element and totaled at each level. An overall estimate consists of the total of all the levels.

The engineering method is more expensive than analogy, requiring more time and personnel and is used most often when the data cannot be directly fitted to an analogy.[6]

Parametric Method

The parametric method is a statistical approach in which cost estimating relationships (CERs) with parametric explanatory

---

[5] See James L. Storrs, "Taking the Art Out of Tool Estimating: Business Research Report, Proceedings of 1985 Federal Acquisition Research Symposium, Defense Systems Management College, pp. 241-45.

[6] Lemire, p. 36.

variables, such as weight, speed, power, frequency, and thrust are used to predict costs. For example, in the area of airframe manufacturing, known CERs exist in terms of dollars per pound of weight, per pound of thrust, and so forth. These relationships are used with the variables of a new airframe to develop its estimated cost. This method is applied at a higher level of aggregation than the industrial engineering approach.

Worthwhile use of this method requires that sufficient data exist and that historical costs are fairly consistent for statistical analysis. In an area where there are constant changes in technology, the CERs are invalidated faster than new ones can be developed. Hence, the parametric method is difficult to apply in a case like this.

CURRENT GOVERNMENT REGULATIONS

The government published Military Standard 881A in order to standardize the process of defense material acquisition. It is a summary of the upper three levels of a work breakdown structure. A work breakdown structure is defined by Military Standard 881A as:

> ...a product-oriented family tree composed of hardware, services and data which result from project engineering efforts during the development and production of a defense material item, and which completely defines the project/-program. A WBS displays and defines the product(s) to be developed or produced and relates the elements of work to be accomplished to each other and to the end product.[7]

Military Standard 881A is to be used by both contractors and

---

[7] Department of Defense, "Work Breakdown Structure for Defense Material Items," Military Standard 881A, 25 April 1985, p. 2.

the government during the acquisition process. The work breakdown structure has become a foundation of DoD cost estimation data requirements.

In 1973, the Secretary of Defense introduced the Contractor Cost Data Reporting (CCDR) system which was intended "to maximize effective utilization of data resources... to provide the the primary database for use in most cost estimating efforts."[8] The CCDR is, by law, the fundamental cost data reporting guide for all contractors doing business with the government.

Although the Military Standard 881A and CCDR guidelines are clear, there is no systematic procedure for applying them. An examination of contractors' WBS and cost estimating relationships based upon them shows that, at the lowest level of the WBS, both analogy and parametric approaches can be found in costing the work element.

AN OVERVIEW OF CURRENT PRACTICE

To estimate nonrecurring costs associated with establishing a second source, both analogy and parametric CER methods have been used. However, government cost analysts face several difficulties under the current cost data reporting system. This section discusses these difficulties.

Difficulty of Using The Analogy Method At the Aggregate Level

---

[8] Department of Defense Instruction 7000.11, "Contractor Cost Data Reporting (CCDR)," September 5, 1973. This instruction was reissued on March 27, 1984.

The analogy method as applied here bases the second source's nonrecurring costs, especially tooling and test equipment costs, on the original producer's cost. A study by the Institute for Defense Analysis (IDA) cited the opinion of a cost analyst that the cost of special tooling and test equipment is about 80% of the amount incurred by the original source.9 But available data examined by the IDA authors do not allow generalization of this estimate. Our earlier work also found other attempts to use the analogy method for nonrecurring cost estimation.

Results from our interviews with contractors shed some light on the difficulty of using the analogy method at the aggregate level. First, the sole source or the original source supplier of a system is also the developer of the system. Some of the production tooling costs are actually incurred during the development phase (sometimes called system planning phase in contractor's WBS) and never specifically identified. Therefore, the data for nonrecurring costs are not entirely consistent with what might be incurred by a second source. Second, a study by Carrick shows that the original source's production capacity is sometimes larger than necessary.10 A second source, if determined to be desirable, is most likely to be sized to some production rate smaller than the original source.

---

9 See G. G. Daly, H. P. Gates, and J. A. Schuttinga, The Effect of Price Competition on Weapon System Acquisition Costs, the Institute for Defense Analysis, P-1435, Arlington, VA, 1979.

10 P. M. Carrick, "Estimating the Savings from Competitive Acquisitions: A Review of Previous Investigations," Chapter III of a draft Institute for Defense Analysis report, "Competition as an Acquisition Strategy: An Assessment of Selected Army Weapon System Procurements."

However, initial production start-up costs are not separated from production rate related start-up costs under the current cost data reporting system. These initial costs are driven by design considerations, while the rate-related costs are driven by the number of units. Therefore, use of the analogy method faces the built-in difficulty of noncomparable data.

Difficulty of Using Parametric CER models at the Aggregate Level

The second method commonly used by government cost analysts calls for using parametric CERs. However, parametric models are based on statistical analysis of historical data. As mentioned earlier, worthwhile use of this method requires that a sufficient data base exists and that historical costs are fairly consistent for statistical analysis. Due to the limited number of second-sourced major programs and the absence of systematic accumulation of nonrecurring cost data it should be obvious that any attempt to construct a parametric CER for nonrecurring costs is premature at this stage in time.

REQUIREMENTS FOR A PARAMETRIC MODEL

Since nonrecurring costs consist of several catagories of cost items, a parametric cost estimating model with a small number of available observations and a large number of potential explanatory variables would be unreliable, even if possible. A feasible solution is to disaggregate the nonrecurring costs into relatively homogeneous groups of cost items for data accumulation purposes.

With a consistent data base and relatively homogeneous cost items, a parametric model for each group may be constructed with a relatively small number of observations, a typical constraint in major weapon system cost estimation.

Our research effort focused on identifying the components of nonrecurring second source start-up costs, their general patterns of variation, and cost drivers. It is important to identify the cost drivers of most nonrecurring cost items, as the development of a parametric cost estimating model requires a comparable database of costs as well as cost drivers. The results of our field study are discussed in the next chapter.

CHAPTER 3

ANALYSIS OF COST BEHAVIOR OF NONRECURRING COSTS

To become a competitive second supplier the new source incurs nonrecurring costs in six areas: the preparation of bid and proposal, research and development, data management, production start-up, test and evaluation, and project management. This chapter will present research findings regarding functions typically included in each cost element and the cost estimating methods, which includes cost behavior and cost drivers, used by the contractors studied. A summary of findings and our recommendations can be found in Chapter 4.

BID AND PROPOSAL

This group of cost items include preparation of bid packages, contract bidding, and document preparation for meeting reporting requirements. Since these costs are considered to be part of future business expenses, they are included in overhead expenses and distributed across all government contracts. We found that for all contractors, the amount budgeted for a project proposal is considered a fixed cost and is determined by the analogy method.

RESEARCH AND DEVELOPMENT

Cost Components

Included in this group of cost items are engineering efforts ranging from initial design analysis and interpretation/translation

through design integration. It is important to note that the level three drawings that become government property in the technical data package are not the same as the level-three drawings maintained in-house by the first source. The original contractor is not required to reveal the processes used to translate the drawings into hardware. The level-three drawings available to the Government and the second source shows dimensions, surface finishes, and materials, but no processes.

A second source may be provided a technical data package containing level-three drawings and a system engineer to help interpret the drawings but may still have to redo everything the original source has done, except for the original development of the system. In the reinterpretation of the drawings to redevelop the drawing base in accordance with the way that second contractor does business, it can be as though it were redesign.

It should be pointed out that the research and development cost discussed in this section refers to initial design analysis, interpretation/translation, or reverse engineering. It is not the independent research and development (IR&D) covered by Cost Accounting Standard 420. The cost discussed here is typically accounted for by the second source as a part of "Design, Testing & Evaluation Engineering Labor"

Cost Estimation Method

The R & D tasks involved in becoming a competitive second source depend largely on the acquisition strategy employed by the Govern-

ment. At one extreme, the second source may be required to produce a model identical in every aspect to the sample provided by the original source, or the so-called "Chinese copy". To do this, the second source and its subcontractors must do reverse engineering. In this case the R & D costs are roughly the same as the R & D costs incurred by the first producer.

At the other end of the spectrum, the contractor can be relatively free of constraints as long as the final product is compatible in form-fit-function. This strategy allows the second source to explore some cost savings alternatives, but the savings may be offset by the additional R & D costs incurred.

The amount of material cost varies with the competition strategy and system complexity. Direct labor and overhead costs are driven by the amounts of hours for various engineering specialties. For cost estimation purposes, it is logical to estimate the number of engineering hours needed and apply the applicable labor and overhead rates to derive the total direct labor and overhead costs. Contractors' cost estimating personnel indicated that engineering hours are variable and are affected by both the complexity of the system and whether the contractor has prior experience with a similar system.

TECHNICAL DATA

Nonrecurring cost items related to technical data include technical manuals and drawings, engineering data, and data management. It should be noted that, although some separate contracts may exist

which purchase technical data, these costs are incremental, nonrecurring costs from the standpoint of second sourcing decision. Some technical data packages include clauses which prohibit the second source from altering technical manuals and drawings. In such cases, engineering changes must be proposed to and made by the first source. This process involves Engineering Change Proposals (ECP) and Engineering Change Orders (ECO). The typical cost components are discussed below.

Technical Manuals and Drawings

The nonrecurring cost items in this category include the preparation of technical manuals and maintenance support for preliminary design. Design personnel are supported by draftpersons in the preparation of drawings, parts lists, system correlation drawings, and design instructions.

These costs are considered variable; the causal factor is the complexity of the task, which determines the level of effort necessary to deliver a finished product. For cost estimation purposes, it is logical to estimate the number of drafting hours needed and apply the applicable labor and overhead rates to derive the total direct labor and overhead costs. Contractors' cost estimating methods vary, with one using the total number of drawings and another using the number of drawings to be modified. These are then multiplied by an average hours per drawing to obtain total hours.

If there is an ECO involved, cost estimation relies on a

complexity score and a schedule impact index. As an example, complexity may be measured by the range or weight of a missle. The value for the complexity score is influenced by the degree of uncertainty concerning design requirements, the level of risk due to technical advancement, whether the program is joint or single service, and whether it will be a single or multi-purpose system.

Engineering Data

Cost items in this category include the preparation of a variety of coordinating and correlating documents (e.g., drawings, plans, procedures, specifications, computer programs, and flow diagrams), corrective design, and documentation update.

As in technical manuals and drawings, these costs are considered variable; the causal factor is the complexity of the task, which determines the number of labor hours necessary to deliver a finished product. It is interesting to note that, although different classes of technical personnel are used and separately identified, no such distinction was made in computing the cost data in all supporting documents we examined accompanying contract proposals. Only the total number of direct labor hours are used in cost computation. This rudimentary method seems to be an accepted practice. Therefore, it seems to be logical to group cost items related to technical manuals and engineering data into a single element. This grouping is advantageous for parametric model building and estimation purposes. However, for budgetary purposes, these costs may need to be separately reported.

Data Management

Tasks such as maintaining master documents at the latest approved revision level, assuring that all data items are prepared and submitted in accordance with contract requirements, and monitoring subcontract data are included in this cost element. For one group of contractors this cost element was treated as a variable cost of total engineering labor hours. Under this circumstance, this cost element can be grouped with the preceding two cost elements. For another group of contractors, data management cost was estimated on a per Contractor Data Requirement List (CDRL) item basis. It should be noted, however, that the number of CDRL items can be an alternative measure of the complexity of a system, since more tracking of business/financial items may be required for a more complex system. Therefore, it is reasonable to conclude that, although different measures have been used as cost drivers for technical data handling, these different measures all reflect the degree of complexity of the system.

PRODUCTION START-UP COSTS

Nonrecurring costs incurred by the second source in production start-up generally fall into one of three categories: tooling, production engineering, and buildings or facilities. Test equipment will be treated in the following section.

Tooling

Tooling equipment needed to produce the contract item is included

in this cost element. It should be noted that some contractors distinguish initial tooling from rate tooling, but some do not. As we noted above, initial tooling costs tend to be driven by design and complexity considerations while rate tooling costs tend to be driven by the number of production units. However, separation into these two categories is not necessary in concept if both cost drivers are available for model building. All contractors stressed that production phase special tooling equipment is not directly charged to the government at the outset. However, the cost to the government remains the same, as this cost item is charged to the government through amortization. Alternative policies merely change the form of recoupment from the government for these expenditures.

Labor and labor related costs account for most of the cost items in this cost element. Material costs include purchased tools or tool manufacturing material if the tool is made in house. This presents a problem for forecasting purpose, as making the tool in-house increases labor costs but decreases the cost of tool purchases. Tool manufacturing material was typically estimated according to tool manufacturing and tool proofing labor hours based on prior history.

The major factors affecting labor estimates are the complexity of the system and the production rate. It is apparent that the former is more related to the initial tooling and the latter is related to rate tooling. In most cases, the distinction between initial tooling and rate tooling is not made. Where the distinction

is made, a rather crude method is used by the contractor to project nonrecurring tooling costs. The nonrecurring ramp (to increase monthly rate) is treated as variable dependent on quantity and rate. A ratio of dollar increase to rate increase is calculated by using prior experience, and this delta factor is applied to prior costs.

Production Engineering

The original industrial engineering efforts to translate design into an efficient manufacturing technique (for example, redesigning plant layout and operations planning) are included in this cost element.

This cost element is estimated by determining the engineering hours on the basis of the level of effort required. Therefore, the real driver is the complexity of the system involved. In this case, it is clear that the complexity of the weapon system is serving as a proxy for the complexity of production of the system. In cases where this is not true, production complexity will have to be treated directly.

Buildings or Facilities

Unless the program is going to be a long term effort, no new facilities will usually be built. Contractors track existing programs to see when they will terminate and what facilities will become available for the new program. Therefore, the cost items involved are primarily related to conversion of existing facilities

and construction of special facilities.

The cost is estimated by the number of square feet of floor space adjusted for the level of effort required to modify it. The the level of effort requires a surrogate measure, such as the degree of similarity between the existing program and the proposed new program. The number of square feet of floor space required is variable, depending on the production rate desired.

TEST AND EVALUATION

Nonrecurring costs incurred by a second source in test and evaluation include first article test quantities, test equipment, and related engineering costs. Cost items included in this element exhibit two kinds of cost behavior: variable cost and fixed/variable cost.

Variable costs include assembly and test labor and materials. These cost items clearly are related to the quantity of test items. For comparison across programs, however, one must add another explanatory variable, complexity of the system.

Fixed/variable costs, which are both time dependent and quantity dependent, are also affected by the complexity of the test and test equipment. Cost items included in this category consist of hardware as well as engineering support costs.

In the case of quality assurance, engineering inspection is estimated as a percentage of the number of hours required to build test units. Receiving inspections are factored against total engineering material.

PROGRAM MANAGEMENT

Included in this cost element are program planning and technical direction, system engineering, administrative support, procurement planning, liaison with the government, preliminary design reviews, systems requirements review, management support, subcontract selection and coordination, scheduling, and cost analysis.

Cost estimation depends upon the structure of the program management effort. In the pure or functional program management structure all resources, personnel and material, are dedicated to a specific program. Contractors view this cost element as mostly fixed and use past experience with similar programs.

In a matrix program management structure, personnel in the organization may work on a variety of projects and material resources are drawn from a shared pool. In this case, labor estimates are variable and estimated on a labor hours basis according to prior experience with similar programs. In essence, the degree of complexity determines the labor hours.

FIRST SOURCE COSTS

In developing a competitive environment, technical transfer to and coordination with the second source are the two areas in which nonrecurring costs accrue to the original source of supply.

Technical Transfer

There are two types of nonrecurring costs in technical transfer. These are the costs of the engineering task of preparing a technical

data/reprocurement package and the costs of production of hardware, for example, missiles. Missile hardware in various stages of completion and special test equipment are transferred to the second source to assist in the learning process. Note that the hardware involved is the training version which differs from the tactical unit in that the tactical unit warhead, rocket motor, and hydraulic actuation system are replaced with a ballast, a signal processor, and a tape recorder unit with cartridge loading capability. In some cases, however, for cost estimation purposes, no distinction is made between the two versions since the cost of the deleted items is not significantly different from the cost of the added items.

The data/reprocurement package cost estimation is done by experienced engineering staff based on manhours, much as the preparation of technical manual and drawings discussed earlier in this chapter. The missile hardware costs are variable. The total cost of labor and material are driven by the quantity supplied as well as the complexity of the system.

Coordination

Coordination with the second source is primarily the task of training and supporting the second source's engineers. The costs involved are primarily travel expenses and labor costs.

Cost estimation is based on the time required which is related to the quality/experience of the engineers as well as the adequacy of the data package.

CHAPTER 4

SUMMARY OF FINDINGS AND RECOMMENDATIONS

This study was designed to examine the nature of nonrecurring cost items and develop systematic procedures for the government and contractors to follow in order to generate a database of nonrecurring costs which is both consistent and comparable. The objective was to develop a method for generating an analyzable set of data for parametric estimation of nonrecurring costs.

This study relies heavily on first-hand data gathering. Five missile system contractors were visited. Individuals interviewed included cost-estimating specialists, financial managers, program managers, contract managers, and engineering/technical division managers. Cost estimation documents supporting contractors' proposals were examined to determine the cost estimation practice and identify relevant cost drivers.

SUMMARY OF FINDINGS

In Chapter 2, we have shown that, given current practices of cost reporting, it is impractical to develop a viable model for estimating nonrecurring costs when second sourcing is contemplated. The analogy method at the aggregate level has been shown to be unreliable. The development of a parametric CER model, however, requires a sufficient data base which is not currently available. To develop such a data base, knowledge of major nonrecurring cost categories and their cost drivers is necessary. Exhibit 1 summarizes

the results of our endeavour for this purpose. It contains the cost elements discussed in the previous chapter, measures of the cost elements, whether that particular element is fixed or variable, and the cost drivers for that element. Relative sizes for the major groupings of cost elements are discussed in our previous report.11

A few notable observations should be mentioned. First, it is necessary to separate nonrecurring material costs from labor and overhead costs for estimating purpose. The main reason is that the cost drivers for each are not always the same. Lumping material and labor costs together requires adding more explanatory variables to a CER model, which would quickly exhaust the degrees of freedom because of the limited database for major weapon systems.

Second, parametric CER models for nonrecurring labor costs must be based on labor hours, not on labor dollars as some cost analysts do now. There are several reasons for this. For one, all contractors interviewed indicate that they estimate anticipated manpower levels (in labor hours) required to support the contract before they cost it. For another, although different types of engineering elements are distinguished in the Work-Breakdown-Structure, all engineering hours for a given work element are grouped together for costing purpose. Furthermore, different contractors have different labor and overhead rates, which would cloud the development of CER models if labor dollars are used as the dependent variable.

Third, the most important explanatory variable that needs to

---

11 Boger and Liao, September 1985.

be operationalized is the complexity of the weapon system. Most of the manpower needed is variable and is driven, according to contractors, by both labor hours and complexity. When prodded to define how this is predicted, contractors' cost estimating personnel typically indicated that they use the analogy method if the firm has prior experience or a commercially available model which uses several relatively subjective inputs (such as complexity) if a task is new. One can infer that "prior experience" was most likely the result of using such a model when the firm performed a specific task for the first time. Note that the use of such a model requires calibration of the model according to the complexity level of the item. Therefore, defining the complexity level of a system in objectively measurable terms is of paramount importance if a reliable parametric CER model for nonrecurring cost is to be developed. In fact, most contractors have used certain surrogate measures for complexity level, such as the number of Contract Data Requirement List items, the number of drawings, etc.

COMPLEXITY AND ITS MEASUREMENT

Throughout Chapter 3 the complexity of a weapon system is repeatedly mentioned as the main cost driver. Picking those particular variables which can precisely measure the complexity of a missile system is a difficult task, since little, if any, work has been accomplished in this area. Therefore, we propose that several variables be examined for their adequacy in generating good cost estimating relationships. Subsequent to this exploratory examina-

tion, requirements may be more closely focused on those variables which yield the best results.

The candidate variables which we propose are analogous to surrogate measures of aircraft complexity, i.e., range of the missile, speed of the missile, weight of the missile, and weight of the guidance and control section of the missile. That each of these variables might serve as a proxy for complexity under certain conditions is quite clear. Which one or two of these is best under all, or almost all, conditions is an empirical question which cannot be settled until data are available.

RECOMMENDATIONS

Apart from responses to our interview questions, much of our information about the behavior of nonrecurring cost items comes from supporting documents accompanying contractors' proposals. Therefore, implementing a modified cost reporting system to facilitate the development of a parametric CER model for nonrecurring cost would not be a major task.

Two major pieces of information are missing from current contract proposal supporting documents that are needed to develop a consistent database for statistical analysis. The first is the breakdown of costs and labor hours according to the major cost elements outlined in Chapter 3. The second is data on explanatory variables, the cost drivers.

The cost breakdown available in the supporting documents accompanying contractors' proposals typically follows the Work

Breakdown Structure which does not distinguish between recurring and nonrecurring costs, because the Work Breakdown Structure is based upon work elements and not costs. If the breakdown of costs and labor hours according to the major cost elements outlined in Chapter 3 is to be accomplished, it requires only regrouping of costs and labor hours already available to the contractor.

Our recommendation is that material and labor costs should be separately reported. The main reason is that separate CER models must be developed for each, one with material cost in dollars as the dependent variable and another with labor hours as the dependent variable. The labor hours can then be used as the basis for estimating labor and overhead cost according to each contractor's labor and overhead rates structure. The secondary reasons for separate CER models are that cost drivers for each are not always the same and that separate models would require fewer explanatory variables, a major consideration when the database is limited.

Defining the complexity level of a system holds the key to developing viable parametric CER models for nonrecurring costs. The RCA/PRICE model and the Air Force's tool cost estimating model are the prime examples of using complexity level as the explanatory variable. The cost drivers for tooling and test equipment costs developed by Naval Weapon Center in China Lake include per unit hardware cost as well as production rate.[12] The conventional method for estimating hardware costs typically takes into consideration

---

[12] Advanced Intercept Air-to-Air Missile (AIAAM) Life Cycle Cost Estimates (U), Naval Weapons Center, Code 081, NWC TM 4899, September 1982. (C)

the capability of the system via inclusion of physical or performance characteristics of the system. For example, aircraft and missiles typically use some measures of speed, range, etc. It may be logical to examine the feasibility of using capability as a measure of the complexity of a system. The production rate variable was confirmed in our study as a major cost driver. However, we believe that the China Lake CER model would have been more reliable had they estimated materials cost and labor hours separately.

Exhibit 1

Major Nonrecurring Cost Elements and Cost Drivers

Cost Elements	Measure	Cost Behavior	Cost Drivers
A. Bid & Proposal:	(Included in contractor's overhead expenses)		
B: R & D:			
Material	$	Variable	Complexity, methods of second source development
Labor and overhead	hrs.	Variable	Complexity, prior experience
C: Technical Data:			
Technical manuals/drawings	hrs.	Variable	Complexity, # of drawings, # of drawings to be modified
Engineering data	hrs.	Variable	Complexity
Data Management	hrs.	Variable	Complexity, # of CDRL items
D: Production Start-Up:			
Tooling (initial)	hrs.	Variable	Complexity
Tooling (rate)	hrs.	Variable	Production rate, predetermined ramp ratio
Production engineering	hrs.	Variable	Complexity
Facility conversion	s.f.	Variable	Level of efforts depends on similarity to previous program
Special construction	s.f.	Variable	Production rate
E: Test and Evaluation:			
Hardware- Labor	hrs.	Variable	Quantity of test items, complexity
Material	$	Variable	Quantity of test items, complexity
Quality assurance	hrs.	Variable	Fabrication hours, engineering material
F: Program Management:			
(functional structure)	hrs.	Fixed	Past experience
(matrix structure)	hrs.	Variable	Complexity
G: First Source Cost:			
Technical Transfer- Data	hrs.	Variable	Complexity
Hardware	$	Variable	Complexity, quantity supplied
Coordination	$	Variable	Experience of engineer & adequacy of data

DISTRIBUTION LIST

Agency	No. of copies
Defense Technical Information Center Cameron Station Alexandria, VA 22314	2
Mr. James Weathersby Code 524 Naval Air System Command Washington, D. C. 20361	1
Mr. Tom Gilbride Code 524 Naval Air System Command Washington, D. C. 20361	10
Dr. Dan Nussbaum Naval Center for Cost Analysis Washington, D. C. 20350-1100	1
COL Robert Skipp Air Force Business Research Management Center Building 125, Rm. 2063 Wright-Patterson AFB, OH 45433-5000	1
Director Air Force Cost Center (AFCCE) c/o HQ USAF/ACC Washington, D. C. 20330-5018	1
Dr. Robert F. Williams Director Army Procurement Research Office Ft. Lee, VA 23801-6045	1
Dudley Knox Library, Code 0142 Naval Postgraduate School Monterey, CA 93943	2
Office of Research Administration Code 012 Naval Postgraduate School Monterey, CA 93943	1
Professor Dan C. Boger Department of Administrative Sciences Naval Postgraduate School Monterey, CA 93943	10
Professor Shu S. Liao Department of Administrative Sciences Naval Postgraduate School Monterey, CA 93943	10

END

9-87

DTIC