FORSCOM HANDBOOK
FOR
COST AND PRICE ANALYSIS

FY 00
FORCES COMMAND
DCS FOR LOGISTICS

CONTRACTING DIVISION
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Purpose of the Manual

Accountability for use of public resources is one of the Government's primary mandates. Consequently, the total cost to the Government for goods and services must always be a substantial factor in selecting sources for Government contracts, even when employing “best value” methods. For that reason, justification of prices paid for goods and services is often complex and always critical. Cost and price analyses are extremely important information because they shape the determination that the Government is getting fair value for its dollars spent.

The purpose of this manual is to give the contracting professional a solid underpinning of knowledge about cost, price and value analysis, and to provide a number of concepts and tools intended to ground the beginner and refresh the knowledge of the experienced practitioner. The index at the back provides a topical guide to the major concepts.

The Tools of Cost and Price Analysis

There are many factors in determining the reasonableness and realism of prices offered for goods and services. These include quality, reliability, endurance and maintainability; economic order quantity; performance schedule, "life cycle" costs; and data rights. The contracting officer has a number of tools with which to assess costs, prices and value offered. These include the disciplines of cost accounting, engineering, quality assurance, financial management, economic analysis, and management science.

Bridging the statutory mandate for fair prices on the one hand and this profusion of business disciplines on the other, is the regulatory framework of acquisition. The heart of this framework is the application of prudent business practice and economic principles to the task of Government contracting. The intent is to harness the carrot of the profit motive (insofar as possible) and the stick of Government authority (where given and necessary) to assure that the Government receives quality goods and services, where and when desired, in the quantity needed, at the fair market value.

The Terminology

There are a few terms that everyone connected with Government procurement will hear quite often in his or her career – sometimes used incorrectly. They are part of the key vocabulary of pricing, and a thorough understanding of them is a critical part of procurement training.

Fair and reasonable price. The term may be "defined" by trying to point out some of what it does and does not mean:

- It does not mean necessarily the lowest price obtainable anywhere. In a competitive procurement the lowest price obtainable from a technically capable, established, financially sound offeror who can reasonably be expected to meet the Government's needs and objectives is presumed fair and reasonable. Where competition is not effective, or where best value is the determining factor, establishment of price reasonableness becomes more difficult and analytical. The highest offer may not be unreasonable for the quality offered, and the lowest offer may not be reasonable in the sense of realistic or in terms of the level of quality offered.

- It does not mean a price that is "fair and reasonable" in a one-sided sense. A fair and reasonable price is one that is acceptable to both parties, that both can live with.

- It does mean a price or pricing arrangement that harnesses the profit motive to incentivize quality performance and cost control.

Pricing arrangement. The Government has available a spectrum of contract pricing arrangements, each of which has characteristics suitable to different acquisition phases or situations. These range from "flavors" of cost-reimbursement to firm fixed price. While it is beyond the scope of this introduction to discuss the types in detail (see Part 3), some basic pricing principles can be taught by highlighting certain characteristics:

- The closer a contract type comes to reimbursing the contractor for all legitimate costs generated ("incurred"), the less incentive there is for controlling costs. The closer it comes to a firm fixed price, the more the profit motive exerts pressure for cost control.

- In principle the Government, as a prudent buyer, puts as much cost risk on the contractor as he will bear and rewards him proportionately through the size of the fee or profit margin. In the full spectrum of contract types the contractor's share of cost risk varies along a continuum from nearly zero to total risk.

- Technical and performance risk are key considerations in estimating the magnitude of cost risk and in developing a pricing arrangement that will insure good performance and success in meeting the Government's objectives. We examine this in greater detail in Part 3.

Adequate competition. A relative term, this one easily lends itself to "sacred cow" reactions that make "sole source" a dirty word in every situation. In an economic sense, competition is a matter of the degree to which certain conditions prevail in a purchasing transaction:

- Many buyers and sellers, each with little or no influence over market price
- Full market knowledge by all buyers and sellers
- Identical product from all sellers
- Easy entry into, and exit from, the market

To the extent that one or more of these conditions is absent, the competitive forces that result in prices agreeable to both buyer and seller become increasingly ineffective. In the situation of the Department of Defense, as a single buyer of goods and services that are often complex, specialized or unique, the number of sellers is sometimes relatively small. In addition, the Government may have inadequate information about the market. Therefore, we usually cannot speak of competition in the ideal sense, so we speak of “adequate competition.”

The Federal Acquisition Regulation (FAR) gives some working criteria for determining whether "adequate" price competition exists. Adequate competition enables the presumption that the lowest price from a responsive, responsible offeror is the best obtainable in the given situation. These criteria are stated in FAR 15.403-1(c)(1).

Negotiation. Negotiation has two meanings in the sphere of Government contracting:

- In a general sense it is the total process of procuring by other than sealed bids.

- In a more specialized sense, it is the process of coming to mutual agreement on the terms and conditions of a proposed contract, especially price or pricing arrangement.

- These can become confused in the mind of the practitioner. For example, one is under negotiation as a procurement process even if one eventually decides after receipt of proposals that there is no need for a negotiation in the second sense.

Price analysis. This is analysis of a price or prices offered, without regard to the costs and profit/fee that make up the price(s).

Cost analysis. This is analysis of the costs and the fee or profit that make up the offered price. We bring various analytic tools to bear to assess the allowability, allocability and reasonableness of each proposed cost (for details see Part 2).

Value analysis. This term refers essentially to the determination implicit in a cost-benefit analysis: given the cost, is it worth it to us? It is important enough an idea to warrant more extensive discussion, which we give later on in this part.

Now that we have a basic grasp of some key ideas, we will look at the discipline of price/cost analysis.

The Discipline of Price/Cost Analysis

INTRODUCTION

Some form of cost or price analysis is required for every procurement. The dollar value, complexity and circumstances of the proposal(s) determine the extent of the analysis [FAR 15.404-1(a)(1)]. Even in sealed bidding, we perform price analysis in determining the low acceptable bid.

Cost or price analysis, to fulfill its purpose, must be based on objective information, scientific analytic methods, expertise, and sound judgment. There is no room for gut level feeling, bias, expediency, and shooting from the hip.

The analysis must be fully spelled out. No one can read the mind of the one doing the analysis. Therefore anyone not familiar with the procurement must be able to follow what has been done to arrive at the conclusions given. Figure 1-1 shows what the documentation must explain:

Figure 1-1

Documenting the Analysis

- Background
- Data Sources
- Assumptions
- Methodologies and limits
- Issues Identified
- Results - fixed value or range
- Available alternatives, if any

- The background pertinent to the analysis including the resource and regulatory constraints involved,
- The sources of data for the analysis,
- The assumptions made for the analysis, where information is lacking, and the basis for them,
- The methodologies used in analysis, and any special limits or uncertainties in the analysis,
- The issues identified by analysis,
- The results of analysis expressed as a fixed amount or range of values, as appropriate, based on the uncertainties and limits inherent in the methodologies or data used, and

- Available alternatives, if applicable.

Prices submitted by a sole source contractor who clearly perceives his status are normally those of a monopolist. In the commercial world, a monopolist uses the law of supply and demand to manipulate prices by manipulating quantity offered. In the situation of sole source Government contractors, this mechanism of quantity manipulation is largely ineffective, and the sole source supplier desiring to control price must usually resort to other mechanisms, such as withholding key cost information, and stone-walling ("That's my price, take it or leave it"). These ploys are based on the perception of the Government's need for the item and lack of viable alternatives. Against them the Government negotiator has only the potential influence of higher authority; stalling tactics designed to "smoke out" the contractor's real need for the work; and when all else fails, value analysis.

Value Analysis

Implicit in every cost or price analysis is a value analysis of the proposal(s) or the negotiated result. This analysis essentially answers the question: "Knowing how much this contract is likely to cost the Government, is the expected result perceived to be worth it?" This is not entirely subjective, but depends on:

- an analysis of its importance to, or impact on, Government objectives and programs, and their relative importance;

- comparing proposed costs against available alternatives with known or estimable costs

- potential future alternatives, their feasibility and development leadtime, and whether the Government can afford to wait for a less-expensive, but not yet available, alternative; and

- potentially improved mission capabilities or long-run life cycle cost savings which may offset perceived over-pricing by a sole source contractor, as opposed to available or potential alternatives.

Figure 1-2 below puts these questions or issues into plain English.

Figure 1-2

Value Analysis Questions

- ❖ Do we really need it (mission-critical)?
- ❖ Have we got anything else as good?
- ❖ Can we get something else suitable if willing (and able) to wait?
- ❖ Are we paying for technological improvement over existing alternatives?
- ❖ Will it enhance existing capabilities?
- ❖ Will it decrease cost of ownership sufficiently to offset the up-front difference in cost?

This sort of value analysis is going on in one way or another throughout the acquisition process. In justifying a negotiated price, we are making this value analysis explicit.

Every determination of price reasonableness should ultimately take the form of a value analysis, but this is especially true under sole source conditions in which the Government has little or no leverage in negotiations. However, it is true even when the cost objective is met.

The value analysis considerations involve both qualitative and quantitative factors that have usually been looked at by requirements personnel or engineering/technical personnel. The negotiator must lean on their expertise in answering the value questions posed. These form a part of the determination of fair and reasonable price.

Sources of Information

The various methodologies used in cost and price analysis encompass the fields of cost accounting, statistics, trend analysis techniques, regression, improvement curve, economic analysis, financial analysis, and related fields. No one is an expert in all these areas, although a good analyst has some familiarity with most of them. The Government maintains staffs of experts in all these fields who can help in the tasks of analysis and price justification.

Suffice it for this introduction to point out the various specialists the Price/Cost Analyst relies on, and what they can do for him or her.

The Defense Contract Audit Agency (DCAA) maintains a staff of auditors charged with inspection of contractor cost records, accounting policies and practices, and any other systems or methodologies employed by contractors in generating cost proposals, expense records and payment requests. The analyst looks to their expertise for verification of:

- wages and salaries,
- fringe benefits,
- overheads and burden rates,
- G&A recovery rates,
- cost of capital factors,
- other rates (ADPE usage charges, for example)
- costs for which historical data is available, such as purchase order histories or vendor quotes,
- contractor accounting and estimating practices in conformity with Cost Accounting Standards and FAR Part 31.

The Defense Contract Management Command (DCMC) maintains staffs of price and financial analysts, industrial specialists, quality assurance personnel, packaging and transportation specialists, and others qualified to give input on:

- proposed labor hours (for production and service items with labor history);

- allocability and accuracy of Bills of Material;
- forward pricing/bid rate agreements; and
- contractor accounting, estimating and planning systems.

The Bureau of Labor Statistics (BLS), Department of Labor is the chief source of information on the economic fluctuation of price levels for materials, goods and labor. The BLS provides information on price level changes for all goods by industry and sub-industry in its Producer Price Indexes database. It also maintains indexes of labor rate changes by SIC code, cost of employment indexes (labor and fringe benefits) and numerous other indices of cost changes. The keyword searchable databases may be found on the Internet at http://www.bls.gov/.

Dun and Bradstreet is a primary source of financial and resources data on potential contractors. Other sources are offeror fiscal and sales reports and DCAA records.

Department of Labor wage determinations for services contracts effected by the Service Contract Act or Davis-Bacon Act can be obtained through the following web site: http://www.acqnet.sarda.army.mil/labor. This will link you to the US Army Corps of Engineers (USACE) CEALS website.

For more detailed information on various aspects of price and cost analysis consult the five volume cost and pricing reference guide set compiled by the air Force Institute of Technology and the Federal Acquisition Institute, which can be downloaded from the web site http://www.gsa.gov/staff/v/guides/volumes.htm.

Putting It All Together

By now it should be clear to the reader that price analysis, cost analysis, and value analysis are interrelated concepts. They all contribute to cost-benefit evaluation of a proposed acquisition, which is what every economic entity must do to be a good manager of its resources.

Figure 1-3 shows the "organization" of these concepts and their relationship to various other concepts, methodologies and techniques. These basic concepts and analytic tools will be dealt with in greater detail as you proceed through the pamphlet.

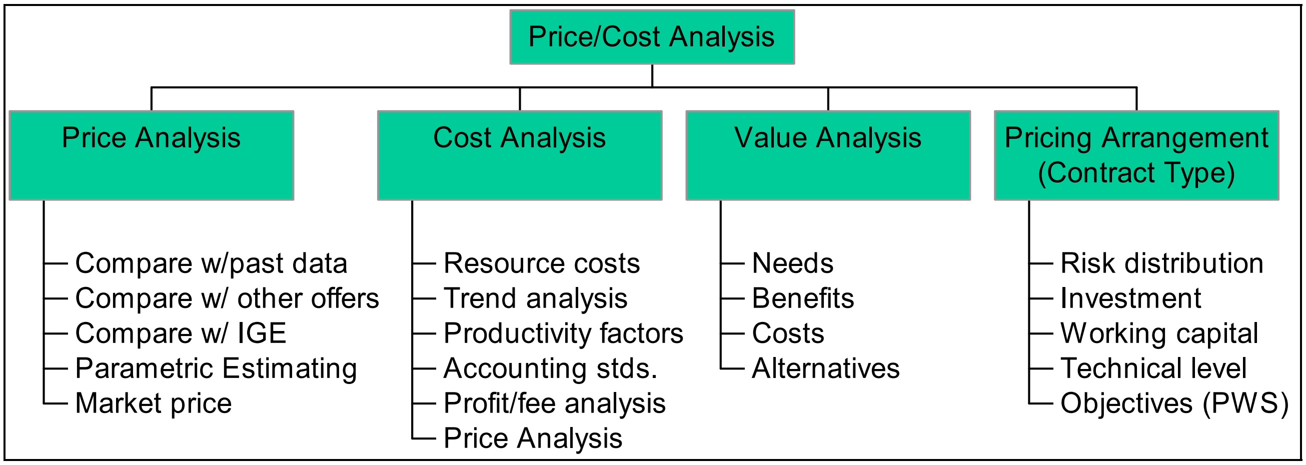


Figure 1-3 Organization of Price/Cost Analysis

This Part first introduces the terminology of cost analysis, then delves into the Truth in Negotiations Act and the issues it brings to the negotiation process. Then the policy regarding cost or pricing data is explored in depth, as well as what the Government must, may and may not do with such data. Next the requirement for, and uses of, "other than cost or pricing data" are explored. Finally, we summarize the decision process for requiring cost or pricing data.

Definitions

Cost or pricing data means all facts that, as of the date of price agreement, prudent buyers and sellers would reasonably expect to significantly affect price negotiations. As stated in FAR 15.401, *Cost or pricing data is data requiring certification in accordance with FAR 15.406-2.* Such data are factual, not judgmental, and are therefore *verifiable*. While they do not include the prospective contractor's judgment about estimated future costs or projections, they do include the data forming the basis for that judgment.

Information other than cost or pricing data means any type of information *not requiring certification* in accordance with 15.406-2 and necessary to determine price reasonableness or cost realism (defined in Part 1). For example, such information may include pricing, sales, or cost information. It also includes cost or pricing data for which certification is determined inapplicable after submission.

Cost analysis is the systematic review and analysis of available cost and pricing data and the judgmental factors applied in arriving at proposed costs. The purpose is to arrive at an informed opinion on the degree to which the proposed cost elements accurately reflect what contract performance should cost, given *reasonable* contractor economy and efficiency.

Direct costs are those costs directly allocable (assignable) to the cost objective (the job, task, process or contract). Examples are direct labor and direct material.

Indirect costs are those costs that are not directly allocable to the work done, being shared with other work. This is due to the nature of the tasks for which costs are incurred. They are tasks that transcend an individual contract. For instance, factory workers assigned to produce items under contract spend all their time on this contract and are charged as direct labor. The foremen or supervisors oversee both these workers and others working on other contracts or jobs. Therefore, only part of their time each day may be allocated to any one contract, and the amount is likely different each day and not directly assignable. So, the contractor develops a formula by which a proportional amount of the cost of supervisory labor may be allocated to each contract in a fair and reasonable degree. All such costs are indirect costs.

Allowable costs are those costs that FAR cost policy in subpart 31.2 permits to be charged to government contracts. A cost in its entirety is either allowable or unallowable. It also must be allocable, reasonable and in conformance with proper cost accounting principles.

Allocable costs are those *allowable* costs of which all or a part is properly assignable to a particular contract. A cost is allocable to the extent it can be shown to contribute to a benefit of the government under that contract. Sometimes the benefit may be indirect, but usually relates directly to a final cost objective (hardware, data or service) of that specific contract. If in doubt, consult FAR 31.201-4.

Reasonable costs are those costs that a prudent seller, under the constraint of competition, would recognize as justifiable in amount, and that a prudent buyer would recognize as a fair cost of doing business.

Price means total cost plus any fee or profit applicable to the contract type.

Price analysis refers to the process of examining and evaluating a proposed price without evaluating its separate cost elements and proposed profit or fee.

Truth in Negotiations

The first clarification that must be made concerns certification of cost or pricing data. The Truth in Negotiations Act (TINA) requires certification of, coupled with government reliance on, cost or pricing data when attempting to establish defective pricing by the contractor (see below for the definition of defective pricing).

When cost or pricing data is required the offeror must submit, ***after*** price agreement, a formal certification that he has *submitted* – not simply made available – all cost or pricing data reasonably available until time of agreement and that this data is *current, complete and accurate*.

Non-certified data ("information other than cost or pricing data") does not require formal certification. However, under TINA, failure to certify cost or pricing data does not preclude a finding of defective pricing, provided the Government establishes reliance on the data and the cost impact of the defective data.

Defective pricing essentially charges that an offeror, contrary to the assertion of its certification, possessed but did not disclose cost or pricing data that was more current, complete or accurate than that given the government by the close of negotiations. Disclosure means active presentation and explanation of the impact of the data.

Requiring Cost or Pricing Data — Policy

Federal policy regarding the requirement for cost or pricing data is set forth in FAR 15.402. Below we reproduce the policy verbatim:

15.402 – Pricing Policy.
Contracting officers shall --
(a) Purchase supplies and services from responsible sources at fair and reasonable prices. In establishing the reasonableness of the offered prices, the contracting officer shall not obtain more information than is necessary. To the extent that cost or pricing data are not required by 15.403-4, the contracting officer shall generally use the following order of preference in determining the type of information required:
(1) No additional information from the offeror, if the price is based on adequate price competition, except as provided by 15.403-3(b).
(2) Information other than cost or pricing data:
(i) Information related to prices (e.g., established catalog or market prices or previous contract prices), relying first on information available within the Government; second, on information obtained from sources other than the offeror; and, if necessary, on information obtained from the offeror. When obtaining information from the offeror is necessary, unless an exception under 15.403-1(b) (1) or (2) applies, such information submitted by the offeror shall include, at a minimum, appropriate information on the prices at which the same or similar items have been sold previously, adequate for evaluating the reasonableness of the price.
(ii) Cost information, that does not meet the definition of cost or pricing data at 15.401.
(3) Cost or pricing data. The contracting officer should use every means available to ascertain whether a fair and reasonable price can be determined before requesting cost or pricing data. Contracting officers shall not require unnecessarily the submission of cost or pricing data, because it leads to increased proposal preparation costs, generally extends acquisition lead time, and consumes additional contractor and Government resources.

The previous emphasis – based on the Competition in Contracting Act (CICA) – was that, above the stated threshold, the Contracting Officer (CO) *would* require cost or pricing data unless an exception applied. The current emphasis, based on the Federal Acquisition Streamlining Act of 1994 (FASA), is that the CO ***shall not*** require cost or pricing data ***if*** an exception applies. The first prohibition, given in FAR 15.403-1(a), is that the contracting officer shall not require cost or pricing data below the current threshold, given in 15.403-4(a)(1). Then the exceptions to the requirement for cost or pricing data are given by FAR 15.403-1(b), which can be summarized as follows: The contracting officer *shall not* require submission of cost or pricing data (but may require information other than cost or pricing data to support a determination of price reasonableness or cost realism) in the following circumstances:

- Prices are based on adequate price competition or are set by law or regulation.
- Acquisition of an item determined to be a commercial item.
- Exceptional cases where a waiver has been granted.
- For modifications to contracts or subcontracts awarded based on adequate competition, legally determined prices, or as a commercial item, and the modification does not change the item to other than a commercial item.

FAR 15.403-1(c) sets forth standards for exceptions from cost or pricing data requirements that correspond to each of the four conditions summarized above.

FAR 15.403-2 discusses other circumstances in which cost or pricing data is not required. These are: (1) the exercise of an option at the price established at contract award or initial negotiation, and (2) for proposals used solely for funding overruns or interim billing price adjustments.

FAR 15.403-4 then states the requirement for cost or pricing data "*only if the contracting officer concludes that none of the exceptions in 15.403-1(b) applies*" [emphasis added] and details the procedures for requiring cost or pricing data. *Unless an exception applies, cost or pricing data is required* before accomplishing any of the following actions expected to exceed the threshold in effect (stated in the paragraph):

- The award of any negotiated contract except for undefinitized actions such as letter contracts.

- The award of a subcontract at any tier, if the contractor and each higher-tier subcontractor have been required to furnish cost or pricing data (but see the waivers at 15.403-1(c)(4)).

- The modification of any sealed bid or negotiated contract whether or not cost or pricing data were initially required. Price adjustment amounts shall be based on the aggregate magnitude without regard to obligation or deobligation (see the example in 15.403-1(a)(1)(iii)). This requirement does not apply to unrelated and separately priced changes in the same modification.

Unless prohibited because an exception at 15.403-1 (b) applies, the head of the contracting activity may, with written justification, authorize the contracting officer to obtain cost or pricing data for pricing actions below the pertinent threshold provided the action exceeds the simplified acquisition threshold. Authorization is by a Determination and Findings (D&F).

Cost or pricing data shall be submitted on a SF 1411 unless required to be submitted on one of the termination forms specified in FAR Subpart 49.6. The SF 1411 must not be used unless cost or pricing data is required to be submitted. Contract pricing proposals submitted on a SF 1411 are to be prepared in accordance with Table 15-2 of the FAR or as specified by the contracting officer.

Requiring "Information Other than Cost or Pricing Data"

If cost or pricing data are not required/permitted because an exception applies, or an action is at or below the cost or pricing data threshold, the contracting officer is r*equired* to perform a price analysis to determine price reasonableness and any need for further negotiation.

The contracting officer shall require submission of "information other than cost or pricing data" only to the extent necessary to determine price reasonableness or cost realism. Unless an exception under 15.403-1(b) applies, the contracting officer shall obtain, at a minimum, appropriate price history for the same or similar items that is adequate for evaluating the reasonableness of the proposed price. Such information shall generally be submitted in the contractor's format (see FAR 15.403-5(b)(2)). Such data *shall not be certified* in accordance with 15.406-2.

If information other than cost or pricing data is required to support price reasonableness or cost realism, the contracting officer may require such information to be submitted using a SF 1448. Requests for information should be tailored so that only necessary data are requested. Information submitted on a SF 1448 shall be prepared following the instructions provided in Table 15-3 of the FAR.

The contracting officer must ensure that information used to support price negotiations is sufficiently current, complete and accurate.

Under conditions of adequate price competition, if it is determined that additional information is necessary to determine the reasonableness of the price, the contracting officer must, insofar as possible, obtain the additional information from sources other than the offeror. In addition, the contracting officer may request information to determine the cost realism of competing offers or to evaluate competing approaches.

The contracting officer shall, to the maximum extent practicable, limit any request for information relating to *commercial items* to information in the form regularly maintained by the offeror in commercial operations.

Cost Analysis – General Guidance

Regulatory guidance appropos to cost analysis spans several sections of the FAR :

- FAR 15.404-1(c) spells out in general terms what constitutes cost analysis.
- FAR 31.201 spells out how to determine whether or not submitted costs are reasonable, allowable and allocable.
- FAR 31.205 gives many specific examples of types of cost and their allowability.

- In cases in which the offeror is subject to Cost Accounting Standards (CAS), consult the FAR Appendix (Part 99) or seek the advice of the cognizant Defense Contract Audit Agency auditor concerning potential violations of CAS.

The Air Force Institute of Technology (AFIT) and the Federal Acquisition Institute (FAI) jointly prepared a five-volume set of Contract Pricing Resource Guides to guide pricing and negotiation personnel. The five guides are: I Price Analysis, II Quantitative Techniques for Contract Pricing, III Cost Analysis, IV Advanced Issues in Contract Pricing, and V Federal Contract Negotiation Techniques. These references provide detailed discussion and examples applying pricing policies to pricing problems. Free copies of the references are available on the World Wide Web at URL http://www.gsa.gov/staff/v/guides/volumes.htm..

Use of cost analysis triggers the requirement for use of the Weighted Guidelines method in determining a fair and reasonable profit or fee, except in those documented instances in which the regulations proscribe it or it is unsuitable to an equitable result. DoD FAR Supplement 15.9 discusses use of Weighted Guidelines in detail.

Government profit policy is elaborated in FAR 15.404. Stated succinctly, that policy is: Ultimately it is total price that is of prime concern, and not eventual realized profit. Profit should be negotiated in such a way as to harness the profit motive for cost control and for incentivizing contractors to assume greater cost risk by a commensurate reward.

Submission of Cost or Pricing Data – SF1411

The conventional method for submission of cost or pricing data is on SF1411. Although this form 'per se' is not mandatory, submitted data must in effect give all information required, in the format specified by the form.

Now, cost or pricing data by itself is not a sufficient submission. With the numbers must come a fairly comprehensive explanation of the significant facts and judgments underlying the numbers. Knowing that the offeror proposed 7,000 hours of carpenter labor to renovate a building does no good unless one knows the basis of the estimate. Once we know the rationale for the estimate it often becomes apparent what type of analysis will verify or question it.

Solicitation Specifications Regarding Cost or Pricing Data

FAR 15.403-5 – Instructions for Submission of Cost or Pricing Data or Information Other Than Cost or Pricing Data, states that the contracting officer shall specify in the solicitation (see 15.408 (l) and (m)):

1. whether or not cost or pricing data are required;
2. that, in lieu of submitting cost or pricing data, the offeror may submit a request for exception from the requirement to submit cost or pricing data;
3. any information other than cost or pricing data that is required; and

4. necessary preaward or postaward access to offeror's records.

FAR 15.403-5(2) allows the offeror to submit a request for exception to a requirement established in the solicitation for submission of cost or pricing data. FAR 15.408(l) specifies that when the contracting officer expects to require cost or pricing data or information other than cost or pricing data, the solicitation may include FAR 52.215-20, *Requirements for Cost or Pricing Data or Information Other Than Cost or Pricing Data (Oct 1997).*

The clause at FAR 52.215-20 gives offerors instructions for submitting such requests. There are essentially two bases for granting an exception:

1. prices set by law or regulation. If the price is controlled under law by periodic rulings, reviews, or similar actions of a governmental body, identify the law or regulation and attach a copy of the controlling document, unless previously submitted to the contracting office.

2. commercial item exception. For a commercial item exception, the offeror shall submit, at a minimum, information on prices at which the same item or similar items have previously been sold in the commercial market that is adequate for evaluating the reasonableness of the price for this acquisition. Such information may include --

- For catalog items, identification of the catalog and its date, or the appropriate pages for the offered items, or a statement that the catalog is on file in the buying office to which the proposal is being submitted. The offeror must also provide a copy or describe current discount policies and price lists. They must also explain the basis of each offered price and its relationship to the established catalog price, including how the proposed price relates to the price of recent sales in quantities similar to the proposed quantities;

- For market-priced items, the source and date or period of the market quotation or other basis for market price, the base amount, and applicable discounts. In addition, they must describe the nature of the market;

- For items included on an active Federal Supply Service Multiple Award Schedule contract, proof that an exception has been granted for the schedule item.

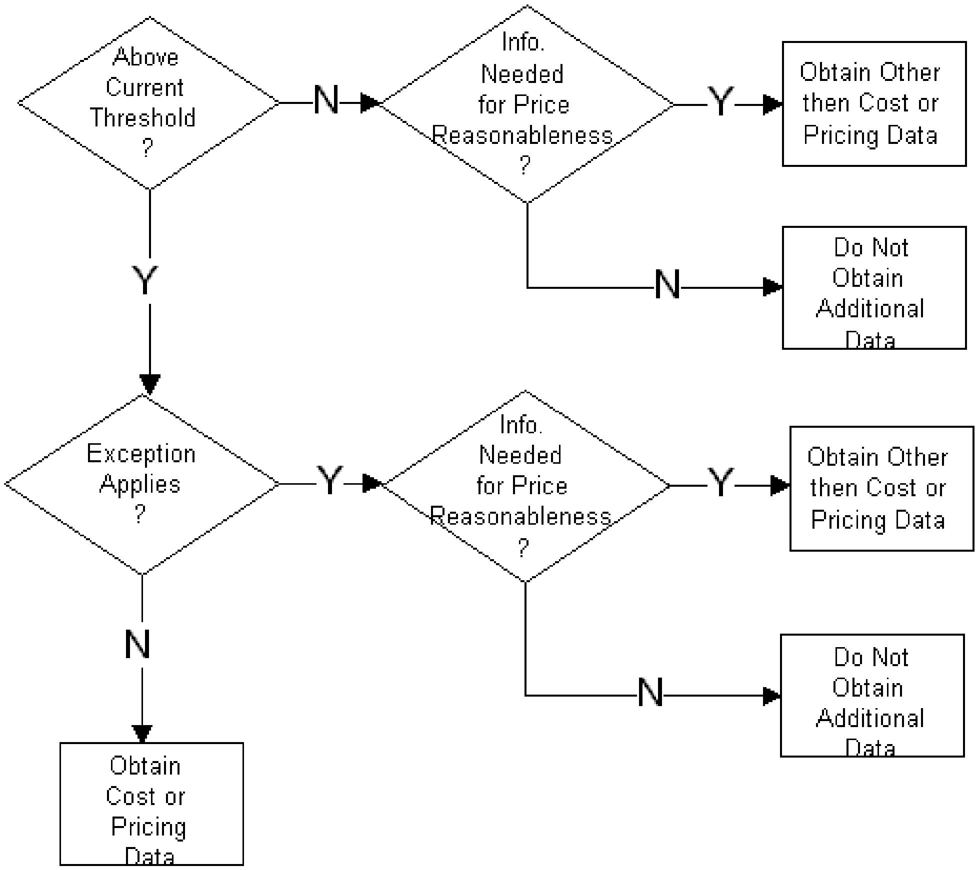
Decision Process for Requiring Cost or Pricing Data or Other than Cost or Pricing Data

The preceding narrative shows just how convoluted is the current decision process for determining whether to require cost or pricing data, information other than cost or pricing data, or no cost-related data whatsoever.

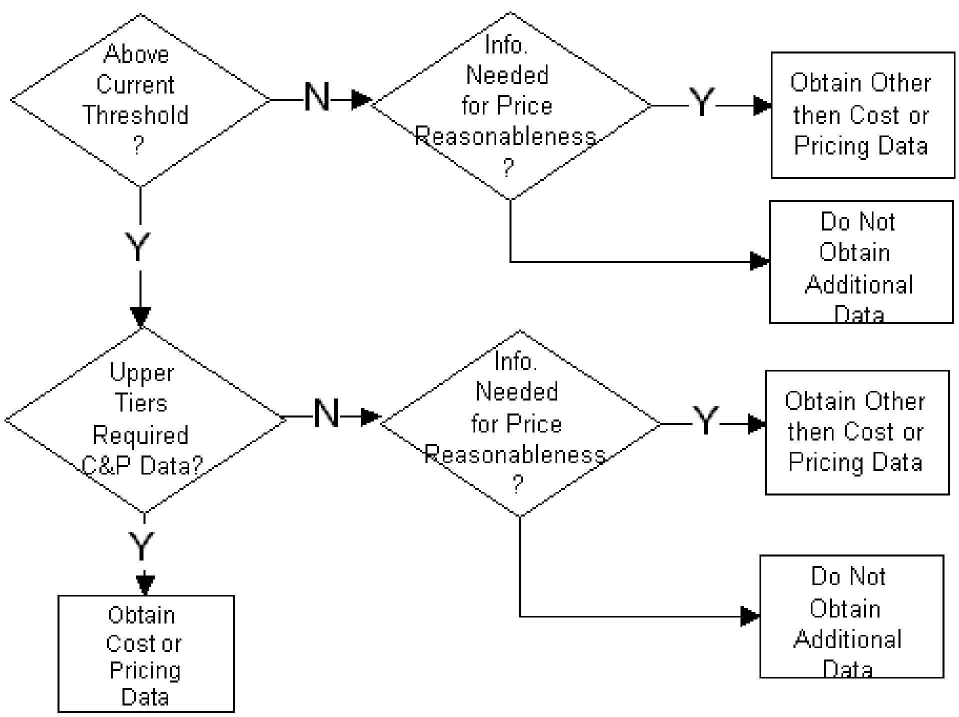
The decision flowcharts on the following pages are offered in an attempt to clarify (or at least simplify) this decision process. These are based on the narrative at FAR 15.403-1 and 15.403-3. The first flowchart summarizes the decision process for initial contracts and subcontracts. The second summarizes the process for modifications to contracts and subcontracts.

The key point to remember is that there is a requirement to obtain cost or pricing data for all negotiated contract and subcontract actions exceeding the threshold, BUT ONLY IF NO EXCEPTION APPLIES AND/OR NO WAIVER IS GRANTED BY THE HCA. When obtaining either cost or pricing data, or information other than cost or pricing data, do not obtain more data than is necessary to justify price reasonableness or cost realism.

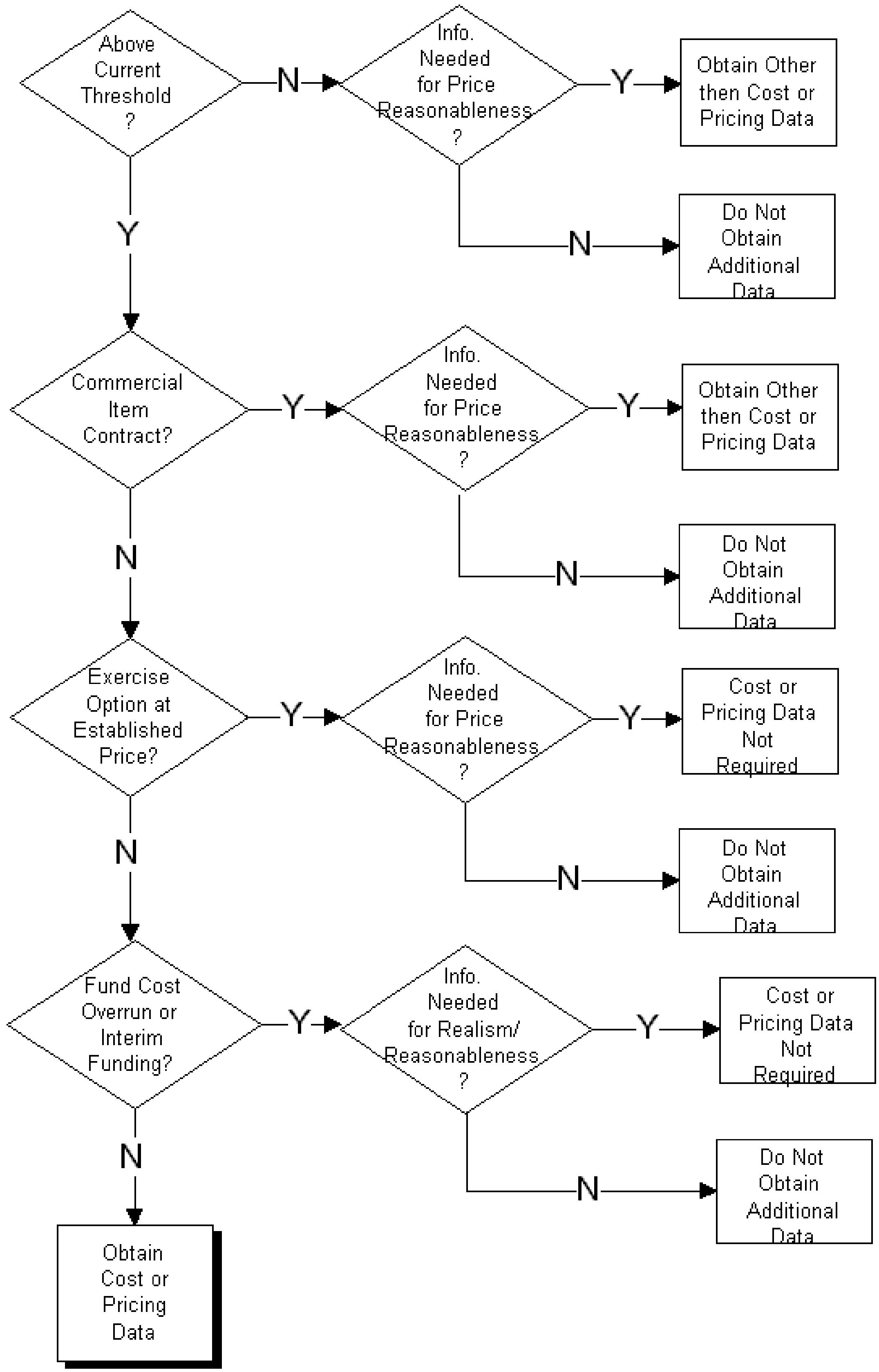
Contract



Subcontract



Modification to Contract



Why Different Contract Types?

As stated in Part 1, fair and reasonable price means a price *or pricing structure* that harnesses the profit motive to incentivize quality performance and cost control. This gives the government the maximum "bang for the buck." Different contract situations entail different ways of harnessing that motive.

Contract Type and Pricing Structure

"Contract type" here refers to the type of pricing structure spelled out in the contract. The Government has available a spectrum of contract pricing structures each of which has characteristics suited to different acquisition phases or procurement situations. This includes a range of cost-reimbursement structures and fixed-price-based arrangements.

As noted in Part 1, the closer a pricing structure comes to reimbursing the contractor for all legitimate costs incurred, the less incentive it provides for controlling costs. The Government attempts to negotiate pricing structures

- that provide as much cost control incentive as possible,
- that put as much cost risk on contractors as they are able to bear, and
- that reward them proportionately through the size of the fee or profit margin.

Under cost-reimbursement contracts the contractor's cost risk is very limited and fee amount is proportionately small. The contractor bears full risk under a firm fixed price contract, and profit margin should be commensurate. Sometimes, as previously noted, a contractor will agree to a straight cost contract, or even to a cost-sharing structure based on commercial applicability or potential market advantages.

Technical risk is a key consideration in developing a pricing structure that will insure good performance and eventual success in meeting the Government's objectives. Technical risk refers to the degree of probability that the objective is "do-able." The more advanced skills it requires, or the more it borders on the state of the art, the higher the technical risk.

Technical risk reflects itself directly in cost risk in the sense that as technical risk rises, expected costs are usually more speculative. It can also impact performance risk in the sense of being able to do the work within the contractual performance schedule. Everything else being equal, as risk increases the Government must assume more of the risk through incentive provisions or cost-reimbursement contracts. If contractors are forced to bear most of the cost risk in technically risky ventures, there will be increased tendencies to load up proposals with contingent costs and higher profit requirements to mitigate risk. This can substantially increase the total cost to the government. Incentive structure use cost sharing provisions to avoid these tendencies by sharing cost risk.

In selecting the most suitable contract pricing structure remember that the Government must:

- achieve a fair and reasonable price
- incentivize cost control without sacrificing quality and performance,
- preserve the Government's rights and leverage, and
- satisfy as much as possible contractors' business goals so that they will not leave the government market, thus shrinking the DoD industrial base.

In summary, the reason for having different contract pricing structures is that understanding the acquisition situation, and suiting the pricing structure to the situation, is the key to harnessing the profit motive for achieving the government's objectives of fair price and quality performance.

Understanding the Acquisition Situation

The government, as a buyer, procures goods and services in the marketplace. The provision of goods and services in the DoD environment, however, is a more complex and speculative enterprise than in the private sector.

- Goods and services desired are often unique, or border on the state of the art, or require characteristics or properties not found in commercial counterparts.

- Developmental leadtime may be extremely long, and costs highly speculative.

- The statement of what is desired ("Statement of Work" [SOW] or "Performance Work Statement" [PWS]) may be potentially ambiguous and susceptible to misunderstanding, may be complex and demanding, and is often susceptible to change during performance.

- Customer requirements such as delivery date are often dictated more by internal concerns than by a realistic assessment of how long performance should reasonably take.

- The government has many socioeconomic mandates it must incorporate into its contracts that have little or nothing to do with its primary objective(s) but cost money, extend leadtime, increase contractors' organizational complexity and cause them to incorporate non-business goals into their operations.

Ambiguity in the statement of work is well illustrated in the area of maintenance and overhaul of vehicles. The statement of work may be something like: "The contractor will provide all facilities, tools, test equipment, labor and expertise necessary to ascertain the condition and effect the overhaul of 100 Army half-track vehicles." There is no way the contractor can know the condition of each vehicle before inspecting it, what work needs to be done on each, and therefore, how much it will cost to do the total job. A firm fixed price contract is not feasible for these reasons:

- There is an almost total lack of specificity in the statement of work and that specificity cannot be established prior to release of the contract;

- There is minimal confidence in any estimate of cost prior to inspection or teardown; and

- Performance risk is unacceptable to both parties because the contractor must build in a tremendous amount of contingency costs or risk not being able to complete performance and end up in contract default.

Another example typical in Research and Development contracting is one in which the contractor must simultaneously prove out an incompletely developed technology, and provide the government with a working model or prototype of the resultant item. Technical risk is extremely high, cost estimates have very low confidence, and a realistic performance period may not be ascertainable.

A third example concerns a twenty-year contract for privatization of military housing, including construction, maintenance and management. Here performance risk has much more to do with economic and business uncertainties than with technical risk or lack of specificity in the statement of work. Yet it does provide cost risk to the contractor in a situation of potential long-term volatility in costs and business base.

In all these examples technical, performance or economic risk translates directly into cost uncertainty. It has long been the conventional wisdom that profit is the reward due to the entrepreneur for the assumption of risk. The oil industry experienced abnormal risk during the OPEC oil crisis of the 1970's, yet all the while there was a cry in the news media about "windfall" profits. So how much profit is reasonable for the assumption of risk? And is risk the only factor in profit?

A better understanding of the economic theory of profit will aid us in our attempt to fit the proper contract pricing structure to the particular acquisition situation.

The Theory of Profit

Economic theory looks at profit somewhat differently than business does, and the difference is important for correctly using profit as a tool in contracting.

From an accounting standpoint, profit is the residual revenue after accounting for all costs incurred by the company in producing and/or selling the item. It is the amount payable to equity capital (i.e., shareholders). But economists view profit as residual revenue after payment of all factors of production. To economists, equity capital is simply another factor of production, therefore another cost of doing business.

What businesses consider part of profits, economists consider an implicit cost. Therefore, "economic profit" means the profits left over after firms have met the expectations of shareholders for a reasonable return on investment. We might think of economic profit as “windfall” profit.

Economic theory states that in a perfectly competitive industry there are no economic profits. In other words, after all production resources are paid for and shareholders receive a fair dividend, no profits are left. The industry does not grow (without an additional injection of equity capital or debt), but it does not shrink because everyone involved is satisfied with their return on investment and they "stand pat".

But in an imperfect world, market frictions and changes in demand patterns sometimes allow economic ("windfall") profits to be made. When this happens, it draws additional resources into that industry until competition drives the price down to the point at which economic profits dry up, less efficient sellers go out of business, and equilibrium between supply and demand is restored.

Sometimes market frictions and changes in demand reduce profits to the point that dissatisfied investors sell out of that industry or business to invest in one that they feel will give a better return. Thus the industry feels a capital "pinch" and shrinks.

Naturally, all firms wish to foster expansion and avoid recession; therefore return to shareholders is of primary importance to managers and is a primary indicator of corporate success. Additionally, surplus profits are an almost cost-free source of expansion for the firm.

Investors look at the value of a firm (vis-a-vis others) as the net present value of the stream of expected profits over the investment horizon. What this means is that they want to know the value in today's dollars of their potential return on investment over a certain number of years. This is because today's dollars put in a low-risk financial instrument over the same number of years will draw substantial interest, providing a baseline return on investment with which to compare other investments.

Reducing everything to current dollars (its "net present value") allows direct comparison of investments having potentially different rates of return over different periods. Therefore, we express the value of a firm as the expected profits over *x* years, stated in terms of current dollars by applying the appropriate discount factor to each year's expected revenues and costs. (See section 6-4 for further discussion of this concept.)

Since profit is the difference between total revenue and total costs, maximization of profits requires maximizing revenues, minimizing costs, or both. This is a key to the contractor's motivation, maximizing profit either by maximizing the selling price or minimizing costs, or both.

The above strategic objectives require or include:

- Marketing capability
- Solid management
- Efficient use of resources
- Technological innovation or expansion of facilities allowing for more efficient production
- Bearing risk, and
- Legal rights in data, which can confer monopoly status or limit competition through licensing costs.

The economic theory of profit includes these considerations as an explanation of profit, specifically of economic profits.

There are two levels at which we can apply the theory of profit: selection of contract type and structuring the DoD industrial base. We will here look only at the first of these.

Applying the Theory of Profit To Contract Pricing

In measuring the appropriate level of profit or fee due the contractor, we must address four of the above factors in the theory of profit: management, efficiency, investment and innovation, and risk-bearing. This is the analytical level, analogous to "cost analysis" in terms of allowable profit.

In a more holistic sense, we must assess whether our profit or fee objective falls within the minimum return on investment expectations of investors in that industry. Otherwise, the industry will rapidly begin to find it difficult to obtain equity capital and either begin to rely too heavily on debt financing, or leave DoD business altogether. This is analogous to a "price analysis" in terms of allowable profit. It is not formalized as with Weighted Guidelines, but is an implicit part of the overall assessment of reasonableness.

This is not all there is to selection of contract type. Understanding the acquisition situation and matching it against the economic factors in the theory of profit can suggest to us whether a fixed price structure is possible, or another structure is better suited to the situation as we understand it. Here is a hypothetical scenario.

The KO has determined that the particular procurement situation involves moderate technical risk, high performance and cost risk. Performance is not at the state of the art, but requires solid expertise and continuous judgment. Cost estimates have only moderate confidence, that is, we can only give a range within which labor and material costs may fall, and there are many contingencies to be considered.

Obviously, management capability will be tested to the maximum in this scenario. Efficient use of resources will be paramount but may not be possible due to the cost uncertainties. Investment in facilities or new equipment may or may not be necessary, depending on the contractor chosen. Present facilities may be perfectly adequate but expensive to maintain. Technical innovation may not be required, but is considered likely by Government engineers to result from the effort and may carry real leverage as decreased performance costs.

Naturally, the KO wants to develop a pricing structure that integrates these concerns. Let us analyze them:

- Based on the contingencies, performance risk and cost risk, cost control will be difficult. However, there is some confidence in the range of possible costs and the government rates technical risk as moderate.

- We want to incentivize efficient use of resources, since this is one way to decrease costs.

- Additionally, we may want to capitalize on any resulting technological innovation that will reduce costs, since windfall profits may otherwise result (and we do not want to encourage windfall profits in the normal situation).

- From the contractor's standpoint, since there will be such difficulty reducing and managing costs, maximizing profit will in their view relate more to maximizing selling price. This may involve building in contingencies that hedge against risk, and we want to discourage this as a strategy. What should we do?

It would appear that some kind of incentive contract using cost control incentives would address most of the concerns of both parties. If we offer to trade higher potential profit rates for more efficient performance, and incorporate a cost sharing arrangement then both parties get what they want:

- The contractor gets reduced cost risk based on the government sharing some portion of costs incurred over the agreed to cost target, and a chance for a range of higher profits based on performance.

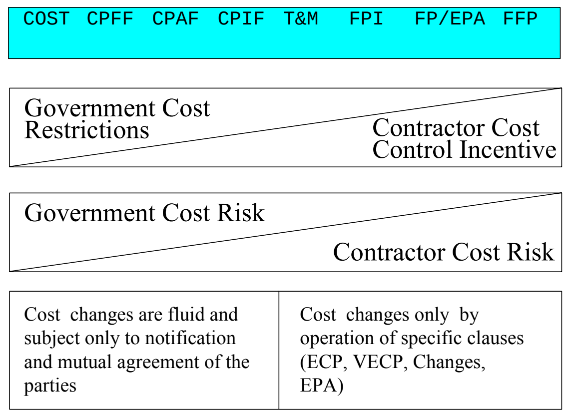
- The government has the chance to share in any cost reductions and incentivizes the contractor to the most cost-efficient performance possible.

The incentive contract can be cost-reimbursable or fixed price based on an agreement on the level of technical, performance and cost risks. The structure of the two types is somewhat different, and will be discussed in a later section.

Classification of Contract Types

Figure 3-1 on the next page classifies the basic contract types as to distribution of cost risk, level of cost control incentive, level of government cost restrictions (Limitation of Cost clause, cost ceilings, audit of cost allowability), and the degree to which contract cost may be fluid.

Figure 3-1
The Contract Spectrum



Now that we have discussed contract types in general, we proceed to discuss in detail each basic contract type as a form of pricing structure. First we discuss the types of cost-reimbursable contracts, then proceed on to the variants of the fixed price contract.

Cost-Reimbursement Contract Types

There are several types of cost-reimbursement contracts, but all share one characteristic: whatever the amount obligated on contract, the contractor will be reimbursed every penny of its "allowable, allocable, reasonable" costs *if notification requirements are met*. Obviously there is little economic incentive to control costs so as to complete the effort at or below the estimated cost.

Generally, we use such contract types when

- Cost is a secondary concern to technical or schedule concerns in source selection, and only a wide range of possible costs can be postulated with any confidence, making cost risk a primary factor.
- Level of effort required to perform the statement of work is unknown or known only in broad outline.
- Performance evaluation criteria may or may not be definable in some objective or subjective sense.
- The government bears most or all of the financial risk.

FAR 16.301-3 restricts use of cost-reimbursement contracts to those situations in the contractor has an adequate accounting system to segregate costs incurred under this contract from those incurred under all other efforts, government surveillance assures relatively efficient performance.

Let us now examine those types of cost-reimbursement contracts that require special attention. For the characteristics of the other types, see Figure 3-1 above.

<u>Cost plus fixed fee (FAR 16.306):</u>

The following must be kept in mind when awarding cost plus fixed fee (CPFF) contracts:

- By statute the amount of fixed fee cannot exceed certain statutory limitations as a percentage of cost excluding cost of money. FAR 15.404-4(c)(4)(i) prescribes these fee limits. FAR 15.404-4(c)(4)(ii) states that the contracting officer's signature on the price negotiation memorandum or other documentation supporting determination of fair and reasonable price documents the contracting officer's determination that the statutory price or fee limitations have not been exceeded.

- FAR 16.301-3 limits and procedures must be complied with to obtain authority to award this contract type. This type of contract carries the greatest amount of cost risk to the government.

- The fixed fee is not changed unless the scope of work under the contract is changed.

- The applicable clauses prescribed by FAR 16.307 must be incorporated into the contract.

The CPFF contract can assume two types: completion and term.

Under the completion type, the contractor is obligated to deliver the specified end product within the contract cost, if possible, for the fixed fee. If the contractor delivers at a cost greater than the estimated cost, we may not increase the fee, but the cost overrun is payable. Failure to progress may result in termination for default, unless technical impossibility can be asserted as a defense.

Under the term type, the contractor is obligated only to perform at a satisfactory level for the specified term, not to deliver anything. This is close to a "blank check" contract. Cost uncertainty is therefore the key to appropriate use of this type. CPFF completion contracts are suitable when the contractor is given a clearly defined goal or specific end product as a deliverable, complete performance is theoretically possible but includes large uncertainties, and a key concern is maximum flexibility for changes.

The CPFF term contract is appropriate when even specific goals and/or milestones cannot be specified, and obligates the contractor only to a specific level of effort for a specified period. To receive the fixed fee, the contractor must certify that it did expend the required level of effort for the requisite period. Renewals are new acquisitions.

Cost Plus Award Fee (FAR 16.305)

Although FAR categorizes cost plus award fee under incentive contracts, we list it here right after the CPFF contract type because it is a combination of CPFF and incentive contract. It provides for a fixed base fee of 0 to 3% – the regulatory limit on base fee per DFARS 216.405-2(c)(2)(B) – and an "award fee" portion that is not limited.

The purpose of the award fee is to incentivize specific performance levels that cannot be objectively quantified, but can be judgmentally assessed by government personnel. The amount of award fee due the contractor during or after completion is a unilateral decision of the contracting officer or other designated official, and is not subject to the Disputes clause.

A scoring scale can be incorporated into the contract tying total performance points to the specific percentage of award fee payable.

Remember that average or mediocre performance is not the intent of the incentive. Average performance should receive little or no award fee, and only exceptional performance merits the entire allocable award fee.

Although the scaling can be directly proportional (i.e., linear), a scale with an accelerating rate of profit for higher performance can increase the incentive. Figure 3-2 is the graph of such a schedule in comparison with a proportional (linear) scale; the non-linear scale pays less for average performance (60 - 80) and more for above-average to exceptional performance (81 - 100).

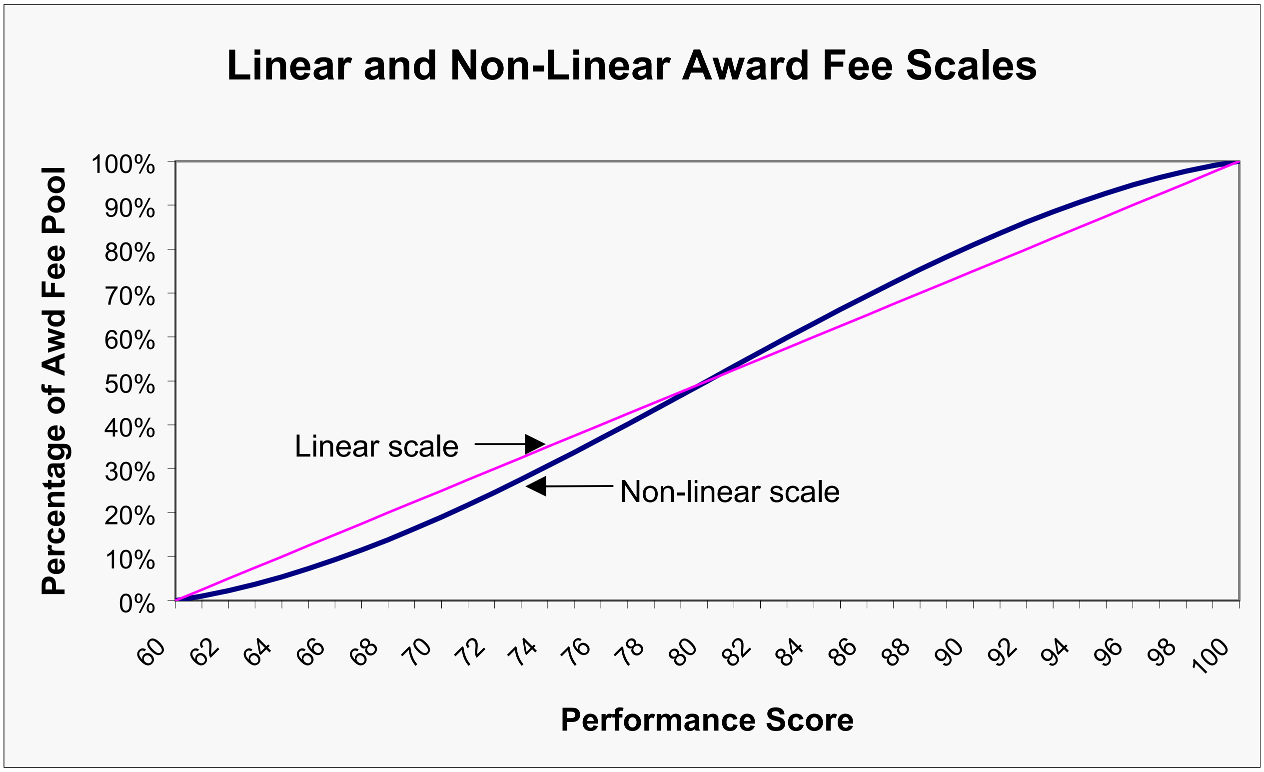


Figure 3-2

FAR 16.301-3 limits and procedures must be complied with to obtain authority to award this contract type.

Do not change the fee structure unless the scope of work changes.

The applicable clauses prescribed by FAR 16.305 must be incorporated into the contract.

Per DFARS 216.470 the award fee approach is appropriate for use with other contract types, including fixed price contracts, when specific performance objectives cannot be quantified adequately, but where an incentive based on subjective evaluation criteria is felt to be of benefit to the government, and the additional administrative expense is justified. Note that DFARS forbids base fee in other contract types (216.470(2)).

<u>Cost Plus Incentive Fee (FAR 16.304)</u>

The Cost Plus Incentive Fee (CPIF) contract provides for a target cost and a target fee. A maximum fee and a minimum fee are also established along with a formula for sharing the cost outcomes above or below the target. The contractor share is added to or deducted from the target fee as appropriate.

Regardless of the outcome, the fee paid may not exceed the maximum nor fall below the minimum.

The minimum and maximum fees are usually established at the agreed-to high cost estimate and low cost estimate, respectively.

Figure 3-3 gives an example of a CPIF contract sharing arrangement.

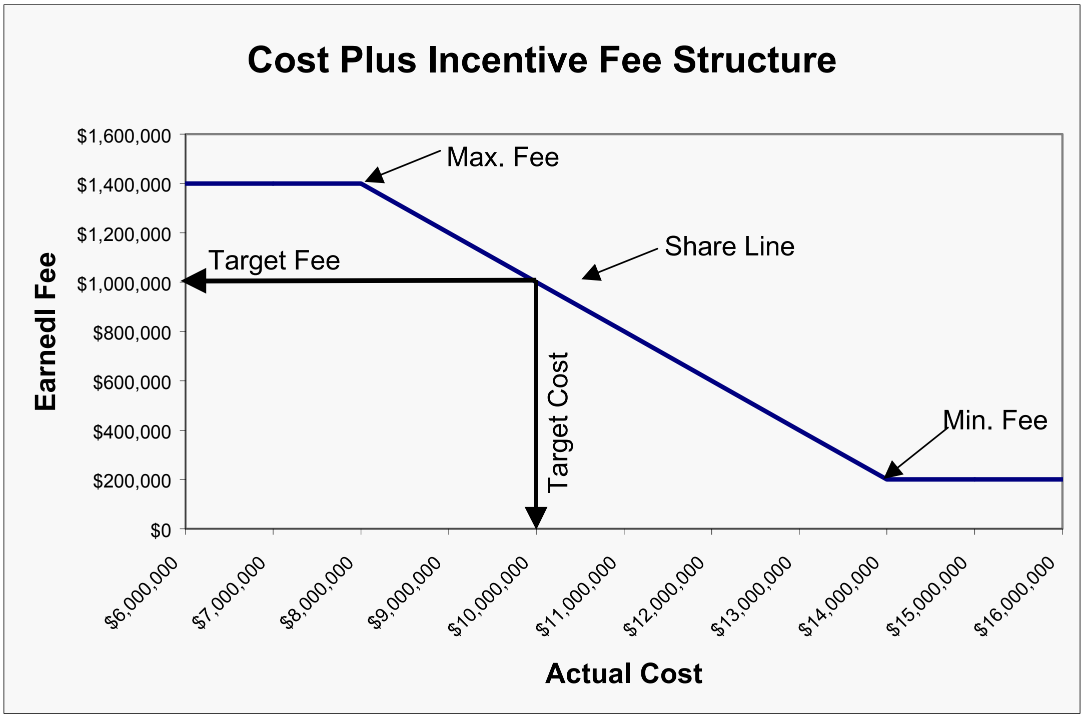


Figure 3-3

In the example the target cost is $10,000,000 and the target fee is $1,000,000 with a minimum fee of $250,000 and a maximum fee of $1,400,000. This defines an 80/20 share line. At any point on the share line down to the minimum fee, the contractor's target fee is reduced 20% of the difference between the actual cost and the target cost. The government picks up the other 80% of the overrun (100% after reaching the minimum fee). This can be shown mathematically as follows:

$$\text{Ktr. share} = \frac{\$1{,}400{,}000 - 200{,}000}{\$12{,}000{,}000 - 6{,}000{,}000} = 0.2 = 20\%$$

The Government's share is 100% less contractor share (80%).

Similarly for a cost underrun, the contractor has 20% of the difference between actual cost and target cost added to the target fee until it reaches the maximum fee. The government receives the 80% savings (100% after maximum fee) as a cost avoidance.

Any distribution of cost risk (i.e, share line) from 99/01 to 01/99 is possible. Additionally, mi.nimum fee can be $0 or even a negative percentage if warranted.

As discussed in FAR 16.402, other aspects of performance besides cost control can be the subject of an incentive structure. A multiple incentive structure is possible, but is exceedingly complex to construct and administer.

FAR 16.301-3 limits and procedures must be complied with to obtain authority to award this contract type.

You are not permitted to change the fee structure unless the scope of work under the contract is changed.

The applicable clauses prescribed by FAR 16.307 must be incorporated into the contract.

The CPIF contract is appropriate when contract uncertainties are primarily technical and can to some extent be identified and quantified. It is preferable to the CPFF when uncertainties preclude use of a fixed price instrument but cost risk is not severe enough to warrant a CPFF contract type.

Fixed Price Contracts (FAR 16.2)

Under fixed price contracts the burden of cost risk shifts almost completely to the contractor. This is because under this type of contract, the contractor will not be reimbursed all incurred costs. Whatever the eventual cost outcome, the contractor will be paid the agreed upon price unless the extra costs were due to increased scope of work.

Whereas under cost-reimbursement contracts the contractor earns a fee, under fixed price contracts profit results from any difference between the contractual price and the actual costs incurred in performance. The contractor can therefore wind up in a loss position under a fixed price contract.

<u>Fixed Price Redeterminable (FAR 16.205, 16.206):</u>

This type of contract is almost never used currently due to the disincentive it generates to control costs, the administrative difficulties in its use, and negotiation problems experienced in the past. See the above FAR coverage for use, limitations, and clause prescriptions regarding this contract type.

<u>Fixed Price Incentive (FAR 16.204)</u>

The fixed price incentive structure is similar to the CPIF structure, with the following exceptions:

- The target price is a firm price, so the contract is not subject to the Limitation of Cost clause;

- The ceiling price, an amount above which the government will not usually pay, controls funding.
- The target cost is the anticipated outcome, not just one in a range of possible outcomes.
- There is no ceiling or floor for profit.
- Like the CPIF type, there is provision for a sharing arrangement, or share line, for cost overruns and underruns.

A peculiarity that sets this type of contract apart from any other type is the "Point Of Total Assumption" or PTA. This is a provision by which, after a certain cost level, the government no longer shares a portion of any overrun. Thus at the PTA the contractor assumes full cost risk.

This point arises due to the operation of the sharing arrangement. If the government were to share in overruns until the point at which the contractor's profit is zero, the contract could actually cost more than the established ceiling price. Therefore, there must be a "break" in the share line such that profit reaches zero at the ceiling price.

This point at which the share line "breaks" is the PTA, and the share line from the PTA to the ceiling price is 0/100. This means that from the PTA the contractor loses a dollar of profit for each additional dollar spent. Figure 3-4 on the next page shows a FPI firm target structure with an 80/20 share line.

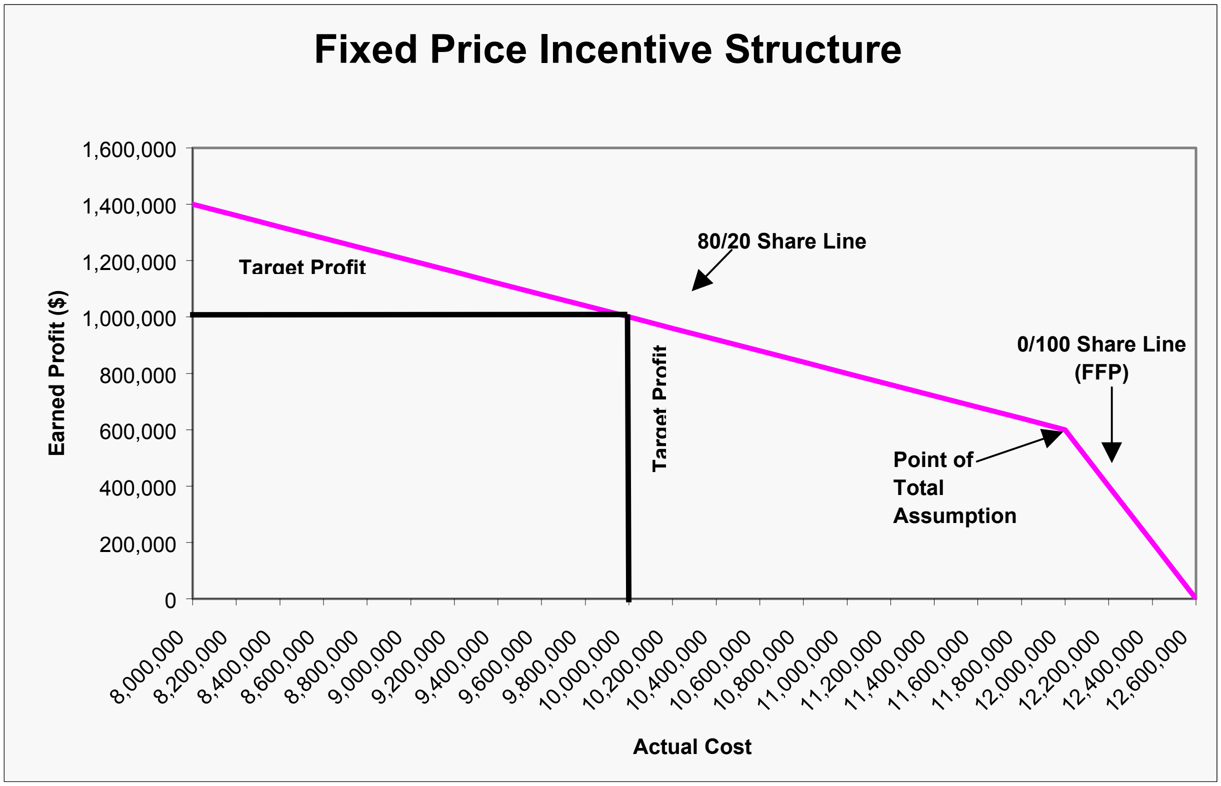


Figure 3-4

There are two methods to determine the PTA.

- One method is to use the high cost estimate (HCE) as the PTA and negotiate the profit at that point, using the sum of these to calculate the ceiling price. Or, if we establish ceiling price independently, the difference between ceiling price and the PTA (HCE) is the amount of profit left, since from that point on the contractor loses a dollar of profit for every additional dollar of incurred cost.

- The other method is to calculate the PTA from the following formula:

$$\text{PTA} = \frac{\text{ceiling price} - \text{target price}}{\text{government share}} + \text{target cost}$$

If the contractor's total incurred costs exceed the ceiling price, it is in a loss position from that point. By the operation of contract law, it must complete the work even so. ***Therefore, from the PTA the contract incentive structure reverts to a firm fixed price***.

Do not change the incentive structure unless the scope of work under the contract is changed.

The applicable clause prescribed by FAR 16.406 must be incorporated into the contract.

There are two types of FPI contract: that with a firm target (FPI-F) and that with successive targets (FPI-S).

The FPI-S contract is appropriate when available cost information is not sufficient to permit the negotiation of a firm target initially, but it is possible to negotiate initial targets, and there is reasonable confidence that the information needed to establish a firm price or a firm target cost will become available early in performance. It is preferable to the CPIF contract type when cost uncertainties preclude use of a fixed price instrument but are not severe enough to warrant a cost-reimbursement contract type.

- At the outset the parties negotiate an initial target cost, target profit, share formula, a ceiling price which may be negotiated downward only, a firm target profit ceiling and floor, and a renegotiating point early in performance when there is reasonable assurance of the availability of data to develop a firm price or firm targets.

- At the re-negotiation point, the share formula established initially will be used with incurred costs to determine the final target profit. This result may not exceed the profit ceiling nor fall below the profit floor. Final fixed price or final target cost will be negotiated based on the relationship between cost experience and the proportion of the work completed. Then a final sharing arrangement or a firm fixed price will be negotiated.

FAR 16.403-2(c) limits use of FPI-S contracts to those in which:

1. the contractor has an adequate accounting system to support negotiation of final cost and incentive revision, and

2. cost or pricing information adequate for establishing a reasonable firm target cost is reasonably expected to be available at an early point in contract performance.

The FPI-F contract is appropriate when all technical and cost uncertainties can be specified and quantified to some extent, so as to give at the outset a firm cost target and high and low cost estimates. There is no re-negotiation of the targets unless the scope of work changes. Limitations of use are discussed in FAR 16.403-1(c).

As discussed in FAR 16.402, other aspects of performance besides cost control can be the subject of an incentive structure. A multiple incentive structure is possible, but is exceedingly complex to construct and administer. Extensive trade-off analyses are necessary to structure the incentives properly.

<u>Fixed Price with Economic Price Adjustment (FAR 16.203; DoD FAR Supp 16.203-4, 16.203-4-70)</u>

In a fixed price with economic price adjustment (FP/EPA) contract, certain costs or prices are subject to increase or decrease based on the operation of an objective price level indicator such as an index or change in an established market price, or actual labor and/or material costs incurred.

This is not a redeterminable contract, since there is not a negotiation but an adjustment based on an objective criterion. It is not a cost-reimbursement contract since actual cost experience has nothing to do with the adjustment (except when the basis of the adjustment is variance from specified cost elements)

An FP/EPA contract is suitable when the Government anticipates serious fluctuation in resource markets over an extended performance period, and contingencies that offerors would otherwise include in the contract price can be identified and covered separately under the contract. DoD FAR Supplement 16.203-4 establishes minimum price levels and performance periods for which this contract type may be used.

The contingency allowances to be handled through economic price adjustment must not also be priced into the contractor's proposal.

The contracting officer must establish a proper baseline price to which the adjustment(s) will be made. This baseline should ***not*** include:

- profit,
- fixed portions of overhead costs, and
- costs within the contractor's control.

In the case of established market prices, the increase in the market price shall be the basis for the adjustment.

The contracting officer must perform the determination set forth in FAR 16.203-3 to be authorized to use this contract type.

The contracting officer must incorporate one of the applicable contract clauses listed in FAR 16.203-4.

The Economic Price Adjustment clause must not be complex or ambiguous in its operation, and should leave no room for judgmental factors. No ceiling or floor on adjustments should be applied unless the acquisition meets the criterion in DoD FAR Supplement 16.203-4(d)(3)(ii). The Job Order Contract (JOC) has its own specific EPA clause.

The adjustment clause should cover the entire period of performance, and adjustment should be based on comparison with either

- the index value(s) in a base period, or
- the baseline market price, or
- specified labor and/or material cost estimates, as applicable.

Per DoD FAR Supplement 16.203-4(d)(3)(xiv), the economic adjustment clause should state that pricing actions pursuant to the Changes clause shall be priced without provision for economic adjustment.

Special Contract Types

These include time and materials and labor hour contracts, letter contracts, and indefinite delivery contracts. Time and materials (T&M) and labor hour contracts combine aspects of cost-reimbursement and fixed price contracts, and so warrant special attention.

T&M contracts incorporate fixed burdened labor rates by labor classification, and a ceiling on expenditures. The Government cannot quantify the extent of effort, so a fixed price contract is unattainable. Material must be charged at cost, but may include material handling charges or G&A as long as those costs are not included in the burdens in the labor-loading factor. The contractor bills all incurred labor hours at the contractual burdened labor rates, and invoices for all incurred material costs with allowed burden.

Labor hour contracts are essentially T&M contracts with no provision for material costs.

These types are appropriate for service contracts where we cannot specify the extent of labor effort to perform the task(s). Task Order contracts for engineering services are usually one of these types, as are maintenance and overhaul contracts where the extent of repair/replacement cannot be predetermined prior to teardown and inspection.

Strict government surveillance is necessary since charging of labor hours for work not performed is extremely difficult or impossible to detect without it.

Abuses of Contract Types

Most of the government abuses of contract types stem from an inappropriate use of a particular contract type. Normally this involves either (1) cost-sharing type contracts on high-risk R&D applicable only to DoD projects, or (2) use of fixed price contracts on high-risk developments. In other words, the abuse stems from forcing the industrial base to assume a burdensome share of the technical and cost risk of DoD requirements. While this may seem shrewd from a strictly short-term perspective, it is very detrimental to DoD contracting in the long term because it erodes the industrial base.

b. Other abuses stem from arbitrary or imprudent factors in incentive structures. Some examples are: overly tight ceiling prices based on application of some arbitrary percentage to the target price; unattainable or unfair target costs; and share lines having unusually large contractor shares in technically risky projects.

c. Contractor abuses usually stem from mistaken or unethical accounting practices or fraud, such as: (1) mischarging costs incurred under a fixed price contract to a cost-reimbursement contract to avoid a loss or decrease in profit; (2) fraudulent charging of labor hours to a time and materials or labor hour contract; (3) double charging a cost as both direct and indirect through overhead pools; (4) not crediting large production contracts for scrap metal sold to scrap dealers; (5) various methods of overcharging or double charging for materials.

d. While it is the business of the Defense Contract Audit Agency (DCAA) to detect contractor abuses of the various contract types, it is up to the government to police itself when it comes to its own abuses. Selection of the contract type must be based on as much knowledge about the acquisition situation as the contracting officer can obtain, and on a genuine sense of fairness regarding assumption of risk by both parties.

e. A fair and reasonable price or pricing structure presumes that both parties act in good faith and that the economic wellbeing of both is preserved. In the long term this determines the size and strength of the DoD contractor base and the adequacy of appropriations, which in turn determines the level of difficulty facing the contracting officer in getting quality performance at fair and reasonable prices.

Negotiating Incentive Contract Awards

<u>Cost Plus Incentive Fee:</u>

The keys to negotiating CPIF contracts are the target cost (TC) and the low and high cost estimates (LCE, HCE). These should be realistic and achievable, and should challenge the contractor to efficient performance.

The target fee (TF) objective should be based on Weighted Guidelines with normative weights. The maximum fee objective should correspond to the low cost estimate (LCE) and receive higher weights; the minimum should correspond to the high cost estimate (HCE) and should receive lower weights.

The share ratio "falls out" by computation based on this structure. The contractor share is equal to the change in fee divided by the change in cost, from the target to the LCE and/or the HCE.

The negotiated agreement should include these elements as a "package" since they are all interrelated. Although they can be negotiated individually, final agreement should be a total agreement, not piecemeal.

The share ratio does not have to be the same on both sides of the target cost. One could negotiate a ratio of, say, 80/20 on the underrun side (LCE to target) and 90/10 on the overrun side (target to HCE).

NOTE: The greater the difference between the target cost and the LCE or HCE the flatter the slope of the share line. The flatter the slope, the smaller the contractor share. For example, a horizontal line represents a 100/0 share line where the contractor has no share of underruns/overruns (essentially a CPFF contract). A 0/100 line, which is the steepest, means the contractor pays the total cost of overruns, and receives the total difference in an underrun situation (i.e., firm fixed price).

<u>Fixed Price Incentive - Firm Target:</u>

The keys to negotiating FPI-F contracts are the target cost (TC), the high cost estimate (HCE), and the ceiling price. These should be based on as accurate an analysis as practicable, and should challenge the contractor to efficient performance without overburdening management or maximizing contractor cost risk.

The target profit (TP) should be based on Weighted Guidelines with approximately normative weights. The high cost estimate becomes the point of total assumption (PTA). The profit here should be based on Weighted Guidelines and should receive lower weights than the target. The share ratio "falls out" by computation based on this procedure. Contractor share is equal to the change in profit divided by the change in cost, from the target to the point of total assumption (PTA). The ceiling price is the sum of the PTA and available profit at the PTA.

Again, the negotiated agreement should include these elements as a "package" since they are all interrelated.

If it is not practical to establish a HCE, the ceiling price may be an agreed-to percentage of the target cost or price. Calculate the PTA by the formula given above. Budgetary considerations alone should not dictate the ceiling price. If the available information shows there is a good probability that the ceiling is too tight or the target will likely be overrun, a CPIF contract is probably more appropriate. Also, if the HCE is considerably higher than the target cost (say, more than 25%), a CPIF is probably the better structure.

<u>Fixed Price Incentive - Successive Targets:</u>

The parties establish a target cost, target profit and HCE as before, but these are initial figures. The parties also must negotiate a profit floor and profit ceiling at agreed-to points along the costline; these are not necessarily based on weighted guidelines.

From this we calculate the initial share ratio. The ceiling price must be set for the entire contract, and probably should not be based on the initial HCE as this may be too tight a constraint at this point. At this point the parties must agree on a re-negotiation production point for negotiation of the final pricing structure.

At the re-negotiation point the contractor must submit a new cost proposal based on incurred costs and an estimate to complete. Based on the level of the remaining technical, performance and cost uncertainties, either a FPI-F or a firm fixed price will be negotiated.

A FPI-S structure has as its final target cost the incurred costs plus negotiated estimate to complete.

The final target profit is found by calculation from the initial share ratio. For example, if the initial target cost was $10,000,000 with a target profit of $1,000,000 and an 80/20 initial share ratio, and the negotiated final target cost is $11,000,000, then the final target profit would be:

Final TC	$11,000,000	
Initial TC	$10,000,000	
Difference	1,000,000	
Ktr Share:	200,000	(Difference × 20%)
Initial TP	1,000,000	
Less:	200,000	(Ktr Share)
Final TP	$800,000	(7.3% of final TC)

This final target profit cannot be higher than the profit ceiling or lower than the profit floor previously established with the initial targets.

The final share ratio may or may not be the same as the initial share ratio, if the uncertainties of performance or cost have changed substantially from the initial estimates.

The ceiling price cannot be increased, though it may be lowered. Calculate the PTA from the PTA formula unless a high cost estimate is agreed to.

NOTE: There is an incentive for the contractor to overrun the initial target cost so that the final target cost will be fairly easy to underrun.

Cost Plus Award Fee:

Award fee is not based on weighted guidelines, but on an alternate method per DFARS 215.902(a)(1)(ii). A base fee of from 0 to 3% may be negotiated. **The full base fee (up to 3%) should reflect the expectation of acceptable performance.** Remember that this is like a fixed fee in a CPFF contract, with the exception that unacceptable performance need not have any fee allocated.

The factors in negotiating the award fee should be functional and relate to the tasks contracted. They should be meaningful to the contract performance objectives. They also should be within the contractor's control, and there should be no overlap in these factors.

Allocations of the award fee pool should reflect the complexity, risk and importance of the tasks in each period. If these are the same, then allocation should be equal. Save a significant portion of the pool as a carrot for the final period.

Recoupment of unallocated fee pool is not possible unless there is a specific contract provision for recoupment and switching of funds between factors or periods.

Describe the performance criteria in the solicitation or contract, but do not reveal the scoring system, as this may precipitate a dispute of fact over whether the government correctly follows the methodology.

Negotiating Changes to Incentive Contracts

The following methods apply both to fixed price incentive and cost plus incentive fee contract types. Differences in application of the methods between the two categories will be emphasized.

Individual Adjustment Method. This is essentially a renegotiation of the entire pricing structure. It is appropriate when there are major program changes, in or out of scope, altering the risk elements of the contract. It is costly and there is the danger that a contractor in an overrun or loss position can "get well." To negotiate changes using this method, follow the steps and principles in the section "Negotiating Incentive Contracts."

Severable Change method. Under this method, changes are priced separately, that is, they may have their own pricing structure and even a different type structure. This method is appropriate only when: (1) the change is clearly severable from the contracted work, and (2) the contractor will separately account for the costs.

Constant Dollar method. This method is appropriate when contract technical uncertainty remains essentially unchanged. Under this method, the parties agree to a new target cost and target profit or fee.

In CPIF contracts, the minimum and maximum fees change by the same number of dollars as the target fee. Here the new share ratio parallels the original, and the minimum fee increases as a percentage of target cost, acting as a 'de facto' disincentive to cost-effective performance.

In FPI contracts, the ceiling price changes by the same number of dollars as the target price. The share ratio stays the same, but the profit at PTA increases substantially as a percentage of PTA, which lessens the incentive to hold down costs.

Constant Percentage method. This method is appropriate when contract risk remains essentially unchanged or increases slightly, or there are large dollar changes. Under this method, the parties agree to a new target cost and target profit or fee.

In CPIF contracts, the minimum and maximum fees are changed to be the same percentage of the new target cost as of the old target cost. Here also the new share ratio parallels the original. The minimum fee increases as a dollar amount, lowering the incentive to cost-effective performance. However, it increases more slowly than under the constant dollar method.

In FPI contracts, the ceiling price changes to be the same percentage of the new target price as of the old target price. The share ratio up to the PTA remains the same. The profit at the PTA remains the same percentage of PTA, although it increases substantially as to dollar amount. This again decreases the incentive to hold down costs, though perhaps to a lesser degree than the constant dollar method.

Structuring Award Fee Contracts

As indicated, an award fee contract provides incentives for effort not susceptible to description in terms of the firm, quantifiable goals necessary for use of the CPIF or FPI contract types. It allows the government to vary unilaterally a portion of the fee paid based on the government's *subjective evaluation* of contractor performance.

Evaluation Criteria: The first step in negotiating a CPAF contract is to determine what performance factors should be incentivized. We do this through an analysis of the Performance Work Statement (PWS). Broad functional categories should provide the factors. Figure 3-5 below gives an example relating factors to broad functional areas and to the PWS.

Sample CPAF Performance Factors

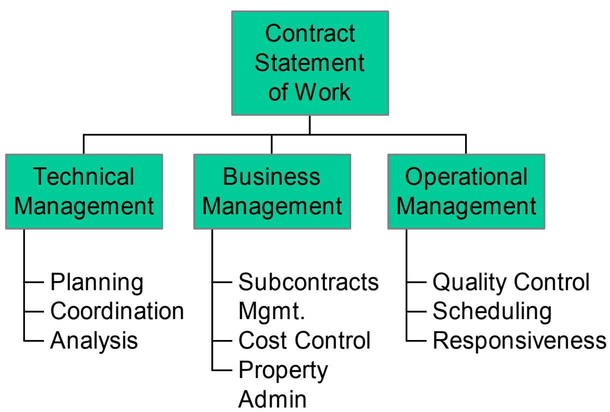


Figure 3-5

Take care, in choosing the number of factors, not to fragment the incentive. Too many performance factors or subfactors may dilute the incentive effectiveness.

The basic criteria for performance factor selection are:

- They are meaningful and important to performance objectives.

- The contractor has effective management control over each performance factor and its results.

- Each factor/subfactor can be fully described to avoid duplication in the evaluation process.

- Standards can be fully developed and described for each performance factor.

- Each evaluation factor and subfactor should be weighted for evaluation and scoring purposes. The weights chosen should reflect the relative importance of each subfactor to its factor and each factor to the total effort. These are not revealed to the contractor.

The contract should contain a provision allowing the government unilaterally to change the evaluation criteria as long as we notify the contractor of the change before the start of the affected evaluation period.

Evaluation is periodic throughout the contract. Evaluation periods may be approximately quarterly, although they should be long enough for the contractor to accomplish a measurable effort.

<u>Award Fee Pool Allocation</u>:

- The award fee must be allocated to each evaluation period. The amount allocated per period should relate to the significance and risk of the work to be performed in each period.

Regardless of the award fee allocation plan, the final evaluation period must contain a significant amount of the award fee pool as a performance "carrot." Figure 3-6 gives an example of a graph of an allocation table, graphically depicting the periodic fee allocation, and the cumulative allocation over the life of the incentive. Note that here the allocation of award fee pool increases over the life of the contract on the assumption that the contractor will start low but will achieve increased scores over the life of the contract.

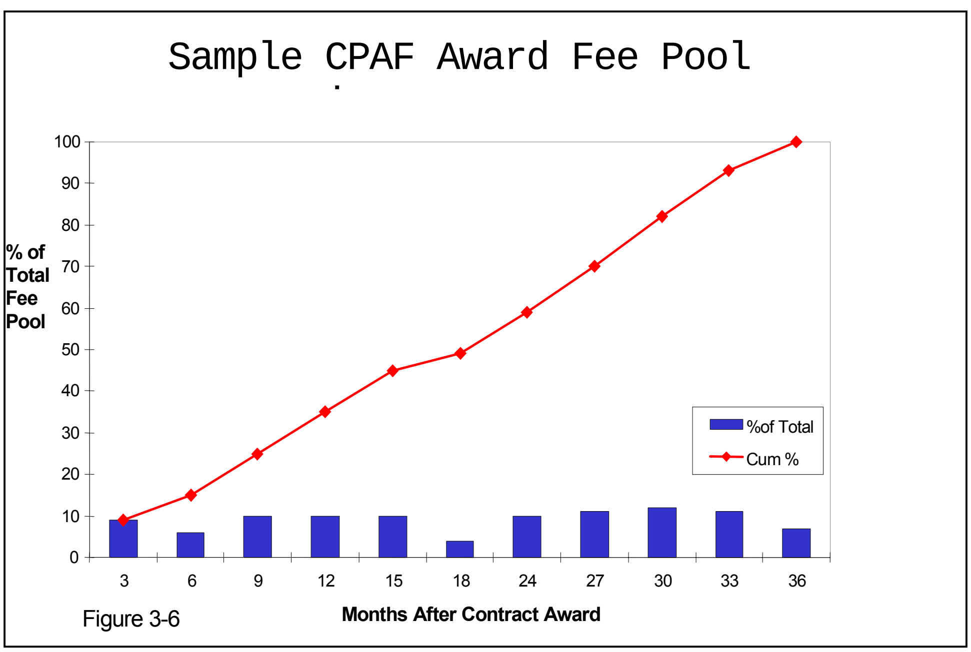


Figure 3-6

Consideration should be given to the problem of recouping unallocated fee, especially if the contract is a requirements-type contract. Contractor recoupment of partial or entire unearned fee for a particular period(s) is possible only with a specific contractual provision. Without such a provision, the general incentive may be reduced since the maximum fee cannot be earned regardless of the contractor's performance the remainder of the contract. With it, the initial incentive may be reduced since fee lost "up front" is recoverable later.

Grading Systems: The evaluation grading system is not disclosed to the contractor, but is a definite feature of the award fee plan. Figure 3–7 below shows a sample grade structure. Note that anything below a score of 61 is unacceptable performance, and no award fee can be granted. Performance below this lowest level may subject the contractor to a "Cure Notice" or a "Show Cause" letter. In such an event, even the base fee is potentially forfeit.

Sample CPAF Grading Table		
GRADE	DESCRIPTION	POINT RANGE
A	Overall performance exceeds standard by a substantial margin. No sub-standard performance on any tasks. Few improvements needed, all minor.	91 - 100
B	Overall Performance exceeds standard. Several task elements need minor improvements; tasks performance at or above standard exceeds tasks performed below standard.	81 - 90
C	Overall Performance meets standard. Sub-standard performance in some tasks is offset by above-standard performance in other tasks. Improvements needed are largely minor.	71 - 80
D	Overall performance is less than standard. Sub-standard task elements exceed above-standard elements. A few major improvements and/or many minor improvements needed.	61 - 70
E	Overall performance is significantly below standard. Many sub-standard task elements not offset by performance in other elements. Many major improvements needed.	0 - 60

Figure 3-7

The overall grade structure relates to the performance evaluation criteria set forth for the various tasks and subtasks.

The reader can find a sample rating criterion sheet in DFARS 216.4. This example spells out the criteria for rating contractor performance on various sub-factors related to major performance factors such as delivery schedule, quality and cost control.

DFARS 216.4 also gives a sample contractor performance evaluation report. This stems from the evaluation plan, and includes the factor and subfactors shown in the criterion sheet referenced in paragraph 2. Numerical ratings receive weights developed in the evaluation plan, and additionally are weighted in the aggregate for each major factor. We sum these to give an overall rating.

Figure 3-8 below is a sample award fee conversion chart showing the contractor how rating scores convert to percentages of the allocable award fee for that period.

Sample Award Fee Conversion Chart

PERFORMANCE POINTS	PERCENT OF AVAILABLE AWARD FEE	PERFORMANCE POINTS	PERCENT OF AVAILABLE AWARD FEE
60	0.0%	81	53.3%
61	1.0%	82	56.6%
62	2.3%	83	59.8%
63	3.7%	84	63.1%
64	5.4%	85	66.2%
65	7.3%	86	69.4%
66	9.3%	87	72.4%
67	11.5%	88	75.4%
68	13.9%	89	78.2%
69	16.4%	90	81.0%
70	19.0%	91	83.6%
71	21.8%	92	86.1%
72	24.6%	93	88.5%
73	27.6%	94	90.7%
74	30.6%	95	92.7%
75	33.8%	96	94.6%
76	36.9%	97	96.3%
77	40.2%	98	97.7%
78	43.4%	99	99.0%
79	46.7%	100	100.0%
80	50.0%		

Figure 3-8

Many scales can be used, both linear and non-linear. The scale in Figure 3-8 corresponds to the non-linear graph in Figure 3-2. It is based on the following specifying equation, with X = number of performance points:

$$Y = -0.000001X^3 + 0.004795X^2 -0.35062X + 8.090409$$

As shown in figure 3-2, it produces an S-shaped curve designed to provide additional incentive for the contractor to gear performance in the 85 to 95-point range. Compared to a linear scale, there is disproportionately less fee below 80 points and disproportionately greater fee above 80. The reason for the curve tailing off up in the upper 90's is the law of diminishing returns: the cost to the government of the attempt to reach perfection would not be proportional to the benefit reached. Therefore we aim at excellence, not perfection.

Many other types of non-linear scale are possible. Appendix A discusses the technicalities of developing linear and non-linear conversion scales.

A grading system should be reasonable, make sense, provide a clear description of the criteria to be used, and provide for a zero fee for unsatisfactory performance. It should clearly differentiate each level of performance from every other and spell out what is required to reach that level of performance. The above figures are an attempt to demonstrate these requirements, recognizing the subjectivity of the process.

We can now begin to look more closely at how one goes about analyzing various cost elements**.** Remember that the objective of cost analysis is a determination of what it should cost to perform the contractual requirements, given *reasonable* contractor economy and efficiency. In this Part we will look at analysis of direct costs. Later parts will discuss analysis of other cost elements.

Labor and Capital

a. Economics categorizes two basic resources used in conducting a business: labor and capital. Capital includes all non-human resources, including monetary resources. Human resources constitute labor. Every business uses some combination of human and non-human resources (buildings, equipment, money, IT) to manufacture goods or to perform services or construction. In this part we discuss labor, material and "other direct" costs that can be directly traced to a specific contract. Material will include raw materials, parts and subassemblies. Part five will deal with indirect labor and material costs, including machinery and equipment costs.

Although human beings may utilize machinery and equipment in manufacture or services, machinery and equipment are not considered a part of labor cost. When people use machinery in performance of their tasks, their hours are logged in labor accounts, whereas the time the machinery is in use may be posted to a separate account. Labor time accounting is the primary basis of the payroll accounts, whereas the machine usage account, if used, provides a basis for depreciation of the value of the machinery over time and for regulating such things as scheduled maintenance and replacement.

Capital costs are composed of the up front "capitalization" cost (purchase price, installation and setup costs) plus costs of ownership (maintenance, repair, insurance and associated costs such as utilities). Capitalization costs of machinery and equipment are normally depreciated over time in depreciation accounts (see Part 5). Ownership costs are normally logged as expenses at the time of incurrence or may be accounted for as accruals (funds set aside or paid prior to actual incurrence of the cost). All of these costs are usually posted in indirect cost accounts.

Technology often replaces labor because it has a higher index of efficiency and its efficiency is relatively constant, whereas labor efficiency can fluctuate over time. Labor efficiency can increase due to learning, employment of higher skilled workers, and training. It can decrease due to turnover (more new employees with lower skills and higher on the "learning curve"), fatigue, psychological factors such as morale, inadequate working conditions, and so forth.

Labor costs are classifiable as (1) hours worked paid at set wages per hour, and (2) salaries paid at periodic intervals regardless of hours worked. Labor costs vary with the actual number of hours worked by wage earners, and the salaries of salaried employees. Hours worked can vary based on a number of factors such as turnover, hire lag, layoffs, strikes and other labor actions. New hires and lower skilled workers are paid lower hourly wages. The changing mix of skills and seniority can make total labor cost rise or fall despite the overall upward trend of wages and salaries.

On the basis of these considerations, labor and capital costs must always be analyzed separately since the market forces acting on each are different and arise out of different causes. Even when we utilize price analysis rather than cost analysis, we need to be aware that labor and capital costs reflected in past prices will be responding to different economic factors over time, and for that reason there is no one adequate gauge of price trends. We deal with these difficulties in discussing price analysis in Part 7.

Skill Mix and Head Count

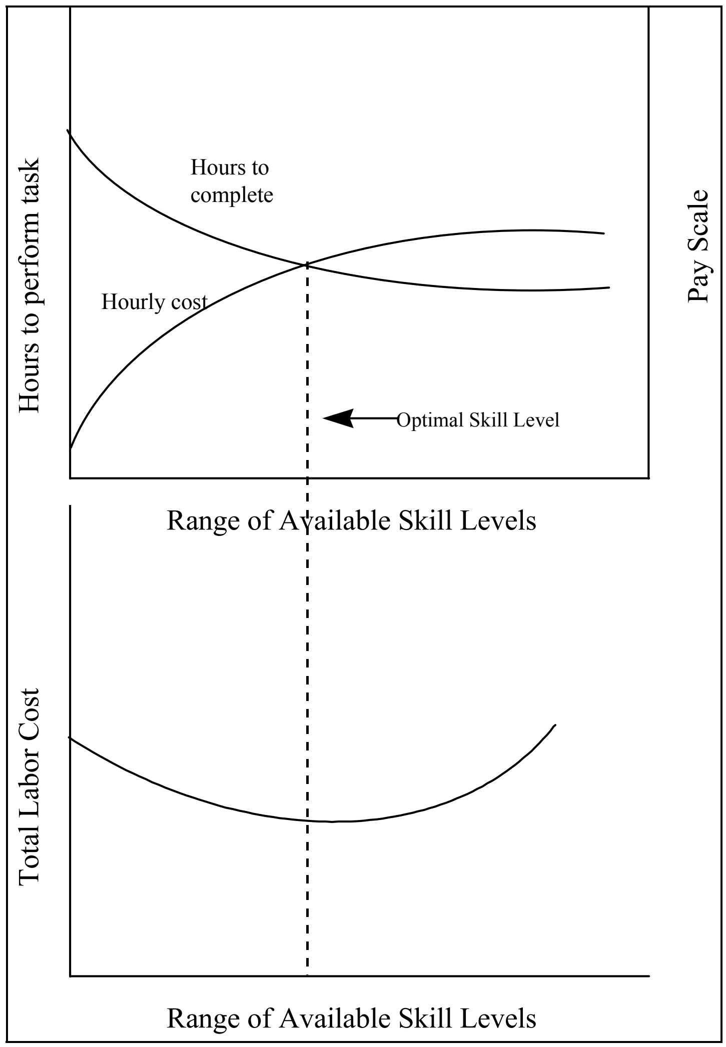
Consider the overall market for labor. Young people graduate and enter the labor force; older workers retire and leave the labor force; workers of all ages quit, are fired or laid off. Along the way everyone gains experience, training and – sometimes – further education. For these reasons the overall mix of skills in every firm is constantly changing to some degree.

Most businesses offer higher wages or salaries to those in the same occupation having higher skills. Most have graduated pay scales based on factors such years of service, certification, college degrees attained, awards, merit pay, and so forth. Additionally, most firms pay different wages or salaries for different occupations, in proportion to the value to the firm of those sets of skills.

Based on these facts, analysis of labor hours must begin with the technical question of the type of skill mix necessary to perform the statement of work. Without knowing the types and level of skills necessary to achieve the contract objectives, we have no basis to estimate contract labor hours. There are certain basic questions that the contractor must answer in pricing the labor portion of a cost proposal. First, what subset of the firm's skills will be needed, and what levels of experience in each of those skills? Secondly, will the firm need to subcontract for some of the skills needed?

There are two factors that pull against one another in determining the skill mix for a contract. Higher skilled employees are normally paid higher wages, yet higher skills usually translate into higher efficiency, hence fewer hours to perform a task than less skilled employees. The trick, then, is to find the optimum skill mix that balances hours and rates of pay.

The chart below graphically illustrates this concept. The point of intersection between the two curves (efficiency rate and pay scale) is the optimal skill mix that results in the highest efficiency and lowest possible cost. The X-axis shows a range of skills. The left Y-axis shows hours to complete a task, while the right Y-axis shows the hourly wage range for that skill set. To the left of the intersection point, hourly wages are low but hours to complete are high. To the right of the intersection point, hourly wages are higher without an accompanying reduction in hours to complete. The lower graph shows the labor cost for each corresponding point on the two curves. At the intersection point total labor cost is lower than at any other point.



The problem with such a concept is that it is very difficult to quantify, since usually a firm does not have voluminous data for comparable projects on which different skill levels were used, in order to assess the relationship between hours and level of skill. However, the same basic task may have been performed on a number of otherwise dissimilar jobs. If varying skill levels were utilized on these jobs, there is a basis for quantitatively specifying the relationship through some type of regression analysis.

The point is even more germane to best value source selection, where different offerors may propose labor hours differently based on higher or lower levels of experience or skills. The technical and cost evaluators must be able to assess the relative efficiencies being offered and determine whether they are realistic or optimal based on personnel resumes and contractor approach.

Another labor factor is head count, which deals more with seniority in firms where this is a substantial factor in the pay scales of the various occupational categories. If head count decreases in such a firm due to downsizing, the younger employees and those employed more recently will be the first to go. Since these employees are normally paid less than the more senior employees, the overall average wage rate will tend to go up, making each labor hour more expensive. However, sometimes overall efficiency increases because the less skilled employees have been laid off, leaving behind more “total years of experience” in the business. In this situation less non-productive hours are devoted to skill enhancement training.

Often there will be some historical labor data on past projects or jobs similar to the one under analysis, and this labor data may be broken down into occupational titles and skill levels. If so, the analysis can proceed by starting with the historical data and modifying it as necessary for any known differences in the solicitation statement of work.

Where such historical data is lacking or is inadequate, the analyst must lean on the expertise of technical personnel in the requiring activity. There are several engineering methods for determining theoretical hours to complete the different tasks involved in the statement of work, including time and motion studies, industry standards, and government data such as the MARK system.

Productive and Non-Productive Hours

Not everyone works 2,080 hours per year; in fact most do not. By definition part time workers do not. Even full time workers do not actually work 2,080 hours. For costing purposes, annual work hours are divided into productive hours and non-productive hours.

- *Productive hours* are those hours that a worker is productively working at tasks for which they were hired.

- *Non-productive hours* can be subdivided into two categories: leave time and idle time. Leave time comprises those hours when the employee is not at work. Idle time is comprised of personal time (bathroom breaks, smoke breaks, rest breaks), training (other than on-the-job), meetings (other than those related to the specific job), and time when the employee is at his/her “station” but cannot work due to circumstances beyond their control.

When contractors employ both full-time and part time workers on a contract, for the purpose of estimating hours and staffing we refer to **“full time equivalents” or FTEs**. A full time equivalent is equal to one work year of effort, whether performed by one full time or several part time personnel.

So, a productive work year for one FTE is normally less than 2,080 hours. Staffing must take account of this fact. If technical personnel determine that a task in the statement of work will require 208,000 work hours per year, this does not convert to a staff of 100 people. Below we estimate the size staff needed to perform work requiring 208,000 work hours.

Each contractor will have a different **productive** work year, depending on the number of holidays, leave days, and idle time built in. We give an example in the table below to demonstrate this point. Below are two hypothetical contractors. Both start from 2,080 total annual work hours per employee, but each arrives at a different productive work year.

ABC Company			XYZ Company		
Total work hours/yr		2,080	Total work hours/yr		2,080
Less:			Less:		
10 holidays	(80)		9 holidays	(72)	
7 days sick leave	(56)		10 days sick leave	(80)	
10 days vacation	(80)		10 days vacation	(80)	
2 15-min breaks/day	(117)		Annual Training	(40)	
	(333)			(272)	
Productive work hrs		1,747	Productive work hrs		1,808

Given a requirement for 208,000 work hours to perform the statement of work, ABC Company should propose a staff of 208,000÷1,747 ≈ 119 FTEs, while XYZ Company should propose a staff of 208,000÷1,808 ≈ 115 FTEs.

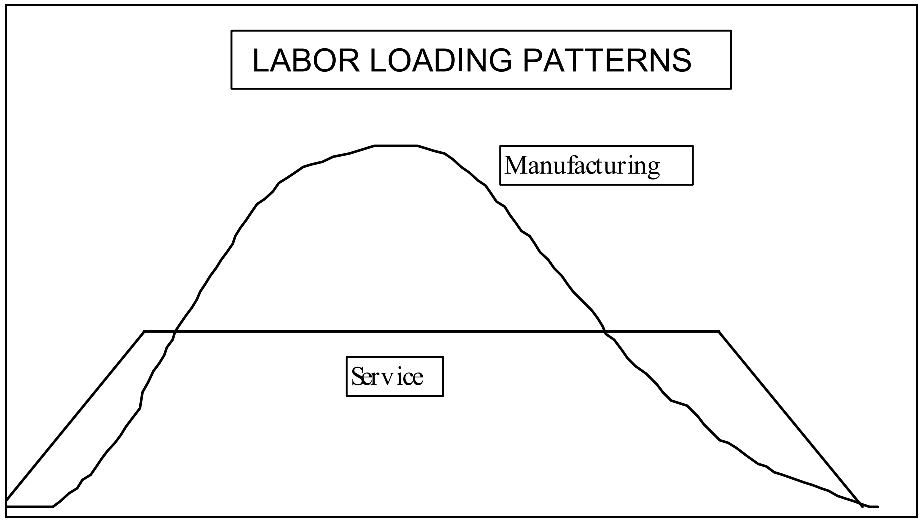
Given the above scenario, both firms' staffs would be productive 208,000 hours per year. However, ABC Company would be charging an additional 119×216 = 25,704 hours to several accounts for leave time and would charge it to the contract through "Fringe Benefits" overhead. It would charge the "break" hours (117 × 119 = 13,923) to another overhead pool account. Total indirect hours would be 39,627. XYZ Company, on the other hand, would charge an additional 115×232 = 26,680 hours to Fringe Benefits and 115×40 = 4,600 hours to another labor overhead account for the employee training time.

One of the keys to labor analysis, then, is to determine each contractor's actual productive work year. From it flow staffing, fringe benefits (leave hours paid), and other labor hours issues. This also helps determine relative contractor labor efficiencies. We must not, however, assume that XYZ Company is a more efficient contractor because each employee works a greater number of productive hours per year; the more generous benefits package offered by ABC Company may help attract higher skilled workers resulting in a more efficient workforce.

Labor Hour Loading

Another aspect of labor analysis is an evaluation of labor hour loading. This is the pattern of labor hours over the performance period of the contract. There is a different general pattern of labor hour loading for manufacturing than there is for a repetitive service (e.g., janitorial), and different patterns for construction projects. If a contract requires a phase-in and/or phase-out effort, the pattern will also be different. The important points in analyzing labor loading are: (1) the offerors' understanding of the statement of work, and (2) duplication of effort or inefficient use of labor.

The chart on the next page shows the typical pattern for a manufacturing effort versus a repetitive service with phase-in and phase-out.



Note that, after the initial ramp up to full staff, the expenditure of hours is uniform for the service until phaseout, when they decline rapidly.

For the manufacturing effort, labor hours are low while long-lead parts are procured and delivered, then begin to increase rapidly as production begins. As more parts are fabricated and assembly of the first end items begins, total labor hours increase very rapidly as more laborers are incorporated into this job. It peaks at about the middle of the production cycle, then begins to decrease as parts fabrication ceases, releasing more workers to other jobs. Labor decreases continually as the production cycle nears its end. The pattern is similar to the familiar "bell curve" that underlies many processes and physical characteristics. These patterns do not include improvement curve effects.

The pattern for a construction project is much more complicated but will resemble a mixture of the patterns for manufacturing and repetitive services. This is because some occupational skills will be utilized a relatively short time whereas others will continue through most of the project. Additionally, while many tasks may be performed simultaneously, some cannot begin until others end. For example, not much else can be accomplished until the land is graded and the foundation poured and dried. As the second story is being framed, other occupational skills can be used on the first story such as electricians, plumbers, sheetrock installers, and so forth. When the roof is added, most of the skill mix will be constrained to carpenters and roofers.

Proposed hours should be proportional to the effort for each task. Even though a contractor's overall proposed hours may be determined reasonable, its offer may be unbalanced by allocating hours to the wrong time period or to the wrong task or CLINs. One firm's offer was ruled unbalanced by GAO because, although its overall offer was reasonable, over 46% of total hours were in the phase-in effort, which made it appear that he was the low evaluated offeror for the overall contract. Contractors that submit unbalanced costs normally will do so for Indefinite Quantity/ Indefinite Delivery (ID/IQ) contracts based on knowledge of which CLINs will be exercised extensively and which will be relatively little used. They then bid in such a way that, while appearing to be low in price, they overprice CLINs they believe will see a lot of action, and under price the remainder. The hours proposed do not resemble actual effort on each CLIN.

Management hours are loaded differently than for “worker bee” hours. Project Managers and Site Managers plan, control, supervise other workers and account for cost, schedule and quality variances to their bosses. They may be dedicated 100% to a project (or site operation), or they may be matrixed to several projects. In the former case their hours may be charged directly to a particular contract, and the latter case their time may be charged to labor overhead (or G&A if they are at the corporate level). Other types of managerial and technical labor may also be loaded the same way. Although this is often the lion’s share of their time, there do not appear to be any hard and fast rules for loading the supervisory time of managers, only rules of thumb. One rule of thumb is that first line supervisors optimally supervise 15 employees, while second line supervisors optimally supervise four to five first line supervisors. Above this level, positions are normally considered strategic in nature and do not involve direct supervision.

Learning and Efficiency Improvements

Aeronautical engineers analyzing historical labor data in aircraft production discovered the concept of the learning curve or cost improvement curve. As commonly used it specifies a constant rate of improvement, or labor hour/cost reduction, for each successive doubling of production quantities completed. The "slope" of the curve is the percentage of labor time taken for each successive doubling, compared with the previous doubling.

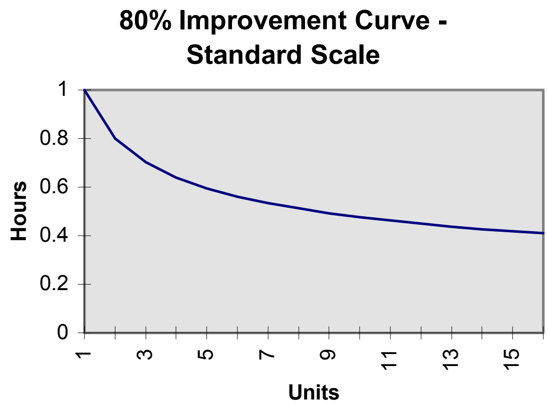
Improvement in labor time comes from a number of factors: improvements in dexterity and know-how with practice, changes in the environment, improved morale, workflow improvements, work simplification, engineering changes, workstation setup changes, and others. All but the first are due to management decisions, which is why the term "learning curve" is somewhat inadequate to describe the process.

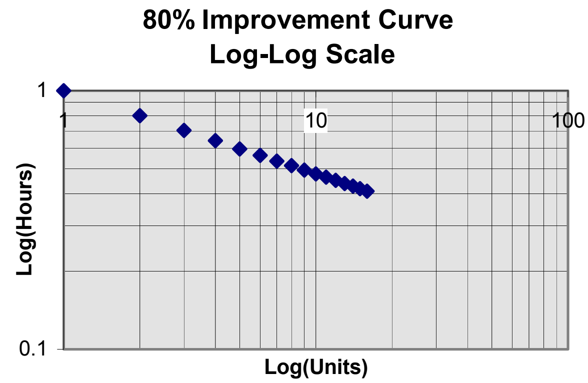
Learning and other improvement effects are not limited to the manufacturing sector, although they are more prevalent and pronounced there due to the complexity and repetitiveness of the tasks involved. Technical and complex services experience learning-related reductions as well. Any task is subject to learning effects if it is sufficiently complex and repetitive.

Since the learning curve specifies a constant rate of decrease for each successive doubling of output, it is a form of exponential curve described by the equation

$$Y = AX^b, \tag{1}$$

where Y is the dependent variable (cost or hours), A is the first unit value, X is either the unit number or total quantity produced up to unit X, and b is a parameter relating the rate of improvement (in terms of doubling quantities, hence the use of an exponent). Since the slope is downward to the right, the exponent is negative. Since the slope of the curve approaches the horizontal, $-1 < b < 0$. The following figures give an example of an improvement curve with a "slope" of 80% as it looks plotted on ordinary graph paper (left) and on paper with a logarithmic scale on both axes ("log-log").





The first unit labor is set at one (1) hour to give the reader a feel for the percentage of decline in hours for each unit. Note that on the log-log scale, the curve becomes a straight line. This is because the inverse of a power function is a logarithmic function. In other words, converting the equation $Y= AX^b$ to

$\log(Y) = \log(A) + b \cdot \log(X)$	(2)

gives the equation for a straight line with log(A) as the y-intercept and b as the slope parameter.

Readers working for activities where supply commodities procured are normally commercial items may consider this concept irrelevant to their knowledge base. The concept is relevant for the following reasons:

- Quantity-based discounts may have a learning curve component.
- Some repetitive types of services are susceptible to the learning curve effect.
- Manufacture of government-unique or highly modified commercial items will likely involve some improvement curve effects.

After discussing the basics of improvement curve analysis, we will use a real world example where improvement curve was factored into pricing of a service to demonstrate labor analysis involving efficiency reductions.

Let us suppose that the first unit takes 1 hour to complete (A = 1). Let us show a generic doubling of quantity by measuring the labor (Y) for completion of unit X and unit 2X. Thus Y_1 relates to X and Y_2 relates to 2X as follows:

$$Y_1 = X^b \text{ and } Y_2 = (2X)^b.$$

The theory states that the ratio of Y_2 to Y_1 will be a constant, which is termed the "slope" of the curve. We express the ratio as follows:

$$
\begin{aligned}
s &= Y_2/Y_1 = (2X)^b/X^b \\
&= 2^b * X^b \div X^b = 2^b*(X^b/X^b) \\
&= (2^b)(1) = 2^b
\end{aligned}
$$

Thus, the "slope" s of the curve relates directly to the exponent, b. We determine b by use of the logarithmic transformation, equation (2), which changes this non-linear equation into a linear equation that we can solve for b:

$$s = 2^b \Rightarrow \log(s) = b \times \log(2) \Rightarrow b = \log(s) \div \log(2).$$

Let's give a concrete example in which we determine the slope of the improvement curve and, from this, the b-factor and the specifying equation or model. Suppose an auditor extracts the following labor hour data from the contractor's records of the first 10 units of a production run:

Unit	Hours	Unit	Hours
1	600.6	6	394.6
2	510.5	7	380.6
3	464.2	8	368.8
4	433.9	9	358.8
5	411.8	10	350.0

The slope of the improvement curve can be loosely found by the ratio of any unit to its double. For instance, the ratio of unit 8 to unit 4 is 0.849965 or approximately 85%. The same holds for 2:1, 4:2, 6:3 or any other ratio 2:1. Therefore s = 0.85 or 85%. The b-factor for a slope of 85% is found as log (0.85)/log (2) = -0.234465254. The specifying equation for the labor hours for any unit of this production lot is:

$$Y = 600.6*(X^{-0.234465254}).$$

Alternatively, the log-linear equivalent is:

$$\log(Y) = \log(600.6) - 0.234465254 \times \log(X).$$

So, if we can specify the change in unit cost by improvement curve theory, and if we know the ratio of Y values (labor hours or costs) for units X and 2X, then we can find the b-factor for the equation. If we also know the labor cost of the first unit built, we can completely specify an equation describing the improvement rate, hence the labor cost, for this item.

There are actually two learning curve models, but the model we have been discussing is sufficient for our purposes.

Now we will demonstrate the use of improvement curve in pricing services, based on a real world example in which the contractor proposed improvement curve as part of its methodology for arriving at labor hours. The case involves IT technician labor in the diagnosis and repair of a complex IT system over a five-year period. The contractor's technician's are "on call" and expected to respond immediately to user trouble calls.

- The contractor estimates that 1 user call in 3 will result in some form of repair being accomplished and that 5% of the workstations will generate trouble calls each month.
- The contractor further proposes that initially, the average repair will take 3.25 hours including diagnosis, replacement of parts, testing / re-certification of the unit, and reinstallation in the system.
- This estimated repair time is expected to decline over time roughly according to an 90% improvement curve due to increased knowledge of the system, expertise in diagnosis, and to a reduction in the number of major failures caused by weak initial components.
- The contractor's proposal for technician hours is shown in the table below. It is based on the number of units purchased in years one through four of the contract; maintenance and repair extending through an additional year. The proposal first establishes the estimated number of trouble calls per month, and extends these on an annualized basis. On this basis the contractor attempts to establish the number of repairs per unit, and to annualize this to all units then in-house. Then, using the initial 3.25 hours and the 90% improvement curve, the contractor projects yearly repair hours.

CONTRACTOR PROPOSAL
ADPE REPAIR TECHNICIAN LABOR HOURS

TROUBLE CALLS	Year 1	Year 2	Year 3	Year 4	Year 5
Year 1 units	200	200	200	200	200
Year 2 units		400	400	400	400
Year 3 units			400	400	400
Year 4 units				400	400
Total units	200	600	1000	1400	1400
NO. CALLS/MO.	10	30	50	70	70
NO. MONTHS	6	12	12	12	12
TOTAL CALLS	60	360	600	840	840
REPAIRS CALCULATION					
NO. REPAIRS/UNIT	0.3	0.6	0.6	0.6	0.6
NO. UNITS	200	600	1000	1400	1400
TOTAL REPAIRS	60	360	600	840	840
HRS./REPAIR*	2.04	1.27	0.87	0.60	0.42
TOTAL HRS./YEAR	**122.1**	**456.6**	**521.4**	**501.2**	**356.4**

HOURS/REPAIR CALCULATION					
EST. UNIT 1 HRS.	3.25	2.64	1.96	1.41	1.00
AVG. UNIT FACTOR @ 90%	0.6262	0.4799	0.4444	0.4225	0.4224
HRS./REPAIR	2.0353	1.2682	0.8690	0.5966	0.4243

LOST LEARNING CALCULATION				
FIRST REPAIR - HOURS	3.25	2.64	1.96	1.41
AVG REPAIR HOURS PER UNIT	2.04	1.27	0.87	0.60
AVG. LEARNING HOURS/UNIT	1.21	1.37	1.09	0.82
LOST LEARNING @ 50%	0.61	0.69	0.54	0.41
NET LEARNING PER UNIT	0.61	0.69	0.54	0.41
FIRST REPAIR - NEXT YEAR	2.64	1.96	1.41	1.00

Analysis of the contractor's labor proposal discloses the following issues:

- Although the contractor has proposed that only 1 call in 3 will result in an actual repair – with which the DOIM personnel agree – the estimated repairs per unit figures reveal that a ratio of 1 repair for each call has been built in. The price analyst's recommendation correctly incorporates the 1:3 ratio of repairs to calls.

- The contractor's application of improvement curve assumes that there is total loss of learning each year, as can be seen by the fact that for each year the "Est. Unit 1 Hrs" figure is 3.25. The price analyst takes exception to the idea of 100% loss of learning. Discussions with the DOIM concerning personnel turnover in the repair technician category lead to a conclusion that 50% loss of learning each year would be more appropriate for the estimate.

During discussion of analysis procedures we will demonstrate how to account for lost learning. Our analysis proceeds as follows:

We first determine learning for year one. This is based on applying a 90% learning curve to the initial value of 3.25 hours. We agree with the contractor's assessment of 60 trouble calls for the first year; however, only every third call results in an actual repair, so we expect 20 repairs during the first year (note that the first year extends only six months). We apply the 90% unit curve values for the first 20 units to the initial value of 3.25 hours. This is shown in the first column of the table on the next page. The second column gives the cumulative hours for the repairs. Cumulative hours divided by number of repairs gives the hours per repair in column 3.

We then determine the loss of learning due to turnover.

- Based on learning, the time to repair has dropped from 3.25 hours per unit to 2.06 hours per unit. This means that we expect, based on 20 repairs with 90% improvement rate, that the average year one repair will take 2.37 hours or 72.9% of the initial time of 3.25 hours. Total learning is $(3.25 – 2.37) \times 20 = 17.6$ hours. This averages 0.88 hrs/unit.

- However, for year 2 we assume 50% of that learning is lost due to personnel turnover during year one. Half of total learning per unit is 0.44 hours. This lost learning is added to the average unit hours. Adding 0.44 hours to the average unit figure of 2.37 hours per repair gives a hypothetical first unit figure of 2.81 for year 2, which is a factor of 0.8646 of first unit hours.

- Looking at a table of 90% learning curve factors, we see that 0.8646 lies somewhere between the values for unit 2 and unit 3. For simplicity our analysis assumes starting at the unit 3 value. (The actual algebraic "unit" corresponding to 0.8646 is 2.6 which is rounded up to unit 3.)

- The model estimates 120 repairs in year two. If we begin with unit 3, the last unit becomes unit 123. The Hrs per Repair figure for this last unit is 1.35 hours. Based on 120 repairs beginning with repair 3, we estimate that the average repair in year two will take 1.5859 hours or 56.4% of the initial time of 2.81 hours.

- The loss of learning for year two is 50% of the difference of 2.81 hours and 1.5859 hours, or $0.5 \times (2.81 - 1.5859) \approx 0.61$. Adding 0.61 to 1.59, we come to a hypothetical first unit value of 2.20 for year three, which is 0.7829 of the initial value of 2.81 hours. Looking again at a 90% Improvement Curve table, the 0.7829 corresponds roughly to starting at repair 5. Year three, which we estimate to have 200 repairs, begins with unit 5, and runs through unit 205. The average learning factor for this “lot” of repairs amounts to 0.5229, which gives average repair hours of 1.15 per unit. We proceed this way through the five contract years.

PRICE ANALYST RECOMMENDED OBJECTIVE
ADPE REPAIR TECHNICIAN LABOR HOURS

TROUBLE CALLS	Year 1	Year 2	Year 3	Year 4	Year 5
Year 1 units	200	200	200	200	200
Year 2 units		400	400	400	400
Year 3 units			400	400	400
Year 4 units				400	400
Total	200	600	1000	1400	1400
NO. CALLS/MO.	10	30	50	70	70
NO. MONTHS	6	12	12	12	12
TOTAL CALLS	60	360	600	840	840
REPAIRS CALCULATION					
NO. REPAIRS/UNIT	0.3	0.6	0.6	0.6	0.6
NO. UNITS	200	600	1000	1400	1400
TOTAL REPAIRS	20	120	200	280	280
HRS./REPAIR*	2.3738	1.5859	1.1498	0.8331	0.6235
TOTAL HRS./YEAR	**47.5**	**190.3**	**230**	**233.3**	**174.6**
HOURS/REPAIR CALCULATION					
EST. UNIT 1 HRS.	3.25	2.81	2.20	1.67	1.25
AVG. UNIT FACTOR @ 90%	0.7304	0.5640	0.5229	0.4976	0.4973
HRS./REPAIR	2.3738	1.5859	1.1498	0.8331	0.6235
LOST LEARNING CALCULATION					
FIRST REPAIR - HOURS	3.25	2.81	2.20	1.67	
AVG REPAIR HOURS PER UNIT	2.37	1.59	1.15	0.83	
AVG. LEARNING HOURS/UNIT	0.88	1.23	1.05	0.84	
LOST LEARNING @ 50%	0.44	0.61	0.52	0.42	
NET LEARNING PER UNIT	0.44	0.61	0.52	0.42	

FIRST REPAIR - NEXT YEAR	2.81	2.20	1.67	1.25

The reader may wonder why, since the government model assumes only 1/3 the number of repairs in the contractor's estimate, we arrive at objectives which are much greater than 33% of the proposed figures. The reason for this is that the contractor has assumed a much greater number of repairs, which gives many more opportunities for learning. The contractor's estimate therefore achieves greater reductions through learning, even though total hours is much greater because of the greater number of assumed repairs.

Wages and Salaries

Direct labor cost consists of time worked multiplied by appropriate pay rates. We have discussed the major factors that affect time worked. We now discuss direct pay, consisting of wages and salaries.

There are essentially two types of compensation: wages and salaries.

Wages can be defined as the rates of remuneration for employees classified as "Non-exempt" under the Fair Labor Standards Act (FLSA). Employees thus classified must be paid a base hourly rate for each hour worked. FLSA and the Contract Work Hours and Safety Standards Act also set standards for workweek length, overtime pay. The FLSA also mandates payment of the prevailing minimum wage.

Employees classified under the FLSA as "Exempt" are *salaried* individuals, meaning that they are paid on an annual amount regardless of hours worked during that period. Note that salaried personnel are not paid one lump sum annual amount, however; they are usually paid weekly, biweekly, or monthly the same as wage earners. The difference between wage employees and salaried employees is that wage employees must be paid an amount for each hour worked; salaried employees are paid a fixed amount per period regardless of hours worked. This usually means no additional pay for overtime, but may also indicate that time off (within reason) is not deducted from the salary. We discuss leave in subpart 4-7 below and overtime in subpart 4-8.

These definitions and the provisions of these acts are taken over by two additional labor acts that circumscribe pay rates. The Service Contract Act of 1965 (SCA), incorporated into all solicitations and contracts totally or predominantly for services estimated to exceed $2,500, provides a mechanism for determining ***minimum*** wages for certain classes of labor categories determined to be "Non-Exempt" under the FLSA. The Davis-Bacon Act (DBA), incorporated into all solicitations and contracts estimated to exceed $2,000 for construction, alteration, or repair (including painting and decorating) of public buildings or public works within the United States, also provides a mechanism for determining minimum wages for construction-related trades classifiable under the FLSA as "Non-Exempt." The table on the next page outlines the current FAR clauses and their applicability to the various types of contract impacted by labor laws:

Nomenclature	Contract Type	Duration	Clauses
Services	FP	Base + Options	52.222-41 52.222-42 52.222-43
Services	FP	Single Year	52.222-41 52.222-42 52.222-44
Services	Cost-Reimb.		52.222-41 52.222-42
Construction, Alteration or Repair of Public Buildings/Works			52.222-6 through 52.222-15
Construction, Alteration or Repair of Public Buildings/Works	Cost-Reimb.		All the above plus 52.222-16
Facilities Contract w/ Construction Work			All the above plus 52.222-17
Dismantling, Demolition or Removal of Improvements	FP	Base + Options	52.222-41 52.222-42 52.222-43
Dismantling, Demolition or Removal of Improvements	FP	Single Year	52.222-41 52.222-42 52.222-44
Dismantling, Demolition or Removal of Improvements	Cost-Reimb.		52.222-41 52.222-42

Under both acts, managerial and supervisory employees are usually classified as "Exempt," hence not subject to the minimum wage provisions. Under the SCA technical and engineering categories, as well as some other occupations, are "Exempt." Occupations normally thought of as "blue collar," trades, and unskilled are usually "Non-Exempt" for the purposes of these acts.

The acts not only prescribe minimum hourly wages for Non-Exempt occupations, but also specify certain minimums for leave, health and welfare, and other benefits (termed "fringe benefits"). The minimum wages and benefits are determined by Standard Metropolitan Statistical Area, county and rural areas based on wage studies conducted by the Office of the Wage and Hour Administrator at the Department of Labor. Periodically that office issues "Wage Determinations" by locality for thousands of occupations.

If wages for various occupations are effectively set for a locality based on a Collective Bargaining Agreement (CBA) between a union and one or more large firms, the DOL wage determination will be conformed to that CBA. However, by the provisions of the law, a recognized CBA takes precedence as a minimum wage if different from the most recent wage determination.

Wages and salaries are set based on the economic forces operating in the market for labor. That is, labor is a marketable commodity subject to the economic laws of supply and demand. Based on a relative lack of labor mobility, those forces operate only over a small geographic area. If there is a labor shortage in a particular area, wages or salaries for certain occupations will be driven up; if there is a labor surplus, wages or salaries for certain occupations will decrease, sometimes dramatically. This is especially true of trades and of low-skilled and unskilled occupations. Over time, extreme highs and lows will tend to even out as more mobile persons gravitate to areas paying higher wages. Still, the variation of certain areas (the West Coast, the Atlantic seaboard cities) from the national average is often dramatic and relatively stable over time. The intent of the SCA and DBA is to attempt to provide a “floor” for wages in occupations that are typically at or below the poverty line. Paradoxically, as we shall see, they also provide a subsequent ceiling for wages under fixed price government contracts that exceed one year.

The relevant provisions of the DBA are incorporated into government solicitations and contracts through FAR 22.4. Those of the SCA are incorporated through FAR 22.10. The basic provisions of both that are relevant for our purposes are similar enough that we shall treat them together. Both require that, for acquisitions exceeding the stated thresholds, the government and offerors must comply with certain requirements, as follows:

- The government, prior to issuing a solicitation or Request for Quotation, must determine what specific occupations will be needed to accomplish the Performance Work Statement and must obtain from the Department of Labor a wage determination for each such occupation that is classified as Non-Exempt under the FLSA. These determinations include a minimum hourly wage as well as certain benefits such as: number of holidays, personal leave, minimum contractor health and welfare contributions (insurance and so forth), and occasionally other benefits.

- These wage determinations must be incorporated into the solicitation and resultant contract(s). If the contract is to include annual options, any succeeding wage determinations must be incorporated into those options when issued by the DOL.

- Offerors must propose Non-Exempt labor based on the wage determinations in the solicitation. That is, the offerors must propose *at least the minimum wage*; they may initially propose wages higher than the stated minimums. Exempt labor may be proposed based on the contractor’s practice for those occupations. Where the offeror is proposing labor categories that do not match any of the occupations in the solicitation, but which are Non-Exempt, the offeror must “conform” those labor categories to one of the ones listed in the solicitation, and must propose at least the minimum wage for that conformed category. Conformation is based on similarity of the proposed job category to those listed.

- ***Under fixed price contracts, offerors cannot propose higher Non-Exempt wages in the out years.*** FAR considers this an unwarranted contingency based on the fact that the contract provides a mechanism for wage adjustments in the out years. *Under cost-reimbursement contracts,* *contractors are not restricted from proposing higher out year wages.* ***Offerors may propose higher out year wages for Exempt employees under both fixed price and cost-reimbursement contracts.***

- In evaluating offerors' proposals, contracting officers must assure themselves that offerors are proposing (at least) the minimum wages and benefits prescribed by the wage determinations. This will usually mean requesting "information other than cost or pricing data" to include proposed hourly wages and benefits by labor classification.

- The firm awarded the contract must pay at least the minimum wage during the first year of the contract for all Non-Exempt labor categories.

- If the contract includes annual options, the contracting officer must insure that successive wage determinations issued by DOL are incorporated into the contract and the contract properly adjusted for the increase. We discuss the details of all this in subpara. f. below.

- If wages for the relevant occupations are set by a recognized Collective Bargaining Agreement in the area, then a successor contractor must agree to pay at least the hourly rates for the last year of the precedent contract (which will be those set according to the CBA). Future minimum wages will be those of the in-place, recognized CBA or its successor.

Adjustment of Wage Determinations: FAR 52.222-43 and 52.222-44 describe adjustment of wage determinations in some detail as regards base wages. However, there are certain aspects that must be emphasized because they are counterintuitive. Additionally, we must emphasize that there are cost elements that must be adjusted, and cost elements that cannot be adjusted, under fixed price contracts. **All costs associated with wage adjustments are adjustable under cost reimbursable contracts, even under the operation of these labor laws.** We now elaborate on the adjustment of a wage determination under both a fixed price and a cost-reimbursable contract.

Assume the following labor classification, initial wage determination, initial proposed wage, successive wage determination, and proposed and allowable wage adjustment for a fixed price contract incorporating provisions of SCA:

Labor Class	Initial Wage Determination	Proposed Base Year Rate	Successive Wage Determination	Proposed Opt Yr 1 Rate	Allowable Opt Yr 1 Rate
Exec Secretary I	$9.25	$9.42	$9.57	$9.75	$9.57

The contractor initially proposed a wage rate higher than the wage determination. This is acceptable within the provisions of the SCA. However, the initial wage determination was succeeded a year later by another which raised the minimum wage for this occupation to $9.57 per hour. Again, the contractor proposed a rate higher than the new wage determination. Under the operation of the SCA, as incorporated by FAR 52.222-43, the government will ***not*** agree to pay the proposed $9.75 rate under the option adjustment; it will

> pay no more than the $9.57 per hour prescribed in the wage determination. ***Paradoxically, successive wage determinations become both a floor and a ceiling for wage rates under fixed price contracts.*** (See the example at FAR 52.222–43.)
>
> Now suppose the same scenario under a cost-reimbursement contract. The clauses at 52.222-43 and 52.222-44, which prescribe wage adjustments, are not applicable to cost-reimbursement contracts. ***Under the operation of the SCA, as incorporated by FAR, the government cannot prohibit the contractor from paying a higher wage than prescribed by either initial or successive wage determinations.*** The principle that the contractor will be reimbursed all allowable, allocable, reasonable costs under cost-type contracts takes precedence over the provisions of the labor laws.

Economic escalation of wages. For those wage earners and salaried employees not subject to wage determination, contractors may propose higher out year rates based on their best judgment as to what the labor market will require to employ and retain productive, loyal employees whose level of skill for their occupation meets the contractor's requirements.

Determination of out year wages under these circumstances is a subjective process based on judgment as well as economic knowledge, therefore factors such as economic escalation factors are not considered to be cost or pricing data. Historical wages paid, however, are considered to be cost or pricing data because they are verifiable facts not requiring the application of judgment. Usually, contractors will use a combination of historical wages paid, wages paid by competitors, and government wage indexes in determining proposed out year wages and salaries.

Price/cost analysts and contract specialists must also carefully consider economic and market forces in evaluating proposed out year labor rates. Market research should already have given some idea of current wages and salaries in the relevant industry, and perhaps wage/salary trends as well. Government indexes maintained by the Bureau of Labor Statistics, Department of Commerce can also be used to gauge trends and probable changes in wages and salaries. These can be found on the World Wide Web at http://www.bls.gov/.

Evaluation of out year labor rates should be based on a combination of historical data, current pay rates, and systematic analysis of trends to project future rates based on statistical analytical tools such as regression analysis. Analysis of historical data from market research, using various types of regression analysis, will often allow the analyst to gauge not only the effect of economic factors but also to assess the impact of other factors such as turnover, headcount, and seniority on wage changes over time. We demonstrate such analyses in Part 7.

Overtime – Compensated and Uncompensated.

Overtime is an important enough, and convoluted enough, cost element of labor to warrant its own coverage.

"Overtime" means time worked by a contractor's employee in excess of the employee's normal workweek. "Normal workweek", means, generally, a workweek of 40 hours. Outside the United States a workweek longer than 40 hours shall be considered standard if it is the norm based on local custom, tradition, or law; and the hours worked in excess of 40 in the workweek are not compensated at a premium rate of pay. "Overtime premium" means the difference between the contractor's regular rate of pay to an employee for the shift involved and the higher rate paid for overtime. It does not include shift premium.

FAR 22.103-2 states that "Contractors shall perform all contracts, so far as practicable, without using overtime, particularly as a regular employment practice, except when lower overall costs to the Government will result or when it is necessary to meet urgent program needs."

Solicitations normally are not to specify delivery or performance schedules that may require overtime at Government expense. If it becomes apparent during negotiations that overtime will be required in contract performance, the contracting officer must secure from the contractor a request for all overtime to be used during the life of the contract, to the extent that the overtime can be estimated with reasonable certainty.

Overtime approvals. The contracting officer (except as noted in FAR 22.103-5(b)) shall include the clause at FAR 52.222-2, Payment for Overtime Premiums, in solicitations and contracts when a cost-reimbursement contract is contemplated and the contract amount is expected to be over $100,000.

- Approval by the designated agency official of use and total dollar amount of overtime is required before inclusion of an amount in paragraph (a) of FAR 52.222-2.
- Contracting officer approval of payment of overtime premiums is required for time-and-materials and labor-hour contracts (see subparagraph (a)(3) of FAR 52.232-7, Payments Under Time-and-Materials and Labor-Hour Contracts).

- No approvals are required for paying overtime premiums under other types of contracts.

During contract performance, contractor requests for overtime exceeding the amount authorized by paragraph (a) of FAR 52.222-2, shall be submitted to the contract administration section in accordance with paragraph (b) of the clause. If the contracting officer determines that the requested overtime should be approved in whole or in part, the contracting officer shall request the approval of the agency's designated approving official and modify paragraph (a) of the clause to reflect any approval. ***Overtime premiums at Government expense should not be approved when the contractor is already obligated, without the right to additional compensation, to meet the required delivery date.***

FAR 22.301, Statutory Requirements, states the requirement of the Contract Work Hours and Safety Standards Act that certain contracts contain a clause specifying that no laborer or mechanic doing any part of the work contemplated by the contract shall be required or permitted to work more than 40 hours in any workweek unless paid for all such overtime hours at not less than 1 1/2 times the basic rate of pay. FAR 22.305 requires the contracting officer to insert the clause at FAR 52.222-4, Contract Work Hours and Safety Standards Act -- Overtime Compensation, in solicitations and contracts (including basic ordering agreements) when the contract may require or involve the employment of laborers or mechanics, except for:

- Contracts at or below the simplified acquisition threshold.
- Contracts for supplies, materials, or articles ordinarily available in the open market.
- Contracts for transportation by land, air, or water, or for the transmission of intelligence.
- Contracts to be performed solely within a foreign country or within a territory under United States jurisdiction.
- Contracts requiring work to be done solely in accordance with the Walsh-Healey Public Contracts Act.
- Contracts for supplies in which any required services are merely incidental and do not require substantial employment of laborers or mechanics.
- Contracts for commercial items (procured under the provisions of FAR Part 12).
- Any other contracts exempt under regulations of the Secretary of Labor (29 CFR 5.15).

In computing required overtime payments, (i.e., 1-1/2 times the basic hourly rate of pay) the contractor shall use the basic hourly rate of pay in the wage determination, or the basic hourly rate actually paid by the contractor, whichever is higher. The basic rate of pay includes employee contributions to fringe benefits, but excludes the contractor's contributions (in whatever form) for fringe benefits. Overtime is not to be computed on a rate lower than the basic hourly rate in the applicable wage determination.

Uncompensated Overtime (FAR 37.115). The general policy of the Federal Government is that use of uncompensated overtime is not encouraged.

- Since price is always a significant factor in source selection, competition provides an incentive for offerors to propose the lowest overall cost they can achieve. One method of lowering proposed cost for professional and managerial services is to use uncompensated overtime (UCOT). The use of UCOT has been a serious issue for DOD since the early 1990s in offers for professional services, especially where the government specifies the workload data or anticipated level of effort.

- UCOT refers to the practice of working salaried employees, those whose pay is essentially fixed, more than 40 hours per week on a regular basis. The method applies to salaried professional categories exempt from the provisions of the Fair Labor Standards Act, which means that the firm is not required to pay them overtime for hours worked beyond 8 hours per day or 40 hours per week. Examples of professional services, and the types of professional employees that might be subject to UCOT, are as follows:

Type of Service	Professional Categories
ADP Services such as	Systems Analyst
database design & admin	Data Analyst/Designer
	Programmer
	Systems Programmer
	Database Administrator
Logistics services	Logistician
	Requirements Analyst
	Engineering Planner
	Operations Research
	Systems Analyst
	Transportation Specialist
Energy Management Svcs	Physical Scientist
	Engineer
	Analyst
	Technician
Managerial Employees	Any salaried employee

- In proposals for T&M contracts where the offeror uses the UCOT practice, the billable hourly labor rate is calculated on the basis of a workweek of more than 40 hours. This allows the offeror to propose what appears to be a lower hourly billing rate.

`An example of this practice could proceed as follows:

A salaried employee is paid $48,800 per year. Under the standard 40-hour workweek, the salary is divided by 2,080 hours to determine the direct hourly labor rate for billings, i.e., $23.46. Under the UCOT method, the same salary is divided by 2,080 hours plus the UCOT. For example purposes, 416 UCOT hours added to 2,080 hours = 2,496 total hours. The $48,800 salary divided by 2,496 hours yields an hourly labor rate of just $19.55. Table 1 compares the standard and UCOT methods of arriving at proposed billing rates.

Table 4-1
Calculation of Hourly Rates

Standard Method
(40-hour work week)

Annual salary / 2,060 hours	=	Hourly rate
$48,800 / 2,080	=	$23.46 /hour
Overhead, G&A, etc @ 75%	=	17.60
Profit/fee @ 10%	=	4.10
Fully burdened billable hourly rate		$45.16 /hour

Billable amount for a work year = 1,864 hours x $45.16 = $84,178.24
(Excludes 216 hours vacation/holiday/sick leave paid out of overhead)

UCOT Method
(Assumes 48-hour work week)

Annual salary ÷ (Actual hours to be worked + leave time)	=	Hourly rate
$48,800 / 2,496 hours	=	$19.55 /hour
Overhead, G&A, etc @ 75%	=	14.66
Profit/fee @ 10%	=	3.42
Fully burdened billable hourly rate		$37.63 /hour

Billable amount for a work year = 2,237 hours x $37.63 =$84,178.31
(Excludes 259 hours vacation/holiday/sick leave paid out of overhead)

NOTES:
1. 2,496 hours is based on 48 hours/week times 52 weeks.
2. Hours used for billable amount per work year are known as the base productive hours, which in this example are 1,864 for the standard method and 2,237 for the UCOT method.
3. The billable amount for a work year is $384,178 in both cases even though the Latter hourly rate is ($45.16 - 37.63=) $7.53 lower than the former. This is because the work year is 20% longer.

Under T&M contracts the contractor must work more hours to break even under the UCOT approach. There is an incentive to work additional hours, in order to realize greater profit as the billable amount exceeds the fixed cost of the salary. This practice can lead to difficulties for the government if the contractor is tempted to: bill for unproductive work hours, lower productivity so as to "run up" hours, or use fraudulent billing practices.

Under cost-reimbursement (CPFF, CPAF) contracts, the concern is to avoid an offeror benefiting from a "hollow" low price and the government not receiving the value it has anticipated in its evaluation as the promised lower price is not realized based on overworked employees and declining productivity.

Pricing and technical evaluation personnel must analyze the workweek or workyear basis used in proposing hourly billing rates for salaried professional personnel. UCOT must be evaluated by cost realism, value analysis, and the provisions of FAR 52.222-46, Evaluation of Compensation for Professional Employees. Use the following procedures in evaluating proposals potentially based on UCOT:

- For employees exempt from the Fair Labor Standards Act (salaried employees), annual salaries should be requested and reviewed against proposed hourly rates to determine the proposed work year in hours. Alternatively, the contractor could be required to provide the work year basis for hourly rates for these employees, and should be required to justify use of other than the standard 40-hour workweek for salaried employees.

- For standard workweeks greater than 40 hours, evaluate the value of these additional hours, realizing that productivity is bound to decline at some point.

- Determine whether or not the proposed work year provides surge capability to handle peak workloads. Contractors using 48-to 50-hour workweeks to handle the normal workload have little or no surge capability.

- Determine whether there are a significant number of work hours that will be unsupervised. This can lead to fraud, waste and abuse.

Direct Material

As previously noted, direct material can be raw materials, structures (such as metal extrusions), parts, subassemblies or components (including machinery or equipment) incorporated into end products. Direct material does not include the cost of machinery and equipment used to manufacture or assemble end products or to perform services. The costs of these are treated separately and are discussed in Part 5.

Material incorporated into end products is normally purchased by the contractor. Machinery and equipment used to manufacture end items or to perform services may either be purchased or leased. In this Part we discuss purchase only; leasing is covered in Part 6.

Most material is sold on a competitive basis since so many firms must compete for raw materials and structures, parts and subassemblies made of those materials. However, many firms do not routinely compete their material requirements. More prevalent is the tendency to develop a business relationship with a particular firm or perhaps a select group of firms with which the contractor exclusively does business due to factors that may or may not include cost. Therefore, even if material may be considered commercial pricing, the contracting officer cannot just assume that proposed material costs are automatically fair and reasonable.

There are several ways to ascertain that proposed material costs are fair and reasonable:

- Market research
- Contractor purchase orders based on competitive solicitations or quotes
- Price history based on competition, adjusted to current price levels using indexes
- Catalog prices (using current catalogs freely available to the public for items sold in substantial quantities to the general public)
- Industry literature

As with any cost element, the data justifying the proposed cost of material must be current, accurate and complete. The costs must be allocable, allowable and reasonable.

Contractor documentation is preferable to Government price histories for the reason that price histories often obscure many of the factors that went into the previous pricing decisions. Competitive purchase orders are preferable to sole source buys justified through cost analysis. Market pricing (including catalog prices) is preferable to competitive purchase orders because it demonstrates a long-term competitive tendency that is part of an on-going market rather than a one-time price based on specific circumstances and possibly only a selected market segment.

For costs to be allowable, they must not be one of the costs proscribed by FAR 31.205. To be allocable they must be consistently charged as direct or indirect costs in the same or similar circumstances. To be reasonable, they must be justifiable through cost analysis or price analysis.

The following should be borne in mind when using competitive contractor purchase instruments to justify material prices:

- Contractor purchase documentation should be legally binding, based on recent quotes on the same item or work specification, from independent firms capable of providing the material necessary within the established time frame.

- If award was based on just on price-related factors, but included other significant factors, the analyst must consider whether the contractor did make a best value selection.

i. The following should be borne in mind when using non-competitive contractor purchase instruments to justify material prices:

- On what basis was the non-competitive price justified?

- Why was it non-competitive? Were the specifications the same as on the current buy?

j. Use the following when basing justification of material costs on commercial pricing:

- Current price lists for the same or similar material (same quantity)
- Market research results
- Demonstrated market price

k. The following considerations apply to justification through comparison to price history:

- Price history data should be as current as possible

- Non-current data must be escalated to current price levels (i.e., current as of the period of performance)

- Quantities must be similar to quantity for the current procurement, or the analyst must adjust the analysis for the difference in quantity (price break structure and so forth)

- The analyst must determine if previous prices for material are based on separate orders or on consolidation of quantities for several orders into one

Factors such as quantity purchased, grade of material, and consolidation of several orders into one can markedly affect the unit price of material. The analyst must be prepared to make adjustments to comparative data to ensure “apples to apples” analysis. If there are price breaks for quantity or customary trade discounts for “best customer” status, this should be ascertained and factored into the price comparison.

Capitalization and Depreciation

Most large equipment and assets used in a business are not expensed when purchased, but are capitalized and depreciated over time. Capitalization refers to the process of entering the cost of these items into the accounting records as assets. Depreciation refers to the accounting process of assigning a portion of the capitalized cost to an expense account each accounting period. Most firms have a time and/or cost threshold for capitalizing rather than expensing items. For example, a firm may have a policy that all items costing $3,000 or more and having a useful life of more than a year will be capitalized and depreciated.

Capitalized cost of a piece of equipment or item such as a computer system, refers to all costs of purchasing, shipping, installing and setting up the equipment for use. For the purposes of depreciating the cost of an item over time, the capitalized cost does not usually include any estimated residual value of the item after its useful or economic life is over. Such residual value is the estimated market value of the time of disposal. An example is the trade-in value of a car. There is the wholesale value, which dealers often use for assessing trade-in value, and the blue book value, which is the market value for selling a car. The capitalized cost, less residual value, is termed the depreciation basis of the asset.

The firm sets up a depreciation account for each capitalized asset. The undepreciated value of the asset is termed its “net book value” or NBV. The NBV of an asset at inception is its depreciation basis (purchase price less its residual value). At the end of each successive accounting period, the NBV is the previous value less the depreciation assigned to that period. At the end of its useful life, the NBV of an asset should be the residual value, if any.

There are a number of mathematical methods of depreciating an asset. Some assign more depreciation to earlier periods and less depreciation to later periods, termed accelerated depreciation. Straight line depreciation, the simplest method, assigns the same amount of depreciation to all periods. In this pamphlet we will describe the three most used methods of depreciation: Straight Line, Sum of the Years Digits, and Declining Balance.

The accounting principal related to depreciation is to select a depreciation method that fairly represents the actual use of the asset, since pattern of usage theoretically is the most pronounced factor in an asset’s value being “used up” or reduced to zero. If an asset’s value is reduced steadily over its life, straight line depreciation would be appropriate. If an item’s value is reduced more quickly early in its life, then an accelerated method is appropriate. In the 1980’s the IRS began, for tax purposes, to limit firms in their use of accelerated methods since in the 1970s’ and early 1980’s many firm were using accelerated methods to create a higher depreciation cost, thus lowering their profit figures substantially on paper and lowering their tax burden. By trading in the assets earlier, they could keep this cycle of accelerated depreciation going indefinitely and appear to be less profitable for tax purposes. For financial reporting purposes, they would use a different method such as straight line. The IRS also put a stop to those practices, stating that the contractor had to use the same method for tax reporting that it used for financial reporting.

The straight line method of depreciation uses a simple proportion to assign the same amount of depreciation to each accounting period. The formula for this method is

SL = (Capitalized Cost – Residual Value)/Useful Life (years)

As an example, suppose that a contractor purchases a computer system for all operations and accounting functions. The cost of the computer system is $55,000, shipping is $4,600; installation and set up by the OEM is $6,400. The useful life of the system is estimated at six years and the OEM estimates the residual market value to be $3,000. The straight line method is proposed for depreciation of this system. Calculation of the depreciation amount is as follows:

Purchase price	$ 55,000
Shipping	4,600
Install/set up	6,400
Capitalized Cost	$ 66,000
Residual value	(3,000)
Depreciation basis	$ 63,000

SL = $63,000/6 = $10,500 per annum. The following schedule shows the depreciation and NBV at the end of each accounting period (year, in this case).

Year	Beginning Value	Depreciation	Net Book Value
1	$ 66,000	10,500	55,500
2	55,500	10,500	45,000
3	45,000	10,500	34,500
4	34,500	10,500	24,000
5	24,000	10,500	13,500
6	13,500	10,500	$ 3,000

The first accelerated method taught will be the “Sum Of The Years Digits” (SOYD) method. In this method, the number of years of useful life, n, becomes a series whose sum provides the denominator for the fraction of depreciation recorded each year. In each year, the sequence number of that year is used to calculate the numerator in the factor for that year. For example, given that the useful life is n = 7 years, the sum of the years’ digits is equal to S = 1+2+3+4+5+6+7 = 28. This is the denominator in each depreciation factor. The numerator is equal to (n-y+1) where y is the sequence number of the year (i.e., 1, 2, 3) in which the depreciation is recorded. The following are the factors used.

Year	Numerator	Denominator	Factor
1	7	28	7/28
2	6	28	6/28
3	5	28	5/28
4	4	28	4/28
5	3	28	3/28
6	2	28	2/28
7	1	28	1/28
Total Depreciation Factor			28/28

Note: Using SOYD the depreciation basis (capitalized cost less residual value) is the value used with the appropriate annual factor to calculate annual depreciation each year, and the NBV reduces to zero (0). This is different than the straight line method, which uses the capitalization cost as the initial value and depreciates the asset until it reaches its residual value. Using the values given in the straight line example, we obtain the following results:

Year	Beginning NBV	Depreciation Factor	Depreciation Recorded	Ending NBV
1	63,000	7/28	15,750	47,250
2	47,250	6/28	13,500	33,750
3	33,750	5/28	11,250	22,500
4	22,500	4/28	9000	13,500
5	13,500	3/28	6,750	6,750
6	6,750	2/28	4,500	2,250
7	2,250	1/28	2,250	0

Another accelerated method is termed the "Declining Balance" (DB) method. This applies the calculated depreciation factor to the declining balance of the NBV, not to the original cost as with the SOYD method. The formula for calculation of the DB rate is as follows:

$DB = 1 - \sqrt[n]{\frac{RV}{CV}}$, where n = the number of years of useful life, RV = residual value, and CV = the capitalized value.[1] Please note that the n is a root power. In this case, take the 7th root of RV/CV. Given the same values we have been using, i.e.,

CV = $66,000
RV = $ 3,000
n = 7 years,

the depreciation factor is found as

$$DB = 1 - \sqrt[7]{\frac{3{,}000}{66{,}000}} = 1 - 0.6430213 = 0.3569787$$

which is applied each year to the NBV (the declining balance) from the end of the previous year. The schedule on the following page shows the application of the method for each of the seven years.

Year	Beginning NBV	Depreciation Recorded[2]	Ending NBV
1	$63,000.00	22,489.66	40,510.34
2	40,510.34	14,461.33	26,049.01
3	26,049.01	9,298.94	16,750.07
4	16,750.07	5,979.42	10,770.65
5	10,770.65	3,844.89	6,925.76
6	6,925.76	2,472.35	4,453.41
7	4,453.41	1,453.41	$3,000.00

[1] This is also known as the 100% Declining Balance method. Firms have used other factors such as 125% DB, 150% DB, and 200% DB or Double Declining Balance (DDB). IRS rules do not currently permit firms to use anything above the 150% DB method. We demonstrate only the basic DB method for pedagogical purposes.

[2] The calculated depreciation in year 7 is higher than that shown. Depreciation taken in the last year must not reduce NBV below recorded residual value.

Depreciation accounts are normally part of a firm's overhead pools because use of the asset benefits more than one final cost objective. If an asset is purchased solely for one final cost objective, such as one government contract, recorded depreciation *may not* be transferred to an overhead pool and allocated to all final cost objectives. It must be charged to that final cost objective that it benefits.

If an asset is purchased for use on one contract, but its useful life exceeds the contract life and it may be used for other future business or sold at a fair market value, then its depreciation basis (cost less residual market value after the contract) should be charged direct to that contract on a pro rata basis. For example, an asset with a seven year life, purchased for use on a five year government contract and meeting the stated criteria, should have no more than 5/7 of its depreciation basis charged to that contract.

Contractors may lease equipment or other assets for use on one or more final cost objectives. This situation is addressed in Part 6, Lease-Purchase Analysis, and in the FORSCOM Manual *entitled Pricing Contracting Furnished Equipment in Service Contracts.*

The Nature of Indirect Costs

Indirect costs are those costs that cannot be traced directly back to the final cost objective (end product, service or contract) for which the costs are incurred.

By contrast, direct costs can be directly traced back to the final cost objective. Labor performed on an assembly line can be traced to the assembled end item. Material purchased for an end item can be traced to that end item or to work-in-progress inventory.

However, the time spent by foremen supervising a number of workers that are working on different end items or projects cannot be traced directly to each end item or project without an enormously expensive and burdensome timekeeping system. The oil, grease, solvents, lubricants and so forth used in an automotive repair shop cannot be assigned directly to each repaired car without very precise measuring systems and extensive bookkeeping. The same is true of electricity used by the equipment, lighting and so forth. Janitorial services likewise cannot be directly apportioned.

For indirect costs, the best that can be accomplished is to "pool" those costs and proportion them fairly to each final cost objective by some mathematical method. There are a number of ways this can be accomplished. This Part discusses the principles of fair allocation (apportionment) of indirect costs to cost objects, and some methodologies that are used. Discussion of Cost Accounting Standards for assignment of indirect costs will be held to a minimum; for a fuller treatment the reader is invited to consult FAR Part 30 and the FAR Appendix (48 CFR 99).

Certain functions, termed "service centers," perform specialized tasks for other organizational units of the contractor. They may perform related tasks for specific contracts. For example, an Information Technology Service Center (ITSC) may do all the data processing for the personnel and payroll departments, provide management data to management, and keep databases for reporting on specific government contracts. A portion of the ITSC costs is therefore allocated to certain indirect cost pools, and the remainder is charged directly to those contracts. When costs are collected in a cost center (such as a service center) before being transferred ("allocated") to one or more indirect cost pools, the collection account is termed an "intermediate cost objective." In Table 4-2 above, the "Allocations" section shows allocations from use and occupancy services, computer services, and operations to the labor overhead pool.

Most contracting practitioners know the basics of indirect costs, but they make the mistake of thinking that there is a "standard" or "proper" rate for labor overhead, material overhead, G&A, and so forth. ***There is no single rate that is standard or proper***. For example, labor overhead can vary from around 15% to over 200% of direct labor. G&A

rate can vary from a few percent to 30% or more. It depends on the size of the firm, the type of business it does, how it structures its indirect cost pools, and the bases it chooses for its rates.

Indirect Labor Costs

Indirect labor costs are composed of the following broad categories, each of which we discuss in more detail below:

- Fringe Benefits
- Payroll Taxes
- Workmen's Compensation Insurance
- Labor Overhead

Fringe benefits are all those "perks" such as health and welfare, stock options, leave, and so forth for which the employer pays all or a substantial portion, either directly or as cash remuneration to the employee. Some accounting systems treat these as part of direct labor, while others pool them with the other labor overhead costs.

Health and welfare includes any health and life insurance coverage provided by the employer, or whose periodic fees the employer substantially pays. DOL wage determinations usually prescribe a minimum dollar amount per hour worked for health and welfare benefits. They also prescribe a minimum number of paid holidays and may specify a minimum number of days of paid personal leave. Occasionally other benefits customarily paid to certain occupations are included, such as hazardous duty pay, or special night and weekend pay for sea duty.

In evaluating fringe benefits, the analyst must be able to assure the contracting officer that the offerors' proposals comply with the wage determinations. If the various components are rolled into labor overhead or shown as a percentage of base pay, the analyst must be able to convert this to an approximate hourly rate or individual costs corresponding to the language of the wage determination. Alternatively, the analyst may take the components stated in the wage determination, convert them to a percentage of average base pay, and compare this factor with that proposed. After discussion of the other components of fringe benefits, we will demonstrate this type of analysis.

Payroll Taxes. Payroll taxes are those dollar amounts the contractor must withhold from the employees' paychecks to cover various federal and state taxes. These are as follows:

- Federal Individual Compensation Act (FICA, or Social Security). Every employer must withhold a specified percentage of each employee's wages or salary, up to a ceiling amount called the "cap." Currently, the employer must withhold 7.65% of base pay, up to a cap of $72,600. The current rate and cap can be found at the Social Security Administration Website at http://www.ssa.gov/pubs/10003.htm.

- Federal Unemployment Tax Act (FUTA). This act mandated the reservation of funds to cover unemployment payments to temporarily unemployed workers. This is set at a rate of 0.8% of base pay for the first $7,000 of wages or salary.
- State Unemployment Tax Act (SUTA). Each state also mandates reservation of funds for provision of monetary assistance to unemployed workers in that state. The rate and cap are different for each state, but usually the cap is low (most do not exceed the first $9,000 of wages/salary).

Workmen's Compensation Insurance (WCI). This is not a payroll tax per se, because it purchases insurance against severe injuries or debilitation suffered based on performance of one's work. The rate or factor will depend on what the employer can establish with firms that provide WCI.

Computation of Fringe Benefits. A hypothetical scenario will illustrate calculation of fringe benefits costs and a fringe benefits factor. The scenario is based on the proposal for labor in Table 5-1 below.

Table 5-1
Direct Labor
Base Year

Labor Classification	Fulltime Equivalents	Annual Workhrs	Hourly Rate	Labor Cost
Project manager	1	1,880	33.75	63,450.00
Asst project manager	1	1,880	31.64	59,483.20
Quality assurance manager	1	1,880	29.66	55,760.80
Quality Assurance Analyst	1	1,880	27.81	52,282.80
Senior operations research analyst	1	1,880	26.07	49,011.60
Senior Computer Systems analyst	1	1,880	24.44	45,947.20
Computer Systems analyst I	1	1,880	22.91	43,070.80
Computer Systems analyst II	1	1,880	21.48	40,382.40
Computer Systems analyst III	1	1,880	20.14	37,863.20
Computer based trng spec/instr	1	1,880	18.88	35,494.40
Senior application engineer	1	1,880	17.70	33,276.00
Application engineer	2	1,880	16.59	31,189.20
Application programmer	4	1,880	15.55	29,234.00
Configuration mgmt specialist	1	1,880	14.58	27,410.40
Senior database mgmt spec	1	1,880	13.67	25,699.60
Database mgmt specialist	3	1,880	12.82	24,101.60
Data entry clerk	5	1,880	12.02	22,597.60

Based on the above direct labor, the following fringe benefits table recounts the correct amounts for fringe benefits. We discuss each component of fringe benefits and its calculation separately after the table.

Payroll Taxes	FTEs	Hrs/Labor $	Rate	Cost
FICA		$676,254.80	7.65%	51,733.49
FUTA	27	7,000.00	0.80%	1,512.00
SUTA	27	9,000.00	1.08%	2,612.25
WCI	27	2,080	13.32%	7,480.51
				63,338.25
Leave	FTEs	Hrs	Rate	Cost
Holiday Leave	27	80	$13.32	28,776.80
Vacation Leave	27	40	13.32	14,388.40
Sick/Family Leave	27	80	13.32	28,776.80
				71,942.00
Health and Welfare	27	1880	2.02	102,535.20
Total Fringe Benefits				237,815.45
Fringe Benefits Rate				35.2%

Payroll Taxes:

- FICA (Social Security): Calculated at 7.65% of the first $72,600 of wages or salary. Since all proposed labor earns less than this cap, the appropriate way to calculate FICA is to multiply total direct labor dollars times 7.65%. If some personnel will earn more than the cap, the earnings above the cap must be deducted prior to applying the withholding factor.

- FUTA (Federal Unemployment Tax): This is assessed at 0.8% of the first $7,000 of salary and wages. Since *all* proposed labor earns more than the cap, we use the cap. The appropriate way to calculate FUTA is to multiply the 27 FTEs times the $7,000 cap times the 0.8% rate.

- SUTA (State Unemployment Tax): For the scenario this is assessed at 1.08% of the first $9,000 of salary and wages. Since *all* proposed labor earns more than the cap, we use the cap. The appropriate way to calculate FUTA is to multiply the 27 FTEs times the $9,000 cap times the 1.08% rate.

- WCI (Workmen's Compensation Insurance): The offeror, based on competitive bids, proposes a rate of $1 per $100 of total employee compensation. Since this includes productive and non-productive time, the appropriate way to compute this is to multiply FTEs times 2,080 hours per year times average hourly rate times 1%. (If total employee compensation included cash for health and welfare rather than paid benefits, then this would also have to be factored into WCI cost.)

- Leave Cost: Leave is based on the hours shown for each category. Multiplying the leave hours per FTE times proposed FTEs times the average hourly rate gives total leave cost.

- Health and Welfare: This is based on a $2.00 per hour minimum required by the Area Wage Determination for that area (the contractor provides paid coverage equivalent to $0.02 more than this amount). Although only a requirement for Non-Exempt employees, the proposed cost includes the same hourly amount for Exempt employees, which is acceptable.

Based on the proposed amounts for the components of fringe benefits, the equivalent fringe benefit overhead rate is 35.2% of direct labor cost. Some contractors calculate fringe benefits as a cost per hour of labor, but in using that method one must remember that higher paid employees will to some extent receive higher fringe benefits and pay disproportionately more in payroll taxes than will lower paid employees. Use of this method is not recommended because it is only accurate taken over all the contractor's work. For a job for with an atypical skill mix, use of this method may distort the true fringe benefits cost. Use of the percentage overhead rate method does not cause this distortion.

Labor Overhead. Although fringe benefits costs are often included in labor overhead, we will use the term to mean those indirect costs not associated with payroll costs but which have their genesis in labor. The labor overhead pool typically includes costs that cannot be directly assigned to each contract, and may include costs such as:

- Management and supervision: Unless a manager or supervisor is dedicated to one contract full time, their time must be prorated to all contracts to which they are assigned. Their total salary or wages are entered into the pool and allocated to each contract in proportion to some base cost, typically total labor dollars.
- Vehicles, equipment, supplies and tools directly used by labor in performing its tasks. Depreciation on vehicles and durable equipment used in all work would be posted in overhead accounts. The cost of supplies and tools consumed in all work would also be included. This would include "indirect material" such as oils, lubricants, fasteners, gasoline for vehicles, and so forth, which cannot readily be assigned to any particular contract. It would not include any vehicles, equipment, supplies or tools used in running the company (typically in G&A) or dedicated to one contract (usually charged direct or prorated as appropriate).
- Insurance associated with labor, but not included in fringe benefits. This would include insurance on management and supervision in overhead, on vehicles, and so forth. It may also include special insurance coverage for hazardous duty or special circumstances faced by particular employees on a routine basis. Special insurance applicable only to one contract would be charged direct to that contract.
- Fringe benefits for management and supervision in overhead.
- Use and occupancy costs. This may be largely the cost of utilities consumed by labor in performing its tasks. This might include electricity, gas and water used for environmental control in a shop area, or in a large office in which engineers, architectural draftsmen, and technicians work. Often, in an office building or large plant in which there are not separate utility meters for each area, the total dollar amount for utilities must be prorated into each overhead pool. Other costs such as leases, maintenance, security and fire protection, janitorial, and perhaps others, if they can be segregated to the building or area used by labor. There are

several factors one can use to prorate occupancy costs, but typically it is by square footage since such costs are normally correlated to the size of a building in square feet.

Table 5-2 below gives a typical labor overhead structure for a Defense contractor.

Table 5-2
Labor Overhead Structure

INDIRECT COSTS	($000s)		
Salaries and Wages:			
Supervision	1,853		
Indirect Labor	16,655		
OTP	460		
Idle Time	22		
Training	2,750		
Total Salaries & Wages	21,740		
Fringe Benefits:			
Health & Life Ins	15,325		
Workmen's Comp	921		
Annual Leave	3,521		
Holiday Leave	4,652		
Sick & Pers Leave	1,861		
FICA Taxes	7,435		
FUTA	901		
SUTA	958		
Retirement Plan	8,612		
Savings Plan	1,712		
Total Fringes	45,898		
Supplies/Services:			
Operating	450		
Maintenance	24		
Perishable Tools	508		
Office Supplies	614		
Total Supplies/Svcs	1,596		
Other Expenses:			
Travel	3,532		
Telephone	2,346		
Business Meetings	466		
Employee Relocation	255		
Dues & Subscriptions	185		
Employee Welfare	98		
Total Other Expenses	6,882		
Allocations:			
Operations Svcs	246		
Use & Occupancy	30,387		
Computing Svcs	11,222		
Total Allocations	41,855		
Total Indirect Expenses	**$117,971**		
Allocation Base DL$	**$96,028**		
Overhead Rate	**122.9%**		

Note: Fringe benefits costs for direct and indirect labor are included here in labor overhead pool. Fringe benefits for direct employees can be pulled out and included separately as a part of direct labor.

In this scenario, we included fringe benefits for both direct and indirect labor in the labor overhead pool. Another acceptable way to propose is to segregate fringe benefits costs associated with direct labor out of the pool and propose them direct as a part of direct labor. Let us suppose that analysis of the data provided shows that $10,390,000 is fringe benefits for indirect labor. This leaves ($45,898,000 – 10,390,000 =) $35,508,000 as fringe benefits applicable to direct labor. Segregating out fringe benefits this way gives the following summary labor proposal:

Direct Labor	$ 96,028
Fringe Benefits	35,508

Total Direct Labor	$131,536	
Labor Overhead	$ 82,463	**62.7%**

Note that pulling out fringe benefits attributable to direct labor reduces the contractor labor overhead from 122.9% to 62.7%. **However, the application base for labor overhead is now direct labor plus associated fringe benefits.**

All labor overhead burdens should be based on a pool of costs that are labor-related. In other words, there should be a causal connection between the pool cost and the base. Of course, the base for application of the overhead factor is direct labor. If fringe benefits are proposed separately as a direct charge, then it is part of direct labor and would typically be part of the base for application of the labor overhead factor.

Material Overhead

Material overhead pool consists of those costs associated with the purchasing, receiving and inspection, handling and storage, inventory control, issuing, and shipping of material. However, not all contractors include all these functions in their material overhead. Many, for example, include the purchasing function in the G&A pool.

With a retail business such as a mail order catalog company, there is almost always a "shipping and handling" charge after the total of all items purchased. Sometimes the shipping and handling charge is a flat rate, other times it is a graduated amount based on shipping address and/or weight. In job cost firms such as do business mostly with the government, costs are not structured this way, since the material is incorporated into an end item or used in performance of a service.

A typical set of overhead pool costs for material overhead is shown in Table 5-3

Table 5-3

Material Overhead Pool ($000)

INDIRECT COSTS	MATL HDLG POOL
Salaries and Wages:	
Supervision	4,235
Indirect Labor	33,876
OTP	42,345
Training	2,879
Idle Time	85
Total Salaries & Wages	83,420
Fringe Benefits:	
Health & Life Ins	6,288
Workmen's Comp	5,336
Vacation Leave	2,287
Holiday Leave	1,906
Sick & Personal Leave	953
FICA Taxes	3,049

Unemployment Taxes	381
Retirement Plan	3,430
Savings Plan	762
Total Fringe Benefits:	24,392
Supplies/Services:	
Operating	4,235
Maintenance	898
Office Supplies	728
Total Supplies/Services	5,861
Other Expenses:	
Travel	847
Telephone	1,186
Business Meetings	493
Employee Relocation	102
Dues & Subscriptions	31
Employee Welfare	38
Total Other Expenses	2,697
Allocations:	
Use & Occupancy	27,845
Information Tech Svcs	14,145
Operations Svcs	18,280
Total Allocations	60,270
Total Indirect Expenses	176,640

The base for material overhead is total direct material, that is, material incorporated into end items or used in the performance of contractual work statements.

5-4. Allocation of Indirect Costs

The discussion at this point has alluded to, but has not formally addressed, the important aspects of allocating indirect costs to bases (related direct costs) and the calculation of indirect cost or burden rates.

Allocation of costs is usually based on prorating or apportioning a pool of costs to intermediate cost objectives – to other pools or to their respective bases, which are related direct costs – and thence to final cost objectives such as products, services or contracts.

Indirect costs are normally not directly visible to the manager, and are thus more difficult to control than direct costs. The establishment of separate cost pools improves visibility of, hence control over, these costs. Contractors usually group indirect costs into logical pools relating to major functions and activities, types of products, organizational structure, or other relational schema. The costs assigned to the different pools should relate to some benefit provided to a function, organizational unit, or the company as a whole.

As previously mentioned, some organizational functions (service centers) benefit other functions within the company (as well as some contracts), and their costs are thus collected and transferred to the indirect cost pools of those functions or organizational units they benefit. The cost pool to which the service center costs are transferred is known as an "intermediate cost objective," the "final cost objectives" being the end items or contracts indirectly receiving the benefits of the costs incurred.

The diagram in Figure 5-1 below shows the allocation of service center costs, indirect cost pools and direct costs to several different government contracts. In each case, allocation of the overhead pool costs to the three contracts is through relation of the costs to an appropriate base. Each base is an aggregate of direct costs, such as total direct material or labor (which may or may not include fringe benefits).

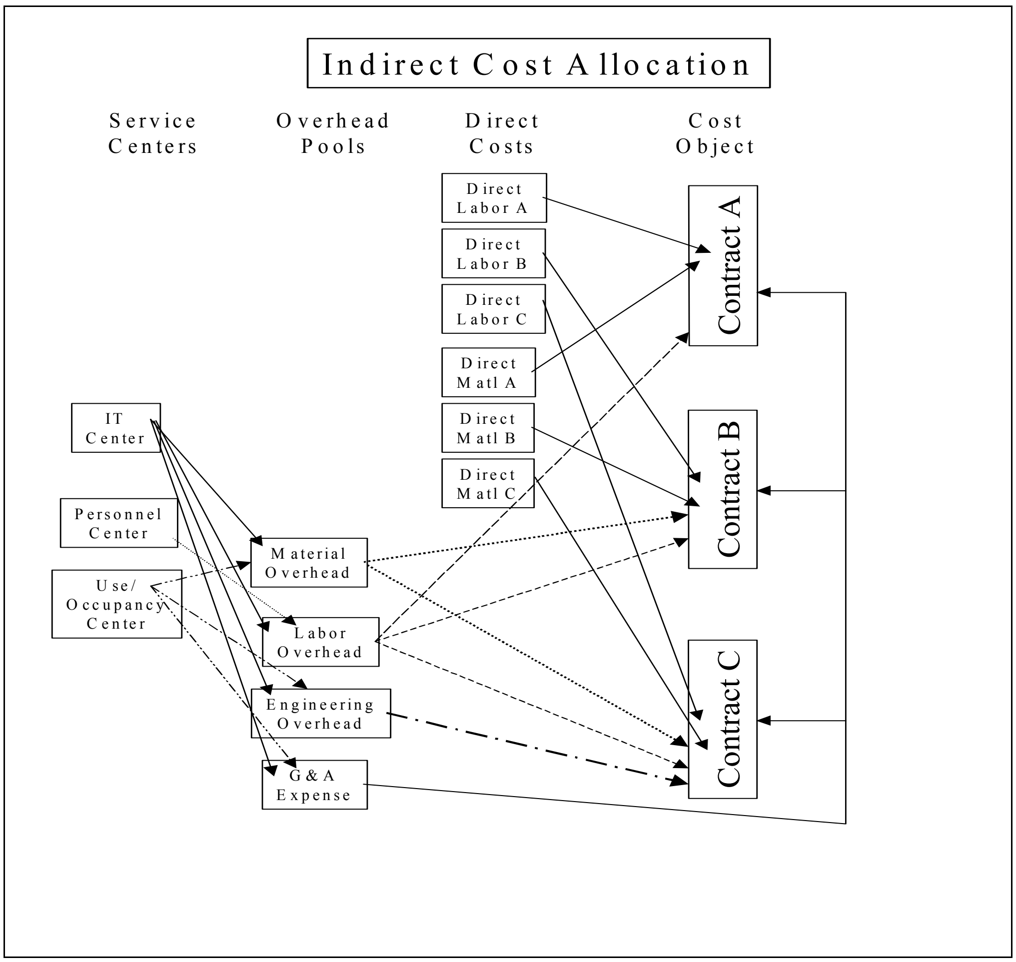


Figure 5-1 Cost Allocation to Contracts

Not shown is the fact that some of the service centers may benefit one another. For example, the Personnel Service Center benefits the IT Center and vice versa. The costs associated with those benefits may be allocated to the service center benefited, then re-allocated to an appropriate overhead pool. Description of how this is done requires knowledge of matrix algebra and is beyond the scope of this pamphlet.

A contractor may allocate costs through any reasonable method as long as it complies with the requirements of Generally Accepted Accounting Principles (GAAP) and, if applicable, Cost Accounting Standards. There is no one logical grouping of costs or method of allocation that is the "right" one. Some small businesses have one overhead pool encompassing all indirect costs, and this is applied to the total direct costs of a final cost objective such as a contract. Others break indirect costs up into several pools such as labor overhead, material overhead, and G&A expense. Very large weapon system contractors may use several dozen pools.

Under GAAP and Cost Accounting Standards, there are three overarching principals that apply to the development and application of overhead structures:

1. **Every cost must be treated in like manner in like circumstances**. If a cost would normally be treated as a direct cost on a product, then it must be so treated under a contract for that product. If a cost is normally treated as an indirect cost and pooled, it should be so treated. The same cost cannot be treated both ways in application to a final cost objective. For example, a contractor cannot have a supervisor's entire salary in the labor overhead pool and also charge an estimated amount directly to a government contract for which he/she will be a supervisor. The reason is that application of labor overhead to the contract will charge a portion of his/her salary to the contract. Charging a portion of that salary direct will double-count some of the cost of their time.

2. **Incurrence of indirect costs has some *cause* in work performed or in operation of the facility for work done, or the business as a whole.** Those activities are normally direct costs of some final cost objective (product, service or contract). For example, foreman costs are incurred in support of the activities of direct labor. ***Therefore, application of those indirect costs to final cost objectives must bear some logical relationship to an aggregate of direct costs.*** All the costs in a labor overhead pool must have some relationship to direct labor. Material-related costs would not be appropriate in an overhead pool whose costs are otherwise incurred in support of direct labor. The logical relationship usually is based on some demonstrable benefit to the direct activity of incurring the indirect costs.

3. **Costs must be estimated, accumulated and reported in a consistent manner**. This has two parts: (a) A contractor's practices used in estimating costs in pricing a proposal must be consistent with its cost accounting practices used in accumulating and reporting costs. (b) A contractor's cost accounting practices used in accumulating and reporting actual costs for a contract must be consistent with its practices used in estimating costs in pricing the related proposal. Below is an example of a consistent practice in developing direct labor rates.

Practices Used in Estimating Costs for Proposals	**Practices Used in Accumulating and Reporting Costs of Contract Performance**

Contractor estimates an average direct labor rate for tech services direct labor by labor category or function.	Contractor records tech service direct labor based on actual cost for each individual and collects such costs by labor category or function.

Here is an example of an inconsistent practice for developing direct labor rates.

Practices Used in Estimating Costs for Proposals	**Practices Used in Accumulating and Reporting Costs of Contract Performance**
Contractor estimates engineering labor by cost function, i.e. drafting, production engineering, etc.	Contractor accumulates total engineering labor in one undifferentiated account.

In the first case, costs are accumulated in greater detail, then averaged for estimating purposes. In the second case the inconsistency involves the inability to track development of the cost from estimate to accumulating and reporting. It is not possible to take an undifferentiated account and from it accurately develop costs at a more detailed level (function). ***Normally, the level of detail used for estimating must be at least the same level used for accumulating and reporting that cost.***

Development of Application Rates

There are three methods, in this priority, of allocating costs to final cost objectives.

1. Identification of costs for direct allocation to final cost objectives to the maximum extent practical (direct costs);

2. Accumulation of significant non-directly allocated expenses into logical and relatively homogeneous pools to be allocated on bases reflecting the relationship of the indirect costs to the functions or activities they support or arise from (overhead); and

3. Allocation of any remaining or residual indirect costs to all final cost objectives based on a measure relating to the total activity of the entity, such as managing the organization as a whole (G&A).

In order to develop a method of applying indirect costs to final cost objectives (products, services, or contracts), a firm must:

- develop one or more overhead pools from the pool of non-directly applied costs, and if applicable, a pool of residual expenses for application to the entity as a whole;

- relate those pools of cost to appropriate aggregates of direct cost by means of an overhead rate(s) or factor(s), and if applicable, a G&A rate; and

- apply pooled costs to final objectives through application of these rates or factors to their respective bases on each contract.

Table 5-4 below shows a firm's entire indirect cost structure grouped into pooled and residual costs and related to appropriate bases (with residual costs assigned to G&A).

Table 5-4

Allocation of Costs to Indirect Cost Pools

INDIRECT COSTS	ENG	FAB	ASSY	TOOLING	MATERIAL HANDLING	OFF SITE	G&A
Salaries & Wages							
Supervision	$ 3,701	$ 19,674	$ 6,246	$ 729	$ 4,235	$ 260	$ 21,982
Indirect Labor	33,310	91,Bll	28,105	4,666	33.B76	1,214	88,636
OTP	925	16,362	4,164	198	42,345	87	2,836
Training	5,552	1,202	520	255	2,879	130	2,978
Idle Time	19	219	104	24	85		
Total Salaries & Wages	$ 43,507	$ 131,267	$ 39,139	$ 5,872	$ 83,420	$ 1,692	$ 116,432
Fringe Benefits							
Health & Life Ins	$ 29,609	$ 40,768	$ 17,176	$ 4,008	$ 6,288	$ 1,388	$ 1,595
Workmen's Comp	1,851	31,041	12,491	1,093	5,336	173	4,432
Annual Leave	7,402	8,744	4,164	972	2,287	347	3,90C
Holiday	9,253	10,930	5,205	1,214	1,906	434	2,482
Sick & Pers Lv	3,701	7,651	3,123	559	953	173	1,773
FICA Taxes	14,804	17,488	8,327	1,943	3,049	694	1,578
Unempl Taxes	1,851	2,186	1,041	243	381	87	*1,064*
Retirement Plan	16,655	19,674	9,368	2,186	3,430	781	2,570
Savings Plan	3,701	4,372	2,089	486	762	173	2,322
Total Fringe Benefits	$ 88,827	$ 142,853	$ 62,977	$ 12,703	$ 24,391	$ 4,250	$ 21,716
Supplies/Svcs							
Operating	$925	$ 18,624	$ 6,402	$ 1,241	$ 4,235		$ 106
Maintenance	37	1,093	520	121	898		21
Perishable Tools	1,110	9,181	4,372	1,020	51		
Cal & Cert	370	656	312	73	34		
Office Supplies	925	874	427	97	728		1,950
Total Supplies/Svcs	$3,368	30,429	$ 412,033	$2,553	S E,,945		$2,078
Other Expenses							
Travel	$7,032	$ 1,749	$ 833	$ 194	$ 8,469		$ 8,864
Telephone	4,626	1,093	520	12'	1,186		10,016
Busn Meetings	925	66	31	20	593		1,773
Employee Relocation	555	44	21	5	102		124
Dues & Subscriptions	370	46	*21*	8	31		1,773
Employee Welfare	185	334	159	37	38		121
Total Other Expenses	$13,694	$ 3,331	$ 1,585	$ 386	$ 10,418		$ 22,669
Allocations							
Use & Occupancy	$ 60,653	$98,423	$31,705	$13,785	$27,845		$ 3,,,705
Computing Svcs	22,465	14,145	4,160	2,496	14,145		23,297
Operations Svcs	556	33,381	20,665	2,384	18,260		3,179

Industrial Eng		5,464	2,484	1,987	-		
Total Allocations	$83,675	$151,413	$59,014	$ 20,652	$60,270		$ 58,181
Total Indirect Expenses	$ 233,070	$ 459,294	$ 174,748	$ 42,165	$ 184,445	$ 5,942	$ 221,076

Note that most costs must be allocated across several pools. This is because these costs are incurred to benefit several of the firm's activities. For example, employee relocation costs are incurred for relocating Engineers, fabrication personnel, assembly personnel, material handlers, and officers of the firm. Therefore, the appropriate costs are assigned to each pool.

Now that indirect costs have been pooled into specific overhead pools as labeled in the table header, the firm must develop overhead recovery rates for each pool, including G&A. To do that it must estimate its related direct costs. The appropriate base for each pool is given in Table 5-5 below.

Table 5-5 Matching Pools and Bases	
Overhead Pool	Appropriate Base
Engineering	Engineering Direct Labor $
Fabrication	Fabrication Direct Labor $
Assembly	Assembly Direct Labor $
Tooling	Tooling Direct Labor $
Material Handling	Material
Off-Site	Off-Site Direct Labor $
G&A	Total Cost Input

With the information given, developing the overhead cost recovery factors is a matter of estimating the bases and using the mathematical relation

$$\text{rate} = \frac{\text{indirect cost pool expenses}}{\text{allocation base}}$$

Table 5-6 on the next page gives the bases and rates for the overhead structure given in Tables 5-4 and 5-5 above.

Table 5-6
Overhead Recovery Rate Development

INDIRECT COSTS	ENG	FAB	ASSY	TOOLING	MATL HDLG	OFFSITE	G&A
Total Indirect Expenses	$ 233,070	$ 459,294	$ 174,748	$ 42,165	$ 184,445	$ 5,942	$ 221,076
Allocation Base Dir Lbr $	$ 185,055	$218,597	$ 104,094	$ 24,289		$ 8,674	
Allocation Base Dir Mat $					$ 1,693,812		
Total Cost Input Base							$ 1,739,386
Recovery Rate	125.95%	210.11%	167.88%	173.60%	10.89%	68.50%	12.71%

Background

Leasing, as opposed to outright purchase of assets, has become more prevalent in recent years in certain industries and in government purchasing offices. In the Army, there are several reasons for this. Other Procurement Army (OPA) appropriations have been hard hit by budget cuts, especially in the BASOPS arena. There is increasing rigor in justifying purchasing equipment to be used for short duration rather than as assets. With leasing there is relative ease of disposition, property administration and maintenance.

Leasing from a Regulatory Perspective

By statute, Operation and Maintenance Army (OMA) dollars cannot be used to purchase equipment with a unit price greater than the current expense/investment threshold in Appendix A of AR 37-100 (set annually). However, OMA appropriations can be used to lease equipment **under operating leases** for uses other than as long-term assets. Since many of the recent budget cuts have more heavily hit the OPA appropriations, equipment to be used in one-time projects such as R&D and testing, or in Army exercises, have been leased using OMA money. The equipment is kept for the duration of the contract, then returned to the lessor in good condition. That ends the government's liability and property accounting, with no unused assets lying around.

Under lease-to-purchase option contracts the government may decide after entering into the lease contract that it does have long-term use for the item and may purchase it under the terms of the contract. Such a buyout is usually with OPA funds, but may be made with OMA funds if the lease does not meet the terms of a capital lease and the buyout price is less than the expense/investment threshold.

A capital lease is defined as a lease that meets one or more of these criteria:

1. Under the terms of the lease, ownership is effectively transferred from the lessor to the lessee;

2. The lessee can purchase the item at less than its true market value when the lease expires;

3. The lease runs for a period greater than or equal to 75% of the asset's useful life; or

4. The present value of the sum of the lease payments is at least 90% of the purchase price of the item.

There is a potential conflict here with the government's role as steward of public resources. Leasing may or may not represent a "good deal" in comparison with purchase, depending on the circumstances of the action. Thus, a decision must be made whether or not leasing represents a prudent, cost-effective method for satisfying the government's need.

FAR 7.402 addresses the factors that buying activities must consider in making the decision to lease or purchase equipment, and states the general guidance that:

- The purchase method is appropriate if the equipment will be used beyond the point in time when cumulative lease payments will exceed the purchase price, and

- The lease method is appropriate when it is to the government's advantage under the circumstances.

Under certain parameters outlined in DODI 7041.3, "SPECIAL PROCEDURES FOR LEASING" A.1., the government must perform a lease-purchase evaluation in accordance with the principles and procedures outlined in DODI 7041.3, especially in that section. However, the outlined procedures should be followed even when the projected lease terms do not match those in paragraph A.1.

Interest rates for the required net present value conversions (explained later in this Part) must be obtained from OMB Circular A94, Appendix C.

The purpose of this Part is to provide the analytical framework and understanding necessary for making the lease-purchase decision with special attention to the requirements for an adequate lease-purchase evaluation in accordance with DODI 7041.3.

Leasing from a Cost Perspective

Anyone who has ever rented or leased equipment will discover that, depending on the terms of the contract, they may have more than paid for the item after leasing for a term. In other words, if the cost of an item is $5,000 and one leases it for 24 months, one may find that they have paid substantially more than $5,000 in leasing payments when the 24 months is over. At the very least they will have paid a substantial portion of the purchase cost with nothing substantive to show for it.

Leasing may be looked upon as a form of "cut-rate" installment buying with the exception that, after the lease term is complete, the lessee (the one to whom the item is leased) does not own the item and may not keep it.

The reason that leasing may produce smaller payments than installment buying is that the depreciation and amortization schedules may be based on the useful life of the item rather than a period of time tied to the investment schedule of a lending institution. Usually the period of a leasing contract is substantially less than the useful life of the item, so that the item may be leased more than once or sold for a residual fair market value. Therefore the financial formulas, calculated based on the useful life of the item, will tend to produce smaller periodic payments. The effect of this will be shown under the section on "Leasing Methodology."

The Time Value of Money

Lease-purchase evaluation is a form of economic analysis. All economic analyses must adhere to two principles (see DODI 7041.3):

1. Each feasible alternative for meeting an objective must be considered, and its life-cycle costs and benefits evaluated.

2. All costs and benefits are adjusted to "present value" by using discount factors to account for the time value of money. Both the size and the timing of costs and benefits are important.

Before we can proceed it is necessary to understand something of the time value of money. All comparisons of alternatives with cash flows projected in the future must be based on what is called "net present value". This concept is based on the fact that money invested in a relatively safe investment will earn a return on investment as time goes by.

For example, at 6% interest compounded yearly, $1,000 invested at the beginning of year 1 will be worth the amounts shown in Table 6-1 over the next 3 years:

Table 6-1

Table 6-1 Compounding Interest

Beginning of Year	Principal	Interest	End of Yr Balance	Formula
1	$1,000.00	60.00	$1,060.00	$1000.00 × $(1.06)^1$
2	$1,060.00	63.60	1,123.60	$1000.00 × $(1.06)^2$
3	1,060.00	63.60	1,191.02	$1000.00 × (1.06)3

These amounts are termed "future values" of the investment.

In looking at the future, we can reverse this process, and ask what one needs to invest today to have $1,191.02 at the end of 3 years, which of course is $1000.00. This process is called "discounting" and is the inverse of compounding.

Note that we can arrive at the total through Year 3 (beginning of year 4) by multiplying the original $1,000 investment by the factor $(1.06)^3$. Analogously, we can discount the Year 3 principal back to the equivalent amount today by *dividing* by the same factor. The amount today which is equivalent to a specified amount *n* years in the future is called the "present value" of that amount.

Similarly, we can ask what we will have in total at the end of the fourth year if we invest $1,000 at the beginning of each of the 4 years. This is called finding the future value of an *annuity* or periodic payment. Each $1,000 investment will receive compounded yearly interest from its date of investment to the end of the fourth year, as shown in the following table:

Table 6-2
Compounded Interest on Annuities

$1,000 Annuity	**Future Value at the end of**				
	Year 1	Year 2	Year 3	Year 4	Total
Year 1	$1,060.00	1,123.60	1,191.02	1,262.48	1,262.48
Year 2		1,060.00	1,123.60	1,191.02	2,453.50
Year 3			1,060.00	1,123.60	3,577.10
Year 4				1,060.00	4,637.10

The total future value of a series of four annuities of $1,000 each deposited at the beginning of each year, sums to $4,637.10 at 6% compounded annually. Note that this is the same as $1,000 multiplied by the sum of the series:

$$(1.06)^1 + (1.06)^2 + (1.06)^3 + (1.06)^4 = 4.6371$$

We can also reverse this process (i.e., discount) by asking how much we would be willing to invest at the beginning of each year for 4 years if we were to have $4,637.10 at the end of the fourth year. We would find the answer by dividing $4,637.10 by the cumulative discount factor 4.6371, which gives $1,000.

In looking at investments having different cash flows in different years, it becomes apparent that determining the most profitable investment among several depends on putting them all in terms of today's value of money. This is termed "net present value analysis," attained by proper application of discounting.

Appendix C presents tables of single year and cumulative discount factors. Tables 1 and 3 are based on that investment at the beginning of the year. Tables 2 and 4 are mid-year factors that are used to increase accuracy based on the concept that the "most probable" award date for a contract is the middle of the fiscal year. End of year factors for year *n* are equal to beginning of year factors for year (*n*+1). To find the present value of the following, use the table specified in the matrix on the next page:

Future Value Single/Annuity	Investment @ Time of Year	App. C Table
Single amt	Beginning	1
Single amt	Mid-year	2
Annuities*	Beginning	3
Annuities*	Mid-year	4

Pricing Leases

The lessor usually buys the equipment from the manufacturer and may be a distributor, a leasing company, or a financial institution. The methodology for setting the lease payments is therefore based on recovering the full purchase price of the equipment, plus any maintenance and repair costs if that is part of the lease contract, and a return on investment.

Calculation of the lease payment schedule is similar to calculation of an installment payment schedule, with two differences. As noted above, the payment term may be equal to the useful life of the equipment if the lessee expects to lease or sell the equipment after the expiration of the lease term. There are also depreciation and tax considerations not present in selling on credit terms.

Let us suppose that the government has issued a solicitation requesting purchase and lease terms for certain equipment, with lease period of four years and annual payments. Suppose further that the lessor is to provide maintenance as part of the lease contract. How does an offeror decide what to charge for the annual lease payment (payment to be made on the last day of the fiscal year)? These additional facts are important:

- Purchase price = $1,000,000
- Residual value year 5 = $500,000
- Yearly maintenance cost = $30,000
- Lessor is in the 40% tax bracket
- Depreciation method is straight line over 10 years
- Firm's cost of capital is 10% (6% after taxes)
- Firm will sell the equipment at expiration of lease

Case I: Lease payment is based on contract term
Case II: Lease payment is based on useful life

Now we can establish a theoretically correct lessor methodology for determining the appropriate lease payment.

1. As noted above, firms can obtain a 6% after-tax rate of return on other investments, such as bonds, CDs, and so forth over the same timeframe using the $1,000,000 it will cost to purchase or manufacture the equipment for sale or lease to the government.

Therefore, the methodology must build in at least a 6% after-tax rate of return to be attractive.

2. Next, a firm must consider its other cost outlays, including the "paper" outlay called depreciation, since its value for future leasing or sale decreases each year of its useful life. These outlays are $30,000 yearly for maintenance, and $100,000 per annum for straight-line depreciation over 10 years.

3. Tax effects must be considered. Both the maintenance expense and the depreciation allowance are tax-deductible, so this must be factored into calculation of the lease payment.

4. The time value of money is considered by discounting each year's cash flows by the cost of capital rate (6%, the desired after-tax return on investment). The firm must in effect preserve this equality:

$$\sum_{t=1}^{n} COF_t / 1.06^t = \sum_{t=1}^{n} COF_t / 1.06^t$$

where $\sum_{t=1}^{n}$ means sum a series of t terms from t=1 to t=n, COF_t = cash outflows in year *t*, CIF_t = cash receipts in year *t*, and $(1.06)^t$ = the year *t* discount factor.

5. Cash receipts or inflows will be the lease payments and the return on sale of the equipment at the expiration of the lease. Cash outflows will be $1 million at the beginning of Year 1 to purchase the item, $30,000 per year for maintenance and $100,000 annual depreciation (not an actual expense but allowed as an expense on paper for tax purposes).

Case I: Lease Payment Based on Contract Term

The table on the next page outlines the formulas for figuring net cash flows for each year, with revenue (annual lease payment) = X. (Dollar figures are in $000's).

Table 6-3
Formula View of Pricing a Lease

Year	Revenue	Maint	Deprec.	Tax @40%	Net Cashflow	Discount Factor
1	X	30	100	0.4(X-30-100)	X-30-[0.4(X-30-100)]	0.9433962
2	X	30	100	0.4(X-30-100)	X-30-[0.4(X-30-100)]	0.8899964
3	X	30	100	0.4(X-30-100)	X-30-[0.4(X-30-100)]	0.8396193
4	X	30	100	0.4(X-30-100)	X-30-[0.4(X-30-100)]	0.7920937
4	500					0.7920937
Total					X-30-[0.4(X-30-100)] +$500(0.7920937)	3.4651056

Here $30,000 is the maintenance cost and [(X-30-100)×0.4] represents the taxes paid on the revenue less maintenance and depreciation expenses. The $500 (actually $500,000) in year four is the expected revenue from sale of the used equipment.

Since each year the net cash flow is identical, with the exception of year 4 where there is revenue both from the lease payment and the sale of the equipment at the end of the lease, we simply use the term X-30-[0.4(X-30-100)] times the total discount factor, which is 3.4651056 as shown. In year 4 we add the discounted cash inflow from selling the equipment, $500(0.7920937).

The term X-$30-[0.4(X-$30-$100)] reduces to 0.6X + $22. The product of this term and the total discount factor 3.4651056 is the term 2.07906336(X) + $76.232323. Add to this the discounted residual value of $396.04683. Total net cashflow is the sum of these, or 2.07906336X + $472.27915.

Since net cash flow must equal the purchase price of $1,000 (in $000s),

$$\begin{aligned} \$1{,}000 &= 2.079063X + \$472.27915 \\ 2.079063X &= \$527.72085 \\ X &= \$253.826 \\ &= \$253{,}826 \text{ per annum} \end{aligned}$$

Thus, to provide itself with a 6% after-tax return, the firm must set the yearly lease payment at $253,826.

Table 6-4 on the next page shows the actual cash flows by year:

Table 6-4							
Lease Analysis from the Lessor's Viewpoint ($000's)							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Yr.	Lease Pmt.	Maint. Exp.	Deprec. Exp.	Taxes =0.4× [2-3-4]	Net Cashflow: [(2)-(3)-(5)]	PVIFs for 6%	PV of After-tax Cashflows [(6)x(7)]
1	253.83	30	100	49.530	174.300	0.9434	164.430
2	253.83	30	100	49.530	174.300	0.8900	155.120
3	253.83	30	100	49.530	174.300	0.8396	146.340
4	253.83	30	100	49.530	174.300	0.7921	138.060
4					500.000	0.7921	396.050
Total	1015.30	120	400	198.120	1197.180		1000.000
0	Purchase of equipment by Lessor						(1000.000)
NPV of the lease investment							0.000

Although it appears that the lease gives no return, the NPV of the investment is $0 when the *discounted* cash flows are equal. In this case, the net cash flow (Column 6) includes the 6% target return on investment. Therefore, the lessor is "breaking even" at a 6% return on investment. This can be mathematically proven, but is beyond the scope of this pamphlet.

Case II: Lease Payment Based on Useful Life

In this scenario, we assume that the offeror makes its decision based on the assumption that it will lease the equipment again under the same terms upon expiration of the current lease contract. The item has no residual value.

Based on those assumptions, all other factors being equal, the following analysis gives the correct lease payment (see the detailed analysis of Case I for development of the table below):

Table 6-5					
Construction of Proposed Lease Payment					
Year	X-term	Discounted$	Year	X-term	Discounted$
1	0.566	20.755	7	0.399	14.631
2	0.534	19.580	8	0.376	13.803
3	0.504	18.472	9	0.355	13.023
4	0.475	17.426	10	0.335	12.285
5	0.448	16.440			
6	0.423	15.509	**Total**	**4.415**	**161.924**

The following equation emerges from the above totals. Solve for X to obtain the yearly payment.

$$4.415X + \$161.924 = \$1{,}000$$
$$4.415X = \$838.076$$
$$X = \$189.82468$$

Thus, using a 10-year term for the payment schedule in lieu of the 4-year contract term, the appropriate periodic payment is $189,824.68. This is the reasonable lease payment based on useful life rather than lease term.

Lease Evaluation

The total lease cost over the four year period exceeds $1 million in the first case and is just over $759,000 in the second. At the end of the lease, the lessee does not own the equipment, but has paid more or less its purchase price. Thus, leasing is not a good deal for the lessee unless the cost of borrowing to finance the purchase of the equipment is even more costly. Therefore, for the private sector the proper comparison for lease-buy decisions is the cost of leasing versus the cost of outright purchase and/or financing purchase of the equipment through installment debt.

However, this is not the appropriate analysis for the government since the government activity doing the lease-purchase analysis does not borrow the money. (During times of deficit spending, the government as a whole does borrow the money, but this is not part of the analysis for the leasing entity.)

- The buying activity is not a taxable entity. There are no tax implications of lease versus purchase for the government.

- The decision does not consider any recoverable market value of purchased real or personal property.

- The analysis must compare "apples to apples":

If the lease payment includes all executory costs (such as transportation, set, and maintenance) then the same costs must be calculated and added to the purchase cost (as applicable).

If any executory costs (such as maintenance) are not included in the lease payment, then the analyst should cost them out for the leased equipment and for purchase if there would be any difference in cost or timing of outlays. Otherwise, the analysis may omit these costs.

All anticipated future costs associated with lease and with purchase (such as maintenance) must be timed appropriately and discounted to the proposed time of award ***using the appropriate nominal Treasury rate set forth in OMB Circular A94, Appendix.*** This is discussed in section 8.of the Circular.

The rates given in OMB Circ A94, Appendix C are set for projects of specific duration: 3, 5, 7, 10, and 30 years. The appropriate rate for any contract whose performance period is between two of these durations is found through linear interpolation. For example, if a contract will run for 4 years beginning Jan 2000, the interpolated interest rate is found as the average between the 3- and 5-year rates. The 4 year rate = $\frac{4.7+4.8}{2}=4.75\%$.

3-Year	4.7%
5-Year	4.8%
7-Year	4.9%
10-Year	4.9%
30-Year	5.0%

Find the interpolated interest rate through use of the following formula:

$$\text{Amt Rate changes annually} = \frac{(\text{Next higher maturity period rate}) - (\text{Next lower maturity period rate})}{(\text{Next higher maturity period}) - (\text{Next lower maturity period})}$$

For example, estimate the change for each year between a 10-year maturity and a 30-year maturity:

$$\frac{\text{30-Year Rate - 10-Year Rate}}{\text{30 Years - 10 Years}}$$

$$= \frac{5.0 - 4.9}{30-10}$$

$$= 0.1/20$$

$$= .005$$

and add this incremental annual amount for each year after the lower maturity period to the lower maturity period rate. For example, for an 20-year contract, the appropriate interpolated rate would be the 10-year rate plus 10 x the annual interpolated rate calculated above, or 4.9+(10*0.005) = 4.95%.

Calculation of net present value should be based on incremental benefits and costs. Sunk costs (such as facilities that must be built in either case) and realized benefits (such as any gains realized on replaced equipment) should be ignored. Past experience is relevant only in helping to estimate what the value of future benefits and costs might be.

The following example analysis uses the proposed lease payment (based on useful life) of $189,824.68 per year derived in section 6-5.versus the purchase price of $1,000,000 and maintenance of $30,000 annually. Timing of the cash outlays is critical in the lease versus purchase evaluation. Lease payments will be made monthly at the beginning of each month, therefore mid-year discount factors would be used to discount those outlays. The purchase will take place in month 1 (Jan 2000). **Note the timing of each cost**:

Purchase - Month 1 (Jan 00)
Maintenance - Quarterly beginning 4/1/00.
Lease Payments - Annual beginning 1/1/00

Purchase Evaluation

Outlay	Date	Amount	4.8% Disct. Factor	Discounted Cost
Purchase	1/1/2000	$1,000,000	1.0000	$1,000,000.00
Maintenance	4/1/2000	7,500	0.9768	$7,326.23
	7/1/2000	7,500	0.9768	$7,326.23
	10/1/2000	7,500	0.9768	$7,326.23
	1/1/2001	7,500	0.9321	$6,990.68
	4/1/2001	7,500	0.9321	$6,990.68
	7/1/2001	7,500	0.9321	$6,990.68
	10/1/2001	7,500	0.9321	$6,990.68
	1/1/2002	7,500	0.8894	$6,670.49
	4/1/2002	7,500	0.8894	$6,670.49
	7/1/2002	7,500	0.8894	$6,670.49
	10/1/2002	7,500	0.8894	$6,670.49
	1/1/2003	7,500	0.8487	$6,364.98
	4/1/2003	7,500	0.8487	$6,364.98
	7/1/2003	7,500	0.8487	$6,364.98
	10/1/2003	7,500	0.8487	$6,364.98
	1/1/2004	7,500	0.8098	$6,073.45
	4/1/2004	7,500	0.8098	$6,073.45
	7/1/2004	7,500	0.8098	$6,073.45
	10/1/2004	7,500	0.8098	$6,073.45
		$1,142,500		$1,126,377.09

Lease Evaluation

Year	Date	Payment	4.8% Disct. Factor	Discounted Cost
1	1/1/2000	$189,824.68	1.0000	$189,824.68
2	1/1/2001	$189,824.68	0.9542	$181,130.42
3	1/1/2002	$189,824.68	1.0480	$198,936.26
4	1/1/2003	$189,824.68	0.8688	$164,918.29
5	1/1/2004	$189,824.68	0.8290	$157,364.78
				$892,174.44

Purchase NPV	$1,126,377.09
Lease NPV	$892,174.44

The correct interest factors are based on the timing of outlays (and inflows, if applicable) as follows:

- If payments will be made at the beginning of a year, use the beginning of year factors in Appendix C.
- If payment will be made at the end of a year, use the Appendix C beginning of year factors ***for the next year.***
- If payments will be made through the year, use the mid-year factors in Appendix C.

In the above example, even though maintenance charges are quarterly, they are the same and so we used mid-year factors to discount each year's cash flow. However, since lease payments would be made annually in January, we used beginning of year factors to discount lease payments. Purchase would be made in month one, so it is not discounted.

Lease to Ownership Concepts

There are two combinations of leasing and purchasing options used in the commercial world: Lease with Option to Purchase (LWOP), and Lease to Purchase (LTOP).

The LWOP option essentially credits a portion of the principal in the lease payments toward purchase and tells the lessee, for each periodic payment, what the balance of the purchase price is. Usually, there will be a portion of the principal due as a “balloon” payment at the end of the lease in order to complete the purchase. Table 6-6 below shows an evaluation of a LWOP proposal using the contractor proposal developed in section 6-5. The proposal gives the customer a 30% purchase credit taken on the paid principal in each lease payment.

Purchase Price	1,000,000.00
Lease Payment	189,864.68
Purchase Credit	30%

Year	Beginning Balance	Lease Payment	Interest	Principal	Purchase Credit	Ending Balance
1	1,000,000.00	189,864.68	100,000.00	89,864.68	26,959.40	973,040.60
2	973,040.60	189,864.68	97,304.06	92,560.62	27,768.19	945,272.41
3	945,272.41	189,864.68	94,527.24	95,337.44	28,601.23	916,671.18
4	916,671.18	189,864.68	91,667.12	98,197.56	29,459.27	887,211.91

Sum of Lease Pmts	759,458.72
Residual Payment	887,211.91
Total Cost to Govt.	1,646,670.63
Less: Purchase Price	-1,000,000.00
	$ 646,670.63

As can be seen, the government pays an extra $646,670.63 above the purchase price based on the LWOP structure. The lease payment includes all maintenance costs, depreciation allowance, and taxes plus 10% interest (6% after tax).

Under the LTOP option, the full principle portion of each periodic payment is credited toward purchase, making this type of lease very similar to installment buying, with the exception that failure to continue payments after a specified minimum lease period constitutes simply a cancellation of the lease contract with no further obligation by either party. Usually the full amount of principal is paid through the purchase credits by the end of the lease term, though not always. Table 6-7 below shows an evaluation of a LTOP proposal using the contractor proposal developed in section 6-5. The proposal gives the customer full purchase credit taken on the paid principal in each lease payment.

Purchase Price	$ 1,000,000.00
Lease Payment	189,864.68
Purchase Credit	100%

Year	Beginning Balance	Lease Payment	Interest	Principal	Ending Balance
1	1,000,000.00	189,864.68	100,000.00	89,864.68	910,135.32

2	910,135.32	189,864.68	91,013.53	98,851.15	811,284.17
3	811,284.17	189,864.68	81,128.42	108,736.26	702,547.91
4	702,547.91	189,864.68	70,254.79	119,609.89	582,938.02

Sum of Lease Pmts	759,458.72
Residual Payment	582,938.02
Total Cost to Govt.	$ 1,342,396.74
Less: Purchase Price	-1,000,000.00
	342,396.74

As can be seen, the government pays an extra $342,396.74 above the purchase price based on the LTOP structure. The lease payment includes all maintenance costs, depreciation allowance, and taxes plus 10% interest (6% after tax).

Definitions and Concepts

According to FAR 15.404-1(b)(1), price analysis "… is the process of examining and evaluating a proposed price without evaluating its separate cost elements and proposed profit." Price analysis is thus an evaluation strictly of the "bottom line" and does not concern itself with the eventual costs to the supplier or his ultimate profit margin.

According to FAR 15.404-1(a), price reasonableness is the government's real concern, so price analysis should not be thought of as the "last, desperate recourse" or the "weak sister" to cost analysis. FAR 15.404-1(a)(3) unequivocally states that all cost analysis should be corroborated through price analysis.

Price analysis is essentially value comparison. This comparison may be made generally in five different ways, depending on available data. Per FAR 15.404-1(b)(2), price analysis can be:

- comparison of proposed prices received in response to a solicitation;
- comparison of previously proposed prices and contract prices with current proposed prices for the same or similar items;
- use of parametric estimating methods/application of rough yardsticks (such as dollars per pound or per horsepower);
- comparison with published price lists or published market prices, including discount or rebate arrangements;
- comparison of proposed prices with independent Government cost estimates; or
- comparison of proposed prices with prices obtained through market research for the same or similar items.

We will deal with each of these techniques in turn after more background preparation in pricing philosophy.

In a competitive market, a seller's price may be related more closely to the prices he believes his competition will offer, than to his actual costs. This can be good or bad. It may promote healthy competition, or it may promote the buy-in tendency that in the long term is very unhealthy for the company and the DoD industrial base.

In a non-competitive situation, or when technical uncertainty or performance risk is high, there is far less incentive to perform economically, and determining what constitutes efficient performance becomes more difficult. Here price analysis is even more important as a "cross-index" of different viewpoints on price reasonableness.

Price reasonableness is the primary goal of analysis, not price reduction. The objective of analysis is to determine whether the buyer feels justified in paying the prices quoted for the goods offered, which is a value analysis. There are three perspectives on what constitutes a reasonable price:

- Acquisition philosophy presumes the competitive or open market price to be reasonable if there are many sellers in the market. Here is where full and open competition realizes its strength in acquiring goods and services at fair, economical prices.

- The seller's price is ideally the price that fully recovers his costs and gives him at least the minimal profit acceptable to the owners of the company.

- The buyer's price is the lowest for which he/she can obtain the item considering need, alternatives, and perceived desirability or usefulness of the item.

The tension between these viewpoints is part of every price analysis and negotiation. A "fair and reasonable" determination must somehow encompass all three viewpoints, for all are legitimate in their context.

Factors Influencing Differences in Price

Why do prices vary over time or between firms for the same item? Some factors that influence price are:

- economic price level differences (inflationary forces within the economy or an industry)
- order quantities or optimal production runs
- contractor production efficiencies, including "learning" or labor improvement
- facilities and technology differences
- amount of corporate experience
- constraints such as unionization, company policies, industry position, or tooling prerequisites
- amount of fixed or nonrecurring costs to be absorbed
- available skill levels and expertise in a particular area
- different perceptions of "reasonable" profit

These various factors are to one degree or another susceptible to analysis; however, some go beyond the scope of price analysis. There are price analysis tools that, if used with considerable caution, will still allow valid comparisons. Primarily, though, price analysis can only incorporate factors of economic price level, differences in scope of work or quantity, and production efficiency measures such as the improvement curve. We turn now to tools and techniques for analyzing the impact of these factors on price as we simultaneously look at the methods of price analysis.

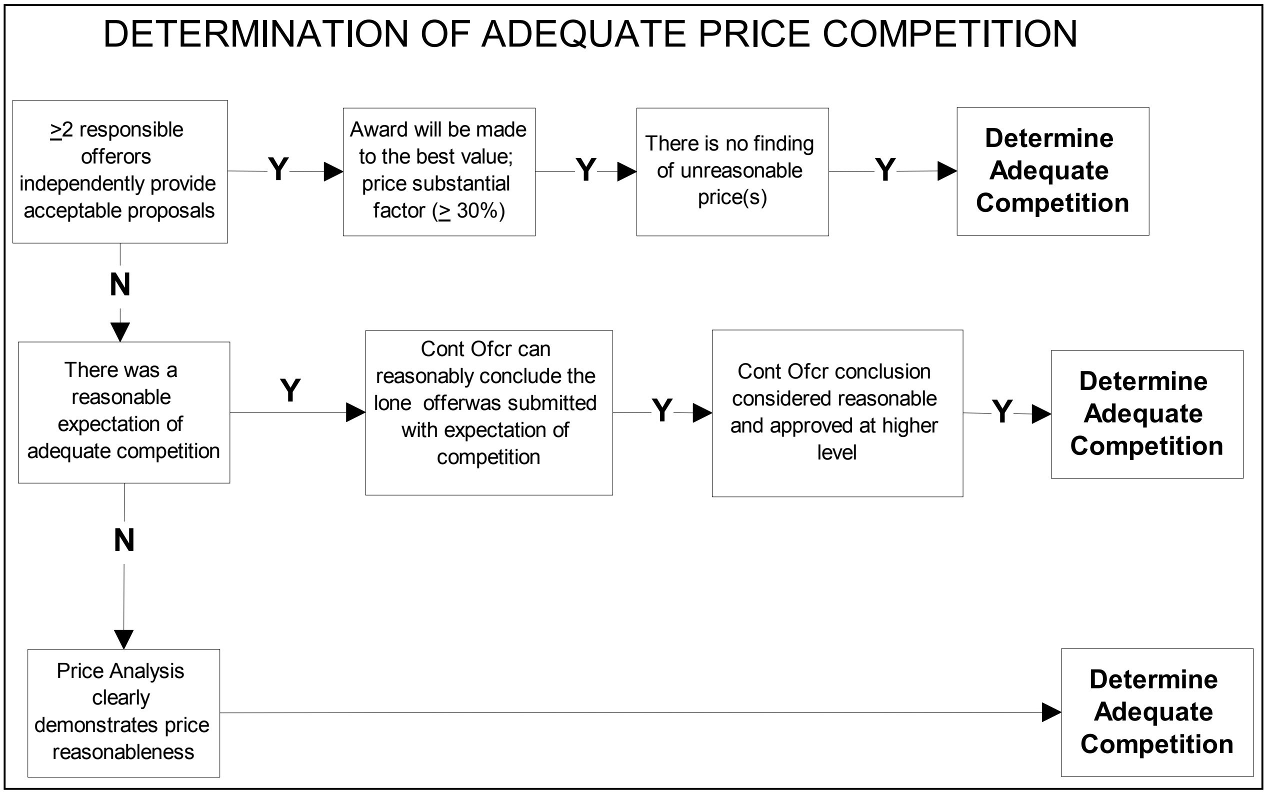
Comparison of Two or More Submitted Offers

We noted previously the regulatory presupposition that open market competition produces fair and reasonable prices. However, competition is a relative term, as discussed in Part 1. A market with many buyers and sellers, transacting for identical items with full market pricing knowledge produces perfect competition, where no one firm can change its prices without risking loss of business.

Other factors influence pricing in markets with only a few firms or price leaders, or with non-standardized products. One factor is market differentiation: firms try to persuade the consumer that the higher price charged for their item is justified by superior quality. Another factor is firm size: several large firms can drive smaller, less resource rich firms out of business, especially through use of cut-throat pricing. When consumers do not have full market knowledge, they are more likely to fall prey to these other pricing factors.

In situations of other than full and open competition it is often one buyer, the government, and a relative handful of suppliers that are in the market. Is this a competitive situation? There may be what was termed "imperfect competition" even with as few as two offerors. Then again, there can be many offerors but no true price competition if they are not dealing in a standardized product or service or if one or more have a determinative competitive advantage over the others.

FAR 15.403-1(c)(1) defines the requirements for "adequate price competition" in negotiated procurements. The following decision flowchart encapsulates these requirements:



In the case where only one viable offer was submitted, the contracting officer must base any determination that it was submitted with the expectation of competition on circumstances indicating (a) the offeror believed that at least one other offeror was capable of submitting a “meaningful” offer, and (b) the offeror had no reason to believe that other potential offerors did not intend to submit an offer.

The price analysis must be based on a comparison with current or recent prices for the same or similar items under contracts ***that resulted from adequate competition***, adjusted to reflect changes in market conditions, quantities or terms and conditions.

Suppose that all of the conditions of FAR 15.403-1(c)(1) are met. Is there adequate price competition? There is *if none of the following is determined to be the case*:

- The solicitation or conditions of its issue unreasonably deny one or more potential offerors a chance to compete, such as overly restrictive or targeted specs; or

- The low offeror has a determinative price advantage such that he is practically immune to the influence of competition, such as: master tooling, unique processes, having already absorbed substantial start-up or phase-in costs, and so forth; or

- The lowest final price is not reasonable as established by an independent set of facts.

Comparison with Historical Prices

For supply items, order quantity often influences price as much or more than any other single variable. It usually costs more to build a greater number of units, but it often costs ***less per unit***. This is largely due to the behavior of "fixed" and "variable" costs. Variable costs per-unit remain constant (ignoring learning curve), while fixed costs per unit decrease as production quantity increases.

In a broader sense the quantity effect on unit price level may be due to:

- improvement effects ("learning" and other labor efficiency increases)
- amortization of fixed, nonrecurring and start-up costs over a greater number of units or scope of work
- economies of scale
- material discounts for large lot quantities

The important point for price analysis is: how do we measure this price/quantity relationship over time or between offerors? There are several techniques, differing in level of mathematical sophistication and reliability. All require price history data. We present them in the remainder of this Part.

- For those instances in which previous price history for the same item is inadequate, contractor or industry experience with a similar item or items may reveal this relationship. Questions that may be answered by such market research are:

- Is this item or service susceptible to improvement curve effects? If so, what is the estimated rate of improvement, or what is the industry experience with similar items/services?

- Are start-up or phase-in costs involved? What percentage of total cost would be attributable to these costs? Are there other significant fixed capital costs to be amortized? If so, what percentage of total cost would be attributable to these costs?

- What kinds and levels of skills are needed? Does the offeror possess them, or must he hire or subcontract for them?

- What would each offeror consider to be the "optimal" order quantity? What would be an optimal delivery schedule? This is important for both improvement curve and fixed costs.

These questions, even without adequate price history, can still help in gauging the relative efficiency and technical expertise of each offeror, leading to a more realistic value analysis of proposed price(s) through the potential for timely delivery, economical performance, and reliable product. And they may reveal a quantity/price relationship for use in price analysis.

Price Analysis Using Parametric Comparisons

The Air Force and, to a lesser extent the Navy, have pursued the establishment of a large generalized body of knowledge relating price and certain parameters such as: dollars per pound of structural steel (aircraft, ships); cost per additional increment of speed, durability, height, and so forth; time per task (services, engineering). These may sometimes be available through program or project engineers or cost analysts, industry knowledge, or other activities such as DCMC.

If these relationships are available and the amount of the parameter related to unit price can be determined for the item under consideration, then the proposed price(s) may be compared to this "guideline" to assess price reasonableness. As an example let us suppose that the analyst is evaluating a proposal for mobile cranes. Analysis reveals that there are two primary cost drivers, engine horsepower and boom height. Furthermore, the information shown in Table 7-1 is available regarding ranges of price as they relate to ranges of boom length and horsepower.

Table 7-1
Cost Estimating Relationship Data Matrix

	BOOM LENGTH (FEET					
HORSEPOWER	20	25	30	35	40	45	50
100	$49,650	50,900	52,212	53,600	55,050	56,575	58,180
200	$52,025	53,275	54,588	55,975	57,425	58,950	60,555
300	$54,468	55,718	57,030	58,418	59,868	61,393	62,997
400	$56,820	58,070	59,383	60,770	62,220	63,745	65,350
500	$58,805	60,055	61,368	62,755	64,205	65,730	67,335
600	$60,913	62,163	63,475	64,862	66,313	67,838	69,443
700	$63,150	64,400	65,712	67,100	68,550	70,075	71,680

We now have three variables: price, horsepower and boom length, which we presume are fairly closely correlated (associated in their movement upward or downward).

By a mathematical technique known as multiple regression analysis we now generate a single mathematical equation for the interrelationship of these variables. We use that equation to approximate the price for an item having specified levels of these variables, say, a crane with 350 horsepower and a 45-foot boom. Although the mathematics for generating this Cost Estimating Relationship (CER) is not extremely difficult, it is tedious and time-consuming. There are computer programs available that will do the job in minutes. See Appendix D for an analysis of the above data performed in MS Excel version 7.0.

If the price of an item is also quantity-sensitive it can be one of the variables incorporated into the CER. However, multivariate regression assumes a linear relationship between price and the other parameters, while improvement curve is a non-linear relationship between price and quantity. The resulting multivariate equation will likely distort this relationship. Manufacturers having improvement experience with an item, however, will often average out expected improvement over large production lots, so that it may be treated as a roughly linear relationship.

There are several prerequisites that must be met for this analysis to have validity:

1. For each variable the changes in price should reflect only the influence of that variable on price; that is, *the independent variables must be independent of one another*.

- For example, if in design or function boom height affects horsepower in some consistent fashion, then price and horsepower really correlate to boom height and horsepower is really a dependent, not an independent, variable. It therefore provides little or no additional price information over boom height alone.

- One way of checking on the relationship of the independent variables (those other than price) is to do "canonical correlation" of them. This generates a correlation coefficient (R) for each combination of two or more independent variables. If R (which may fall between –1 and +1) is not extremely low (say, between -0.25 and +0.25) for some combination, then those variables are really not independent of one another. One or more of those having high correlation should be eliminated to minimize distortion.

2. Correlating each variable individually with price can indicate those parameters that really are cost drivers. Here, the correlation must be high to assume statistical validity.

3. Statistical analysis should be performed to rule out insignificant relationships, autocorrelation (spurious association of a variable with itself), and other aspects that could reveal a useless or distorted CER.

A good statistical analysis package is necessary for basing price analysis on CERs.

Inflation and Price – Trend Analysis of Indexes

Economic escalation ("inflation") is a concept of how prices vary over time, as for example in consumer prices paid for cars or factory prices paid for tools or raw materials.

The Bureau of Labor Statistics, Department of Commerce has established price level indexes that provide a measure of price movement in comparison with prices in a base year. For example, the aggregate total of consumer prices for most of the economy's consumer goods in December 1967 were originally used as the "base" for the Consumer Price Index (CPI). The price level was set at 100 for the base year/month. ***Note that an index is a unit-less number.***

If by the end of 1968 the same aggregate price rose to 109% of those in 1967 (base year), the CPI would then be 109. Therefore the percentage change (%□) from the base can be expressed by the following formula:

$$\%\Delta = \text{new index} - \text{base index} \tag{1}$$

It becomes a little more difficult if we are comparing an index number to other than the base year index. For example, suppose in year *x* the CPI was 174.8 and in year (*x+8*) it was 302.5. To find the change in index here by formula (1) would be incorrect because both numbers are in comparison to the base year and we want to express the latter index as a percentage of the former. Therefore, the index for year *x* becomes our new base year for comparison.

Since the index for year *x* (I_X) equals 1.748 times the base index, to convert the year *x* index to a base year requires that we divide by this proportion. That is, if $I_X = 1.748 \times$ base, then base = $I_X \div 1.748$. The index becomes 174.8/1.748 = 100.0, which by definition is the base year value.

Now, whatever we do to one side of an equation we must do to the other side to maintain equality. To make our year (*x+8*) index of 302.5 relate properly to our new base requires that we also divide it by 1.748. Therefore, it becomes $I_{X+8} = 302.5 \div 1.748 = 173.1$ in the new base year, which means 173.1% of I_x. Another way to conceptualize this is to divide I_{X+8} by I_x, which gives 1.731. Multiplying this factor by 100 gives I_{X+8} = 173.1% I_x.

The formula for finding the percentage change in two non-base index numbers is as follows:

$$\% \quad = \frac{\text{newer index} - \text{older index}}{\text{older index}} \times 100 \tag{2}$$

For the index numbers given above the percentage change would be (302.5 - 174.8)÷174.8 x 100 = 73.1% increase, which squares with our previous calculation. By "older index" we mean the one most distant in time, and by "newer index" the one closest in time, to the time the measurement is made.

Let us apply this technique to a price analysis. Suppose that the last price paid for an item was $50 in April 1975. Based on the CPI, what would we expect the current price to be, all other factors being the same?

If the CPI is currently 366.0, and was 142.7 in April 1975 (1967 base), then the expected current price (assuming identical item and quantity) would be found by formula (3) on the next page:

current price = previous price $\times$ (%□ index) $\div$ 100 (3)

Of course, the % change in CPI is given by formula (2), as follows:

$$\%\Delta = \frac{366.0 - 142.7}{142.7} \cdot 100 = 156.5\%.$$

Using this result in formula (3) gives \$50 x 156.5% $\div$ 100 = \$50 x 1.565 = \$78.25 as the expected current price.

See the Bureau of Labor Statistics World Wide Web page at http://www.bls.gov/ for data and information on the various indexes.

Usually there is a need to forecast future price levels with some degree of confidence when determining price reasonableness by price analysis. Various techniques based upon least-squares statistics are available for doing this in a sophisticated manner, but most are tedious and require knowledge of statistics and regression analysis for proper interpretation.

One may extrapolate index points graphically; if accuracy were not critical, this would be satisfactory. The procedure is simply to plot index numbers against their month/year on graph paper and draw a straight line as accurately as possible through the "middle" of the scatter of points. Of course, the more random the scatter, the harder it is to decide on the location of the "middle".

Should we need greater accuracy, there are regression models available in statistics packages, and most spreadsheet programs perform linear and multivariate regression on spreadsheet data. The trend line feature on MS Excel will draw a trend line on a graph at the touch of a button and will even indicate the equation for the line and some measures of how well the line "fits" the data, such as the Coefficient Of Variance, R^2.

Be careful when using indexes to use one appropriate to the item or service under analysis. Many indexes track a very specific item or group of items while others track a more general collection of goods. Do not mix "apples" and "oranges" in your analysis.

The price movement of services and construction over time are not tracked by these indexes. The closest match for a service would be a labor index for a particular generic service. Since the cost of services is driven by labor rate fluctuations, this will provide an acceptable track of price increases for a service. Indexes for construction-related labor are available, but since the cost of construction is also driven by the cost of materials, a labor index alone may distort the cost trend. For construction we will need to use a combination of labor and material indexes as demonstrated in the next section (there are also construction cost indexes, but for illustration of the concept we will use separate labor and material indexes).

Using Multiple Indexes

In the event that the analyst cannot find a commodity index at all similar to the item under analysis, or is dealing with a construction project such that one generalized index will not accurately "track" price level variances, what can be done?

If certain information can be obtained, there is a variation of the previous price index analysis that will give a more accurate picture. To work this method requires certain information. We need to know the predominant materials which compose the end item (such as a generator or a building), and their proportions if there is more than one primary material. We also need the Standard Industrial Classification (SIC) or industry for the predominant type of labor used. And we need the proportion of unit price attributable to material cost and to labor cost, including burdens and profit on both (for example, 55% material and 45% labor).

The following example will show how the technique proceeds:

We are to analyze renovation of a building. The materials code for the industry is PCUBMRP, Construction – Maintenance and Repair. The labor code is ECU22302I, Construction Wages/Salaries. The proportion of labor to material in the price is 65%/35%. The previous buy was for similar repairs to the same kind of building with approximately 25% of the required square footage at a price of $180,000 in Jan 200X. It is now Jan 200(X+2). What should be the expected price, other factors being the same?

We first consult the BLS website under *Producers Prices and Price Indexes* and under *Employment Cost Index* for the appropriate material and labor indexes. Using the "Selective Access" search feature in the website we find the following index values (yearly averages):

BLS Code	Series Nomenclature	200X	200(X+1)	200(X+2)
Code PCUBMRP	Maint/Repair, Constr	127.1	129.3	131.0
Code ECU22302I	Construction Wages	116.2	119.8	123.8

Using the technique for estimating economic price level changes demonstrated in the previous section, we find the change in price level for

Construction Material = (131.0 – 127.1) ÷ 127.1 = 0.0259 = 2.6% higher than the cost two years earlier

Construction Wages/Salaries = (123.8 – 116.2) ÷ 116.2 = 0.0654 = 6.5% higher than the price two years earlier

Next we amalgamate the percentage changes in material and labor into a simple composite percentage change in price. Using the knowledge that labor is 65% of price and material 35%, the computation is

$$\begin{aligned}\text{Change in price} &= \%L \times (\%\Delta L) + \%M \times (\%\Delta M)\\ &= 0.35(0.0259) + 0.65 \cdot (0.0654)\\ &= 0.051575 \approx 5.16\%\end{aligned}$$

where L = labor, M = material, and Δ = change or difference.

This composite price level factor tells us that – all other factors being the same – the price of this item should be around 105.16% of the price paid two years ago. Since there is approximately 4 times the previous effort and the typical price for that industry would have increased 5.16% in that time, the expected price for the new renovation project would be

$$4 \times \$180,000 \times 1.0516 = \$757,150$$

which would be used to benchmark the proposed price(s) for reasonableness based on price analysis.

Price Analysis Using Commercial Prices

Frequently the contract specialist will not have adequate price history to perform valid comparisons, and may have only one valid offer. In certain situations, he or she may be fortunate enough (or unfortunate enough, as we shall see later) to have catalog or commercial prices as a benchmark. The immediate price may be based on a catalog or price list, or the item we are buying may be a modified version of an item whose price is a catalog/commercial price.

If the price of the commercially available item or version can be established as a market price, and the differences between the immediate item and comparison item can be priced out with a good degree of confidence, then we can establish a reasonable price for the modified item.

An established catalog commercial price is one that is based on commercial items sold in substantial quantities to the general public. Established catalog prices must be current prices listed in a published form regularly maintained by the manufacturer and available for public inspection. Commercial items are defined in FAR 2.101.

- Established market prices are current prices that are established by competitive market transactions, and can be verified by sources independent of the offeror.

- An item is "sold in substantial quantities" only when the quantities regularly sold are sufficient to constitute a real market; models, samples and prototypes usually are sold in nominal quantities and do not qualify. Services qualify if they are provided normally by a business set up specifically to provide those services ***at a fixed price for the same service***. For example, a price of $49.95 for a dealer shop or garage to tune up your car may qualify as a commercial service price, but an hourly rate of $49.95 for a mechanic will not qualify as a commercial service price even when multiplied by the estimated amount of time to perform the service.

- "The general public" is a significant number of buyers other than affiliates of the offeror. Direct sales to federal, state, local and foreign governments or firms are considered to be sales to the general public.

What the buyer has, if he or she has established that the item meets the above criteria, is the basis for an exemption from submission of cost or pricing data. Nonmodified commercial items are expressly exempted from the requirement for cost and pricing data in FAR 15.403-1(b)(3). However, the contracting officer can require limited information other than cost or pricing data as deemed necessary to establish price reasonableness.

In cases where the submitted price is ***not*** "based on" that of another commercial item, only such limited “information other than cost or price data” as are necessary should be requested in pricing out differences between the order item and the comparison item. This should be done before granting the exemption from cost or pricing data.

For services contracts where price is based on hourly rates, the same principles apply. Quantities of services would normally be compared based on estimated hours per task or normal schedule fees for duration and type(s) of service. Again, listed prices based on *hourly rates* ***are not*** commercial prices and are not exempt from the requirement for cost or pricing data if otherwise required. However, services based on ***listed prices*** for specific tasks or jobs *are* commercial items if the service is a standard service offered to the general public.

Price Analysis Using Independent Government Estimates

Another type of price analysis is comparison with an independent government estimate (either price or cost) prepared before issue of the solicitation.

Caution should be exercised in using an IGE as a comparison with proposed price(s). The rationale, assumptions and methodologies used in arriving at the estimate should be thoroughly elaborated and validated.

Such estimates may not be truly independent, but may be based on budgetary quotations from some of the same sources that will later submit proposals (directly as primes, or indirectly as subcontractors).

Comparison should be made of the assumptions behind the IGE and the proposed prices: approaches to performance, quantity, milestones, and so forth. If a technical proposal is part of the total response, the technical and management approach must be compared to the specs, plans, and other criteria established for the IGE. Any differences should be reconciled, or the IGE "tailored" to the (acceptable) approach of the offeror.

By their very nature, independent government cost estimates must use generalized industry-level rates and the expertise of the Government technical personnel. This in itself will often cause the comparison to be difficult at price level. Tolerance bands should be established around the government costs, which if exceeded will cause the comparison to be considered inadequate for price justification without further analysis.

Summary

In price analysis, the "name of the game" is comparison. One must be careful to compare apples to apples. One may compare Jonathans to Red Delicious (if one can price out the differences), but not apples and oranges.

The yardsticks one uses are often statistical, but the most important tools are value analysis and common sense.

Although above specified thresholds FAR requires cost analysis of certified cost or pricing data, or an exemption, it also requires corroboration through price analysis. Therefore price analysis is not to be looked upon as inferior to cost analysis, but its complement (and, in certain instances, its necessary replacement.

Source Selection

Whenever the government decides to contract for goods or services competitively, it must solicit offers from available sources and select one of those sources to do the work. With elegant simplicity this process is known as source selection.

In selecting a source for a good or service, the government must first determine (1) how much it is willing or able to afford, and (2) what level of quality it desires. Affordability and estimated price should be determined before the requirements document reaches the contracting office.

The government may specify a minimum acceptable level of quality by specifying particular characteristics and minimum standards for those characteristics. Source selection then proceeds by ruling out any offers that not meeting minimum quality requirements and selecting the low evaluated offer from among those offers determined acceptable and responsible. This selection method is termed the ***low price technically acceptable*** (LPTA) method. In the past this was the standard way of specifying quality level, but this led to a proliferation of MIL-SPECS and FED-SPECS. That in turn led to higher prices and a reduction in the number of firms willing to do business with the government.

The government may also specify the desired performance of the good or service and leave it to offerors to work out how this will be satisfied. The government then compares the implicit quality levels against offered prices and determines which offer gives “the most bang for the buck.” This method is termed the ***best value*** method.

Selection Factors and Weights

The LPTA method selects sources based on only one selection factor – price. (Actually, evaluated price is the factor, which includes any price-related factors such as packaging, transportation, and so forth.) The weight of price may be said to be 100% in this selection method. There are technical factors and quality factors. However, all offerors in the competitive range are considered “equal” as to these factors because all will have been determined to meet the minimum stated requirements in the solicitation prior to the selection decision.

The LPTA method is used when specifications are explicit enough for offerors to be able to determine clearly what the minimum quality requirements are. The evaluation process can clearly determine whether or not a given offer meets or exceeds those requirements, which means that the quality specifications are objectively measurable. Normally in this type of scenario, the contract type will be fixed price, and the procurement method will normally be sealed bid.

When the government cannot draft explicit quality standards that must be met or exceeded, the LPTA method will not work. This is because offerors will not be able to determine clearly what the minimum quality requirements are, and the evaluation process cannot clearly determine whether or not a given offer meets or exceeds the government's needs. This requires use of the negotiation method of procurement and a more flexible method of source selection. That method is *the best value* method.

When the government cannot pre-select a clear "inner circle" of offers qualified for award on low price, it must explicitly determine what factors are involved in quality performance and how important each factor is in assuring quality performance. These factors begin at the general level and are broken down into more specific subfactors and even sub-subfactors as necessary. The importance of each selection factor is indicated by a percentage weight given each. Weights of all factors must sum to 100%.

Cost or price must always be one of the source selection factors, and it must be a "significant factor" in the selection. It has generally been the rule of thumb that to be a significant factor, the weight of cost must be at least 20%. If cost is not perceived by offerors to be a significant selection factor, there will be inadequate competitive pressure on proposed costs, resulting in the government paying inflated prices for "gold plated" goods and services.

The weighting scheme must be devised in such a way that:

- There are not so many selection factors and sub-factors that their power to discriminate quality levels is diluted by small weights attached to subfactors. This results in large variances in capability being masked by small differences in weighted scores.

- The weights are consistent with the actual importance of each factor/subfactor in the whole scheme.

- Cost and Past Performance, which must also be a factor, are significant.

Section M of the solicitation divulges the source selection factors and their *relative* weights, stated in qualitative terms. The solicitation may divulge the percentage weights for the major factors, but should not give the weights for all factors. For instance, suppose the following factors have the following weights:

Technical Quality	30%
Management Capability	25%
Past Performance	25%
Evaluated Cost	20%

The solicitation may state: "The overall source selection factors are technical quality, management capability, evaluated cost to the government, and past performance. The weight of technical quality is greater than the weights of the other individual factors. The weights of management capability and past performance are equal, and the weight of each is slightly greater than that of evaluated cost" or it may specify the above weights.

An evaluation plan must be devised and documented prior to issuing the solicitation, and evaluation of proposals submitted in response to such a solicitation must be done strictly in accordance with the evaluation plan. One of the most difficult parts of subjective evaluations is to give the proper weight to each factor and subfactor in the evaluating and scoring processes.

One way to aid this process is to turn the weight percentages into a range of possible points for each factor and related subfactors. For example, the maximum possible score might be 1,000 points with technical quality 0 – 400, management capability and past performance each 0 – 250. ***Cost is weighted but is not scored.*** Subfactor point ranges would be based on their respective weights (each of which must sum to the percentage of their parent factor). A more detailed weighting scheme and point scheme for the above factors might be as shown in Table 8-1 below.

Table 8-1
Selection Factor Weighting Scheme

Factor	Factor Weight	Subfactor	Subfactor Weight	Overall Weight	Point Range
Technical Quality	30%	Technical Approach	50%	15%	1 - 150
		Technical Experience	50%	15%	1 - 150
Mgmt. Capability	25%	Technical Mgmt.	50%	12.5%	1 - 125
		Personnel Mgmt.	25%	6.25%	1 – 62.5
		Contract Mgmt.	25%	6.25%	1 – 62.5
Past Performance	25%			25%	1 - 250
Evaluated Cost	20%			20%	Not scored
Total Weight				100%	1 - 800

Something appears to be wrong with the total point range, which goes only to 800! This results from the fact that cost may be weighted but not scored. Twenty percent of the weight receives no score. Therefore, the other non-cost factor weights must be normalized to 100% and the point ranges adjusted accordingly. Each non-cost factor weight is normalized to 100% by the following formula:

$$\text{Normalized weight} = \text{Assigned weight} \times \frac{100\%}{100\% - \text{cost weight}}$$

For example, the normalized weight of technical quality would be 30% $\times$ 100%/(100%-20%) = 30% $\times$ 100%/80% = 37.5%. Table 8-2 shows the normalized weight scheme and point ranges.

Table 8-2
Normalized Quality Factor Weight Scheme

Factor	Factor Weight	Subfactor	Subfactor Weight	Overall Weight	Point Range
Technical Quality	37.5%	Technical Approach	50%	18.75%	1 – 187.5
		Technical Experience	50%	18.75%	1 – 187.5

Mgmt. Capability	31.25%	Technical Mgmt.	50%	15.625%	1 – 156.25
		Personnel Mgmt.	25%	7.8125%	1 – 78.125
		Contract Mgmt.	25%	7.8125%	1 – 78.125
Past Performance	31.25%			31.25%	1 – 312.5
Total Weight				100%	1 – 1,000

The use of such a large point range allows significant variances in evaluated capability to receive proportionate differences in score, which allows the decision maker(s) to mentally visualize these differences as significant. If the total point range is 1 – 100, a 10% difference in technical management capability receives a score difference of only 1.6 points (10% x 15.625 points)! This is not easily perceived as a substantial difference, whereas a difference of 16 points (on a 1000-point scale) is more easily gauged to be significant for that subfactor.

Cost Evaluation – General Principles

Evaluated price or cost to the government (including any price-related factors) is to be a significant factor in ***all*** source selection decisions. In the case of LPTA, it is the sole factor. In the case of Best Value, it is one of several factors, the others being related to the government's objectives in the contract. Evaluated price/cost must still be weighted so as to be a significant factor (for both offerors and the source selection authority).

When LPTA is used, the contract will almost always be fixed price. Evaluation of price in this instance is simply ranking of offers from low to high. In the rare cases in which special packaging or F.O.B. Destination are used, evaluation of prices may include adding appropriates amounts for packaging and/or shipping costs to proposed prices.

Best value methodology may be used with all contract types. When a cost-reimbursement contract is contemplated, FAR 15.404-1(d)(2) mandates that evaluation of proposed costs (including fee) shall include development of an estimate of probable cost of performance, termed a "Most Probable Cost Estimate (MPCE)".

> "Cost realism analyses shall be performed on cost-reimbursement contracts to determine the probable cost of performance for each offeror. (i) The probable cost may differ from the proposed cost and should reflect the Government's best estimate of the cost of any contract that is most likely to result from the offeror's proposal. ***The probable cost shall be used for purposes of evaluation to determine the best value*** [emphasis added]***."***

FAR 15.404-1(d)(3) states that cost realism may be used for fixed price contracts but may *not* be the basis of price adjustments.

> "Cost realism analyses may also be used on competitive fixed-price incentive contracts or, in exceptional cases, on other competitive fixed-price-type contracts when new requirements may not be fully understood by competing offerors, there are quality concerns, or past experience

> indicates that contractors proposed costs have resulted in quality or service shortfalls. Results of the analysis may be used in performance risk assessments and responsibility determinations. However, proposals shall be evaluated using the criteria in the solicitation, and the offered prices shall not be adjusted as a result of the analysis."

The most probable cost is determined by adjusting each offeror's proposed cost, and fee when appropriate, to reflect any additions or reductions in cost elements to realistic levels based on the results of the cost realism analysis. DFARS 215.404-4(c)(1) adds "…[D]o not perform a profit analysis when assessing cost realism in competitive acquisitions." This refers to a formal, structured analysis such as Weighted Guidelines.

Evaluated Cost in Best Value Determinations

In competitive negotiated procurements where best value is the selection basis, the type of contract determines what constitutes evaluated price/cost for purposes of determining the best value.

In fixed price contracts, the *offered prices* shall be the basis of best value determination. As stated above in the quote from FAR 15.404-1(d)(3), cost realism analysis may be a basis for performance risk assessment but not for adjusting offered prices. In cost-reimbursement contracts, the *most probable cost estimate* for each offer shall be the basis for the best value determination.

In fixed price procurements where the contracting officer determines that there is adequate price competition and cost realism is not used, the evaluated prices will be the proposed prices. Prior to the decision phase, any cost deficiencies and problems are noted and conveyed to offerors in discussions. Contracting officers may develop price objectives based on the noted pricing problems. However, after submission of Best and Final Offers (BAFOs) the contracting officer may not adjust offered prices for the purpose of determining best value.

In cost-reimbursable procurements, where the primary objective is to develop as realistic an estimate of costs as possible, the contracting officer must use cost not just as a basis for determining fair and reasonable price, but also as a check on offerors' understanding of the requirements of the solicitation. Cost data will allow the government to assess whether the offerors have a realistic understanding of the scope and complexity of the work and the resources required to perform the various tasks that make up the work.

Adjustments to proposed cost elements will largely be based on areas where the contractor does not have a solid understanding of the government's requirements, or the resources necessary to accomplish those requirements. They may also be based upon unrealistic indirect cost factors as assessed by the Defense Contract Audit Agency. (Although in a competitive negotiated procurement the contracting officer should rarely ask for audits of offers, a "desk audit" of direct or indirect rates is permissible since this does not require submission of cost or pricing data.)

Adjustments for most probable cost should not be based solely on differences from the Independent Government Cost Estimate (IGCE). The IGCE is based on the government's implicit approach to the work, which may differ from the offerors' approaches. Also, the IGCE rates used may not be comparable. The technical evaluation should reveal areas where each contractor's approach is inadequate or its resourcing unrealistic, and may or may not state what resourcing is optimal given the approach (assuming the approach is viable and acceptable). The technical evaluators and the cost evaluator(s) should crosswalk technical deficiencies and their estimated impact on cost to assure proper adjustments can be made to the proposed costs.

The primary role of the IGCE in any procurement is as a benchmark for price analysis. In single source procurements where the specifications are well defined it may also serve as a benchmark for direct cost elements such as labor, material and other direct costs. But in a competitive negotiated procurement where performance specifications are used, the IGCE should not be used as the benchmark for costs without itself being adjusted to each offeror's proposed approach.

Cost evaluation can include other price-related considerations than just total cost. These include proper balance of costs over the years of performance (not front-loading costs that should be distributed over the total life of the contract). It may also include balance over the contract line items (not underpricing CLINs that will likely be less utilized and overpricing CLINs that will likely be utilized more, so as to come up with a price that appears low but will really cost the government more). It may include cost risk to the government, especially in cost-reimbursable procurements.

Cost evaluation in best value procurements uses the same tools discussed in the other parts of this pamphlet, and the reader is referred to those parts for additional detail.

Source Selection Using Price/Cost and Other Factors

Many contracting personnel (the author included) feel uncomfortable with subjective bases for source selection, preferring more objective methods. However, it is often not possible to develop totally objective criteria, nor practicable to objectively measure offerors' relative technical, business and management capabilities. The best that can be done is to objectivize the process to the maximum practical extent and then rely on the professionalism and expertise of the evaluation committees to eliminate bias and mentally "weigh" factors in a proper manner as they score proposals on technical merit.

As stated in section 8-2, each non-cost factor must be weighted as to its importance and each offeror must be scored on all non-cost factors. Every factor and subfactor should be tied to one or more of the government's objectives in contracting the work. Obviously, a factor or subfactor that influences the accomplishment of a number of objectives must receive a large weight. Also, if a factor or subfactor is a driver in the accomplishment of an objective, it should be duly weighted. Subfactors that influence more minor objectives or do not drive the accomplishment of important objectives would receive smaller weights. Weights should all be between zero and one, and should sum to 1.0 when aggregated.

Based on DoD policy, ***cost may be weighted but cannot be scored***. Cost does not have to be explicitly weighted, but must always be a significant factor in the source selection decision. Even when cost does not receive an explicit weight, the fact that it must be considered effectively weights it. If the contracting officer plots technical scores on the x-axis of a graph and evaluated cost on the y-axis, he/she is effectively giving cost the same weight as the total of non-cost factors.

Not only must cost not be scored, it may not be combined in any formula with scored elements as the basis for source selection. This means that “objective” methods such as Greatest Value Scoring and its variants may not be used as the basis for selecting the best value. It may be used as an indicator of whether or not the selection decision is roughly in line with the weights and scores. However, the decision must always be justified by the facts of the case, not by appeal to any formalistic device.

Certain ways of looking at cost vis-à-vis technical or quality scores may be more in line with economic principles than others. Economics encourages cost-benefit analysis in terms of the impact of changes “at the margin” rather than average or total differences. This is the subject of the section 8-6.

Evaluation Tools and Techniques

One major concept in coming to grips with the economic or pricing aspects of source selection is called marginal analysis. In economics, inputs and outputs are looked at in terms of their behavior "at the margin," which for our purpose means at the last unit of cost or benefit considered. (“Benefit” here means technical merit as measured by the scoring of proposals.)

When the government ranks offerors as to their value to the government, how does it proceed?

- Does it rank them strictly in order of their scores? What about higher scores that entail higher evaluated costs? What does this say about the implicit weight of cost?

- Does it rank them strictly in accordance with evaluated cost? This would weight cost much higher than technical merit, which is rarely the case.

So, how does the government rank offers? Rankings must somehow reflect the relative values of each of the proposals given all selection criteria. Dividing the total evaluated cost by the total technical score gives $ per technical point for each offer. Table 8-3 shows seven offers ranked by $ per technical point. Note that offer F is ranked second even though it has the second lowest technical score, because its evaluated price is the lowest. Also note that the top score is ranked third due to the relatively high evaluated cost. The problem with this ranking scheme is that it gives equal weight to cost and non-cost factors, which may not reflect the intended weights.

Table 8-3
Offeror Ranking

Offeror	Tech. Score	Evaluated Cost/Price	$ per Tech. Pt
B	89	$2,754,884	$30,954
F	77	$2,484,145	$32,262
A	93	$3,002,554	$32,286
E	79	$2,615,858	$33,112
C	86	$2,852,585	$33,170
D	84	$3,747,447	$44,612
G	74	$3,349,858	$45,268

Another way to rank offers is to consider the marginal cost to increase each offeror's score to the maximum score. Find $ per technical point as before, then multiply this figure by the difference between the offeror's score and the maximum score (100 in this case). Add this cost to the evaluated cost. This gives an estimate for each offer to achieve a maximum score (i.e., a "perfect" approach from a technical standpoint). Table 8-4 displays the results of this analysis.

Table 8-4
Analysis of Marginal Cost

Offeror	Technical Score	Evaluated Cost	$ per Tech. Point	$ to achieve 100 score	Total Cost 100 score
B	89	$2,754,884	$30,954	$340,491.28	$3,095,375.28
G	74	$2,349,858	$31,755	$825,625.78	$3,175,483.78
F	77	$2,484,145	$32,262	$742,017.34	$3,226,162.34
A	93	$3,002,554	$32,286	$225,998.69	$3,228,552.69
E	79	$2,615,858	$33,112	$695,354.66	$3,311,212.66
C	86	$2,852,585	$33,170	$464,374.30	$3,316,959.30
D	84	$3,747,447	$44,612	$713,799.43	$4,461,246.43

As can be seen, the top score of 93 now ranks fourth due to the highest marginal cost of achieving the additional technical merit, while the lowest technical score is ranked second due to the relatively small amount necessary to raise its score from 74 to 100.

This ranking scheme, however, may often significantly underestimate the additional cost for technical proposals to reach a perfect score. Based on the law of diminishing returns, to raise a low score to an above-average score may only require low cost improvements, while to raise it to an exceptional score will likely require expensive improvements. A more realistic procedure may be to "raise" all other scores to the highest score rather than to the maximum using the above procedure. An even better approach is to use cost estimating to build up a cost picture of such improvements using knowledge of the resources required to achieve such improvements.

Looking at the above seven offers, we temporarily set aside any offers for which we can find a higher score at the same or lower cost. Offers C and D are temporarily eliminated because they fit this criterion. Five offers remain. Table 8-5 below details the competitive range with score, evaluated cost and marginal cost.

Table 8-5
Competitive Range

Offeror	Technical Score	Evaluated Cost	$ per Tech. Point
A	93	$3,002,554	$32,286
B	89	$2,754,884	$30,954
E	79	$2,615,858	$33,112
F	77	$2,484,145	$32,262
G	74	$2,349,858	$31,755

Note that for each increase in score there is an increase in evaluated cost. The column "$ per Tech. Point" indicates that offer B may actually be a better value than A; it costs less per point to achieve a score that is only 4 points lower. The other offers are significantly lower in technical merit than B while not significantly lower in cost. However, at least F and G are significantly less than A in cost although also significantly lower in score. Again, selection depends on the weight (relative importance) of quality versus cost.

Offer B seems the likely candidate for best value unless the selection official can justify paying the $247,670 marginal cost for offer A's 4 point margin of technical merit. To do so, they will have to look closely at what each offers in terms of strengths and weaknesses, innovative techniques, lower risk, and other discriminators.

If cost is not weighted, or is weighted equally with the total of non-cost factors, there is a graphic technique that can often render the picture clearer. One plots evaluated cost on the x-axis and total technical score on the y-axis. Since the best value will be that which has the highest score for the lowest possible cost, we look for the plotted point that is closest to the top left corner of the graph. The graph in figure 8-1 on the next page depicts the seven offers we have been using.

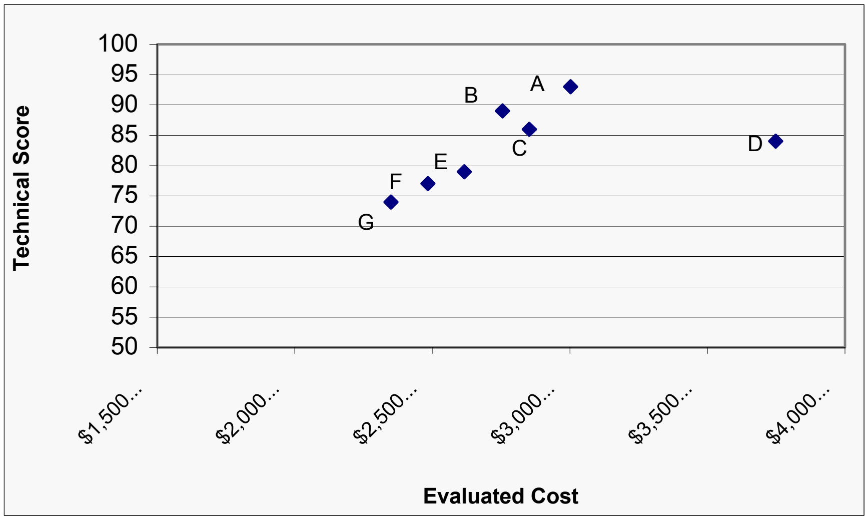


Figure 8-1

The example was constructed to give a difficult example. However, it is fairly clear from the chart that, if quality and cost factors are equally weighted (or cost is not weighted), offer B is the closest to the top left corner, hence the best value – even though it is not the lowest evaluated cost nor the highest score.

But suppose quality is weighted higher than cost. For example, suppose the total of non-cost factors is weighted 70% and cost is weighted 30%. How do we represent this scenario? There are two ways to do this. One way is to multiply each Quality score times 0.7 and multiply each evaluated cost times 0.3, then plot these on a graph, and use the same "northwest corner" indicator of best value. The result for the above offers is shown in Figure 8-2.

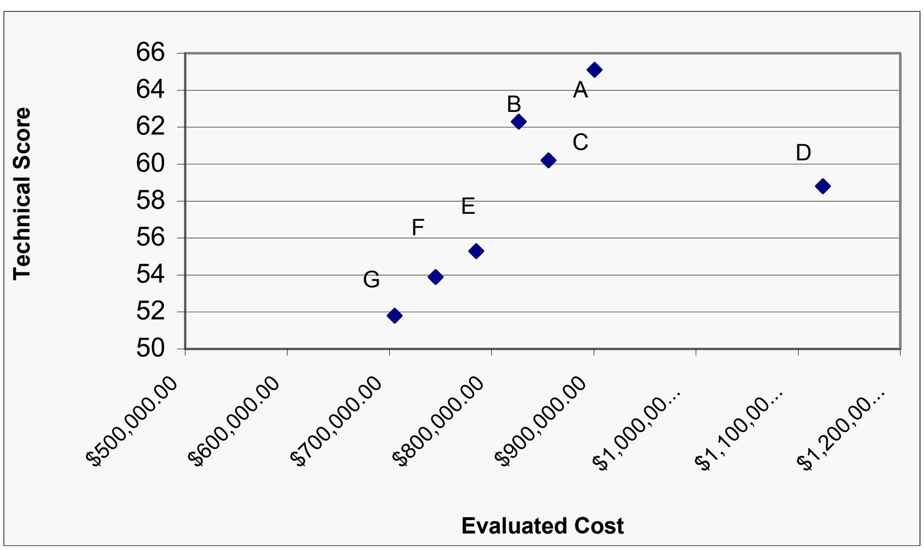


Figure 8-2

Offer B is even more clearly the best value when the weight of Quality is increased from 50% to 70%.

A second technique is to normalize evaluated costs, weight raw scores and normalized costs each by its respective weight, then sum them. This is known as the "Greatest Value Scoring" technique. Follow these steps to develop the GVS.

- Take the raw total Quality score and multiply it by the Quality weight (70%). Table 8-6 gives the weighted scores.

Table 8-6
Weighted Technical Scores

Offer	Raw Score	Weighted Score
A	93	65.1
B	89	62.3
C	86	60.2
D	84	58.8
E	79	55.3
F	77	53.9
G	74	51.8

- Normalize evaluated cost as follows: (1) for each offer, ratio the difference (eval. cost - lowest eval. cost) to the lowest evaluated cost, (2) subtract this fraction from 1.0, (3) Multiply the resulting fraction by 100, then (4) multiply by the cost weight (30%). For these offers, normalization of cost is shown in Table 8-7.

Table 8-7
Normalization of Cost

A	B	C	D	E	F	G
Offeror	Evaluated Cost	Diff. from Lowest Cost	C× Lowest Cost	1 – D	E× 100	F× 30%
A	$3,002,554	$652,696	0.27776	0.72224	72.22	21.67
B	$2,754,884	$405,026	0.17236	0.82764	82.76	24.83
C	$2,852,585	$502,727	0.21394	0.78606	78.61	23.58
D	$3,747,447	$1,397,589	0.59475	0.40525	40.52	12.16
E	$2,615,858	$266,000	0.11320	0.88680	88.68	26.60
F	$2,484,145	$134,287	0.05715	0.94285	94.29	28.29
G	$2,349,858	$0	0.00000	1.00000	100.00	30.00

- Summing the two weighted scores produces the Greatest Value Score (GVS). Table 8-8 below shows the process and ranks the offerors by GVS.

Table 8-8
Greatest Value Scoring and Ranking

	A	B	C
Offeror	Weighted Quality Score	Weighted Normalized Eval. Cost	Greatest Value Score (A+B)
B	62.3	24.83	87.13
A	65.1	21.67	86.77
C	60.2	23.58	83.78
F	53.9	28.29	82.19
E	55.3	26.60	81.90
G	51.8	30.00	81.80
D	58.8	12.16	70.96

Just as with the first method, offeror B appears to be the best value "by a whisker" over A. Although A has a higher Quality score, its evaluated cost appears to be slightly too high to be a better value than B with its slightly lower Quality score but lower evaluated cost.

In accordance with DoD policy, however, the selection cannot be made by formula on the basis of this analysis of combined Quality/cost scores. The selection official must look at what is being traded off between cost and technical capability in selecting B over A. If B's lower technical score is due to some deficiency considered to be significant to achievement of one or more of the government's objectives, then selection of A despite its higher evaluated cost may be the better choice, GVS or other formula scores notwithstanding.

Value Added in Source Selection

Part of the NASA approach to Best Value source selection is to identify “desirable characteristics” sought by the government as focal points for assessing all proposals. The government can develop a list of desirable characteristics, then, based on reasonable criteria, assign a dollar value to each desirable characteristic and use this as a basis to quantify “value added” for each proposal.

A similar process was “sanctioned” by GAO in denying a protest of a similar Air Force procedure. This process provides a somewhat more objective look at relative merit and enables the government to focus more attention on what it considers value added in proposals. It does require more analytical time of source selection officials, but is well worth the effort for all parties.

This analysis is only necessary when there is no clear choice, such as an offer with the lowest evaluated price and highest technical score. The process concentrates on determining in a systematic manner whether or not the proposed selectee, which is not the lowest evaluated price, is actually worth the incremental difference in price because it offers value added which is worth at least that much extra cost.

After all proposals have been evaluated and scored as usual, the procedure next determines which, if any, of the desirable characteristics are incorporated into each proposal. Each offer is assigned a total value added dollar amount based on the number of desirable characteristics it demonstrates. Next, all offers are ranked by value added. A lead proposal is chosen based on either the highest value added, or there may be a clear front runner having the highest technical score and highest value added. This front runner is compared to all offers higher and lower priced using a combination of price difference and value added.

When the front runner is compared to a proposal having a lower price and lower value added, two adjustments are made to the *front runner's total value added amount*. The first adjustment deducts the price difference between the front runner and the compared offer. If the front runner's remaining value added (hereafter V_{FR}) is still greater than zero (>0), a second adjustment deducts the compared offer's value added from the remaining V_{FR}. If the remaining V_{FR} after both adjustments is still >0, it is a Best Value. If it is negative (<0), then the compared offer becomes the new front runner, and the process continues by comparing the new front runner to the other lower priced offers (as well as higher priced offers) until a front runner is found which has the optimal combination of price and value added.

Under this method, for comparing the front runner with higher priced offers the procedure would be to subtract the compared offer's value added from the front runner's value added (V_{FR}) and add the result plus the price difference to the V_{FR}. The reason is that the *extra* value added of the front runner is the difference between its value added and that of the compared offer, plus the difference in price. The table on the next page demonstrates these adjustments with a hypothetical scenario of seven offers:

Example (Ranked by Value Added)							
	(1)	(2)	(3)	(4)	(5)	(6)	
				Front Runner	Column (4)		
		Value	Price	Value Added	Less Offeror	Tech.	
Offeror	Price	Added $	Difference	$ Less Col (3)	Value Added $	Score	NOTES
3	3,500,000	1,000,000	-	-	-	95	Front Runner 1
5	2,950,000	675,000	550,000	450,000	(225,000)	89	Front Runner 2
2	3,300,000	510,000	(350,000)	1,025,000	515,000	87	No Change (N/C)
6	2,780,000	418,000	170,000	505,000	87,000	85	N/C
1	2,575,000	220,000	375,000	300,000	80,000	87	N/C
7	3,645,000	115,000	(695,000)	1,370,000	1,255,000	84	N/C
4	2,200,000	0	750,000	(75,000)	(75,000)	81	Not Selected

Note that in this scenario, the first front runner, offeror 3, does not have enough additional value added (difference between its value added and that of offeror 5) to compensate for the difference in price ($3.5M - $2.95M). This is shown in the table by the ($225,000) next to offeror 5, which means that offeror 3's value added, adjusted for offeror 5's value added and the price difference, is less than 0. Offeror 3 therefore is no longer the front runner, offeror 5 assumes that mantle. The combination of offeror 5's value added and price is better (as shown by the positive adjusted value added in column (5)) until we come to offer 4. Offer 4's price is so low that, even with no value added, offer 5's value added cannot overcome the price difference.

Here is where formulaic answers give way to business acumen and judgment. It should be obvious that the only advantage offer 4 has is low price. Its price may even be outside of a reasonable range of prices for this effort -- that is where the IGE and/or statistical analysis of the pricing can help. Offer four's technical score is 8 points (9%) lower than that of offer five, and has no value added. There may be more risk with offer 4 and few desirable characteristics. It meets the government's minimum needs and no more. The "savings" to the government of picking offer 4 rather than 5 is $75,000 (column (5) next to offer 4). Business judgment would lead to the conclusion that 4 is probably under-priced (or "low balled") and is not a better choice than 5, even given the price difference.

Two caveats are in order: (1) Value added characteristics must be benefits to the government, not the contractor, and (2) offerors must all be treated equitably when applying this method.

The final selection must be made based on the criteria stated in Sections L and M, and must not be based solely on the above procedure, as helpful as it is. The source selection authority can use it, however, to do a sanity check on the process to make certain that the selection does represent the best value to the government.

No quantitative technique can overcome all the issues that each procurement raises between quality and price; judgment and business acumen must still be the guiding forces behind each decision. But insofar as possible, we must indicate in some specific, understandable way what the government is getting in advantages for a particular technical score. If the difference between a 95 score and an 89 represents only the ability to write an appealing, elegant proposal, then selecting the first offer over the second has no advantage, especially at a higher price. This process attempts to quantify in dollar terms the relative magnitude of the extra technical merit offered by each proposal over the government's minimum needs, for ease of comparison of proposals. It offers the advantage of making the differences in relative merit more concrete in terms everyone understands.

Assessing the Incentive

The first step in developing a performance score - award fee conversion scale is to determine the incentive structure one wishes to invoke in the contract. One's philosophy of doing business with contractors will determine this. Some contracting officers may feel that each additional performance point should be worth the same percentage of the available award fee pool. This is what we call a proportional or linear scale. Others may feel that lower level performance should be disincentivized by making the lower half of the range yield smaller proportions of the fee and the upper half of the range yield larger proportions. This would produce a non-linear (non-proportional) scale.

There are several types of non-linear scale that could be used:

Power: The familiar power curve, which resembles a fishhook shape, yields very small proportions of the fee in the lowest range of scores, but quickly "accelerates" (increases at an increasing rate), giving much greater proportions of the fee in the upper range of points. This sort of scale has several problems: (1) it is exceedingly difficult to specify properly, and (2) it defies the law of diminishing returns in that it may cause an ambitious contractor to put forth so much effort to reach 100 points that the incremental benefits received by the government are not worth the additional incurred costs.

Parabolic: The parabolic, or quadratic, curve resembles the shape of the exponential curve except that its slope changes more slowly. The incentive structure differs slightly from the exponential, but they share the same acceleration problem.

Cubic: The cubic, or third order, curve has the S-shape shown in figure 3-2. This curve, unlike the other two, tails off as it approaches 100 points. This scale is more appropriate to recognition of the law of diminishing returns, although it does give more fee than the others in the lower ranges.

Figure A-1 on the next page shows the general shape of these three types of non-linear scales and compares them to the linear scale. In the next section we show how to go about developing specifying equations to generate these types of scales.

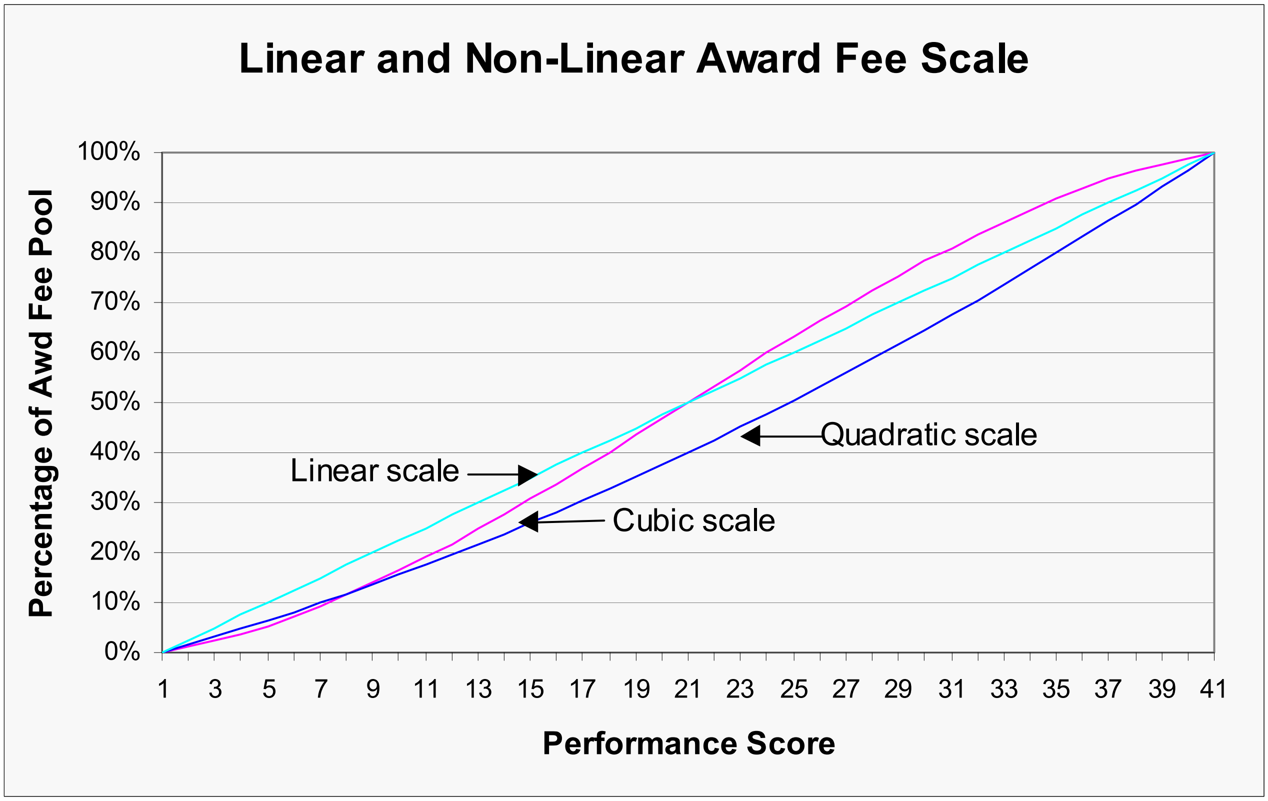


Figure A-1

Specifying Equations.

To generate scales we first need to generate equations that relate performance points to proportionate amounts of award fee. This takes some knowledge of algebra and access to a spreadsheet program that will perform matrix algebra.

We first must know the general form of the equation for the type of scale we wish to generate. The four types of scale discussed above have the following general types of equation:

Linear	$Y = A + BX$, B positive.
Power	$Y = AX^b$, b positive
Parabolic	$Y = AX^2 + BX + C$
Cubic	$Y = AX^3 + BX^2 + CX + D$

Knowing the general form, we know how many parameters we have in the equation. This is the key to generating the scale.

The linear and power equations have two coefficients (A and B), the parabolic has three (A, B, C) and the cubic has four (A, B, C, D). To develop specifying equations for these coefficients (that is, replace the letters with appropriate coefficients) we must be able to write an equation for each coefficient we must find.

Each equation we write must specify an X (in our case a value for a performance score) and a Y (here an appropriate proportion of available award fee). We insert these values for X and Y into general forms of the equation and then determine the coefficients using methods for solving simultaneous equations.

A few spreadsheet programs now incorporate capabilities of solving simultaneous equations quickly and easily, and some modern calculators will also do the job. The examples given below use the ability of LOTUS 1-2-3 version 2.2 and higher to solve matrix algebra as the method for determining the coefficients.

<u>Example 1: Linear scale</u>. A linear equation specifies a slope value (B) and a y-axis intercept value (A), therefore we must specify and solve two simultaneous equations of the linear form. To do this, all we need to do is specify the range of performance points we will use. If our range is 60 to 100, then the number of points in the range is (100 - 59) = 41; this is the change in X. Our proportion of fee will go from 0 (at 60 points) to 1.0 (at 100 points); this is the change in Y. Our two equations are therefore as follows:

$$\underline{Y = A + BX}$$
$$1 = A + 100B$$
$$0 = A + 60B$$

Solving these two simultaneous equations requires only that we subtract the second equation from the first and divide by the coefficient of B. We then plug the B value into either of the simultaneous equations to solve for A:

$$40B = 1$$
$$B = 0.025$$
$$A = 0 - 60B$$
$$A = -1.5$$

giving a specifying equation of $Y = -1.5 + 0.025X$, where X is the number of performance points earned.

What this essentially says is that the contractor gets 0% at 60 points, and gets 2.5% of available award fee for every additional performance point. The reader can verify that at 80 points (midpoint of the range) the contractor gets 50%, at 90 points (3/4 of the range) it gets 75% and at 100 points, 100%.

<u>Example 2: Quadratic (parabolic) scale</u>. A quadratic equation specifies three coefficients: one for X^2 (A), one for X (B), and a constant, C, which is really the parameter

for X^0, or 1. We must have three equations of the general form to solve for these three coefficients.

We therefore specify three values of X (performance points) and three values of Y (proportion of award fee). These values reflect critical points in directing the shape of the curve, hence the total distribution of fee relative to performance.

Since the performance values are constrained to a minimum and a maximum these should be two of the points specified, with 0% award fee at the minimum and 100% at the maximum. The other point can be anywhere between, but should be picked to reflect a critical minimum performance point, with the percentage fee the contracting officer (CO) believes appropriate. For example, in a range from 60 to 100 the midpoint is 80. If the CO wishes most of the fee to be earned above this midpoint, attach a fee percentage below 50% to this performance point. The equation generated will smoothly proportion all other points in the range so that more than 50% of fee is earned above 80.

Below is an example of the development of a parabolic scale with a performance range from 60 to 100, with 0% fee at 60, 100% at 100, and 33% at 80. We generate 3 equations in X and Y, with X the selected performance points and Y the attached fee percentages:

$$Y = AX^2 + BX + C$$

$$\begin{aligned} 0 &= A*(60)^2 + B*(60) + C*1 \\ 0.33 &= A*(80)^2 + B*(80) + C*1 \\ 1.0 &= A*(100)^2 + B*(100) + C*1 \end{aligned}$$

Now that we have three equations in three unknowns we solve for the unknowns (A, B, and C) using matrix algebra. The following is the result of Matrix commands in Excel.

	A	B	C	D	E
1|	3600	60	1		0.00
2|	6400	80	1		0.33
3|	10000	100	1		1.00

Minverse A1..C3

7|	0.00125	-0.0025	0.00125
8|	-0.225	0.4	-0.175
9|	10	-15	6

MMult A7..C9 by E1..E3

0.000425 (These are the coefficients A, B, and C)
-0.043

1.05

$$Y = 0.000425X^2 - 0.043X + 1.05 \qquad \text{(Specifying equation)}$$

The above equation yields the following proportions of fee for each performance point in the specified domain:

PERF	% FEE	PERF	% FEE
60	0.0000	81	0.3554
61	0.0084	82	0.3817
62	0.0177	83	0.4088
63	0.0278	84	0.4368
64	0.0388	85	0.4656
65	0.0506	86	0.4953
66	0.0633	87	0.5258
67	0.0768	88	0.5572
68	0.0912	89	0.5894
69	0.1064	90	0.6225
70	0.1225	91	0.6564
71	0.1394	92	0.6912
72	0.1572	93	0.7268
73	0.1758	94	0.7633
74	0.1953	95	0.8006
75	0.2156	96	0.8388
76	0.2368	97	0.8778
77	0.2588	98	0.9177
78	0.2817	99	0.9584
79	0.3054	100	1.0000
80	0.3300		

As can be seen, 67% of the available fee requires performance equivalent to 81 points or better. Plotting these points on graph paper will confirm a smooth parabolic shape curve for the interval. The problem with parabolic curves is also clearly visible -- there is a huge jump in percentage of fee earned as we go from 95 to 100 points because parabolic curves increase at an increasing rate. Fully 20% of award fee is in the interval from 95 to 100 points, yet the incremental cost of achieving performance up around 100 points is probably disproportional to any benefits received. This may be alleviated to an extent by specifying greater percentage of fee at the critical point (80). This causes the curve to "accelerate" more slowly.

Example 3: Cubic (S-shaped) curve. A cubic equation specifies four coefficients: one for X3 (A), one for X2 (B), one for X (C), and the constant (D) for X0. We must have four equations of the general form to solve for these coefficients.

We therefore specify four values of X (performance points) and four values of Y (proportion of award fee). These values again reflect critical points in directing the shape of the curve, hence the total distribution of fee relative to performance.

Since the performance values are again constrained to a minimum and a maximum, these should be two of the points specified, with 0% award fee at the minimum and 100% at the maximum. The other points can be anywhere between, but again should be picked to reflect critical performance points. These two points are assigned the fee percentages the contracting officer believes appropriate to a proper incentive structure. For example, in a range from 60 to 100, we can specify the points one-third and two-thirds of the way through the range, but there are many other points. Using the procedure below, the resulting equation will smoothly proportion all other points.

Below is an example of the development of a cubic scale with a performance range from 60 to 100, 0% fee at 60, 100% at 100, 50% at 80 and 88.5% at 93.

We generate four third-order equations in X and Y, with X again representing the selected performance points and Y the associated fee percentages:

$$\underline{Y = AX^3 + BX^2 + CX + D}$$
$$1 = A*(100)^3 + B*(100)^2 + C*(100) + D*1$$
$$0.885 = A*(93)^3 + B*(93)^2 + C*(93) + D*1$$
$$0.5 = A*(80)^3 + B*(80)^2 + C*(80) + D*1$$
$$0 = A*(60)^3 + B*(60)^2 + C(60) + D*1$$

Now that we have four equations in four unknowns we solve for the unknowns (A, B, C and D) using matrix algebra. The following is the result of using the Matrix commands in Excel:

Cubic Specification Equations

	A	B	C	D	E
3	1000000	10000	100	1	1
4	804357	8649	93	1	0.885
5	512000	6400	80	1	0.5
6	216000	3600	60	1	0

Minverse A3..D6

10	0.000178	-0.00033	0.000192	-0.00003
11	-0.04160	0.079920	-0.04865	0.010340
12	3.182142	-6.26040	4.015384	-0.93712
13	-79.7142	159.8401	-107.307	28.18181

MMult A10..D13 by E3..E6

The procedure generates the following coefficients in Excel:

-0.00001	A
0.004795	B
-0.35062	C
8.090409	D

giving this specifying third-order equation:

$$Y = -0.00001X^3 + 0.004795X^2 -0.35062X + 8.090409$$

The above specifying equation generates the performance table shown in figure 3-8 above and is S-shaped as shown by figure 3-2 above. A study of figure 3-8 shows that, while 50% of profit is earned in the range from 60 - 80, more than half is earned by scores from 70 to 80. Conversely, above 80 points almost 22% of the fee is earned by scores 90 or above. The S-shape can be made more extreme (that is, pack more of the fee in the middle and upper ranges) by changing X and Y in the two interior points; however, it will tend to tail off more drastically in the upper 90 point range.

While the other non-linear scales (power, exponential, hyperbolic, and logarithmic) can be specified, they are extremely difficult to use with a constrained range. Therefore, we will not go into their specification here. The three types given are enough to provide a wide range of incentive structures. However, in the next section we will develop a scale based on the well-known normal, or bell-shaped, curve.

The Normal Curve

The normal curve is a statistical curve based on the normal frequency distribution with its characteristic bell shape. Most human physical characteristics, as well as performance of mental tasks, form such a frequency distribution. Therefore it seems logical to measure contractor performance using that distribution.

The basic coefficients for generating a normal distribution are the mean (average) and the standard deviation (STD), a measure of score dispersion around the mean score. Each potential score in the range can then be converted to what is termed a "z-score" which is the numerical score expressed in number of standard deviations (STD) from the mean score.

Statisticians have generated a table called "The Area under the Normal Curve" which is based on z-scores. Essentially this table tells us the cumulative area under the bell curve from the mean (z-score of 0) to the z-score of interest.

What makes this useful is that the area under the total normal curve is equal to 1. Therefore, any portion of the area will be a proportion between 0 and 1.

As we have repeatedly showed, we are trying to assign a proportion of total fee (between 0 and 1) to each possible performance score in our range, so assigning areas under the normal curve amounts to the same result.

In order to generate a normal scale for our purposes, we must again know the range of points we will consider. Suppose this time we decide that a range from 70 to 100 is appropriate, since in schools this is usually the range for passing grades.

The mean or average value of this range is, of course, 85 points. The standard deviation is approximately 8.944 (any business calculator or a spreadsheet program will calculate this). Using these figures, we convert each point in the range to a z-score using the following formula: $z = (\text{score} - \text{mean})/\sigma$.

If you do the above procedure, you will probably note that the z-scores range from around -1.69 to +1.69. This does not encompass the entire normal curve, which ranges from -3.9 to +3.9 standard deviations. The standard deviation for the performance range must be adjusted so that the top and bottom point scores have z values of 3.9 and -3.9, respectively. Knowing that a score of 100 must be 3.9 STD from the mean of 85, we simply manipulate the z-score formula to solve for STD:

$$z = (\text{score} - \text{mean})/\sigma \tag{3A-1}$$

$$\begin{aligned}\sigma &= (\text{score} - \text{mean})/z \\ &= (100 - 85)/3.9 \\ &= 3.846\end{aligned}$$

We then use this adjusted STD in the original formula (3A-1) for converting the performance score range to equivalent z-scores.

When each point score has a corresponding z-score, find the proportion of the normal curve for each z-score from a table of areas under the standard normal curve. Such a table is included at the end of this appendix. The area under the curve will range from 0 (at z = 0) to .5000 (at z = 3.90). Assign the appropriate area to each z-score from the table. Subtract these values from 0.5 for scores below the mean (70 - 84), and add these area values to 0.5 for scores above the mean (86 - 100). Assign 0.5 to the mean value.

You now have a series of decimal amounts ranging from 0 to 1.0 corresponding to your chosen performance score range. These amounts are the proportion of fee assigned by the normal distribution. Figure A-2 below shows the cumulative fee curve, which resembles a flattened S, and also shows that the distribution roughly follows the bell shaped normal curve. Table A-1 below the graph gives the corresponding conversion scale.

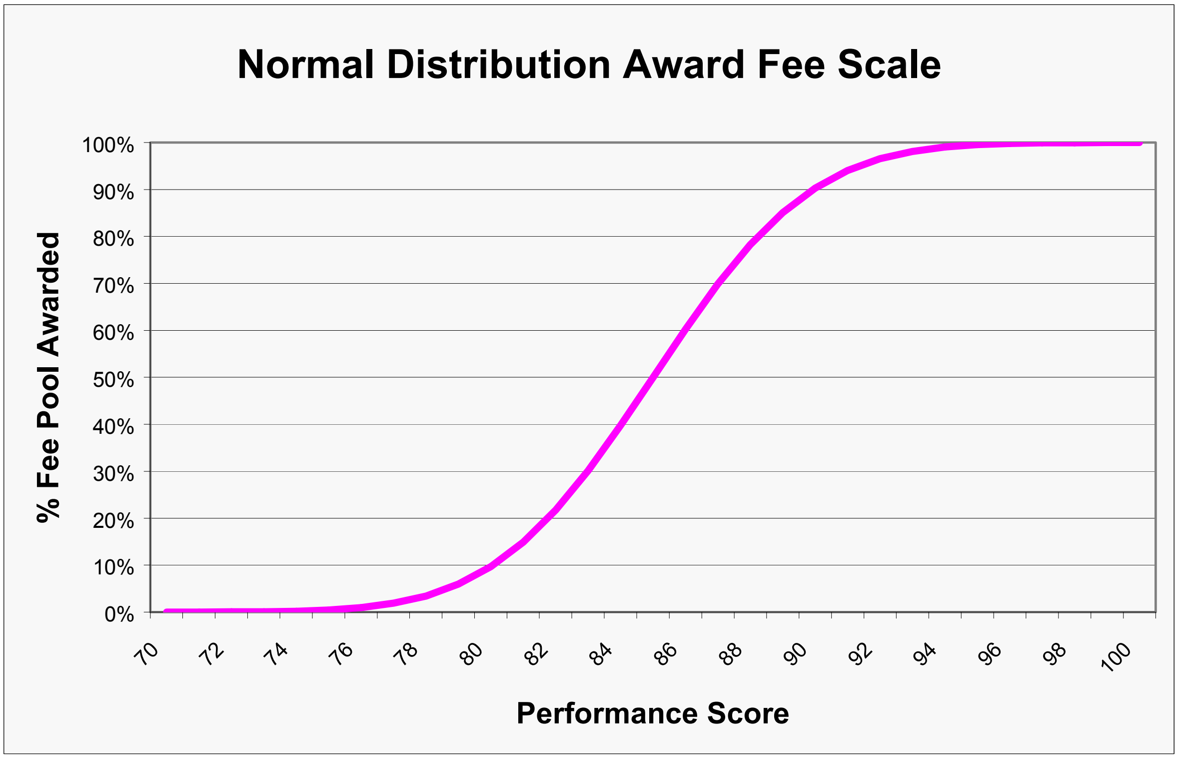


Figure A-2

Table A-1
Normal Distribution Award Fee Scale

Perf Score	Pct Fee	Perf Score	Pct Fee
70	0.00%	86	60.26%
71	0.01%	87	69.85%
72	0.04%	88	78.23%
73	0.09%	89	85.08%
74	0.21%	90	90.32%
75	0.47%	91	94.06%
76	0.96%	92	96.56%
77	1.88%	93	98.12%
78	3.44%	94	99.04%
79	5.94%	95	99.53%
80	9.68%	96	99.79%
81	14.92%	97	99.91%
82	21.77%	98	99.96%
83	30.15%	99	99.99%
84	39.74%	100	100.00%
85	50.00%		

The observant reader will no doubt notice that the normal distribution tends to skyrocket after the midpoint, "cramming" 49% of the fee pool into the range from 85 to 94, and giving almost no additional fee after 94 points.

Although this once again squares with the law of diminishing returns, it may be disconcerting that the contractor can make 85% of his fee by scoring 89 points, and 90% of fee by scoring 90. (On a linear scale, a score of 90 would achieve 76% of fee). The disparity arises because the normal distribution "values" above-average scores much more highly than a linear distribution. Since this is so, it might provide an incentive for a contractor to "target" or accept a lower performance score than under another fee distribution.

On the other hand, under a linear distribution a contractor must score 97 to achieve 90% of his fee; due to the law of diminishing returns, scoring that high will cost the government considerably more than achieving an 87 or 89. It can be argued that, from an overall efficiency standpoint, it is more cost-effective for a contractor to perform in the high 80's than in the high 90's. That high a performance level gives the government the "maximum bang for the buck" since the additional award fee is less than one percent of overall cost, whereas the contractor may expend 5% additional cost to achieve the same fee level under a linear distribution.

The primary consideration, however, is that this distribution is one of many available, and the contracting officer has a spectrum of distributions to choose from.

Rationale for the Method

The point of this whole exercise should not be lost. It is more than just a matter of devising elegant curves. The government does have a duty, despite the subjective nature of the award fee process, to conduct all aspects of it in a manner clearly not arbitrary and capricious. The award fee performance scale is an area where we can give at least the appearance of arbitrariness if the scale does not have coherent logic behind it.

While the scale should reflect our desire to incentivize certain levels of performance (and perhaps disincentivize anything higher or lower), it also should be based on some unifying principle that enables it to "hang together" logically. One such unifying logic is the mathematical logic reflected in the curve generating procedures outlined above. These procedures generate a whole conversion scale that reflects to a significant degree the exact incentive structure the contracting officer wishes to portray to the contractor.

TABLE A-2
TABLE OF AREAS UNDER THE STANDARD NORMAL CURVE

z	0*	1	2	3	4	5	6	7	8	9
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0754
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2258	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2518	0.2549
0.7	0.2580	0.2612	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2969	0.2996	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4978	0.4979	0.4980	0.4981	0.4982	0.4983
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990
3.1	0.4990	0.4991	0.4991	0.4991	0.4992	0.4992	0.4992	0.4992	0.4993	0.4993
3.2	0.4993	0.4993	0.4994	0.4994	0.4994	0.4994	0.4994	0.4995	0.4995	0.4995
3.3	0.4995	0.4995	0.4995	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996	0.4997
3.4	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4998
3.5	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998
3.6	0.4998	0.4998	0.4998	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999
3.7	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999
3.8	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999
3.9	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000

*** To read the table, note that the columns to the right of the z-score column represent a number in the hundredths decimal place (0.01). For example z=2.96 is in the row marked “2.9” in the column marked "6" with a corresponding area of 0.4985.**

The Generic Learning Curve Model

From equation (1) of Part 4, $Y = AX^b$, , we can show how the "slope" – which we will call s – relates to the exponent, b. We stated in Part 4 that the improvement curve theory specifies a constant rate of improvement, or percentage labor hour/cost reduction, for each successive doubling of production quantities. Therefore "s" will be a positive decimal between 0 and 1.

Let us suppose that the first unit takes 1 hour to complete, i.e, A = 1. Let us show generally a doubling of quantity by measuring the labor (Y) for completion of unit X and unit 2X. Thus Y_1 relates to X and Y_2 relates to 2X as follows:

$Y_1 = X^b$ and $Y_2 = (2X)^b$.

The theory states that the ratio of Y2 to Y1 will be a constant, which is termed the "slope" of the curve. We express the ratio as follows:

$$
\begin{aligned}
s &= Y_2/Y_1 = (2X)^b/X^b \\
&= (2^b \times X^b) \div X^b \\
&= 2^b \times (X^b/X^b) = (2^b)(1) \\
s &= 2^b
\end{aligned}
$$

Thus, the "slope" s of the curve relates directly to the exponent, b. We find b using the logarithmic transformation, equation (2), $\log(Y) = \log(A) + b \cdot \log(X)$, which changes this non-linear equation into a linear equation which we can solve for b:

$$s = 2^b \Rightarrow \log(s) = b \times \log(2) \Rightarrow b = \log(s)/\log(2).$$

For example, given the 80% learning curve shown in the previous graphs, the slope is 80% or 0.8. This means that, for each doubling of quantity produced, the number of labor hours decreases by 20%, or only 80% of the previous hours are expended. The b-factor is found by taking the logarithm of this slope, and dividing it by the logarithm of 2 (for doubling of quantity). Thus, the b-factor for an 80% curve is

$$b = \log(0.8)/\log(2) = -0.09691 \div 0.30103 = -0.3219281.$$

The number is negative because the slope of the curve is always negative, that is, the Y value is always decreasing as X increases.

Usually, the slope of the curve is determined from historical data, often by the use of regression analysis. We now give an example using historical hours with a simple comparative method for estimating the slope, from which we calculate the b-factor.

Suppose we extract the following labor hour data from the contractor's records of the first 10 units of a production run:

Unit	Hours	Unit	Hours
1	600.6	6	394.6
2	510.5	7	380.6
3	464.2	8	368.8
4	433.9	9	358.8
5	411.8	10	350.0

The slope of the improvement curve can be loosely found by the ratio of any unit to its double. (The reduction is usually not exactly the same for each doubling, hence the use of regression analysis to establish a “best fit line” through the data). For instance, the ratio of unit 8 to unit 4 is 0.849965 or approximately 85%. The same holds for 2:1, 4:2, 6:3 or any other ratio 2:1. Therefore s = 0.85 or 85%. The b-factor for a slope of 85% is found as log(0.85)/log(2) = -0.234465254. The specifying equation for the labor hours for any unit of this production lot is:

$Y = 600.6 * X^{-0.234465254}$, where X = unit selected.

We check the accuracy of the model by calculating the value for any unit, say unit 6, and comparing it with the actual value. Y(6) = 600.6*(6-0.234465254) = 394.59 which is virtually identical to the actual value of 394.6 hours.

Note that this gives us the hours for any individual unit. To accurately determine the number of hours for a production lot (say, from unit Xi to unit Xj, i≠j), we must calculate Y for each unit in that lot and sum them. There is, however, an equation for estimating total hours for any given number of consecutive units, the results of which are accurate enough in most cases.

$$Y_{total} = \sum Y \approx A \frac{[(L + 0.5)^{b+1} - (F - 0.5^{b+1})]}{b + 1},$$

where L stands for the last unit in the lot, and F stands for the first unit, b+1 is 1 added to the b-factor, and A is again the first unit hours (or labor cost). We now use this equation to estimate the total hours of the hypothetical lot of ten units given in the previous table.

$$Y_{total} = \sum Y \approx (600.6) \frac{[(10 + 0.5)^{.76553471} - 0.5^{.7655347}]}{0.7655347} = 4{,}285.03.$$

Calculating and adding up the hours for the ten units gives 4,273.8 actual hours. The estimation is inaccurate by only 0.3%. This is acceptable for analysis of most proposals, although where the labor cost is in $millions, it would be wise to calculate each individual unit and sum them.

The Lot Midpoint and the Average Value

Thus far we have developed formulas for finding

- The labor hours/cost of an individual unit X when the first unit value (A) and the learning curve slope or b-factor are known:

  $Y = AX^b$,

and

- The total labor hours/cost for any consecutive units:

$$Y = A\frac{[(L+0.5)^{b+1} - (F-0.5)^{b+1}]}{b+1}$$

There are actually two learning curve models. The one previously discussed is the Unit Model. In that model, Y refers to the hours for a single unit, X. Shortly we will introduce another learning curve model which uses the concept of the cumulative average labor hours/cost as the basis for the model. Therefore, we now discuss the concept of average value for the unit learning curve.

The average value for a series of observations which fit a linear pattern, i.e., whose numbers fit a line, is simply the sum of the numbers divided by the number of observations,

$$\frac{1}{N}\sum_{i=1}^{N} X_i \ .$$

The average may be thought of as the balancing point for the line, because the sum of the differences of each observation from the average value is zero. However, the concept of average value must be altered when one refers to the average value of a series of observations that have a non-linear pattern, i.e., that fall along a curve. The balancing point for a curved board would obviously be different than that for a straight board because the distribution of weight has changed.

For the learning curve, the average or mean value corresponds to the lot midpoint, which is that unit that coincides with the average hours to build the lot containing that unit. Almost never will that unit be the middle unit for the lot. Going back to the 10 units whose values were given along an 85% learning curve slope several pages back,

Unit	Hours	Unit	Hours
1	600.6	6	394.6
2	510.5	7	380.6
3	464.2	8	368.8
4	433.9	9	358.8
5	411.8	10	350.0

we saw that the total value for this lot is 4,273.9 hours. The average for the lot is thus (4,273.9÷10) = 427.39. To what unit does that average correspond? Looking at the table above we can see that the average does not correspond to any exact unit, but is somewhere between units 4 and 5, and closer to 4 than to 5. In using the learning curve concept we must be as exact as possible, so we cannot say that either unit 4 or unit 5 is the lot midpoint. We also cannot interpolate the value by simple proportionality because we are dealing with values along a curve, not a line. But we can algebraically manipulate our basic equation to come up with an expression which will allow us to calculate the "algebraic lot midpoint" as it is termed.

By definition, the lot midpoint is that unit, $X\mu$, corresponding to the average lot value $\Sigma Y/N$. Thus,

$$\Sigma Y/N = AX_{\mu}^{b}$$

We want to find X_{μ}, so we change the equation to

$$\frac{\sum Y}{A \cdot N} = X_{\mu}^{b} \Rightarrow X_{\mu} = \left(\frac{\sum Y}{A \cdot N} \right)^{1/b} \tag{3}$$

Thus, if we take the average lot value and divide it by the first unit value, then raise this resulting factor to the "1/b" power (i.e., the b^{th} root), we obtain the unit which is the algebraic lot midpoint. In this case, the average value is 427.39 hours and the unit corresponding to it is

$$Y_{\mu} = [(427.39/600.6)](1/-0.23447) = 4.26777$$

The algebraic midpoint of this lot of 10 units, whose hours fall along an 85% learning curve slope, is less than one-third of the way between the fourth and fifth units. This is significantly different than 5.5, the arithmetic midpoint unit of the lot (which we find by adding up the units and dividing by 10). For larger lots, and for steeper learning curve slopes, the algebraic lot midpoint deviates even more sharply from the arithmetic midpoint. Table _-1 at the end of this Appendix is a table of true lot midpoint values for lots of 10 to 1000, along learning curve slopes from 80% to 95%.

The algebraic or true lot midpoint is useful in finding the cumulative hours for a lot when the starting point is not unit 1. For example, suppose we want the cumulative hours for a lot of units 26 through 50 on an 80% curve. To find the lot cum average curve value (if not already available) we subtract 25 times the Table _-1 value for 25 raised to the "b" power from 50 times the Table _-1 value for 50 raised to the "b", then divide by the total number of units in the lot, which is 25. Raising this lot cum average value to the "1/bth" power (b = -0.3219281), gives the true lot midpoint of

$$\frac{[50(16.90167)^b - 25(9.03444)^b]^{1/b}}{(50-26+1)} = 37.07$$

which is the actual figure. The average labor hours for a lot of units 26 through 50 on an 80% curve would then be expressed by using the true lot midpoint value for X in the basic learning curve equation, $Y = AX^b$.

$$Y = A\times(37.07)^{-0.3219281} = A \times 0.3124270 = 950 \times 0.3124270 = 296.8 \text{ hours.}$$

What this equation says is that the 37.07th "unit" is the algebraic midpoint of the lot and that the average labor time for the lot (the time to build this "unit") is just under 31.25% of the time taken to build the first unit, or 296.8 hours, given the stipulated improvement rate. If we multiply this by the 25 units in the lot, we are using the average unit time for the lot times the total number of units in the lot, which gives the total lot time of 7,420 hours.

The Cumulative Average Learning Curve Model

In the other major learning curve model, the Cumulative Average (CumAv) model, Y refers to the *cumulative average hours for a production lot*. In the CumAv model, $Y_{avg} = AX^b$. This means that the average hours for units 1 to X_L is equal to $AX_L{}^b$, where X_L is the last unit in the lot. To find the value of an individual unit, X_i, we must calculate the value for a lot from 1 to X_i, then subtract from that the value of a lot from 1 to $X_{(i-1)}$.

<u>Scenario</u>: Given that an analysis of a production lot of 25 units disclosed a CumAv learning curve slope of 80%, the total build time was 11,693 labor hours, and the first unit took 950 hours, how long did it take to build unit 10?

The first thing to notice is that we are given cumulative total production lot hours, not the cumulative average. Whenever we are given the total hours for the lot, it must be divided by the number of units in the production lot to arrive at cumulative average hours. Reversing this process gives the equation

$$Y_{cum} = AX^b(X) = AX^{b+1}, \text{where (X) is the lot quantity.}$$

But in this case we already know the total hours for the production lot. Thus, $Y_{10} = AX_i^{b+1} - AX_{i-1}^{b+1} = A(X_i^{b+1} - X_{i-1}^{b+1}) = 950(10^{0.6780719} - 9^{0.6780719}) = 312.125 \text{ hours}$. It took just under a third of the first unit time to build the tenth unit in the lot.

The table below compares two sets of 25 units as in the previous example, the first based on an 80% Unit curve and the other based on an 80% CumAv curve.

	Unit Curve			Cumulative Average Curve		
(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Unit	Col (A)	Unit	Unit	Cum	(F)/2
Unit	Hours	x Col (B)	Ratio	Hours	Hours	Cum AvRatio
1	950.0	950.0	-	950.0	950.0	-
2	760.0	1520.0	0.800	570.0	1,520.0	0.800
3	667.0	2001.0	0.702	481.0	2,001.0	0.702
4	608.0	2432.0	0.640	431.0	2,432.0	0.640
5	565.9	2829.3	0.596	397.3	2,829.3	0.596
6	533.6	3201.6	0.562	372.3	3,201.6	0.562
7	507.8	3554.4	0.534	352.8	3,554.4	0.534
8	486.4	3891.2	0.512	336.8	3,891.2	0.512
9	468.3	4214.7	0.493	323.5	4,214.7	0.493
10	452.7	4526.8	0.477	312.1	4,526.8	0.477
11	439.0	4829.1	0.462	302.2	4,829.1	0.462
12	426.9	5122.5	0.449	293.5	5,122.5	0.449
13	416.0	5408.3	0.438	285.7	5,408.3	0.438
14	406.2	5687.0	0.428	278.7	5,687.0	0.428
15	397.3	5959.3	0.418	272.4	5,959.3	0.418
16	389.1	6225.9	0.410	266.6	6,225.9	0.410
17	381.6	6487.2	0.402	261.3	6,487.2	0.402
18	374.6	6743.6	0.394	256.4	6,743.6	0.394
19	368.2	6995.4	0.388	251.8	6,995.4	0.388
20	362.1	7243.0	0.381	247.6	7,243.0	0.381
21	356.5	7486.6	0.375	243.6	7,486.6	0.375
22	351.2	7726.5	0.370	239.9	7,726.5	0.370
23	346.2	7962.9	0.364	236.4	7,962.9	0.364
24	341.5	8196.1	0.359	233.1	8,196.1	0.359
25	337.0	8426.1	0.355	230.0	8,426.1	0.355
Total	11,693.2			8,426.1		

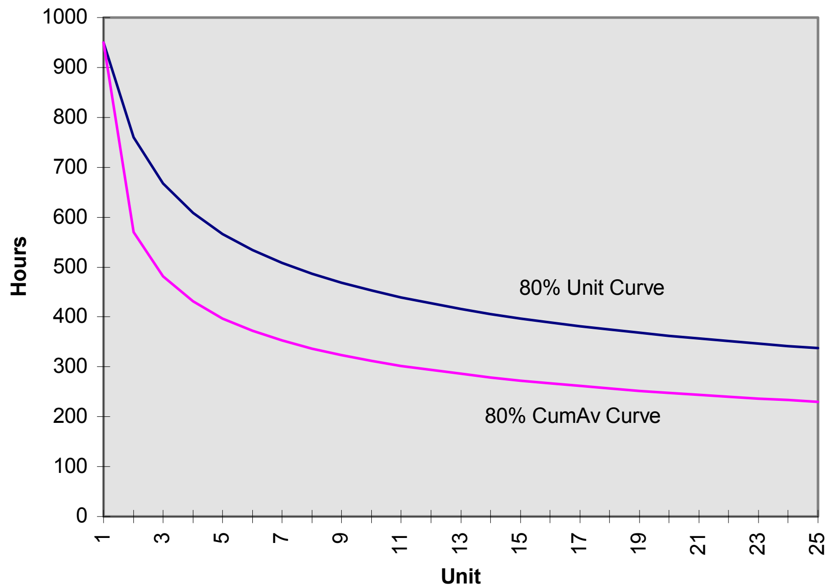
Note four important points of comparison:

1. The two production lots do not take the same total production hours to make, even though the first unit time is the same and the slope of each learning curve is 80% as shown by the “Ratio” columns. Each doubling of units in the Unit Curve columns reduces hours to 80% of the value of the previous doubling. Each doubling of *cumulative average* hours in the CumAv curve columns reduces hours to 80% of the value of the previous doubling.

2. Obviously, the 80% CumAv curve is a steeper curve than the 80% Unit curve. Although they are not directly comparable, a check of the ratio of successive cumulative

averages shows that they eventually approach the same ratio as the unit ratios for the Unit curve. In other words, as the number of units increases the CumAv curve begins to parallel the Unit curve of the same general slope (e.g., 80%). The following graph shows this and also shows that the largest difference between the two curves occurs in the first 8 to 12 units, where the CumAv curve drops precipitously compared to the Unit curve.

Comparison of Learning Curve Models 80% Slope



3. While the Unit curve becomes a straight line on log-log paper, the CumAv curve remains curved. It is appropriate to use the cum av model when individual lot data plotted on log-log paper does not give a line, but a curve. This result shows that the unit theory is inappropriate to the historical experience of this item or this contractor.

4. Also note that the figures in Column (C) are the same as those in Column (F). For the CumAv curve, (F) represents cumulative hours through each unit X_i. For the Unit Curve, (C) represents total hours given that all units are produced using the same hours as given for unit X_i. For example, the cumulative hours would be 6,995.4 if the first 19 units were all built at the rate of unit 19, i.e., 368.2 hours. Note that if all units on the Unit Curve were built at the rate of the last unit, the cumulative hours would match that of the cumulative hours for the CumAv curve, i.e., 8426.1.

The CumAv curve can be converted to the equivalent Unit curve for the same number of units by starting with the cumulative hours for each unit X_i and dividing by the number of units produced. For example, to find the equivalent Unit Curve value for unit seven (7) on the CumAv curve, take the cum hours at that point (3,554.4) and divide it by seven, giving 507.77 or approximately 507.8 hours, which is the value given for the seventh unit under the Unit Curve.

Unlike the Unit curve, the CumAv curve does not use the concept of algebraic lot midpoint because it deals in cumulative average in lieu of unit values in constructing the learning curve.

Using the CumAv Curve for Lot Data

Assume the following data available from the contractor's production records:

(1) LOT NUMBER	(2) LOT SIZE	(3) TOTAL LOT HOURS	(4) CUM TOTAL	(5) CUM UNITS	(6) CUM AVERAGE
1	7	2030	2030	7	290
2	15	1578	3608	22	164
3	24	1544	5152	46	112
4	30	1460	6612	76	87

For use with the Unit model, column (2) becomes our series of X values and column (3) becomes the series of Y values. But for use with the CumAv model, column (5) = X's and (6) = Y's.

The first requirement is to find the appropriate learning curve slope or b-factor. This is accomplished through linear regression analysis using the logarithmic transforms of the lot sizes and corresponding lot hours.

Table 1
Single-Year Discount Factors - Beginning of Year

Year	6%	7%	8%	9%	10%	11%	12%	13%
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.9434	0.9346	0.9259	0.9174	0.9091	0.9009	0.8929	0.8850
3	0.8900	0.8734	0.8573	0.8417	0.8264	0.8116	0.7972	0.7831
4	0.8396	0.8163	0.7938	0.7722	0.7513	0.7312	0.7118	0.6931
5	0.7921	0.7629	0.7350	0.7084	0.6830	0.6587	0.6355	0.6133
6	0.7473	0.7130	0.6806	0.6499	0.6209	0.5935	0.5674	0.5428
7	0.7050	0.6663	0.6302	0.5963	0.5645	0.5346	0.5066	0.4803
8	0.6651	0.6227	0.5835	0.5470	0.5132	0.4817	0.4523	0.4251
9	0.6274	0.5820	0.5403	0.5019	0.4665	0.4339	0.4039	0.3762
10	0.5919	0.5439	0.5002	0.4604	0.4241	0.3909	0.3606	0.3329
11	0.5584	0.5083	0.4632	0.4224	0.3855	0.3522	0.3220	0.2946
12	0.5268	0.4751	0.4289	0.3875	0.3505	0.3173	0.2875	0.2607
13	0.4970	0.4440	0.3971	0.3555	0.3186	0.2858	0.2567	0.2307
14	0.4688	0.4150	0.3677	0.3262	0.2897	0.2575	0.2292	0.2042
15	0.4423	0.3878	0.3405	0.2992	0.2633	0.2320	0.2046	0.1807
16	0.4173	0.3624	0.3152	0.2745	0.2394	0.2090	0.1827	0.1599
17	0.3936	0.3387	0.2919	0.2519	0.2176	0.1883	0.1631	0.1415
18	0.3714	0.3166	0.2703	0.2311	0.1978	0.1696	0.1456	0.1252
19	0.3503	0.2959	0.2502	0.2120	0.1799	0.1528	0.1300	0.1108
20	0.3305	0.2765	0.2317	0.1945	0.1635	0.1377	0.1161	0.0981
21	0.3118	0.2584	0.2145	0.1784	0.1486	0.1240	0.1037	0.0868
22	0.2942	0.2415	0.1987	0.1637	0.1351	0.1117	0.0926	0.0768
23	0.2775	0.2257	0.1839	0.1502	0.1228	0.1007	0.0826	0.0680
24	0.2618	0.2109	0.1703	0.1378	0.1117	0.0907	0.0738	0.0601
25	0.2470	0.1971	0.1577	0.1264	0.1015	0.0817	0.0659	0.0532
26	0.2330	0.1842	0.1460	0.1160	0.0923	0.0736	0.0588	0.0471
27	0.2198	0.1722	0.1352	0.1064	0.0839	0.0663	0.0525	0.0417
28	0.2074	0.1609	0.1252	0.0976	0.0763	0.0597	0.0469	0.0369
29	0.1956	0.1504	0.1159	0.0895	0.0693	0.0538	0.0419	0.0326
30	0.1846	0.1406	0.1073	0.0822	0.0630	0.0485	0.0374	0.0289

Table 2
Single-Year Discount Factors - Midyear

Year	6%	7%	8%	9%	10%	11%	12%	13%
1	0.9713	0.9667	0.9623	0.9578	0.9535	0.9492	0.9449	0.9407
2	0.9163	0.9035	0.8910	0.8787	0.8668	0.8551	0.8437	0.8325
3	0.8644	0.8444	0.8250	0.8062	0.7880	0.7704	0.7533	0.7367
4	0.8155	0.7891	0.7639	0.7396	0.7164	0.6940	0.6726	0.6520
5	0.7693	0.7375	0.7073	0.6785	0.6512	0.6252	0.6005	0.5770
6	0.7258	0.6893	0.6549	0.6225	0.5920	0.5633	0.5362	0.5106
7	0.6847	0.6442	0.6064	0.5711	0.5382	0.5075	0.4787	0.4518
8	0.6460	0.6020	0.5615	0.5240	0.4893	0.4572	0.4274	0.3999
9	0.6094	0.5626	0.5199	0.4807	0.4448	0.4119	0.3816	0.3539
10	0.5749	0.5258	0.4814	0.4410	0.4044	0.3710	0.3407	0.3132
11	0.5424	0.4914	0.4457	0.4046	0.3676	0.3343	0.3042	0.2771
12	0.5117	0.4593	0.4127	0.3712	0.3342	0.3012	0.2716	0.2452
13	0.4827	0.4292	0.3821	0.3405	0.3038	0.2713	0.2425	0.2170
14	0.4554	0.4012	0.3538	0.3124	0.2762	0.2444	0.2165	0.1921
15	0.4296	0.3749	0.3276	0.2866	0.2511	0.2202	0.1933	0.1700
16	0.4053	0.3504	0.3033	0.2630	0.2283	0.1984	0.1726	0.1504
17	0.3823	0.3275	0.2809	0.2412	0.2075	0.1787	0.1541	0.1331
18	0.3607	0.3060	0.2601	0.2213	0.1886	0.1610	0.1376	0.1178
19	0.3403	0.2860	0.2408	0.2031	0.1715	0.1451	0.1229	0.1042
20	0.3210	0.2673	0.2230	0.1863	0.1559	0.1307	0.1097	0.0923
21	0.3029	0.2498	0.2064	0.1709	0.1417	0.1177	0.0980	0.0816
22	0.2857	0.2335	0.1912	0.1568	0.1288	0.1061	0.0875	0.0722
23	0.2695	0.2182	0.1770	0.1438	0.1171	0.0956	0.0781	0.0639
24	0.2543	0.2039	0.1639	0.1320	0.1065	0.0861	0.0697	0.0566
25	0.2399	0.1906	0.1517	0.1211	0.0968	0.0776	0.0623	0.0501
26	0.2263	0.1781	0.1405	0.1111	0.0880	0.0699	0.0556	0.0443
27	0.2135	0.1665	0.1301	0.1019	0.0800	0.0629	0.0496	0.0392
28	0.2014	0.1556	0.1205	0.0935	0.0727	0.0567	0.0443	0.0347
29	0.1900	0.1454	0.1115	0.0858	0.0661	0.0511	0.0396	0.0307
30	0.1793	0.1359	0.1033	0.0787	0.0601	0.0460	0.0353	0.0272

Table 3
Cumulative Discount Factors - Beginning of Year

Year	6%	7%	8%	9%	10%	11%	12%	13%
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	1.9434	1.9346	1.9259	1.9174	1.9091	1.9009	1.8929	1.8850
3	2.8334	2.8080	2.7833	2.7591	2.7355	2.7125	2.6901	2.6681
4	3.6730	3.6243	3.5771	3.5313	3.4869	3.4437	3.4018	3.3612
5	4.4651	4.3872	4.3121	4.2397	4.1699	4.1024	4.0373	3.9745
6	5.2124	5.1002	4.9927	4.8897	4.7908	4.6959	4.6048	4.5172
7	5.9173	5.7665	5.6229	5.4859	5.3553	5.2305	5.1114	4.9975
8	6.5824	6.3893	6.2064	6.0330	5.8684	5.7122	5.5638	5.4226
9	7.2098	6.9713	6.7466	6.5348	6.3349	6.1461	5.9676	5.7988
10	7.8017	7.5152	7.2469	6.9952	6.7590	6.5370	6.3282	6.1317
11	8.3601	8.0236	7.7101	7.4177	7.1446	6.8892	6.6502	6.4262
12	8.8869	8.4987	8.1390	7.8052	7.4951	7.2065	6.9377	6.6869
13	9.3838	8.9427	8.5361	8.1607	7.8137	7.4924	7.1944	6.9176
14	9.8527	9.3577	8.9038	8.4869	8.1034	7.7499	7.4235	7.1218
15	10.2950	9.7455	9.2442	8.7862	8.3667	7.9819	7.6282	7.3025
16	10.7122	10.1079	9.5595	9.0607	8.6061	8.1909	7.8109	7.4624
17	11.1059	10.4466	9.8514	9.3126	8.8237	8.3792	7.9740	7.6039
18	11.4773	10.7632	10.1216	9.5436	9.0216	8.5488	8.1196	7.7291
19	11.8276	11.0591	10.3719	9.7556	9.2014	8.7016	8.2497	7.8399
20	12.1581	11.3356	10.6036	9.9501	9.3649	8.8393	8.3658	7.9380
21	12.4699	11.5940	10.8181	10.1285	9.5136	8.9633	8.4694	8.0248
22	12.7641	11.8355	11.0168	10.2922	9.6487	9.0751	8.5620	8.1016
23	13.0416	12.0612	11.2007	10.4424	9.7715	9.1757	8.6446	8.1695
24	13.3034	12.2722	11.3711	10.5802	9.8832	9.2664	8.7184	8.2297
25	13.5504	12.4693	11.5288	10.7066	9.9847	9.3481	8.7843	8.2829
26	13.7834	12.6536	11.6748	10.8226	10.0770	9.4217	8.8431	8.3300
27	14.0032	12.8258	11.8100	10.9290	10.1609	9.4881	8.8957	8.3717
28	14.2105	12.9867	11.9352	11.0266	10.2372	9.5478	8.9426	8.4086
29	14.4062	13.1371	12.0511	11.1161	10.3066	9.6016	8.9844	8.4412
30	14.5907	13.2777	12.1584	11.1983	10.3696	9.6501	9.0218	8.4701

Table 4
Cumulative Discount Factors - Midyear

Year	6%	7%	8%	9%	10%	11%	12%	13%
1	0.9713	0.9667	0.9623	0.9578	0.9535	0.9492	0.9449	0.9407
2	1.8876	1.8702	1.8532	1.8366	1.8202	1.8043	1.7886	1.7732
3	2.7520	2.7146	2.6782	2.6427	2.6082	2.5746	2.5419	2.5099
4	3.5675	3.5038	3.4421	3.3824	3.3246	3.2686	3.2144	3.1619
5	4.3369	4.2413	4.1493	4.0609	3.9758	3.8939	3.8149	3.7389
6	5.0627	4.9305	4.8042	4.6834	4.5678	4.4571	4.3511	4.2495
7	5.7474	5.5747	5.4106	5.2546	5.1060	4.9646	4.8298	4.7013
8	6.3934	6.1768	5.9721	5.7785	5.5953	5.4218	5.2573	5.1012
9	7.0028	6.7394	6.4920	6.2592	6.0401	5.8336	5.6389	5.4550
10	7.5777	7.2652	6.9733	6.7002	6.4445	6.2047	5.9796	5.7682
11	8.1200	7.7567	7.4190	7.1048	6.8121	6.5390	6.2839	6.0453
12	8.6317	8.2160	7.8317	7.4760	7.1463	6.8401	6.5555	6.2905
13	9.1144	8.6452	8.2138	7.8166	7.4501	7.1114	6.7980	6.5076
14	9.5698	9.0464	8.5677	8.1290	7.7262	7.3559	7.0146	6.6996
15	9.9994	9.4213	8.8953	8.4156	7.9773	7.5761	7.2079	6.8696
16	10.4047	9.7717	9.1986	8.6786	8.2056	7.7744	7.3806	7.0200
17	10.7870	10.0992	9.4795	8.9198	8.4131	7.9531	7.5347	7.1531
18	11.1477	10.4052	9.7396	9.1411	8.6017	8.1142	7.6723	7.2709
19	11.4880	10.6912	9.9804	9.3442	8.7732	8.2592	7.7952	7.3752
20	11.8090	10.9585	10.2033	9.5305	8.9291	8.3899	7.9049	7.4674
21	12.1119	11.2084	10.4098	9.7014	9.0708	8.5076	8.0029	7.5491
22	12.3976	11.4418	10.6009	9.8582	9.1997	8.6137	8.0903	7.6213
23	12.6671	11.6600	10.7779	10.0020	9.3168	8.7092	8.1684	7.6852
24	12.9214	11.8640	10.9418	10.1340	9.4233	8.7953	8.2381	7.7418
25	13.1613	12.0546	11.0936	10.2551	9.5201	8.8729	8.3004	7.7919
26	13.3876	12.2327	11.2341	10.3662	9.6081	8.9427	8.3560	7.8362
27	13.6011	12.3991	11.3642	10.4681	9.6881	9.0057	8.4056	7.8754
28	13.8025	12.5547	11.4846	10.5615	9.7608	9.0624	8.4499	7.9101
29	13.9925	12.7001	11.5962	10.6473	9.8269	9.1135	8.4895	7.9408
30	14.1718	12.8360	11.6994	10.7260	9.8870	9.1595	8.5248	7.9680

What are Cost Estimating Relationships?

Cost Estimating Relationships (CER) are mathematical relationships between cost and cost drivers based on regression analysis of historical data. Cost is the dependent variable (Y) and the cost drivers are independent variables (X_I) representing properties of the item whose changes correlate significantly with changes in cost.

The Process

Below is a print of the regression analysis of the cost data given in the militarized crane example on page 7-6. Prices are in current year dollars.

	Boom Length (feet)						
Horsepower (HP)	20	25	30	35	40	45	50
100	$49,650	$50,900	$52,212	$53,600	$55,050	$56,575	$58,180
200	$52,025	$53,275	$54,588	$55,975	$57,425	$58,950	$60,555
300	$54,468	$55,718	$57,030	$58,418	$59,868	$61,393	$62,997
400	$56,820	$58,070	$59,383	$60,770	$62,220	$63,745	$65,350
500	$58,805	$60,055	$61,368	$62,755	$64,205	$65,730	$67,335
600	$60,913	$62,163	$63,475	$64,862	$66,313	$67,838	$69,443
700	$63,150	$64,400	$65,712	$67,100	$68,550	$70,075	$71,680

Regression Output:		
Constant	41,746.4	
Std. Error of Y Est.	200.718	
R^2	0.99865	
No. of Obs.	49	
Degrees of Freedom	46	
X-Coefficients	22.3616	284.122
Std. Error of Coeff.	0.14337	2.86740

The constant and X-coefficients given below the table constitute the cost estimating relationship for these cranes. Given a requirement for a crane with a specified boom length and horsepower, we can use the following equation constructed from the above regression data table to generate a prediction of its unit price:

$$\text{Price} = \$41{,}746.40 + (\$22.3616 \times \text{HP}) + (\$284.122 \times \text{Boom Length}).$$

The equation indicates that the basic price of the crane is $41,746.40. Each additional increment of horsepower costs $22.36; each additional foot of boom length costs $284.12.

For cranes whose specs match those in the table above, one goes to the row having the required horsepower and the column having the required boom length, and reads the estimated unit price. For cranes having horsepower and/or boom length in between those listed in the table, one must enter the required specs into the estimating equation to determine an estimated price. For example, if an activity requires a crane with 375 horsepower motor and a boom length of 38 feet, enter these into the estimating equation: Price = $41,746.40 + ($22.3616 $\times$ 375) + ($284.122 $\times$ 38) = $60,928.64. Assuming such a crane is available or can be built, it should cost approximately this amount.

Best Fit Statistics

It is important that the regression equation chosen "fits" the data well. In statistics, best fit means that, mathematically, the chosen regression line (or curve) goes through the data in such a way as to minimize the variance between the points on the line and the individual data points. There are a number of indicators of best fit, but it is beyond the scope of this pamphlet to delve into them and what they actually measure. The two statistics we will briefly cover are the Coefficient of Determination, R^2, and Standard Error of Coefficient(s), which are all in the data table on the previous page.

The Coefficient of Determination, R^2, is a measure of how well the independent variable(s) chosen explain(s) the behavior of the dependent variable. With regard to regression analysis, it is an indicator of how well the regression line "fits" the data, i.e., how well the regression line goes through the data so as to minimize the variance between the points on the line and the data points. R^2 can range from -1 to +1. An R^2 of 0 indicates no correlation between the dependent and independent variables, therefore the regression line will not be a good fit of the data. If R^2 is close to +1 or -1 it means that the regression line is likely a very good fit of the data and will provide an adequate predictor of the value of the dependent variable as it correlates to specific value(s) of the independent variable(s).

The Standard Error for the coefficients of the estimating equation gives the average error in estimation attributable to each coefficient. If each number is a significant proportion of the size of the respective coefficient, then the estimating equation is probably not an accurate predictor. The Standard Error of the Y estimate is also a number that is the average variance between the calculated value of Y for a given X (or Xs) and the actual value of Y in the data. If this number is a significant percentage of the average Y value in the data, then the estimating equation is not a good cost estimating relationship.

There are two statistics, the t-statistic and the F-test statistic, that are also commonly used to determine goodness of fit and may be the best overall indicators. They indicate whether the cost estimating equation produces a "match" to the data for which we can be x% confident (usually 90%, 95%, or 99% confidence level) that it did not occur at random, but is due to an actual relationship between the variables that is well described by the estimating equation. Several spreadsheets, and most statistical analysis programs, will generate a critical t-value or F-test value and give the corresponding value for the estimating equation, given the level of confidence desired. Consult a statistics text for the use of these statistics in determining goodness of fit of estimating equations.

Such analysis should be performed by persons well versed in statistical testing, because a bad CER is not any better than no CER at all.

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