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Does A Rubber Baseline Guarantee Overruns?' A Study of Cost Performance and Contract Changes in Major Defense Acquisition Programs

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A STUDY OF COST PERFORMANCE AND CONTRACT CHANGES
IN MAJOR DEFENSE ACQUISITION PROGRAMS

THESIS

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AFIT/GSM/LAS/96S-5

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THESIS

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James A. Gordon

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Abstract

This thesis explores the assumption that cost overruns are related to contract changes. A common assertion in defense literature says that contracts which are relatively stable suffer smaller overruns than those which are highly volatile. The stability or volatility of contracts is characterized by their change history. A contract which is modified frequently or by large amounts is more unstable, or volatile, than one which is not changed either as often or by lesser amounts. This study attempts to find evidence supporting this common assertion by examining the relationship between cost growth and baseline stability on over 400 Major Defense Acquisition Program contracts over the last 26 years. The results are intriguing because, counter-intuitively, no significant evidence is found. Possible explanations and implications of this discovery are provided.

"DOES A RUBBER BASELINE GUARANTEE OVERRUNS?"

A STUDY OF COST PERFORMANCE AND CONTRACT CHANGES IN MAJOR DEFENSE ACQUISITION PROGRAMS

I. Problem Description

1.1 Introduction

Large defense programs can often take a long time to develop and produce, seven to ten years according to Fox (1988:28). During this time, requirements frequently change as does the commitment from Congress. In addition, policies and regulations are reformed periodically. Thus, a large multi-year contract will probably be modified during its life.

Frequently, a contract is not fully defined even when it is awarded, and modifications become a way of life almost from the start. Observers and practitioners often cite this instability as a major source of cost overruns and schedule slippage (Gilbraeth, 1986: 37; Augustine, 1983: 110-140; Archibald, 1976: 196; Augustine, 1990: 2). This instability is termed a "rubber baseline" because the target changes from month to month rather than remaining steady (Gilbraeth, 1986: 139). This thesis will explore whether historical evidence can be found to support this popular belief.

The importance of such evidence lies in the ability to make policy to regulate change. If the assertion that an unstable baseline is always accompanied by poor cost and schedule performance is found to be true, then policies which restrict modifications may

produce fewer overruns and schedule slippage. If the assertion is not supported, then frequent contract changes will no longer stand as an excuse for cost overruns or schedule slippage, and other possible causes of poor performance should be more closely examined.

1.2 Background

Since the early 1970s, major defense acquisitions exceeding specific dollar thresholds or deemed important by the Secretary of Defense are required to report regularly on their program status to the Office of the Secretary of Defense (OSD). These data are compiled into the Selected Acquisition Report (SAR) which is presented to Congress. Another report that programs submit to the OSD is called a "Defense Acquisition Executive Summaries" (DAES). These two names are often used interchangeably, but they refer to two entirely different reports.

Among the data reported in the DAES are cost and schedule status in terms of the cumulative Budgeted Cost of Work Scheduled (BCWS), the cumulative Budgeted Cost of Work Performed (BCWP), and the Actual Cost for that Work Performed (ACWP). In addition to this performance measurement data, contract status data are also provided, such as the amount of Management Reserve (MR) budget the contractor is holding for unforeseen problems and the total Contract Budget Base (CBB). For a complete description of these terms see Appendix A, Glossary of Defense Acquisition Acronyms & Terms.

Adjustments to the cost or schedule performance which result from acceptance of an infeasible cost or schedule target are also provided in the DAES. These adjustments

(Over Target Baseline Cost Variance Adjustment (OTBCVA) and Over Target Baseline Schedule Variance Adjustment (OTBSVA)) may be subject to change in the near future. A draft *Earned Value Management System* (November 1995) addresses OTB. The EVMS is being developed by the Management Systems Subcommittee of the National Security Industrial Association in cooperation with the Aerospace Industries Association, Electronic Industries Association, Performance Management Association, and the Project Management Institute as a commercial standard to replace the Cost/Schedule Control System Criteria (C/SCSC JIG). The EVMS describes OTB as follows:

> Over target baseline is a term used, normally on a government contract, to describe a situation where the budget or schedule in the performance measurement baseline exceeds the project targets. An OTB may be applied by a company when it is determined that current program overruns do not permit the performing organizations to have realistic plans for completion of the project. The customer must be notified, and substantiation provided, when an OTB is implemented on a government contract. For the purposes of investigating baseline changes, it is sufficient to say that the existence of an OTB represents a change in the original baseline of the contract. These data are adequate to broadly describe the pertinent variables. [*EVMS* Sec 3.10.6]

1.3 Purpose of the Study

The purpose of this study is to test the popular assumption that changes on defense contracts are correlated with poor cost performance. This study lies in a continuum of research with similar purpose. The range of possible factors is too large to be evaluated in a single thesis, and so must be evaluated piecemeal.

The current practice of estimating the cost of a contract takes two basic forms. Prior to execution, predictions are based on similarity to related work. These predictions are either entered into parametric models or simply summed together. Historically based

estimating models have been shown to be inaccurate. For example, one of the Air Force's preferred software cost estimating models, Revised Intermediate COCOMO (REVIC), has been reported accurate to within 25%, half the time (Ferens and Albanese, 1989).

The other occasion to estimate contract costs is during execution. Techniques range from simply adjusting the budgeted cost of work remaining using historically based performance indices to more complex, non-linear or higher order models. Nystrom (1995) found that non-linear estimation techniques yielded no more accurate results than simple linear ones. This is attributed partially to the large variance among contractors' performances. The search for contributing factors is hoped to explain some of the variance and yield better estimates. Further, awareness of the drivers of bad performance is the first step in managing it.

Based on a review of 197 programs, Drezner *et al.* (1993:49) reports the "weighted average total program cost growth is about 20%." Because cost growth is the difference between a baseline estimate and the latest prediction of total cost (Hough, 1992:10), and the observation that the average overrun is only 8%, the difference must be attributable to contract modifications. These modifications may result in contract baseline volatility.

1.4 Statement of Problem

The basic problem is whether contract cost performance is sensitive to contract baseline volatility. The null hypothesis is that contracts with large or frequent changes ultimately perform worse than those with small or infrequent changes. A large change

may be arbitrarily defined as greater than 10% of the baseline. A frequent change would be several smaller changes which add up to 10%. In the exploratory phase of this study, large changes are defined simply as the quantity of changes to CBB either individually or collectively exceeding a 10% threshold. The number of changes is then compared to an indicator of final cost for contracts in each of four quarters of completion. In the second phase of this study, a more descriptive statistic is used to define contract baseline volatility, and the sample population is limited to completed or nearly completed contracts. The statistic, the coefficient of variation of a performance management baseline, is chosen based on observation of the population's baseline performances (Appendix B).

1.5 Scope of the Study

There are numerous ways to describe the volatility of a contract. One could count the number of changes, or possibly sum the magnitude of changes to contract price. Other measures may be changes in the number of end-items required, or extensions and contractions of program schedules. One could even differentiate between contracts which are volatile early in contract execution from others which are volatile in later phases. Further, if one looks at the baseline as a cumulative probability distribution, a plethora of descriptive statistics can be generated for comparison purposes, such as variance, skewness, kurtosis, standard error, or the range of baseline values.

For this study, contract volatility is measured differently in each of two phases. The first measure is a simple count of the number of changes as indicated by increases or decreases in the contract budget. The second measure is the coefficient of variation

calculated from the baseline values, CBB minus Management Reserve plus OTBCVA, reported over the life of the contract. The procedure used to measure volatility is discussed in Chapter 3. The first measure is a simple parameter, the other a statistic. Each is zero for a perfectly stable baseline, and each increase with adjustments to the contract.

A mature contract, one in the final quarter of completion, will not normally be able to improve its cumulative cost variance (CV) (Christensen and Heise, 1993), the difference between actual and budgeted cost of work performed. For comparison between contracts of different sizes, the Cost Performance Index is preferable because it is a dimensionless measure of efficiency, averaged over 75% or more of the work completed for mature contracts.

$$CV = BCWP - ACWP \quad (1.1)$$

$$CPI = BCWP / ACWP \quad (1.2)$$

The CPI can be stated as the amount of planned work (in budgeted dollars) which is completed for a dollar. When the CPI is less than 1.00, budgeted costs are less than actual costs of the completed work. This is known as a "cost overrun." When the CPI is greater than 1.00, budgeted costs are greater than actual costs of completed work. This is called a "cost underrun." The cumulative CPI based on the latest reported performance of these mature contracts is taken as the final cost performance for the second phase of this study. This is reasonable because the mature contracts averaged 92.3% complete.

The first phase, however, augmented the CPI with a Schedule Performance Index to produce a Schedule and Cost performance Index (SCI).

$$SPI = BCWP / BCWS \quad (1.3)$$

$$SCI = CPI * SPI \quad (1.4)$$

The SCI has the benefit of being one of the best predictors of final cost at completion available (Terry and Vanderburgh, 1993: 59), and thus is a good indicator of final overruns even for contracts which are less than 75% complete.

1.6 Outline of Remainder of Thesis

This thesis is organized in a traditional format. This chapter introduced the purpose of the study, the scope of the problem and some necessary background. The next chapter briefly illustrates how this thesis fits into related research. The methodology, results, and conclusions are presented in subsequent chapters. In addition to this discussion, appendices containing illustrative and supporting data are provided along with a comprehensive bibliography.

II. Literature Review

2.1 Introduction

Numerous studies, Tables 2-1 and 2-2, have been conducted to find the driving factors which affect whether a contract will overrun its budget and if so by how much. Sources of variance have been identified in nearly any characteristic imaginable (Nystrom, 1995; Christensen, 1993). Some of these characteristics, such as type of weapon system or military service, have been explored more thoroughly than others. Although some of these studies have suggested that cost performance is sensitive to baseline changes (Terry and Vanderburgh, 1993), this relationship is one which has not been thoroughly explored. Terry and Vanderburgh found that EAC predictions for 321 major defense program contracts are sensitive to "Contract Completion Stage, Program Phase, Contract Type, Branch of Service, System Type," and in particular, "Major Contract Baseline Changes." However, Drezner *et al.* in a study of defense program cost growth found that "no single factor explains a large portion of the observed variance in cost growth outcomes" (1993;52).

In their paper to the 5th Annual National Cost Schedule Performance Management Conference, "The Importance of Scope Management," Harroun, McCarthy and Epperson reported that "when there is poor scope definition, final project costs can be expected to be higher because of the inevitable changes that will disrupt the project's rhythm, increase the project's time, lower the productivity and morale of the workforce, and cause work to be repeated (1993:10)." They based this conclusion on recent research reported in project

management literature. Other writers have declared "concern" over baseline changes and their impacts on performance (Gilbraeth, 1986: 37; Augustine, 1983: 110-140; Archibald, 1976: 196; Augustine, 1990: 2). Therefore, while others have attempted to improve cost estimates through the use of indices and factors (Elkinton and Gondeck, 1994; Bright and Howard, 1981; Christensen and Heise, 1993; Covach *et al.*, 1981; Fleming, 1992; Terry and Vanderburgh, 1993), this study examines whether the degree of baseline volatility can be a useful predictor of completion costs.

Table 2-1. COST GROWTH RAND REPORTS

Author (Year)	FINDINGS	SENSITIVITY FACTORS
Jarvaise, *et al.* (1996)	The Defense System Cost Performance Database	Derived from SARs
Drezner, *et al.* (1993)	Cost Estimates biased toward underestimation by about 20% from PE and DE and 2% from PdE	Program Size, Maturity, Prototyping (counter), Mod vs. New Start, Program Duration
Drezner (1992)	No demonstrated relationship between prototyping and cost or schedule outcomes (67)	No Program Phase, Not System Type
Hough (1992)	Selected Acquisition Reports can Delay, Mask or Exclude Significant Cost Growth	Economic, Quantity, Schedule, Engineering, Estimating and Other Changes

RAND Cost Growth: Total Program Life Cycle Cost changes from either the Planning (PE), Development (DE) or Production Estimates (PdE)

2.2 Chronology of Cost Growth Research

Although research on the factors affecting cost estimates can be traced back to the early 1970s, Glover and Lenz (1974) and Babiarz and Giedras (1975), it was not until the middle of the last decade that sensitivity analysis of cost growth factors began (Blacken, 1986). Blacken studied the characteristics of numerous contract changes on a single

Table 2-2. COST GROWTH AFIT THESES

Author (Year)	FINDINGS	SENSITIVITY FACTORS
Nystrom (1995)	Complex non-linear EAC methods not superior to simpler index based EAC methods	Stage of Completion, System Type, Program Phase, Contract Type, Service Component, and Inflation
Buchfeller and Kehl (1994)	No Significant Differences in Cost Variances between contract categories	Not Service, Not Program Phase, Not Contract Type, Not Stage of Completion
Elkinton and Gondeck (1994)	BAC Adjustments Factors derived from Historical "Cost Growth[1]" do not Improve EACs	Not Contract Type, Not Stage of Completion
Pletcher and Young (1994)	Contracts which Improved Cost Performance over time differ from those which Worsen	Performance Management Baseline Stability
Terry and Vanderburgh (1993)	SCI based EAC best predictor of CAC for all Stages of Contract Completion	Contract Completion Stage, Program Phase, Contract Type, Service Component, System Type, Major Baseline Changes, but not Management Reserve
Wandland (1993)	Competed Contracts have more "Cost Growth[2]" than Sole Source	Not Contract Type, Not Absolute Price
Wilson (1992)	Cost Overruns at Completion are Worse than between 15 and 85% complete (α=.15)	Service (except Navy), Contract Type, System Type, and Program Phase, but not relative time
Singleton (1991)	"Cost Growth[3]" can be predicted based on three factors	Schedule Risk, Technical Risk and Configuration Stability
Obringer (1988)	"Cost Growth[4]" is not attributable to increased Industry Direct or Overhead to Total Cost Ratio	Specific Contractors (8 of 16) showed growth between 1980 and 1986
Blacken (1986)	"Cost Growth[5]" Varies with Characteristics of Contract Changes	Scope, Number of Effected SOW Pages, Contract Type, Change Type, Time to Definitize, Time to Negotiate, Not to Exceed Estimate, Stage of Completion, Stage of Development, Schedule Changes, Length of ECP, Length of Period of Performance

1 Includes only cost of changes
2 Includes only cost of changes
3 Includes cost of changes and overruns
4 Includes costs of Aerospace Industry Operations and Overhead
5 Includes only cost of changes

program. He was able to characterized those changes into very specific parameters, as indicated in Table 2-2. He related the descriptive parameters of contract changes to the cost of those changes. This was done in terms of negotiated costs, not actual. Therefore, his study only gives insight to the portion of cost growth which is not dependent on performance. A few years later in 1988, a study by Obringer attempted to capture the effects of indirect costs and the changing costs of production in the aerospace industry. Overall, during the period studies, 1980 to 1986, Obringer did not find that cost growth could be attributed, across the board, to increased indirect costs in the industry. It is important to note that this period was associated with heavy expansion of the defense budget, therefore Obringer's conclusion may not hold in the currently shrinking defense industry.

One of the first studies to consider both the cost of changes and performance in executing those changes was done by Singleton (1991). She related cost growth, both changes and overruns, to two traditional sources of risk, schedule and technical. She considered configuration stability separately from technical risk by addressing the former as the risk estimated at inception. She was able to show cost growth was sensitive to these three factors using a sample of 16 programs in both development and production. She also found significant interaction between these factors.

The studies mentioned above have relied on program specific data and the Defense Acquisition Executive Summary Databases. In 1992, Hough evaluated cost growth based on historical Selective Acquisition Reports (SAR). The SARs were intended to identify the source of reported cost growth, in a program, attributable to six categories:

Economic, Quantity, Schedule, Engineering, Estimating and Other Changes. What he found is that the practices employed in preparing the SAR could mask, delay or exclude significant areas of cost growth. Because the SAR is a estimation report rather than a measurement tool, it was subject to manipulation by the program managers preparing it. In contrast, the DAES reports performance measurement data as well as cost, schedule and technical estimates. This allows the analyst to gauge the validity of the estimates.

Also in 1992, studies of two assertions were conducted. Wilson tested the idea that contracts with overruns between 15 and 85% complete were worse off at completion. He found this assertion to be supported by evidence from the DAES database at a confidence level of 85% (α=.15). The other assertion, studied by Drezner, is that using prototypes in a development program reduces cost growth. Based on SAR data, he found no demonstrated relationship between prototyping and cost or schedule outcomes (1992: 67).

Three studies in 1993 explored such questions as: are cost estimates biased low (Drezner, *et al*), does competition reduce cost growth (Wandland and Wickman) and what estimating technique best predicts cost at completion (Terry and Vanderburgh).

Drezner, *et al.* (1993) found that estimates are biased lower than final costs. Using the SAR database, correcting for quantity and inflation effects, he showed that planning and development estimates are on average 20% below the final cost. This includes the cost of changes as well as cost overruns. He showed that these results were sensitive to Program Size, Maturity, Prototyping (counter), Modification Programs *versus* New Starts, and Program Duration. The relationship of each of these factors were correctly

hypothesized except for prototyping. In other words, large, immature, new start programs of lengthy duration WITH prototyping were the most underestimated. Small, mature, modifications to existing programs which were quickly accomplished had the least underestimation of costs, particularly without prototyping. Each of the factors relate to opportunities for change during execution. The programs with the worst estimates, have the greatest opportunity for changes. That is, except for the role of prototyping, which is suppose to reduce requirements volatility, and according to Drezner, it may not actually do so.

Interestingly, Wandland and Wickman (1993) showed that although competed contracts have more cost growth than those awarded sole source, this result is insensitive to either contract type and absolute price. In other words, fixed price contracts don't grow anymore for competed programs than they do for ones awarded on a sole source basis. Further, a large contract award does not improve the cost growth potential of a sole source contract over a competed one. This insensitivity to risk, as reflected in the contract type, says that either it does not exist, or the effect of competition overwhelms it. Likewise, if contractors are drastically undercutting their prices in competition, simply increasing the price would not ensure lower cost growth.

One of several significant studies of estimating techniques, Terry and Vanderburgh (1993), showed that a combined measure of cost and schedule performance, the Schedule Cost Index (SCI), is the best predictor of final cost at completion. Further, this result holds for contracts at all stages of completion. Besides identifying a good predictor of final cost performance, this study also indicated sensitivity of final cost performance to

Contract Completion Stage, Program Phase, Contract Type, Service Component, System Type, and Major Baseline Changes, but not Management Reserve. This both supports and contradicts some studies mentioned earlier. Of importance though, is that this study addressed Cost at Completion, rather than Cost Growth. By doing so, it was one of the first studies to divorce contract performance (i.e. overruns) from program baseline changes or contract modifications.

Three important theses in 1994 attempted to understand cost growth and how to predict it. Buchfeller and Kehl (1994) found no significant differences between cost variances between contracts categorized by military service, program phase, contract type or stage of completion. There sensitivity analysis failed to address possible differences between stable and unstable contracts. Elkinton and Gondeck (1994) attempted to quantify cost growth using a "Budget at Completion Adjustment Factor" derived from historical data. They found that this historical measure of instability did not improve cost estimates over techniques based solely on performance of the program being estimated. Finally, Pletcher and Young (1994) discovered that a key difference between contracts which improve cost performance over time, the minority, and those which worsen, the majority, was a measure of performance measurement baseline stability.

The following year, another study of cost growth estimating techniques was completed by Nystrom (1995). He evaluated the accuracy of complex non-linear cost estimating techniques against simpler performance index based ones. Although he found that the complex techniques did not perform any better than the simpler ones, he failed to test that result for sensitivity to baseline stability. He did show, however, that although no

single estimating technique was best across the categories tested (Stage of Completion, System Type, Program Phase, Contract Type, Service Component, and Inflation), composite cost and schedule indices performed best overall.

2.3 Opportunities for Current and Future Research

The most recent contribution to cost growth research is a report by Jarvaise, *et al.* (1996) of the RAND Corporation. They have published a summary database extracted from SARs upon which RAND studies have been conducted over the past decade, primarily by Hough and Drezner. The report and the accompanying database on electronic media will facilitate a greater variety of research participants and topics. As Hough (1992) did earlier, Jarvaise warns the reader of the pitfalls of using the SAR to calculate cost growth. However, combined with the DAES database, this "Defense System Cost Performance Database," as she calls the summarized SARs, should boost the confidence in both sources through cross validation and the exposure of inconsistencies.

As can be seen, the study of cost growth has evolved along two lines, which sometimes cross. First is the idea that cost growth is predominantly the result of changing scope, quantity and period of performance. This philosophy says that the additional cost of each change is reflected in changes to contract price as these sometimes unilateral changes are placed on contract. A study of the stability of program targets, then should yield knowledge about how much a program will cost to develop and produce over the planning, development or production estimates. The second idea is that an important part of cost growth is the amount in excess of the estimated budget or schedule that a contractor uses to complete a given contract. Studies in this area attempt to find the cost

at completion of individual contracts based on performance in those contracts and factors which influence future performance. One of those factors, often tested, is the idea of baseline stability. Indeed, baseline stability is the link between the two areas of cost growth research. One can not talk about cost growth without considering the effects of changes to targets (cost, schedule or technical) just as one should not study cost performance without consideration of how those changes influence the cost, schedule and technical performance of contractors. This thesis attempts to do part of just that, test the relationship between baseline stability and cost performance. Additional research into the relationship with schedule and technical performance has yet to be addressed.

III. Methodology

3.1 Basic Hypothesis: Cost Growth Sensitive to Baseline Instability

The basic hypothesis is that cost growth is sensitive to baseline instability. This concept can be broken down into two assertions. First, the predicted final cost performance differs among contracts with differing numbers of changes. The second assertion is that predicted final cost performance varies linearly with a measure of baseline volatility. This thesis is structured in two phases. Each phase of this study will address one of the assertions based on the original hypothesis.

3.2 Definitions

Cost Growth. Cost growth is one of the primary constructs used in this thesis, yet it is difficult to universally define. It is the "difference between the most recent or final estimate of the total acquisition cost for a program and the some initial estimate;" and the problem is deciding "what to count" and "when to start counting" (Hough, 1992:10). As discussed in the previous chapter, we will consider cost growth to consist of two portions. The first being additions or deletions to the target cost associated with changes made to contracts. The second portion, which is termed cost performance, is how much money, either over or under the budgeted cost of all the work, was actually spent. For a further description of cost performance see Cost Variance and Cost Performance Index in Appendix A.

Baseline Stability. There are numerous ways to describe the volatility of a contract. One could count the number of changes, or possibly sum the magnitude of all changes to the contract price. Other measures may be changes in the number of end-items required, or extensions and contractions of program schedules. One could even differentiate between contracts which are volatile early in contract execution from others which are volatile in later phases. Further, if one looks at the baseline as a cumulative probability distribution, a plethora of statistics can be generated for comparison purposes, such as variance, skewness, kurtosis, standard error, and the range of baseline values.

For this study, contract volatility is measured differently in each phase. The first measure is a simple count of the number of changes as indicated by increases or decreases in the contract budget. The second measure is the coefficient of variation calculated from the baseline values, CBB minus Management Reserve plus OTBCVA, reported over the life of the contract. The procedure used to measure volatility is discussed below. The first measure is a simple parameter, the other a statistic. Each is zero for a perfectly stable baseline, and each increase with adjustments to the contract.

In the first phase of this study, the baseline is defined as the CBB, and changes are defined as any increases or decreases in the CBB greater than 10% or adding up to greater than 10% of the CBB prior to the change. For example, suppose that a 12 month contract is awarded for $100 million, excluding profit or fee. In the second month, the contract is modified to increase several minor performance specification, and the budget is raised to $120 M. This is one change. The following month, a contractor credit proposal is accepted to waive several Military Standards, resulting in a cost savings of $6 M, or 5%.

This is too small by itself to be considered a significant change. Six months later, the contractor received $6 M to conduct a subsystem design review, which had been deleted in the previous modification. Although the last two changes result in $120 M on contract, or no effective change to the baseline, together they are significant because they collectively add up to over 10%. Thus, in this example, the contract is changed significantly twice. This analysis is conducted on all contracts which are beyond 10% complete and the number of changes is compared against a combined cost and schedule performance index which is explained below.

The second phase of the study looks more closely at the baseline used to manage the program, the Program Management Baseline, which is defined as the CBB minus MR and adjusted for OTB. Because the OTBCVA is reported as a positive number in some cases, a negative one in others, and skipped in some reports altogether, a simple method is used to implement the adjustment. The PMB is increased by the magnitude of the last reported OTBCVA, regardless of sign. In some cases, it is apparent that the program was being managed to some other baseline (for examples see plots 166-94, 166-98, 177-2; Appendix B), so the PMB becomes the greater of the expression just stated, BCWS or BCWP. The standard deviation of the PMB (σ_{PMB}) is normalized by division with the mean PMB yielding the coefficient of variation (C.V.).

$$C.V. = \sigma_{PMB} / \overline{PMB} \qquad (3.1)$$

where C.V. is the coefficient of variation of the PMB, σ_{PMB} is the standard deviation of the PMB, *PMB bar* is the *mean program management baseline*, and *n* is the number of

reports. For the 401 contracts observed, the central limits theorem assures that the samples' coefficient of variation will be normally distributed. Further, to avoid bias for incomplete or partially reported contracts, only contracts reporting data from before 25% through greater than 75% complete are included in the second portion of this study. Contract volatility is compared with cost performance using the cumulative CPI as described in Chapter 1 (Eq. 1.1 and 1.2).

3.3 Justification for Choices of Variables

3.3.1 Cost Growth

Phase I: SCI Best Predictor of Final Cost Performance for PC > 10%. The first phase augments the CPI with a Schedule Performance Index to produce a Schedule and Cost performance Index (SCI).

$$SPI = BCWP / BCWS \quad (1.3)$$

$$SCI = CPI * SPI \quad (1.4)$$

The SCI was chosen because it is one of the best predictors of final cost at completion available (Terry and Vanderburgh, 1993: 59). It is also a composite index which considers both cost overruns and schedule slippage. Nystrom (1995) found that composite indices were usually better at predicting completion cost performance than cost alone for contracts in the early stages of execution. As the percent complete approaches 100%, the SPI goes to unity which means, for mature contracts, SCI approximately equals CPI.

Phase II: CPI Best Predictor of Final Cost Performance for PC > 75%. Phase II of this study limited the population to mature contracts, therefore there was no need to

supplement the cost performance with schedule information. At or near completion, the final cost performance is given as the final cumulative CPI.

3.3.2 Baseline Volatility

Phase I: Number of Changes in CBB. An example of counting significant contract changes is illustrated in Figure 3-1 and Table 3-1. All of the mostly complete contracts for a single program are presented to illustrate the procedure. As can be seen in the graph, five major contracts were in progress during the period from 1986 to 1995 in program number 203. Of these, the second, 203-2, appears very stable because the PMB is nearly flat. Indeed, it had no changes either singularly or collectively exceeding 10%. This contrasts sharply with contract 203-6, which had a total of 4 significant changes. Although changes can be counted directly from the graph, a numerical evaluation is used for simplicity, consistency, and accuracy. It should be noted that although contract 203-7 shows the greatest growth, it only contains two significant changes, both of these are greater than 10% each. Contract 203-6 illustrates how a negative change, one that reduces budget, is counted as a change, even though it does not represent and increase in budget.

Phase II: PMB Coefficient of Variation. Prior to the second phase, a graphical analysis of baseline behavior is required to determine the best descriptive statistic to use. The PMB as well as BCWS, BCWP and ACWP are graphed against time for each of the mature contracts. Candidate descriptive statistics for the dispersion of PMB are variance, range, skewness and kurtosis. Although it would be ideal to find a parameter which

combined all of these, the coefficient of variation is both simple and adequately descriptive.

Tables 3-1 and 3-2 illustrate a comparison of measures of stability. The first table summarizes descriptive statistics for 5 contracts from one program. Table 3-2 lists how many times each contract would have been ranked in each position, based on the different measures. The rank order indicates an overall measure of stability. By comparison to the overall rank order, the normalized standard deviation and normalized standard error showed the most consistency. They also agree with the number of significant changes. For simplicity, therefore, the normalized standard deviation or coefficient of variation is chosen for the descriptive statistic of contract stability, or volatility.

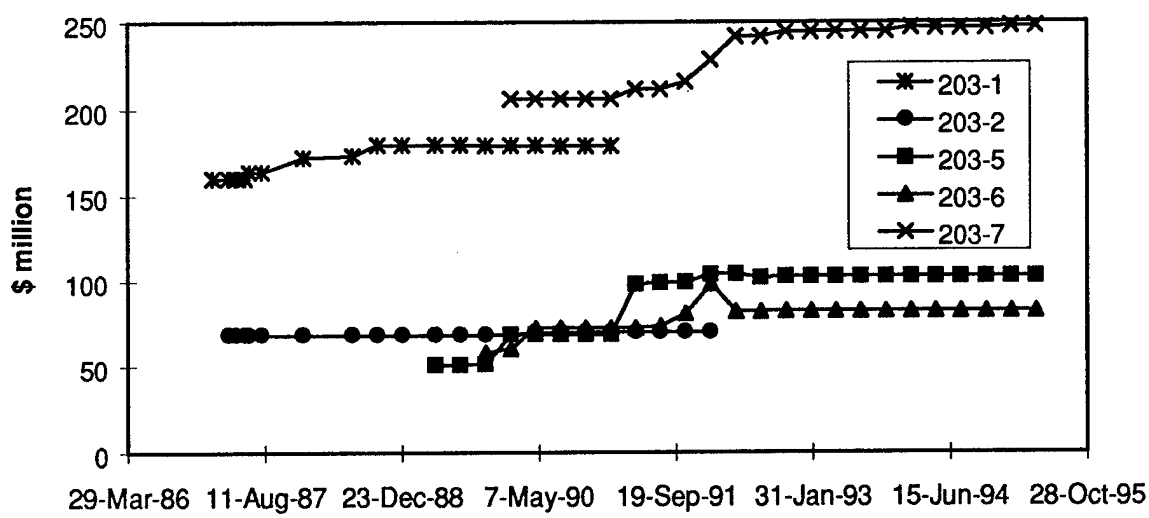


Figure 3-1. PMB for Program 203 Contracts

Table 3-1. Comparison of Measures of Stability

	203-2	203-1	203-7	203-5	203-6
Mean	68.905	172.50	231.29	89.284	78.500
Standard Error	0.168	2.007	3825	3.948	1.748
Normalized Std Err	0.0002	0.012	0.017	0.044	0.022
Coef of Variation	0.011	0.049	0.078	0.221	0.107
Kurtosis	-1.896	-1.537	-1.718	-0.669	-1.949
Skewness	0.524	-0.658	-0.540	-1.023	-0.620
% Range	2%	11%	18%	60%	51%
Significant Changes	0	1	2	3	4

Table 3-2. Rank Frequency Analysis for Dimensionless Statistics

Contract 203 - #	1st	2nd	3rd	4th	5th	Rank Order
2	6					1.5
1		5	2			2.3
7		1	4	2		3.1
6		1	1	3	2	3.9
5	1			2	4	4.7

Rank = the number of times a contract scored in each position

3.4 Sensitivity to Population Selection

The subgroups evaluated in Phase II of this study are service, buying activity and contract type. These are chosen to see if management styles of one group are confounding the observations of other groups. The military service and buying activities are identified from the first characters of the contract number, where an "F" indicates Air Force, "N" for Navy, and "DA" for Army. The next 5 digits are unique to each buying activity. For example, contract numbers beginning with F04701 belong to the Air Force (F) and are managed by the Space and Missile Systems Center (04701). This simulates the effect of segregating the population by product type, because the buying activities are organized by product centers (e.g., Naval Aircraft, Air Force Space Systems, Army Missiles, etc.). Finally, the predominant contract types reported in the DAES are variations of Fixed Price or Cost Reimbursable.

3.5 Statistical Test

3.5.1 The Phase I Model

The basic hypothesis, that cost performance is sensitive to baseline stability, can be modeled two ways. In the first phase of the study, the hypothesis is modeled as a two factor ANOVA experiment with the following form.

$$SCI_{ij} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \varepsilon_{ij} \qquad (3.2)$$

Where SCI is the Schedule Cost Index of the ith level of factor A and the jth level of factor B, μ is the population average, α_i is the variation due to factor A (stage of completion), β_j is the variation due to factor B (the number of changes), $\alpha\beta_{ij}$ is the variation due to interaction between factors A and B, and ε_{ij} is the variation due to all other possible factors and random error. For this model to hold, ε_{ij} must be normally distributed and have a common variance among all treatment groups.

3.5.2 The Phase II Model

The second model, upon which Phase II of this study is based, is a simple linear regression of cost performance against baseline stability. The model takes the form:

$$CPI = \beta_0 + \beta_1 * \sigma_{PMB} + \varepsilon \qquad (3.3)$$

where CPI is the last reported Cost Performance Index, β_0 and β_1 are the regression coefficients, σ_{PMB} is the Performance Management Baseline Coefficient of Variation, and ε is random error. Once again, ε must be normally distributed and have a common variance among population samples for this model to hold.

3.5.3 The Procedures

As mentioned, this analysis was conducted in two phases. Figure 3-2 illustrates the steps followed in each phase. Before a statistical test for significant differences could be performed, the variables described above were extracted from the DAES database (Figure 3-2, Step 1) according to the procedure described in Appendix C.

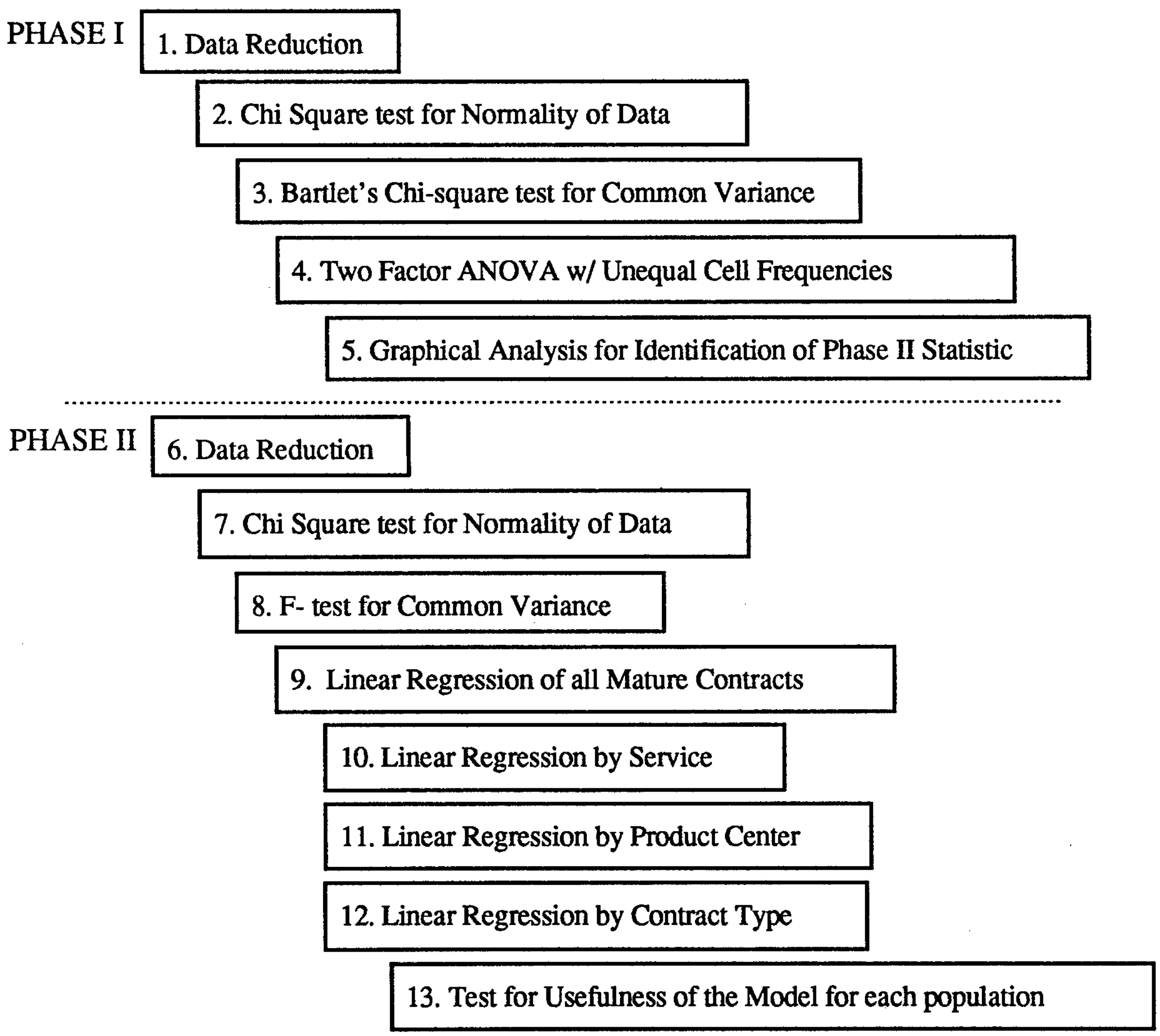


Figure 3-2. ANALYSIS PROCEDURE FLOW

Chi-Square Test for Normality (Phases I and II). In both phases of the study, the first test required was for normality and common variance (Figure 3-2, Steps 2, 3, 7 and 8). Normality was tested using Chi-square tests of the cumulative frequency distributions against that of a normal distribution. The null hypothesis, Ho, is that the distributions are not different. The rejection criteria for Ho is that the test statistic, Chi-square, is greater than the critical value. The procedure is as follows (Guide, 1996):

1. Using the MS *Excel* "Histogram" function, the data were counted according to bins. The bin values were selected to ensure not less than 5 samples in the smallest bin.

2. The histogram data were then divided by the sample size to arrive at a frequency distribution.

3. Using the mean and standard deviation from the sample, the probability that a sample would be in each bin was calculated from a normal distribution.

4. The ratio of the squared difference between the observed and expected frequencies to the expected value was then calculated for each bin.

5. Summing these ratios provides the Chi-square statistic.

6. The critical Chi-square value was chosen using α=.05 and the number of bins minus one as the degree of freedom.

7. If the Chi-square value is less than the critical value, the distribution can not be rejected as normal.

Bartlet's Chi-Square test for Common Variances (Phase I, Step 3). The test for common variances was accomplished using Bartlet's test (Figure 3-2, Step 3) in the first phase and a simple F-test of the population variances (Figure 3-2, Step 7) in the second

phase. The Bartlet test is a weighted sum of squares technique which is more complex than other methods but necessary when cell frequencies vary (Winer, 1962:94), but is not appropriate for Phase II, because samples are not independent. The procedure requires generating the Chi-square, χ^2, statistic according to the following formulae:

$$\chi^2 = \frac{2.303}{c}\left(f \log MS_{error} - \sum f_j \log s_j^2\right) \tag{3.4}$$

where

$$f_j = n_j - 1 \tag{3.5}$$

$$f = \sum f_j \tag{3.6}$$

$$c = 1 + \frac{1}{3(k-1)}\left(\sum \frac{1}{f_j} - \frac{1}{f}\right) \tag{3.7}$$

$$MS_{error} = \frac{\sum SS_j}{\sum f_j} \tag{3.8}$$

$$SS_j = \sum x_j^2 - \frac{\left(\sum x_j\right)^2}{n_j} \tag{3.9}$$

$$s_j^2 = \frac{SS_j}{n_j - 1} \tag{3.10}$$

and k is the number of treatment groups, x_j is the SCI observation in the jth treatment group, n_j is the number of observations in the jth treatment group, f_j is the degrees of freedom of s_j, f is the degrees of freedom of MS_{error}, MS_{error} is the mean standard error, SS_j is the Sum of Squares of the sample deviations, and s_j^2 is the variance of the jth treatment group. If Chi-square is larger than critical Chi-square at α=.05 and f degrees of freedom, then the variances between the treatment groups are heterogeneous. The null hypothesis,

Ho, is that the variances are all equal, $\sigma_i^2 = \sigma_j^2$ for all i and j, and the rejection criteria for Ho is that $\chi^2 > \chi^2_{\alpha,f}$. If the variances are the same, Ho will not be rejected.

F-test for Common Variances (Phase II, Step 8). In the second phase (Figure 3-2, Step 8), the F max statistic is the ratio of the largest sample variance to the smallest. The critical F value comes from $\alpha/2$, degrees of freedom for the sample with the larger sample variance, and the degrees of freedom for the sample with the smaller sample variance. If Fmax is greater than F critical, then the variances between the sample populations are not heterogeneous. The null hypothesis, Ho, is the same as above, but the rejection criteria is $F > F_{\alpha/2,f1,f2}$.

Winer's Two Factor ANOVA with Unequal Cell Frequencies (Phase I, Step 4). The data extracted from the DAES database were placed into a spreadsheet to facilitate analysis. The data were organized into cells of a 4x5 factorial design. Specifically, each cell was defined by the stage of completion, factor A, and the number of changes, factor B. The four levels of factor A were: 10-25% complete, 25-50% complete, 50-75% complete and greater than 75% complete. The five levels of factor B were: no changes, one change, two changes, three changes, and four or more changes. The cell frequencies varied from 3 to 134 observations per treatment group.

Winer presents a procedure for performing ANOVA with unequal cell frequencies when the frequencies vary greatly and can not be assumed independent of the factors (1962:291-297). This procedure, termed the "Least-squares Solution," centers upon finding an adjusted sums of squares for each factor and interaction. The method effectively weights observed values according to the number of observations. Treatment

groups with more observations influence the calculations more than those with few. The tables in Appendix E, replicate Winer's example using data from this study.

The Winer procedure relies on one of two techniques for making the final calculation of $SS_{b(adj)}$, the sums of squares attributable to factor B adjusted by cell frequency. The first offered is the Doolittle algorithm, which requires the calculation of three sets of weighting factors, b_{iB}, b_{iB}' and b_{iB}''. The second, less complex procedure is the Dwyer square root algorithm, which only requires two sets of weighting factors. Other than the wide acceptance claimed of the Doolittle algorithm, Winer offered no conditions under which it is preferable to the Dwyer algorithm.

Once derived, as indicated in Appendix E, the $SS_{b(adj)}$ is used to find $SS_{a(adj)}$, $SS_{ab(adj)}$, according to the following sequence.

$$SS_{a(adj)} = SS_a + SS_{b(adj)} - SS_b \quad (3.11)$$

$$SS_{ab(adj)} = SS_{cells} - SS_a - SS_{b(adj)} \quad (3.12)$$

where SS_a is the sums of squares attributable to factor A, SS_b is the sums of squares attributable to factor B, SS_{cells} is the sums of squares of all deviations. The equations for the unadjusted sums of squares are commonly available (see Winer, 1962: Table 6.14-1(iii), page 292.)

The resulting ANOVA summary takes the standard form, Table 3-3. The null hypothesis in each case is that no differences are attributable to the sources of variance. If the F statistic is greater than the critical F, then the null hypothesis can be rejected and the differences identified by a method of multiple comparisons. If it is not rejected, then one can not conclude that the model is sensitive to the factors tested.

Table 3-3. Summary of Analysis of Variance

Sources of variation	Sum Squares	Degrees of Freedom	Mean Square	F max
Factor A	SSa(adj)	I-1	$MSa = \frac{SSa(adj)}{I-1}$	$\frac{MSa}{MSE}$
Factor B	SSb(adj)	J-1	$MSb = \frac{SSb(adj)}{J-1}$	$\frac{MSb}{MSE}$
AB Interaction	SSab(adj)	(I-1)(J-1)	$MSab = \frac{SSab(adj)}{(I-1)(J-1)}$	$\frac{MSab}{MSE}$
Error	SSerror	N-1	$MSE = \frac{SSerror}{(N-1)}$	

Graphical Analysis (Phase I, Step 5). Before proceeding to phase II of this study, it was necessary to determine which descriptive statistic to use for regression analysis. The selection procedure is described above, the result is described here.

The data extracted from the DAES during Step 1 (as described in Appendix C) became the basis of graphical analysis with the goal of identifying the most descriptive statistic of baseline stability. To do this, data about each contract were visually evaluated for completeness (i.e., data from before 10% to near completion) and continuity. Contracts, the history of which appear to be nearly completely reported, were then graphed using a standard format (as illustrated in Appendix B).

Each graph was then evaluated for unusual or unexpected characteristics. The definition of PMB was then adjusted to account for inconsistencies such as BCWS exceeding CBB, or irregular application of OTB. Finally, the range of PMB curve shapes influenced the determination of what constituted stability and volatility. These purely qualitative assessments influenced the choice of distribution coefficient of variation as a

measure of stability. This, by no means, reduces the credibility of other descriptive parameters. Further discussion of the Performance Management Baseline stability is presented at the end of this chapter.

Simple Linear Regression (Phase II, Step 9). The linear regression was based upon testing the usefulness of the Phase II model.

$$CPI = \beta_0 + \beta_1 * \sigma_{PMB} + \varepsilon \qquad (3.3)$$
$$\varepsilon \sim N(0, \sigma^2)$$

where

$$\beta_1 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n}(x_i - \bar{x})^2} = \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2} \qquad (3.13)$$

$$\mathrm{var}(\beta_1) = \frac{MSE}{\sum_{i=1}^{n}(x_i - \bar{x})^2} = \frac{\sum_{i=1}^{n}\left(y_i - [\beta_o + \beta_1 x_i]\right)^2}{(n-2)\left[n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2\right]} \qquad (3.14)$$

Specifically, by evaluating the β coefficients in the model, a determination about whether the PMB coefficient of variation could be a useful predictor of final cost performance can be made. The hypothesis takes the form

Ho: $\beta_1 = 0$ vs. Ha: $\beta_1 \neq 0$

If β_1 can be shown to be non-zero (i.e. rejection of Ho), then the model is useful, otherwise it is not.

Three possible tests can be used to evaluate these hypotheses. First, a t-test of difference between β_1 and 0 where

$$t = \frac{\beta_2}{\sqrt{\mathrm{var}(\beta_1)}} \qquad (3.15)$$

and the rejection criteria for Ho is

$$|t| > t_{\alpha/2, n-2} \qquad (3.16)$$

The second possible test of the hypothesis is through the use of a Confidence Interval. If the Confidence Interval contains zero, then Ho can not be rejected. The Confidence Interval can be found according to:

$$CI = \beta_1 \pm t_{\alpha/2, n-2} \times \sqrt{\mathrm{var}(\beta_1)} \qquad (3.17)$$

The third technique available to test the hypothesis is an F-test through ANOVA. Performing an ANOVA for regression requires partitioning the variance contribution from regression from the error variance. The following equations are required for this procedure:

$$SS_{error} = \sum_{i=1}^{n} \left(y_i - [\beta_o + \beta_1 x_i]\right)^2 \qquad (3.18)$$

$$SS_{total} = \left(\sum_{i=1}^{n} y_i^2\right) - \frac{\left(\sum_{i=1}^{n} y_i\right)^2}{n} \qquad (3.19)$$

$$SS_{regression} = SS_{total} - SS_{error} \qquad (3.20)$$

where the ANOVA Summary takes the form of Table 3-4. As in phase I, if the F max statistic is greater than F critical for $\alpha = .05$, with 1 and n-2 degrees of freedom, then Ho can be rejected and the model declared usefully predictive.

Table 3-4. Summary of Analysis of Variance for Regression

Sources of variation	Sum Squares	Degrees of Freedom	Mean Square	F max
Regression	$SS_{regression}$	1	$MSR = \frac{SSregression}{1}$	$\frac{MSR}{MSE}$
Error	SS_{error}	n-2	$MSE = \frac{SSerror}{(n-2)}$	

3.6 The Database

3.6.1 Sources of the DAES

This study, like others before it (Pletcher and Young, 1994; Nystrom, 1995; Drezner, 1993; Terry and Vanderburgh, 1993; Elkinton and Gondeck, 1994; Buchfeller and Kehl, 1994) utilizes the Defense Acquisition Executive Summary Database (DAES). This study benefits from an updated copy of the DAES which contains records as late as 1995. These records are summary data from Major Defense Acquisition Programs (MDAP) (DoDR 5000.2-R, 1996: Sec C.7.) as derived from Cost Performance Reports (CPR) and reported to the Undersecretary of Defense for Acquisition and Technology (USD(A&T)). Program Managers are required to report cost, schedule, and technical data at least quarterly and in a specified format for ultimate inclusion in the DoD Selected Acquisition Report (SAR) to Congress.

3.6.2 Size of the DAES

The DAES is extremely large and difficult to analyze. The current version contains 18,747 records (each an individual DAES report), from 378 programs covering

1,843 contracts from throughout the DoD. After eliminating records not containing cost and schedule data, the reduced database contains 11,345 records on 1,009 contracts valued up to $12.7 billion. For the purposes described below, contracts less than 10% complete are eliminated, leaving 672 contracts from 165 programs. This data set of contracts over 10% complete with non-zero Cost/Schedule data is used for Phase I of this study. In Phase II, the database was further reduced by eliminating contracts which are less than 75% complete or had not reported performance prior to being 25% complete. This left a data set of mature contracts with nearly complete histories consisting of 401 contracts covering 131 programs. All three services are well represented with the Air Force having 42 programs and 151 contracts, the Army 41 and 108, and the Navy 48 and 142.

3.6.3 Accuracy of Data

A high degree of confidence can be placed in the data because of two factors, compliance to the Cost/Schedule Control System Criteria (C/SCSC) and Independent Reporting. The former ensures accuracy of the data, and the latter ensures accuracy of the reporting processes. Fundamental changes are underway which may reduce the confidence in future contractor performance measurement data. The C/SCSC may be replaced by the Earned Value Management System, a commercial standard currently in development, described in Chapter 1. Yielding government control of the standards from which contractor performance measurement systems are judged, can be equated to giving the contractor the checkbook. The next two sections, explain why.

C/S Compliance. The C/SCSC are a set of criteria, upon which judgments about the adequacy of contractors' performance measurement systems (PMS) are based. A dependable PMS is essential to administrate government contracts for several reasons. First and foremost, data from the PMS are used to evaluate cost and schedule performance, not only by the government, but by the contractor's management. The PMS identifies functional areas and projects which are in trouble, enabling timely and efficient allocation of management attention. If the PMS can not be relied upon to provide objective measurements of earned value, then opportunities exist for manipulation of the data to paint an overly optimistic picture.

Secondly, the PMS derived data are used for estimating completion costs. Estimates are made by every level including the Cost Account Manager, the contractor's Program Manager, the Contract Administration Office (government), the Program Office and sometimes even higher management. These estimates rely heavily on the accuracy of reported costs incurred (ACWP) and work performed (BCWP), as well as a stable plan or baseline (BCWS and BAC). Without control over a contractor's performance measurement system and changes to it, the data can be manipulated to hide impending overruns and schedule slippage. This can lead to failure to take the right corrective action in time to avert a potentially catastrophic problem.

Some would say that the opportunity to distort the facts is always with us. That is true whenever data are summarized, categorized and reported. According to Hough (1992), that is a real problem with the cost, schedule and technical information presented

to Congress in the SAR. However, the availability of a sound data source enables independent reporting to moderate any accidental or intentional misinformation.

Independent Reporting. In response to public concerns over alleged cover-ups in the defense acquisition industry, the Defense Contract Management Command (DCMC) was created out of the former services' plant representative offices (AFPROs, NAVPROs, and ARPROS) and the Defense Contract Administration Service. It was feared that because the PROs reported to their military services on the activity and performance observed at their contractors' facilities, their independence may be compromised by allegiance to or coercion from higher management.

A new position, the Program Integrator (PI), was created in DCMC to act as the plant focal point for the government program manager, but also as an independent observer to report on both contractor and government activities through independent channels to the Office of the Secretary of Defense (OSD). The PI analyzes contractor performance measurement data and combines them with observations of contractor and government activities to form an independent monthly assessment of status and completion predictions. These reports, termed Program Support Data (PSD), are forwarded through an Executive Information System (EIS) which is directly available to the OSD, as well as Program Managers. The availability of an independent report with which to compare information in the DAES, ensures that inconsistencies and abuses will be easily identified.

A weakness in the system, is that both reports, the PSD and the DAES, are based on the same contractor provided PMS data. While manipulation of the analysis remains

possible, manipulation at the source would invalidate both reports. Before receiving multi-million dollar contracts, typically over $100 million depending on the type of work, contractors must demonstrate that their PMS is in compliance to the C/SCSC. With such ideas as self certification to a commercial standard (EVMS, 1995), what assurance does the government have that performance reports and completion estimates are reliable?

3.7 Limitations

3.7.1 Experimental Design

This thesis is based on an *ex-post facto* pseudo-experimental design. It is divided into two phases, exploratory and regression. The exploratory phase consisted of a simple experiment and a survey of the data. The regression phase is a more rigorous evaluation of a theoretical model. The data are extracted from historical records so no effort to control for extraneous variables is possible. This is because the characteristics studied are based on multi-million dollar projects taking years to accomplish. Interaction with a dynamic and often unpredictable environment is anticipated to be a major intervening variable. Furthermore, most of the data are from C/SCSC compliant contracts; hence, there were internal controls to ensure the accuracy of the data.

3.7.2 Threats to Internal Validity (Construct Validity)

Characteristic of *ex-post facto* designs, this study was not able to control internal threats to validity. This is acceptable, because this study did not attempt to test for causation, but merely for correlation. Several threats to internal validity make the

establishment of a causal relationship impossible. First, a history effect may be present in which political, social or technological changes may have occurred during some contracts. Contracts executed before or after these changes may be different from each other and from the contracts in execution at the time of the change. Second, a maturation or learning has occurred over the past 26 years. Program management science has evolved and Program Managers benefit from the lessons learned from the failures and successes of their predecessors and contemporaries.

An instrumentation effect is also possible. This is because the requirements and practices for reporting the data have not been rigorously standardized across time, services or contract types. Finally, the selection of groups may be systematically biased by the elimination of certain samples. The C/SCSC are not normally required on Firm Fixed Price contracts nor for contracts for research, development, test and evaluation less than $70 million (FY'96 constant dollars) and procurement less than $300 million (FY'96 constant dollars)(DoDR 5000.2-R: Sec 3.3.4.3). It is possible that these samples are the most or least likely to demonstrate the behavior being studied. Their elimination could bias the observed behavior toward the mean. By contrast, the possibility of data manipulation by Program Managers is controlled through the use of a certification procedure for performance data management, an audit function and independent reporting. Therefore, the data which are reported are expected to be free of excessive manipulation by the subjects.

3.7.3 Threats to External Validity (Generalizability)

Threats to external validity may limit the generalizability of this study. Three types of segregation are employed. First, only Major Defense Acquisition Programs (MDAP) are studied. Therefore, the results can not be reliably generalized to smaller programs, or even large ones that fail to meet the MDAP thresholds (DoDR 5000.2-R). These thresholds are adjusted every few years for inflation and restated in base year dollars. The latest definition of an MDAP is.

> An acquisition program that is not a highly sensitive classified program (as determined by the Secretary of Defense) and that is: (1) designated by the Under Secretary of Defense (Acquisition and Technology) (USD(A&T)) as an MDAP, or (2) estimated by the USD(A&T) to require an eventual total expenditure for research, development, test and evaluation of more than 355 million in fiscal year (FY) 1996 constant dollars or, for procurement, of more than 2.135 billion in FY 1996 constant dollars. (**10 USC 2430**) (DoDR 5000.2-R Sec C.7. page 3)

Second, as stated above, programs not reporting their cost and schedule status are excluded. These contracts are predominantly Firm Fixed Price, so it is difficult to apply these results to FFP contracts. And finally, some contracts are excluded because of an absence of data for some stages of completion. Specifically, contracts less than 10% complete are excluded from both phases of the study. These tended to be very recent contracts or ones in which reporting terminated either because the contract lost MDAP status, was restructured into another contract, or was simply terminated.

The second phase of the study only looks at mature contracts, greater than 75% complete, which have reported data since before completion of their first quarter. This segregation, based on stage of completion, results in recent programs being proportionally under represented in the sample population. This is because, at any given

snapshot in time, some programs will in progress. These programs may be excluded, even though they will eventually be reported through completion. Generalizability rests then on the assumption that current and future contracts will not differ substantially from historical ones. Although research has indicated that contract performance has not degraded over time (Obringer, 1988 and Wilson, 1992), this trend does not guarantee future performance will be the same.

3.7.4 Weaknesses

Normality of Data. Several weaknesses should be mentioned. The first is the assumption of normally distributed population parameters. Although the Wilkes-Shapiro procedure is more powerful, the simple Chi-square test was considered adequate. It is possible that peculiarities in the data invalidate the assumptions of the ANOVA and Regression procedures used.

Independence of Samples. Each program is considered an independent sample for the purposes of the analysis. This may not be the case as management practices and personnel are often applied to multiple contracts. Indeed, in a given program, every contract is under the direction of a single manager. Some level of autocorrelation therefore may be present. If true, then the confidence about each of the subdivided populations should be less than that of the whole population.

Causal Relationships. Additionally, this study has the weakness that the results can not be used to support a causal relationship. Even for the cases where positive correlation is found to be significant, it is impossible from this experiment to ascertain whether

changes caused improved cost performance, or if better cost performance encouraged additional changes. Further, both may be attributable to a third extraneous factor such as a peculiar product characteristic.

Volatility Construct Alternatives. Other weakness deal with the definition of constructs. Contract volatility and cost performance are the primary constructs. Each is represented by one or more operational variables. The chosen operational definitions may mask or distort observation of the construct.

Number of Changes. For example, the volatility variable defined as number of significant changes focuses on the dollar value of changes. While this is a somewhat arbitrary choice, it is commonly used for setting thresholds for management attention (DoDR 5000.2-R: Sec 1.4.5.2; FAR 43.101). This definition will not identify highly significant technological or performance changes which may be underestimated or considered inconsequential. Yet it may be just such unanticipated challenges which drive cost and schedule performance. For example, a change of maximum operating temperature from 200 to 205 degrees Celsius may be considered insignificant until it is discovered that a key lubricant in the system breaks down at an unacceptable rate at the new temperature. This discovery may not occur until the system is built and under environmental testing. Correction of the problem may be costly in terms of repeated testing, repair of prime equipment, or even redevelopment of a new design. What originated as a low or no cost contract modification could result in jeopardizing the success of the entire program.

<u>PMB Coefficient of Variation and the Various Baselines</u>. The measure of volatility used in the second phase of this study is likewise subject to some potentially arbitrary operationalization. The calculation of a program baseline requires consideration of many factors. Besides the negotiated price, there are a variety of costs which different managers consider their baselines. A government program manager may see the life cycle cost of the program as the baseline, including research, development, production, deployment, logistics and disposal. Each of these would have associated contracts or other demands for resources, and the cost of each could be traded off to some extent between them.

A contractor's division president may consider the collection of related contracts a management baseline. These may be multiple contracts for a given program or from a variety of programs covering multiple government agencies and military services. He may trade away efficiency on a smaller Air Force program to gain long term cost savings on a larger Naval or Department of Energy program. These levels of management outside the limits of a single contract can have tremendous influence in the resources and commitment provided to an individual contract's program manager.

The program manager, sometimes referred to as a project manager, either within a contractor or the government will typically focus on a single contract or possibly two closely related ones. Within the scope of a contract, such things as corporate overhead and future business base have effects on cost, but are beyond the control of the program manager. These uncontrollable factors are typically managed through the use of Management Reserve budget distribution or offset by loss of profit margin. Money in excess of the budgeted cost of the project are held to cover unforeseen cost growth.

Management Reserve in particular can be distributed to cost account budgets by a program manager, but Profit or Fee (profit share) are just consumed as offset for overruns. The level of fee or profit will normally be negotiated between the program managers based on the level of uncertainty anticipated in the contract. More uncertainty will require more profit or fee. Management Reserve, however, may be negotiated, but will be managed almost exclusively by the contractor.

Budget is actually consumed at a level below the program manager, the Cost Account Manager (CAM). The CAM who originally estimated the work may have tried to inflate his estimate, but it would be challenged by his superiors and the government to keep the cost of the program as low as possible. Remember that even if the contractor negotiates an inflated cost for contract pricing purposes, he may turn around and authorize a reduced budget to accomplish the work. The remainder would become Management Reserve. These authorized budgets are the ultimate management baseline. They may be changed through the usage of management reserve or changes in scope, quantity or period of performance.

OTB Complication. A complicating factor in baseline management is the Over Target Baseline. As described earlier, it will be used to reestablish a realistic baseline once the original cost and schedule targets are declared unreasonable. As such this can be considered a change in baseline. The OTB may be an adjustment to cost or schedule or both.

Summary of Baselines. In summary, several variables can define a baseline, depending on the management level being studied. This study focused on the program

manager of a single contract, either commercial or government. Therefore, the Program Management Baseline included the Budgeted at Completion (BAC) cost, which is the Contract Budget Base (CBB) less Management Reserve (MR), and Over Target Baseline (OTB) cost adjustment only. If the program, or project, manager does not have the most significant influence over contract cost performance, then a different definition of the primary performance drivers should be identified and the appropriate terms used in the PMB definition.

IV. Results And Discussion

4.1 Findings

The models tested in this study were based on the assertion that increased contract baseline volatility, changes, would correlate with decreased cost performance, overruns. Analysis of the data does not support this assertion. Both the ANOVA and regression analyses failed to show evidence that the hypothesized relationship exits. The ANOVA results indicate that it is impossible to conclude at 95% confidence that cost performance is sensitive to baseline changes. Furthermore, the 95% confidence interval of the slope of the regression model includes zero, meaning the model is not usefully predictive, for all but three cases. For these three cases, the relationship is small, but positive. In other words, contract changes are related to better performance, rather than worse, in a few cases.

4.1.1 Phase I

Analysis of Variance. This exploratory analysis indicates a lack of evidence for significant difference attributable to number of changes or stage of completion by quarter. Table 4-1 summarizes the two-factor ANOVA with repetition of unequal cells frequencies.

Table 4-1. Two Factor ANOVA with Repetition and Unequal Cell Frequencies

Summary of Analysis of Variance

Sources of Variation	Sums of Squares	Degrees of Freedom	Mean Square	F max	F critical (α=.05)
Factor A: Quarters	0.109868	3	0.036623	1.250668	2.618236
Factor B: Changes	0.089045	4	0.022261	0.760225	2.385271
Interaction	0.591415	12	0.049285	1.683069	1.766665
Error	19.56077	668	0.029283		

Assumptions. The basic model tested in this exploratory phase was that the predictor of final cost performance, SCI, was sensitive to the stage of completion and number of significant changes as defined above. The ANOVA test required that the data be normal and have a common variance. Normality was tested by comparing the cumulative frequency distribution with a cumulative normal probability distribution using a Chi-square test as described in the previous chapter. The Chi-square value found, χ^2 = 0.05, is less than the critical value of χ^2 = 3.94 (α=.05). Therefore, the null hypothesis, Ho: the distributions are the same, can not be rejected. The distribution is illustrated in Figures 4-1 and 4-2, Distribution of Schedule Cost Index. Figure 4-1 compares SCI to a normal distribution and Figure 4-2 shows the variation of SCI by stage of completion and number of changes. The variances were tested using Bartlet's Chi-square procedure, Table 4-2, and both analysis are summarized in Table 4-3.

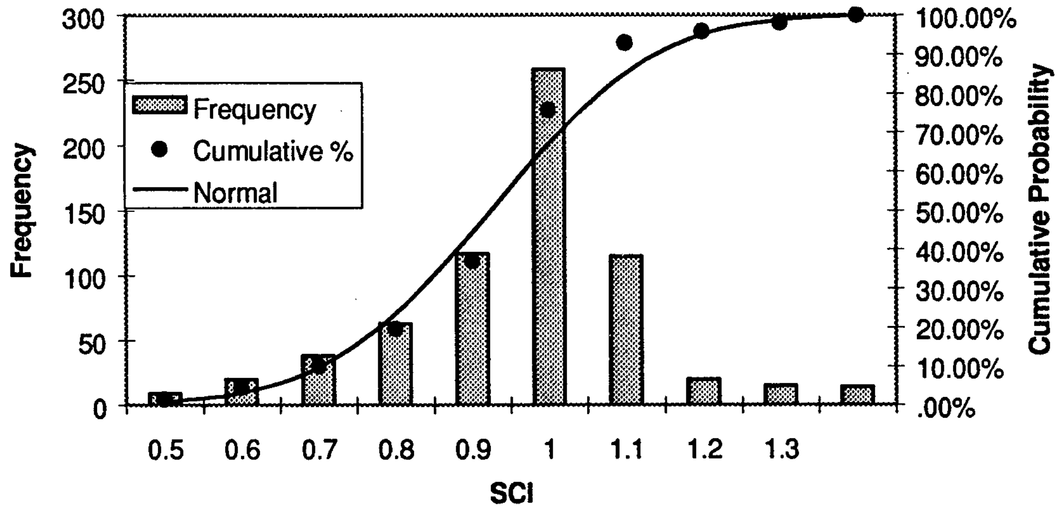


Figure 4-1. Distribution of Schedule Cost Index, Normality

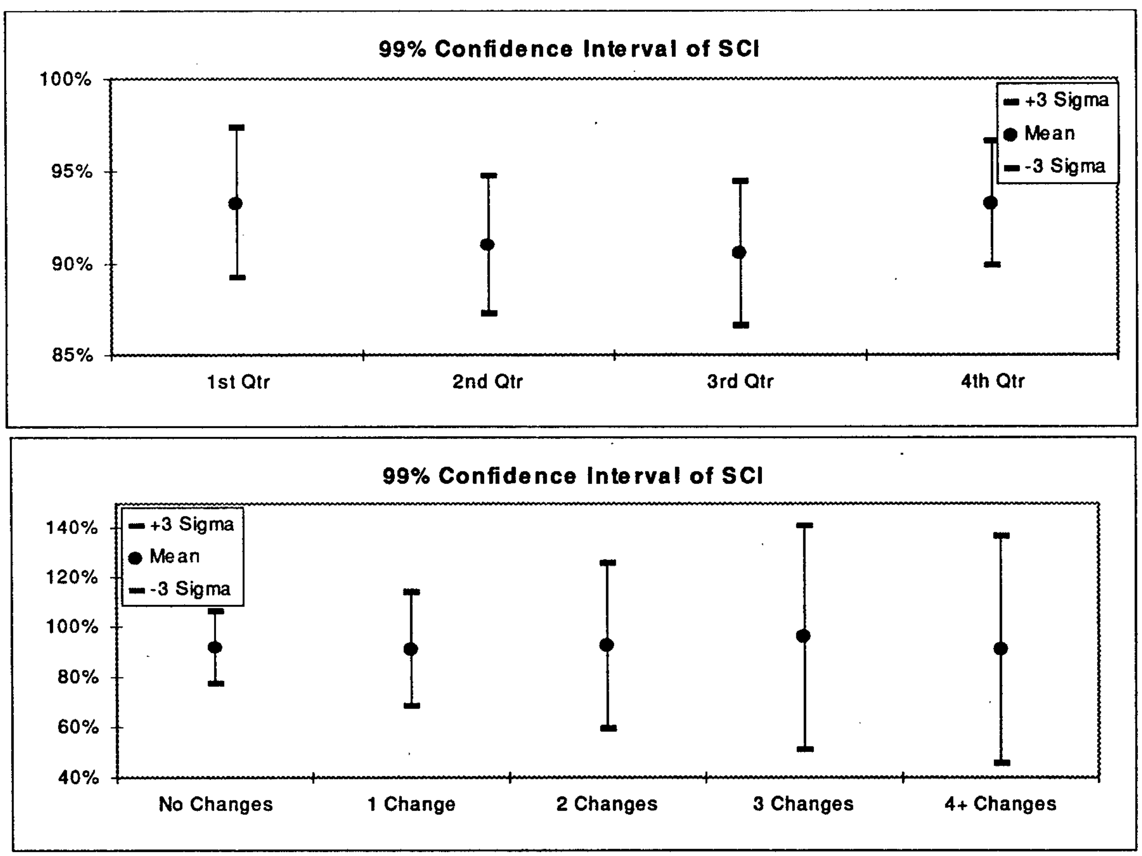


Figure 4-2. Distribution of Schedule Cost Index, by Factor

Table 4-2. Bartlet's Chi Square Test for Common Variances

	No Changes				**1 Change**			
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr
SS_i	5.62	3.76	1.95	0.97	2.60	0.68	0.65	0.37
f_i	133	99	70	68	53	38	28	22
$1/f_i$	0.00752	0.01010	0.01429	0.01471	0.01887	0.02632	0.03571	0.04546
$\log s_i^2$	-1.3742	-1.4205	-1.5559	-1.8438	-1.3094	-1.7486	-1.6369	-1.7723
$f_i \log s_i^2$	-182.77	-140.63	-108.92	-125.38	-69.400	-66.448	-45.834	-38.990

	2 Changes				3 Changes			
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr
SS_i	1.04	0.28	0.12	0.12	0.49	0.05	0.08	*
f_i	26	19	12	10	13	9	12	4
$1/f_i$	0.03846	0.05263	0.08333	0.1	0.07692	0.11111	0.08333	0.25
$\log s_i^2$	-1.3997	-1.8254	-2.0030	-1.9371	-1.4200	-2.2984	-2.1507	*
$f_i \log s_i^2$	-36.392	-34.682	-24.036	-19.371	-18.460	-20.686	-25.809	*

	4 or more Changes			
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr
SS_i	0.45	0.23	*	*
f_i	8	16	7	2
$1/f_i$	0.125	0.0625	0.14286	0.5
$\log s_i^2$	-1.2542	-1.8341	*	*
$f_i \log s_i^2$	-10.034	-29.346	*	*

MSerror = 0.02997
c = 1.03745
Chi-square = 19.0439
Chi-square critical = 26.2962

alpha = 0.05

Chi-square is less than Chi-square critical, therefore can not reject Ho: Variances are common.
(*excluding cells n < 9)

Table 4-3. Summary of Data Assumption Tests, Phase I (α=.05)

Assumption, Ho	**Test**	χ^2	χ^2 **critical**	**Result**
Normality	Chi-square	0.05	3.94	Not Reject Ho
Common Variance	Bartlet's	19.04	26.30	Not Reject Ho

4.1.2 Phase II

Regression. Regression analysis was performed as described in Chapter 3, on each of the subgroups as indicated in Table 4-4, Regression Summary. This table lists the size of each group, the mean final cost performance index and its standard deviation, the PMB coefficient of variation, and the 95% confidence interval for the slope of the regression line, β_1. The confidence intervals are also presented graphically in Figure 4-3. Additional detail of the regression and ANOVA analysis are available in Appendix D. As can be seen, in nearly all cases, the confidence interval contains zero. This means that one can not conclude that the slope is not equal to zero with greater than 95% confidence in nearly every case.

Two exception to this result are product centers F04704 (fixed price only) and DAAB07. These groups both indicate slopes significantly greater than zero. The implications of this are discussed below.

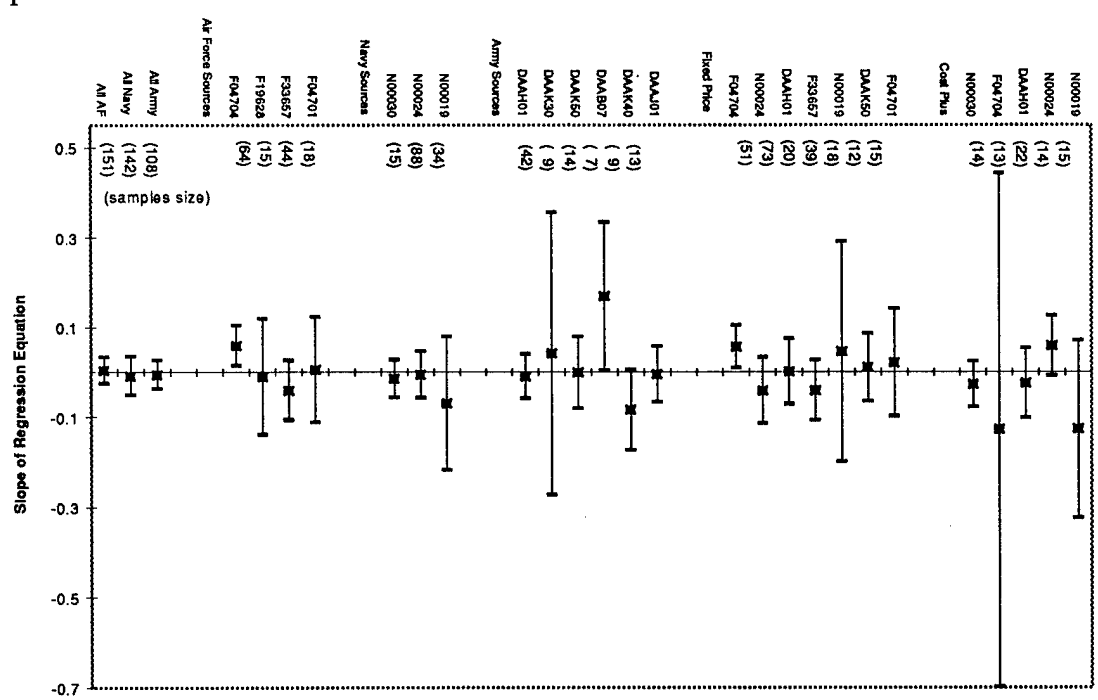


Figure 4-3. Regression Slope, 95% Confidence Interval

Table 4-4. Regression Summary

SAMPLE		CPI Last		PMB Coef Var		95% CI for Slope, β_1		
Name	Size	Mean	Std Dev	Mean	Std Dev	Low	Mean	High
All AF	151	0.96	0.11	0.36	0.58	-0.03	0.00	0.03
All Navy	142	0.94	0.11	0.32	0.42	-0.05	-0.01	0.03
All Army	108	0.92	0.12	0.62	0.72	-0.04	-0.01	0.03
Air Force Sources								
F04704	64	1.00	0.10	0.32	0.53	0.01	0.06	0.10
F19628	15	1.00	0.09	0.32	0.42	-0.14	-0.01	0.12
F33657	44	0.93	0.10	0.29	0.48	-0.11	-0.04	0.03
F04701	18	0.89	0.09	0.36	0.43	-0.11	0.01	0.12
Navy Sources								
N00030	15	0.97	0.04	0.43	0.49	-0.06	-0.01	0.03
N00024	88	0.96	0.11	0.32	0.46	-0.06	-0.01	0.05
N00019	34	0.90	0.12	0.29	0.28	-0.22	-0.07	0.08
Army Sources								
DAAH01	42	0.95	0.09	0.49	0.60	-0.06	-0.01	0.04
DAAK30	9	0.93	0.20	0.67	0.56	-0.27	0.04	0.36
DAAK50	14	0.93	0.09	0.66	0.71	-0.08	0.00	0.08
DAAB07	7	0.89	0.11	0.91	0.51	0.00	0.17	0.33
DAAK40	9	0.89	0.09	0.58	0.69	-0.17	-0.08	0.01
DAAJ01	13	0.89	0.12	1.10	1.25	-0.07	0.00	0.06
Fixed Price								
F04704	51	1.01	0.10	0.35	0.10	0.01	0.06	0.10
N00024	73	0.96	0.12	0.24	0.12	-0.12	-0.04	0.03
DAAH01	20	0.94	0.10	0.57	0.70	-0.07	0.00	0.07
F33657	39	0.94	0.10	0.30	0.50	-0.11	-0.04	0.03
N00019	18	0.93	0.11	0.26	0.24	-0.20	0.05	0.29
DAAK50	12	0.91	0.08	0.70	0.76	-0.07	0.01	0.09
F04701	15	0.88	0.09	0.35	0.46	-0.10	0.02	0.14
Cost Plus								
N00030	14	0.97	0.04	0.36	0.43	-0.08	-0.03	0.02
F04704	13	0.97	0.07	0.19	0.08	-0.70	-0.13	0.44
DAAH01	22	0.96	0.08	0.41	0.50	-0.10	-0.02	0.05
N00024	14	0.95	0.08	0.73	0.66	-0.01	0.06	0.13
N00019	15	0.86	0.12	0.32	0.33	-0.32	-0.13	0.07

Assumptions. As in phase I above, the first analysis was to establish the validity of the assumptions of the model being tested. In this case, multiple F-tests of population variances were accomplished. Table 4-5 summarizes these results by listing the test, the resulting test statistic, and the critical value of the statistic. With the exclusion of two product centers, as noted in the table, the variance of CPI between groups was not significantly different. The data were also found to be normally distributed as indicated in Figure 4-4, Distribution of Cost Performance Index.

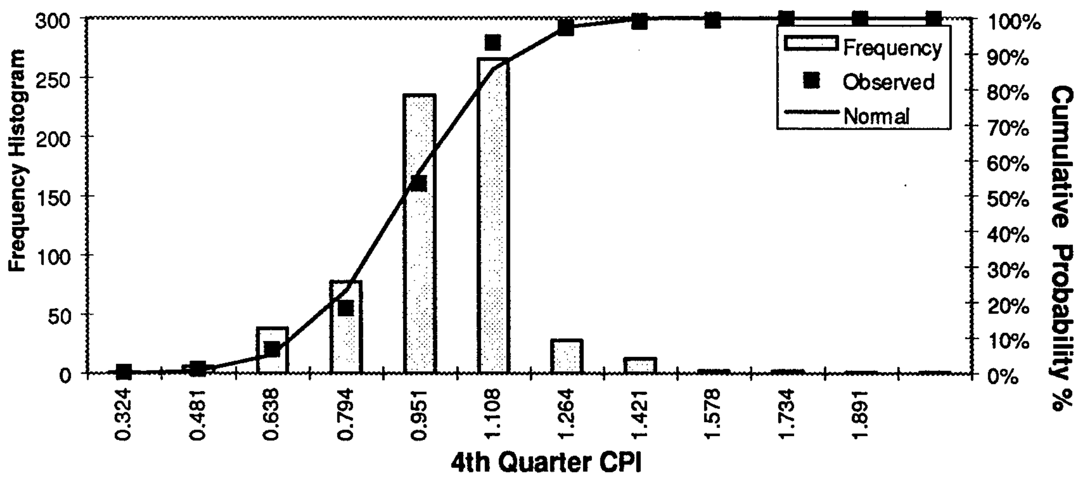


Figure 4-4. Distribution of Cost Performance Index

4.2 Relationship to Cited Research

These findings run counter to the cited research. As reported earlier, writers (Augustine, 1983; 1990 and Gilbraeth, 1986), and researchers (Hough, 1992; Pletcher and Young, 1994; Terry and Vanderburgh, 1993) are concerned with the instability of contracts and speculate that contract performance is sensitive to baseline changes. These findings indicate that in most cases, the sensitivity can not be demonstrated. This leaves

the vast majority of the variance in contract performance to be attributable to other variables.

Table 4-5. Summary of Data Assumption Tests, Phase II (α=.05)

Assumption, Ho	Test	Statistic	Critical	Result
Normality	Chi-square	0.03	19.7	Not Reject Ho
Common Variance by Service	Multiple F-tests	1.24	1.41	Not Reject Ho
Com Var by AF Product Center	Multiple F-tests	1.33	2.66	Not Reject Ho
Com Var by Navy Product Center[1]	Multiple F-tests	1.09	1.71	Not Reject Ho
Com Var by Army Product Center[2]	Multiple F-tests	1.65	3.15	Not Reject Ho
Com Var by Contract Type FP	Multiple F-tests	2.06	2.98	Not Reject Ho
Com Var by Contract Type CP[1]	Multiple F-tests	2.82	3.21	Not Reject Ho

[1] Excludes 14, N00030 contracts with low CPI standard deviation, s = .04.
[2] Excludes 9, DAAK30 contracts with high CPI standard deviation, s = .20.

4.3 Influencing Uncontrolled Factors

Many variables are not controlled in this study. A modest effort is made to isolate military service, product type (buying activity), and contract type. This effort yields an unexpected positive relationship between changes and cost performance in two cases. Other factors, as suggested in earlier research cited above, include changes in acquisition

policy, the technological challenges in each contract or modification, and the effect of changing the quantity or period of performance as opposed to technical performance.

Additionally, the unique talents of the personnel involved, program managers, project officers, engineers, and others, may be the key to making or breaking a contract. If this is the case, it would suggest that contract performance is sensitive not only to individual contractors, but to contractor divisions and even program teams. Indeed, this and other statistical studies assume that the contributions of individuals are normally distributed and fixed over time. However, this may not be the case. The talents of personnel in a field may ebb and flow with changes in the industrial base, competition for key positions, the supply of highly educated or experienced specialists, and advances in management science. These uncontrolled factors are not considered in this analysis, but should be the basis for a more qualitative analysis.

4.5 Resolution of Conflicting, Inconsistent and Misleading Findings

Phase II of this study, regression analysis, mostly supports the findings in the exploratory ANOVA in phase I; cost performance is insensitive to baseline changes. However, the regression analysis did reveal two populations in which the sensitivity can be supported, though in the counter-hypothesized direction. Specifically, for two groups, F04704 (fixed price contracts only) and DAAB07, the data indicate that cost performance improves with the level of instability. This may be attributed to the level of significance used in each phase, α=.05. This means that there is a 5% chance that either analysis results in a false negative. In other words, the chance that the first study is correct is only

95%. Likewise, the chance that the populations which show no correlation actually are positively or negatively correlated is less than 5%.

Additionally, the variance due to the mixed population of the first study can mask the effects of sub-populations. This is demonstrated in the second study, when for all Air Force contracts considered, no significant correlation is found. However, when this population is divided into buying activities, one group is found to have a significantly positive correlation. The slight degree of correlation in this and one other case and the overwhelming lack of correlation corroborate both phases of the study.

4.6 Summary

Of the 669 contracts representing 165 programs considered in Phase I, the average predicted overrun of 8%, based on cumulative SCI, is found insensitive to either stage of completion or number of significant changes. A subset of these contracts totaling 401 samples from 131 programs corroborates the earlier results. Specifically, contracts for which data are present from before 25% to after 75% complete, almost no correlation is found between contract baseline instability and final cost performance. This result holds for sub-populations by military service, buying activity and contract type with only two exceptions. For one AF and one Army buying activity, a positive correlation is demonstrated. Specifically, this says that in these specialized cases, more variability in contract baseline is associated with better cost performance. The AF case, F04704, contains 64 contracts, mostly fixed price, while the Army sample only contains 7 contracts. Of the 64 AF contracts, the 51 Fixed Price contracts demonstrate the positive

relationship, while the 13 Cost Reimbursable contracts do not. The average predicted overrun, based on cumulative CPI, found in the second phase is 6%, which is not significantly different from the 8% found in the first phase.

Finally, in illustration of these results, plots of baselines and cost and schedule parameters illustrate a wide variety of cases. Over 500 plots indicate numerous cases of relatively stable or flat baselines culminating in dramatic overruns (e.g. Appendix B: 166-94, 166-95) as well as cases where the baseline changed significantly many times, a "rubber baseline", but the cost at completion is well within budget (e.g. Appendix B: 168-7, 177-2, 166-4). These illustrations suggest possible explanations of the experimental results and will be discussed in the next chapter.

V. Conclusions and Recommendations

5.1 Interpretation

This chapter interprets the findings reported in the previous chapter. Recall that the basic hypothesis was that cost performance is sensitive to baseline stability. This was tested using two models. The first model, in Phase I of this study, tested the predictor of final cost performance, Schedule Cost Index, for sensitivity to two factors, stage of completion and number of significant changes, as defined earlier in this thesis. A complex version of an ANOVA was performed to detect significant differences due to either factor. The second model hypothesized that contract baseline stability, as represented by PMB coefficient of variation, was a good predictor of final cost performance, taken as cumulative Cost Performance Index because only nearly complete contracts were considered. This model was testing using regression analysis to see if the slope of the regression line was significantly different from zero, indicating a useful predictive model.

The first phase of the study was inconclusive. Specifically, no significant differences were evident. While some groups of contracts with numerous changes performed better than others with fewer changes at the same stage of completion, the opposite is also true. These results cast a shadow of doubt on the operational definitions and suggested the possible effects of unidentified intervening variables.

The second phase sought to characterize the baseline change behavior on mature (greater than 75% complete) contracts only. These results were equally surprising. Of the various sub-populations tested, grouped by service (Air Force, Army and Navy), by

system families (Product Centers), and by contract types (Fixed Price versus Cost Reimbursable), almost no significant correlation was found. That is almost, because two cases were found to be significantly correlated, but counter to the hypothesized relationship. They suggest that the more volatile the baseline, the better these contractors performed.

5.2 Graphical Illustration

One beneficial product of the analysis is a series of baseline performance plots of each contract (PMB, BCWS, BCWP, ACWP against time) (see Appendix B). Graphical analyses illustrate cases of every extreme. There are extremely stable contracts (no apparent changes in PMB) with very high cost overruns (ACWP exceeding BCWP by more than 50%) (see plot 166-95, Appendix B). There are also examples of "rubber baselines" (PMB which did not remain the same for more than one or two reports, but grew throughout the program at different rates (Gilbraeth, 1986: 139)) with final costs incurred equal to or less than budgeted (see plot 168-7; Appendix B). These 521 graphs give a comprehensive view of the variety of conditions in which contracts can be found.

At first glance, the results would indicate that contracts do as well or as poorly under conditions of change as they do under conditions of stability. The observations that volatile contracts do no worse than stable ones, could be attributed to an appropriate amount of management attention directed on those changes. This conclusion would be welcome in the defense industry after several decades of highly publicized allegations of

mismanagement (Christensen, 1994; Garland, 1990; Ghosh, 1995; Fox, 1988). However, to be complete, alternative conclusions must be explored.

The accuracy of the data must be questioned based on some observed abnormalities. The most obvious are cases when the cumulative work complete is far more than the work either on contract or authorized. These are either mistaken uses of an Over Target Baseline or are simply erroneously reported or entered data. If this basic cost data is not correct, then other errors may be present as well.

5.3 Possible Explanations

The nature of changes suggests two possible explanations of why a volatile contract would not overrun more than a stable one. The first is the possibility of funding an overrun, and the other is the effect of "buying in."

When a change in the content of work on a contract occurs, an equitable adjustment should be made (FAR 43.101). If different terms and conditions would result in increased cost to the contractor, then they are due additional budget and possibly profit or fee to accept those terms and conditions. If the new terms decrease the scope either in quantity, compliance level, or simply change the period of performance, then the government may be due a reduction in contract price. The converse of these is also true. When a contractor receives more or less money for work, then the nature of that work should have also changed. If, however, a contractor who is in an overrun situation, excessively overvalues the cost of new work, the contractor could be attempting to capture excess funds to cover losses.

A related situation can occur when a contractor is under market pressure to reduce the estimate of the cost of a new project. This pressure could be either from competition or the suspicion that if the full cost of a project were known, then it would not be funded. This practice of intentionally underestimating the magnitude of a contract is termed "buying in." A common expression heard in defense circles is "bid 'em low and watch 'em grow," referring to the opportunity to regain losses from an under-budgeted project from overpriced changes (Augustine, 1983). If in practice, this characteristic would also explain the results observed earlier. A more unstable contract would have more opportunities to "watch 'em grow." Furthermore, because the contractors could perform better on these overpriced changes, they would appear as increased budget on the PMB *and* decreased cost variance over time.

Anticipation of this may be why most studies of defense programs focus on "program cost growth" rather than "contractor cost performance" (Drezner *et al.*, 1993; Elkinton and Gondeck, 1994; Peck and Scherer, 1962; Rich and Dews, 1986). Drezner describes program cost growth by including such things as quantity, period of performance and technical scope changes in his studies. He does not exclude the effects of cost performance, overruns or under-runs, but rather, addresses the change in the cost of a program to the tax-payers as a whole. By saying that a program grew by 20 to 30 percent, Drezner and others are not saying that a contractor overspent his budget by that much. Rather they are saying that the final bill for the program increased. Thus when Cost Growth is found sensitive to Baseline Changes, it is trivial because Cost Growth

includes Baseline Changes. On the contrary, cost performance in non-trivial, because an overrun is the amount of cost above the negotiated price of baseline changes.

A more practical and less sinister alternative also exists. Early in the contracting process, proposals are often made with a great deal of uncertainty. Work may only be vaguely analogous to previous experience. New technology may be envisioned which could reduce the cost, or if troublesome, increase it. Personnel projections are difficult to make when the lure of the next big project may draw away the assembled team of experts. Corporate dynamics can also be hardly anticipated. The project may be in a division swallowed up into an entirely different contractor, or divested to make it on its own. Also important is the future business base. If a contractor fails to win enough future work, the cost of supporting their infrastructure would be born on fewer and fewer projects. These higher overhead rates could then scare away potential new work, perpetuating the problem, and driving up the cost of existing work. All of these things bear on the total cost of a project, for which a contract price is based on the most tenuous of estimates. Combined with the pressures mentioned previously, a winning bidder would almost always estimate on the low end of a wide distribution of likely costs.

Having agreed to a price which ensured a 50% or greater chance of an overrun at completion, the contractor would welcome additional incremental changes. These incremental changes, often well after the work has been dissected and detailed, are much easier to estimate. The ultimate example would be to add one more unit to an order after a few units had already been produced, or vice versa. The cost of the new or last unit would be predictable with a great deal of certainty. Therefore, the chance of under-

running on the new work, or taking advantage of well understood costs to pad the estimate upward would be very high. Making this a virtual certainty is that most modifications are executed without competition. Competition is an important reason the contractor did not pad their original estimate to reduce risk in the first place.

5.4 Future Research and Application of Findings

It is evident from the range of possible explanations, that further research in this area is needed. Specifically, management practices relative to change management, if better understood, could lead to a sharing of lessons learned. The programs which experienced high volatility without suffering overruns, may have developed techniques to cope with their environment. Similarly, programs enjoying stable baselines and negative cost performance may have discovered pitfalls which should be avoided. In particular, analysis of the 51 fixed price contracts from activity F04704 may reveal peculiarities or techniques used to ensure the best cost performance in the study population, averaging 1% under budget in their final quarter and a positive relationship with contract changes. Finally, if unethical practices exist, they should be discovered and eradicated. Whatever the actual source of these results, the program management community stands to gain from a better awareness and understanding of the variety of situational realities *versus* dependence on anecdotal evidence and popular opinion.

Appendix A: Glossary of Defense Acquisition Acronyms and Terms

This Appendix contains the official definition of C/SCS terms which were extracted from the *DSMC Glossary of Defense Acquisition Acronyms and Terms.*

Actual Cost of Work Performed (ACWP). The cost incurred and recorded in accomplishing the work performed within a given time period.

Authorized Work. Effort that has been definitized and is on contract plus that for which definitized contract costs have not been agreed to, but for which written authorization has been received.

Apportioned Effort. Effort that is not readily divisible into work packages, but is related proportionally to measured effort.

Budgeted Cost of Work Performed (BCWP). The sum of the budgets for completed work packages and completed portions of open work packages, plus the applicable portion of the budgets for level of effort and apportioned effort.

Budgeted Cost of Work Scheduled (BCWS). The sum of budgets for all work packages, planning packages, etc., scheduled to be accomplished (including in-process work packages), plus the amount of level of effort and apportioned effort scheduled to be accomplished within a given time period.

Contract Budget Base (CBB). The negotiated contract cost plus the estimated cost of authorized unpriced work.

Contractor. An entity in private industry which enters into contracts with the Government. The work may also apply to Government owned, and operated activities that perform work on defense programs.

Cost Account. A management control point at which actual costs may be accumulated and compared to the budgeted cost of the work performed. A cost account is a natural control point for cost/schedule planning and control, since it represents the work assigned to one responsible organizational element on one contract work breakdown structure element.

Cost Variance. The difference between the budgeted and actual cost of work performed. A negative value indicates an overrun position.

Cost Performance Index. The ratio of budgeted to actual cost of work performed. A value less than 1.00 indicates an overrun position.

Direct Cost. Any costs that may be identified specifically with a particular final cost objective.

Estimate at Completion (EAC). Actual direct costs plus indirect costs allocable to the contract, plus estimate of costs (direct and indirect) for authorized work remaining.

Indirect Costs. Costs, which because of their incurrence for common or joint objectives, are not subject to treatment as direct costs.

Level of Effort (LOE). Effort of a general or supportive nature that does not produce definite end products.

Management Reserve or Management Reserve Budget (MR). An amount of the total allocated budget withheld for management control purposes, rather than designated for the accomplishment of a specific task or set of tasks. It is not a part of the performance measurement baseline.

Negotiated Contract Cost. The estimated cost negotiated in a cost plus fixed fee contract, or the negotiated contract target cost in either a fixed price incentive contract or a cost plus incentive fee contract.

Performance Measurement Baseline (PMB). The time phased budget plan against which contract performance is measured. It is formed by the budgets assigned to scheduled cost accounts and the applicable indirect budgets. For future effort, not planned to the cost account level, the performance measurement baseline also includes budgets assigned to higher level contract work breakdown structure elements and undistributed budgets. It equals the total allocated budget less management reserve. [Not to be confused with Performance Management Budget, a term introduced in this thesis and described in chapter 3.]

Planning Package. A logical aggregation of far term work within a cost account which may be identified and budgeted in early baseline planning, but is not yet defined into work packages.

Procuring Activity [Product Centers]. The subordinate command in which the Procurement Contracting Officer is located. It may include the program office, related functional support offices, and procurement offices. Examples of procuring activities are the Army Missile Command, Naval Sea Systems Command, and Air Force Electronics Systems Center.

Reprogramming. Replanning of the effort remaining in the contract, resulting in a new budget allocation that exceeds the contract budget base [Over Target Baseline].

Significant Variances. Those differences between planned and actual performance requiring further review, analysis or action. Thresholds should be established as to the magnitude of variances that will require variance analysis, and the thresholds should be revised as needed to provide meaningful analysis during execution of the contract.

Total Allocated Budget (TAB). The sum of all budgets allocated to the contract. Total allocated budget consists of the performance measurement baseline and all management reserve. The total allocated budget will reconcile directly to the contract budget base. Any differences will be documented as to quantity and cause.

Work Package Budgets. Resources that are assigned formally by the contractor to accomplish a work package, expressed in dollars, hours, standards or other definitive units.

Work Packages. Detailed tasks or material items identified by the contractor for accomplishing work required to complete the contract.

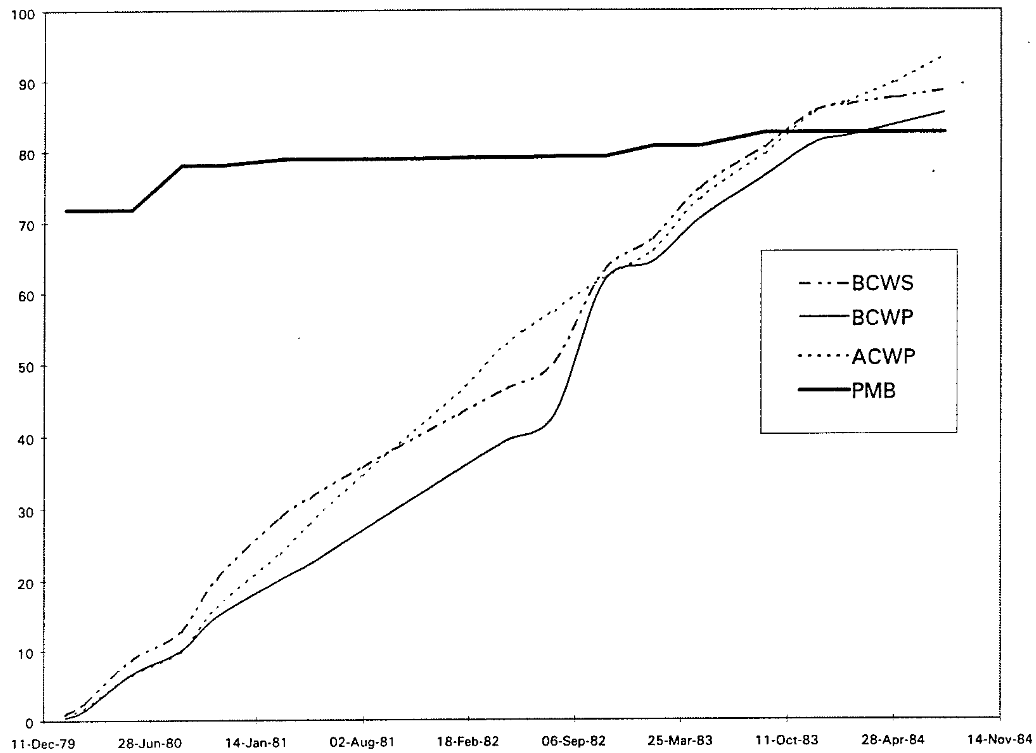
Appendix B: Baseline Plots

This section contains a sample of the plots of cost and schedule data from the mostly complete contracts in the DAES database. Each plot contains four series, or variable, against time. The variables are identified above each plot as: Series1=BCWS, Series2=BCWP, Series3=ACWP, Series4=PMB. The legend at the side of each plot indicates which line represents each series. All data are plotted in millions of dollars not adjusted for inflation, then year dollars.

Each plot is identified by a pair of numbers (i.e., 166-7). These numbers are unique to each contract and are taken from the DAES. The first number is the Program Number, and the second is the Contract Number. These numbers are not systematically assigned to any military component, product center or other activity. However, all plots with a common Program Number, represent contracts from a single program. The programs, contractors, and product centers are intentionally not identified. This is because a condition of use for the DAES was to ensure the anonymity of data sources. The PNO-CNO numbers accomplish this goal.

The complete collection of plots are available from AFIT/LAC or DTIC by request. They are being provided both in printed and electronic form. The hardcopy is approximately 521 pages in length. The electronic form is comprised of Microsoft *Excel* workbooks totaling approximately 12 megabytes.

166-94



100
90
80
70
60
50
40
30
20
10
0
11-Dec-79
28-Jun-80
14-Jan-81
02-Aug-81
18-Feb-82
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25-Mar-83
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28-Apr-84
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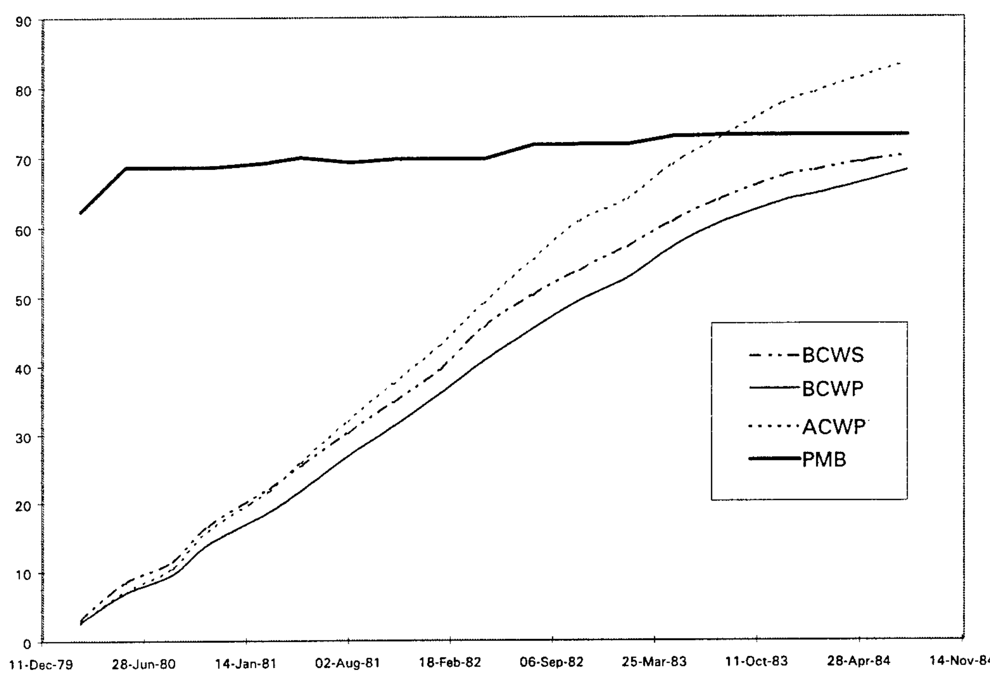
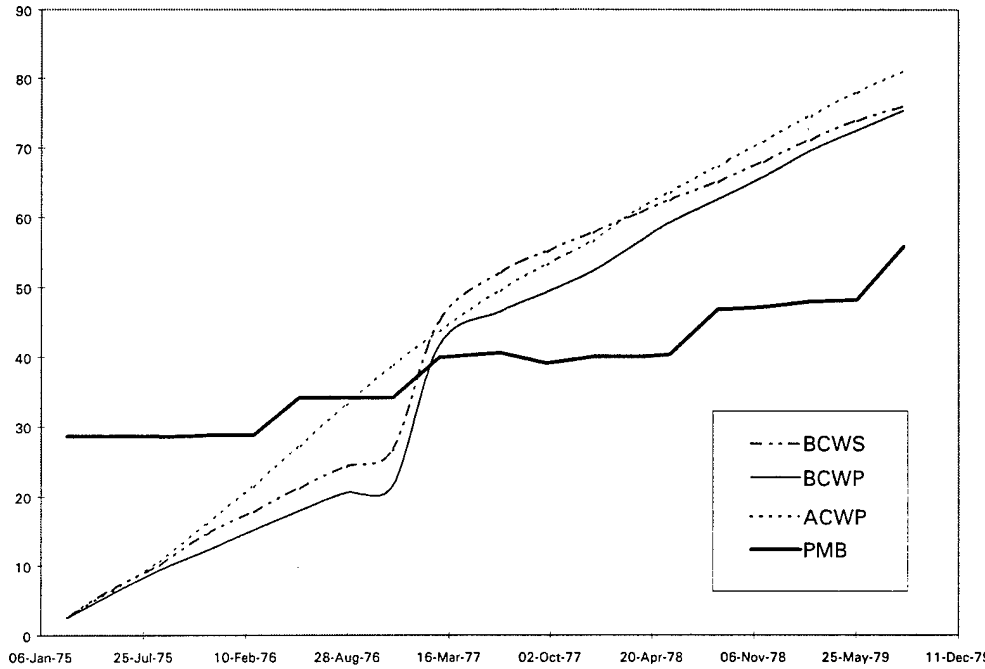
BCWS
BCWP
ACWP
PMB

166-95



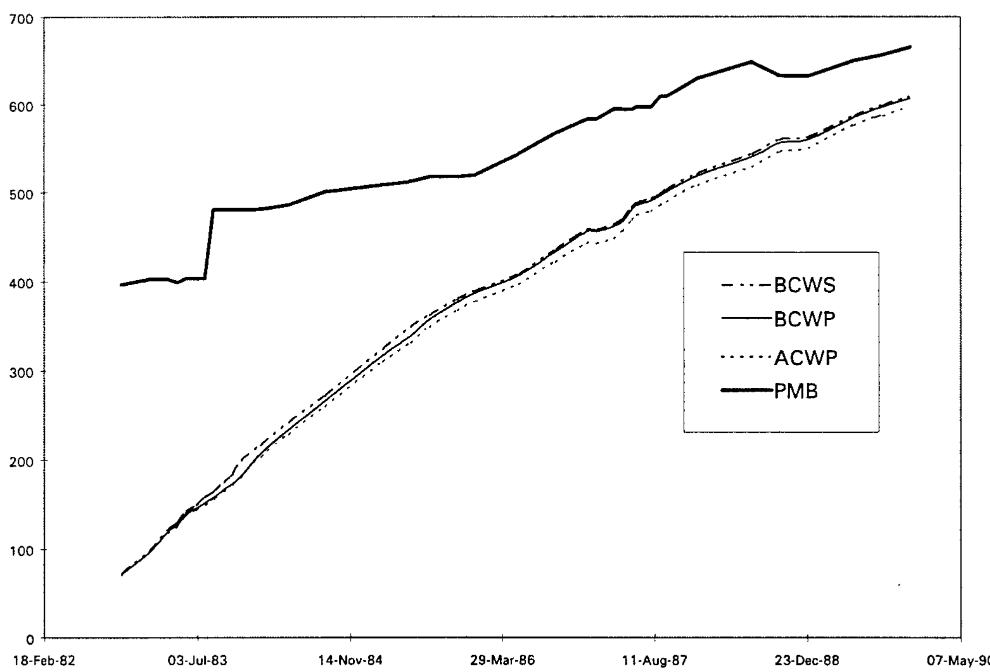
90
80
70
60
50
40
30
20
10
0
11-Dec-79
28-Jun-80
14-Jan-81
02-Aug-81
18-Feb-82
06-Sep-82
25-Mar-83
11-Oct-83
28-Apr-84
14-Nov-84
BCWS
BCWP
ACWP
PMB

166-98



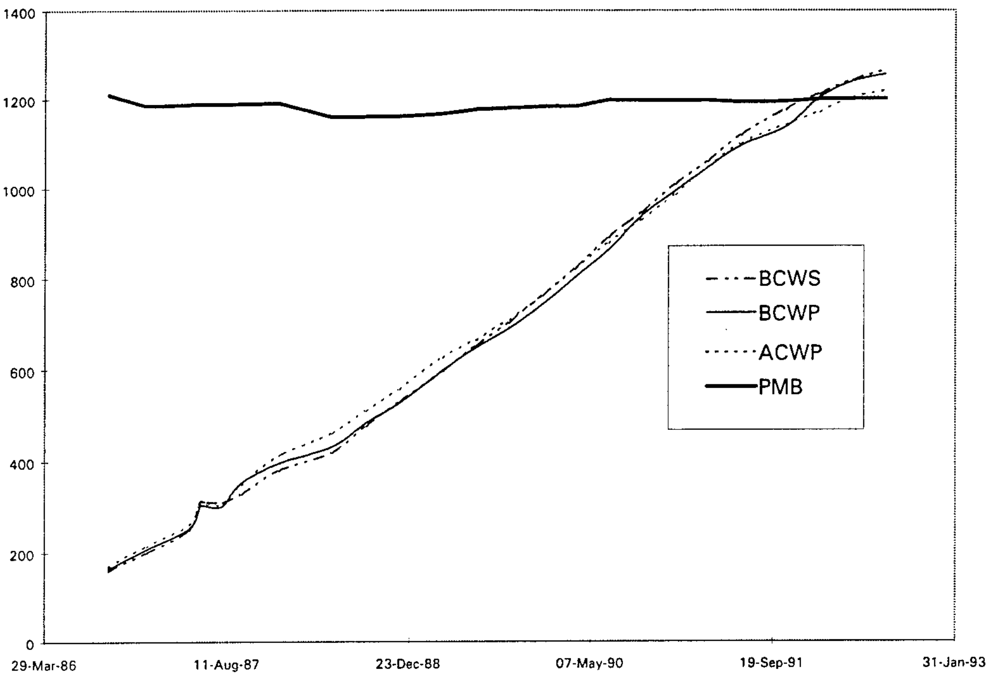
90
80
70
60
50
40
30
20
10
0
06-Jan-75
25-Jul-75
10-Feb-76
28-Aug-76
16-Mar-77
02-Oct-77
20-Apr-78
06-Nov-78
25-May-79
11-Dec-79
BCWS
BCWP
ACWP
PMB

168-7



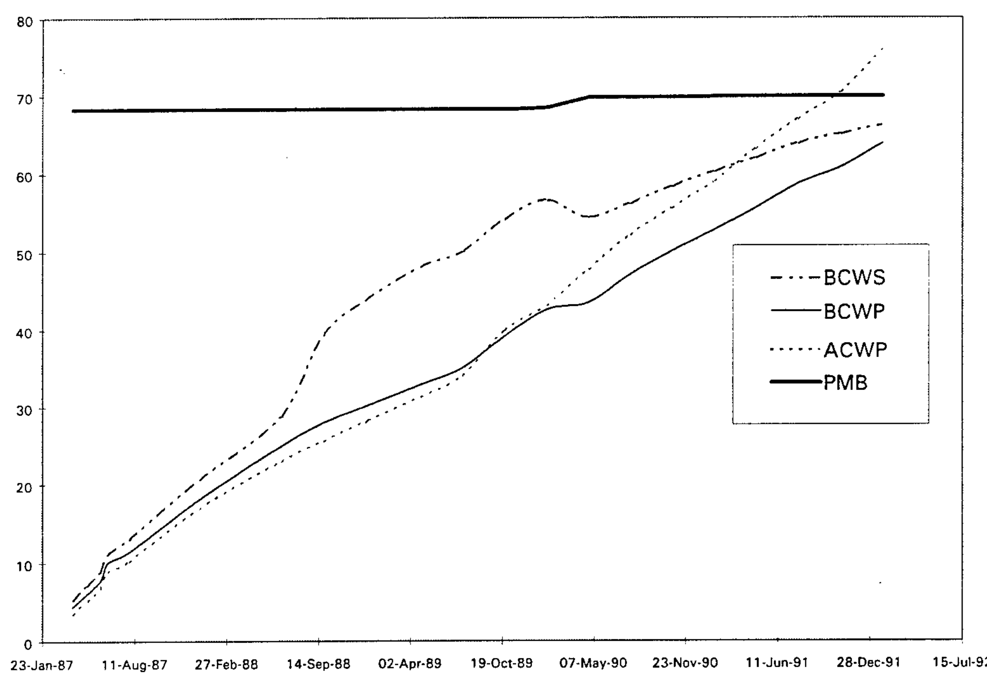
700
600
500
400
300
200
100
0
18-Feb-82
03-Jul-83
14-Nov-84
29-Mar-86
11-Aug-87
23-Dec-88
07-May-90
BCWS
BCWP
ACWP
PMB

177-2



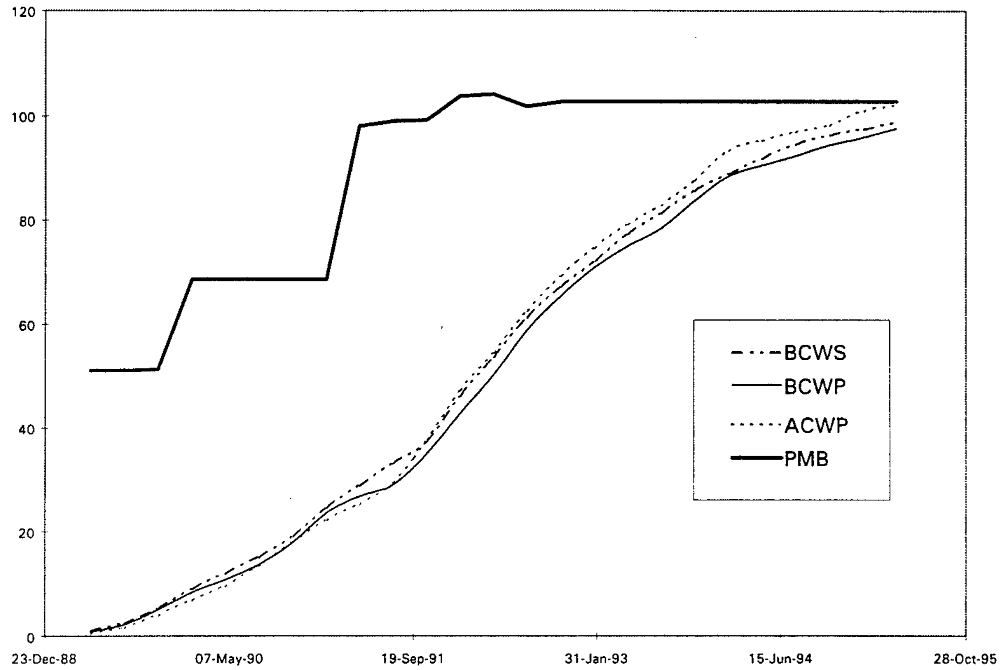
1400
1200
1000
800
600
400
200
0
29-Mar-86
11-Aug-87
23-Dec-88
07-May-90
19-Sep-91
31-Jan-93
BCWS
BCWP
ACWP
PMB

203-2



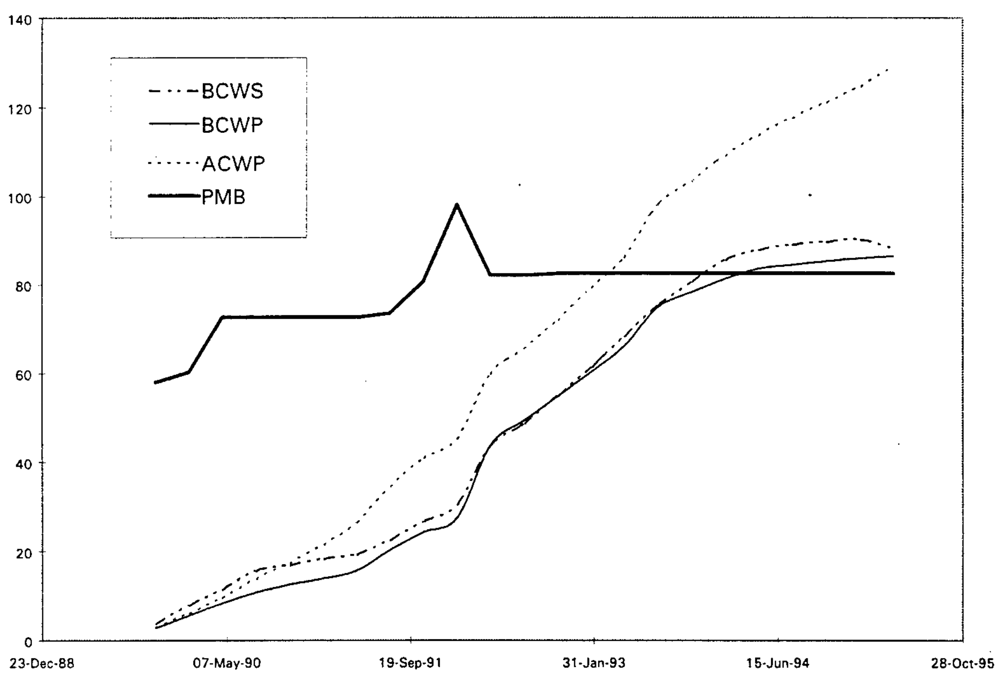
80
70
60
50
40
30
20
10
0
23-Jan-87
11-Aug-87
27-Feb-88
14-Sep-88
02-Apr-89
19-Oct-89
07-May-90
23-Nov-90
11-Jun-91
28-Dec-91
15-Jul-92
BCWS
BCWP
ACWP
PMB

203-5



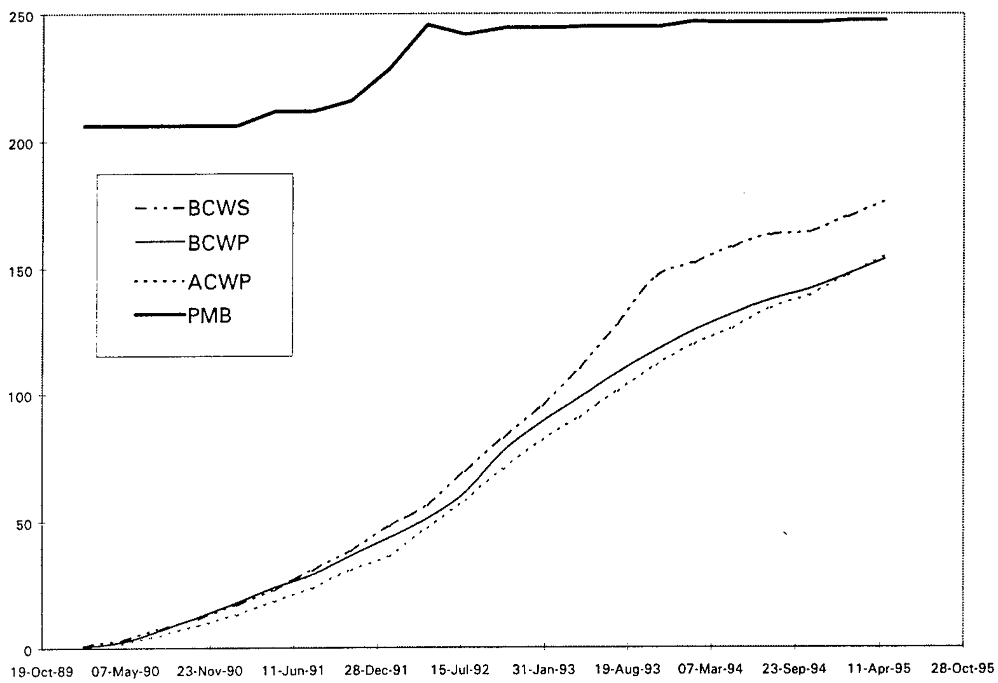
120
100
80
60
40
20
0
23-Dec-88
07-May-90
19-Sep-91
31-Jan-93
15-Jun-94
28-Oct-95
BCWS
BCWP
ACWP
PMB

203-6



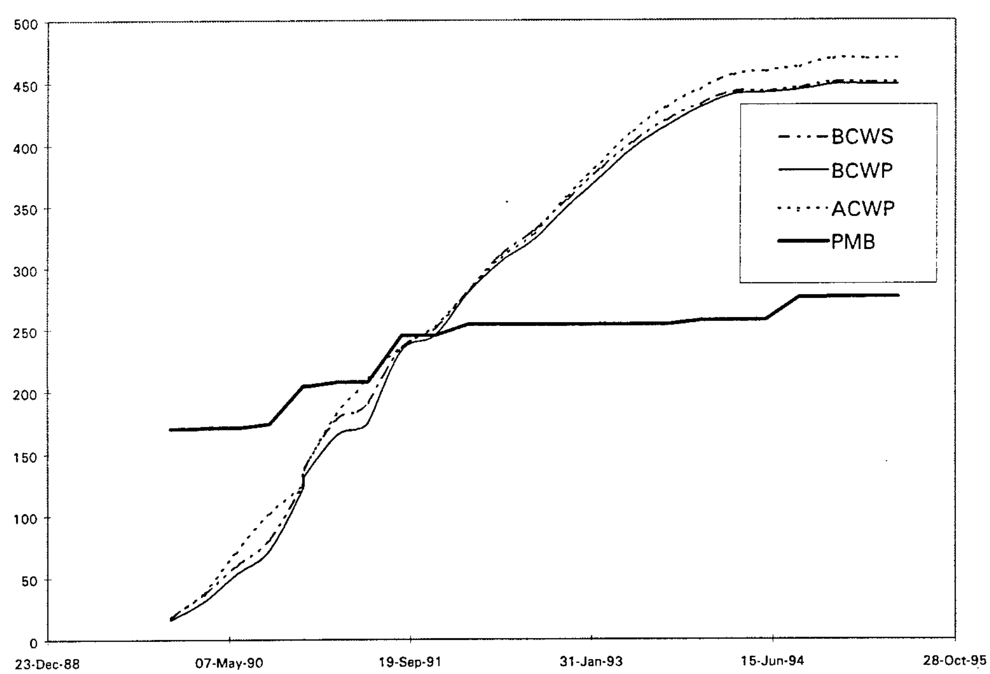
140
120
100
80
60
40
20
0
23-Dec-88
07-May-90
19-Sep-91
31-Jan-93
15-Jun-94
28-Oct-95
BCWS
BCWP
ACWP
PMB

203-7



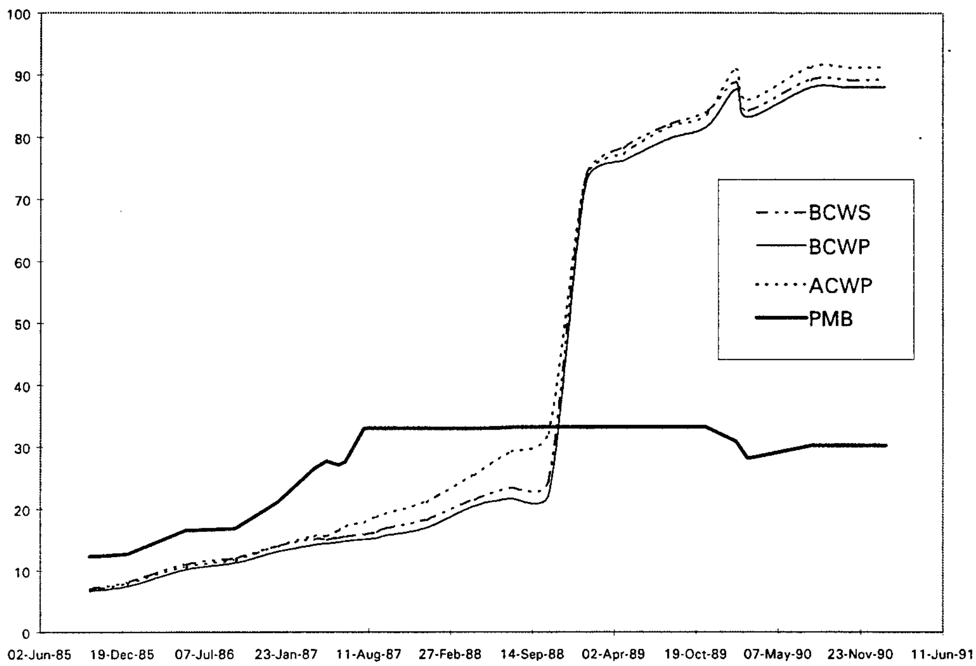
250
200
150
100
50
0
BCWS
BCWP
ACWP
PMB
19-Oct-89
07-May-90
23-Nov-90
11-Jun-91
28-Dec-91
15-Jul-92
31-Jan-93
19-Aug-93
07-Mar-94
23-Sep-94
11-Apr-95
28-Oct-95

280-1

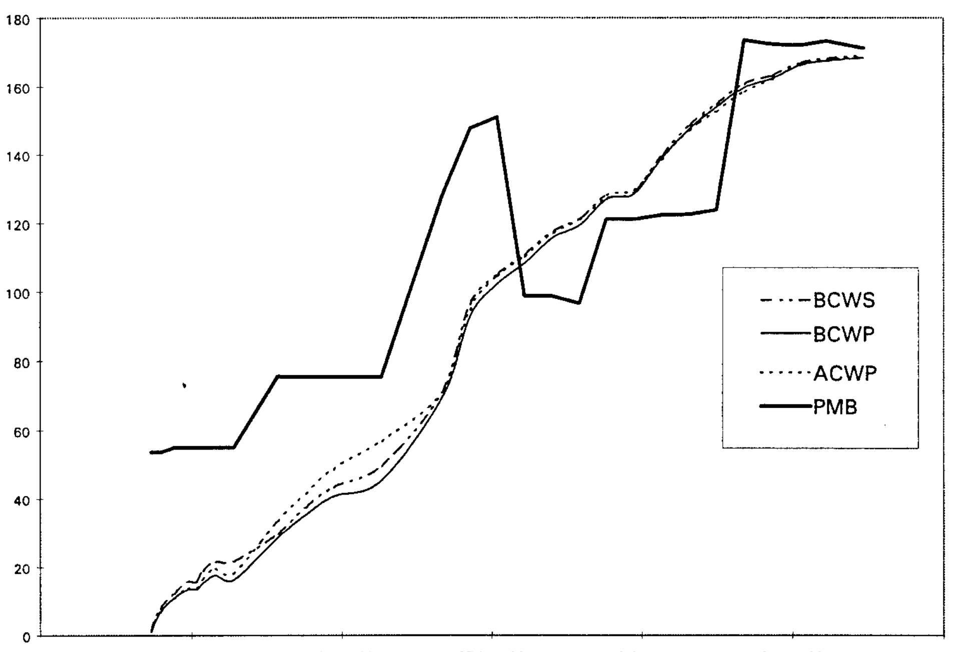


500
450
400
350
300
250
200
150
100
50
0
BCWS
BCWP
ACWP
PMB
23-Dec-88
07-May-90
19-Sep-91
31-Jan-93
15-Jun-94
28-Oct-95

321-1


100
90
80
70
60
50
40
30
20
10
0
02-Jun-85
19-Dec-85
07-Jul-86
23-Jan-87
11-Aug-87
27-Feb-88
14-Sep-88
02-Apr-89
19-Oct-89
07-May-90
23-Nov-90
11-Jun-91
BCWS
BCWP
ACWP
PMB

580-1


180
160
140
120
100
80
60
40
20
0
29-Mar-86
11-Aug-87
23-Dec-88
07-May-90
19-Sep-91
31-Jan-93
15-Jun-94
BCWS
BCWP
ACWP
PMB

Appendix C: Data Reduction Software

The DAES database is not conveniently structured to facilitate comparative analysis. It is intended to be read by custom application software which produces tabular and graphical displays of individual contracts. Generating the required parameters, number of changes and performance indices, from the application software is deemed inefficient so another method is developed.

The first step is to reduce the volume of the database. The database structure contains some parameters which are not needed for this study. Further, each record contains a single DAES report submission on a single contract. Compounding the problem is that many of the records contain missing or meaningless data in the pertinent fields. Many firm fixed price contracts either listed their BCWS, BCWP, ACWP as "N/A", "0" or are simply blank. Using Microsoft *Access* to generate a query which selectively eliminated meaningless records and irrelevant parameters results in a manageable datafile sorted chronologically and by contract. However, before comparisons between contracts can be automated, the data must be further reduced to a single record per contract.

Accomplishment of the Herculean feat of reducing each contract from a series of records to a meaningful single record requires some minor programming. The most convenient language for this purpose is Microsoft *QBasic*. The special purpose software incorporates extracting the number of changes, volatility, and performance parameters in the process of reformatting the datafile. The reduced sets of data are then easily imported to a *Microsoft Excel* spreadsheet for statistical analysis.

parameters in the process of reformatting the datafile. The reduced sets of data are then easily imported to a *Microsoft Excel* spreadsheet for statistical analysis.

The following pages contain the Microsoft *QBasic* data reduction code mentioned above.

Phase I Code:

```
REM  CAS Analysis Program, by Captain James A. Gordon
REM  Created:  19 FEB 96
REM  Purpose:  To read text database extraction of CAS database.
REM  Input:    Selected records from DCONTRCT.DBF, sorted by
REM            PNO, CNO and Submission Date.
REM  Output:   Parameters by PNO and CNO:  PC, SCI and delta% CBB
REM            for each change over 10% as well as final PC and SCI.
REM  Use:      To be imported into MS Excel for statistical testing.
REM
REM  Set up screen and initialize variables
REM

CLS
PRINT "PNO", "CNO", "Submission Date", "Report Date"
PRINT
PRINT "BCWS", "BCWP", "ACWP", "MR"
PRINT
PRINT "CBB", "TABUDG", "AUW"
PRINT
PRINT "TPRICE", "NEGCST", "CPRICE"
PRINT
PRINT "        % complete"

I = 0
J = 0
t = 0
dumpflg = 0

REM  Open data files and read records.  Extract variable values from data.
REM
OPEN "sorted.txt" FOR INPUT AS 1
OPEN "output.txt" FOR OUTPUT AS 2
10 IF EOF(1) GOTO 20
INPUT #1, a$
t = t + LEN(a$)
IF LEFT$(a$, 1) = "-" GOTO 10
PNO = VAL(MID$(a$, 2, 10))
IF PNO = 0 GOTO 10
CNO = VAL(MID$(a$, 11, 10))
sbdt$ = MID$(a$, 21, 17)
rdt$ = MID$(a$, 39, 11)
```

```
bcws = VAL(MID$(a$, 51, 9))
bcwp = VAL(MID$(a$, 63, 10))
acwp = VAL(MID$(a$, 73, 10))
mr = VAL(MID$(a$, 84, 7))
cbb = VAL(MID$(a$, 92, 12))
tabudg = VAL(MID$(a$, 105, 12))
auw = VAL(MID$(a$, 118, 13))
tprice = VAL(MID$(a$, 132, 11))
negcst = VAL(MID$(a$, 144, 12))
cprice = VAL(MID$(a$, 157, 11))

REM   Calculate basic parameters
REM
pc = bcwp / tabudg
cpi = bcwp / acwp
spi = bcwp / bcws
sci = cpi * spi

REM   New Program?  If yes, output data record and start again

IF PNO <> PNOI THEN
    b$ = b$ + "," + STR$(pc) + "," + STR$(sci)
    PRINT #2, b$
    b$ = STR$(PNO) + "," + STR$(CNO)
    dumpflg = 1
    I = I + 1
    PNOI = PNO
    cbb0 = cbb
END IF

REM  New Contract?  If yes, output data record and start again
REM  unless record has already been dumped.
REM
IF CNO <> CNOJ THEN
    IF dumpflg = 0 THEN
        b$ = b$ + "," + STR$(pc) + "," + STR$(sci)
        PRINT #2, b$
        b$ = STR$(PNO) + "," + STR$(CNO)
    END IF
    J = J + 1
    CNOJ = CNO
    cbb0 = cbb
END IF
```

```
dumpflg = 0

REM  If the CBB has changed by more than 10%, then record the PC,
REM  the SCI, and the percent change in CBB.
REM
IF ABS(cbb - cbb0) > cbb0 * .1 THEN
     deltacbb = (cbb - cbb0) / cbb0
     cbb0 = cbb
     b$ = b$ + "," + STR$(pc) + "," + STR$(sci) + "," + STR$(deltacbb)
END IF

REM  Print status of data extraction.
REM
LOCATE 1
PRINT: PRINT "                                        "
PRINT: PRINT "                                        "
PRINT: PRINT "                                        "
PRINT: PRINT "                                        "
PRINT "                              "

LOCATE 1
PRINT: PRINT PNO, CNO, sbdt$, rdt$
PRINT: PRINT bcws, bcwp, acwp, mr
PRINT: PRINT cbb, tabudg, auw
PRINT: PRINT tprice, negcst, cprice
PRINT USING "###.#"; 100 * t / LOF(1)
PRINT b$

REM   Loop back to next record unless interrupted from keyboard
REM
20 z$ = INKEY$
IF z$ = "" THEN GOTO 10

REM  Output Contract and Program Counters and close files.
REM
PRINT I, J
CLOSE 1
CLOSE 2
```

Phase II Code:

```
REM  CAS Analysis Program version 2.0, by Captain James A. Gordon
REM  Created:  17 APR 96
REM  Purpose:  To read text database extraction of CAS database.
REM  Input:    Selected records from DCONTRCT.DBF and CONTRACT.DBF,
REM            sorted by PNO, CNO and Submission Date
REM  Output:   Parameters by PNO and CNO:  Std Error, CPI Min, CPI final
REM            for each contract with history from <25% thru >75% complete.
REM  Use:      To be imported into MS Excel for statistical testing.
REM
REM  Set up screen and initialize variables
REM

CLS
PRINT "PNO", "CNO", "Submission Date"
PRINT
PRINT "BCWS", "BCWP", "ACWP"
PRINT
PRINT "PMB", "OTBCVA", "OTBCVS"
PRINT
PRINT "CONTRACT", "CPI MIN", "CPI LAST"

DIM pmbi(120)
cpimin = 1
good = 0
PNOI = 0
CNOI = 0
pc = 0
i = 0
j = 0
t = 0
dumpflg = 0

REM  Open data files and read records.  Extract variable values from data.
REM
OPEN "sorted_n.txt" FOR INPUT AS 1
OPEN "output.txt" FOR OUTPUT AS 2

INPUT #1, a$, b$, c$, d$, e$, f$, g$, h$, i$
10 IF EOF(1) GOTO 20

INPUT #1, PNO, CNO, subdate$, BCWS, BCWP, ACWP, pmb, OTBCVA, OTBSVA
```

```
IF PNO = 0 GOTO 10

REM   Check for new contract
REM
IF CNO <> CNOI OR PNO <> PNOI THEN

REM   Check for pc > 75%.  If true go to Output subroutine
REM
      IF pc > .75 AND good = 1 THEN GOSUB 2000
      out$ = ""
      cpimin = 1
      i = 0
      good = 0
END IF

REM   Calculate basic parameters
REM
pc = BCWP / pmb
cpi = BCWP / ACWP
spi = BCWP / BCWS
sci = cpi * spi

REM   Check for initial pc < 25%
REM
IF pc < .25 AND good = 0 THEN
      good = 1
      pci = pc

REM   Go to Getcontract subroutine
REM
      GOSUB 1000

END IF
IF good = 0 THEN GOTO 10

REM   Load Registers

IF i = 120 THEN STOP
pmbi(i) = pmb
i = i + 1
IF cpi < cpimin THEN cpimin = cpi
lastsub$ = subdate$

REM  Print status of data extraction.
```

```
REM
LOCATE 1
PRINT: PRINT "                              "
PRINT: PRINT "                              "
PRINT: PRINT "                              "
PRINT: PRINT "                              "
PRINT "                              "

LOCATE 1
PRINT: PRINT PNO, CNO, subdate$
PRINT: PRINT BCWS, BCWP, ACWP
PRINT: PRINT pmb, OTBCVA, OTBSVA
PRINT: PRINT contract$, cpimin, cpi

REM   Loop back to next record unless interrupted from keyboard
REM
z$ = INKEY$
IF z$ = "" THEN GOTO 10

20 REM  Output Contract and Program Counters and close files.
REM
PRINT i, j
CLOSE 1
CLOSE 2
PRINT "The End"
STOP

1000 REM  Subroutine Getcontract
contract$ = STR$(PNOI) + " " + STR$(CNOI)
service$ = STR$(CNOI) + " " + STR$(PNOI)

REM     Read records from contract.txt
OPEN "contract.txt" FOR INPUT AS 3
30 IF EOF(3) GOTO 40
INPUT #3, pn, cn, kt$, tp$
IF pn <> PNO OR cn <> CNO THEN GOTO 30
contract$ = kt$
service$ = LEFT$(kt$, 6)
40 CLOSE 3

PNOI = PNO
CNOI = CNO
subdatei$ = subdate$
```

```
RETURN

2000 REM  Subroutine Output

REM     Calculate pmb mean
REM
 sum = 0
FOR j = 0 TO i
 sum = sum + pmbi(j)
NEXT j
 mean = sum / (i + 1)

REM     Calculate Standard Deviation of pmb
REM
 sum = 0
FOR j = 0 TO i
 sum = (mean - pmbi(j)) ^ 2
NEXT j
 stderr = (sum / (i)) ^ .5 / mean
i = 0
n = n + 1

REM     Format output
REM
LOCATE 14: PRINT contract$, service$
LOCATE 15: PRINT "    N      PCI     PC  CPIMIN  CPILAST  STDERR"
LOCATE 16: PRINT USING "####.###"; n; pci; pc; cpimin; cpi; stderr
x$ = STR$(PNO) + "," + STR$(CNO) + "," + service$ + "," + tp$
x$ = x$ + "," + STR$(cpimin) + "," + STR$(cpi) + "," + STR$(stderr) + ","
x$ = x$ + STR$(mean) + "," + subdatei$ + "," + lastsub$
PRINT #2, x$

RETURN
```

Appendix D: Regression Summaries

The following pages contain regression summaries for each of the populations for which linear regression was attempted. The sheets are the "Summary Output" from Microsoft *Excel* and contain five parts. The first part is titled "Regression Statistics" and contains information about the quality of the line fit. Beside this data are graphs of the data and best fit line. The data are last reported CPI which is plotted against Coefficient of Variation, which in this case is the PMB coefficient of variation.

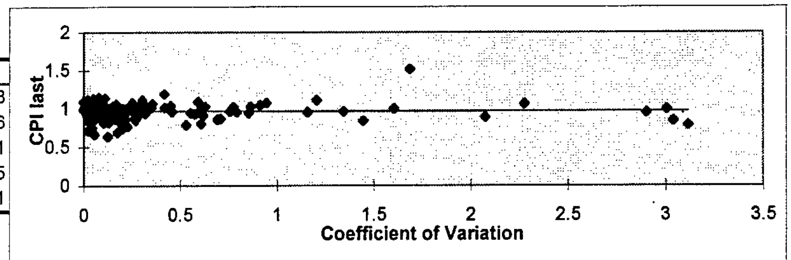
Below is an ANOVA table indicating the allocation of variation attributable to regression and error. When the F value is less than the Significance F, then the regression does not explain a significant portion of the variation.

The final section is the description of the linear regression coefficients. The coefficient for the variable labeled "C.V." is the β_1 from our model. The P-value indicates the level of confidence at which we can declare the coefficient to be zero. Also provided are the 95% confidence interval for the coefficients.

One sheet is provided for each population described in Chapter 3. The population is identified at the top of the sheet.

Air Force

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.022216788
R Square	0.000493586
Adjusted R Square	-0.006214511
Standard Error	0.106286075
Observations	151

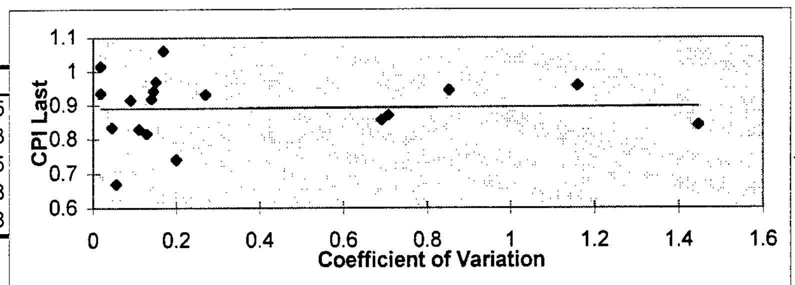
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.00083122	0.00083122	0.07358058	0.786568507
Residual	149	1.683212716	0.01129673		
Total	150	1.684043936			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.96317984	0.01019661	94.46079015	7.4513E-135	0.943031199	0.98332848
C.V.	0.004038256	0.014887173	0.271257406	0.786568507	-0.025379002	0.033455514

F04701

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.023117595
R Square	0.000534423
Adjusted R Square	-0.061932175
Standard Error	0.097687768
Observations	18

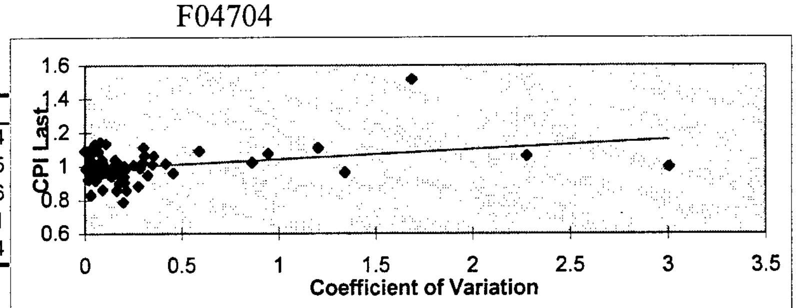
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	8.16428E-05	8.16428E-05	0.008555344	0.927452929
Residual	16	0.152686401	0.0095429		
Total	17	0.152768044			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.890558722	0.03030357	29.38791468	2.37204E-15	0.826318039	0.954799406
C.V.	0.00511952	0.055349099	0.092495101	0.927452929	-0.1122153	0.122454341

F04704

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.316198364
R Square	0.099981405
Adjusted R Square	0.085464976
Standard Error	0.095187571
Observations	64

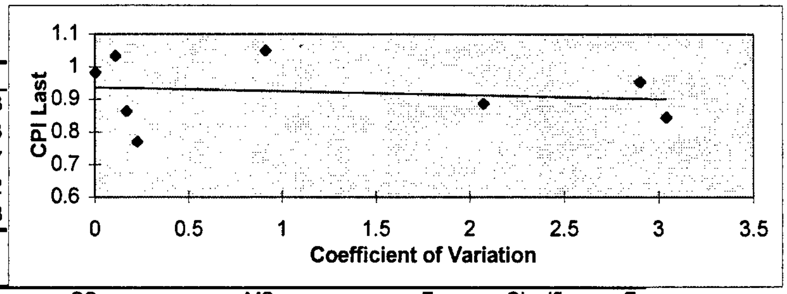
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.062405078	0.062405078	6.887465624	0.010915162
Residual	62	0.561761767	0.009060674		
Total	63	0.624166845			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.983958087	0.013855011	71.01821288	4.1811E-61	0.956262347	1.011653828
C.V.	0.059110311	0.022523378	2.624398145	0.010915162	0.01408677	0.104133853

F08635

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.15693783
R Square	0.024629483
Adjusted R Square	-0.13793227
Standard Error	0.103943642
Observations	8

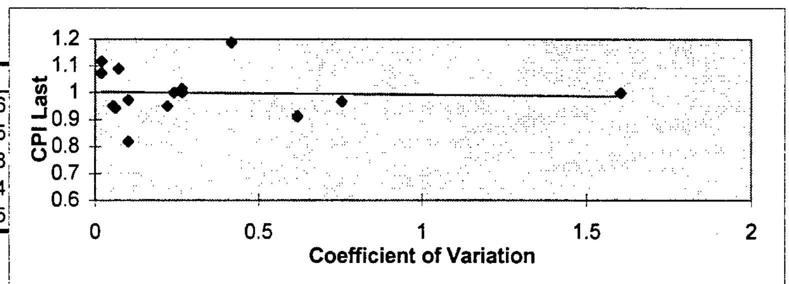
ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.00163694	0.00163694	0.151508471	0.71053749
Residual	6	0.064825684	0.010804281		
Total	7	0.066462624			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.937071146	0.051314785	18.26123108	1.73696E-06	0.811508299	1.062633993
C.V.	-0.011801791	0.030320019	-0.38924089	0.71053749	-0.085992258	0.062388676

F19628

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.049308366
R Square	0.002431315
Adjusted R Square	-0.074304738
Standard Error	0.093338054
Observations	15

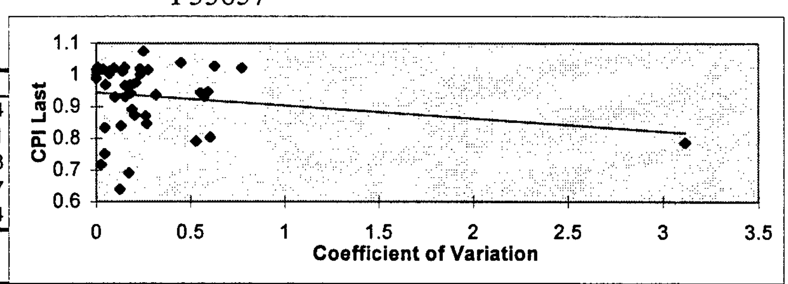
ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.000276032	0.000276032	0.031684129	0.861466462
Residual	13	0.1132559	0.008711992		
Total	14	0.113531932			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	1.003608769	0.030871788	32.50892896	7.74477E-14	0.936914338	1.0703032
C.V.	-0.010653698	0.059852112	-0.178000362	0.861466462	-0.1399563	0.118648904

F33657

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.188774314
R Square	0.035635741
Adjusted R Square	0.012674688
Standard Error	0.103184477
Observations	44

ANOVA

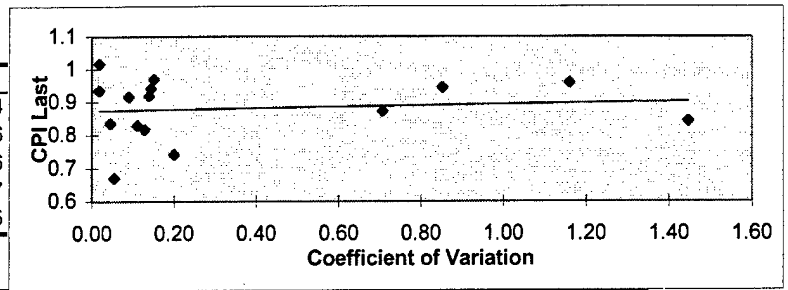
	df	SS	MS	F	Significance F
Regression	1	0.016524287	0.016524287	1.552008102	0.219744165
Residual	42	0.447175527	0.010647036		
Total	43	0.463699814			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.945397857	0.018212759	51.90854667	9.95578E-40	0.908643009	0.982152704
C.V.	-0.040965454	0.032882951	-1.245796172	0.219744165	-0.107325956	0.025395048

F04701 FP

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.104403954
R Square	0.010900186
Adjusted R Square	-0.065184416
Standard Error	0.095363037
Observations	15



ANOVA

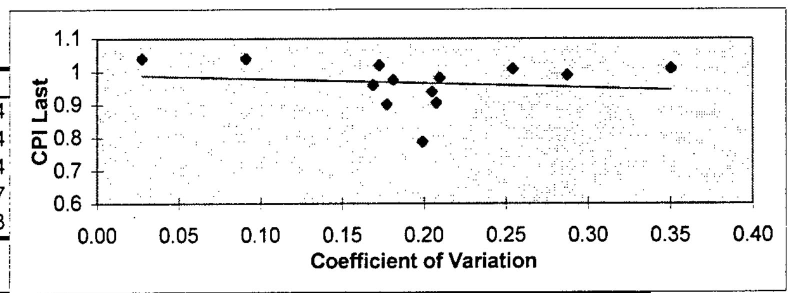
	df	SS	MS	F	Significance F
Regression	1	0.001302859	0.001302859	0.143264016	0.711166559
Residual	13	0.118223416	0.009094109		
Total	14	0.119526275			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.873481089	0.031409376	27.80956513	5.73864E-13	0.80562527	0.941336907
C.V.	0.020982605	0.055435867	0.378502333	0.711166559	-0.098779282	0.140744493

F04704 CP

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.147803634
R Square	0.021845914
Adjusted R Square	-0.067077184
Standard Error	0.07204337
Observations	13



ANOVA

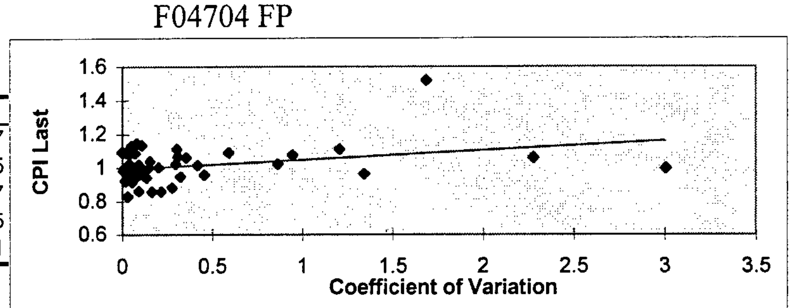
	df	SS	MS	F	Significance F
Regression	1	0.001275098	0.001275098	0.245671986	0.629892463
Residual	11	0.057092719	0.005190247		
Total	12	0.058367817			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.991216119	0.05432836	18.24491137	1.42821E-09	0.871640144	1.110792094
C.V.	-0.128481195	0.259215966	-0.495653091	0.629892463	-0.699011979	0.442049589

F04704 FP

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.321745667
R Square	0.103520275
Adjusted R Square	0.08522477
Standard Error	0.099779075
Observations	51



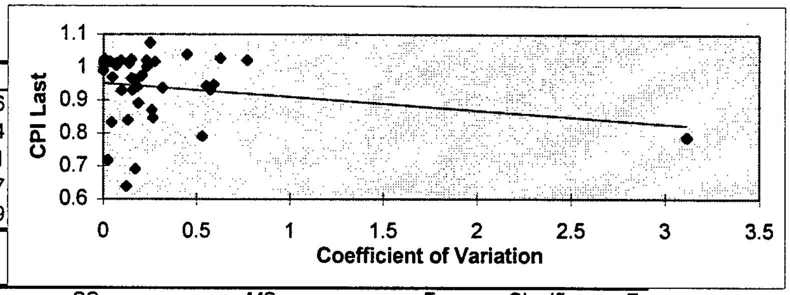
ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.056332622	0.056332622	5.658235548	0.021315147
Residual	49	0.487837326	0.009955864		
Total	50	0.544169949			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.992274927	0.016219253	61.17883081	6.09947E-48	0.959681138	1.024868716
C.V.	0.056659772	0.023819592	2.378704594	0.021315147	0.00879254	0.104527004

SUMMARY OUTPUT

F33657 FP



Regression Statistics	
Multiple R	0.200549006
R Square	0.040219904
Adjusted R Square	0.014279901
Standard Error	0.102122807
Observations	39

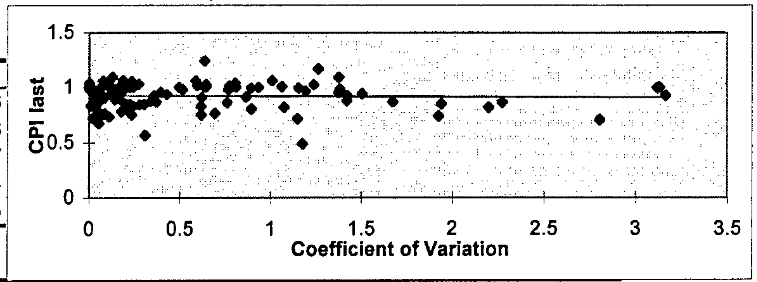
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.016170241	0.016170241	1.550497299	0.22089069
Residual	37	0.385875508	0.010429068		
Total	38	0.402045749			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.952537072	0.019048243	50.00655837	1.40494E-35	0.913941703	0.991132441
C.V.	-0.041005527	0.03293115	-1.245189664	0.22089069	-0.107730309	0.025719255

Army

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.035303083
R Square	0.001246308
Adjusted R Square	-0.008175897
Standard Error	0.118556714
Observations	108

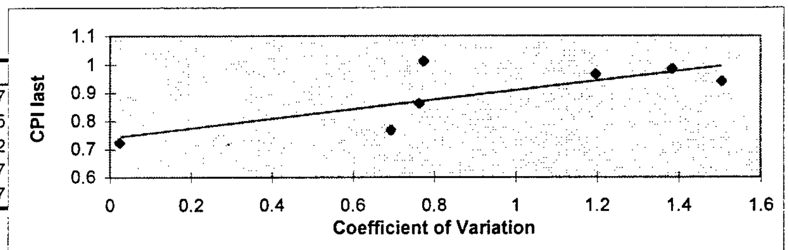
ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.001859195	0.001859195	0.132273464	0.716810758
Residual	106	1.489903599	0.014055694		
Total	107	1.491762794			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.926481995	0.01508828	61.4040818	1.11764E-84	0.896567994	0.956395995
C.V.	-0.005803783	0.015957865	-0.36369419	0.716810758	-0.037441821	0.025834255

DAAB07

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.761905627
R Square	0.580500185
Adjusted R Square	0.496600222
Standard Error	0.079400187
Observations	7

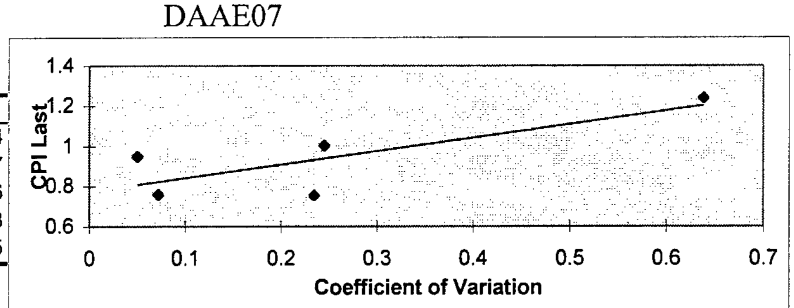
ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.043619798	0.043619798	6.918956389	0.046511348
Residual	5	0.031521949	0.00630439		
Total	6	0.075141747			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.742019187	0.065428065	11.34099233	9.32254E-05	0.573831266	0.910207108
C.V.	0.168801069	0.064173377	2.630390919	0.046511348	0.00383842	0.333763717

DAAE07

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.788713374
R Square	0.622068787
Adjusted R Square	0.496091716
Standard Error	0.142425328
Observations	5

ANOVA

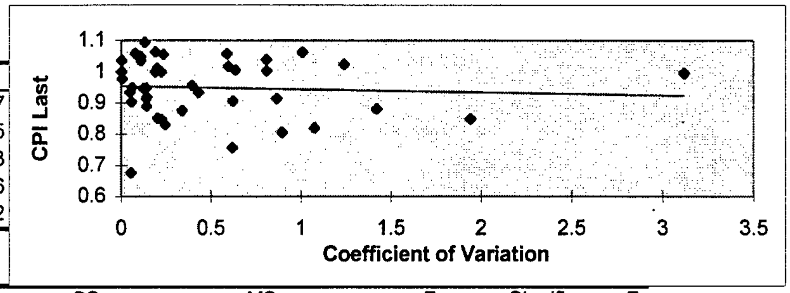
	df	SS	MS	F	Significance F
Regression	1	0.100166237	0.100166237	4.937952452	0.112817129
Residual	3	0.060854922	0.020284974		
Total	4	0.161021159			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.775535528	0.098374399	7.883509706	0.004253151	0.462463993	1.088607064
C.V.	0.67085322	0.301893705	2.222150412	0.112817129	-0.289908186	1.631614627

DAAH01

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.064511047
R Square	0.004161675
Adjusted R Square	-0.020734283
Standard Error	0.094566396
Observations	42



ANOVA

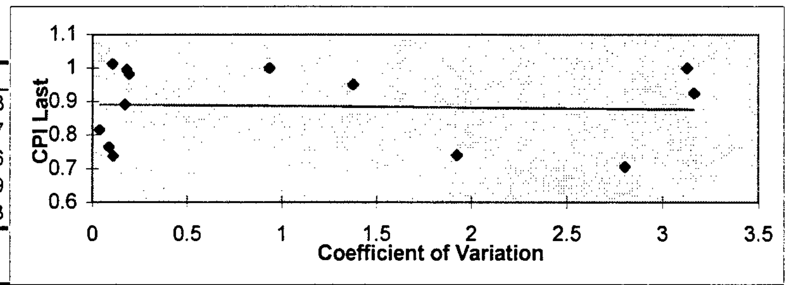
	df	SS	MS	F	Significance F
Regression	1	0.001494903	0.001494903	0.167162686	0.684826676
Residual	40	0.357712128	0.008942803		
Total	41	0.359207031			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.955175704	0.018861229	50.64228378	6.72416E-38	0.917055753	0.993295654
C.V.	-0.009997847	0.024453263	-0.408855336	0.684826676	-0.059419714	0.03942402

DAAJ01

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.05136893
R Square	0.002638767
Adjusted R Square	-0.088030436
Standard Error	0.121422209
Observations	13



ANOVA

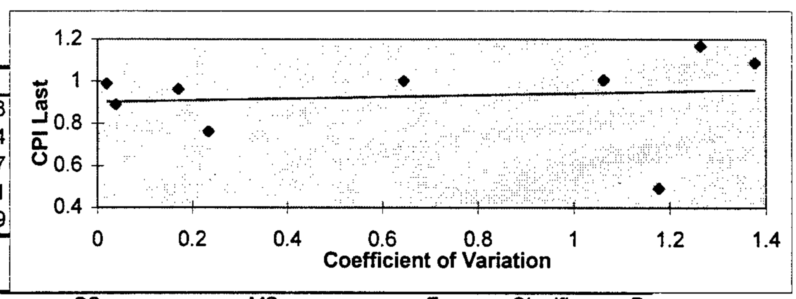
	df	SS	MS	F	Significance F
Regression	1	0.000429079	0.000429079	0.029103234	0.867638274
Residual	11	0.162176882	0.014743353		
Total	12	0.162605961			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.891922798	0.045604528	19.55776821	6.79223E-10	0.791547856	0.992297739
C.V.	-0.004788992	0.028072011	-0.170596699	0.867638274	-0.066575103	0.056997118

DAAK30

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.116790043
R Square	0.013639914
Adjusted R Square	-0.12726867
Standard Error	0.211351771
Observations	9



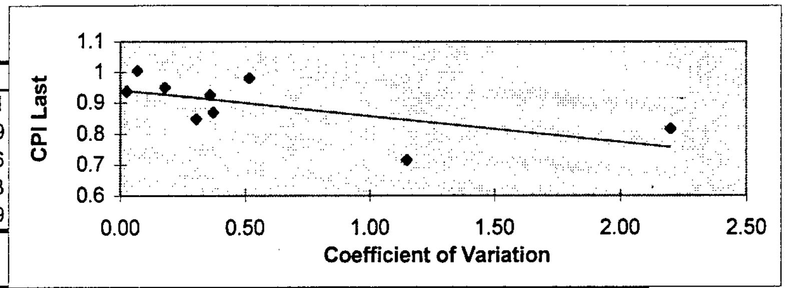
ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.004324003	0.004324003	0.096799739	0.764765077
Residual	7	0.312686997	0.044669571		
Total	8	0.317011			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.901992592	0.11315026	7.971635181	9.32394E-05	0.634434935	1.169550249
C.V.	0.041369847	0.132967905	0.311126565	0.764765077	-0.27304906	0.355788755

DAAK40

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.642548901
R Square	0.41286909
Adjusted R Square	0.328993246
Standard Error	0.074641173
Observations	9

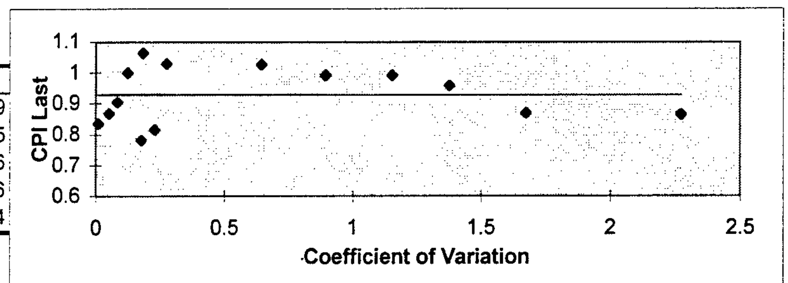
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.0274241	0.0274241	4.922383712	0.062001154
Residual	7	0.038999133	0.005571305		
Total	8	0.066423233			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.943202819	0.033147198	28.45497918	1.7023E-08	0.864822208	1.02158343
C.V.	-0.084421428	0.038050903	-2.218644566	0.062001154	-0.174397451	0.005554594

DAAK50

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.009531849
R Square	9.08561E-05
Adjusted R Square	-0.083234906
Standard Error	0.094276246
Observations	14

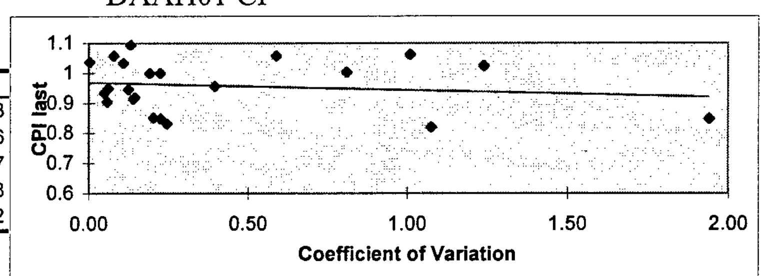
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	9.69124E-06	9.69124E-06	0.001090373	0.974200894
Residual	12	0.106656127	0.008888011		
Total	13	0.106665818			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.929749067	0.034774931	26.73618721	4.60172E-12	0.853981002	1.005517131
C.V.	-0.001208041	0.03658426	-0.033020793	0.974200894	-0.080918295	0.078502213

DAAH01 CP

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.146893623
R Square	0.021577736
Adjusted R Square	-0.027343377
Standard Error	0.085372168
Observations	22

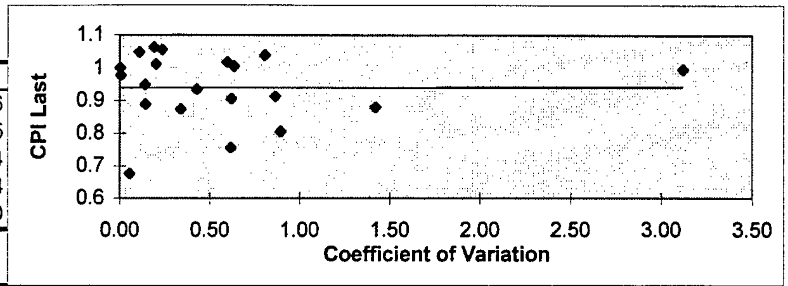
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.003214713	0.003214713	0.441072065	0.51418988
Residual	20	0.145768142	0.007288407		
Total	21	0.148982855			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.969336485	0.023813004	40.70618241	1.03122E-20	0.919663452	1.019009518
C.V.	-0.02473185	0.037239327	-0.664132566	0.51418988	-0.102411688	0.052947989

DAAH01 FP

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.008377526
R Square	7.01829E-05
Adjusted R Square	-0.055481474
Standard Error	0.10713224
Observations	20

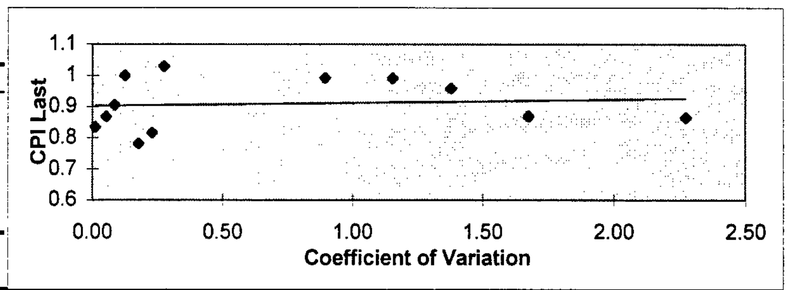
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.45002E-05	1.45002E-05	0.001263382	0.972037109
Residual	18	0.206591703	0.011477317		
Total	19	0.206606203			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.939845028	0.031195023	30.12804408	7.4359E-17	0.874306666	1.00538339
C.V.	0.001240018	0.034886768	0.035544082	0.972037109	-0.072054418	0.074534454

DAAK50 FP

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.094993742
R Square	0.009023811
Adjusted R Square	-0.090073808
Standard Error	0.085811205
Observations	12

ANOVA

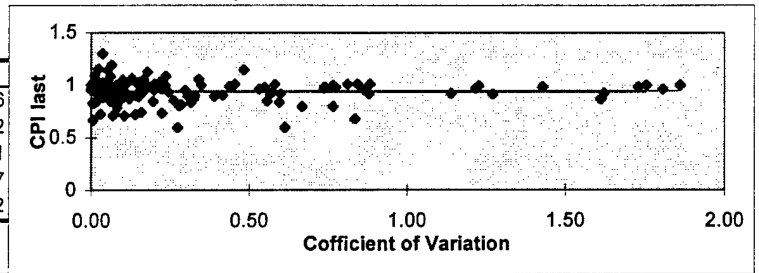
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.000670525	0.000670525	0.091059816	0.7690163
Residual	10	0.073635628	0.007363563		
Total	11	0.074306153			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.902420433	0.034195997	26.38965153	1.40729E-10	0.826226991	0.978613874
C.V.	0.010235111	0.033917915	0.30176119	0.7690163	-0.065338728	0.085808949

All Navy

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.03384926
R Square	0.001145772
Adjusted R Square	-0.005988901
Standard Error	0.109461127
Observations	142



ANOVA

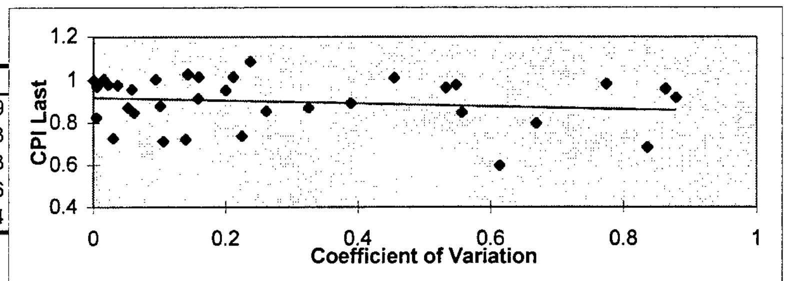
	df	SS	MS	F	Significance F
Regression	1	0.001924173	0.001924173	0.160592139	0.689222842
Residual	140	1.677443362	0.011981738		
Total	141	1.679367535			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.946684844	0.011610086	81.53986512	6.8586E-120	0.923731065	0.969638623
C.V.	-0.008767229	0.021877626	-0.40073949	0.689222842	-0.0520205	0.034486043

N00019

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.168035689
R Square	0.028235993
Adjusted R Square	-0.002131633
Standard Error	0.117091946
Observations	34



ANOVA

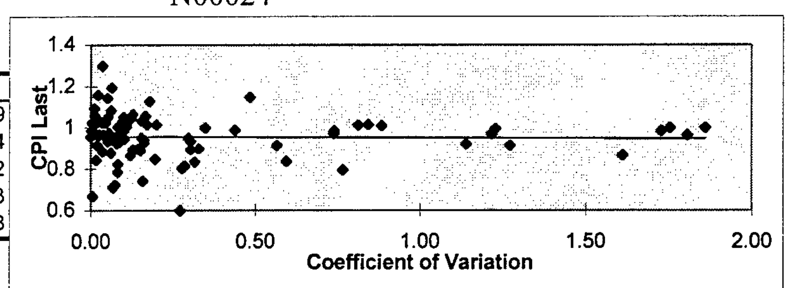
	df	SS	MS	F	Significance F
Regression	1	0.012748124	0.012748124	0.929805756	0.342144333
Residual	32	0.438736761	0.013710524		
Total	33	0.451484885			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.919626207	0.029021856	31.68736716	9.73697E-26	0.86051067	0.978741743
C.V.	-0.070214958	0.072817124	-0.96426436	0.342144333	-0.21853846	0.078108545

N00024

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.024694619
R Square	0.000609824
Adjusted R Square	-0.011010992
Standard Error	0.112403083
Observations	88



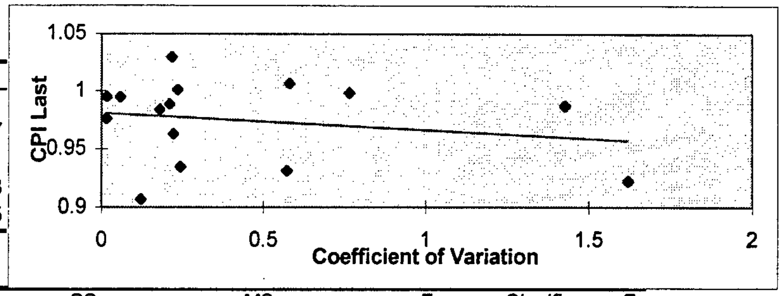
ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.000663017	0.000663017	0.052476885	0.819351928
Residual	86	1.086562966	0.012634453		
Total	87	1.087225982			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.958540661	0.014624592	65.54307085	3.38537E-75	0.929467958	0.987613364
C.V.	-0.005972186	0.026070495	-0.229078338	0.819351928	-0.057798572	0.045854201

N00030

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.208592851
R Square	0.043510977
Adjusted R Square	-0.030065101
Standard Error	0.035943338
Observations	15

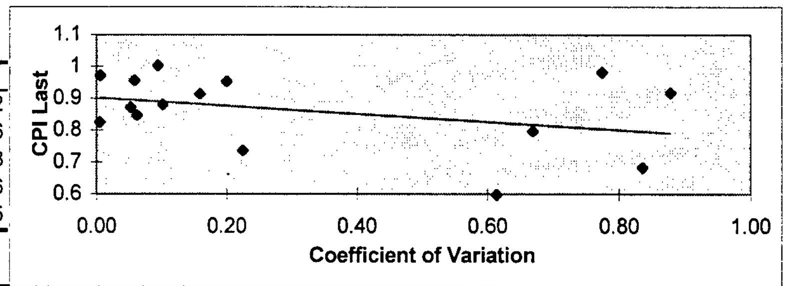
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.00076401	0.00076401	0.591373967	0.455633376
Residual	13	0.016795006	0.001291924		
Total	14	0.017559016			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.981173558	0.012533056	78.28685406	8.98916E-19	0.954097541	1.008249575
C.V.	-0.01494506	0.019434196	-0.769008431	0.455633376	-0.056930079	0.027039959

N00019 CP

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.359682952
R Square	0.129371826
Adjusted R Square	0.062400428
Standard Error	0.113474476
Observations	15

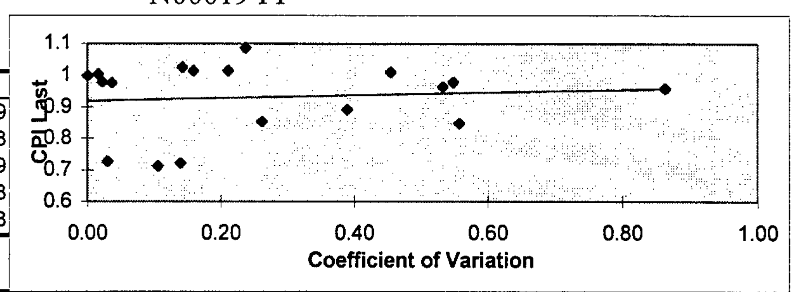
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.024874062	0.024874062	1.931747424	0.187909654
Residual	13	0.167393936	0.012876457		
Total	14	0.192267998			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.902642775	0.041113359	21.95497529	1.16736E-11	0.81382278	0.991462769
C.V.	-0.126844566	0.091263411	-1.389873168	0.187909654	-0,324007139	0.070318008

N00019 FP

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.097949669
R Square	0.009594138
Adjusted R Square	-0.052306229
Standard Error	0.116500688
Observations	18

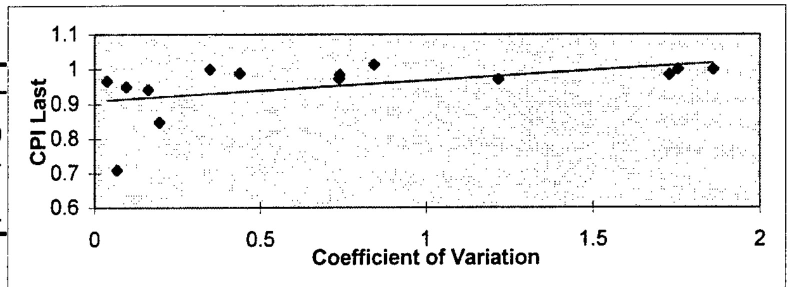
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.002103632	0.002103632	0.154993229	0.699005469
Residual	16	0.217158566	0.01357241		
Total	17	0.219262198			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.919780538	0.040899802	22.48863082	1.55754E-13	0.833076851	1.006484224
C.V.	0.045537864	0.115668816	0.393691795	0.699005469	-0.199669018	0.290744745

N00024 CP

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.482932841
R Square	0.233224129
Adjusted R Square	0.16932614
Standard Error	0.073426111
Observations	14

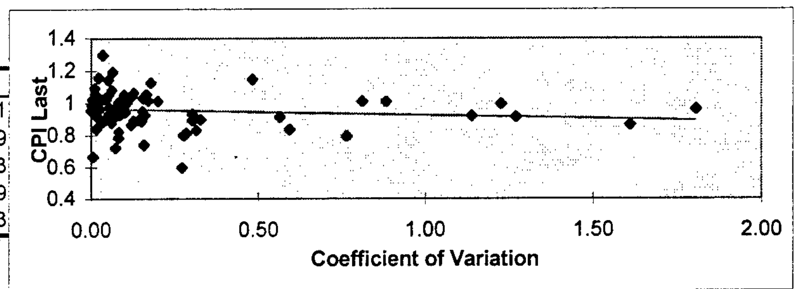
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.019678289	0.019678289	3.649944735	0.080254199
Residual	12	0.064696724	0.005391394		
Total	13	0.084375014			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.909308316	0.029797144	30.5166261	9.61568E-13	0.844385917	0.974230716
C.V.	0.058586416	0.030665764	1.910482854	0.080254199	-0.008228543	0.125401375

N00024 FP

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.131004501
R Square	0.017162179
Adjusted R Square	0.003319393
Standard Error	0.117800689
Observations	73

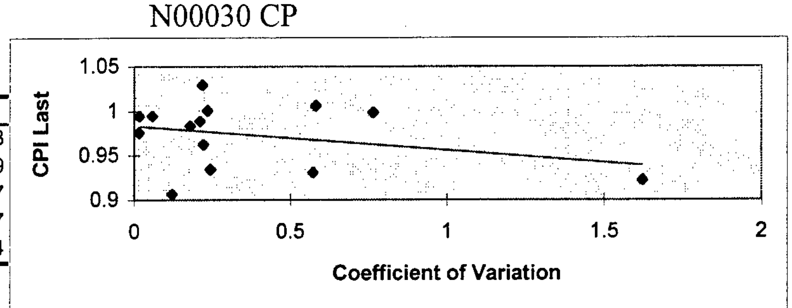
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.0172046	0.0172046	1.239792257	0.269266532
Residual	71	0.985267165	0.013877002		
Total	72	1.002471765			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.967624223	0.016486898	58.69049566	6.54475E-62	0.934750265	1.00049818
C.V.	-0.04135401	0.037140108	-1.11345959	0.269266532	-0.115409318	0.032701299

N00030 CP

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.318312518
R Square	0.101322859
Adjusted R Square	0.026433097
Standard Error	0.036089327
Observations	14

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.001762149	0.001762149	1.352960094	0.267369777
Residual	12	0.015629274	0.00130244		
Total	13	0.017391423			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.983706146	0.012865546	76.46050728	1.66798E-17	0.955674531	1.011737761
C.V.	-0.02733525	0.023500687	-1.163168128	0.267369777	-0.078538846	0.023868347

Appendix E: Winer's Two Factor ANOVA With Unequal Cell Frequencies

Because the cell frequencies are related to the factors, the unweighted means approach is not appropriate. The Least Squares approach is given in Winer pp291-297

Least Squares Method

(i) Cell frequencies nij

	0C	1C	2C	3C	4C	ni.	
Q1	134	54	27	14	9	238	
Q2	100	39	20	10	17	186	
Q3	71	29	13	13	8	134	
Q4	69	23	11	5	3	111	
n.j	374	145	71	42	37	669	n..

(ii) Cell Totals Aij

	0C	1C	2C	3C	4C	Ai	Ai^2/ni.
Q1	122.42	52.00	25.77	13.06	8.77	222.0191	207.1112
Q2	94.19	32.83	17.87	9.43	14.88	169.2069	153.93
Q3	62.98	25.87	12.57	12.84	7.05	121.313	109.8273
Q4	64.32	21.50	9.69	4.98	3.00	103.4958	96.49892
Bj	343.9204	132.2054	65.90124	40.30858	33.69918	616.0348	G
Bj^2/n.j	316.2601	120.5397	61.16864	38.68528	30.69283		

(iii) Equations

(1) = G^2/n.. 567.2629

(2) = sum(X^2) 587.6086

(3) = sum(Ai^2/ni.) 567.3674

(4) = sum(Bj^2/n.j) 567.3466

(5) = sumsum(ABij^2/nij) 568.0479

Cell Totals Squared by cell frequency

111.8421	50.07925	24.59285	12.18437	8.539248
88.72631	27.64044	15.96843	8.892834	13.02201
55.87158	23.0732	12.15248	12.68545	6.215587
59.96085	20.10291	8.541163	4.952036	3.00472

Least Squares Method for levels greater than 2

(i) Cell Frequencies nij

	0C	1C	2C	3C	4C	ni.	Ai
Q1	134	54	27	14	9	238	222.0191
Q2	100	39	20	10	17	186	169.2069
Q3	71	29	13	13	8	134	121.313
Q4	69	23	11	5	3	111	103.4958
n.j	374	145	71	42	37	669	n..
Bj	343.9204	132.2054	65.90124	40.30858	20.50164		

(ii) n'ij

	0C	1C	2C	3C	4C	B'j
0C	164.2799	-81.0341	-39.6803	-23.2549	-20.3107	(0.67)
1C		113.5286	-15.4123	-9.12271	-7.9595	(1.35)
2C			63.43515	-4.42019	-3.92238	0.49
3C				39.15242	-2.35464	1.72
4C					34.54721	(13.40)

Dwyer Square Root Algorithm

						B'	B'^2	
OC'	12.81717	-6.32231	-3.09587	-1.81435	-1.58465	-0.05199	0.002703	
1C'		8.576541	-4.07919	-2.40115	-2.0962	-0.19538	0.038172	
2C'			6.10008	-3.2511	-2.84898	-0.07599	0.005774	
3C'				4.418751	-4.41875	0.205902	0.042396	
4C'						0.089045	0.089045	SSb(adj)

Unadjusted Sums of Squares

SScells = (5) - (1) 0.784921
SSqtr = (3) - (1) 0.10446 = SSa
SSchgs = (4) - (1) 0.083637 = SSb
SSerror = (2) - (5) 19.56077

Adjusted Sums of Squares

SSab(adj) = SScells -SSb(adj) - SSa = 0.591415
SSa(adj) = SScells - SSab(adj) - SSb = 0.109868

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Vita

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His was first assigned as a Satellite Systems Engineer with the historic 1000th Satellite Operations Group, Offutt AFB, Nebraska. In September of 1992, he was appointed the Program Integrator for the Defense Meteorological Satellite Program under the Defense Plant Representative Office for General Electric Delaware Valley, Defense Contract Management Command. While assigned, he completed Squadron Officers' School both by correspondence and in residence, as well as numerous Professional Continuing Education courses from the Defense Systems Management College. He also completed three graduate courses in Mechanical Engineering through correspondence with the University of Idaho. In May 1992, he entered the School of Logistics and Acquisition Management, Air Force Institute of Technology.

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13. ABSTRACT *(Maximum 200 Words)*

This thesis explores the assumption that cost overruns are related to contract changes. A common assertion in defense literature says that contracts which are relatively stable suffer smaller overruns than those which are highly volatile. The stability or volatility of contracts is characterized by their change history. A contract which is modified frequently or by large amounts is more unstable, or volatile, than one which is not changed either as often or by lesser amounts. This study attempts to find evidence supporting this common assertion by examining the relationship between cost growth and baseline stability on over 400 Major Defense Acquisition Program contracts over the last 26 years. The results are intriguing because, counter-intuitively, no significant evidence is found. Possible explanations and implications of this discovery are provided.

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