AFIT/GSM/LAS/93S-20

ANALYSIS OF COST AND SCHEDULE GROWTH ON SOLE SOURCE AND COMPETITIVE AIR FORCE CONTRACTS

THESIS

Klaes W. Wandland, Captain, USAF

Gary P. Wickman, Captain, USAF

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THESIS

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of the Air Force Institute of Technology
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Requirements for the Degree of
Master of Science in Systems Management

Klaes W. Wandland
Captain, USAF

Gary P. Wickman
Captain, USAF

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Preface

The purpose of this study was to determine if differences exist in the cost and schedule growth of competed versus sole source contracts. Prior studies concentrated mainly on estimated savings from competition at the time of contract award. This study expanded prior analysis by investigating the cost and schedule growth over the contract's period of performance.

When comparing competed and sole source contracts the results were consistent, with sole source contracts exhibiting higher cost growths in all areas. The sole source contracts also exhibited a higher schedule growth. Between lower and higher initial priced contracts the results were also consistent with higher priced contracts exhibiting higher cost growth in all areas. The results were mixed however when measured between lower and higher risk contracts.

This thesis effort would not have been possible without the invaluable assistance of Mr. Walt Wilson, Section Chief Financial/Disbursement Section, Function Systems Branch, System RND Support Division, Directorate of Contracting ASC/PK, Wright-Patterson AFB, OH whose guidance and expertise helped focus this research.

The dedication and advice of our advisors, Lieutenant Colonel David J. Murphy and Major T. Scott Graham, were also instrumental in the successful accomplishment of this research effort.

Klaes W. Wandland
Gary P. Wickman

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Abstract

The purpose of this study was to determine if differences exist in the cost and schedule growth of competed versus sole source contracts. Prior studies concentrated mainly on estimated savings from competition at the time of contract award. This study expanded prior analysis by investigating the cost and schedule growth over the contract's period of performance.

In addition to an analysis of cost and schedule growth between competed and sole source contracts, the cost growth analysis also investigated differences between lower and higher risk contracts as well as lower and higher initial priced contracts. The results were consistent in every category with sole source contracts showing a greater cost and schedule growth than competed contracts.

When comparing competed and sole source contracts, the results were consistent with sole source contracts exhibiting an average of 57% higher cost growth in all areas. Sole source contracts also exhibited a higher schedule growth that was over 4 times greater than the schedule growth of competed contracts.

When comparing lower and higher initial priced contracts, the results were also consistent with higher priced contracts exhibiting higher cost growth than lower price contracts. The results were mixed when measured between lower and higher risk contracts however.

ANALYSIS OF COST AND SCHEDULE GROWTH ON SOLE SOURCE AND COMPETITIVE AIR FORCE CONTRACTS

I. Introduction

Chapter Overview

This chapter describes the general issue and specific problem researched by this thesis. Also, the research objectives, investigative questions, hypotheses and research variables are explained. Finally, the scope and limitations of the research are defined.

General Issue

Competition in defense acquisitions has long been recognized as a means to improving performance, reducing risk, benefiting schedule, improving quality, strengthening the defense industrial base, and reducing acquisition costs (9:1-1). Although these benefits seem reasonable, all have been somewhat difficult to measure. Because cost savings are easier to measure than the other parameters, it has become the focus of research on the effects of competition. The emphasis on cost savings as the primary measure of the benefits of competition began in the early 1960's during the tenure of Secretary of Defense McNamara.

> In 1965, the then Secretary of Defense Robert S. McNamara indicated to the Joint Economic Committee (Hearings to the Economic Impact of Federal Procurement) that the General Accounting Office (GAO) had evidence of dollar savings on the order of 25 percent or more when competition was introduced for re-procurement of an item which had a sole-source procurement history. (3:2)

This figure of 25 percent has become a loosely used benchmark of the benefits of competition. This position has consistently been reaffirmed by past and present administrations and Congress. More recently, Public Law 98-369 implemented the Competition in Contracting Act (1984). This act mandates the use of competition to the fullest extent possible on all government procurements. Since McNamara's claim, research efforts have attempted to measure the cost savings achieved through competition. Measuring the savings of competitive versus sole source acquisitions is no trivial task. Numerous costs to develop and maintain competition must be accurately measured to calculate any savings due to competition over sole source awards. Beltramo identified several categories of costs necessary to accurately measure savings due to competition (1:16). These categories are:

Technology transfer to second source
Building educational units
Additional government management
Legal claims against the government
Time value of money

This is not an exhaustive list of the added costs, but serves to illustrate the complexity involved in accurately measuring the "costs of competition".

Separate research by Beltramo (1:16); Boger (4:49), and Berg (2:12) showed general agreement on the categories of costs incurred by the government to compete a procurement, but disagree on the methodologies used to measure the direct contract award savings attributed to the introduction of competition, and any savings resulting from competition. The methodologies developed in prior studies investigating

the "cost of competition" and savings from competition have exclusively used weapon systems that had a period of sole source production followed by competition. These weapon system contracts were used to calculate cost differences between sole source and competitive procurements.

The controversies on methodology primarily focus on how each research study calculates the sole source and competitive unit cost. Due to researchers' inability to develop a standard methodology, the claimed cost savings attributed to competition in most studies have large variations (10:16). Chapter II discusses the differences in research methodologies in prior studies that create variations measuring cost savings. If the methodology used to calculate cost savings can be agreed upon by the researchers studying competition, the DoD may be able to predict the cost reduction achieved with competition at the time of contract award. However, cost savings at the time of contract award is not the only relevant measurement to determine the benefits of competition. For the cost aspects of a program a more pertinent measurement may be the total program cost. Also, since performance schedules are critical source selection criteria, the initial schedules bid by offerors cannot be evaluated as a benefit of competition unless the actual delivery performances on sole-source and competitive acquisitions are evaluated.

Specific Problem

Research to date has not examined the cost and schedule growth during the execution of the contract for sole source

and competitive awards. Research on the benefits of competition has either ignored any differences in cost and schedule growth between competed and sole sourced contracts or has assumed no difference. If cost and schedule growth differences do exist between competed and sole source contracts, then these differences must be considered before claims can be made on the benefits of competition.

Research Objectives

The objective of this research is to determine if cost and schedule growth rates are different on competitive and sole source contract awards. Also, the research will determine if the differences in growth rates on sole source and competitive acquisitions are statistically significant for different program risk levels and initial contract award price levels. Contract risk is identified in this study by the type of contract used by the government. It is generally assumed that cost type contracts are higher risk than fixed priced contracts. Therefore, the higher risk category is comprised of cost-type contracts, while the lower risk category is comprised of fixed price contracts. The initial contract price is simply the total award price of the contract. The sample contracts are stratified by price level in order to determine if high priced efforts have significantly different cost growth than lower priced awards.

By comparing the behavior of cost and schedule growth between sole source and competed contracts, this study will add to the existing body of knowledge on the effects of

competition. Measuring the cost growth rates relative to contract risk gives the Air Force deeper insight into the effects of risk on contract cost growth. By providing the Air Force with an analysis on competition that considers program risk, this research can help decision makers develop acquisition strategies and help select the appropriate type of contract. Measuring cost growth rates relative to initial contract price determines if the dollar amount of a contract is related to the level of competition. At a minimum, the analysis can assist the Air Force developed budgets and schedules based on initial dollar amounts and program risk level.

Research Questions and Hypothesis

To answer the research objective, the following three research questions were investigated and their associated hypotheses were tested.

Research Question #1. For cost growth and schedule growth categories, does the mean growth for a competed contract differ from the mean growth of a sole source contract?

Hypothesis.

Ho: Mean Competed Growth = Mean Sole Source Growth
Ha: Mean Competed Growth ≠ Mean Sole Source Growth

Research Question #2. For the cost growth category only, does the mean cost growth for competed and sole source lower risk contracts differ from competed and sole source higher risk contracts?

Hypothesis.

Ho: Low Risk Mean Growth = High Risk Mean Growth
Ha: Low Risk Mean Growth ≠ High Risk Mean Growth

Research Question #3. For the cost growth category only, does the mean cost growth for competed and sole source lower price contracts differ from competed and sole source higher price contracts?

Hypothesis.

Ho: Low Price Mean Growth = High Price Mean Growth
Ha: Low Price Mean Growth ≠ High Price Mean Growth

These research questions stem from the acquisition phenomenon of "buying-in" to the contract. Buying in is simply the contractor's tendency to bid overly optimistic costs and schedules in hopes of winning an acquisition competition.

> In the competitive bidding for the development contract, contractors frequently submit bids below their expected cost, with the knowledge that price will be renegotiated over time to accommodate engineering change proposals that modify the original design. (10:58)

Contractors on sole source acquisitions may not feel the pressure to bid aggressive schedules and optimistic costs on new work. Based on the buying-in premise, cost and schedule growth may be different on sole source and competitive acquisitions. Figure 1 depicts the anticipated difference in cost growths for sole source and competitive awards.

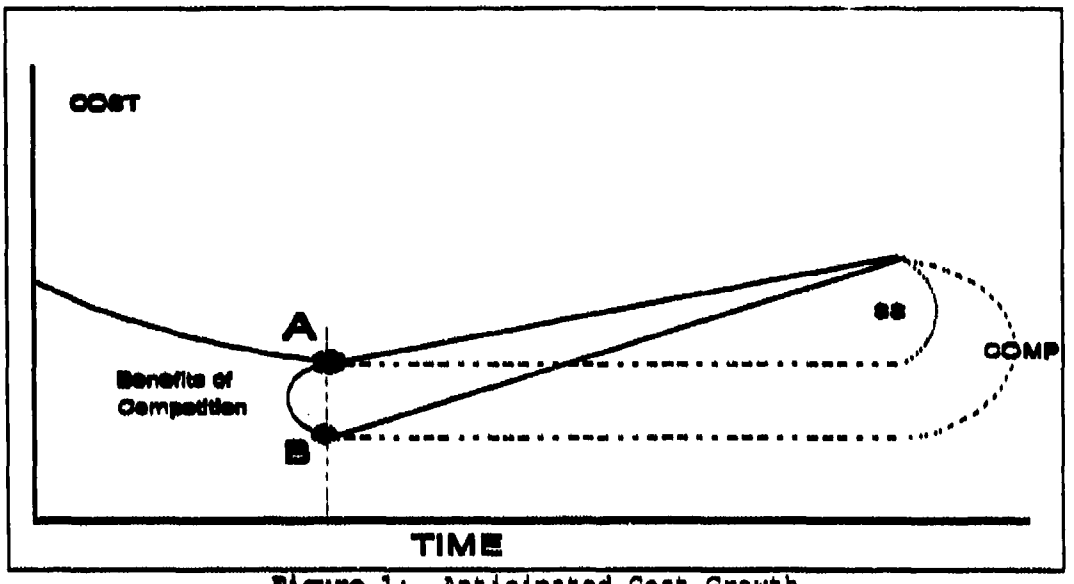

Figure 1: Anticipated Cost Growth

In Figure 1, the points "A" and "B" represent the hypothetical initial contract prices for a sole source and competitive award. The solid lines to the right from points "A" and "B" indicated an anticipated growth in contract price during the period of performance of the contract. It suggests that the competed contract price grows at a faster rate than the sole source award. Although the initial competition seemed to yield a significant cost savings, in the final analysis, no savings were achieved. This is purely for demonstration and not a claim.

Like contract costs, the schedules proposed on competitive acquisitions, may be optimistic. "Competition advocates claim that competition improves the schedule deliveries for defense acquisitions." (4:69). Like costs, researchers merely compare the schedules proposed on competitive and sole source contracts at the time of contract award. If the schedule growth on competed contracts grows at a higher rate than sole source awards,

Figure 1 may also depict how the initial schedule benefits claimed at the time of contract award dissipate over time.

Research Variables

Cost Growth. To complete the research objectives and test the cost growth hypotheses, a sample mean cost growth factor was calculated for each category in 3 phases of tests. The first phase tested the hypothesis for the overall categories of competed and sole source contracts as depicted in Table 3. The second phase tested the hypothesis after the competed and sole source data were segregated into lower and higher risk categories, as depicted in Table 4. The third phase tested the hypothesis after the lower and higher risk data were segregated into lower and higher initial price as depicted in Table 5.

Schedule Growth. To test the schedule growth hypothesis, a sample mean schedule growth factor was computed from a random sample of sole source and competed contracts. A stratification of the data relative to risk and initial contract price similar to cost growth was not possible due to schedule data limitations.

Scope

The research focuses on cost and schedule performance on Air Force Material Command development and production contracts distributed between 1980 and 1990 inclusively. The purpose of choosing these dates is an attempt to mitigate the effects of the defense market business cycle. Boger and Greer believed that the price of defense development and production was somewhat affected by the idle

capacity in the defense industrial base (3:31). Also, this timeframe distributes the sample population 5 years pre CICA and 6 years post CICA. By evaluating contracts over a ten year period, this research attempts to eliminate the bias on the results from both of these factors.

To investigate the research questions associated with cost growth, data was gathered from contracts managed at: Los Angeles AFB, CA; Wright Patterson AFB, OH; Eglin AFB, FL and Hanscom AFB, MA as well as Wright Aeronautical Laboratories, Wright Patterson AFB, OH. To investigate the research question for schedule growth, contracts administered by the Air Force Contract Management Center at Kirtland AFB, NM were used as the sampling population. The purpose of choosing the populations for cost and schedule growth analysis was that they represented a cross-section of the types of weapon systems the Air Force procures.

The contract information that contain the cost and schedule data used in this research was that information captured by the Acquisition Management Information System (AMIS). The AMIS is an acquisition management operating system concerned with pre-award contract, and contract-related data. The system contains information on all AFMC research and development contracts. The AMIS stores data in twenty-six on-line data bases. The two data bases used for this research were the CONTRACT and Program Management System (PMS) data bases. The CONTRACT data base was used to gather contract schedule information while the PMS data base was used to gather cost information.

The CONTRACT and PMS data bases allowed the researchers to measure mean cost and schedule growth on numerous contracts without access to the actual contract files. Because a data base was used rather than original contract documents, the data is subject to input errors. Also, cost and schedule changes due to contract scope changes can not be detected without referencing the original contract documents. Since this research is simply conducting a comparative study of cost and schedule growth on sole source and competed contracts, it is assumed that these affects will be the same on each category under investigation.

The contracts used to test the investigative questions on schedule growth were limited to efforts administered by the Air Force Contract Management Center at Kirtland AFB, NM. This population was used because schedule information on these contracts was more readily accessible than the contracts controlled by other contracting centers. This study limited the contracts considered by eliminating procurements identified as service-type, support, and basic research. These contracts were eliminated from the sampling population because they were not representative of Air Force weapon system development and production contracts.

Also, contracts having a mixture of cost-type and fixed price line items were eliminated because they were not readily identifiable as lower or higher risk.

Conclusion

This thesis does not attempt to quantify the dollar savings resulting from competition nor answer questions

concerning the many possible benefits of competition. This thesis does attempt to assess if differences exist in the cost and schedule growth between competed and sole source contracts. Chapter II provides a comprehensive review of previous research on the effectiveness of competition and controversies surrounding the competition issue. Chapter III describes the methodology used to meet the objectives of this thesis and answer the research questions. Chapter IV presents the findings and analysis of the cost and schedule growth data gathered on competitive and sole source contracts. Finally, Chapter V provides conclusions based on the data analysis as well as recommendations for future research.

II. Literature Review

Introduction

The objective of this research is to determine if a difference exists in cost and schedule growth between sole source and competed Air Force acquisitions. This chapter first highlights the background of the advocacy for the increased use of competition. The differing viewpoints defining competition are then discussed along with some criticisms of competition. The alternative to competition, sole source, is then presented. Lastly, the dual source acquisition strategy is examined along with some of its' criticisms.

This cursory overview of varying acquisitions strategies, along with the historical development of competition, is necessary to fully understand the significance of previous research studies. Those studies are the basis for the savings estimates attributable to competition. Lastly, the savings estimates and the methodology used to develop them are discussed in detail.

Background

The increased push for competition in the early 1960's, which intensified throughout the 1980's, was supported by various studies that showed competition in acquisitions produced dollar savings on the order of 25% (3:2). The culmination of these competition initiatives resulted in the passage of the Competition in Contracting Act (CICA) in 1984, which mandated the use of effective competition for

the procurement of defense goods and services. This act specified that contracts should be awarded on the basis of best value, stating that in many cases, quality may be the dominant factor and cost may be secondary in source selection decisions. Assistant Secretary of the Air Force for Acquisition, John T. Welch Jr., explained in 1988 that the purpose behind CICA "was not to establish competition for competition's sake, but to foster it as part of an overall effort to achieve the best value for our taxpayer's dollars" (5:67).

The current mandates for increased use of competition in weapon system acquisitions exist because competition is believed to provide benefits in many areas. The Department of Defense Directive (DoDD) 5000.1 requires:

> Defense systems, subsystems, equipment, supplies and services shall be acquired on a competitive basis to the maximum extent practical as a means of achieving cost, schedule, and performance benefits. (6:1-6)

Additional benefits from competition can also include: improving quality, strengthening the defense industrial base, enhancing mobilization or surge capability, and reducing risk. Even though these potential benefits were recognized, in 1982, only 34.3% of the total dollars awarded were awarded competitively (10:4).

However, since the implementation of CICA, the total dollar value and relative percentage of competed dollars has risen steadily. In fiscal year 1988, 60.9% of all contracting dollars were awarded as a result of competition, while the dollar value of contracts awarded competitively nearly doubled from fiscal year 1984 to 1988. Competitively

awarded contracts totaled $12.4 billion in 1984. In 1988, that number rose to $23.6 billion (5:67). At that time, John T. Welch Jr. claimed "unparalleled success" for implementing CICA, which resulted in 5 years of increased dollar value of contracts awarded on the basis of competitive bidding" (5:67).

However, it may be misleading to measure the success of CICA based upon increased dollar values of contracts awarded competitively. The 1980's was an era characterized by massive increases in defense spending, and the increased dollar value of competed contracts may simply be attributable to the increases in defense spending.

Not withstanding the dollar level and percentage increases in competitively awarded contracts, the increased pressure for competition demanded an accurate definition of what constituted competition. This definition soon became a highly criticized issue.

Competition Issues

Strong criticism of the services' reporting of competition statistics was made public in March of 1989 with the release of a DoD Inspector General's (IG) report. The key issue raised in the IG report was the question of what is competition? Anthony DeLuca, the Air Force Competition Advocate in 1989, stated "if you have marketplace forces at work, you have competition" (11:42). Taking a more pragmatic view, Joseph F. Grosson and Dr. Joseph H. Augusta contend, "to have competition, there must be a second source, i.e., at least one alternate producer of a weapon

system" (9:33). Clearly, this viewpoint takes DeLuca's definition one step further by stating that competition only exists when more than one actual producer of a weapon system exists. The definition of what constitutes competition is contested, and some criticisms surrounding this issue are discussed below.

Definition of Competition Criticized. In the 1989 IG report, the IG claimed that the services have "grossly exaggerated" competition statistics by inflating competition rates by as much as 50% (11:42). If the IG's accusation is true, then the services have not increased the level of competition, as indicated by the 1988 figure cited earlier. At the center of the controversy was the determination of what is competition. The IG argued that when marketplace forces are artificially created to fulfill the need for competition, the circumstances surrounding the contract award may be suspect (11:42). The IG auditors took exception to the services classifying some contract awards as competitive. Examples cited by the IG were: dual source contracts where the loser would still expect a significant portion of the work, proposals where only one bid was received, and the classification as competitive, those sole source follow-on actions where the original contract was competed. One highly disputed area is the situation where a Request for Proposal is released and only one bidder responds. Policy guidance from the Office of Federal Procurement Policy (OFPP) directs DoD and the services to report such contracts as competed (11:44). For purposes of this research, competition, or competitively awarded

contracts, are considered to exist only where two or more bids were received in response to a solicitation. The views of Grosson and Augusta, that there must be a second source, are the views adopted here. This definition will become apparent in Chapter III where the methodology surrounding the classification of contracts as competitive or sole source is discussed.

The definition of what constitutes competition is only one of its' criticisms. Other significant criticisms discussed in previous research are mentioned here for discussion purposes.

Other Competition Criticisms. John T. Welch Jr. explained the goal of CICA was, through the increased use of competition, to ensure the "best value" in weapon system procurements for the taxpayer's dollars is achieved (5:67). Not withstanding CICA's reported success, criticisms exist concerning competition. The first criticism involves cost and pricing data while the second criticism is how competition may be limited because of non-competitive contract awards early in a program's development.

Cost and Pricing Data. Under federal acquisition regulations, cost and pricing data are not required from a contractor if competition exists. However, by erring on the side of labeling contracts as competitive, the DoD is compromising one of its key safeguards against defective pricing (11:42). A 1988 Defense Contract Audit Agency (DCAA) study reported defective pricing in almost half of the non-competitive contracts audited. Given the DCAA findings, if non-competitive awards are incorrectly being

labeled as competitive, then there is a good chance that defective pricing is occurring at an alarming rate. Anthony DeLuca summed it up well,

> If market forces are really at work, then you don't need cost and pricing data. But if you've created a mirage of competition, and you're hiding behind that mirage to avoid getting cost and pricing data, then that's clearly a mistake. (11:45)

With the debate over the definition of what constitutes competition and the added emphasis for increases in competition, contracts are being labeled as competitive when a competitive environment did not exist. As the previous audit findings indicate, this practice limits the government's insight into a contractor's cost and pricing data and could be allowing significant pricing errors to continue unnoticed.

Applied Research Dollars. In fiscal year 1990, more than 90% of the DoD's $6 billion applied research dollars were awarded non-competitively (14:45). Applied research typically occurs on a program during the Concept Exploration and Demonstration Validation phases and defines the technology that will be developed in later phases of the program. This non-competitive practice establishes DoD's design preferences early in the program, before the program is competitively solicited. According to David Soergel, Executive Director of the VEBEL Society,

> This leveling of pre-competitive technology and design preferences washes out substantive differences between proposals, putting an undue emphasis on highly uncertain cost estimates as the key factor in award, which in turn motivates industrial "price buy-ins" and the politicalization of the contract award process. (14:45)

With the reality of the amount of non-competitive awards for a majority of basic research, the goal of achieving the "best value" for taxpayer's dollars may be lost when the proposed cost becomes the only basis for differentiating between competing proposals. In other words, the technical leveling between competing alternatives further increases the importance and emphasis on price. Even with the emphasis on competitive contracting, awarding a sole source contract may still be a viable alternative.

Sole Source Contracts

The Competition in Contracting Act was passed to emphasize competition, but allows for sole source contract awards in limited circumstances. Justification for a sole source contract will be granted if any one of the following seven exceptions are met:

1. There is only one source available
2. There is a unusual and compelling urgency
3. Required to maintain the defense industrial base
4. It is required by treaty
5. It is required by statute
6. It is in the interests of national security
7. It is in the public interest

The savings estimates of 25% mentioned earlier were based on contracts that were previously sole source, and then were subsequently competed with a dual source strategy. The next section discusses dual sourcing and some of that strategy's criticisms. Again, an understanding of this strategy and its' criticisms is fundamental to an appreciation of the savings estimates attributable to competition, that were derived from analysis of dual source programs.

Dual Sourcing

Dual sourcing occurs when two or more producers of a particular weapon system or component exist. Recalling that over 90% of DoD's applied research dollars are awarded non-competitively, then the only recourse to realizing competitive savings is to develop a second (dual) source for development or production. The second source may have been developed throughout the acquisition, or developed in later phases of the program. Developing a second source later in the program can be used to stimulate price competition during production in hopes of delivering systems at a lower price. On the other hand, developing dual sources early in a program would cause head-to-head competition throughout development, hopefully producing better performing, lower cost weapon systems, at reduced development risk, while delivering systems sooner.

Like the competitive environment, dual sourcing has several criticisms. Some criticisms are now discussed.

Dual Sourcing Criticisms

The following dual sourcing criticisms are not meant to be an exhaustive list of all possible criticisms. However, the criticisms mentioned are considered to significantly affect the cost effectiveness of a dual source strategy. The cost effectiveness or cost savings realized from a dual source strategy will be discussed in the following section. But, it is important that the reader understand dual sourcing along with the following criticisms and their possible effect on cost savings estimates.

Non-recurring Costs. The non-recurring or one-time costs to develop a second source for production can be extensive. These costs can include technology transfer, purchasing re-procurement data, special tooling and test equipment, and second source qualification. Data available from studies on missile programs cite non-recurring costs in the range of $20 million to $100 million (FY84) (12:3-18). A 1985 estimate of the total cost to establish a second source for C-17 production was $2.3 billion in FY81 dollars (15:1). However, these investments are made in anticipation that out year recurring costs will be reduced, offsetting the initial investment. Navy officials estimate that because savings from a second source normally range between 15 and 30 percent, the service recovers the non-recurring cost of going to a second source in less than two years in most cases (11:43).

Contractor Price Gaming. In a dual source competition, the lower price bidder usually is awarded the larger share of the government's annual requirements while the higher priced bidder gets a smaller share. This smaller share is at least a minimally sustaining quantity to keep the production line open. The possibility of the whole award going to the lowest price bidder would undermine competition in future years and essentially waste the government's investment in developing the second source. After the government spends considerable money developing a second source, they are not likely to let that source evaporate by not utilizing the production capacity. Competition advocates concede that once they have paid to bring a second

source into a program, dropping either company altogether rarely makes economic sense (11:44). Therefore, the situation of an assured level of production allows for price gaming where contractors have the opportunity to submit inflated bid prices. Recalling when a contract is categorized as competitive, detailed cost and pricing data is not required, and seldom obtained. Inflated bid prices can be submitted by both the lower and higher priced contractors. The lower priced contractor, normally the initial contractor, will not feel competitive pressure from a recently developed second source. The second source contractor will likewise not feel competitive pressure and, being assured a minimally sustaining production quantity, bid inflated prices content to be a "happy loser" (3:14).

Referring again to the IG report, IG officials believe that guaranteed contracts for the smaller portion of a dual source award should be classified as non-competitive procurements using competitive procedures (11:44). Classifying these awards in this manner would allow closer examination of contractor cost and pricing data, therefore minimizing the potential for contractor price gaming.

Lost Economic Benefits. Loss of economic benefits fall into two categories: reduced learning curve and diseconomies of scale. In a dual source program, production quantities must be split, in some ratio, between two or more contractors. This splitting of production quantities does not allow either contractor to fully realize savings from the learning curve effect. Also, the split production most likely will cause unused production capacity in both

contractor's facilities, not allowing the full realization of economies of scale. In both cases, the result should be higher unit production costs than if the entire quantity were awarded to the low bidder. Again, the argument for competition is that the reduced profit margins bid by the contractors will more than offset the higher unit costs resulting from reduced learning curve effects and diseconomies of scale.

Industry Capacity. When the defense industry has considerable idle capacity, contractors are more likely to bid lower prices as a result of increased competition for limited work. On the other hand, when there are numerous contracting opportunities, contractors face less pressure to bid competitively, and submit higher bid prices. Therefore, there is a correlation between the capacity of the defense industrial base and a contractor's bid price.

Prior Studies

The arguments for increased competition, which culminated in the Competition in Contracting Act, were based on the belief that competition saves time, reduces risk, improves performance, and saves money. However, the prior studies that led up to CICA provided quantitative proof that competition saves money, were limited in scope and depth. In order to quantify the effects of competition, these studies focused on dual source acquisitions that were previously sole source, and then only measured the estimated dollar savings at contract award. Figure 2 shows the price improvement curve and estimated savings from competition and

depicts the methodology used in the prior studies for determining competition's savings.

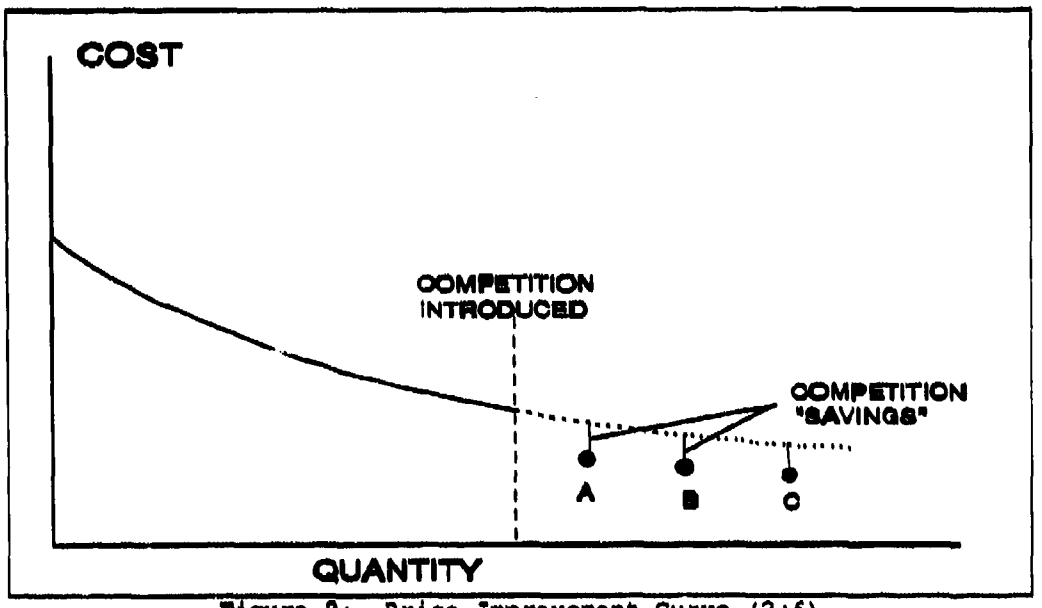

Figure 2: Price Improvement Curve (2:6)

Recall, this methodology was developed for sole source programs that were subsequently competed with dual sourcing. The initial phase of the learning curve was developed with actual sole source unit cost data. From the point where competition is introduced, the sole source learning curve is extrapolated and compared to actual competed unit costs, points A, B, and C. The difference is the realized cost savings resulting from competition.

Even with this fundamental relationship to define the cost savings from competition, the dual source criticisms mentioned earlier cast doubt on the validity of competition's "savings" claim. In 1984, Lieutenant Colonel Richard J. Hampton, USAF, a Research Fellow at the Airpower Research Institute, did an extensive review of 8 previous

studies encompassing 45 previously sole source systems that were since competed using dual source procurement (10:41-83). He reported estimated percentage savings rates from 11.8% to 53.3%. However, he also reported some serious drawbacks in each of the studies.

The foremost drawback, common among all studies, was the lack of consideration of the time value of money. The outyear competitive savings were not discounted to a common base year and, as such, should not have been simply subtracted from up-front non-recurring costs. To make matters worse, seven of the studies never figured any non-recurring costs into their evaluation, while the other only considered some non-recurring costs. Quoting Hampton,

> These figures do not represent the net impact to the government of dual sourcing. Taken together, these concerns cast a shadow of caution on the use of any rule-of-thumb estimate of, for example, a 10%, 25%, or other fixed percentage savings available when systems are competed. (10:61)

Still, blanket estimates of the potential savings from competition are cited. In a 1985 Air Force System Command review of the C-17 second sourcing analysis, officials claimed "When competition is introduced, a 25% decrease in unit price is assumed for both sources" (15:1).

Recalling, the prior studies were based on dual source programs. As Hampton discovered, these prior studies had some serious methodological drawbacks. In addition, dual sourcing has some valid criticisms as mentioned earlier. Still, the prior studies, the results of which became the standard estimate for the savings attributable to competition, were limited in scope and depth. This research

will extend the study of the purported savings attributable to competition by expanding the prior studies in two areas.

This research will expand the scope of the prior studies by examining competitive versus sole source contract awards and analyzing the cost and schedule growths of each. The prior studies were limited in scope because they only looked at previously sole source programs that were subsequently competed with a dual source strategy. A large portion of the cost for weapon systems the DoD procures each year are of a high value, limited quantity nature, that do not apply to annual quantity buys. "Over 50% of the dollars spent by Air Force Systems Command during the first half of the 1980's went to only four major systems" (8:144). Estimating a 25% savings due to competition on a dual source tactical missile program, then applying that same 25% savings estimate to a C-17 program, is a fallacy in reasoning, and assumes the two programs are comparable, simply because they were both competed.

This research will also expand on the depth of the prior studies by examining the cost and schedule behavior over the life of the contract, as opposed to simply estimating savings at contract award.

The expanded scope and depth of this research should make the results more applicable to Air Force managers.

Conclusion

Blanket cost savings estimates continue to be made based on the philosophy of the price improvement curve in Figure 2, and the methodology of comparing system unit costs

on dual source contracts that were previously sole source. Benefits from competition may indeed exist on large programs, but applying savings estimates that were based upon dual source programs is misleading.

Chapter III details the methodology used to answer the research questions and meet the research objectives: Is there a difference in cost and schedule growth between competed and sole source contracts?

III. Methodology

Overview

The methodology employed in this research used data from the Acquisition Management Information System maintained by Aeronautical Systems Center's Directorate of Contracting ASC/PK. Operational definitions of key terms or concepts are required in order to accurately address the investigative questions. These terms and concepts, as well as the methodology used to define these concepts, are covered. Discussion then focuses on the population of interest and data collection efforts. Also, assumptions and limitations of the analysis are identified. Finally, the statistical tests conducted on the research hypotheses are presented.

Research Design

This research was designed to answer the three research questions described in Chapter I. The research questions and the hypotheses tested are listed below.

Research Question #1. For cost growth and schedule growth categories, does the mean growth for a competed contract differ from the mean growth of a sole source contract?

Hypothesis.

Ho: Mean Competed Growth = Mean Sole Source Growth
Ha: Mean Competed Growth ≠ Mean Sole Source Growth

Research Question #2. For the cost growth category only, does the mean cost growth for competed and sole source lower risk contracts differ from competed and sole source higher risk contracts?

Hypothesis.

Ho: Low Risk Mean Growth = High Risk Mean Growth
Ha: Low Risk Mean Growth ≠ High Risk Mean Growth

Research Question #3. For the cost growth category only, does the mean cost growth for competed and sole source lower price contracts differ from competed and sole source higher price contracts?

Hypothesis.

Ho: Low Price Mean Growth = High Price Mean Growth
Ha: Low Price Mean Growth ≠ High Price Mean Growth

Data Collection

The research relied on data from the Air Force's Acquisition Management Information System (AMIS). In particular, this study used the Program Management System (PMS) and CONTRACT data bases. The PMS and CONTRACT data bases were used to capture cost and schedule information respectively, for the period of January 1980 to December 1990. This eleven year period was used to mitigate bias in this study due to fluctuations in the defense business cycle. Also, it provides for 5 years of pre CICA and 6 years post CICA awards. Specifically, the PMS data base was used to capture: initial contract price, final or current

contract price, date of award, type contract, number of respondents, solicitation procedures, and the extent competed. To answer the research question concerning cost growth, data was collected on contracts managed by the Wright Aeronautical Laboratories as well as the following Product Centers in Air Force Material Command:

Aeronautical Systems Center
Electronic Systems Center
Space Systems Center
Armament Systems Center

The population of contracts used to measure schedule growth differed somewhat from that used to measure cost growth. Schedule growth data was collected solely from contracts administered by the Air Force Contract Management Division (AFCMD) at Kirtland AFB, NM. This population was used because AFCMC uses the AMIS system to record contract deliveries for payment purposes. Other data bases were available but the accuracy and validity of the data could not be assured as readily as data from the AMIS system.

Research Population

Cost Growth. The population of contracts for cost growth was establish by first identifying all contracts awarded at the five organizations listed earlier between 1980 and 1990. Then, all contracts having an initial contract price of $0 were eliminated from the population. These contracts were eliminated because an initial award of $0 would not allow a cost growth to be calculated. Also, it is assumed that these contracts were structured with a series of preplanned options which do not truly represent cost growth. Next, contracts identified in the PMS data

base field "Solicitation Procedures" as basic research, time and material, or labor hour contracts were eliminated. Also, contracts described as providing services were eliminated because they are not representative of the weapon systems procurements of interest in this study. Finally, contracts identified in the "Type-Contract" field as being a combination cost and fixed priced line items were eliminated because they did not fit into the risk categories defined for this study.

Schedule Growth. First, all contracts administered by AFCMD with an initial award date between 1980 and 1990 were identified. Then, contracts identified in the PMS Contract Data Base field "Solicitation Procedures" as basic research or time and material type contracts were eliminated. These contracts were eliminated because the scope of this research was weapon system development and production contracts.

Contract Classification

In order to answer the research questions and to test the hypotheses, classification of the contracts into three categories was required. These three categories are either sole source or competed, risk (higher or lower), and initial price (higher or lower). The methodology used to make these classifications is now explained.

Sole Source/Competed. The decision process that classified contracts into sole source and competed categories used the PMS data base fields "Extent Competed" and "Number Received". Figure 3 illustrates the decision process used.

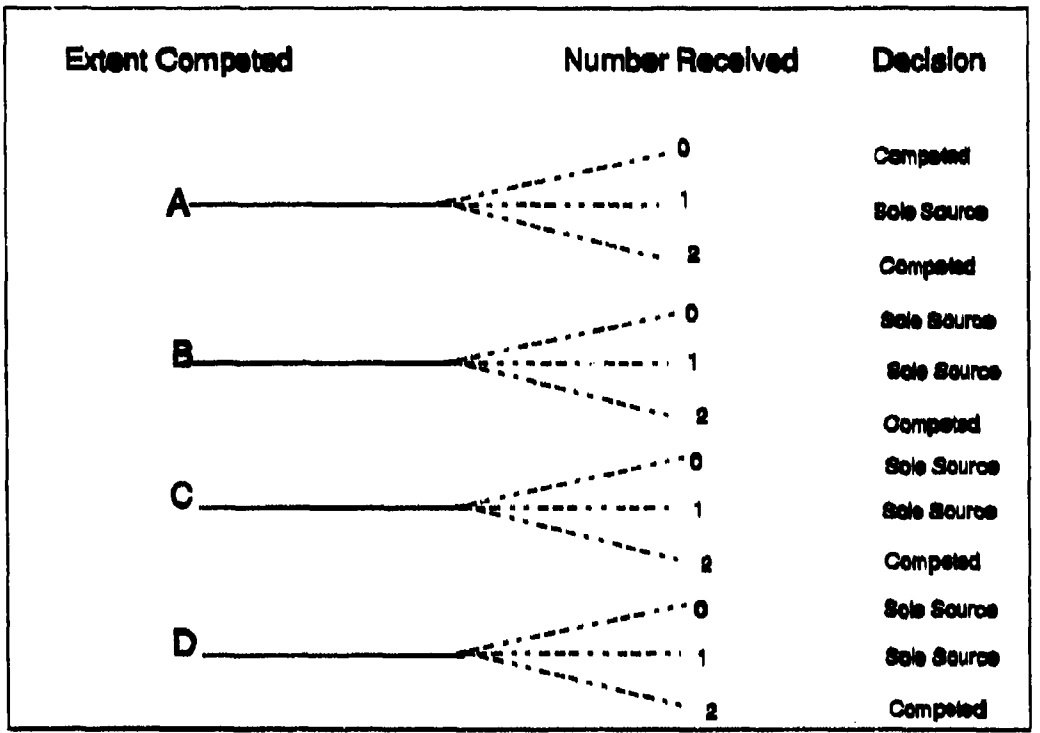

Figure 3: Sole Source/Competitive Decision Tree

The "Extent Competed" column in the PMS data base has four possible classifications:

A: Competed
B: Not Available for Competition
C: Follow-on to Competition
D: Not Competed

The "Number Received" field in the PMS data base has three possible entries; "0", "1" or "2". The "Extent Competed" field was used with the field "Number Received" to categorize each contract as competed or sole source. A "1" entry means only one proposal was received in response to the governments solicitation while a "2" entry means that two or more proposals were received in response to the governments solicitation. The "0" entry identified in Figure 3 is required because this field was not available on

contracts awarded prior to 1985. Contracts issued prior to 1985 are thus categorized solely on the information contained in the "Extent Competed" field. An example helps to illustrate the logic for classifying a contract as competed or sole source. If a contract lists an "A" in the "Extent Competed" category but shows only one response to the governments solicitation, this research defines the contract as sole source. The logic behind this categorization is that competition does not exist when only one source answers the Request for Proposal. In order to receive the benefits of competition, at least two qualified sources must be available.

Risk. Risk categorization is required for the tests on cost growth. The risk assigned to each contract is identified by the "type-contract" field in the PMS contract data base. A letter designation in the field identifies the specific type of contract used for the effort. This research operationally defines all "cost" type contracts as higher risk while defining all "fixed price" type contracts as lower risk. These definitions are generally excepted by Air Force contracting officers.

Initial Price. Contracts were divided into higher and lower initial price categories by selecting the median contract price as the dividing line. This resulted in two equally sized samples for lower and higher price contracts.

Random Sampling

Cost Growth. Contracts from each of the four Product Centers and Wright Aeronautical Labs were categorized into

either competed or sole source and higher or lower risk. After categorizing the population all contracts were numbered in each category and a random number generator was used to select a sample of contracts from the population in each category. The sample size selected from each Product Center and the Labs were determined by the relative percentage of the total population that a Product Center or the Labs were responsible for. Table 1 lists the number of contracts the Product Centers and the Labs contributed to the overall population in each of the categories; competed or sole source and lower and higher risk.

TABLE 1

CONTRACTS CONTRIBUTING TO THE OVERALL POPULATION

	COMPETED		SOLE SOURCE	
	Low Risk	High Risk	High Risk	Low Risk
Space Systems Center	78	37	36	30
Armament Systems Center	189	77	81	35
Aeronautical Systems Center	174	21	226	20
Electronic Systems Center	168	186	81	90
Wright Labs	315	997	124	537
Sub-Total	924	1318	548	712
TOTAL	2242		1260	

The Table 2 lists the population sizes *N*, the sub-totals from Table 1, and the size of the random sample *n* drawn in each category to ensure the desired level of accuracy.

TABLE 2

POPULATION/SAMPLE SIZES

	Lower Risk	Higher Risk
Competed	N = 924 n = 137	N = 1318 n = 145
Sole Source	N = 548 n = 122	N = 712 n = 130

An initial sample of 30 contracts from each category ie. Competed/Lower Risk was drawn, and estimates of the population mean, standard deviation and standard error were determined. These initial estimates were used to calculate the sample size required for each category at a significance level equal to .05 using the following formula described by Scheaffer (12:69).

$$n = \frac{N\sigma^2}{(N-1)D + \sigma^2}$$

$$\text{where: } D = \frac{B^2}{4}, \text{ and}$$

$$B = 2 \times \text{standard error of the estimator}$$

Using the value of 2 for the definition of "B" results in a better than 95% confidence, that with the sample size n, the true mean cost growth is within 2 standard errors of the estimated mean (12:68).

Schedule Growth. After categorizing the schedule growth population relative to the level of competition, the contracts in each category were numbered, and a random number generator was used to select a sample of contracts

from the population in each category. The population sizes for sole source and competitive contracts were 198 and 572 respectively. An sample was taken for each category and an estimate of the population mean, standard deviation and standard error were determined. The initial estimates were used to calculate the sample sizes required for competed and sole source categories using Scheaffers' formula referenced earlier. The resulting sample sizes were n = 18 for sole source contracts and n = 20 for competed contracts.

Operational Definitions

Five terms or concepts must be defined for each contract in the research sample to answer the research questions and test the hypotheses. The purpose of these definitions are to support the calculation of the cost and schedule growth for each individual contract.

Award Date. The contract award date information is required to compute the schedule growth for the contract. The PMS data base field identifying the contract "Date-Distribution" is used as the baseline contract award date for all calculations. This information also allowed determination of the relative contract age.

Initial Contract Schedule. The contract delivery requirement for a contract line item on the original basic contract. The field in the CONTRACT data base defining this variable is "Scheduled Delivery".

Final Schedule. The actual delivery date for a contract line item. The field in the CONTRACT data base defining this variable is "Delivery Date".

Initial Target Price. This is the initial price for the basic contract. This data is available in the PMS Contract Data Base and is required for the calculation of cost growth. The field in the PMS data base defining this variable is "Tot-Amount".

Current Target Price. This is the current price of the contract and includes the rolled up price of the basic contract and all modifications through 15 June 1993. This data is available in the PMS data base and is used with the initial target price to calculate cost growth. The field in the data base defining this variable is "Contract Price".

Research Variables

Schedule Growth. Schedule growth was measured using schedule growth factors which are defined as the difference in the completed date of a contract line item and the line item's initially scheduled date divided by the initial schedule length. A schedule growth factor is therefore the percentage increase or decrease in the delivery of the line item. This increase or decrease was determined using the last completed line item on the contract to obtain the most representative schedule performance. Only line items established with the basic contract award were used in the analysis because this was considered more representative of the true schedule as opposed to a line item established with a later contract modification. The PMS Contract Data Base field "Date-Distribution" allowed calculation of the initial and final schedules. The "Date-Distribution" date was assumed to be the contract award date.

To establish the schedule growth on a contract, the last basic line item was used to establish the schedule growth of the sample contract. This methodology was used to capture a more realistic schedule performance on the contract. The logic of this methodology is that any schedule problems will be magnified with time.

A possible problem with this methodology is that considerable schedule growth may be attributable to "getting the paperwork in order" prior to contract close-out. Schedule growth could be greater in this case, however the increases should be equivalent for the competed and sole source populations. Another possible problem with this methodology is that the contract may have experienced increased schedule growth since the last milestone was completed, yet that information was not captured. When using active contracts to compute cost or schedule growth parameters, the growth calculated may not be indicative of the cost/schedule performance for a completed effort because the last 5% of an effort usually is the slowest part of a program. These effects were monitored by tracking the mean age of the contracts included in the study.

Cost Growth. Cost growth was measured using cost growth factors which are defined as the difference between the final, or latest, contract price and the initial contract price, divided by the initial price. The cost growth factor is therefore the percentage increase or decrease of the contract price. The methodology to determine the cost growth for completed and on-going contracts was the same. Similar to schedule growth, a

possible problem with this methodology is that on-going contracts may exhibit a smaller cost growth. These effects were again monitored by tracking the mean age of the contracts included in the sample.

Assumptions

It was recognized that several factors influence every program's cost and schedule performance. An attempt to quantify the effects of these factors would be impossible. Below is a list of events that can affect the cost and schedule performance for both sole source and competed contracts.

Changing Requirements (Specification, Schedule)
Delays/Cost increases due to funding cuts
Delays due to late GFE (hardware, test facilities)
Effects of follow on contract award potential
Economic conditions
Political considerations

By using a statistically significant sample of the contract populations, these effects are assumed to equally affect sole source and competed contracts.

Limitations

This research was limited by the data available through the AMIS system. Data fields are defined in AMIS documentation but are subject to the users' interpretation. Also, using data base information subjects the research to input errors as well as omission of cost and schedule updates. The AMIS system was used in place of original contract documents due to the time constraints on the research effort. Using a data base allowed the researchers to obtain contract cost and schedule information on numerous

contracts very quickly. Also, this allowed the researchers to include sample contracts from locations all over the country. This provided a sample population representative of Air Force Material Command procurements. Finally, this research methodology was limited in scope to contracts awarded prior to 1 January 1990. This limitation requiring contracts to be active for at least 3 years allowed those on-going contracts enough time to begin to exhibit some schedule and cost growth that may not be apparent on newer contracts. On-going contracts were used because their exclusion would have limited the sample size of the study. Also, it is common for DoD contracts to remain open for many years. These contracts are viable for this research since it attempts to measure growth rates. Older open contracts are likely to establish the true growth trends of the contract thus are suitable for this research.

Statistical Analysis

Statistical analysis was conducted to test the hypotheses and answer the research questions. Before conducting the statistical analysis, the sample size in each category of interest was trimmed by 10%. This trimming was accomplished by deleting 5% of the cost growth factors from the low and high extremes of the frequency distribution.

> Using a trimmed mean with a moderate trimming proportion will yield a measure that is neither as sensitive to outliers as the mean (since any small number of outliers will be deleted before averaging) nor as insensitive as the median.(7:19)

Because the research questions differed between the cost growth analysis and the schedule growth analysis, each

analysis will be discussed separately, with the analysis of the cost growth discussed first.

Cost Growth. Each of the research questions contained a hypothesis that will be tested in the statistical analysis. The analysis of Research Question #1 was conducted in three phases as shown in Figures 4, 5, and 6 respectively. The analysis of Research Question #2 was completed using two phases, as depicted in Figures 5 and 6. The analysis of Research Question #3 was completed in only one phase, as depicted in Figure 6.

Tests of Research Question #1. The first research question was tested in all three phases as showing in Figures 4, 5, and 6. The first phase, Figure 4, tested for differences in the mean cost growth between competed contracts and sole source contracts. The second phase, testing vertically in Figure 5, tested for differences in the mean cost growth between lower/higher risk competed contracts and lower/higher risk sole source contracts. This phase included 2 tests. The third phase, testing vertically in Figure 6, tested for differences in the mean cost growth between corresponding categories of risk and initial price for competed and sole source contracts. For example, one test compared the mean cost growth between lower risk/lower price competed contracts and lower risk/lower price sole source contracts. This phase included 4 tests.

Tests of Research Question #2. The second research question was tested in 2 phases as shown in Figures 5 and 6. The first phase, testing horizontally in Figure 5, tested for differences in the mean cost growth between

competed/sole source lower risk contracts and competed/sole source higher risk contracts. This phase involved 2 tests. The second phase, testing horizontally in Figure 6, tested for differences in the mean cost growth between lower and higher risk contracts, within competed/sole source and higher/lower initial price categories. For example, one test compared the mean cost growth between competed/lower price, lower risk contracts and competed/lower price, higher risk contracts. This phase involved 4 tests.

Tests for Research Question #3. The third research question was tested in only 1 phase. This phase, testing vertically in Figure 6, tested for differences in the mean cost growth between lower and higher initial price contracts, within competed/sole source and lower/higher risk categories. For example, one test compared the mean cost growth between competed/lower risk, lower price contracts and competed/lower risk, higher price contracts. This phase involved 4 tests.

Competed	Sole Source
Mean Cost Growth	Mean Cost Growth

Figure 4: Phase 1 Statistical Tests

	Lower Risk	Higher Risk
Competed	Mean Cost Growth	Mean Cost Growth
Sole Source	Mean Cost Growth	Mean Cost Growth

Figure 5: Phase 2 Statistical Tests

	Lower Risk	Higher Risk
Competed-Lower Initial Price	Mean Cost Growth	Mean Cost Growth
Competed-Higher Initial Price	Mean Cost Growth	Mean Cost Growth
Sole Source-Lower Initial Price	Mean Cost Growth	Mean Cost Growth
Sole Source-Higher Initial Price	Mean Cost Growth	Mean Cost Growth

Figure 6: Phase 3 Statistical Tests

An intermediate step prior to testing the hypothesis was to establish a confidence interval estimation of the true mean.

Confidence Interval Estimation. Because the sample sizes are large, the large sample confidence interval for the population mean is defined by Devore (6:267) as:

$$\bar{x} \pm z_{\frac{\alpha}{2}} * \frac{\sigma}{\sqrt{n}}$$

For this analysis, a 95% confidence interval was used in all cases. The confidence interval can be interpreted to mean, if the experiment were repeated, 95% of the time the true mean cost growth would fall within the computed confidence interval.

Test for Difference Between Population Means. The statistical analysis will also test for a difference in the population means, using the sample mean as an estimator of the population mean. Because the sample sizes are large, the large sample test statistic, as presented by Devore (6:332) is appropriate for these tests.

Large Sample Test Statistic:

$$z = \frac{\bar{x} - \bar{y} - \Delta_0}{\sqrt{\frac{s_1^2}{m} + \frac{s_2^2}{n}}}$$

where $\Delta_0 = 0$ *when* H_0 *is true*

Here, m = the sole source sample size and n = the competed sample size. A two-tailed test was conducted for each of the hypotheses at a significance level equal to .05. The decision rule stated: If the test statistic is either greater than z_{crit} or less than $-z_{crit}$ the null hypothesis (H_0) is rejected, and the difference in population means is statistically significant. Here, z_{crit} is defined as:

$$z_{crit} = z_{\frac{\alpha}{2}}$$

Schedule Growth. The analysis for schedule growth will be more simplified that the cost growth analysis. Because the schedule growth data is not aggregated by level of risk or initial price, the statistical analysis will only consist of a test for the difference between population means.

Test for Difference Between Population Means. This analysis is vastly different from the analysis of the difference between population means conducted for the cost growth data because the sample sizes used for both competed and sole source contracts are not sufficient to assume normality in the test statistic. In this case, the Wilcoxon Rank-Sum Test, is the appropriate test (6:611). The Wilcoxon Rank-Sum test requires respective samples to be

labeled such that, the sample sizes are ordered where m is less than or equal to n. For this analysis, the sample size of the sole source data is $m = 18$, and the competed data is $n = 20$.

After combining and ordering the schedule growth factors for both competed and sole source contracts, the test statistic, w, is defined as the sum of the ranks of the sole source contracts (7:612). According to Devore, when both m and n are greater than 8, the distribution of W can be approximated by an appropriate normal curve (7:613). To obtain the approximation, the mean and variance of W must be determined and are defined as follows (7:613).

Mean of W:

$$\mu_w = \frac{m(m+n+1)}{2}$$

Variance of W:

$$\sigma_w^2 = \frac{mn(m+n+1)}{12}$$

A Central Limit Theorem can then be used to conclude that when H_o is true, the test statistic, Z, has approximately a standard normal distribution. The test statistic Z is defined as (7:613):

$$Z = \frac{W - \mu_w}{\sigma_w}$$

This test statistic was then tested using a two-tailed test with a significance level equal to .05. The decision

rule stated: If the test statistic is either greater than z_{crit} or less than $-z_{crit}$ the null hypothesis, H_o is rejected, and the difference in population means is statistically significant. The value of z_{crit} is the same as defined earlier.

Contract Age. Analysis of the sample's mean contract age was not conducted however, the determination of the mean age allowed monitoring of this variable and its possible effects on the research variables cost growth and schedule growth.

Conclusions

The AMIS system allowed the researchers to access a representative cross section of Air Force Material Command contracts. Also, the data fields in the PMS and CONTRACT data bases allowed the researchers to categorize sole source and competed contracts and to further stratify these contracts relative to risk and initial contract price. Breaking down the population relative to the extent of completion, risk and initial price supports the hypothesis testing required to answer the research questions of this thesis.

IV. Findings and Analysis

Overview

The findings and analysis are presented in two sections. The first section presents the raw data in the form of histograms, sample statistics, and the confidence interval estimations.

The second section presents the results of the statistical analysis on the research hypothesis and the research questions. The results are presented in an order corresponding to the research questions ie., tests between competed and sole source contracts, tests between lower and higher risk contracts, and finally tests between lower and higher initial price contracts.

Raw Data

The raw data consists of: histograms, sample statistics, and confidence interval estimations. The cost growth raw data is presented first, with the data for competed contracts presented first and the data for sole source contracts presented second. Within each category of competed and sole source contracts, the data is presented for lower risk contracts and then higher risk contracts. Within each risk category, both lower and higher price contact data is presented. The first histogram and sample statistics are for the entire sample of competed contracts. Subsequent histograms and statistics result from the breakdown of this sample into risk and initial price categories.

Cost Growth Raw Data

Competed Category.

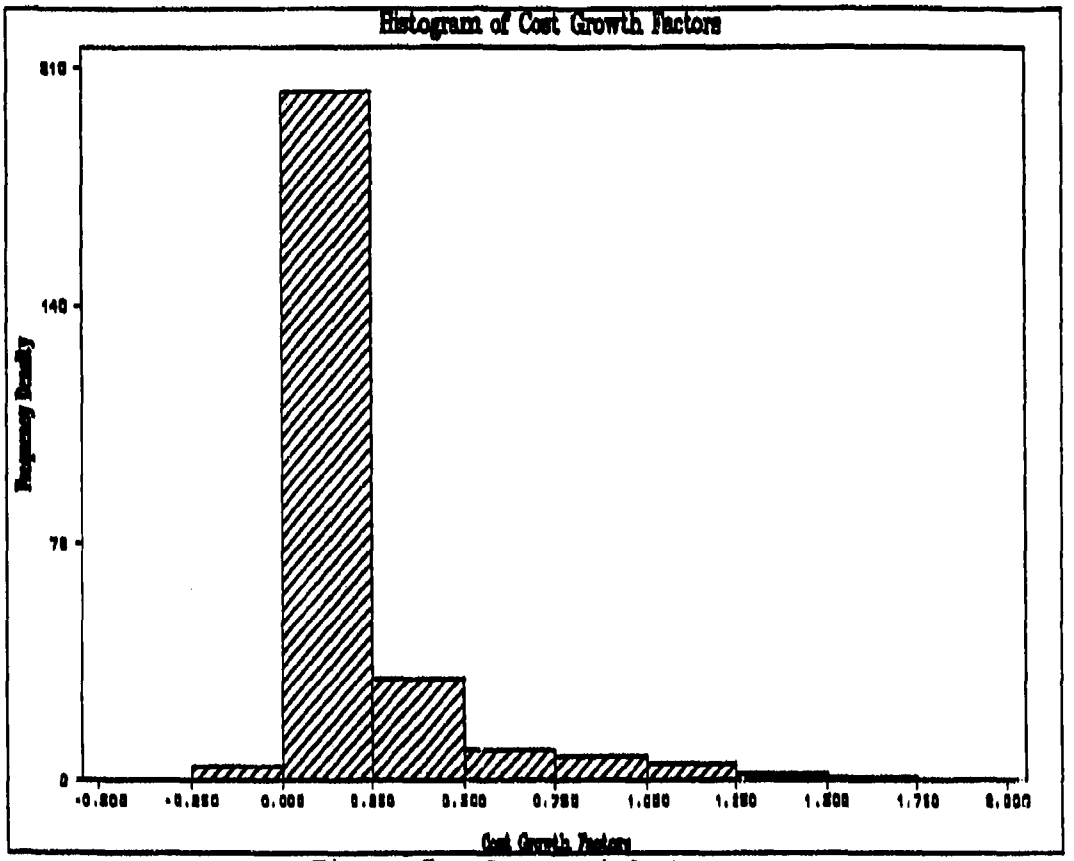

Figure 7: Competed Contracts

Sample Statistics.

Sample Size = 261 Mean = .1444 Variance = .0828

Confidence Interval Estimation. The 95% confidence interval for the mean cost growth for competed contracts is given below. Here, z_{crit} equals 1.96.

$$.1444 \pm 1.96 * \frac{.0828}{261}$$

Lower Limit = .1095 Upper Limit = .1793

Lower Risk. This data represents the competed, lower risk category. The data for the lower and higher initial price contracts that make-up this category follows.

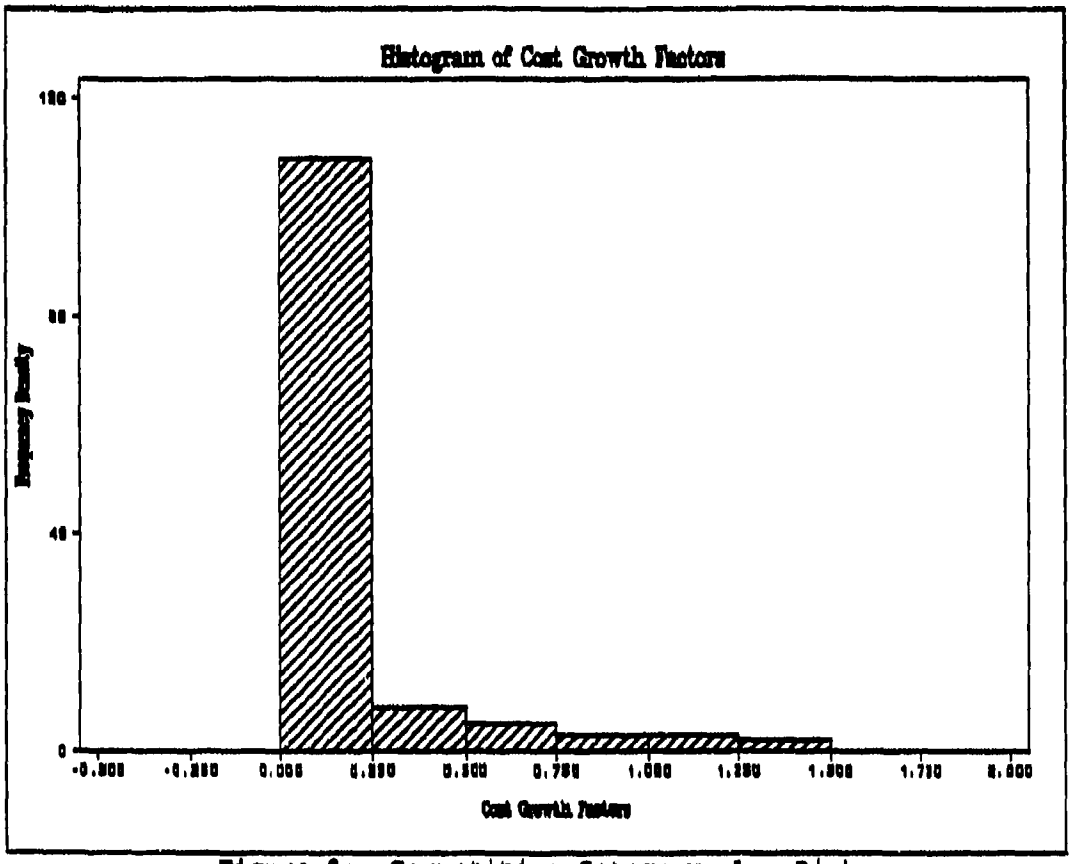

Figure 8: Competitive Category, Low Risk

Sample Statistics.

Sample Size = 130 Mean = .1278 Variance = .0874

Confidence Interval Estimation. The 95% confidence interval for the mean cost growth of lower risk competed contracts is given below.

$$.1278 \pm 1.96 * \frac{.0874}{130}$$

Lower Limit = .0770 Upper Limit = .1785

Lower Price. The following are the cost growth factors for the lower initial price contracts within the lower risk competed category.

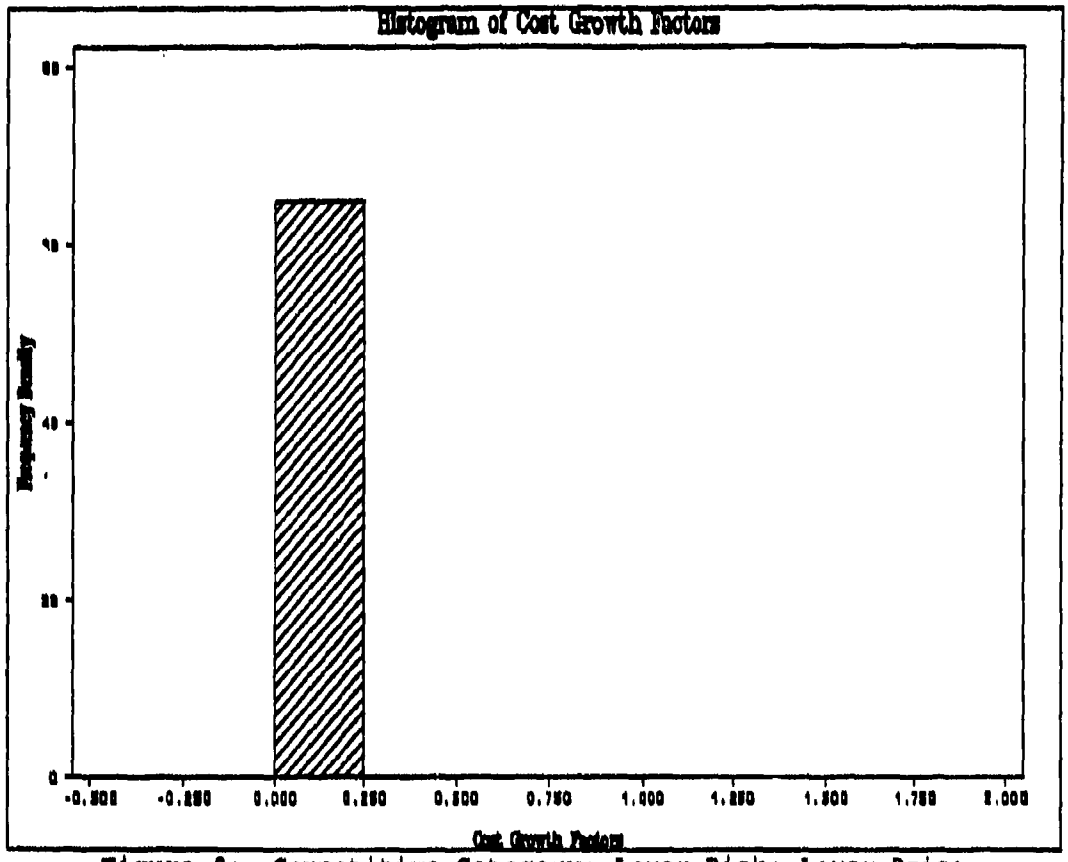

Figure 9: Competitive Category; Lower Risk; Lower Price

Sample Statistics.

Sample Size = 65 Mean = 0 Variance = 0

Confidence Interval Estimation. Because the standard deviation of the sample is zero, there is no confidence interval for the true value of the mean cost growth for this category. All 65 sample contracts in this category exhibited zero cost growth.

Higher Price. The following are the cost growth factors for the higher initial price contracts within the lower risk competed category.

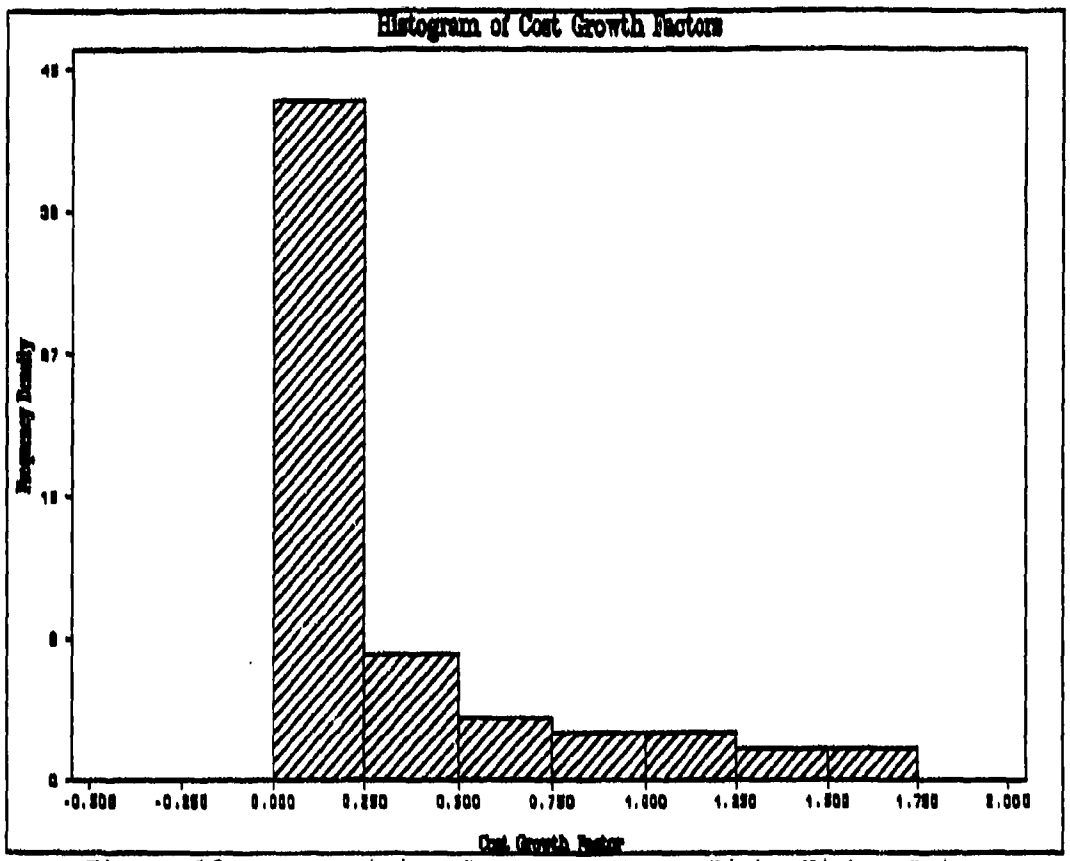

Figure 10: Competitive Category; Lower Risk; Higher Price

Sample Statistics.

Sample Size = 65 Mean = .2929 Variance = .1893

Confidence Interval Estimation. The 95% confidence interval for the mean cost growth for the lower risk, higher price competed contracts is given below.

$$.2929 \pm 1.96 * \frac{.1893}{65}$$

Lower Limit = .1872 Upper Limit = .3985

Higher Risk. Data are presented first for the competed, higher risk category. The stratified data for lower and higher initial price are then presented.

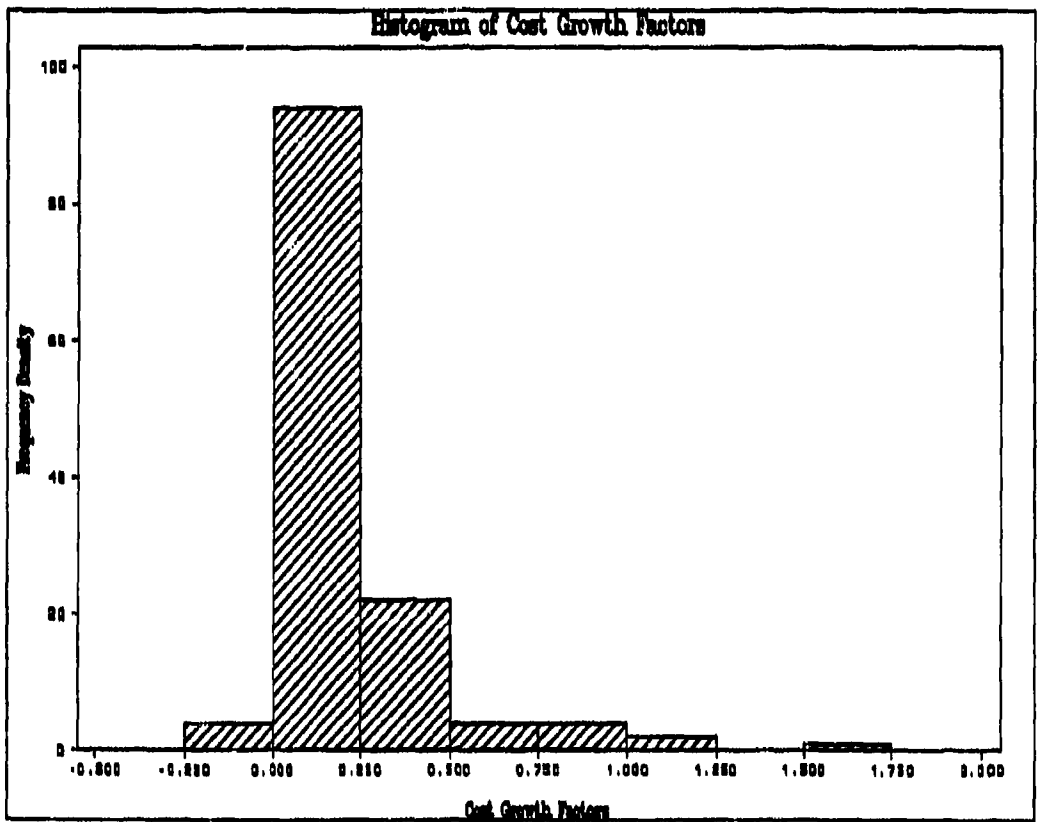

Figure 11: Competitive Category, Higher Risk

Sample Statistics.

Sample Size = 131 Mean = .1609 Variance = .0783

Confidence Interval Estimation. The 95% confidence interval for the mean cost growth for the higher risk competed contracts is given below.

$$.1609 \pm 1.96 * \frac{.0783}{131}$$

Lower Limit = .1130 Upper Limit = .2087

Lower Price. The following are the cost growth factors for the lower initial price contracts within the higher risk competed category.

Figure 12: Competitive Category; Higher Risk; Lower Price

Sample Statistics.

Sample Size = 64 Mean = .1191 Variance = .0497

Confidence Interval Estimation. The 95% confidence interval for the mean cost growth for the higher risk, lower price competed contracts is given below.

$$.1191 \pm 1.96 * \frac{.0497}{64}$$

Lower Limit = .0646 Upper Limit = .1736

Higher Price. The following are the cost growth factors for the higher initial price contracts within the higher risk competed category.

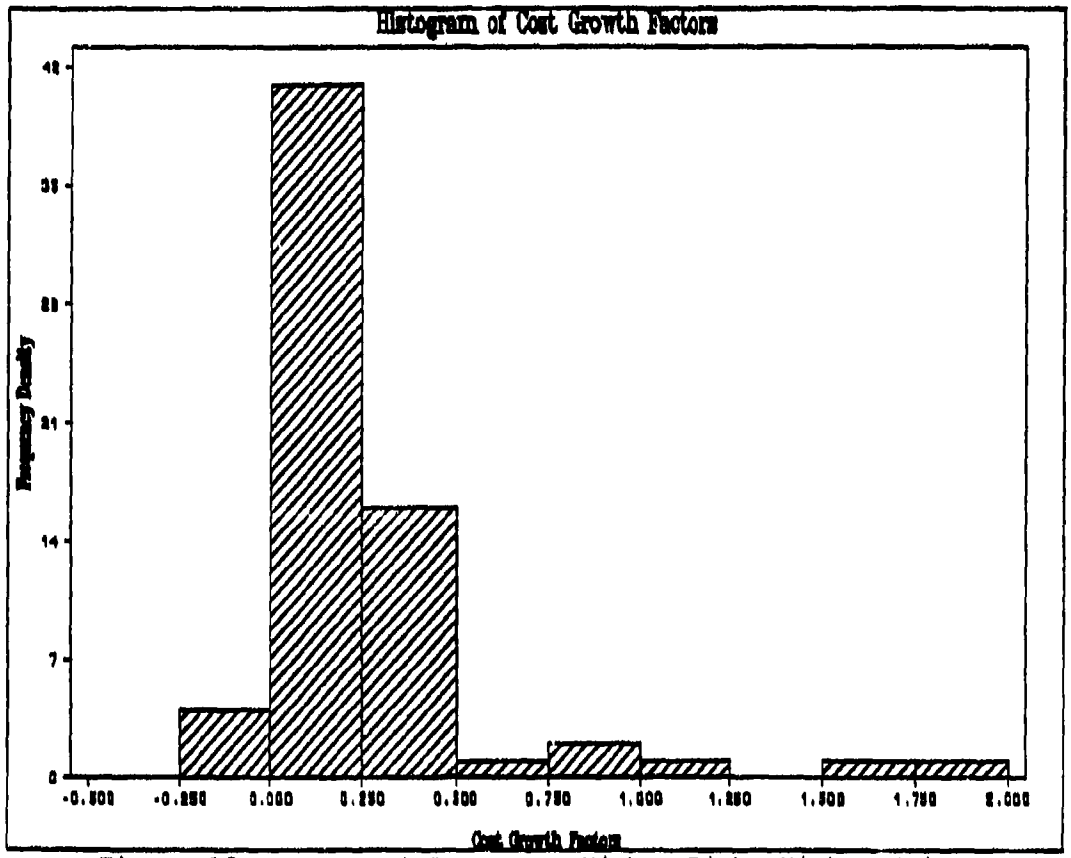

Figure 13: Competed Category; Higher Risk; Higher Price

Sample Statistics.

Sample Size = 67 Mean = .2149 Variance = .1402

Confidence Interval Estimation. The 95% confidence interval for the mean cost growth for the higher risk, higher price competed contracts is given below.

$$.2149 \pm 1.96 * \frac{.1402}{67}$$

Lower Limit = .1253 Upper Limit = .3045

Sole Source Category.

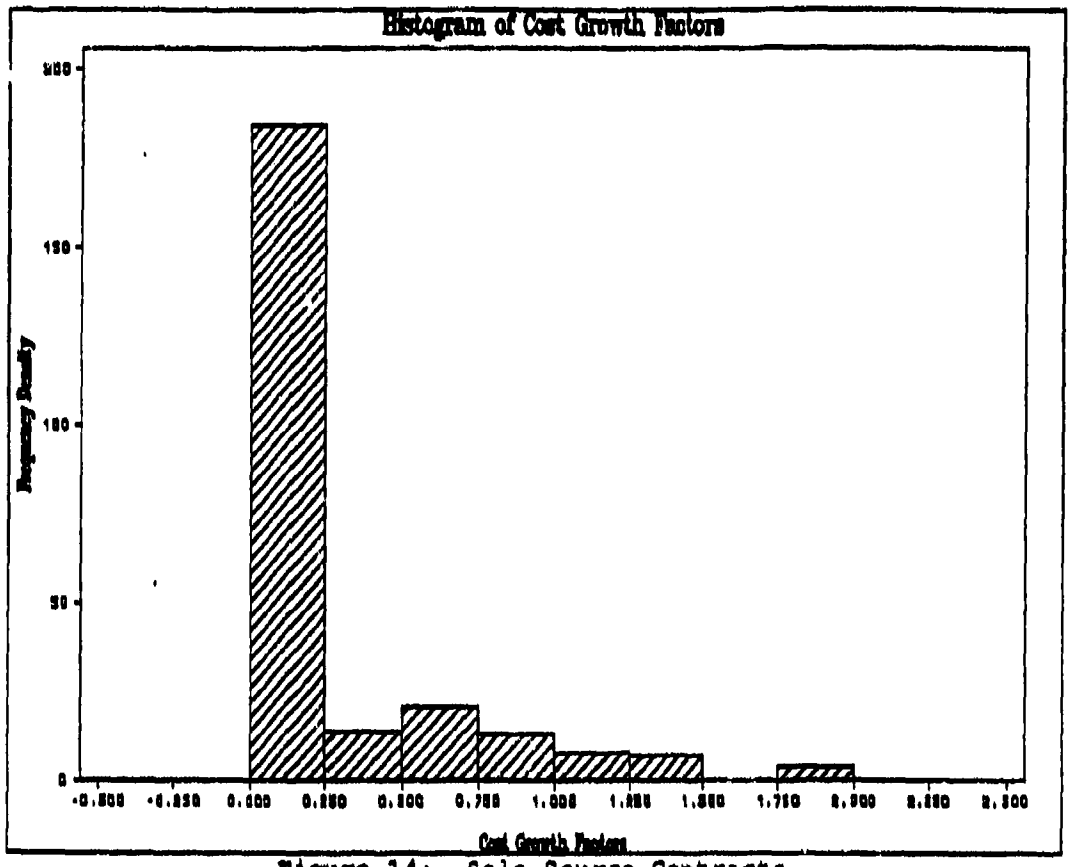

Figure 14: Sole Source Contracts

Sample Statistics.

Sample Size = 251 Mean = .2358 Variance = .1690

Confidence Interval Estimation. The 95% confidence interval for the mean cost growth for sole source contracts is given below. Again, z_{crit} equals 1.96.

$$.2358 \pm 1.96 * \frac{.1690}{251}$$

Lower Limit = .1850 Upper Limit = .2865

Lower Risk. Data are presented first for the sole source, lower risk category. The stratified data for lower and higher initial price contracts are then presented.

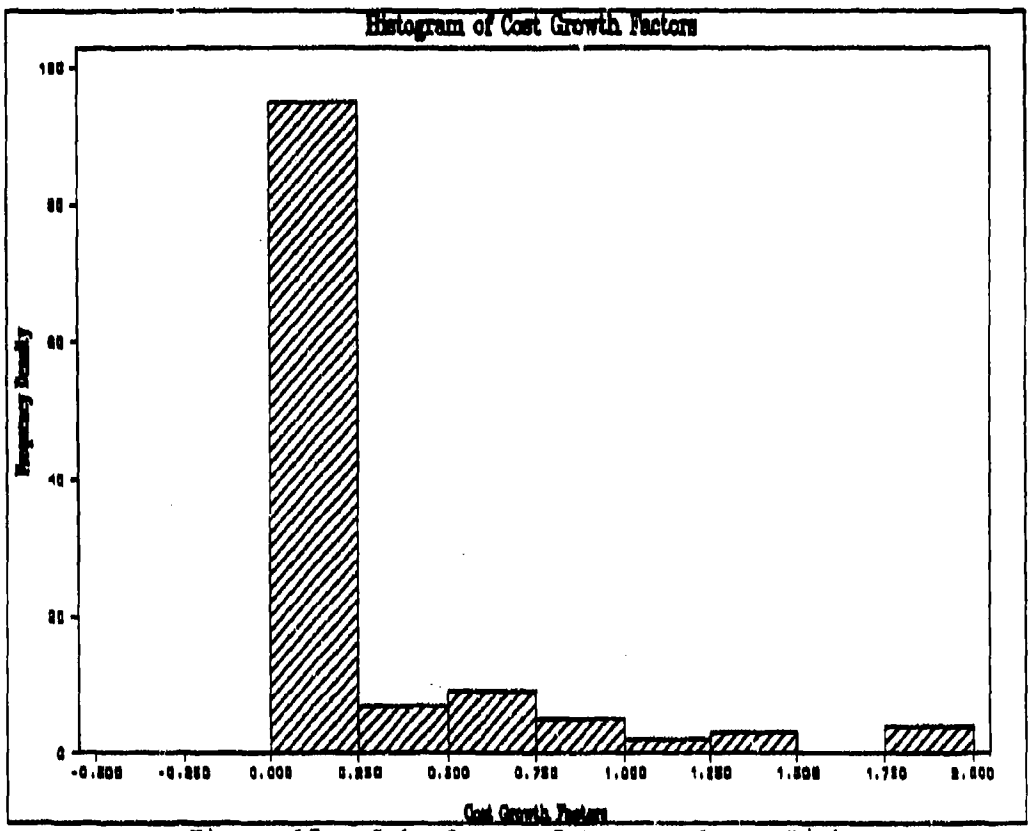

Figure 15: Sole Source Category, Lower Risk

Sample Statistics.

Sample Size = 125 Mean = .2175 Variance = .1900

Confidence Interval Estimation. The 95% confidence interval for the mean cost growth for the lower risk sole source contracts is given below.

$$.2175 \pm 1.96 * \frac{.1900}{125}$$

Lower Limit = .1412 Upper Limit = .2937

Lower Price. The following are the growth factors for the lower initial price contracts within the lower risk sole source category.

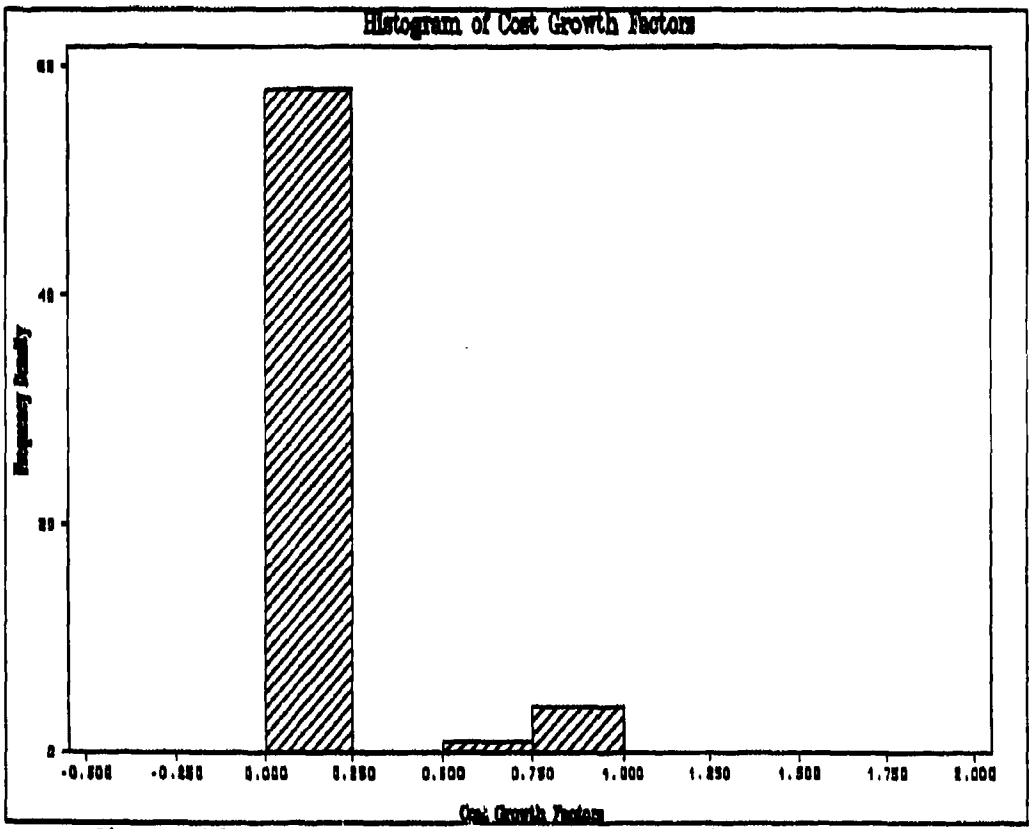

Figure 16: Sole Source Category; Lower Risk; Lower Price

Sample Statistics.

Sample Size = 63 Mean = .0654 Variance = .0491

Confidence Interval Estimation. The 95% confidence interval of the mean cost growth for the lower risk, lower price sole source contracts is given below.

$$.0654 \pm 1.96 * \frac{.0491}{63}$$

Lower Limit = .0107 Upper Limit = .1200

Higher Price. The following are the growth factors for the higher initial price contracts with the lower risk sole source category.

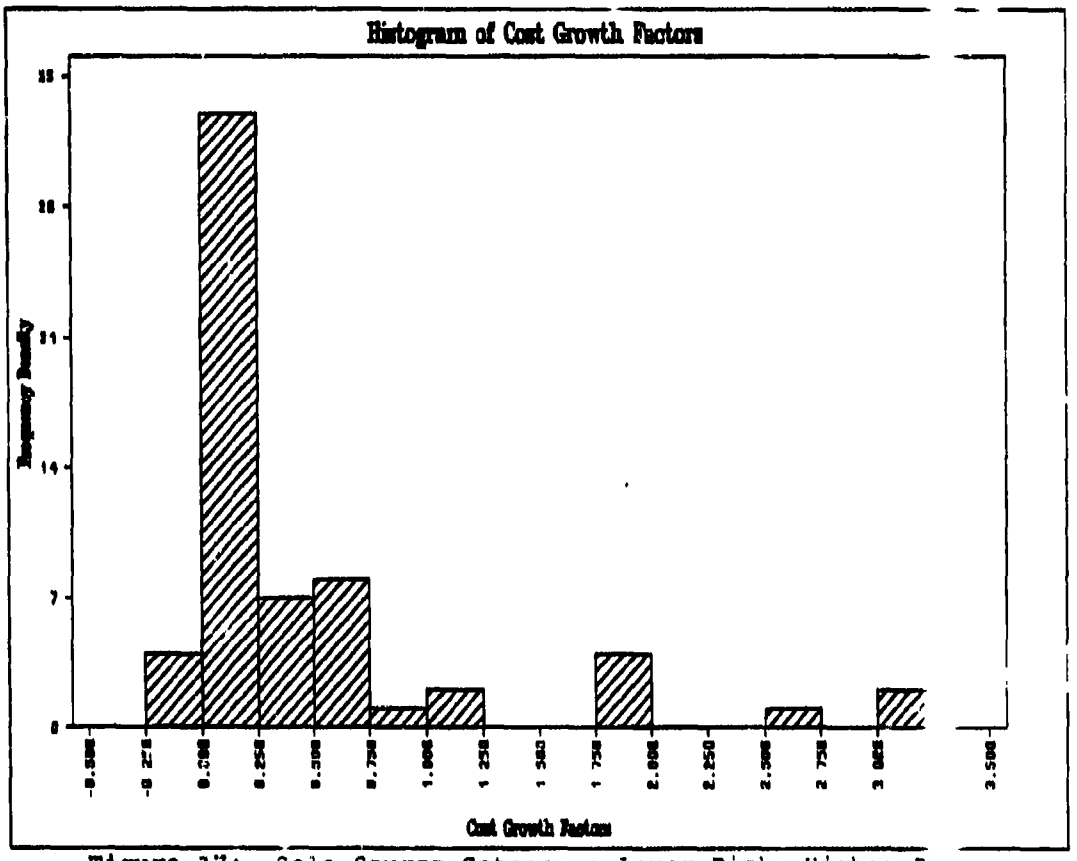

Figure 17: Sole Source Category; Lower Risk; Higher Price

Sample Statistics.

Sample Size = 62 Mean = .4515 Variance = .5797

Confidence Interval Estimation. The 95% confidence interval for the mean cost growth of low risk, higher price sole source contracts is given below.

$$.4515 \pm 1.96 * \frac{.5797}{62}$$

Lower Limit = .2619 Upper Limit = .6410

Higher Risk. Data are presented first for the sole source, higher risk category. The stratified data for lower and higher initial price contracts are then presented.

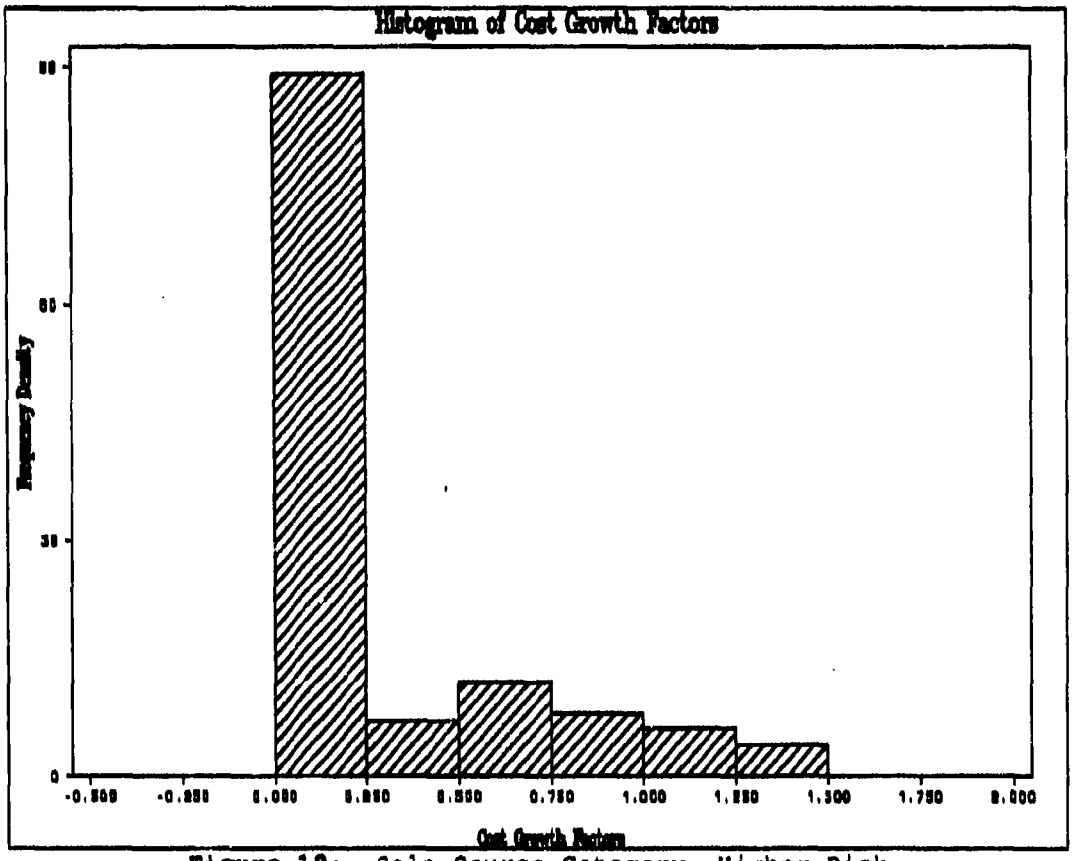

Figure 18: Sole Source Category, Higher Risk

Sample Statistics.

Sample Size = 126 Mean = .2538 Variance = .1488

Confidence Interval Estimation. The 95% confidence interval for the mean cost growth of higher risk sole source contracts is given below.

$$.2538 \pm 1.96 * \frac{.1488}{126}$$

Lower Limit = .1866 Upper Limit = .3210

Lower Price. The following are the cost growth factors for lower initial price contracts within the higher risk sole source category.

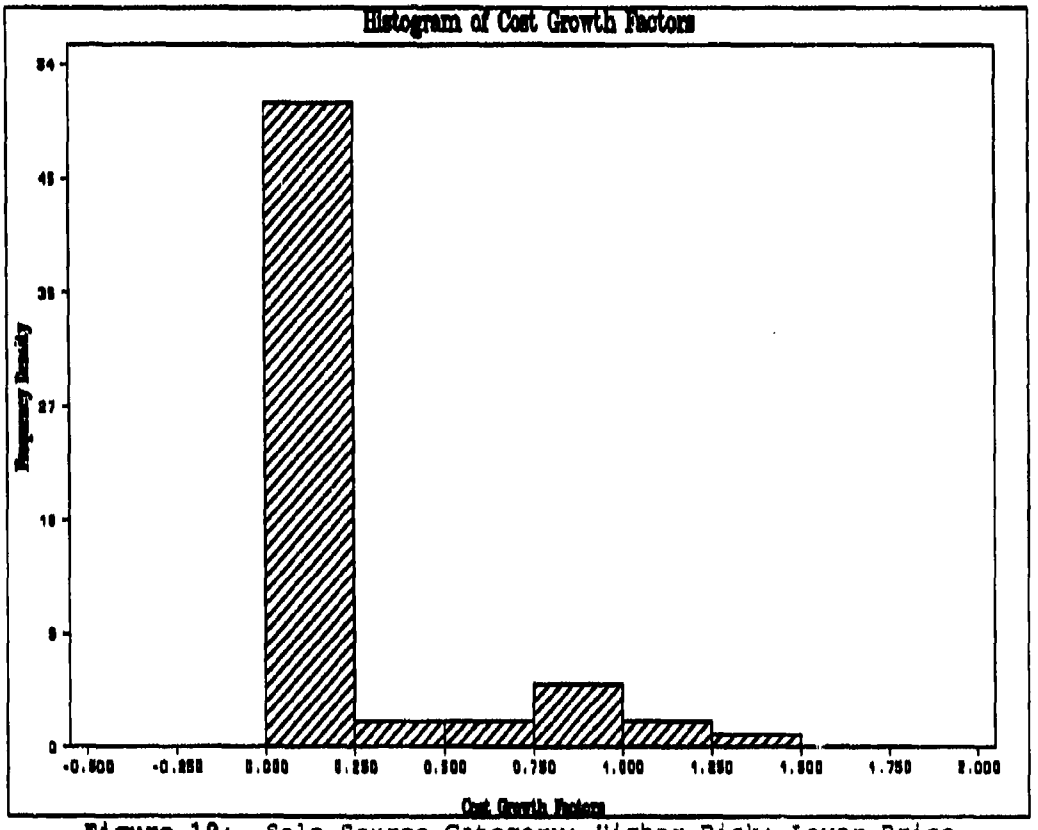

Figure 19: Sole Source Category; Higher Risk; Lower Price

Sample Statistics.

Sample Size = 63 Mean = .1655 Variance = .1156

Confidence Interval Estimation. The 95% confidence interval for the mean cost growth of the higher risk, lower price sole source contracts is given below.

$$.1655 \pm 1.96 * \frac{.1156}{63}$$

Lower Limit = .0816 Upper Limit = .2494

Higher Price. The following are the cost growth factors for the higher initial price contracts within the higher risk sole source category.

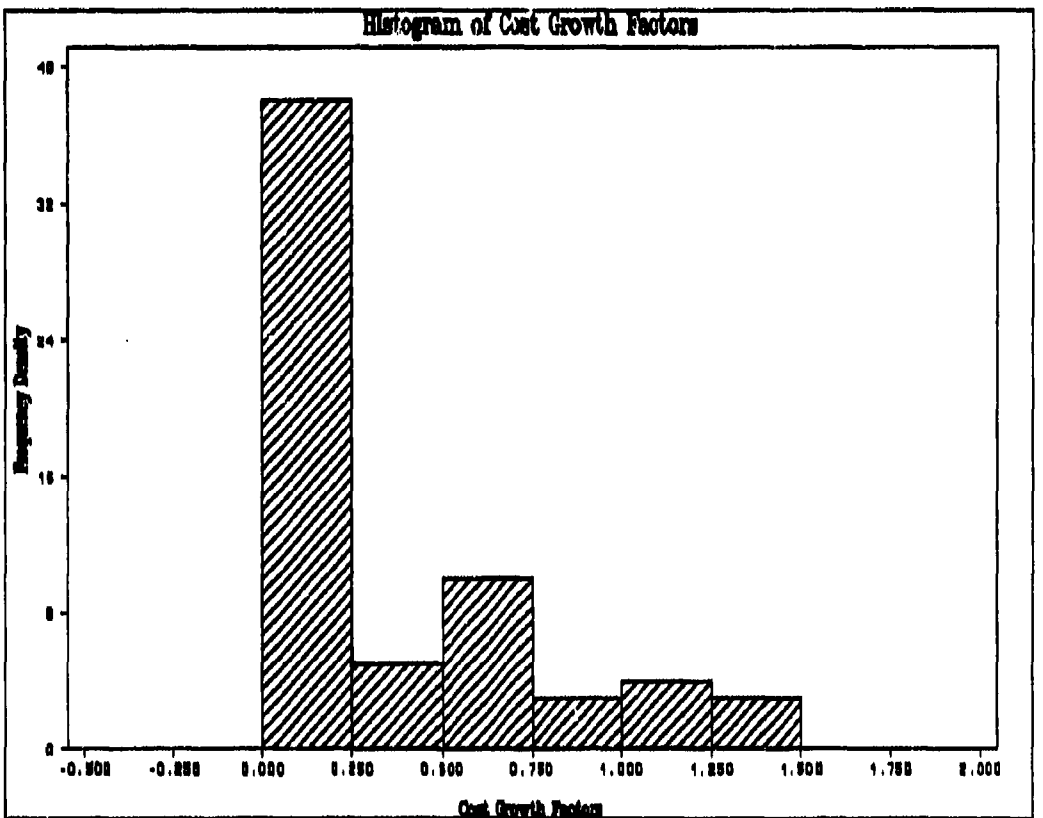

Figure 20: Sole Source Category; Higher Risk; Higher Price

Sample Statistics.

Sample Size = 63 Mean = .3421 Variance = .1687

Confidence Interval Estimation. The 95% confidence interval for the mean cost growth of the higher risk, higher price sole source contracts is given below.

$$.3421 \pm 1.96 * \frac{.1687}{63}$$

Lower Limit = .2408 Upper Limit = .4434

Schedule Growth Raw Data

Competed Contracts. The following are the schedule growth factors for competed contracts.

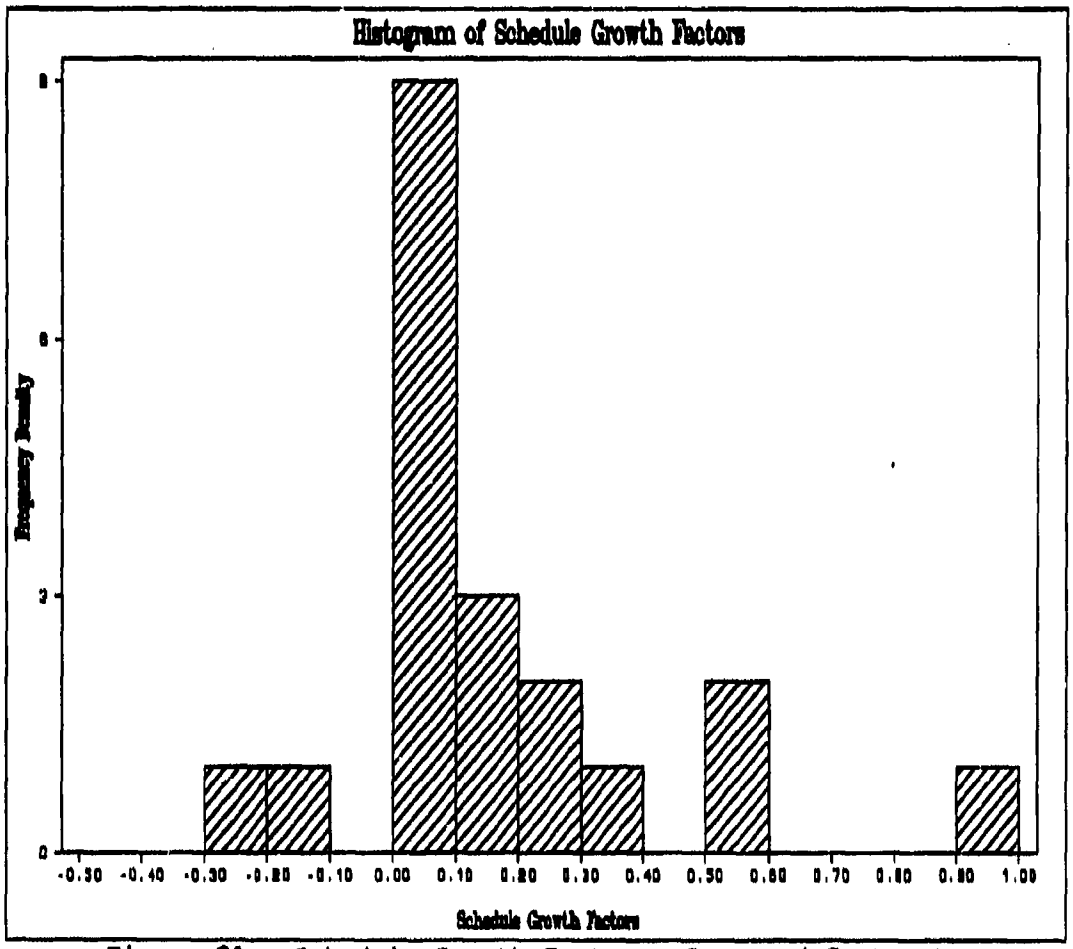

Figure 21: Schedule Growth Factors, Competed Contracts

Sample Statistics.

Sample Size = 20 Mean = .1558 Variance = .0728

Sole Source Contracts. The following are the schedule growth factors for sole source contracts.

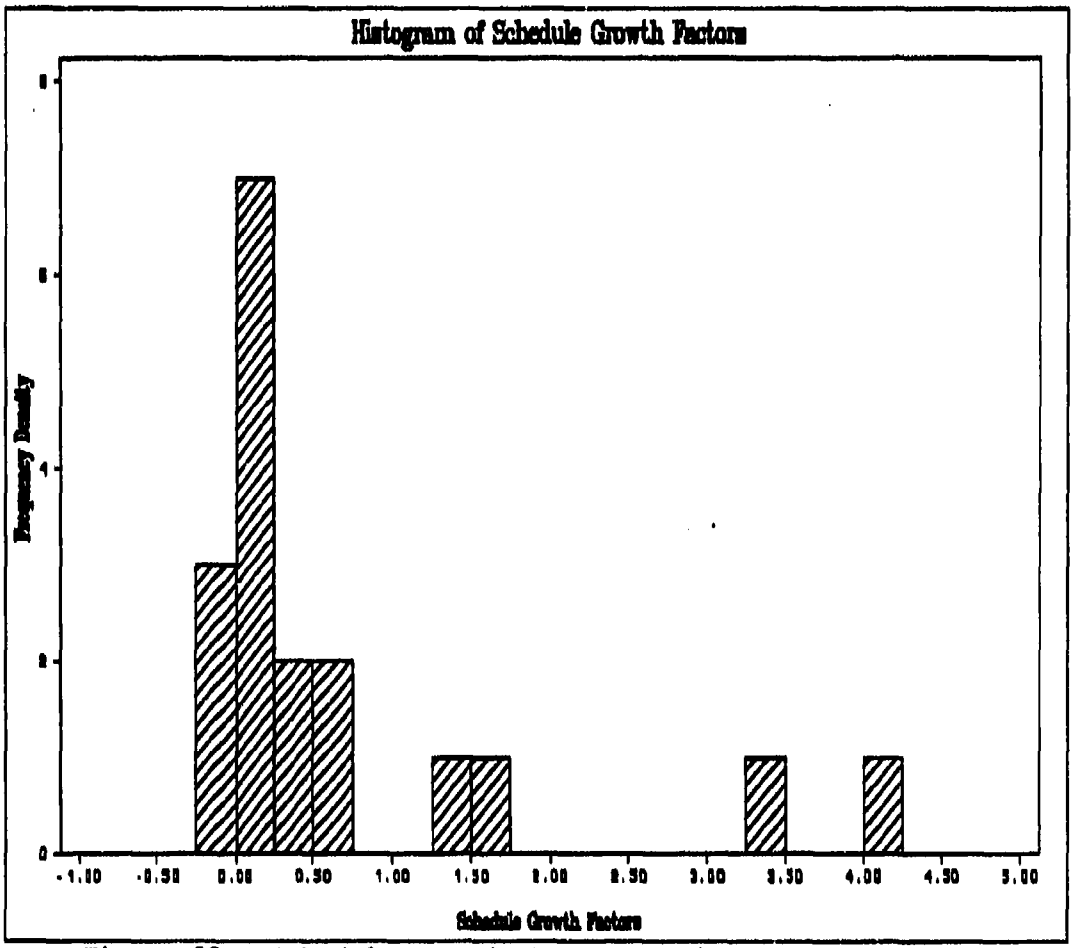

Figure 22: Schedule Growth Factors, Sole Source Contracts

Sample Statistics.

Sample Size = 18 Mean = .7083 Variance = 1.4244

Summary of Cost Growth Raw Data

The following table summarizes the cost data presented earlier. The data are presented in three phases that correspond to the phases of tests conducted for each research question.

TABLE 3

PHASE 1: SUMMARY DATA

Competed	Sole Source
N = 2242 n = 261 mean growth = .1444	N = 1260 n = 251 mean growth = .2358

TABLE 4

PHASE 2: SUMMARY DATA

	Lower Risk	Higher Risk
Competed	N = 924 n = 130 mean = .1278	N = 1318 n = 131 mean = .1609
Sole Source	N = 548 n = 125 mean = .2175	N = 712 n = 126 mean = .2538

TABLE 5

PHASE 3: SUMMARY DATA

	Lower Risk	Higher Risk
Competed-Lower Initial Price	n = 65 mean = 0	n = 64 mean = .1191
Competed-Higher Initial Price	n = 65 mean = .2929	n = 67 mean = .2149
Sole Source-Lower Initial Price	n = 63 mean = .0654	n = 63 mean = .1655
Sole Source-Higher Initial Price	n = 62 mean = .4515	n = 63 mean = .3421

Summary of Schedule Growth Raw Data

The following table summarizes the cost data presented earlier.

TABLE 6

SCHEDULE GROWTH SUMMARY DATA

Competed	Sole Source
N = 572 n = 20 mean growth = .1558	N = 198 n = 18 mean growth = .7083

Analysis Results

The statistical analysis was performed for each research question and corresponding hypothesis using the large sample test statistic to test for the difference in population means. The formula for the large sample test statistic is:

$$z = \frac{\bar{x} - \bar{y}}{\sqrt{\frac{s_1^2}{m} + \frac{s_2^2}{n}}}$$

For the schedule growth data, however, the large sample test statistic is inappropriate and the Wilcoxon Rank-Sum Test is used to test for the difference in population means. The test statistic for the Wilcoxon Rank-Sum Test is:

$$Z = \frac{W - \mu_W}{\sigma_W}$$

The confidence intervals of the mean growth presented earlier provide invaluable information regarding the predictability of the cost growth for a particular category.

Confidence intervals provide a ready reference to the range, upper and lower bounds, for the mean cost growth with a specified level of significance. For instance, referring to the confidence interval for the Lower Risk/Higher Price Competed Contracts on page 50, it can be predicted that if further statistical sampling was conducted, 95% of the samples would have a mean cost growth between 19% and 40%.

The results of the statistical analysis for each research question and the phases of tests that made-up each research question are now presented. Hypotheses and sub-hypotheses accompany the analysis for each research question and phase of test.

Research Question #1

For both cost growth and schedule growth categories, does the mean growth for competed contracts differ from the mean growth of sole source contract?

Hypothesis.

Ho: Mean Competed Growth = Mean Sole Source Growth
Ha: Mean Competed Growth ≠ Mean Sole Source Growth

For the cost growth data, the analysis tested the hypothesis in three phases. The first phase tested the hypothesis for the overall categories of competed versus sole source contracts as depicted in Table 3. The second phase tested the hypothesis after the sole source and competed data were segregated into lower and higher risk categories as depicted in Table 4. The third phase tested the hypothesis after the lower and higher risk data were

segregated into lower and higher initial price categories as depicted in Table 5. For schedule growth data, the analysis tested the hypothesis for the overall categories of competed versus sole source contracts as depicted in Table 6.

The analysis results from testing Research Question #1 are presented first for the cost growth and second for the schedule growth. Recall that the value of z_{crit} for a two-tailed test with a level of significance of .05 is equal to 1.96. Therefore, the decision rule states that if the test statistic, Z, is either greater than z_{crit} or less than $-z_{crit}$, the null hypothesis (H_o) is rejected in favor of the alternate hypothesis (H_a).

Cost Growth Data. The results of the cost growth analyses are presented for the Phase 1 test followed by the 2 tests in Phase 2 and finally the 4 tests of Phase 3. For all Research Question #1 tests, x-bar and y-bar represent competed and sole source mean cost growth respectively.

Phase 1 Test. The raw data and the analysis for the overall categories of competed versus sole source contracts are presented below.

$$\bar{x} = .1444 \qquad s_1^2 = .0828 \qquad m = 261$$
$$\bar{y} = .2358 \qquad s_2^2 = .1690 \qquad n = 251$$

The value of the large sample test statistic, z is:

$$z = -2.903$$

The null hypothesis is rejected at significance level .05. For the overall test for cost growth between sole source and competed contracts, the mean competed cost growth is less than the mean sole source cost growth.

The statistical significance of this first phase test is that the sole source cost growth is almost twice as high as competed cost growth, at 23.6% versus 14.4%. The p-value required to change the result of this test from rejecting to not rejecting the null hypothesis is equal to .004. In other words, the confidence level of the test must equal 99.6% in order for the null hypothesis to not be rejected.

Table 7 summarizes the results of the Phase 2 and 3 statistical tests for the first research question and the related hypotheses.

Phase 2 Tests. After Phase 1 testing, the raw data were segregated into lower and higher risk categories. The results of these 2 tests are now presented and analyzed.

TABLE 7

SUMMARY OF STATISTICAL TESTS FOR RESEARCH QUESTION #1

	Lower Risk	Higher Risk
Competed vs. Sole Source	Do Not Reject H_o	Reject H_o
Lower Price	Reject H_o	Do Not Reject H_o
Higher Price	Do Not Reject H_o	Do Not Reject H_o

Test 1: Lower Risk, Competed vs Sole Source.

Hypothesis.

Ho: Competed Lower Risk = Sole Source Lower Risk
Ha: Competed Lower Risk ≠ Sole Source Lower Risk

The raw data for these categories are:

$\bar{x} = .1278$ $s_1^2 = .0874$ $m = 130$
$\bar{y} = .2175$ $s_2^2 = .1900$ $n = 125$

The value of the large sample test statistic, z is:

$$z = -1.915$$

The null hypothesis cannot be rejected at significance level .05. The mean competed cost growth equals the mean sole source cost growth in the lower risk category. There is no statistical difference in the mean cost growth between competed and sole source contracts at the lower risk level.

Test 2: Higher Risk, Competed vs Sole Source.

Hypothesis.

Ho: Competed Higher Risk = Sole Source Higher Risk
Ha: Competed Higher Risk ≠ Sole Source Higher Risk

The raw data for these categories are:

$\bar{x} = .1609$	$s_1^2 = .0782$	$m = 131$
$\bar{y} = .2538$	$s_2^2 = .1488$	$n = 126$

The value of the large sample test statistic, z is:

$$z = -2.203$$

The null hypothesis is rejected at significance level .05. The mean competed cost growth does not equal, and is less than, the mean sole source cost growth in the higher risk category.

The statistical significance of these second phase tests are mixed. Although the lower risk hypothesis could not be rejected, the higher risk hypothesis was rejected. However, in both cases the results were consistent in that the mean cost for competed contracts is considerably less than, the mean cost growth of sole source contracts. The first row in Table 8 shows the p-values, or the level of significance for the tests, which would conclude the null

hypothesis, or that the mean cost growth between lower and higher risk competed and sole source contracts are equal.

Phase 3 Tests. After Phase 2 testing, the raw data were segregated into lower and higher initial price categories. The results of these 4 tests are now presented.

Test 1: Lower Risk/Lower Price Analysis.

Hypothesis.

Ho: Competed Lower Risk/Lower Price = Sole Source Lower Risk/Lower Price
Ha: Competed Lower Risk/Lower Price ≠ Sole Source Lower Risk/Lower Price

The raw data for these categories are:

$\bar{x} = 0$	$s_1^2 = 0$	$m = 65$
$\bar{y} = .0654$	$s_2^2 = .0491$	$n = 63$

The value of the large sample test statistic, z is:

$$z = -2.344$$

The null hypothesis is rejected at significance level .05. The mean competed cost growth does not equal the mean sole source cost growth for this category. The test indicates that the mean sole source cost growth in the lower risk, lower price category is greater than the competed contracts in the same category.

Test 2: Lower Risk/Higher Price Analysis.

Hypothesis.

Ho: Competed Lower Risk/Higher Price = Sole Source Lower Risk/Higher Price
Ha: Competed Lower Risk/Higher Price ≠ Sole Source Lower Risk/Higher Price

The raw data for these categories are:

$\bar{x}$ = .2929 s_1^2 = .1893 m = 65
$\bar{y}$ = .4515 s_2^2 = .5797 n = 62

The value of the large sample test statistic, z, is:

z = -1.432

The null hypothesis cannot be rejected at significance level .05. The mean competed cost growth equals the mean sole source cost growth in the lower risk/higher price category.

Test 3: Higher Risk/Lower Price Analysis.

Hypothesis.

Ho: Competed Higher Risk/Lower Price = Sole Source Higher Risk/Lower Price
Ha: Competed Higher Risk/Lower Price ≠ Sole Source Higher Risk/Lower Price

The raw data for these categories are:

$\bar{x}$ = .1191 s_1^2 = .0497 m = 64
$\bar{y}$ = .1655 s_2^2 = .1156 n = 63

The value of the large sample test statistic, z, is:

z = -.9077

The null hypothesis cannot be rejected at significance level .05. The mean competed cost growth equals the mean sole source cost growth in this category.

Test 4: Higher Risk/Higher Price Analysis.

Hypothesis.

Ho: Competed High Risk/Higher Price = Sole Source High Risk/Higher Price
Ha: Competed High Risk/Higher Price ≠ Sole Source High Risk/Higher Price

The raw data for these categories are:

$\bar{x}$ = .2149 s_1^2 = .1401 m = 67

$\bar{y}$ = .3421 s_2^2 = .1687 n = 63

The value of the large sample test statistic, z is:

$$z = -1.842$$

The null hypothesis cannot be rejected at significance level .05. The mean competed cost growth equals the mean sole source cost growth in this category.

The statistical significance of these third phase tests are mixed. The lower risk/lower price category, test 1, is the only test that rejected the null hypothesis. However, in all 4 cases the results were consistent in that the mean cost growth for competed contracts is considerably less than the mean cost growth of sole source contracts. The second and third rows in Table 8 show the p-values, or the level of significance for the tests, which would conclude the null hypothesis, that the mean cost growth between lower and higher initial price, lower and higher risk competed contracts is equal to lower and higher initial price, lower and higher risk sole source contracts.

TABLE 8

P-VALUES ASSOCIATED WITH RESEARCH QUESTION #1.

	Lower Risk	Higher Risk
Competed vs. Sole Source	P-Value = .055	P-Value = .028
Lower Price	P-Value = .019	P-Value = .363
Higher Price	P-Value = .135	P-Value = .066

Schedule Growth Data. Recalling from Chapter III, for the sole source data, $n = 18$ and for competed data, $n = 20$. Using the equations given in Chapter III for the mean and variance of W and the above values for m and n, the following values were calculated.

$$\mu_w = 351 \qquad \sigma_w^2 = 1170$$

The test statistic, W, is defined as the sum of the ranks of the sole source data, from a combined and ordered set of competed and sole source data. The value of the Rank-Sum W, was determined to be:

$$W = 394.5$$

Using the test statistic Z defined by Devore and presented in Chapter III, the value of Z is:

$$Z = \frac{394.5 - 351}{\sqrt{1170}} \qquad Z = 1.27$$

The value of z_{crit} for a two-tailed test with a .05 level of significance is equal to 1.96. Therefore, the

decision rule states that if Z is either greater that z_{crit} or less than $-z_{crit}$, the null hypothesis (H_o) is rejected in favor of the alternate hypothesis (H_a).

The mean schedule growth was tested using the Wilcoxon Rank-Sum Test. The results failed to reject the null hypothesis at a significance level of .05. A p-value equal to .204 instead of .05 would result in rejection of the null hypothesis and conclude that there is a difference in schedule growth between sole source and competed contracts.

Although the test failed to reject the null hypothesis at a significance level of .05, the raw data indicates that the schedule growth of sole source contracts is more than 4 times greater than competed contracts.

Research Question #2

For the cost growth category only, does the mean cost growth for competed and sole source lower risk contracts differ from competed and sole source higher risk contracts?

Hypothesis.

Ho: Low Risk Mean Growth = High Risk Mean Growth
Ha: Low Risk Mean Growth ≠ High Risk Mean Growth

This analysis again used the large sample test statistic to test for differences in population means between lower risk and higher risk contracts, within competed and sole source categories. For cost growth data the analysis tested the above hypothesis in 2 phases. The first phase tested for differences in the mean cost growth between lower and higher risk contracts in both competed and sole source categories as depicted in Table 4. The second

phase tested for differences in the mean cost growth when the Phase 1 data is stratified into lower and higher initial price categories for both competed and sole source contracts as depicted in Table 5.

The analysis results are presented first for the 2 Phase 1 tests. This is followed by the results on the 4 Phase 2 tests. The decision rule stated earlier for a two-tailed test also applies for this research question. For all Research Question #2 tests, x-bar and y-bar represent lower and higher risk categories respectively.

Phase 1 Tests. The raw data and analysis for lower and higher risk contracts in both competed and sole source categories, are presented below. There are 2 tests.

Test 1: Competed Category Overall.

Hypothesis.

Ho: Competed Lower Risk = Competed Higher Risk
Ha: Competed Lower Risk ≠ Competed Higher Risk

The raw data for, and the results of the statistical tests on the combined sample in the competed category are:

$\bar{x} = .1278$ $s_1^2 = .0163$ $m = 130$
$\bar{y} = .1609$ $s_2^2 = .0782$ $n = 131$

The value of the large sample test statistic, z is:

$$z = -.9287$$

The null hypothesis cannot be rejected at significance level .05. The lower risk mean cost growth equals the higher risk mean cost growth for competitive contracts.

The statistical tests showed that the null hypothesis could not be rejected at significance level equal to .05.

There is no statistical difference between competed lower risk and competed higher risk cost growth.

Test 2: Sole Source Category Overall.

Hypothesis.

Ho: Sole Source Lower Risk = Sole Source Higher Risk
Ha: Sole Source Lower Risk ≠ Sole Source Higher Risk

The raw data and the results of the statistical tests on the combined sample in the sole source category are:

$\bar{x} = .2175$ $s_1^2 = .1900$ $m = 125$
$\bar{y} = .2538$ $s_2^2 = .1488$ $n = 126$

The value of the large sample test statistic, z is:

$z = -.6984$

The null hypothesis cannot be rejected at the .05 significance level. The lower risk mean cost growth equals the higher risk mean cost growth for sole source contracts.

Statistical tests of Phase 1 showed the null hypotheses could not be rejected at significance level .05. However, in both tests the cost growth on higher risk contracts is greater than the cost growth on lower risk contracts.

Phase 2 Tests. After phase 1 testing, the raw data were segregated into lower and higher initial price categories. The results of these 4 tests are now presented.

The following table summarizes the results of the statistical tests for Phase 2 of Research Question #2. The tests determined if a significant differences existed between the mean cost growths of lower and higher risk contracts when the data was segregated into competed/sole source and lower/higher price categories.

TABLE 9

SUMMARY OF STATISTICAL TESTS FOR RESEARCH QUESTION #2

	Lower Price	Higher Price
Competitive	Reject H_o	Do Not Reject H_o
Sole Source	Do Not Reject H_o	Do Not Reject H_o

Test 1: Competed Lower Price.

Hypothesis.

Ho: Competed Lower Price/Lower Risk = Competed Lower Price/Higher Risk
Ha: Compete Lower Price/Lower Risk ≠ Competed Lower Price/Higher Risk

The raw data for this category are:

$\bar{x} = 0$ $s_1^2 = 0$ $m = 65$
$\bar{y} = .1191$ $s_2^2 = .0497$ $n = 64$

The value of the large sample test statistic, z is:

$$z = -4.284$$

The null hypothesis is rejected at significance level .05. The lower risk mean cost growth does not equal, and is less than, the higher risk mean cost growth in the competitive, lower price category.

Test 2: Competed Higher Price.

Hypothesis.

Ho: Competed Higher Price/Lower Risk = Competed Higher Price/Higher Risk
Ha: Competed Higher Price/Lower Risk ≠ Competed Higher Price Higher Risk

The raw data for this category are:

$\bar{x} = .2929$ $s_1^2 = .1893$ $m = 65$
$\bar{y} = .2149$ $s_2^2 = .1401$ $n = 67$

The value of the large sample test statistic is:

$z = 1.102$

The null hypothesis cannot be rejected at significance level .05. The lower risk mean cost growth equals the higher risk mean cost growth in this category.

Test 3: Sole Source Lower Price.

Hypothesis.

Ho: Sole Source Lower Price Lower Risk = Sole Source Lower Price Higher Risk
Ha: Sole Source Lower Price Lower Risk ≠ Sole Source Lower Price Higher Risk

The raw data for this category are:

$\bar{x} = .0654$ $s_1^2 = .0491$ $m = 63$
$\bar{y} = .1655$ $s_2^2 = .1156$ $n = 63$

The value of the large sample test statistic is:

$z = -1.957$

The null hypothesis is not rejected at significance level .05. The lower risk mean cost growth equals the higher risk mean cost growth in the sole source.

Test 4: Sole Source Higher Price.

Hypothesis.

Ho: Sole Source Higher Price/Lower Risk = Sole Source Higher Price/Higher Risk
Ha: Sole Source Higher Price/Lower Risk ≠ Sole Source Higher Price/Higher Risk

The raw data for this category are:

$\bar{x}$ = .4515 s_1^2 = .5797 m = 62

$\bar{y}$ = .3421 s_2^2 = .1687 n = 63

The value of the large sample test statistic is:

z = .9975

The null hypothesis cannot be rejected at significance level .05. The lower risk mean cost growth equals the higher risk mean cost growth in the sole source, higher price category.

The statistical significance of the Phase 2 tests are mixed. The test between lower and higher risk contracts in the lower price competed category resulted in the rejection of the null hypothesis. This indicates that, higher risk contracts exhibit greater cost growth than, lower risk contracts in the competed, lower price category. For both competed and sole source contracts, for lower priced contracts, higher risk contracts grow at a higher rate than lower risk contracts. Conversely, for higher priced contracts, lower risk contracts grow at a higher rate than higher risk contracts. Table 10 lists the p-values, or the level of significance for these 4 tests which would conclude the null hypothesis, that the mean cost growth between lower and higher risk contracts are equal for categories of competed/sole source and lower and higher initial price.

TABLE 10

P-VALUES ASSOCIATED WITH RESEARCH QUESTION #2.

	Lower Price	Higher Price
Competitive	P-Value = 0	P-Value = .271
Sole Source	P-Value = .05	P-Value = .317

Research Question #3

For the cost growth category only, does the mean cost growth for competed and sole source lower priced contracts differ from competed and sole source higher priced contracts?

Hypothesis.

Ho: Low Cost Mean Growth = High Cost Mean Growth
Ha: Low Cost Mean Growth ≠ High Cost Mean Growth

This analysis consisted of 4 tests for differences in population means between lower and higher priced contracts. The analysis covers contracts of lower and higher risk for both competed and sole source categories. For all Research Question #3 tests, x-bar and y-bar represent lower and higher initial price cost growth respectively. The decision rule stated earlier also applies to these tests. The value of the large sample test statistic Z was computed for the 4 phases of tests. Table 11 summarizes the results of the statistical tests for the third research question and the related hypotheses.

TABLE 11

SUMMARY OF STATISTICAL TESTS FOR RESEARCH QUESTION #3

	Lower Risk	Higher Risk
Competitive	Reject H_o	Do Not Reject H_o
Sole Source	Reject H_o	Reject H_o

Test 1: Competed Category Lower Risk.

Hypothesis.

Ho: Competed Lower Risk/Lower Price = Competed Lower Risk/Higher Price
Ha: Competed Lower Risk/Lower Price ≠ Competed Lower Risk/Higher Price

The raw data for this category are:

$\bar{x} = 0$ $s_1^2 = 0$ $m = 65$
$\bar{y} = .2929$ $s_2^2 = .1893$ $n = 65$

The value of the large sample test statistic is:

$$z = -5.394$$

The null hypothesis is rejected at significance level .05. The lower price mean cost growth does not equal, and is less than the higher price mean cost growth in the competed, lower risk category.

Test 2: Competed Category Higher Risk.

Hypothesis.

Ho: Competed Higher Risk/Lower Price = Competed Higher Risk/Higher Price
Ha: Competed Higher Risk/Lower Price ≠ Competed Higher Risk/Higher Price

The raw data for this category are:

$\bar{x}$ = .1191 s_1^2 = .0497 m = 64
$\bar{y}$ = .2149 s_2^2 = .1401 n = 67

The value of the large sample test statistic is:

z = -1.788

The null hypothesis cannot be rejected at significance level .05. The lower price mean cost growth equals the higher price mean cost growth in this category.

Test 3: Sole Source Category Lower Risk.

Hypothesis.

Ho: Sole Source Lower Risk/Lower Price = Sole Source Lower Risk/Higher Price
Ha: Sole Source Lower Risk/Lower Price ≠ Sole Source Lower Risk Higher Price

The raw data for this category are:

$\bar{x}$ = .0654 s_1^2 = .0491 m = 63
$\bar{y}$ = .4515 s_2^2 = .5797 n = 62

The value of the large sample test statistic is:

z = -3.836

The null hypothesis is rejected. The lower price mean cost growth is not equal, and is less than the higher price mean cost growth in this category.

Test 4: Sole Source Category Higher Risk.

Hypothesis.

Ho: Sole Source Higher Risk/Lower Price = Sole Source Higher Risk/Higher Price
Ha: Sole Source Higher Risk/Lower Price ≠ Sole Source Higher Risk/Higher Price

The raw data for this category are:

$\bar{x}$ = .1655 s_1^2 = .1156 m = 63
$\bar{y}$ = .3421 s_2^2 = .1687 n = 63

The value of the large sample test statistic is:

$$z = -2.628$$

The null hypothesis is rejected at significance level .05. The lower price mean cost growth does not equal, and is less than the higher price mean cost growth in the sole source, higher risk category.

The statistical significance of these 4 tests are mixed. The competed/higher risk hypothesis is the only test that failed to rejected the null hypothesis. However, in all 4 cases the results were consistent with the mean cost growth for higher priced contracts being considerably greater than the mean cost growth of lower priced contracts. Table 12 shows the p-values, or the level of significance for these 4 tests, which would conclude the null hypothesis, or that the mean cost growth between lower and higher initial price contracts are equal in the 4 categories involved.

TABLE 12

P-VALUES ASSOCIATED WITH RESEARCH QUESTION #3.

	Lower Risk	Higher Risk
Competitive	P-Value = 0	P-Value = .073
Sole Source	P-Value = .0002	P-Value = .009

Conclusions

The results consistently showed that the competed contracts, in all sub-categories, have lower cost growth than corresponding sole source contracts. Also, the competed contracts showed less schedule growth than sole source contracts. Even though the statistical tests, in most cases failed to reject the null hypothesis that the two means are equal, across every category, the sole source cost and schedule growth is greater than the corresponding cost and schedule growth for competed contracts.

Chapter V presents conclusions of both statistical and managerial significance based on the findings and analysis presented in this chapter. Recommendations for future research that would extend this research are then discussed.

V. Conclusions and Recommendations

Introduction

This chapter presents conclusions based upon the findings and analysis presented in Chapter IV. Discussion focuses on the managerial implications of the analysis for each research question. Finally, recommendations for future research are suggested.

Research Implications

This research was designed to answer the 3 research questions described in Chapter I. The managerial significance of the conclusions are discussed for each research question and associated hypothesis. This analysis did not, nor did it attempt to determine improvements in performance or quality, reduced technological risk, or the strengthening of the defense industrial base.

When considering the managerial implications of the statistical results, two factors must be considered. First, the significance level at which the null hypothesis is rejected is strictly a management decision. If management requires a high level of confidence in the test, a possibility exists that the null hypothesis could be accepted when in fact, it would be rejected at a lower level of confidence.

The second factor that requires consideration is the amount of variability in the sample mean. In this research, the high variability in the sample mean cost growths caused, in most cases, the null hypothesis to be accepted, when

considerable differences existed in mean cost growths between competed and sole source contracts.

Research Question #1

For both cost and schedule growth categories, does the mean growth for a competed contract differ from the mean growth of a sole source contract?

For this research question, the conclusions of the cost growth analysis are discussed first followed by the conclusions of the schedule growth analysis.

Cost Growth Managerial Implications. Although the significance level selected prevents rejection of the null hypothesis in four cases, cost growths are consistently higher on sole source contracts in all categories of risk and initial price.

Based on the raw data and analysis presented in Chapter IV, managers can expect sole source contracts to grow faster than competed contracts. The analysis conducted with this research reinforces claims that competition is effective in saving the government money on Air Force procurement's. The prior studies discussed in Chapter II identified cost savings ranging from 12% to 53% as a result of competition. These savings coupled with the savings identified in this study make the overall dollar savings resulting from competition highly significant. It is yet to be determined if these savings compensate for the additional costs incurred by the government when using competition. However, past performance does not guarantee future results. The variability of other effects on the defense marketplace

discussed in Chapter III may significantly impact the effectiveness of competition.

The data and analysis presented does not support the concept of contractor "buying-in" discussed in Chapter II. A contractor buys-in to a contract by bidding excessively low prices and aggressive schedules in hopes of recouping losses over time through contract modifications. This practice is readily admitted by contractors however, this analysis would support the contention that buying-in is less prevalent than previously contemplated. This conclusion is reached because it is counter intuitive to imagine that contractors would buy-in to sole source contracts. This may be an area for future research.

In summary, since the growth rate of sole source contracts is greater than competed contracts, the initial savings of competition at the time of contract award does not dissipate over time but in fact the benefits of competition are increased during the execution of the contract.

Schedule Growth Managerial Implications. Although the tests' level of significance does not allow the null hypothesis to be rejected, analysis of the raw data indicates that the schedule growth on sole source awards is over four times greater than competed contracts.

This analysis further supports claims that competition provides benefits well beyond cost. When companies are awarded contracts under competitive conditions, lower profit margins force management to ensure timely schedule performance because of the schedule and cost relationship.

Also, for competed awards, schedule and contractor's past performance are usually part of the source selection criteria. Because of these factors contractors must more closely scrutinize and manage schedules.

Finally, a possible explanation for the differences in the mean schedule growth, the mean age of sole source contracts was more than 2 years greater than that for competed contracts. As discussed in Chapter III, the age of the contract may impact the mean schedule growth calculation. Contractors generally have more flexibility early in a contract to meet contract delivery milestones. By prioritizing contract assets, managers can meet early delivery schedules at the expense of later deliveries. Because schedule delivery problems may not be fully apparent until later in the contract, the competed contracts with a lower average age may not indicate the true schedule performance of the contractor.

Research Question #2

For the cost growth category only, does the mean cost growth for competed and sole source lower risk contracts differ from competed and sole source higher risk contracts?

Managerial Implications. Although the level of significance used in the statistical tests prevents rejection of the null hypothesis in five cases, two significant observations are evident from the data.

1. For lower price contracts the mean cost growth is greater on higher risk contracts than on lower risk contracts, for both sole source and competitive categories.

2. For higher price contracts the mean cost growth is less on higher risk efforts than on lower risk contracts, for both sole source and competitive categories.

For lower price contracts the raw cost growth data intuitively makes sense. It should be expected that the cost growth on a contract with higher risk would grow faster than a lower risk contract regardless of the procurement strategy. For this research, higher risk contracts are defined as any cost type contract. Because a cost contract is used, the contractor does not have the same financial pressures as those found on a fixed price contract.

For higher price contracts, the cost growth raw data is difficult to analyze. A possible explanation for this set of data may be associated with the operational definitions for higher and lower risk contracts used in this thesis. Since the research defined higher risk efforts as some type of fixed priced contracts, the successful offerors may have accounted for the risk in the effort with their initial proposals. Conversely, on lower risk efforts, a relatively higher degree of competition may exist because more sources are qualified to complete the effort being contracted for, thus the initial awards may have tighter margins.

Research Question #3

For the cost growth category only, does the mean cost growth for competed and sole source lower priced contracts differ from competed and sole source higher priced contracts?

Managerial Implications. Again, the factors of significance level and variability have important management implications. Analysis of the raw data shows that the mean cost growth is greater on higher price contracts than on lower price contracts for all categories. Three possible explanations of the results are offered:

1. Higher priced contracts are more complex than lower priced contracts thus are subject to higher cost growth. Just the fact that an effort is high priced may eliminate qualified sources from the competition. The possibility of a loss on a higher priced effort may destroy the company, thus management elects to pass up the opportunity to bid.

2. Lower priced contracts have a higher level of direct and indirect competition than higher priced contracts. In other words, on lower priced efforts, offerors not only compete against each other but the program itself is competing against other items in the budget.

3. Lower priced contracts do not have the same flexibility to expand in scope as the higher priced contracts. Lower priced contracts may have a limited scope and do not have opportunities to expand. Also, large contracts develop their own constituency over time because of the civilian jobs tied to the project. This gives the project a life beyond its military utility or support.

Recommendations for Future Research

This thesis investigated the cost and schedule growth of sole source and competitive contracts relative to risk and initial price. The risk and cost stratification is only

one of many possible ways to segregate the growth rates of competitive and sole source awards. Variables that could be studied to increase the body of knowledge on the "benefits of competition" are:

1. Comparisons of cost and schedule growth among different product centers and/or weapon systems. This may give the government insight to the competitiveness of different segments of the defense industry.

2. Comparisons of cost and schedule growth relative to changes in the defense budget. This analysis may give the government insight to how overall defense expansion or cuts ripple through the defense industry. This may measure the effects of program stretch out, industry capacity or the competitive effects of competing programs.

3. Comparisons of cost and schedule growth before and after the implementation of CICA. This study may help to clarify the true effects of CICA.

4. Comparisons of cost and schedule growth over time. Analysis of how cost and schedule growths have changed in increments of five years, form the early 1970's to the present would possibly provide a predictive ability for future cost and schedule growths.

5. Comparisons of cost and schedule growth during specific acquisition phases. This would give the Air Force insight into the effects of acquisition strategies on cost and schedule growth and how decision early in a programs life can effect the level of competition during the later phases of development.

6. Comparisons of the qualitative aspects between competed and sole source contracts. Although research on competition has focused mainly on cost benefits, it seems intuitively obvious that benefits can be gained on weapon system performance and quality with the introduction of competition.

7. A regression model could be developed to predict cost and schedule growth based on a number of contract parameters. For example contract descriptive data such as, acquisition strategy/phase, number of competitors, type of contract, contract age, initial price, and type of weapon system/Product Center could be used as parameters in a regression model. This can be used by Air Force managers for budget planning or as a tool to develop acquisition strategy.

The future research possibilities on this subject are numerous. The accessibility to valid contract information from the AMIS data bases expands the research possibilities and enables relatively easy data retrieval and analysis.

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Vita

Captain Klaes R. Wandland was born on 29 July 1960 in Worcester, Massachusetts. He graduated from David Prouty High School in Spencer, Massachusetts in 1978 and attended Worcester Polytechnic Institute, graduating with a Bachelor of Science degree in Mechanical Engineering in May 1982. He attended the Air Force Officer Training School and received his commission on 11 June 1983. His first tour of duty was at the Ballistic Missile Office at Norton AFB, California. He began as a Logistics Engineer for the Peacekeeper Launch Control System as well as the Airborne Launch Control Center. In 1985 he was named the Program Manager for the Airborne Launch Control Center Automatic Test Equipment Program. He served in that capacity until reassigned to the Joint STARS program office at Electronics System Division at Hanscom AFB, Massachusetts. On the Joint STARS program he served as a project engineer for the Built-In Test and Maintainability program. In 1990 he was named the Program Manager for the Joint STARS surveillance and Control Data Link. He served in that capacity until May 1992 when he began graduate studies in Systems Management at the Air Force Institute of Technology.

Permanent Address:

84 Ash St.
Spencer, Massachusetts 01562

Vita

Captain Gary P. Wickman was born on 17 April 1960 in Detroit, Michigan. He graduated from Kingsford High School in Kingsford, Michigan in 1978 and attended Lawrence Institute of Technology in Southfield, Michigan and Michigan Technological University in Houghton, Michigan, graduating with a Bachelor of Science in Mechanical Engineering in 1983. He received his commission from Officer's Training School in October 1983 and served at Wright-Patterson AFB, Ohio on his first assignment. He began as an electronic warfare systems project officer on the EF-111A production program, and subsequently several other electronic warfare programs.

In 1988, Captain Wickman was selected into the BEST program, and after attending the Aircraft Maintenance Officer's Course at Chanute AFB, IL, he reported to Minot AFB, ND in December 1988 as an Aircraft Maintenance Officer. There he served as an aircraft maintenance officer in several capacities including: flightline maintenance; OIC, Aircraft Readiness Center; and OIC of Quality Assurance until entering the School of Systems and Logistics, Air Force Institute of Technology in May 1992.

Permanent Address:

125 Balsam
Kingsford, Michigan 49801

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13. ABSTRACT (*Maximum 200 words*) This study investigated if differences exist in the cost and schedule growth of competed versus sole source contracts. Prior studies concentrated mainly on estimated savings from competition at the time of contract award. This study expanded prior analysis by investigating the cost and schedule growth over the contract's period of performance. In addition to an analysis between competed and sole source contracts, this study investigated if differences exist between lower and higher risk contracts as well as lower and higher initial priced contracts. When comparing competed and sole source contracts the results were consistent, with sole source contracts exhibiting an average of 57% higher cost growth in all areas. Sole source contracts also exhibited a schedule growth that was over 4 times greater than the schedule growth of competed contracts. When comparing lower and higher initial priced contracts, the results were also consistent with higher priced contracts exhibiting higher cost growth than lower price contracts. The results were mixed when measured between lower and higher risk contracts however.

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