COST ANALYSIS BETWEEN SABER AND DESIGN BID BUILD CONSTRUCTION

THESIS

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Abstract

The majority of Air Force construction performed by two main contractual methods, Design Bid Build (DBB) and Simplified Acquisition of Base Engineering Requirements (SABER). DBB is the traditional contracting method where each project is competitively bid. SABER uses one contractor to complete multiple projects over the duration of the contract, using unit prices established in the original contract.

The purpose of this research project was to perform a cost analysis between DBB and SABER construction. The research involved finding appropriate projects completed by the two methods that were comparable. This involved going to Wright-Patterson and Holloman Air Force Bases to gather project information. There were a total of 46 projects collected from both bases. Then a methodology was developed to compare the projects collected. Projects were divided into categories containing similar types of construction. Data from the project was then used to calculate a unit cost per dimensional characteristic for the project. Project comparability was demonstrated by showing that the group of projects constructed by each method completed a similar type and scope of work. Time and cost growth were also compared for DBB versus SABER.

The research findings showed that SABER was cheaper but not at a statistical level of significance. The comparison could only be completed in one area of construction, interior renovation, due to the limited number of comparable projects in the remaining construction categories. SABER construction also performed better in cost and time growth for most instances.

COST ANALYSIS BETWEEN SABER AND DESIGN BID BUILD CONSTRUCTION

1. Introduction

There are two main contracting methods used for general Air Force Civil Engineering construction, Design Bid Build (DBB) and Simplified Acquisition of Base Engineering Requirements (SABER). DBB contracting is extremely time consuming due to stringent guidelines established to create a competitive bidding process that is fair for all prospective bidders. The DBB contract solicitation process requires approximately 80 days under ideal situations (Working in the Engineering Flight, 1996:Ch 7, 34). DBB construction also requires complete design. Depending on the complexity of the project and competence of the Architect-Engineer firm hired to do the design, this process can take anywhere from three to nine months.

Combining both design and contracting time creates a construction procurement process that can take up to 12 months from the time a design is started before construction begins. This long process leads to two problems. Using agencies have to wait a minimum of one year before their project is complete, and a backlog of projects develop because the administrative support available for the process is not capable of keeping pace with the number of new projects.

SABER reduces user wait time and project backlog by streamlining the construction procurement process to less than a month, including design in most instances (Furr, 1996:4). SABER provides a contractual mechanism where a general construction

contractor is on call for the duration of the contract, usually five years. The contractor can perform multiple projects, although complexity and content are limited, as long as the maximum dollar limit for the contract is not breached. SABER has experienced tremendous growth during its 12-year existence. When originally established by the Air Force in 1987, SABER delivery orders were limited to $25,000, currently they are capped at $500,000 (AFFARS Appendix DD, 1996:104). Despite the enormous growth of SABER throughout the Air Force, there is still limited knowledge on whether SABER construction is more expensive than DBB construction.

1.1 Research Question

The purpose of this thesis is to compare the cost of projects completed by SABER versus DBB contracting. The hypothesis to be tested is that SABER projects will have lower dollar cost in many applications. The enormous growth and success of the SABER program validates its usefulness to the Air Force. The real question is how much does it cost or save to have the advantages of this faster construction program. A definite answer on the cost of the program will validate the potential of possibly expanding the program to include more construction projects. This research will compare the total project costs for similar projects completed through SABER and DBB construction.

1.2 Research Objectives

The following objectives were established to assist in answering the research question:

1. Gather project information on projects completed using both contracting methods.
2. Develop a system for comparing the projects.

3. Investigate other metrics used to compare the application effectiveness of SABER versus DBB contracting methods.

4. Provide recommendations for future SABER use within the Air Force.

1.3 Research Methodology

This research will be accomplished by comparing the cost of actual construction that has been completed using DBB and SABER contracting methods. Similar types of construction projects already completed by both methods will be compared at the square foot, or dimensional cost level. Construction cost will be expanded to include all applicable costs such as design cost. There are additional factors that influence the success level of a construction project that are not measured exclusively in dollars. To capture these aspects of DBB and SABER, comparisons will be performed for construction cost and time growth. These additional factors will provide measures of the application advantages of SABER versus DBB.

1.4 Scope of Research

Projects used for this research will be limited to those completed in the past three years. These projects will be from Wright-Patterson Air Force Base and Holloman Air Force Base. There will be two, or three construction types depending on the available project data. Ideally five to ten projects in each category completed by each method will be analyzed. The small sample sizes are due to the expected limited number of comparable projects completed by DBB and SABER contracting methods.

1.5 Relevance

This research will evaluate the cost of DBB construction versus SABER construction using empirical data from completed construction. Other relevant comparisons such as time growth and cost growth will also be prepared. These results should provide recommendations on the future use of SABER in the Air Force. The Air Force is using SABER to complete large dollar amounts of construction; therefore, effectiveness of these dollars is critical during times of reduced budgets.

1.6 Summary

This chapter provided background information on DBB versus SABER cost analysis, and outlined the approach that will be used to answer the research question. Chapter two, Literature Review, will provide a detailed comparison of DBB and SABER from current literature concerning construction cost for the two methods. Chapter 3, Methodology, will detail the methods and tools used to accomplish the research objectives. Following this, Chapters 4 and 5, Analysis and Results respectively, will document the cost comparison process and the conclusions derived from this research.

2. Literature Review

Chapter 2 provides a summary of recent and current research to establish the framework for this thesis. This chapter first provides background on Design Bid Build (DBB) and Simplified Acquisition of Base Engineering Requirements (SABER) followed by explanations of the two contracting methods as they relate to the cost of each method. Finally, case studies will be summarized that discussed advantages of the SABER contracting method.

2.1 History of SABER

Historically, DBB contracting was the traditional method used for Air Force construction. The main characteristics of DBB construction are open competition and award to the lowest responsible-responsive bidder. DBB construction is effective because it can be used for any type of construction, and award to the low bidder produces reasonably priced construction. The negative aspects of DBB construction include the long contract solicitation and award process, 100% design is required, and frequent contract modifications. SABER began as a spin off of the Army JOC (Job Order Contracts) program. JOC was started in 1980 to overcome historical problems in the quality of performance, contractor responsiveness to changes in requirements, high cost of detailed design, and the lengthy award process for some DBB construction contracts (typically 12-14 months). In January 1987, the first Air Force test base, McClellan, implemented SABER (SABER References, 1996:1). The program was then implemented for use Air Force wide later in 1987. SABER provided the government with the ability to

award general construction projects quickly by having the same contractor perform multiple delivery orders over the duration of the contract. SABER was established as a compliment and not replacement for DBB construction contracting; therefore SABER was developed for small, non-complex, general construction. Regulations established to ensure SABER's use in this manner include limitations on the level of detail contained in government furnished design, the remaining design can only be performed by the SABER contractor without the use of Architecture-Engineering Firms, and a maximum delivery order of $25,000. Currently the maximum delivery order has been increased to $500,000 (AFFARS Appendix DD, 1996:104). Due to SABER's quick response time it has become an extremely popular tool for performing Air Force construction, in 1998 the 18 bases in Air Combat Command performed $52 million of SABER construction (Bagshaw, 1999:1).

2.2 Description of Construction Methods

There are some similarities and differences between the DBB and SABER contracting methods. The following section will highlight similarities, discuss the differences and provide a basic understanding of how the two processes work.

2.2.1 DBB Construction. DBB construction contracting follows a four-step process developed to produce full and open competition for all prospective bidders. Step 1 is the identification of a construction requirement. Step 2 is the preparation of the design package. The design package includes 100% complete drawings, specifications governing every construction aspect of the project, government cost estimate, and contractual documents needed for solicitation. Design that is 100% complete contains

drawings and specifications that contain enough detail to describe the construction without any additional explanations. Step 2 is significant because of the level of effort required to produce these documents. The documents are required to contain enough detail that any competent contractor could complete the project using appropriate construction methods. The level of detail creates the proper environment for award based on the low bid since there is only one interpretation for the design package. Step 3 is the solicitation of the contract. Contract solicitation includes advertisement of the project, site visits for prospective bidders, clarification of questions concerning the design documents, and receiving the bids. This process requires a minimum of 80 days according to Air Force guidance (Arnavas and Ruberry, 1998:Ch2, 14). The final step, step 4, is awarding the contract to the lowest responsive-responsible bidder. After award of the contract, construction is performed according to the contract and design documents.

2.2.2 SABER Construction. The SABER construction method is based on expediency, with the construction process divided into two major parts, contract solicitation and delivery order execution. The SABER contract is based on the principle of an indefinite delivery indefinite quantity (IDIQ) contract, first the contract is procured then an unspecified number of projects are completed during the duration of the contract. The SABER contract is normally composed of a base year with four optional years creating total contract duration of five years. The procurement process consists of government development of the unit price book, along with a master set of specifications. The unit price book gives labor and quantity cost, for all construction elements that may be applicable to general construction (AFFARS Appendix DD, 1996:102). The master

specifications govern all construction items that are relevant for general construction at that base. These documents are advertised to allow all contractors with the capability and capacity to handle the contract to bid on the contract by preparing a coefficient. The coefficient is used as a multiplication factor for the line items in the unit price book; it modifies the cost of line items to meet that contractor's cost including overhead and profit. Award of the contract is based on the contractor that has the best capability, capacity, and coefficient mix as determined by the contractor selection criteria.

After award, the number of individual projects, called delivery orders, is determined by the needs of the base and a minimum and maximum dollar amount set in the contract. Delivery orders are the individual projects that arise during the life of the SABER contract. Delivery orders must comply with regulations governing SABER that require a $500,000 maximum dollar amount, and 90% of the work elements must come from the unit price book.

Delivery order preparation has undergone some recent changes. When SABER was originally developed the government prepared an independent cost estimate and drawings for each delivery order or project. Then a site visit was held with the contractor, Civil Engineering representative, Contracting Officer representative and the using agency. This was followed by contractor preparation of their estimate. The contractor's estimate and the government estimate would be compared and negotiated to ensure all line items and quantities are in congruence. At this point, the SABER delivery order is treated like a DBB contract and construction proceeds. In October 1999, the government is no longer required to prepare an independent estimate for delivery orders greater than $100,000 (Contracting Policy Memo 99-C-05, 1999:1). This changes the goal of negotiations from

congruence, to government acceptance of contractor line items and quantities for applicable projects.

2.2.3 Summary. There are some similarities and many differences between DBB and SABER. The goal of both methods is to provide contract completed construction for the Air Force, the remainder of this chapter will explore how the differences affect cost.

2.3 Contract Procurement

Contract procurement is the process the government undergoes to acquire a contractor for a project. There are key features of DBB and SABER contract procurement that affect the cost for each method.

2.3.1 DBB Contract Procurement. Under DBB construction each project must undergo the contract procurement process. The contract procurement phase begins after the design is completed and the package is sent to contracting. The Federal Acquisition Regulations (FAR) specify time limits for advertising, site visits, design package clarifications, bid preparation by the contractor, and contract award. Preparation of the bid requires substantial work by the contractor, which is then included in the cost of each project.

2.3.2 SABER Contract Procurement. The SABER contract is procured once, normally with four option years that could extend the contract for a total of five years. In almost every instance, the option years are exercised on SABER type contracts (Erickson and Murphy, 1994:70). The contractor procurement phase of the SABER process represents a substantial portion of the contracting effort for the entire duration of the contract, requiring a minimum of 6 months to develop documents, procure and award the

contract (SABER References, 1996:11). Once in place, average SABER contracts award 40-50 delivery orders per year.

2.3.3 Comparison. Each DBB project requires procurement of a new contract where the SABER contract, once procured, can execute many projects, delivery orders. There is a considerable difference in the amount of work required by the government to solicit and award a DBB contract and that required in negotiating a SABER delivery order. The SABER delivery order process is typically complete in less than a month, where the DBB contract procurement is approximately three times as long, 80 days at a minimum according to Air Force guidance. The time difference between the two contracting methods represents substantial savings in man-hours. This translates into a savings of approximately $100,000 for each SABER contract in existence (Furr, 1996:4). Furr's research does not indicate where the savings are derived. It is not known if the $100,000 per contract annual savings are man-hours only or if it includes the convenience of receiving completed projects more quickly. There are some savings in the contract procurement process, although the level is uncertain after reviewing the current literature.

2.4 Design Cost

Design costs are the cost required to produce design documents, the drawings and specifications for a construction project. The main differences between design costs are due to the levels of design necessary for each method.

2.4.1 DBB Design Cost. DBB requires 100% design, drawings, and specifications that contain enough detail to describe the construction without any additional explanations. The level of detail required to produce DBB designs is often beyond the

capability of in-house staff, thus requiring an additional contractor to produce the design. Design costs for DBB construction is estimated for planning purposes at 10% of the total cost of construction, with a maximum of 6 % for design and an average of 4% for studies (Working in the Engineering Flight, 1996:Ch 6, 3). At 10% of the total construction cost, it would cost $50,000 to contract an architecture-engineering firm to design a $500,000 project. In addition to the high cost, DBB design is extremely time consuming, requiring from 3 to 9 months to complete. DBB construction requires a high level of detail, is expensive, and time consuming.

2.4.2 SABER Design Cost. SABER design is only required to be completed by the government to the point where the project can be priced using the unit price book, this encompasses significantly less detail than in the DBB design. SABER design provides a basic layout and planning of work, the cost of which is included in the coefficient. The government provides an independent design performed to the 35% preliminary design stage. Preliminary design includes a layout of the main systems needed in the project and equipment specifications (AFPAM 32-1005, 1999:36). The SABER contractor would then use a combination of the government's and their preliminary design to continue the design to a level where the delivery order could be constructed. Design performed by the contractor is done without the aid of any architecture-engineer firms. There are only two situations when the government can use the SABER contracting method and architecture-engineer firm designs. These situations are for previously completed designs requiring validation or updating, and when the architecture-engineer design is not completed beyond the 35% preliminary design stage with the remaining design effort not requiring a significant amount of architecture-engineer services (AFFARS Appendix DD, 1996:102).

SABER design regulations are significant for two reasons; they limit the design to significantly less detail than the 100% design required for DBB construction and they make SABER more appropriate for less complex projects. SABER design is also expedited by the absence of writing a complete set of specifications, since the master set of specifications provides guidance for all work elements. Design savings have been estimated from 2-6% of the total construction costs (www.jocinfo.com, 1999).

2.5 Construction Cost Estimating

Accuracy in cost estimating can eliminate many problems that occur during construction, for example, inadequate funds to complete construction, and misinterpretation of the construction requirements. Starting with an accurate cost estimate is beneficial in reducing the possibility of future contractual problems during the construction process. Despite the volumes of research performed on performing DBB estimates, the process remains highly uncertain. There are a great number of factors affecting DBB construction cost estimates. These factors include contractor needs, assumption of risk, the construction market, and subcontractor estimates. SABER construction estimating is guided by procedures established in the contract. The largest single factor affecting SABER estimating is the unit price book. Due to differences in the SABER estimating procedures, there are some SABER unique estimating problems that have developed. This section will explain the construction cost estimating process for DBB and SABER, highlighting the differences between the two methods.

2.5.1 DBB Estimating. There have been volumes of literature written on how to develop a DBB cost estimate. Despite the considerable research performed in this area,

there remains considerable uncertainty in determining the correct DBB cost for a construction contract. This uncertainty arises due to the multiple factors that affect DBB construction bids. A partial listing of the factors influencing DBB construction bids include contractor needs, risk involved with a one-time venture, the current construction market, and subcontractor estimates (Back and Sanders, 1996:18-23). A study of 777 government construction contracts awarded during fiscal year 1983-1984 indicated 277 cases where the government estimate was more than 20 percent higher than the low bid and 93 cases where the government estimate was 20% lower than the low bid (Stark, 1986:Ch1, 1).

2.5.1.1 Contractor Quality. Cost estimates can be affected by the quality of contractors bidding on the project. If the best contractors do not bid on a project that leaves the contractors that are not quite as capable for those projects. This can result in the potential for a higher bid price, lower quality construction, and more problems during the entire process.

2.5.1.2 Risk. Risk is also a main contributor to escalating cost under DBB construction. The majority of risk in a DBB contract is shifted onto the contractor (Arnavas and Ruberry, 1998:Ch 4, 17). For the DBB project, there is also only one chance to make a profit. The risk of something going wrong must be accessed then added to the price of the bid (Al-Bahar and Crandall, 1990:533).

2.5.1.3 Construction Market. The construction market itself also plays a large role in determining the price of DBB construction. If the market is not doing extremely well, and construction contractors are looking for work, they will submit a lower bid to increase their chances of winning the contract. The opposite of this occurs when the

market is doing very well. If contractors are already working on a number of projects they will need greater incentive to do the job. The greater incentive will be expressed in the form of a higher bid (Wallwork, 1999:41-42).

2.5.1.4 Subcontractor Estimates. Under DBB construction, often the subcontractors have not developed estimating systems that are as accurate as the prime contractor. In one study, variability in sub-contractor bids was found to be twice that of the prime contractor, from 13% to 56% (Ackini and Fisher, 1998:71). There are very few construction projects completed without the use of a subcontractor; therefore, variability in their estimates only increases the inaccuracy of the total DBB cost estimate.

2.5.2 SABER Estimating. In contrast to many factors affecting DBB estimating, SABER estimating is almost exclusively regulated by use of the unit price book and procedural steps established in the SABER contract. This section will provide an explanation of the unit price book emphasizing its influence on SABER construction cost estimating, along with procedural problems that affect cost estimating.

2.5.2.1 Unit Price Book. The unit price book defines the SABER cost estimating process. Developed by the government or commercial vendor during contract procurement, the unit price book provides the cost of labor and materials for all line items needed to complete SABER construction projects. The prices listed in the unit price book are contractually guaranteed. This insulates SABER from the effect of inflation and other economic factors that can influence construction costs (Erickson and Murphy, 1994:69). When estimating the cost for a construction project, the line items and quantities needed for that project are identified from the unit price book. This places the risk on the government to identify the proper quantities needed for construction.

Subcontractors must comply with this same process, eliminating potential variability from their estimates. These cost are added up and become the basis for the cost estimate of the project. Items needed to complete the project that are not included in the unit price book, non pre-priced items, are negotiated separately and added to the cost of the items identified in the unit price book. Non pre-priced items are limited to 10% of the total construction cost. The final step in determining the cost estimate is to multiply the line and non pre-priced items by the SABER coefficient.

2.5.2.2 SABER Coefficient. The SABER coefficient is normally the deciding factor in which contractor is awarded the contract; it includes contractor overhead, profit, design cost, and adjust cost listed in the unit price book to meet contractor needs. The SABER coefficient has large influence on determining the price of SABER construction. SABER unit price books are most often developed from industry price books that generally accepted as the cost of construction before contractor markup. Since the coefficient is multiplied by the cost in the unit price book a coefficient greater than one would indicate that SABER construction is more expensive than the industry baseline. At Wright-Patterson AFB, one of the bases studied for this research, the coefficient changed from 1.303 to 0.995 from 1994 to 1995. In this situation the coefficient changed from increasing the cost listed in the unit price book by 30.3% to decreasing then by 0.5%. This would indicate SABER construction is less expensive than construction cost in industry price books.

2.5.2.3 Negotiations. Under the original SABER process, after completion of the SABER cost estimate by both the government and the contractor, negotiations are conducted before award of the delivery order to resolve any differences between the two

estimates. The new process only requires government acceptance of the contractor's estimate. The negotiation process ensures government concurrence in materials used, methods of construction, quantities of line items, quality of line items, and the project timetable. According to Furr, these negotiations result in hundreds of thousands dollars in savings per year (Furr, 1996:4). DBB construction does not contain mechanisms to pre-negotiate details of construction before award. Federal regulations allow the government to answer specific contractor questions concerning their proposal before contractor bids are submitted (Arnavas and Ruberry, 1998:Ch3, 13), but there remain large misconceptions between what the government intended and what the contractor interpreted well after award.

2.5.2.4 SABER Estimating Problems. There original procedural guidelines established for SABER, when followed created an estimating process fair and equitable. The process consisted of the government and contractor preparing independent estimates, followed by government review of the contractor estimate. Air Force Audit Agency (AFAA) reports have found serious problems in the SABER estimating practices in isolated instances. During one report the AFAA found 10 of 17 delivery orders awarded at cost varying from the government estimate by 12% to 95% (Report of Audit WS099012, 1998:8). In the 10 identified cases there was a breakdown in execution of the SABER cost estimating system leaving the government more dependent on the contractor's estimate to determine the final construction cost. No empirical data exists to indicate the number of instances Air Force wide where government estimates varied significantly from the award amount of the delivery order; however, audits 50696037, 53097005 and WP099005 conducted between 1996 and 1998 indicated similar problems.

The recommended fix was having the government contracting office exercise their right to make the government and contractor submit new estimates when scope and cost are too far from agreement on the original estimates. Recommendations for the government-engineering estimates consist of better planning of the year's construction program to eliminate rushed estimates that occur during periods of high operational tempo, or at the end of funding cycles when construction monies become available.

2.5.3 Summary. There are different factors influencing DBB construction cost estimates and SABER cost estimates. The factors influencing DBB estimates include contractor needs, risk, construction market, and subcontractor estimates. Some of these factors increase construction cost, and others decrease construction costs. The unit price book is the main factor affecting SABER cost estimating. The SABER negotiation process provides congruence in government and contractor cost estimates before award of the delivery order. Breakdowns in the SABER estimating process decrease the probability of the government receiving the fairest price for the construction. Multiple sources were found stating that SABER type contracts can produce more accurate cost estimates than DBB construction (Furr, 96:4, Erickson and Murphy, 1994:69, and Back and Sanders 1996:18). There was no empirical data found to support these claims.

2.6 Modifications

Contract modifications are changes in the contract requirements after award. They are the main cause of cost and time growth in DBB construction (Ibbs and Ashley, 1987:507). This section will describe causes and the procedures for resolving DBB and SABER modifications.

2.6.1 DBB Modifications. DBB modifications are often difficult to settle, and are frequently the result of poor design. Under DBB contracts, the government has a difficult task in acquiring a fair modification cost. Since the contract has already been awarded the government no longer has competition to reduce the cost of the modification. This process results in the frequent large construction cost growth of DBB contracts. Past research has indicated that cost growth in DBB construction projects has been a serious problem (Ibbs and Ashley, 1987:507).

Poor design is a main contributor to construction modifications. The main cause of poor design is different site conditions. Poor design appears in the form of incomplete design scope, defective design, errors and omissions, and inadequate specifications (Al-Bahar and Crandall, 1990:538). Another contributor to poor design is the level of design required for DBB construction, because it is nearly impossible to capture everything that might occur during a project. DBB modifications threaten the success of many projects because of the difficulty in resolving them and the potential for multiple modifications to develop during the same project.

2.6.2 SABER Modifications. The SABER negotiation process, discussed in section 2.5.2.2, resolves any conflicting information before project execution. Any time clarification is required the contractor is free to contact the government. In SABER, the same contractor performs the design and construction providing incentive to reduce design errors. These processes have made modifications due to poor design in SABER contracts practically non-existent (www.jocinfo.com, 1999). Despite negotiations and same contractor design, modifications can still occur because of user changes and different site conditions than expected.

SABER modifications are negotiated using the unit price book. Since prices in the unit price book are contractually set, this provides the government with the ability to receive the same price for modifications as the rest of the construction.

2.6.3 Summary. Poor design and difficulties in fairly resolving modifications are the main detriments to a successful DBB construction project. There are many different causes of DBB modifications beginning with the different site conditions, which affect design quality. DBB modifications are negotiated without competition where SABER modifications are governed by the unit price book. SABER's negotiation process was designed to reduce the number of modifications that occur during construction. The research does not provide empirical data on the cost growth, or number of modifications that occur during SABER construction; however, the system was designed to have a distinct advantage over DBB contracts during modification resolution.

2.7 Other Factors Affecting Cost

To this point the chapter has described the DBB vs. SABER construction from contract award to construction completion. There are several other points that affect cost including contractor mobilization, different incentives, and improved relationships that will be discussed in this section.

2.7.1 Contractor Mobilization. The total cost of every construction project includes a cost for establishing a base of operations, mobilizing equipment, and general organizing for the project. The cost and time to acquire and mobilize the contractor for a project also represents a large portion of the procurement costs. The SABER contractor has an established office and area of operations on the base for the duration of the contract,

which may include some equipment. The permanent setup of the SABER contractor allows mobilization for a delivery order at a lower cost than if it were done for each project. For the majority of DBB contracts, the contractor has to establish some type of office near the site, gain access to the base, and mobilize all equipment and materials to the job site. Since this must be done for each project the cost is added in every DBB bid. There was no empirical data concerning the mobilization costs for each method; however, any savings between the two methods will include mobilization.

2.7.2 Different Incentives. DBB and SABER construction provide different incentives for the contractor to make profit. DBB construction is for a single project and provides the contractor one opportunity to make a profit. The contractor's motivation is to make as much money as possible from that one opportunity. This is typically done by the contractor performing the minimum to meet design specifications. The SABER contract provides an on-going financial incentive to the contractor to produce a quality project at a lower cost. If the contractor is performing in a manner that is unsatisfactory to the government, the government can elect to only give the contractor the minimum dollar amount of projects, and not award any option years for the contract. The SABER contractor increases profit by performing more projects, unsatisfactory performance will result in a significant loss of revenue just from the difference in being awarded the minimum and maximum contractual dollar limits (McDermott, 1995:28). The quality motivation under SABER type contracts is a complete reverse of the traditional DBB system where the contractor has been awarded a one-time contract.

2.7.3 Improved Owner-Contractor Relationship. The owner-contractor relationship, government-contractor in this case, influences the resolution of problems encountered

during the construction process. A poor relationship will result in transforming every situation into a major crisis; for example, minor modifications will not be resolved quickly, resulting in long construction delays. Conventional thought is that DBB construction may be subject to a poor owner-contractor relationships where the continuing nature of the SABER relationship provides the opportunity for an improved owner-contractor relationship.

2.7.3.1 DBB Relationships. DBB contracts can create an adversarial relationship between the owner and the contractor due to risk placement and conflicting goals. The contractor has assumed the risk for completing the project within the budget and on schedule, while the government's objective is to receive the highest quality construction. The contractor's objectives for budget and schedule frequently conflict with the government's goal of receiving high quality construction, creating problems during the construction process. This adversarial relationship can lead to significant disputes during the construction process (Ibbs and Ashley, 1987:507).

2.7.3.2 SABER Relationships. The SABER type contract generally improves the relationship between the contractor and the government. It is in both parties' best interest to establish a good relationship, since the success of both will depend on how well they work together (Furr, 1996:4). The contractor will receive more projects, thus increasing profit by completing quality work in a timely manner. The government will be able to complete more construction increasing mission effectiveness. The improved relationship will also encourage SABER contractors to handle changes quickly and fairly. The overall affect of the government SABER relationship will be to increase the amount of

construction completed, and handle disputes quickly providing completed construction in a timely manner.

2.7.4 Summary. There are many differences in the factors influencing DBB and SABER construction costs. SABER provides faster mobilization, incentives for providing higher quality construction in a timely manner, and improved owner-contractor relationships that would appear to produce savings but are qualitative in nature. Potential cost savings from SABER construction cannot be attributed directly to these factors; however, their affect should be noticeable during the application of the contract.

2.8 Limitations of SABER

As discussed earlier, DBB can be used for any type of construction; however SABER is limited in the projects that it can construct. The research is limited by comparable projects completed by both methods. A discussion of the limitations of SABER will provide background and understanding of the scope for this research. SABER limitations include maximum delivery order cost, project complexity, loss of quantity discounts, and non pre-priced items.

SABER delivery orders are limited to $500,000 each. This limitation prevents SABER from being used on larger, complicated construction projects. This limitation was developed based on the theory that larger projects constructed by DBB will have the advantage on being able to seek quantity discounts for the costs of materials and labor (AFFARS Appendix DD, 1996:104). SABER contracts can not seek quantity discounts since cost are set contractually in the unit price book. SABER is also limited in the complexity of projects that it can execute, not only will more complex projects have

increased possibility of violating the maximum dollar limit for a delivery order but they require extensive detail and design. Traditionally the government would only provide the SABER contractor with 35% design. A complex project would require extensive time and effort for government personnel to design to the 35% level. SABER contractors, general construction contractors, are normally not capable of or expected to complete 35% design to the level of detail required to complete complex projects. The combination of limited time and capability for government personnel to perform design, and the contractors limited ability to design capabilities exclude SABER from most complex projects.

SABER is partially limited to the line items in the unit price book. Construction often requires special equipment, or architectural finishes that are not considered part of general construction and therefore not included in the unit price book. These items, briefly introduced in section 2.5.2.1, are called non pre-priced items. SABER type contracts are not designed for determining the cost for non pre-priced items (AFFARS Appendix DD, 1996:104). There will be no other source to compete against for that portion of the work, so the non pre-priced item will cost more than under DBB construction. The cost of non pre-priced items are negotiated before award of the delivery order, and added to the contract as another line item in the unit price book. Due to the tendency of non pre-priced items to raise the cost of construction, they are limited contractually to 10% of the total delivery order cost, up to 25% by waiver.

The current literature does not provide any quantitative analysis on how the disadvantages of SABER affect construction cost. In most cases, the disadvantages are

not mentioned at all, possibly demonstrating bias in the literature towards the positive points of SABER construction.

2.9 Other Relevant Research

There were only two recent case studies found comparing DBB construction cost with construction cost in SABER type contracts. The majority of past research comparing different construction contracting methods focused on new building construction. This focus eliminated SABER due to its limits on project cost and complexity. Despite the lack of past research that is directly applicable to this effort, the past research provided methodologies for comparing construction projects completed using different contracting methods. This section will discuss the past methods used to compare construction performed by two different contracting methods and the two recent case studies comparing DBB construction cost with SABER construction cost.

2.9.1 Past Methodologies. An important part of performing a construction cost analysis between different contracting methods is assuring that the projects being compared are similar in type and scope of work. The many variations present in construction projects makes it nearly impossible to find large numbers of identical projects to compare. Past methods used by Pockock(1996) and Moore(1998) created construction classification systems, grouping projects by defining characteristics, to narrow the variance in projects being compared. The classifications systems provided validity and increased confidence that the results of the research were accurate. A similar method will be used in this research comparing construction costs of DBB and SABER contracting methods.

2.9.2 Case Studies. The following two case studies provide examples of how the SABER concept, started by the military has been applied to other government agencies and civilian businesses. The case studies include projects managed by the City of Chicago that reduced construction cost and time, and a Midwest real-estate owner that performed numerous projects with few modifications using SABER type contracts.

The City of Chicago implemented five job order contracts between 1993 and 1994. They compared the costs of work done with JOCs to Chicago City engineers' estimates. The average cost savings for all JOCs was 8.6% according to Kim M. Megaro, first deputy purchasing agent for the city. In most of Chicago's JOC projects, contractors have a notice to proceed within 30 days of project initiation. This was a tremendous timesavings compared to the three to six months needed for small-medium-sized projects under traditional contracting methods. One of Megaro's conclusions was that there was a real incentive for contractors to bid an attractive price and keep the client happy (Erickson and Murphy, 1996:70).

A Midwest real-estate Owner of multiple commercial office spaces initiated a unit price SABER type contract to renovate new high rise office space for leasing. During an 18 months period, 29 interior construction projects totaling 356,396 square feet were completed. The four projects totaled $1,890, 983 and had only $158,461 of cost growth, which is approximately five percent less than the government average. Of this amount only $7,100 was not user initiated changes (Back and Sanders, 1996:23). In using this SABER type contract the construction was completed with less than 0.5% of the cost growth caused by design problems or any of the other usual causes of construction cost

growth. The Midwest owner was using a slightly modified version SABER. There were no limits on the level of design and no requirement for the contractor to provide an independent proposal. The contractors only responsibility was perform the construction according to the owner's design and quantities. Their single point input concerning the design as compared to multiple inputs in SABER, contracting, civil engineering, and the agency receiving the construction may cause their number for cost growth to not apply directly to SABER.

Civilian organizations are using SABER type contracts to complete construction at lower cost, more quickly, and with reduced construction cost growth. These case studies serve as a validation of the sound principles in which SABER is based.

2.10 Summary

This chapter provided background on DBB and SABER contracting methods followed by explanations of how each method works. Differences between the two methods were explained for each phase of the contracting process including contract procurement, design, cost estimating, and construction. The literature review summarized the current level of cost comparison that has been performed between DBB and SABER construction. The majority of factors that produce SABER's cost savings were in the area of contract procurement, accuracy in estimating, lack of modifications, and the relationship between the government and contractor. There were only a couple of instances that stated the actual SABER construction was cheaper than the DBB construction. In these situations, there was limited support for those claims. There are many questions over the accuracy and validity of the literature. The most glaring is that

there was no mention of comparing completed projects of both types to each other. This leads to questions over the accuracy of the estimates used for comparison, and the interpolation needed to compare the number of modifications and other factors. This research will focus on providing a comparison of similar type projects already completed using each of the two methods. This will eliminate the need to estimate the construction savings, and provide actual numbers for cost and time growth between the two methods. Any information on procurement cost, design cost, or other factors that can be proven with the data gathered will also be explored.

3. Methodology

Chapter 3 outlines the methods used to objectively collect and analyze project cost and schedule data allowing for the comparison of Design Bid Build and SABER contracting methods. This research uses quantitative data collected from construction projects completed by the civil engineering and contracting squadrons at Wright-Patterson Air Force Base and Holloman Air Force Base. The data is from actual projects completed and factual records maintained by both Civil Engineer and Contracting Squadrons. Chapter 3 will continue to explain the system used to classify the projects, and normalize the data for comparison since construction projects completed by the two methods are not in a form that is readily comparable. Finally, this chapter will describe the test used to determine the level of statistical significance in the results. In total, chapter 3 will provide a description of the data gathering techniques and steps taken to prepare the data for the analysis performed in chapter 4.

3.1 Data Collection

Data from completed projects was needed to perform the comparison of DBB and SABER contracting methods. The best available source for finding this data was at the base level through Civil Engineer and Contracting Squadrons. These sources provided the most comprehensive information on construction projects that have been completed by DBB and SABER. Due to limitations on the amount of time that records are kept, projects completed in the last three years were used in this research. The next step in acquiring data for this research is developing a system or procedure for collecting the

data. Following collection, data verification is essential to ensuring the accuracy of the data used in the research. The final step to completing the data collection is determining specific information to gather. This section will analyze the data source, collection procedures, verification procedures, and information gathered.

3.1.1 Data Source. Each Civil Engineer Squadron maintains project data in multiple sources such as construction folders, computer project databases, knowledge of squadron personnel, project drawings and specifications. The different data sources contain a variety of information concerning the construction project; however, this discussion will only focus on information that was useful for this research.

Construction folders serve as the main source of CE record keeping during the construction process. The construction folder contains contract award information, negotiated modifications, general correspondence between all parties involved in the construction, construction schedules, and inspection information. The construction inspector from CE maintains the construction folder. This process ensures the construction folder maintains the most accurate project information through its preparation by the most knowledgeable personnel for that particular project.

The designs documents, project drawings and specifications, are also part of the construction folder, but serve to describe the construction performed. Unlike the previous portion of the construction folder described above the drawings of the construction as-built and specifications describe the work that was performed, detailing dimensions, all elements of work performed, and specifications for all items installed during the construction.

In addition to the construction folders, Civil Engineering is also required to maintain computer databases of project information. These databases keep track of design information including design schedules, construction schedules, number of modifications, dollar amount of modifications, and construction cost.

Outside of Civil Engineering, base contracting squadrons also maintain project folders for construction projects. These folders contain all contractual information including construction schedules, cost paid, and any contractual changes. Information collected from all these sources was used in completing this research.

3.1.2 Sample Bases. After determination of the data source, the next step in gathering the information was to determine how many and which bases to gather sample data. The two main factors influencing determination of sample bases include gathering a representative sample of Air Force Bases performing DBB and SABER construction, and gathering project information within the time constraints of completing the research. Developing a sample representative of construction performed in the Air Force would require gathering information from a large number of bases. Variable factors that affect construction on Air Force bases include size of the base, mission, size of surrounding community, and mission changes. Due to this wide variety in bases it was determined that it would be impossible to develop a sample set of bases representative of the entire Air Force. The next best alternative would be to sample DBB and SABER projects from bases that were fairly different in size, mission, and surrounding community. To meet these qualifications Wright-Patterson AFB, OH and Holloman AF, NM were selected for this study.

Wright-Patterson AFB was chosen first because of its convenient location for the researcher. The close location allowed the researcher multiple opportunities to visit the Civil Engineer and Contracting Squadrons to gather project information. This allowed the streamlining of the data acquisition process without the cost of travel to the base. The determination of how many bases, and which bases to sample was guided by time and resource constraints. Due to the time constraints only one other base was sampled for this research. Holloman Air Force Base met the qualifications as the other site due to its differing mission, and local economic conditions. Thorough descriptions of the two bases are provided in the following sections.

3.1.2.1 Wright-Patterson AFB, OH (WPAFB). WPAFB has a land area of 8,145 acres and a population of 7,100 active duty military, 1,900 Reserve, and 12,600 civilians. The major units include HQ Air Force Materiel Command, Aeronautical System Center, System Acquisition Mission Unit, 88th Air Base Wing, US Air Force Museum, Air Force Institute of Technology, Air Force Research Laboratory, Joint Logistics System Center, National Air Intelligence Center, and the 445th Airlift Wing (Reserve). There are no major weapons systems assigned to WPAFB (www.airpower.maxwell.af.mil). WPAFB is located near the "medium sized" city of Dayton, OH with a community population of approximately 650,000.

3.1.2.2 Holloman AFB, NM (HAFB). HAFB had a land area of 57,000 acres and base population of 4,600 active duty and 960 civilians. The base's major units are the 49th Fighter Wing, 49th Operations, 46th Test Group, and the 4th Space Surveillance Squadron. The major weapon systems include 4 different type of fighter aircraft, and one

helicopter (www.airpower.maxwell.af.mil). The base is located near the "small sized" city of Alamogordo, with a population of approximately 35,000.

WPAFB and HAFB met the requirements of difference in locations needed for the research. These two bases provided samples with different primary missions, and located not only near different size cities, but also in different geographical regions of the United States.

3.1.3 Methods for Collecting Data. The availability and type of project information required data collection by the researcher. The detailed project descriptions needed made data collection by survey infeasible. This limiting factor dictated that researcher collection was the only viable alternative for gathering enough information to determine exactly the scope of work for the project. The data collection consisted of thoroughly screening projects to assure that DBB and SABER sample sets contained projects that were similar in type and scope of work. Approximately 400 projects were screened before selecting the projects used in this research.

Tables 1 and 2 show the data sources by project for DBB and SABER, respectively. There were 10 DBB and 19 SABER projects used for WPAFB. The first column numbers the projects from 1 to the last project. The second column provides the project number, an identifier used by the CE squadron to track and file project. The third column gives the project name, which provides a general description of the construction performed. The fourth column describes which contracting method was used for that project, either DBB or SABER. Columns 5-8 list the data sources; construction folder, computer database, construction inspector, and contracting folder, respectively. These data sources were described in section 3.1.1. The Y indicates the data source was found

for that project, and the N indicates non-availability of that particular data source for the corresponding project.

3.1.4 Verifying Data. Data verification is critical in any research to assuring the collected data is accurate. The only verification measures available during this research were to match information from the different sources to ensure congruence in the data. This process was accomplished by first gathering information from the project folder. Project folder information was then checked against computer database information and contracting folder information. Drawings and specifications were used to determine the work performed. Data detailing work performed was verified by cost estimates and the construction inspector when available. The verification process showed that information maintained was generally accurate but allowed for the correction of some inconsistencies, before analysis of the data. To illustrate this point the researcher found no modifications for Construct Locker Shower, project #2 in Table 2, in the construction folder or computer database. The construction inspector indicated that approximately $30,000 of modifications had been performed. The contracting folder was then used to verify the exact amount of the modifications. Only 14%, 4 out of the 29 projects at WPAFB had inconsistencies that needed correcting.

After collecting the data from WPAFB, it was discovered that the all four inconsistencies could have been eliminated without going to contracting if the researcher had found the contract solicitation summary sheet. It was determined that for data collection at HAFB contracting folders would not be needed unless the contract solicitation summary sheet was not found. Data Sources found in HAFB are summarized

in Table 3, which is to identical Tables 1 and 2 with the exception of the elimination of the contracting folder column.

Table 1. WPAFB DBB Data Sources

WPAFB DBB Data Sources							
				Data Sources			
	Project Number	Project Name	Contracting Method	Construction Folder	Computer Database	Construction Inspector	Contracting Folder
1	95-0089	Repair Construct Digital Memory Lab	DBB	Y	Y	Y	N
2	96-0076	Chapel care Phase 1 Spirit Hall	DBB	Y	Y	Y	N
3	92-0245L	Upgrade Conference Room for VTC	DBB	Y	Y	N	Y
4	96-4008	Repair Officers Quarters Kitchen	DBB	Y	Y	Y	N
5	97-5006	Upgrade Interior Finishes	DBB	Y	Y	Y	Y
6	99-1001	Refurbish Restrroms	DBB	Y	Y	Y	N
7	94-0076	Construct Video Studio Suite	DBB	Y	Y	N	N
8	92-0263	Repair Restrooms	DBB	Y	N	N	N
9	96-8033	Construct Dental Clean Facility	DBB	Y	Y	N	N
10	94-1007	Renovate Courtroom	DBB	Y	Y	N	N

3.1.5 Information Collected. Data was collected on the scope of construction performed, dimensional characteristics, project schedule, and cost. The scope of construction performed included a general description of all work. The dimensional characteristics of the project were either the square footage of facility repaired/renovated, or the size/capacity of mechanical or electrical equipment replaced. Project schedule information collected included the construction start data, estimated construction complete date, and the actual completion date. Cost information included the design cost, construction award amount, cost of modifications, and final construction cost.

Table 2. WPAFB SABER Data Sources

WPAFB SABER Data Sources							
				Data Sources			
	Project Number	Project Name	Contracting Method	Construction Folder	Computer Database	Construction Inspector	Contracting Folder
1	98-1966	Construct Offices Conference Room	SABER	Y	Y	Y	Y
2	97-0151-2	Construct Locker/Shower	SABER	Y	Y	Y	Y
3	96-1995	Construct Conference Room	SABER	Y	Y	N	Y
4	97-1914	Repair Restrooms Fac 30089	SABER	Y	Y	Y	Y
5	96-1951	Repair Remodel 4th Floor	SABER	Y	Y	Y	Y
6	97-1876	Renovate Room 117	SABER	Y	Y	N	Y
7	96-1920	Construct Restrooms Building 2054	SABER	Y	Y	N	Y
8	97-1868	Repair Upgrade Conference Rooms	SABER	Y	Y	Y	Y
9	96-1928	Repair Construct Family Restroom	SABER	Y	Y	Y	Y
10	97-1882	Renovate Room 215	SABER	Y	Y	Y	Y
11	97-1982	Repair Upgrade Training Rooms	SABER	Y	Y	Y	Y
12	97-0140B	BRAC Renovate F117 Supply Facility	SABER	Y	Y	Y	Y
13	95-1852	Renovate Restrooms Building 20028	SABER	Y	N	N	N
14	95-1928	Renovate Classrooms	SABER	Y	N	N	N
15	95-0039A	Renovate South Entrance Etc.	SABER	Y	N	N	N
16	96-1035	Renovate Room 204 Build 20023	SABER	Y	Y	N	Y
17	95-1874	Upgrade Conference Room Building 56	SABER	Y	N	N	N
18	95-1918	Renovate Lobby Facility 2022	SABER	Y	N	N	N
19	97-1945	Renovate Restrooms Facility 10893	SABER	Y	Y	N	N

Table 3. HAFB Data Sources

HAFB Data Sources						
				Data Sources		
	Project Number	Project Name	Contracting Method	Construction Folder	Computer Database	Construction Inspector
1	98-0146	Repair Target Squadron Facility	SABER	Y	Y	Y
2	98-0103	Repair EOD Facility	SABER	Y	Y	Y
3	96-0025	Repair Dormitory 333	SABER	Y	Y	N
4	98-0142	Repair Flight Facility 1022	SABER	Y	Y	Y
5	95-0046	Alter Intel Area Bldg 811	SABER	Y	Y	Y
6	96-0043	Install Electric Bldg 14	SABER	Y	Y	N
7	96-0029	Upgrade Restrooms Bldg 1087	SABER	Y	Y	N
8	97-0022	Repair Showers Dorm 335	SABER	Y	Y	Y
9	97-0053	RPR X-34 Program Offices	SABER	Y	Y	Y
10	97-0069	RPR Det 1 Commander's Office	SABER	Y	Y	Y
11	94-0104	Repair Latrines Bldg 811	SABER	Y	Y	Y
12	98-0150	RPR 8th and 9th FS	SABER	Y	Y	Y
13	92-0101	Repair VOQ Fac 587	DBB	Y	Y	Y
14	97-0031	Conver Dorm 457 1+1	DBB	Y	Y	Y
15	96-0058	RPR F4F Control System Shop	DBB	Y	Y	Y
16	90-0002	Repair Supply Offices	DBB	Y	Y	Y
17	95-0026	Repair Dorm 473	DBB	Y	Y	Y

Descriptions of construction modifications were also collected when available. The information collected allowed the comparison of project cost, project time growth, and project cost growth.

3.1.6 Summary. The data source for this research was construction folders, computer project databases, and contracting folders contained at base level. This was necessitated by the lack of Air Force databases for these type projects, and the level of information needed to determine the project's scope of work. Wright-Patterson and Holloman Air Force Bases were determined to provide a good contrast of bases to gather project data. The process developed to verify consisted of checking the cohesiveness of the different sources. Finally, the data collected included construction costs, schedule, scope of work, and modifications.

3.2 Project Classification

The research required development of construction project classifications in order to perform a comparison of construction projects completed by the two methods. The types of construction projects that can be performed by DBB and SABER are only limited by the size and complexity constraints of the SABER method. The purpose of developing the project classifications was to separate the projects in categories that were practically identical in the type of work performed. The categories provided for comparison of similar projects at statistical levels of significance. Without the project classifications, there would be no method for determining which projects were comparable. The remainder of this section is dedicated to describing these classifications and the reasons these classifications were considered.

3.2.1 Development for Classifications. Classifications for project types were developed considering the sum of all construction projects performed by both DBB and SABER methods. Although DBB can be used for any type of construction project, the

majority of SABER projects are in the area of interior renovation, HVAC repair, electrical repair, and other small infrastructure repair projects. The classifications described the section below were derived from the SABER groupings of projects.

3.2.2 Classifications. A classification is defined as a particular subset of all the possible construction projects that can be completed by both DBB and SABER. The subsets identified for this research were interior renovation, equipment replacement, and utilities. During the process of data gathering another category, demolition, was identified. These classifications will be described in detail in the following sections.

3.2.2.1 Interior Renovation. Interior renovation projects are defined as any project that modifies or repairs the interior of a facility. Interior renovation projects may include those that have minor amounts of mechanical and electrical work. Minor amounts of mechanical or electrical work is defined as relocation of those utilities to meet the interior modifications. When possible, equipment cost was separated from other project cost if they compose more than 20% of the total project cost. 20% is used because most major estimating systems use 20% as the rough error in estimating. Data from interior renovation projects was used to create a square foot cost for interior renovation projects.

3.2.2.2 Equipment Replacement. Equipment replacement projects are those where the main purpose is to replace equipment. Equipment is narrowed to either mechanical or electrical. Examples of mechanical equipment include chillers, boilers, condensing units, cooling towers, etc. Examples of electrical equipment include transformers, generators, switching stations, etc. Project data was used to create a cost per capacity for equipment replacement projects. This creates two categories of equipment replacement projects, mechanical and electrical.

3.2.2.3 Utilities and Infrastructure. Utilities and infrastructure projects are those that focus on water, sewer, and electrical lines. Also included in this group were drainage and irrigation projects. Again, equipment cost was separated from these project cost if they compose more than 20% of the total project cost. Cost per linear foot was created for water, electrical, and sewage line projects. Cost per square foot was used for drainage and landscape type projects.

3.2.2.4 Demolition. Demolition was identified as a category after initial data gathering revealed that SABER was used to complete demolition projects. Demolition projects are defined as those that demolish existing facilities. Square footage of facility demolished and surrounding area repaired was collected for demolition projects.

3.2.2.5 Summary. There exist a practically infinite number of project types that can be completed by DBB and SABER. This research classified these projects into five categories: interior renovation, mechanical equipment replacement, electrical equipment replacement, utilities-infrastructure, and demolition. The classifications were selected to create categories that were similar enough that DBB and SABER projects that fit into the categories could be compared against each other.

3.3 Assuring Comparability of Projects

Comparability of the projects from the two construction contracting methods, DBB and SABER is essential to performing an accurate and realistic cost analysis. Classifying the projects by construction type is not sufficient to assure the projects are comparable. The difficulty in assuring project comparability is that the projects are different. They may be similar in types and scopes of work, but unless it is the same project a direct

comparison is not an automatic assumption. Project comparability was tested using two separate comparisons. First, the type of work was compared using the percentage of key work elements performed in projects from comparable sample sets. An example of a comparable sample set is WPAFB DBB interior renovation projects, and WPAFB SABER interior renovation projects. Then the scope of work was compared using the percentages of key work elements in each project for the same comparable sample set.

3.3.1 Testing Type of Work Performed. To determine if the comparable sample sets contained similar types of work, the percentages of projects containing common key work elements were compared against each other. For example, ceiling construction is considered a key work element in the category interior renovation. The WPAFB DBB sample set contains a percentage of projects that included ceiling construction. Similarly, the WPAFB SABER sample set contains a percentage of projects that contained ceiling construction. The percentages for each sample set are then compared against each other showing the comparison of types of work performed. Similarities in the percentage of key work elements contained in each sample set provide proof that comparable sample sets contained projects performing similar types of work.

3.3.2 Testing Project Scope. The second step in ensuring comparability of the two samples is to test the scope of work performed by projects in comparable sample sets. This research measures project scope by a concept termed project loading. Project loading represents the amount of construction performed in a project, and is calculated by the percentage of all key work elements in each project. For example, if a project contains 7 of the 10 key work elements identified for a construction classification it has a project loading of 70%. Similarities in project loading for comparable sample sets

provide evidence that comparable sample sets performed similar types of work. Comparable project loading cannot be considered as definitive proof of project comparability since not all the projects contain the same key work elements; however, if the results of both tests are close, the comparability of the two sample sets is supported. The combination of percentage of key work elements, and project loading provide the means of assuring the project comparability by both type and scope of construction performed.

3.4 Normalizing Data for Comparison

In order to compare the projects, construction costs must be normalized to the same units. The normalization process consists of developing a common unit for comparison from the project data. The types of projects constructed by SABER and DBB are not readily described by dimensional characteristics. Unlike construction of new facilities, which are described dimensionally in terms of total square footage, there are many variations in the type of projects used in this research. Projects meeting the classifications identified earlier may only cover a certain portion of the facility or a certain mechanical-electrical system. The total cost of the construction is meaningless without knowing the dimensions where the cost was applied. After determining the dimensional characteristics of the project, the total cost was proportioned to that dimension. This creates a cost per dimensional unit for each project that is identical for each project classifications. These normalized costs per unit are used to accurately compare the construction cost of DBB and SABER projects.

3.5 Statistical Test Used

The statistical tests that compare sample means use the sample set as a representation of sample population for each performance measure. The most accurate statistical test requires both sample sets being compared have normal distributions. Preliminary descriptive statistics performed on the sample sets identified several outlying projects that would indicate non-normality. The Wilk-Shapiro Normality Test determined that not all of the sample sets were normally distributed, requiring the use of non-parametric tests to analyze the data. Results of normality test for unit cost, cost growth, and time growth for both the WPAFB and HAFB sample sets are contained in Appendix A.

Non-parametric tests do not require a normal distribution in the sample population to identify statistically significant differences between variables (Devore, 1997:623). In particular, the Wilcoxon Rank and Sum test is highly robust against outliers and only requires that data is symmetrically distributed. Of the available statistical tests for small data sets, the Wilcoxon Rank and Sum Test is approximately 95% as effective as the best available test, the two sample t-test (Devore, 1997:643). The two-sample t-test could not be used in this research because it requires sample sets that are normally distributed, which was not the case for this research.

The Wilcoxon Rank and Sum Test groups sample points from both DBB and SABER data sets at a particular base into a common data set. The order of the data points is then ranked from 1 to the number of sample points contained in the combined set. For each individual sample set, SABER and DBB, there is a lowest and highest possible sum for their ranks. The probability is then calculated for an individual sample set having a sum

of ranks equal to or as extreme as the sum observed. This associated probability provides the statistical significance of the differences in the two sample sets. (Devore, 1997:639).

Testing procedures were established to ensure that analysis for each performance measure was performed exactly the same. The null hypothesis represented that DBB and SABER were equal to each other in the performance metric. The alternative hypothesis represented that the SABER sample mean was less that the DBB sample mean for each performance measure metric. If the alternative hypothesis was proven true this would indicate that SABER had lower unit cost, lower cost growth, and lower time growth that the DBB projects.

Non-parametric tests will also be used to determine the statistical significance of difference in the percentage of key work elements, and project loading comparisons that are used to assure sample set comparability. The testing procedures are identical to those used in the project performance metric tests. The percentage of key work elements will be tested using the Wilcoxon Rank and Sign Test. The Wilcoxon Rank and Sign Test uses paired data points (Devore, 1997:638). The paired data points are used because the key work elements for each sample set are identical. The other metrics used in this research do not contain paired data because the entire sample set is being compared, where the percentage of key work elements compares the individual items that compose the sample set. The Wilcoxon Rank and Sum Test will be used to compare differences in the mean values for project loading.

3.6 Conclusion

Chapter 3 summarized the effort to gather and normalize the appropriate data needed, and described the statistical tests that will be used to complete this research. Project data,

collected from Wright-Patterson and Holloman Air Force Base included cost information, schedule information, and scope of work. Project classifications were developed to create comparable categories of construction out of all the possible construction projects that could be completed by DBB and SABER contracting methods. The final step before analysis was developing a system to normalize project cost into comparable units. Non-parametric statistical test will be used to analyze the data because sample sets were not normally distributed. Chapter 4 will present the analysis and results of the research guided by the methodology outlined in this chapter.

4. Performance Measurement and Data Analysis

Chapter 4 provides an explanation of the project data gathered, definitions, and descriptions of the performance measures used to compare projects and the subsequent statistical analysis methods employed to test differences between DBB and SABER construction contracting methods. Project performance measures were calculated using the normalized cost, and schedule data collected using the methods discussed in chapter 3. Performance measures were used to quantitatively compare DBB and SABER through univariate statistical testing. Comparisons between DBB and SABER were based on results of statistical hypothesis testing of mean performance values. These results provide direct comparison of DBB and SABER for each performance metric.

4.1 Data Collected

Data availability and collection time were the limiting factors in performing the intended research. The data availability does not refer to available project data, instead projects that fit into the categories and provided a large enough set to perform analysis and determine results at statistical levels of significance. Without a data set sufficient to prove statistical significance projects can only be compared on a project by project basis. Project to project comparisons are limited to those two projects and cannot be used for comparing contracting methods. The lack of comparable project data will be discussed in greater detail in Chapter 5, Results and Conclusions. The collection process was time consuming to gather data at the appropriate level to conduct this research. This limited the number of bases sampled. These limitations and the available data provided only one

category for comparison, interior renovation. There were many factors limiting the number of comparable projects, but the two most prevalent were magnitude of construction and projects that crossed multiple categories. The magnitude of a large majority of the DBB projects was much greater than that of the SABER projects. Both DBB and SABER projects contained construction that crossed into multiple categories, providing no means of comparing the similar construction performed in those projects. Project descriptions for all projects are located in Appendix B. There were 10 DBB and 19 SABER interior renovation projects from Wright-Patterson AFB and 5 DBB and 12 SABER interior renovation projects from Holloman AFB. Despite the lack of comparable projects in the other categories, interior renovation projects compose a substantial portion of SABER projects so the analysis was performed with the one category.

4.1.1 Project Information. As expected, there were differences in the individual projects collected. This section describes some of the projects illustrating the range of projects used in this study. Table 4, WPAFB DBB Projects, lists project number, project name, design cost, total construction cost, square footage, cost per square foot, percent cost growth, and percent time growth, for the WPAFB DBB sample set. Project number and project name, as described earlier, provide designators for project tracking, and general descriptions of the project, respectively. Design cost is the amount paid by the government to an architecture-engineer firm to design that project. Architecture-Engineer firms are separate contractors hired by the government to perform the design, as discussed in Chapter 2. Projects designed in house have a design cost listed of $0.00. Determining cost of government time preparing design was beyond the scope of this

research. Total construction cost is final amount paid by the government for that project, this includes design cost and modifications. Square footage for the interior renovation projects is the floor or ceiling area affected by the project. Cost per square foot divides the total construction cost by square footage affected.

Percentage cost growth is the percentage of increase in construction cost after the original award. Percentage cost growth for DBB projects is calculated by subtracting the final cost from the amount originally awarded by the contract and dividing by the original award amount. Percentage cost growth for SABER projects is calculated by subtracting the final construction cost from the negotiated delivery order amount and dividing by the negotiated delivery order amount. There are instances were project contained negative percentage cost growth, this occurs because during construction work is deleted from the contract lowering the construction cost. Percentage cost growth does not include the design cost, only the original and final amount paid for construction.

Percentage time growth is the percentage of time required to complete the project above the scheduled time at award. When projects are awarded in either DBB or SABER the government and contractor agree of the time schedule for the project. Percentage time growth is calculated by subtracting the final number of days to complete the project by the original scheduled number of days then dividing by the scheduled number of days. In some projects scheduled completion time was increased due to modifications. There were several projects that had negative time growth because they were completed before the date required in the original time schedule. For a few projects, certain information was not available; these are noted by NA.

Table 4. WPAFB DBB Projects

WPAFB DBB Projects								
#	Project Number	Project Name	Design Cost	Total Const Cost	Square Footage	Cost Per Sq Ft	% Cost Growth	% Time Growth
1	95-0089	Repair Construct Digital Memory Lab	$26,775.00	$232,182.00	1300	$181.46	3.06%	25.00%
2	96-0076	Chapel Care Phase 1 Spirit Hall	$24,998.00	$252,341.00	6030	$42.52	4.00%	50.48%
3	92-0245L	Upgrade Conf. Room for VTC	$12,300.00	$230,228.00	2125	$108.34	6.94%	NA
4	96-4008A	Repair Officers Quarters Kitchen	$0.00	$25,436.00	300	$86.14	-0.25%	10.00%
5	97-5006	Upgrade Interior Finishes	$0.00	$165,602.00	31200	$5.31	-6.28%	74.18%
6	99-1001	Refurbish Restrooms	$0.00	$23,957.00	420	$57.04	20.39%	-11.11%
7	94-0076	Construct Video Studio Suite	$10,751.57	$192,981.57	3667	$54.36	NA	NA
8	92-0263	Repair Restrooms	$28,271.92	$381,670.92	2753	$148.07	3.47%	NA
9	94-1007	Renovate Courtroom Facility	$43,251.12	$390,592.62	30400	$120.20	0.31%	NA
10	96-8033	Rpr Const Dental Clean Facility	$10,275.18	$181,528.18	2800	$65.87	NA	87.78%

The WPAFB DBB sample set contained projects ranging from $5.36 per square foot, to $181.46 per square foot. Three of these projects, 97-5006 Upgrade Interior Finishes, 99-1001 Refurbish Restrooms, and 95-0089 Repair Construct Digital Memory Lab, are described below to illustrate the range of interior renovation projects in this sample. Appendix A includes descriptions of all the projects used in this research including the three projects presented in the following paragraphs. The project descriptions below are displayed in paragraph format. Project descriptions in Appendix B are displayed in a bullet format, with work performed on a general area grouped together. The bullet format provided any easier method to determine the type of work performed in each project.

Project 97-5006, Upgrade Interior Finishes, had a cost per square foot of $5.36. The key work elements performed in this project include installing 130,000 square feet (SF) of carpet, and installing 450,000 SF of vinyl wall covering. The project included scraping and painting 30,000 SF of ceiling, and lead abatement in 960 SF of rooms. This project is an extreme outlier in the WPAFB DBB sample set, because its cost per square foot was well below any of the other projects in that sample set. Since this project contains many of the key work elements of an interior renovation project it is was not excluded from this research. The low cost per SF can be contributed to the work being applied over a very large area.

Project 99-1001, Refurbish Restrooms, had a cost per SF of $57.04. The key work elements performed in this project include installing 420 SF new floor tile, 700 SF of gypsum wall, and painting 1100 SF of gypsum wall. The project included installation of 420 SF lay–in ceiling and new lighting. Mechanical work consisted of installing a return air grill, diffusers, ductwork, 2 new water closets, and 2 new lavatories.

Project 95-0089, Repair Construct Digital Memory Lab, had a cost per SF of $181.46. The key work elements in this project include installing1300 SF of carpet and painting 4,000 SF of walls. The project included installation of a 1300 SF lay-in ceiling, with light meeting computer room standards. Electrical work included routing electric wires to meet the new design, installing receptacles, and ceiling trays. Mechanical work included installing new ductwork, sprinkler system, and a new variable speed drive on the existing air handle unit. The project also included some asbestos abatement. This project represents the high end of cost in the WPAFB DBB set; however, the project contains the basic key work elements of interior renovation projects. As expected this

project performed a few more key work elements applied to a much smaller area than project 97-5006. This variance is expected over the range of possible interior projects.

Table 5, WPAFB SABER Projects, provides the same information for that sample set that Table 4 provided for the WPAFB DBB sample set. The only difference is the absence of design cost, because the cost of SABER design is included in the construction cost estimate.

Table 5, WPAFB SABER Projects, contains projects ranging from $8.89 to $227.10 per SF. Three of these projects, 96-1035 Renovate Room 204 Building 20023, 96-1955 Construct Conference Room, and 95-1852 Repair Restrooms Building 20028 are described below to illustrate the range of interior renovation projects in this sample. Appendix B includes descriptions of all the projects used in this research including the three projects presented in the following paragraphs.

Project 96-1035, Renovate Room 204 Building 20023, had a cost per SF of $8.89. The key work elements performed in this project include leveling and filling 360 SF of flooring for future carpet. The project included demolishing 560 SF of partition walls, 1200 SF of dry wall, constructing 250 SF of gypsum wall, and painting 1200 SF of walls. The project also included installation of 360 SF of lay-in ceiling. Mechanical work included providing two new junction boxes, and new diffusers.

Project 96-1955, Construct Conference Room, had a cost per square foot of $55.04. The key work elements performed in this project include installing 1036 SF tile carpet, and installing an electrical trench for a video run. The project also included 3 new doors

Table 5. WPAFB SABER Projects

WPAFB SABER Projects							
#	Project Number	Project Name	Total Cost	% Cost Growth	Square Footage	Cost Per Sq Ft	% Time Growth
1	98-1966	Construct Offices Conference Room	$319,457.65	26.42%	3280	$97.40	NA
2	97-0151-2	Construct Locker/Shower	$474,139.00	6.98%	50500	$9.39	0.1548
3	96-1955	Construct Conference Room	$55,204.61	0.00%	1036	$55.04	-0.2143
4	97-1914	Repair Restrooms Fac 30089	$33,227.65	25.41%	400	$84.40	-0.0286
5	96-1951	Repair Remodel 4th Floor	$7,804.00	0.00%	570	$13.91	0.6
6	97-1876	Renovate Room 117	$16,983.72	0.00%	220	$78.43	-0.6667
7	96-1920	Const Restrooms Building 2054	$24,392.38	2.20%	110	$225.30	-0.1957
8	97-1868	Repair Upgrade Conference Rooms	$49,989.00	0.00%	920	$55.21	-0.0182
9	96-1928	Repair Construct Family Restroom	$60,383.00	0.00%	700	$87.64	0.0513
10	97-1882	Renovate Room 215	$38,974.00	13.85%	1000	$38.97	-0.2083
11	97-1982	Repair Upgrade Training Rooms	$40,404.00	0.00%	2250	$18.24	NA
12	97-0140B	BRAC Ren F117 Supply Facility	$219,572.00	5.53%	20000	$10.98	NA
13	95-1852	Renov Restrooms Building 20028	$170,109.17	0.00%	800	$227.10	NA
14	95-1928	Renovate Classrooms	$10,481.00	0.00%	516	$21.69	NA
15	95-0039A	Renovate South Entrance Etc.	$180,255.24	0.00%	3218	$57.86	-0.0083
16	96-1035	Renovate Room 204 Build 20023	$13,680.00	4.50%	1590	$8.89	-0.2
17	95-1874	Upgrade Conf Room Building 56	$35,607.00	0.00%	1200	$31.69	NA
18	95-1918	Renovate Lobby Facility 2022	$10,791.34	0.00%	618	$18.65	NA
19	97-1945	Renov Restrooms Facility 10893	$26,997.76	11.89%	400	$67.49	NA

with frames and created a new entrance to the adjacent room. Work performed on walls included installing 780 square sound absorbing panels, 780 SF of fabric covering for

sound panels, and painting 1500 SF of walls. Installation of 1036 SF of lay-in ceiling was also performed in the project. Electrical work included installing electrical to accommodate the new design (light fixtures, outlets, and tray cables etc.), demolishing existing electrical channels, pull boxes, receptacles, and installing lighting for conference room. Mechanical work consisted of installing new ductwork and diffusers to accommodate design changes. The project also provided and installed 1 projection screen and 1 dry erase board.

Project 95-1852, Repair Restrooms Building 20028, had a cost of $227.10 per SF. The key work elements performed in this project include demolishing 800 SF of existing floor tile, and installing 800 SF new floor tile. The project also contained installation of 4,000 SF of drywall, 6 doors with frames, and painting 540 SF of block wall. A 800 SF lay in ceiling was also installed in this project. Electrical work consisted of modifications to meet design changes including new receptacles, light fixtures, and power supple for new hot water heater. Mechanical work consisted of replacing all drains, plumbing connections, installation of 9 new water closets, 6 new urinals, 12 new lavatories, 3 service sinks, 3 water coolers, and dividers for urinals and water coolers.

Table 6 HAFB DBB Projects contains the same information in the same format as Table 4 WPAFB DBB Projects. The cost per SF of DBB projects in the HAFB sample ranged from $28.77 to $144.91. Three projects, 95-0026 Repair Dorm 473, 92-0101 Repair VOQ Facility, and 96-0058 Repair F4F Control System Shop, are described below to illustrate the range of projects in this sample set. Appendix B includes descriptions of all the projects used in this research including the three projects presented in the following paragraphs.

Table 6. HAFB DBB Projects

HAFB DBB Projects								
	Project Number	Project Name	Design Cost	Total Const Cost	% Cost Growth	Square Footage	Cost Per Sq Ft	% Time Growth
1	92-0101	Repair VOQ Fac 587	$ 69,973.60	$ 999,709.00	0.00%	19920	$ 54.56	31%
2	97-0031	Conver Dorm 457 1+1	$ 47,730.72	$ 837,512.00	5.01%	17654	$ 50.14	0%
3	96-0058	RPR F4F Control System Shop	$ 16,920.00	$ 410,976.00	0.00%	3000	$144.91	-2%
4	90-0002	Repair Supply Offices	$ 33,285.00	$ 477,505.00	0.00%	5200	$104.91	5%
5	95-0026	Repair Dorm 473	$ -	$ 425,244.00	3.88%	16717	$ 28.77	11%

Project 95-0026, Repair Dorm 473 had a cost per SF of $28.77. Key work elements contained in this project include installing 14000 SF carpet and 2,000 SF vinyl base in laundry room and hallway. Work performed on walls consisted of installing 6,000 SF common area vinyl wall coverings, and 2,000 SF tile in bathrooms. The ceiling was removed and replaced as necessary to accommodate new mechanical equipment. Electrical work consisted of installing new lighting in rooms and common areas. Mechanical work included installing 48 fan coil units, and 48 exhaust fans. The project also included installation of 48 new showers with associated plumbing.

Project 92-0101, Repair VOQ Building 587, had a cost per SF of $54.46. Key work elements contained in this project include installing 2,000 SF of rubber base in laundry rooms and 16000 SF of carpet. Work performed on walls included installing 65,000 SF of gypsum wall board and painting 78,000 SF of walls. 16,000 SF of lay in ceilings were installed with lighting. Mechanical work consisted of installing 30 new fan coil units with associated plumbing connecting to hot and cold water supply, The project also provided 30 new cook tops.

Project 96-0058, Repair F4F System Control Shop, had a cost per SF of $144.91. Key work elements contained in this project include sealing 2,400 SF concrete flooring, and installing 400 SF of carpet. Work performed on walls included constructing 5,800 SF of gypsum walls, and painting 12,000 SF of gypsum and concrete walls. A 400 SF lay in ceiling with lighting was also installed in this project. Electrical modification included associated changes to meet the new design, including new outlets, receptacles, wiring for lighting and HVAC equipment, and modifying electrical lay out for equipment relocations. Mechanical work included installing a new fan coil unit, 3 ton unit air cooled unit with heat pump, and ductwork to meet new design.

Table 7, HAFB SABER Projects, contains identical information in the same format as Table 5 WPAFB SABER projects. Projects in the HAFB SABER sample set had cost per SF ranging from $23.67 to $91.11. Projects 97-0053 Repair X-34 Program Offices, 97-0069 Repair Detachment 1 Commander's Office, and 95-0046 Alter Intel Area Building 811 are described below to illustrate the range of projects in this sample set. Appendix B includes descriptions of all the projects used in this research including the three projects presented in the following paragraphs.

Project 97-0053, Repair X-34 program offices had a cost of $23.67 per SF. The key work elements contained in the project include installing 500 SF carpet pad, 59 square yards of carpet. Work performed on walls consisted of constructing 1300 SF of gypsum board walls, painting 1300 SF, and demolishing 1200 SF of partition walls. A 200 SF lay-in ceiling with lighting was installed. Electrical work consisted of minor changes to accommodate new design; for instance new receptacles.

Table 7. HAFB SABER Projects

HAFB SABER Projects							
	Project Number	Project Name	Total Cost	% Cost Growth	Square Footage	Cost Per Sq Ft	% Time Growth
1	98-0146	Rpr Target Squadron Fac	$58,976.00	0.00%	2425	$24.32	27.19%
2	98-0103	Repair EOD Facility	$57,344.00	0.00%	1267	$45.26	-13.33%
3	96-0025	Repair Dormitory 333	$151,153.00	0.00%	3336	$46.03	0.00%
4	98-0142	Repair Flight Facility 1022	$50,610.00	5.45%	776	$65.22	34.78%
5	95-0046	Alter Intel Area Bldg 811	$264,971.00	6.26%	3106	$91.11	0.00%
6	96-0043	Install Electric Bldg 14	$119,824.00	2.09%	1598	$76.18	3.33%
7	96-0029	Upgrade Restrooms Bldg 1087	$57,915.00	0.00%	745	$80.30	0.00%
8	97-0022	Repair Showers Dorm 335	$85,216.00	0.00%	1800	$47.34	58.33%
9	97-0053	RPR X-34 Program Offices	$11,764.00	0.00%	505	$23.67	-10.00%
10	97-0069	RPR Det 1 Command Office	$28,272.00	0.00%	680	$42.24	-35.56%
11	94-0104	Repair Latrines Bldg 811	$39,249.00	0.00%	625	$62.80	0.00%
12	98-0150	RPR 8th and 9th FS	$21,173.00	0.00%	345	$61.37	-1.00%

Project 97-0069, Repair Detachment 1 Commander's Office, had a cost per square foot of $42.24. The key work elements performed in this project included installing 680 SF of carpet. Work performed on walls included painting 1700 SF, demolishing 130 SF of block wall, demolishing 1000 SF gypsum wall, and constructing 1700 SF of gypsum wall. An existing 680 SF gypsum ceiling was demolished and replaced with a 680 SF lay in ceiling with lighting. Electrical work consisted of changes necessary to accommodate design changes including receptacles, and outlets. Mechanical work consisted of

associated modification to meet design changes including some new ductwork, and new diffusers.

Project 95-0046, Alter Intel Area Building 811, had cost per SF of $91.11. The key work elements performed in the project included installing 2500 SF of carpet, and 300 SF of tile. The project also included installation of 8 doors with frames, blocked in 18 existing windows, constructed 4500 SF gypsum walls, and painting 8000 SF of walls. A 3000 SF lay in ceiling was installed with lighting. Electrical work included installing an alarm system, communication lines, and associated modifications to meet design changes including receptacles. Mechanical work performed included installing new plumbing in bathrooms, and associated changes to accommodate new design including diffusers and some ductwork. The project provided 2 water closets, 2 lavatories, and 2 urinals. Asbestos abatement was also performed.

4.1.2 Sample Set Comparability. As apparent from the data collected each sample set contained a wide range of projects. In order to determine project comparability, the methodology outlined in chapter 3 will be applied to the projects collected. These methods compare the percentage of common work elements contained in the comparable sample sets, and project loading contained in those same data sets.

There were 18 key work elements identified in the interior renovation classification. The percentages of projects containing each of the key work elements were determined for each sample set. These percentages were then compared for each contracting method by base. The 18 key work elements are listed below:

1. Floor Covering (FC) consisted mainly of carpet installation. Floor covering also consisted some ceramic tile, vinyl tile, and concrete sealant.

2. Floor Construction (Fcon) included concrete slab floors, raised flooring, wood stage flooring, and trenching in concrete for electrical lines.

3. Floor Repair (Frep) consisted of patching existing floors, and leveling concrete floors.

4. Wall Covering (WC) consisted mainly of painting. There were also some ceramic wall tiles, vinyl wall tiles, and sound attenuation wall covering.

5. Wall Demolition (WD) included demolition of gypsum, partition, and concrete walls.

6. Wall Construction (WC) consisted of gypsum walls, concrete walls, and partition walls.

7. Wall Repair (WR) included patching existing concrete and gypsum walls.

8. Windows (Win) consisted of the installation of windows.

9. Doors consisted of the instillation of doors.

10. Ceilings mainly consisted of installation of lay-in suspended grid ceilings. There were also a couple of incidences of installing gypsum ceilings or scraping and recovering existing ceilings.

11. Electrical (Elec) consisted of the associated electrical needed make the construction a usable project. This included relocation of receptacles, switches, outlets, adding junction boxes, and panels along with the related wiring.

12. Electrical Equipment (Elec equip) included any electrical equipment that added to the capacity of the facility or modified its current power source.

13. Lighting consisted of the replacement of the existing lighting fixtures and wiring.

14. Security (Sec) consisted of any special alarm or security system included in the project.

15. HVAC consisted of the relocation of mechanical components to make the construction a usable project. This included relocation of diffusers, return air grills, and ductwork to accommodate facility changes.

16. Mechanical Equipment (Mech Equip) included any equipment replaced by the project or that added to the current mechanical capacity of the facility.

17. Plumbing consisted of any plumbing work included in the project. Examples of items considered in this work element are bathroom connections and piping to connect floor drains.

18. Sprinkler consisted of installation of any new sprinkler and modifications to the existing sprinkler system.

Tables 8 and 9 list the key work elements contained in the WPAFB DBB projects and WPAFB SABER projects respectively. Tables 8 and 9 list the project number, and the key work elements in the second row of the table. The Y indicates that project included work described by key work element listed at the top of that column, and the N indicates that key work element was not included by that project. For example project 95-0089, the first project listed in Table 8 included floor covering (FC) but did not perform floor construction (Fcon). The last column, Bathrooms, identifies if the project consisted of renovating a bathroom. The Bathrooms column was not considered a key work element because several of the projects only renovated bathrooms. The bathroom column was used to demonstrate the closeness in type of facility renovated by the comparable sample sets. The Total Y row, the next to last row in the table, adds the total number projects containing that work element in the sample set. The last row, percentage (%) calculates the percent of projects in the sample set that contained the key work element listed on the top of the column. For example in Table 8, there were 9 projects containing WC, equating to 90% of the projects in the WPAFB DBB sample set. Tables 8 and 9 are divided between the ceilings and electrical columns for presentation purposes.

Table 10, WPAFB Work Element Percentage Comparisons, shows the comparison of percentages in key work elements between the WPAFB DBB and SABER sample sets. The first column indicates the sample set where the percentage came from, DBB or

SABER, and the absolute difference between percentages completed in the two sample sets. Table 10 is also divided for presentation purposes.

Project comparability is evaluated by key work element. For example, floor construction (Fcon) column showed that 31% of the SABER projects and 40% of the DBB projects in the sample sets contained floor construction. The significance is that 9% more DBB projects than SABER projects contained floor construction as a key work element. Differences in percentages of key work elements for WPAFB DBB and FFP ranged from a low of 0% to high of approximately 27%; however only 5 of the 18 key work elements contained differences greater than 15%.

Further illustrating the comparability of projects Table 11 provides summary statistics for WPAFB key work element percentages. Table 11 is divided into six columns. The first column lists the statistic that calculated for the various sample sets. The second and third columns, one for DBB projects and the other for SABER, show the summary statistics for each of those sample sets. The numbers used to calculate the mean, median, standard deviation, variance, minimum, maximum, and range, are located on the bottom rows of Table 8 for WPAFB DBB and Table 9 for WPAFB SABER percentage of key work elements. The forth column shows the difference in means for the two methods. The fifth column shows the p-value, which provides the statistical significance of the difference in the means. Finally, the sixth column lists if the difference was statistically significant.

Table 8. WPAFB DBB Work Descriptions

WPAFB DBB Project Work Descriptions											
#	Proj #	FC	Fcon	Frep	WC	WD	Wcon	WR	Win	Doors	Ceilings
1	95-0089	Y	N	N	Y	N	N	N	N	N	Y
2	96-0076	Y	N	N	Y	N	Y	N	N	N	Y
3	92-0245L	Y	Y	N	Y	N	Y	N	N	Y	Y
4	96-4008A	Y	N	N	N	Y	N	N	N	N	Y
5	97-5006	Y	N	N	Y	N	N	N	N	N	Y
6	99-1001	Y	N	N	Y	N	Y	N	N	N	Y
7	94-1007	Y	Y	N	Y	Y	Y	N	N	Y	Y
8	94-0076	Y	Y	N	Y	N	Y	N	N	N	Y
9	92-0263	Y	N	N	Y	N	Y	Y	N	Y	Y
10	95-1874	Y	Y	N	Y	Y	Y	N	N	N	Y
	Total Y	10	4	0	9	3	7	1	0	3	10
	%	1	0.4	0	0.9	0.3	0.7	0.1	0	0.3	1

#	Proj #	Elec	Elec Equip	Lighting	Sec	HVAC	Mech Equip	Plumbing	Sprinkler	Bathroom
1	95-0089	Y	N	Y	N	Y	Y	N	Y	N
2	96-0076	N	N	N	N	Y	N	Y	N	Y
3	92-0245L	Y	N	N	N	Y	N	N	Y	N
4	96-4008A	Y	N	Y	N	Y	N	N	N	N
5	97-5006	N	N	N	N	N	N	N	N	N
6	99-1001	N	N	Y	N	Y	N	Y	N	Y
7	94-1007	Y	N	Y	N	Y	N	N	N	N
8	94-0076	Y	N	Y	N	Y	N	N	Y	N
9	92-0263	Y	N	Y	N	Y	N	Y	N	Y
10	95-1874	Y	N	Y	N	Y	N	N	N	N
	Total Y	7	0	7	0	9	1	3	3	3
	%	0.7	0	0.7	0	0.9	0.1	0.3	0.3	0.3

Table 9. WPAFB SABER Project Work Descriptions

WPAFB SABER Project Work Descriptions											
#	Proj #	FC	Fcon	Frep	WC	WD	Wcon	WR	Win	Doors	Ceilings
1	98-1966	Y	Y	N	Y	N	Y	N	N	Y	Y
2	97-0151-2	Y	N	N	Y	Y	Y	N	N	Y	N
3	97-1914	Y	N	Y	Y	Y	Y	N	N	N	N
4	96-1955	Y	Y	N	Y	N	Y	N	N	Y	Y
5	96-1920	Y	Y	N	Y	N	Y	N	N	Y	Y
6	96-1951	Y	N	N	Y	N	N	N	N	N	Y
7	97-1868	N	Y	N	Y	N	N	N	N	Y	Y
8	97-1876	N	N	N	Y	N	Y	N	N	Y	Y
9	96-1928	Y	N	N	N	Y	N	N	N	N	Y
10	97-1882	Y	Y	N	Y	N	N	N	N	N	Y
11	97-1982	Y	N	N	Y	Y	N	N	N	N	N
12	97-0140B	Y	N	N	Y	N	N	N	N	N	Y
13	95-1852	Y	N	N	Y	N	Y	N	N	Y	Y
14	95-1928	Y	N	N	Y	Y	Y	N	N	N	Y
15	95-0039A	Y	N	N	Y	N	N	Y	N	Y	Y
16	96-1035	N	N	Y	Y	Y	Y	N	N	N	Y
17	95-1918	Y	N	N	Y	N	N	N	Y	N	Y
18	97-1945	Y	N	N	Y	N	Y	N	N	N	Y
19	95-1874	Y	Y	N	Y	Y	Y	N	N	Y	Y
	Total Y	16	6	2	18	7	11	1	1	9	16
	%	0.84	0.32	0.11	0.95	0.37	0.58	0.05	0.05	0.47	0.84

Table 9. Continued

#	Proj #	Elec	Elec Equip	Lighting	Sec	HVAC	Mech Equip	Plumbing	Sprinkler	Bathroom
1	98-1966	Y	N	Y	Y	Y	Y	N	N	N
2	97-0151-2	Y	N	Y	N	Y	Y	Y	Y	Y
3	97-1914	N	N	N	N	N	N	Y	N	Y
4	96-1955	Y	N	Y	N	Y	N	N	N	N
5	96-1920	Y	N	Y	N	Y	N	Y	N	Y
6	96-1951	N	N	Y	N	Y	N	N	N	N
7	97-1868	N	N	Y	N	Y	N	N	Y	N
8	97-1876	Y	N	Y	N	N	N	Y	N	N
9	96-1928	Y	N	Y	N	Y	N	Y	N	Y
10	97-1882	Y	N	Y	Y	Y	N	N	N	N
11	97-1982	N	N	N	N	N	N	N	N	N
12	97-0140B	Y	N	Y	Y	Y	Y	N	N	N
13	95-1852	Y	N	Y	N	N	N	Y	N	Y
14	95-1928	N	N	Y	N	N	N	N	N	N
15	95-0039A	Y	N	Y	N	Y	N	N	N	N
16	96-1035	Y	N	N	N	Y	N	N	N	N
17	95-1918	N	N	N	N	N	N	N	N	N
18	97-1945	N	N	Y	N	N	N	Y	N	Y
19	95-1874	Y	N	Y	N	Y	N	N	Y	N
	Total Y	11	0	15	3	12	3	7	3	6
	%	0.58	0.00	0.79	0.16	0.63	0.16	0.37	0.16	0.32

Table 10. WPAFB Work Element Percentage Comparisons

WPAFB Work Element Percentage Comparisons										
Sample	FC	Fcon	Frep	WC	WD	Wcon	WR	Win	Doors	Ceilings
DBB	100.00%	40.00%	0.00%	90.00%	30.00%	70.00%	10.00%	0.00%	30.00%	100.00%
SABER	84.21%	31.58%	10.53%	95.00%	36.84%	57.89%	5.26%	5.26%	47.37%	84.21%
Difference	15.79%	8.42%	10.53%	5.00%	6.84%	12.11%	4.74%	5.26%	17.37%	15.79%

Sample	Elec	Elec Equip	Lighting	Sec	HVAC	Mech Equip	Plumbing	Sprinkler	Bathroom
DBB	70.00%	0.00%	70.00%	0.00%	90.00%	10.00%	30.00%	30.00%	30.00%
SABER	57.89%	0.00%	78.95%	15.79%	63.16%	15.79%	36.84%	15.79%	31.58%
Difference	12.11%	0.00%	8.95%	15.79%	26.84%	5.79%	6.84%	14.21%	1.58%

The mean of WPAFB DBB percentage of key work elements was only 1% higher than the mean of WPAFB SABER percentage of key work elements. Statistical significance of the difference was tested using the Wilcoxon Rank and Sign Test. The test used the null hypothesis that there was no difference between the DBB and SABER mean values for percentage of key work elements completed. A p-value higher than 0.05 would indicate there is no statistical significance between the means, accepting the null hypothesis as true. The test calculated a p-value of .4678, supporting the hypothesis there is no difference in the means. This indicates that both sample sets performed practically the same percentage of all key work elements. The similar ranges and standard deviations show similarity in the distribution of key work element percentages for the two sample sets. This test demonstrates the strong similarities in type of work performed in the two sample sets, validating sample set comparability.

The project-loading test was performed to determine if scopes of work contained in the sample sets were comparable. This test validates sample set comparability by comparing the amount of work contained in projects for each sample set. A sample set containing higher project loading would indicate the projects contained more key work elements and possibly have a higher unit cost. Project loading for the WPAFB DBB and SABER sample sets are contained in Table 12, WPAFB Project Loading. The table contains four columns, listing project number and percentage of key work elements performed in that project, for WPAFB DBB and SABER. The percentages of all work elements listed in columns 2 and 4 were calculated using information in Tables 7 and 8. The number of key work elements contained in a project were divided by the total number of key work elements. For example, Project 98-1966 located in Table 8

contains 11 of the 18 key work elements for a project loading of 67%. Summary statistics for the project loading are located in Table 13.

Table 11. WPAFB Summary Statistics Percentage of Key Work Elements

WPAFB Summary Statistics Percentage of Key Work Elements					
	DBB	SABER	Difference	p-value	Significance
Mean	0.42	0.41	0.01	0.47	Not Significant
Median	0.30	0.37			
Standard Deviation	0.36	0.30			
Variance	0.13	0.09			
Range	1.00	0.95			
Minimum	0.00	0.00			
Maximum	1.00	0.95			

Table 12. WPAFB Project Loading

WPAFB Project Loading			
WPAFB DBB		WPAFB SABER	
Proj #	% of all Work Elements	Proj #	% of all Work Elements
95-0089	44.44%	98-1966	66.67%
96-0076	33.33%	97-0151-2	61.11%
92-0245L	50.00%	97-1914	33.33%
96-4008A	33.33%	96-1955	50.00%
97-5006	16.67%	96-1920	55.56%
99-1001	38.89%	96-1951	27.78%
94-1007	55.56%	97-1868	38.89%
94-0076	50.00%	97-1876	38.89%
92-0263	55.56%	96-1928	38.89%
95-1874	50.00%	97-1882	44.44%
		97-1982	16.67%
		97-0140B	44.44%
		95-1852	44.44%
		95-1928	33.33%
		95-0039A	44.44%
		96-1035	38.89%
		95-1918	33.33%
		97-1945	22.22%
		95-1874	61.11%

Table 13, WPAFB Summary Statistics for Project Loading was calculated using the percentages in columns 2 and 4 in Table 12 for the respective sample sets represented. Table 13 has an identical format to Table 11, Summary Statistics Percentage of Key Work Elements.

Table 13. WPAFB Summary Statistics Project Loading

WPAFB Summary Statistics Project Loading					
	DBB	SABER	Difference	p-value	Significance
Mean	0.43	0.42	0.01	0.39	Not Significant
Median	0.47	0.39			
Standard Deviation	0.12	0.13			
Variance	0.02	0.02			
Range	0.39	0.50			
Minimum	0.17	0.17			
Maximum	0.56	0.67			

The mean of WPAFB DBB project loading was only 2% higher than the mean of WPAFB SABER project loading. Statistical significance of the difference was tested using the Wilcoxon Rank and Sum Test. The test used the null hypothesis that there was no difference between the DBB and SABER mean values for project loading. A p-value higher than 0.05 would indicate there is no statistical significance between the means, accepting the null hypothesis as true. The test calculated a p-value of .3857, indicating there is no difference in the means. The small sample variance in both sample sets indicates there was a small range in the project loading percentages. The significance of this results is that most projects contain approximately the same number of key work elements. This test demonstrates closeness in scopes of work performed in projects for the two sample sets, validating sample set and project comparability.

The WPAFB DBB and SABER sample sets also had strong comparability in the percentage of common facilities where projects were completed. 21 % of the WPAFB SABER and 30 % of the WPAFB DBB projects renovated conference rooms. Similarly, 30% of the WPAFB DBB projects and 32 % of the WPAFB SABER projects renovated bathrooms.

Tables 14 and 15, which have identical formats to Tables 8 and 9 list the key work elements contained in the HAFB DBB projects and HAFB SABER projects respectively. Table 16, which has an identical format to Table 10 shows the comparison of percentage in the HAFB DBB and SABER sample sets. The percentages in Table 16 were calculated on the bottom lines of Tables 14 and 15 for their respective sample sets.

Table 16 shows the relative closeness in percentage of projects containing each of the key work elements. Differences ranged from a low of 0% to high of approximately 25%. There was a higher number of differences in percentages of key work elements contained performed than in the WPAFB sample set with 8 of the 18 key work elements having differences greater than 15% between the two sample sets. Percentages of key work elements were greatly influenced by the smaller number of projects. For instance in the HAFB DBB data set, one additional project containing a key work element would change the total percentage of projects containing that key element by 20%.

Table 17, which has an identical format to Table 11 provides the summary statistics for HAFB projects. The summary statistics were calculated using values in Table 16. The mean of HAFB DBB percentage of key work elements was only 4% lower than the mean of HAFB SABER percentage of key work elements. Statistical significance of the difference was tested using the Wilcoxon Rank and Sign Test. The test used the null

Table 14. HAFB DBB Project Work Descriptions

HAFB DBB Project Work Descriptions											
#	Proj #	FC	Fcon	Frep	WC	WD	Wcon	WR	Win	Doors	Ceilings
1	92-0101	Y	N	N	Y	N	Y	N	N	N	Y
2	97-0031	Y	N	N	Y	Y	Y	N	N	N	Y
3	96-0058	Y	N	N	Y	N	Y	N	N	Y	Y
4	90-0002	Y	N	N	Y	N	Y	N	N	Y	Y
5	95-0026	Y	N	N	Y	N	Y	Y	N	Y	N
	Total Y	5	0	0	5	1	5	1	0	3	4
	%	1	0	0	1	0.2	1	0.2	0	0.6	0.8

#	Proj #	Elec	Elec Equip	Lighting	Sec	HVAC	Mech Equip	Plumbing	Sprinkler	Bathroom
1	92-0101	Y	N	Y	N	Y	Y	N	N	N
2	97-0031	Y	N	Y	N	N	N	Y	N	Y
3	96-0058	Y	N	Y	N	Y	Y	N	N	N
4	90-0002	Y	Y	Y	N	Y	N	N	N	N
5	95-0026	N	N	Y	N	Y	N	Y	N	Y
	Total Y	4	1	5	0	4	2	2	0	2
	%	0.8	0.2	1	0	0.8	0.4	0.4	0	0.4

Table 15. HAFB SABER Project Work Descriptions

HAFB SABER Project Work Descriptions											
#	Proj #	FC	Fcon	Frep	WC	WD	Wcon	WR	Win	Doors	Ceilings
1	98-0146	Y	N	N	Y	N	Y	N	N	Y	Y
2	98-0103	Y	N	N	Y	Y	Y	N	N	Y	Y
3	96-0025	Y	N	N	Y	N	Y	N	N	Y	Y
4	98-0142	N	N	N	Y	Y	Y	N	N	N	Y
5	95-0046	Y	N	N	Y	N	Y	Y	N	Y	Y
6	96-0043	Y	N	N	Y	N	N	N	N	N	Y
7	96-0029	Y	N	N	Y	N	N	N	Y	N	Y
8	97-0022	Y	N	N	Y	Y	Y	N	N	N	Y
9	97-0053	Y	N	N	Y	Y	Y	N	N	N	Y
10	97-0069	Y	N	N	Y	Y	Y	N	N	N	Y
11	94-0104	Y	N	N	Y	N	Y	N	Y	Y	N
12	98-0150	Y	N	N	Y	N	Y	N	N	Y	Y
	Total Y	11	0	0	12	5	10	1	2	6	11
	%	0.92	0.00	0.00	1.00	0.42	0.83	0.08	0.17	0.50	0.92

#	Proj #	Elec	Elec Equip	Lighting	Sec	HVAC	Mech Equip	Plumbing	Sprinkler	Bathroom
1	98-0146	Y	N	Y	N	Y	N	N	N	N
2	98-0103	Y	N	Y	N	Y	N	Y	N	Y
3	96-0025	Y	N	Y	N	N	N	Y	N	Y
4	98-0142	Y	Y	Y	N	Y	N	N	N	N
5	95-0046	Y	N	Y	Y	Y	N	Y	N	Y
6	96-0043	Y	N	Y	N	Y	N	Y	Y	Y
7	96-0029	Y	N	Y	N	Y	N	Y	Y	Y
8	97-0022	Y	N	Y	N	Y	N	Y	N	Y
9	97-0053	Y	N	Y	N	N	N	N	N	N
10	97-0069	Y	N	Y	N	Y	N	N	N	N
11	94-0104	Y	N	Y	N	Y	N	Y	N	Y
12	98-0150	Y	N	Y	Y	Y	N	N	Y	N
	Total Y	12	1	12	2	10	2	7	3	7
	%	1.00	0.08	1.00	0.17	0.83	0.17	0.58	0.25	0.58

Table 16. HAFB Work Element Percentage Comparison

HAFB Work Element Percentage Comparison										
Sample	FC	Fcon	Frep	WC	WD	Wcon	WR	Win	Doors	Ceilings
SABER	91.67%	0.00%	0.00%	100.00%	41.67%	83.33%	8.33%	16.67%	50.00%	91.67%
FFP	100.00%	0.00%	0.00%	100.00%	20.00%	100.00%	20.00%	0.00%	60.00%	80.00%
Difference	8.33%	0.00%	0.00%	0.00%	21.67%	16.67%	11.67%	16.67%	10.00%	11.67%

Sample	Elec	Elec Equip	Lighting	Sec	HVAC	Mech Equip	Plumbing	Sprinkler	Bathroom
SABER	100.00%	8.33%	100.00%	16.67%	83.33%	16.67%	58.33%	25.00%	58.33%
FFP	80.00%	20.00%	100.00%	0.00%	80.00%	40.00%	40.00%	0.00%	40.00%
Difference	20.00%	11.67%	0.00%	16.67%	3.33%	23.33%	18.33%	25.00%	18.33%

hypothesis that there was no difference between the DBB and SABER mean values for percentage of key work elements completed. A p-value higher than 0.05 would indicate there is no statistical significance between the means, accepting the null hypothesis as true. The test calculated a p-value of .4135, indicating there is no difference in the means. This indicates that both sample sets performed practically the same percentage of all key work elements. This test demonstrates the strong similarities in type of work performed in the two sample sets, validating sample set and project comparability.

Table 17. HAFB Summary Statistics Percentage of Key Work Elements

HAFB Summary Statistics Percentage of Key Work Elements					
	DBB	SABER	Difference	p-value	Significance
Mean	0.46	0.50	0.04	0.41	Not Significant
Median	0.40	0.50			
Standard Deviation	0.39	0.38			
Variance	0.16	0.14			
Range	1.00	1.00			
Minimum	0.00	0.00			
Maximum	1.00	1.00			

There was a clear division between the types of projects performed by SABER and DBB at HAFB. The common facility uses among the HAFB projects was not as prevalent as in the WPAFB projects. The only comparable facility use was bathrooms with 40% the HAFB DBB projects and 58% of the HAFB SABER projects renovated bathrooms. SABER at HAFB is used for almost all interior renovation projects under the maximum dollar limit of SABER. Three of the projects used in this research from the HAFB DBB sample set were above the maximum dollar amount for a SABER delivery order. Testing the percentages of key work elements per sample set and percentage of key work elements per project indicated these projects were acceptable for this research.

The projects were also considered non complex by the researcher, because the work was repetitive over a large facility. These factors, combined with the ability to waiver SABER projects above the maximum dollar limit, made these projects acceptable.

Results from the HAFB project loading test are displayed in the Table 18, which has an identical format to Table 12. The percentages of all work elements listed in columns 2 and 4 were calculated using information in Tables 13 and 14. Summary statistics for HAFB project loading are listed in Table 18, which has an identical format to Table 12. Summary statistics in Table 19 were calculated using values from Table 18 for the respective sample set.

Table 18. HAFB Project Loading

HAFB Project Loading			
HAFB DBB		HAFB SABER	
Proj #	% of all Work Elements	Proj #	% of all Work Elements
92-0101	44.44%	98-0146	44.44%
97-0031	44.44%	98-0103	55.56%
96-0058	50.00%	96-0025	44.44%
90-0002	50.00%	98-0142	44.44%
95-0026	44.44%	95-0046	61.11%
		96-0043	44.44%
		96-0029	50.00%
		97-0022	50.00%
		97-0053	38.89%
		97-0069	44.44%
		94-0104	50.00%
		98-0150	55.56%

Table 19. HAFB Summary Statistics Project Loading

HAFB Summary Statistics Project Loading					
	DBB	SABER	Difference	p-value	Significance
Mean	0.47	0.49	0.02	0.38	Not Significant
Median	0.44	0.47			
Standard Deviation	0.03	0.06			
Variance	0.00	0.00			
Range	0.06	0.22			
Minimum	0.44	0.39			
Maximum	0.50	0.61			

The mean of HAFB DBB project loading was only 2% lower than the mean of HAFB SABER project loading. Statistical significance of the difference was tested using the Wilcoxon Rank and Sum Test. The test used the null hypothesis that there was no difference between the DBB and SABER mean values for percentage of key work elements completed. A p-value higher than 0.05 would indicate there is no statistical significance between the means, accepting the null hypothesis as true. Test of the statistical significance of the mean difference resulted in a p-value of 0.3769, indicating there is no difference in the means. The small sample variance in both sample sets indicates there was a small range in project loading percentages. The significance of this finding is that most projects contained approximately the same number of key work elements. This test demonstrates closeness in scopes of work performed in projects for the two sample sets, validating sample set and project comparability.

The percentage of key work elements and project loading indicated that the two sample sets were comparable. These two tests along were the best available methods to determine overall sample set comparability. It is important to note the weakness of these tests. The main weakness is that the means for the sample sets are composed of different key work elements. The closeness in sample means is slightly misleading since each

mean has slightly different key work elements. With the limited sample size, there were no other available options to assure sample set comparability. The percentage of key work elements and the project loading tests provide the best available assurance that at least on the aggregate level the sample sets are comparable.

4.1.3 Summary. This section presented the data collected, and methods used to test the comparability of appropriate sample sets. The only category providing sufficient sample size to run statistical analysis was interior renovation. Project comparability was tested using two methods, comparing percentages of similar key work elements contained in each sample set, and comparing the percentages of key work elements contained in each project. These tests provided assurance that projects were comparable in both type and scope of work.

4.2 Project Performance Measures

Project folders and computer databases provided actual cost and schedule records used to record and track performance of DBB and SABER construction projects. Three performance measures were used as independent variables in analyzing project data to compare DBB and SABER interior renovation projects. These measures are cost, cost growth, and time growth.

4.2.1 Cost. The cost of the construction was compared using the unit cost, or cost per SF listed in Tables 4 through 7. The methods used to calculate the cost per SF have already been described in section 3.4, normalizing data for comparison. Total construction cost excluded any cost for government effort in management of contracted designs for DBB construction projects, and cost to government of employee time in

preparing SABER projects. The unit cost measure represents the relative cost per unit area of project, as determined in the normalizing process. The cost per SF was adjusted for inflation over time using Means 1998 historical cost indices. This allows direct and equitable comparison of construction completed over the past three years. The following formula was used to calculate unit cost:

(1) *Unit cost ($/S.F.) = [(Final Design Cost + Final Construction Cost)/Area]* Inflation Index*

The unit cost for each project is shown in Tables 4 through 7 for the respective sample sets. The mean, number of samples, standard deviation, variance, minimum, and maximum are listed in column 2 for DBB and column 3 for SABER in Table 20 for the WPAFB sample sets and Table 23 for the HAFB sample sets. The difference in the means, p-value of that difference, and determination of statistical significance are listed in columns 4 through 6 respectively.

4.2.2 Cost Growth. Cost growth was calculated to evaluate the resultant percentage of growth of project cost throughout its construction phase. Values for cost growth are located in Tables 3 through 6. Final versus contracted costs for construction was used to calculate the cost growth measure. The final cost of the project is the award cost plus any additional cost added to the contract by modifications during construction. Cost growth was calculated as follows:

*(2) Cost growth (%) = [(Final Project Cost – Award Project Cost)/Award Project Cost] * 100*

The percentage cost growth for each project is shown in Tables 4 through 7 for the respective sample sets. The mean, number of samples, standard deviation, variance,

minimum, and maximum are listed in column 2 for DBB and column 3 for SABER in Table 21 for the WPAFB sample sets and Table 24 for the HAFB sample sets. The difference in the means, p-value of that difference, and determination of statistical significance are listed in columns 4 through 6 respectively.

4.2.3 Time Growth. Time growth, also listed in Tables 4 through 7, was calculated as the percent by which the overall construction schedule was extended during the course of constructing the project. This measure calculated the difference between the as-built and as-planned schedule duration for construction. The time started from the construction start date and concluded at the construction complete date. The formula used for time growth was:

*(3) Time growth (%) = [(Total As-Built Time – Total As-Planned Time)/Total As Planned Time] * 100*

The percentage time growth for each project is shown in Tables 4 through 7 for the respective sample sets. The mean, number of samples, standard deviation, variance, minimum, and maximum are listed in column 2 for DBB and column 3 for SABER in Table 22 for the WPAFB sample sets and Table 25 for the HAFB sample sets. The difference in the means, p-value of that difference, and determination of statistical significance are listed in columns 4 through 6 respectively.

4.3 Data Analysis

This research relied upon various statistical tests to identify the existence of any significant relationships between DBB and SABER for each performance measure. Data analysis utilized non-parametric statistical comparisons of delivery systems by

performance metric to identify individual significance based on the central tendencies of the sample means. This research identified specific benchmark performance measures for both DBB and SABER based on statistical hypothesis testing of mean values. The remainder of this section presents the analysis results and explanations of the factors that caused these results as observed from the data used in this research.

4.3.1 Analysis Results. The analysis results are presented in two sections, WPAFB results and HAFB results. Tables 20 through 25 list the results of the analysis, for the different measures, the raw results from the statistical tests are located in Appendix C. They provide the test statistics used by the Wilcoxon Rank and Sum Test to determine the p-value for each performance measure. The Tables all have identical formats. Column 1 lists the various measures used to describe the sample sets. These measures include the mean, number of samples, standard deviation, variance, minimum, and maximum values, for both DBB and SABER at a particular base for the performance metric analyzed in that table. For the purposes of classification a p-value of .05 is considered significant. The p-value of .05 can be translated as a 95% confidence level that the values for SABER sample set are lower than the values for DBB sample set.

Table 20. WPAFB Cost/SF

WPAFB Cost/SF					
	DBB	SABER	Difference	p-value	Significance
Mean Cost/Sq Ft.	$82.05	$63.59	$18.46	0.13	Not Significant
Number of Samples	10	19			
Standard Deviation	64.15	51.82			
Variance	4115.2	2685.5			
Minimum	$8.89	$5.31			
Maximum	$227.10	$181.46			

The Cost/SF in the WPAFB projects had a mean of $82.05 for the DBB projects and $63.59 for the SABER projects, equating to the SABER projects being $18.46 less per SF than the DBB projects. Both sample sets contained high variance and large ranges in values. The p-value for WPAFB cost per square foot was 0.13. This p-value indicates that there is no statistically significant difference between the mean DBB and SABER cost per SF.

Table 21. WPAFB Percentage Time Growth

WPAFB Percentage Time Growth					
	DBB	SABER	Difference	p-value	Significance
Mean % Time Growth	39.38%	-6.67%	46.05%	0.01	Significant
Number of Samples	6	11			
Standard Deviation	38.2	30			
Variance	4115.2	30.837			
Minimum	-11.11%	-66.67%			
Maximum	87.78%	60%			

The time growth in WPAFB projects had a mean value of 39.4 % for DBB projects and –6.7% for SABER projects, equating to SABER having 46.5% less cost growth that DBB at WPAFB. The negative value for SABER time growth indicates that for the overall sample set SABER projects were finished before the original scheduled completion date. The analysis yielded only one finding, WPAFB percentage time growth, that could be determined statistically significant at 95% confidence level. The finding was that the construction time growth in SABER construction projects was less than that in DBB projects, this value was determined at a confidence level of 99%, or p-value of 0.01.

Table 22. WPAFB Percentage Cost Growth

WPAFB Percentage Cost Growth					
	DBB	SABER	Difference	p-value	Significance
Mean % Cost Growth	1.44%	6.45%	5.01%	0.26	Not Significant
Number of Samples	8	15			
Standard Deviation	2.43	9.09			
Variance	5.92	82.63			
Minimum	-0.07%	0.00%			
Maximum	6.49%	26.40%			

The cost growth for the WPAFB projects indicated the SABER projects had a larger cost growth than the DBB projects. This is contrary to the literature and expected results of this thesis. The mean values for percentage cost growth were 1.44% for the WPAFB DBB sample set and 6.45% for the WPAFB SABER sample set. The main factors contributing to this finding are the existence of some outliers in the WPAFB SABER sample. Two of the fifteen projects had cost growth greater than 25%. The distance between these outlying points and the remaining data points can be viewed graphically in Appendix A, test for normality.

Table 23. HAFB Cost/SF

HAFB Cost/SF					
	DBB	SABER	Difference	p-value	Significance
Mean Cost/Sq Ft.	$76.66	$55.49	$21.17	0.24	Not Significant
Number of Samples	5	12			
Standard Deviation	47.27	21.13			
Variance	2235.3	446.84			
Minimum	$28.77	$23.67			
Maximum	$144.91	$91.11			

The mean cost per square foot of SABER projects was lower than DBB by $21.17 per square foot at HAFB respectively. The p-value for HAFB cost per square foot was 0.24. This p-value was also out of the range of statistical significance.

Table 24. HAFB Percentage Time Growth

HAFB Percentage Time Growth					
	DBB	SABER	Difference	p-value	Significance
Mean % Time Growth	18.00%	5.73%	12.37%	0.2	Not Significant
Number of Samples	5	11			
Standard Deviation	22.17	25.56			
Variance	0.0491	0.0653			
Minimum	-2.00%	-36.00%			
Maximum	50.00%	58%			

HAFB SABER projects performed better than the HAFB DBB projects in time growth by 12.37%. The p-value for this calculation was 0.2, indicating there was no statistical difference between SABER and DBB time growth at HAFB.

Table 25. HAFB Percentage Cost Growth

HAFB Percentage Cost Growth					
	DBB	SABER	Difference	p-value	Significance
Mean % Cost Growth	1.80%	1.08%	0.72%	0.43	NotSignificant
Number of Samples	5	12			
Standard Deviation	0.0249	0.02155			
Variance	6.2 E-04	4.62 E-04			
Minimum	0.00%	0.00%			
Maximum	5.00%	6.00%			

There was a minimal difference between DBB and SABER cost growth at HAFB, less than 1%. The high p-value, 0.43 indicates there is no difference between cost growth for the two sample sets.

4.3.2 Explanation of Results. There were varying factors that led to some of the results being higher or lower than expected. Possible explanations of cost per square foot at both bases, time growth results at WPAFB, and cost growth at WPAFB are presented in this section.

4.3.2.1 Cost Per Square Foot. The mean cost per square foot for WPAFB and HAFB sample sets were $18.17 and $21.17 respectively, lower for SABER than DBB. This value represents approximately 30% savings in construction cost alone. This savings is misleading and distorted because of the effect outlying projects have on the smaller DBB sample sets. Despite the sample sets containing similar types and scopes of work, the individual project differences account for a portion of the difference in cost. This occurs because the mean cost per square foot for a sample set is influenced heavily by the individual low and high project cost per square foot. This indicates that the mean DBB cost per square foot is influenced to a greater degree by projects at the ends of the cost per square foot range. Four of the 10 projects in the WPAFB DBB sample set are above $100 per square foot and have a greater affect on the DBB mean, than the 2 out of 19 projects above $200 in the SABER sample set which has no projects in the $100-$199 range. The overall result is that the mean is distorted, indicating greater overall savings through SABER because of a few DBB projects with high cost per square foot. The same situation occurs in the HAFB sample sets. A solution for this could be to eliminate the upper and lower 25% of projects for each sample set, which was not possible in this research because the sample sizes were already small. The research indicated the SABER sample set had a lower cost for the similar types and scopes of works performed; however, the exact amount could not be determined from with the available data.

Despite the large difference in means there was no statistical significance in the cost per square foot at either base sampled. This was due to the large standard deviation of the sample sets. This large standard deviation is expected since the sample sets represent the range of interior renovation projects typically constructed in the Air Force. The

assumption that the sample sets observed represent the range in cost per square foot for WPAFB and HAFB is fairly safe considering the range of projects. It would take approximately 900 projects at WPAFB and 350 at HAFB in each sample set to show a $10 statistically significant difference in cost between the two methods. There is minimal likelihood of gathering this number of interior renovation projects. A larger sampler size would explain some of the variance by allowing the interior renovation category to be further divided by facility type or by construction with equivalent project loading per square foot. Any of these additional categories will provide a closer comparison within the interior renovation category, reducing the standard deviation. This research could only make a comparison for the entire interior renovation category due to the small sample size.

4.3.2.2 Time Growth. The two conclusions observed during the research for the time growth result were better ability to predict SABER construction time and fewer lengthy delays during the construction.

The first plausible explanation for the lower time growth in SABER construction is more accurate time estimating methods. The majority of SABER unit price books are modified forms of industry unit price books. These books contain time estimations for the units of work. By identifying the line items and quantities needed to complete the work, the unit price book contains algorithms that automatically calculate the time required for that project. The method for determining the time allotted for a DBB project is more ambiguous than for a SABER project. DBB contract award documents contain a construction schedule that accepted by the contractor as achievable. Despite this

contractually binding document, high time growth frequently occurred in the DBB projects.

The WPAFB sample set supports the concept that disputes are handled more quickly in SABER projects. There were four projects involving work delays and stoppages in the DBB sample set at WPAFB. Two of these projects had long delays due to difficulties receiving materials, one had problems meeting the phasing schedule, and the other had a labor problem. Despite having more projects, there were less delays in the WPAFB SABER projects. Where the SABER projects did have delays and work stoppages they were resolved more quickly than the DBB delays demonstrated by the lower amount of time growth. A key factor for creating SABER was its ability to begin the construction process more quickly, and to increase contractor responsiveness. In personal interviews with the SABER chiefs at WPAFB, HAFB, and contracting at WPAFB it was noted that SABER timeliness is not only expected during project procurement but also during construction. This places additional emphasis on completing SABER projects during the scheduled construction period (Vanscoy, Kester, Yiri, 1999).

4.3.3 Cost Growth Results. Cost growth was generally caused by one of two main factors, differing site conditions and additions to the scope of work. The two projects in the WPAFB SABER sample set with cost growth above 20% can be attributed to these situations. Differing site conditions were present in Project 96-1920 which had to replace plumbing connections and lines that could not be identified for replacement until after the construction exposed the damaged connections and lines. Project 98-1966 increased in scope by adding architectural finishes and installing mechanical systems when additional funds were made available for the project. The one project in the DBB sample set with

cost growth greater than 20% was also caused by the replacement of plumbing connections and lines that could not be identified until after the construction had started.

4.4 Summary

This chapter discussed the information that was collected during this research, performance measures examined and results of statistical analysis performed on the data. The available data provided only enough samples to perform the DBB versus SABER cost analysis in one category, interior renovation. Due to the small sample size and lack of normality in the data sets, non-parametric tests were chosen to analyze the data. There was only one finding of statistical significance, time growth at WPAFB. The remaining performance measures although not proven statistically significant showed better performance by the SABER projects, with one exception, cost growth at WPAFB. Chapter 5 will discuss conclusions derived from this research, recommendations for research improvements, and future research in this area.

5. Conclusions and Recommendations

This chapter provides a summary of the research performed, discusses the main findings, limitations, lists future research topics, and details the contributions of this effort. The main findings showed that SABER performed better than DBB in cost and time growth. Limitations include the small sample size and inability to capture qualitative aspects of the construction methods.

5.1 Summary of Research

The research consisted of five main areas; hypothesis formulation, review of relevant literature, development of methodology, data collection, and data analysis. The hypothesis tested in this research was that SABER is less expensive than DBB construction. The literature explained many advantages of SABER construction that potentially make it more cost effective. The methodology developed to complete this research involved finding data sources, grouping the construction by classification, assuring sample sets were comparable and finally comparing the two construction methods. Data was collected from the base level CE and Contracting Squadrons at WPAFB and HAFB. Due to the small sample size of comparable projects, non-parametric tests of the means was used to compare construction performed by the two methods.

5.2 Main Findings

The three performance measures used in this research were cost per square foot, cost growth and time growth. Time growth at WPAFB provided the only statistically

significant difference, a 99% confidence level that the SABER sample set had lower time growth than the DBB sample set. SABER was observed to have a 46% lower time growth in these sample sets. The observed causes of the difference in time growth were better ability to predict the time required in SABER construction, and faster resolution of conflict during the construction process.

The cost per square foot provided noticeable, although statistically insignificant, differences between DBB and SABER projects, with the SABER projects performing better at both WPAFB and HAFB. The mean cost per square foot indicated that SABER was approximately 30% lower than DBB for interior renovation projects. The research suggested that the SABER sample set was less expensive than the DBB sample set completing a similar type and scope of construction. The exact level of the cost difference could not be determined with the small sample size used in this research.

Contrary to other research efforts discussed in the literature review, cost growth was slightly higher in the WPAFB SABER projects, and only lower by less than one percentage in the HAFB projects. The mean cost growth in the WPAFB SABER sample set was strongly influenced by two projects both having cost growth greater than 25%. The causes of this cost growth were adding additional work to the scope and different site conditions. Different site conditions was the most common cause of cost growth in both sample sets.

This research compared projects completed at only two bases, WPAFB and HAFB. Both bases are classified as "large" by the Air Force, however neither produced a large number of comparable SABER and DBB projects. Despite the differences in the bases, the similar distributions of cost per square foot, cost growth, and time growth in the

sample sets leads to the tentative conclusion that performing a comparison of DBB and SABER construction Air Force wide might provide similar results on a base by base basis. Comparing DBB projects from the entire Air Force with SABER projects from the entire Air Force would reduce the variability in the sample sets reducing the mean cost difference between the two methods, by allowing further division of the interior renovation category. This research indicates that SABER would still have a lower cost; however, any estimate of that amount from this research would require much speculation.

5.3 Research Limitations

There were three limitations in this research that will provide the proper perspective of the results determined during this effort. The limitations include differences in projects, limited sample size, and no cost for qualitative aspects of the construction projects.

The only method to assure a construction cost comparison is 100% accurate is to compare projects that are identical in all ways. Identical projects were not available for this research. Every effort was made to ensure sample set comparability, including tests of key work elements performed, and number of key work elements contained in each project. Despite this effort results obtained in this research will not be as accurate if SABER and DBB had been used to complete the exact same projects.

Sample size limited the research by distorting sample means and limiting the types of construction compared. The small sample sizes of comparable DBB and SABER interior renovation projects available limited the possible ways projects could be categorized to reduce the standard deviation of the two sample sets. Due to the limited sample size, data sets were greatly influenced by extreme points. The small sample sizes of projects

available also did not allow the comparisons in the four remaining construction classifications. This limited to conclusions from the overall SABER and DBB construction contracting methods to just the interior renovation category.

The majority of the literature on SABER type contracts focused on the timesaving of this method compared to DBB construction. SABER projects are normally awarded one month after design begins where DBB projects are awarded nine months to a year after design begins. The time savings was identified in both project preparation time and contracting time required of Air Force personnel at WPAFB and HAFB. This research did not include the reduced cost of labor for Air Force personnel. An actual number of hours saved and cost for those hours would have increased the cost savings of interior renovation projects completed by SABER compared to DBB.

5.4 Future Research

This research focused on one particular issue in the construction management area with a limited sample set. There are numerous research topics that will benefit SABER and construction management. This research was limited by the sample size of comparable project. The cost comparison could be performed again using projects from multiple bases with local adjustment factors to normalize the cost to a common base. This would possibly provide enough projects to compare construction in the four remaining classifications.

Compare the qualitative advantages of SABER compared to DBB construction projects such as speed in awarding delivery orders, quality and lower time growth. This research focused on the cost of DBB versus SABER construction.

SABER is currently operating under the original design guidance despite the 1900% increase in delivery order dollar limit. This research has shown that SABER contracting method is being used to complete projects that are fairly complex and detailed. An analysis of the current SABER design policy may indicate if changes need to be made to meet the current dollar limit of delivery orders.

Compare performance of construction management between the current Civil Engineer Squadron and the new competitively sourced Civil Engineer Squadrons. This research was performed at two bases using the current Civil Engineer Squadron to perform construction management.

Perform a case study on the Solution Order Contracting method implemented at Langley Air Force Base during calendar year 1999. This research focused on two of the many construction management practices currently used in the United States Air Force. Solution order Contracting is a design build contract, where the government has multiple (3-5) contractors with the capability to 100% design and build multiple projects for the duration of the contract, similar to the length of a SABER contract. Research could be performed to determine the effectiveness of this program and implications of Air Force wide implementation.

5.5 Contributions of this Research

This research provided two main contributions; a comparison of actual construction performed by DBB and SABER contracting methods, and development of a construction cost comparison method. Although statistical significance was not proven, the research

showed similar interior renovation projects completed through SABER were cheaper than those completed through DBB contracting.

This research involved development of a methodology to compare cost for similar but non-identical projects. The methodology grouped projects into similar categories that involved similar types of work. Cost of the projects were then normalized to a common unit for comparison. The methodology also required development of a system to test project comparability. Project comparability was proven by comparing the percentages of common work elements per sample set, along with the percentages of work elements contained in each project. Following these procedures will allow the accurate comparison of different construction projects, especially when the appropriate sample size is available.

The methodology used in this research has many potential applications in construction management for both government and private organizations. Large construction entities can use this method to compare the performance of separate units performing slightly different but similar types of construction. This method can also be used to compare the performance of new construction contracting methods against those currently used. This will provide a quantitative assessment of which method should be implemented organization wide.

5.6 Recommendations

This research indicated that SABER was more cost effective than DBB in the interior renovation category, which compose a substantial portion of SABER projects. The exact level of savings could not be determined. The Air Force should use this information to

justify the performance of even more construction through SABER. The other advantages of SABER, such as faster procurement time along with this indication of cost savings in actual construction makes the program even more attractive. This research should also be used at the base level to emphasize to using organizations the benefits of SABER. This would alleviate some of the misconceptions of many base personnel that SABER is more expensive, hopefully convincing them to take their projects to SABER earlier providing more time for the construction planning resulting in a better end product. Finally, the Air Force should look into expanded SABER design regulations to allow the completion of more projects through SABER. This would allow the Air Force to complete more construction in a smaller amount of time, with fewer man-hours. The current Air Force movement is towards increased use contracts to perform many functions. It is not always obvious which of the contracts are performing well, but determining the contracts that are performing allows the Air Force to better use limited resources.

Appendix A. Normality Test

Appendix A shows the normality test of each sample set's project performance metrics. The sample sets are located in Tables 4 through 7 for the various bases and performance metrics. The normality tests were used to determine which statistical tests were appropriate for comparing sample set results. Indications of normality in both sample sets would have allowed the use of the two-sample t-test, the most accurate test for determining statistical significance in small sample sets. The Wilk-Shapario Rankit Plot, run through the computer program Statistix, was used to test for normality in the various sample sets. The test orders the individual data points of a sample set from lowest to highest on the y-axis. The x-axis uses Rankits, similar to standard deviations, to show the spatial relationship between an individual data point and the central tendency of the sample set. A Wilk-Shapario statistic of 0.95 or higher provides a strong indication the points in the sample set were selected from a population that is normally distributed. The graph can also provide a rough indication of outlying points that have a large influence on these small sample sets.

Limitations in the space provided for sample set names dictated the use of abbreviations. Abbreviations, the sample sets they represent, and the Wilk-Shapario statistic are listed below in Table A1. Table A1 is divided in four columns. The first column numbers the sample sets from 1 to 12. The second and third columns list the abbreviation and sample set it represents respectively. The fourth column lists the Wilk-Shapario statistic for the sample set.

Table A1. Abbreviations and Wilk-Shapario Statistics

Abbreviations and Wilk-Shapario Statistics			
	Abbreviation	Sample Set	Wilk-Shapario
1	WPDC	WPAFB DBB Cost per Square Foot	0.9484
2	WPDTG	WPAFB DBB Percentage Time Growth	0.9816
3	WPDCG	WPAFB DBB Percentage Cost Growth	0.8209
4	WPSC	WPAFB SABER Cost per Square Foot	0.7572
5	WPSCG	WPAFB SABER Percentage Cost Growth	0.755
6	WPSTG	WPAFB SABER Percentage Cost Growth	0.8717
7	HDC	HAFB DBB Cost per Square Foot	0.9206
8	HDCG	HAFB DBB Percentage Cost Growth	0.7655
9	HDTG	HAFB DBB Percentage Time Growth	0.8515
10	HSC	HAFB SABER Cost Per Square Foot	0.9695
11	HSCG	HAFB SABER Percentage Cost Growth	0.5723
12	HSTG	HAFB SABER Percentage Time Growth	0.9035

The Wilk-Shapario test results indicate only two of the twelve sample-sets represent a normal population. These two sample sets WPDTG and HSC are not comparable sample sets; therefore, this research required non-parametric test to perform statistical analysis for comparable sample sets. The graphical outputs from the Wilk-Shapario tests are shown below in Figures A1 through A12.

Figure A1. Normality test for WPDC

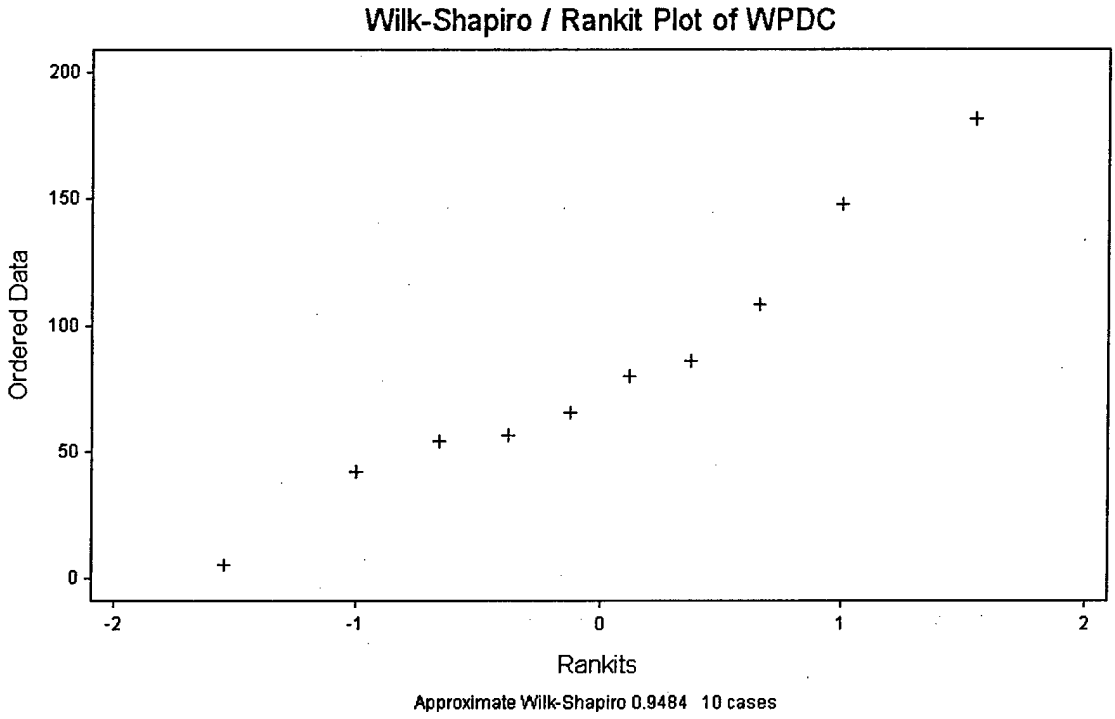


Figure A2. Normality Test for WPDTG

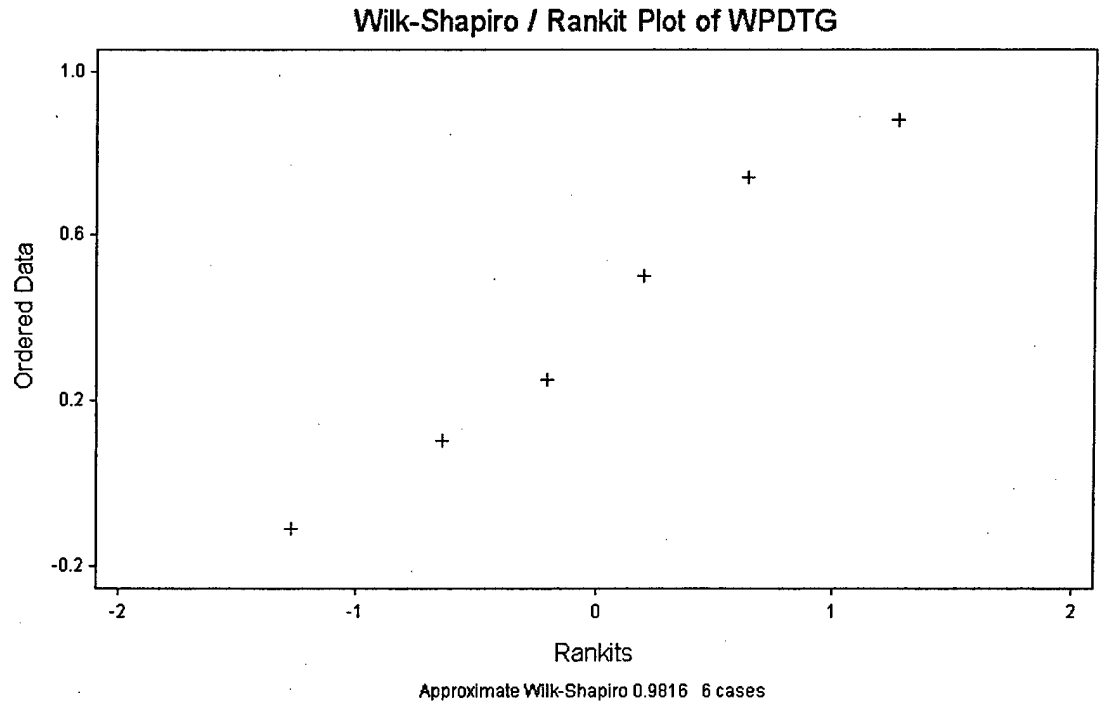


Figure A3. Normality Test for WPDCG

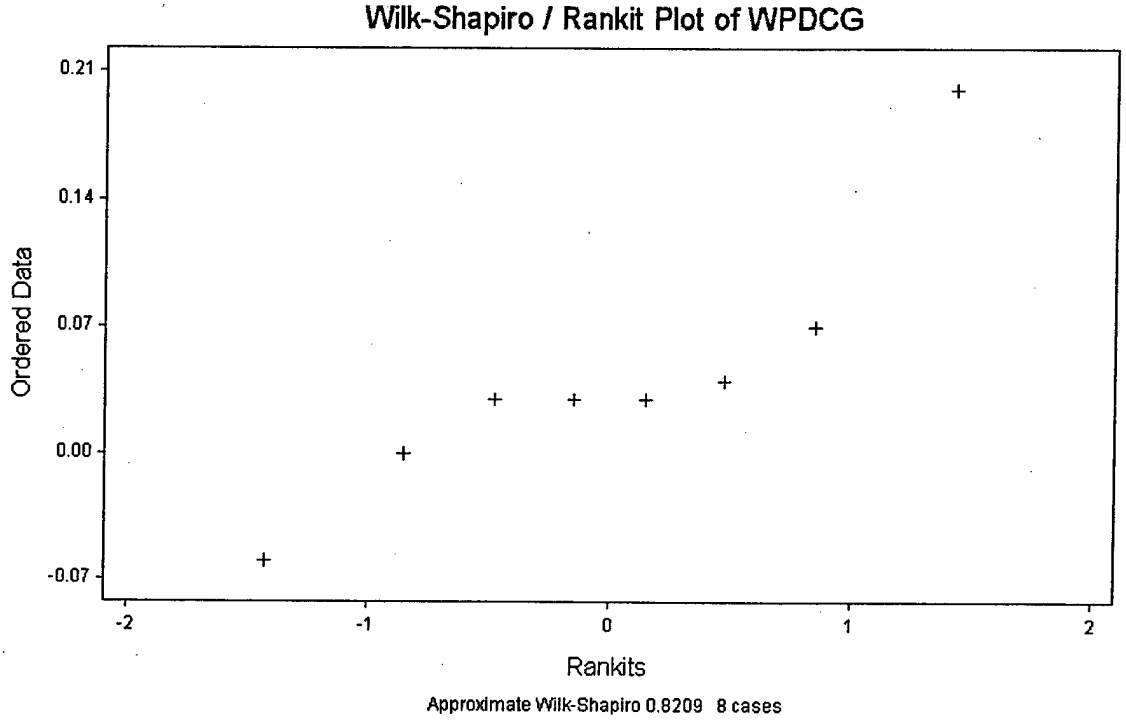


Figure A4. Normality Test for WPSC

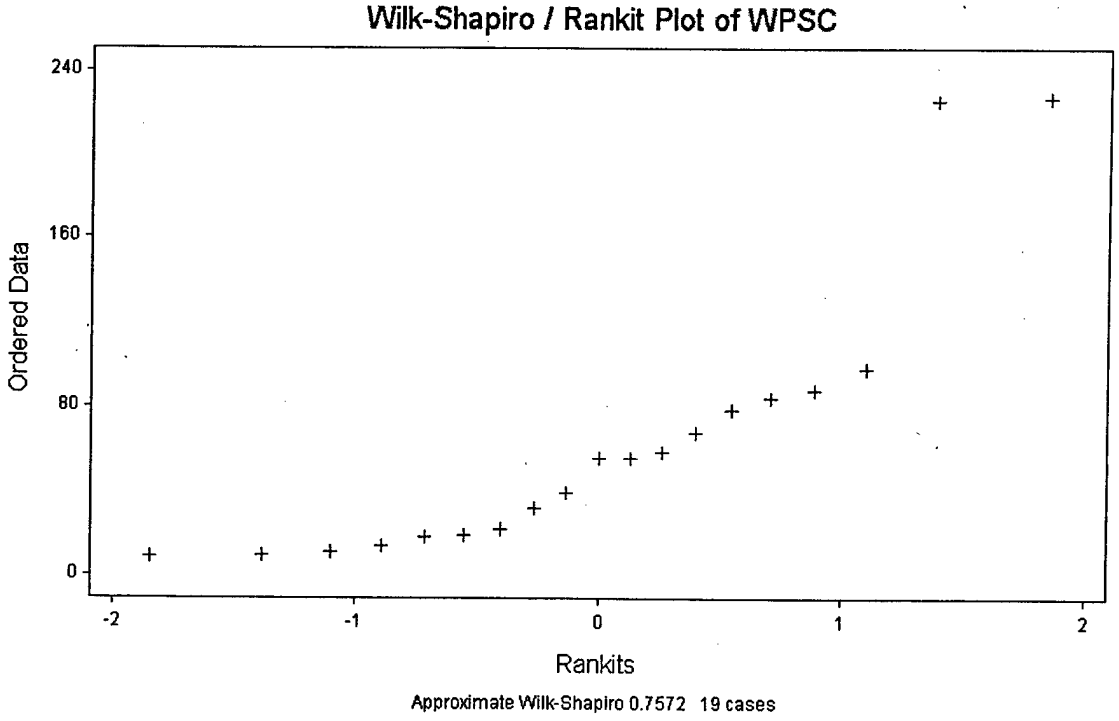


Figure A5. Normality Test for WPSCG

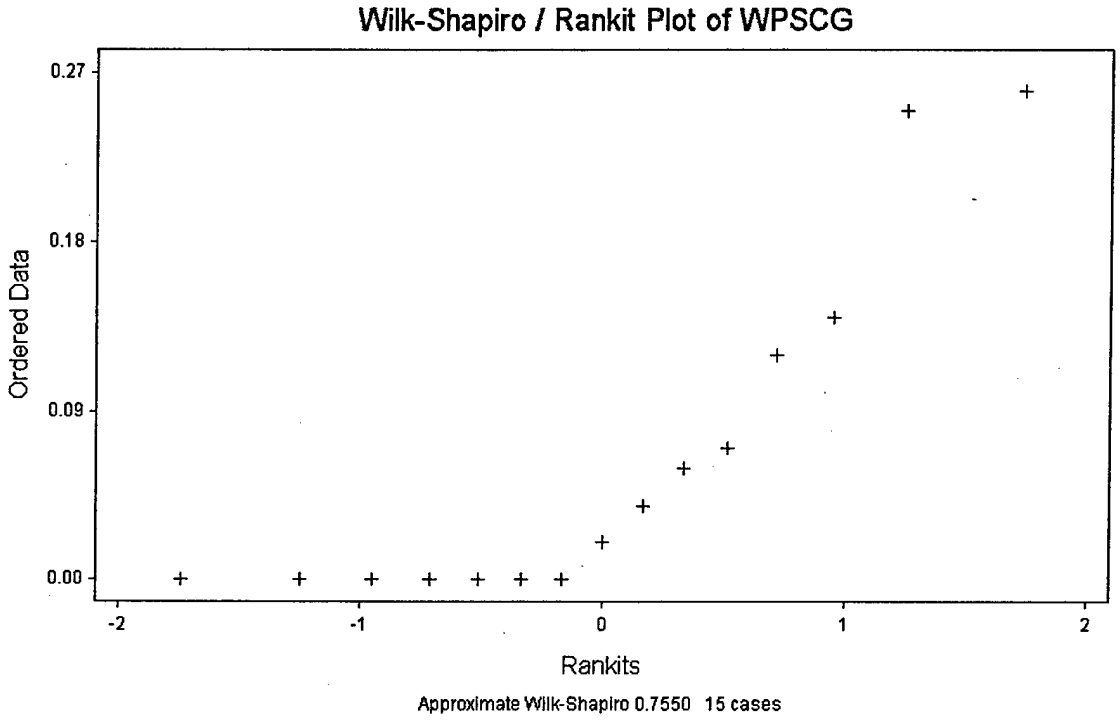


Figure A6. Normality Test for WPSTG

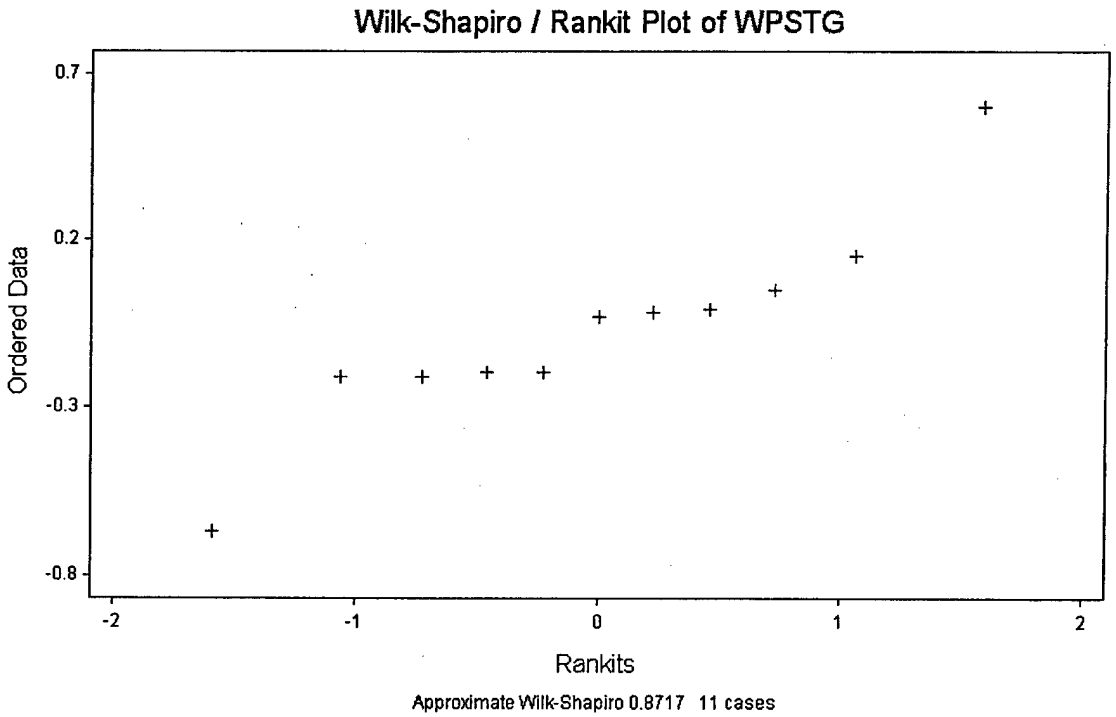


Figure A7. Normality Test for HDC

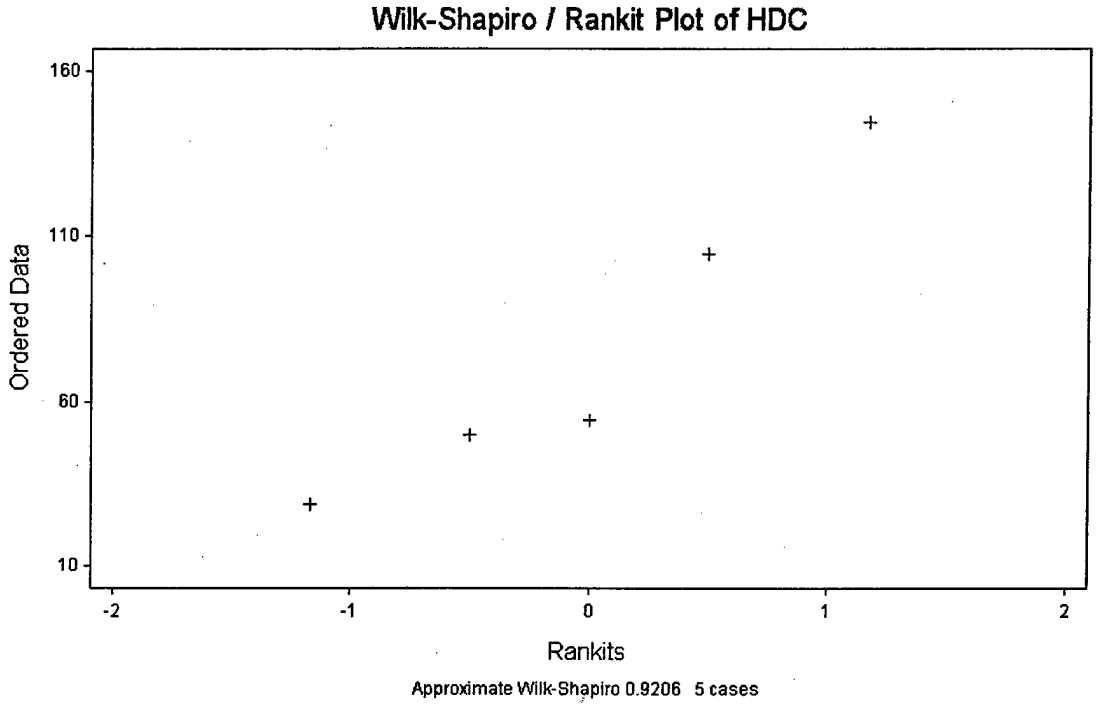


Figure A8. Normality test for HDCG

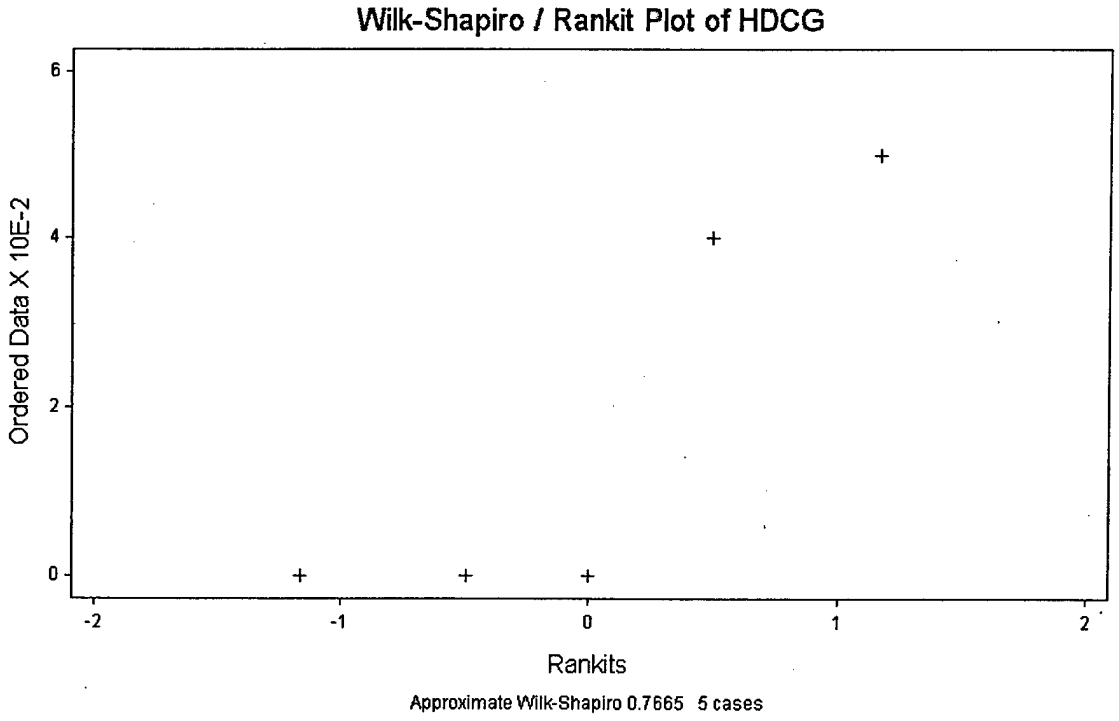


Figure A9. Normality Test for HDTG

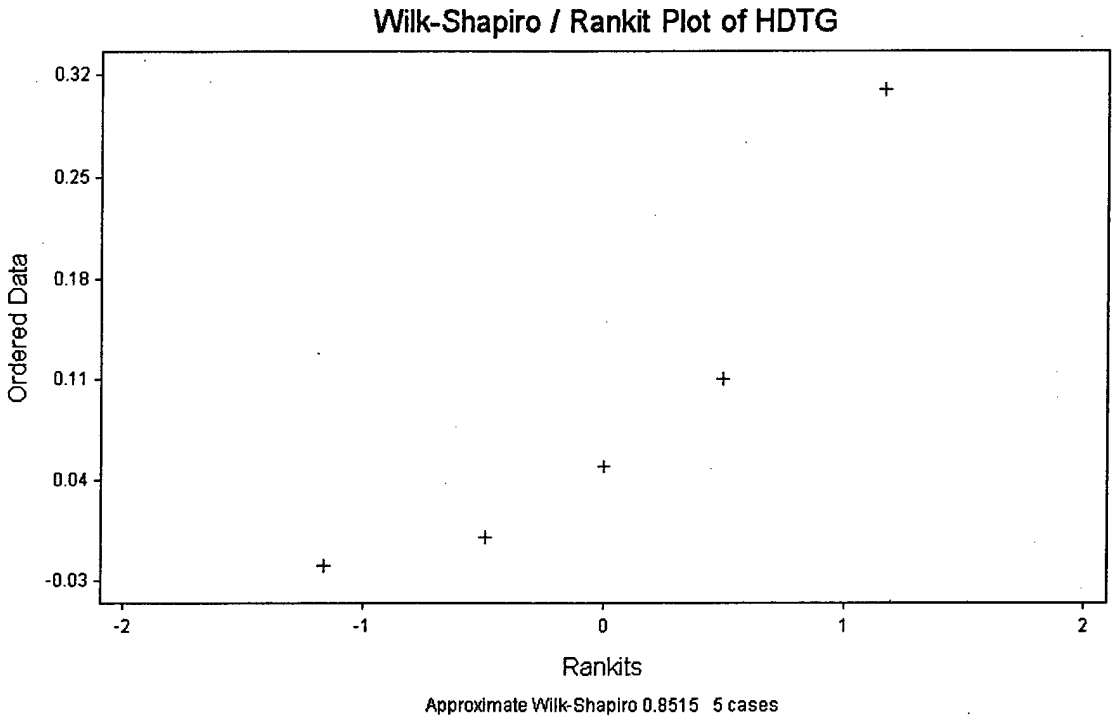


Figure A10. Normality Test for HSC

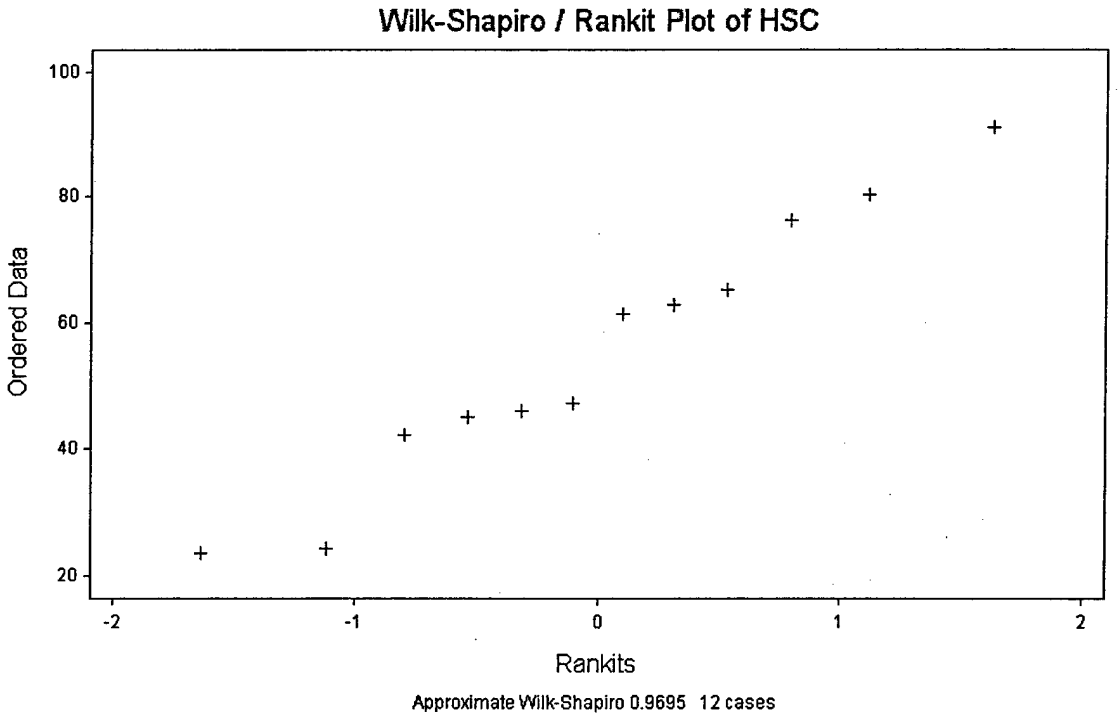


Figure A11. Normality Test for HSCG

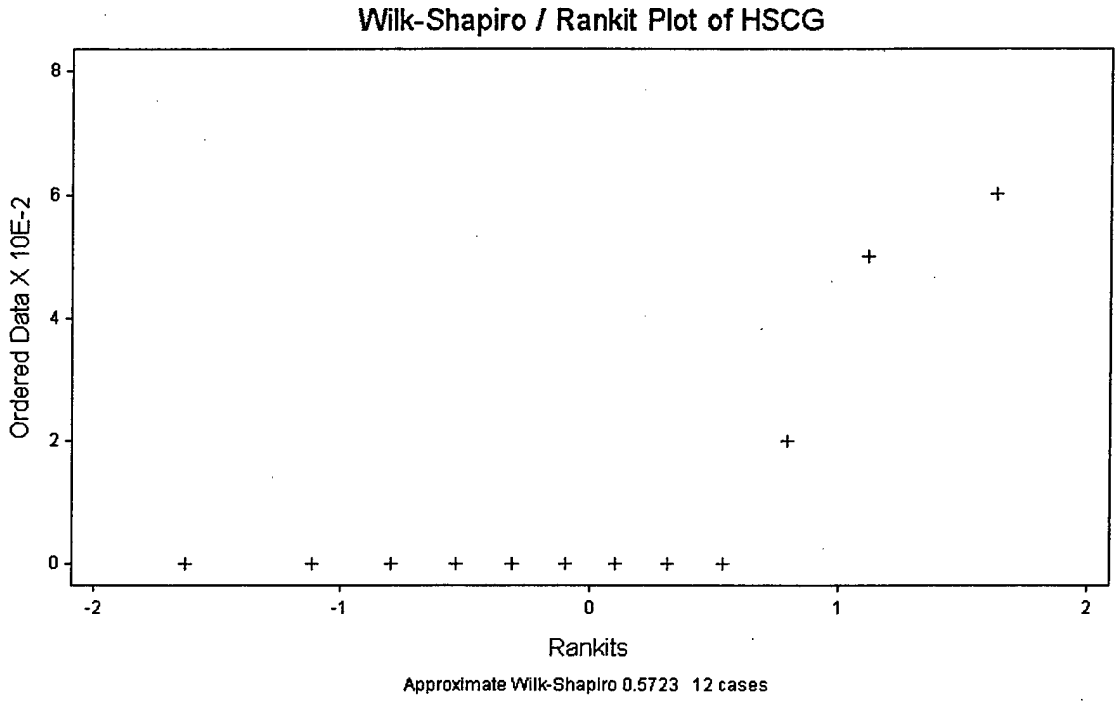
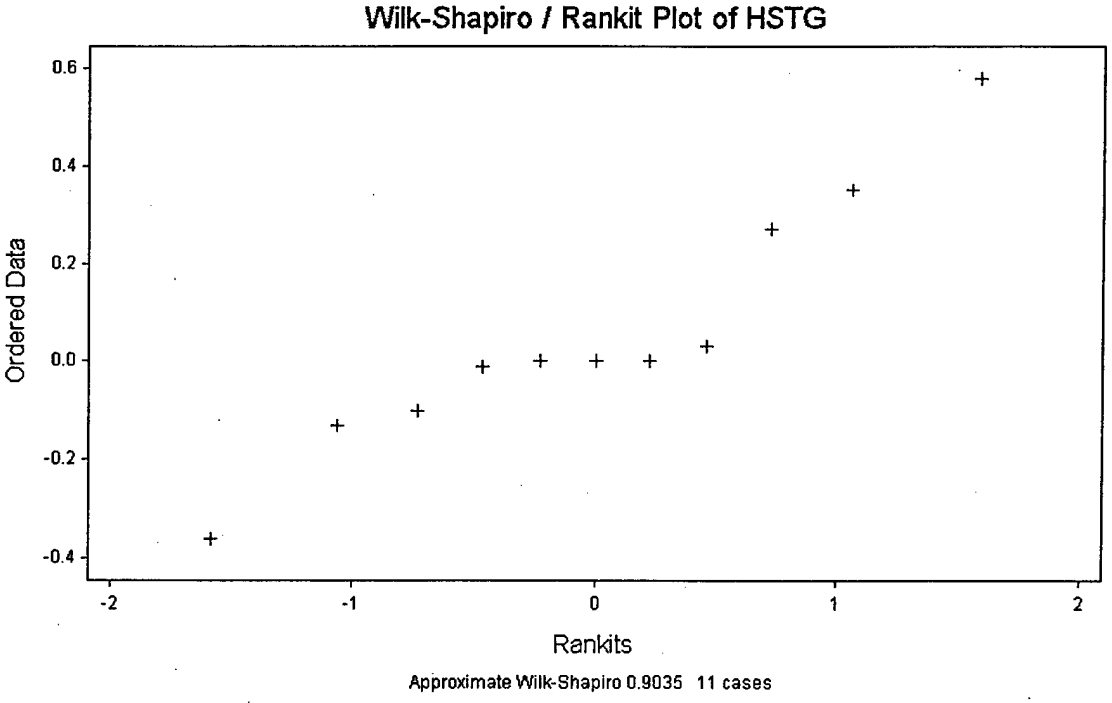


Figure 12. Normality Test for HSTG



Appendix B. Project Descriptions

Appendix B shows the project descriptions for all projects used in this research. Project information is displayed in a bullet type format. This format allowed easy determination of the key work elements contained in each project. Information listed for each project includes project number, contracting method, project name, total construction cost, and project size.

The work descriptions are divided into six categories: floors, walls, ceilings, electrical, mechanical, and miscellaneous. The first five categories describe the work performed on that particular portion of the facility. For example, in the floor category the construction, covering, or repair on the floor would be included in that category. The categories also contain the dimensional characteristics of work performed when available. Examples of the dimensional characteristics would included square feet of floor covering, or tons of HVAC added to the facility.

The miscellaneous category includes key construction work elements that did not fit conveniently into the other construction categories. Work elements typically included in the miscellaneous category include alarm systems, bathroom fixtures such as toilets, or vanities, equipment installed as part of the project. This category may also contain a brief description of requirements in the project that added to the effort needed to complete the project. Modification descriptions include work added, deleted, cost, and time extensions when available.

Descriptions for WPAFB SABER are located on pages 101-119, WPAFB DBB on pages 120-129, HAFB DBB on pages 130-134, and HAFB SABER on pages 135-146.

Project # 98-1966

Contractual Method: SABER (WPAFB)

Project Name: Construct Office Conference Room

Construction Cost: $319,457

Project Size: 3280 SF

Project Description

1. Floors

Construction - Constructed 3280 SF of floors, Constructed 1640 SF of concrete decking
Covering - Installed 3,280 SF of carpet

2. Walls

Wall construction - Constructed approximately 6,800 SF of gypsum walls
Wall covering - Installed approximately 800 SF of vinyl wall covering, Painted 12,000 SF of wall

3. Ceilings

- Installed 3280 SF lay-in ceiling including grid system

4. Electrical
- Installed all wiring for outlets, lighting, condensing unit and security system
- Rerouted electrical power to support design changes

5. Mechanical
- Installed HVAC for new conference room, including ductwork, diffusers, and 5 ton condensing unit

6. Misc.
- Provided special alarm system, and complete sound attenuation in offices
- Project consisted of installing new construction inside existing facility
- Installed 1600 square foot roof

Modifications – 1 modification

Added various work to the scope of the project, increased performance period by 157 days, $84, 389.65

Project # 97-0151-2

Contractual Method: SABER (WPAFB)

Project Name: Construct Locker/Shower

Construction Cost: $474,139.31

Project Size: 50,500 SF

Project Description

1. Floors

Covering - Replaced 800 SF of office flooring with new carpet, Installed 20,000 SF athletic courts, installed 3,500 SF floor tile in shower.

2. Walls

Demolition - Demolished 18,000 SF existing interior walls
Covering – painted 80,000 SF existing block cmu wall
Construction – 14,000 SF gypsum board walls

3. Ceilings - None

4. Electrical

- Relocated electrical to meet new configuration, installed receptacles, junction boxes, trenched cable runs for equipment.
- Installed lighting inside new office areas

5. Mechanical

- Added mechanical equipment for new load, installed two 5 ton condensing units, installed ductwork for all ac areas.
- Added plumbing to support new configuration, include showers and bathrooms.
- Added fire alarm system

6. Misc.
Asbestos removal included

Modifications – 4 modifications
Installed AC on racquetball court $21,389.16, Eliminated lighting -$11,735.63, Installed HVAC unit $6,351.03, Installed ventilation $28,744.28

Project # 97-1914

Contractual Method: SABER (WPAFB)

Project Name: Repair Restrooms

Construction Cost: $33,228

Project Size: 400 SF

Project Description

1. Floors

Covering - Installed 400 square foot new tile flooring
Construction - Resloped floors for drains

2. Walls

Construction - Installed 1100 SF gypsum wall board.
Covering – Installed 1100 SF wall tile.
Demolition - Demo existing 800 SF shower walls

3. Ceilings - None

4. Electrical - None

5. Mechanical

- Installed all new plumbing fixtures for showers

6. Misc. - None

Modifications – 1 modification
Replaced failing plumbing fixtures that were discovered after construction started $8,444

Project # 96-1955

Contractual Method: SABER (WPAFB)

Project Name: Construct Conference Room

Construction Cost: $55,204.61

Project Size: 1036 SF

Project Description

1. Floors

Covering – 1036 SF floor tile carpet.
Construction – Installed electrical trench for video run

2. Walls

Doors – Installed 3 new doors and frames.
Demolition - Created new entrance to adjacent room
Construction – Installed 780 square sound absorbing panels
Covering – Installed 780 SF of fabric covering, painted 1500 SF of walls

3. Ceilings

- Installed 1036 SF lay-in ceiling

4. Electrical

- Installed new electrical to accommodate design (outlets, tray cables, etc.)
Demolition – Demolished existing electrical channels, pull boxes, and receptacles
Lighting – Installed lighting for conference room

5. Mechanical

- Reroute HVAC for new design including ductwork and diffusers

6. Misc.

- Provide and installed 1 projection screen, and 1 dry erase board

Modifications – None

Project # 96-1920

Contractual Method: SABER (WPAFB)

Project Name: Construct Restrooms Building 2054

Construction Cost: $23,855.91

Project Size: 110 SF

Project Description

1. Floors

Construction - Provided 110 SF 6" concrete floor slab
Covering – Installed 110 SF vinyl floor tile

2. Walls

Construction – Installed 960 SF of drywall
Doors - Installed 3 doors with frames, installed access panel in chase wall
Covering – Painted 960 SF of walls

3. Ceilings - Installed 110 SF suspended lay in ceiling

4. Electrical

- Installed new lighting
- Installed associated electrical to support modifications, conduit for hot water heater, receptacles, and exhaust fans.

5. Mechanical

- Installed New branch vent, waste line, 2 floor drains, and clean out in chase wall
- Installed 20 linear feet of hot and cold supply lines 20 linear feet
- Installed 2 new 5 gallon hot water heaters

6. Misc.

- Provided and installed lavatory fixtures, water closet, and urinal

Modifications – 1 modification

1. $536.47 Added funds to contract to replace connections and lines

Project # 96-1951

Contractual Method: SABER (WPAFB)

Project Name: Repair Remodel 4th Floor

Construction Cost: $7,804

Project Size: 570 SF

Project Description

1. Floors

Covering - Installed 780 SF of carpet

2. Walls

Covering – Painted 200 SF of wall, Installed 600 SF of vinyl wall covering

3. Ceilings

- Installed 780 SF lay-in ceiling

4. Electrical

- Installed new lighting

5. Mechanical

- Installed new diffusers, and return air grill

6. Misc. - None

Modifications - None

Project # 97-1868

Contractual Method: SABER (WPAFB)

Project Name: Repair Upgrade Conference Rooms

Construction Cost: $49,989

Project Size: 920

Project Description

1. Floors

Construction - Installed 900 SF of raised floors

2. Walls

Doors - Installed 2 doors and frames
Covering – Installed 2,000 SF of sound attenuation walls

3. Ceilings

- Installed 900 SF lay-in ceiling

4. Electrical

- Installed new lighting new lighting

5. Mechanical

- Installed associated HVAC for new design, including diffusers and return air grill
- Installed new Sprinkler system

6. Misc.

- Asbestos removal
- Installed theater seating

Modifications - None

Project # 97-1876

Contractual Method: SABER (WPAFB)

Project Name: Renovate Room 117

Construction Cost: $16,983.72

Project Size: 220 SF

Project Description

1. Floors - None

2. Walls

Construction - Installed 630 SF of gypsum walls on existing concrete walls
Covering – Painted 630 SF of walls

3. Ceilings

- Installed 220 SF lay-in ceiling

4. Electrical

- Installed electrical panel, 18LF raceways, wiring, and circuit
- Demolished existing explosion proof lighting, installed new explosion proof lighting

5. Mechanical

- Installed chase wall access, and plumbing connection to existing sanitary waste line

6. Misc.

- Provided laboratory furniture, including cabinets, sink, fume hood, and countertops

Modifications - None

Project # 96-1928

Contractual Method: SABER (WPAFB)

Project Name: Repair Construct Family Restroom

Construction Cost: $60,383

Project Size: 700SF

Project Description

1. Floors

Covering - Installed 700 SF of floor tile

2. Walls

Demolition – Demolished existing 150 square foot wall

3. Ceilings

- Installed 700 SF lay-in ceiling

4. Electrical

- Installed new lighting
- Installed associated electrical to meet design changes, including receptacles, and wiring for lighting,

5. Mechanical

- Installed new diffusers, and return air grill
- Installed all new plumbing connections for bathroom fixtures

6. Misc.

- Constructed to ADA specifications, 4 water closets, 4 lavatories, and 2 mirrors

Modifications – 1 modification

1. No dollar change, 45 day time extension

Project # 97-1882

Contractual Method: SABER (WPAFB)

Project Name: Renovate Room 215

Construction Cost: $38,974

Project Size: 1000 SF

Project Description

1. Floors

Construction – Installed 800 SF of raised flooring
Covering - Installed 1000 SF carpet

2. Walls

Covering – Painted 2200 SF of walls

3. Ceilings

- Installed 1000 SF lay-in ceiling

4. Electrical

- Installed associated electrical to meet design changes including new receptacles, and wiring to security system
- Installed new lighting

5. Mechanical

- Installed associated HVAC to meet design changes including new diffusers, and ductwork

6. Misc.

- Installed new security system

Modifications – 2 Modifications
1. No dollar change just modified contract language
2. Installed carpet and some architectural changes $5,399

Project # 97-1982

Contractual Method: SABER (WPAFB)

Project Name: Repair Upgrade Training Rooms

Construction Cost: $40,404

Project Size: 2250 SF

Project Description

1. Floors

Covering - Installed 750 square yards of carpet
Demolition - Demolished existing floor tiles

2. Walls

Windows - Installed 20 square foot opaque glass
Covering - Painted 30,000 SF of walls, Added chair Rail
Doors - Installed 4 door frames

3. Ceilings - None

4. Electrical - None

5. Mechanical - None

6. Misc. - None

Modifications - None

Project # 97-0140B

Contractual Method: SABER (WPAFB)

Project Name: BRAC Renovate F117 Supply Facility

Construction Cost: $219,572

Project Size: 20,000 SF

Project Description

1. Floors

Covering - Installed 2,000 SF of carpet, sealed 10,000 SF of concrete floor

2. Walls

Covering – Painted 5,000 SF of wall, installed 1,100 SF of vinyl wall covering

3. Ceilings

- Installed 600 SF lay in ceiling.

4. Electrical
- Installed new lighting in HVAC
- Installed associated electrical for facility modifications including receptacles, power connection for HVAC unit, and power for new alarm system

5. Mechanical

- Installed new 20,000 CFM Air Handler Unit
- Installed associated HVAC to meet new design, including ductwork for office layout

6. Misc.

- Installed new security system
- Provided new systems furniture for two offices

Modifications – 3 modifications

1. Installed sound attenuating transition duct $3,592
2. Deleted some work added additional work $2,560
3. Installed additional wall covering $5,997

Project # 95-1852

Contractual Method: SABER (WPAFB)

Project Name: Renovate Restrooms Building 20028

Construction Cost: $170,109.17

Project Size: 800 SF

Project Description

1. Floors

Demolition - Demolished 800 SF existing floor tile
Covering – Installed 800 SF of new floor tile

2. Walls

Construction - Installed 4,000 SF of drywall
Doors - Installed 6 doors and frames
Covering – Painted 540 SF of cmu

3. Ceilings

- Installed 1,110 square foot lay-in ceiling

4. Electrical

- Installed associated electrical for new design including new receptacles, light fixtures, and power for new hot water heater

5. Mechanical

- Replaced all drains and plumbing connections

6. Misc.

- Installed 9 new water closets, 6 new urinals, 12 new lavatories, 3 service sinks, provided 3 water coolers, and dividers for urinals and water coolers

Modifications - None

Project # 95-1928

Contractual Method: SABER (WPAFB)

Project Name: Renovate Classrooms 311, 313, 320, and 322 Facility 20 641

Construction Cost: $10,481

Project Size: 516 SF

Project Description

1. Floors

Covering - Installed 120 SF carpet squares

2. Walls

Construction - Installed 864 SF of drywall
Covering – Painted 2,000 SF of block wall and 864 SF of drywall
Demolition – Demolished 900 SF of wall partitions

3. Ceilings

- Installed 516 SF lay-in ceiling

4. Electrical

- Installed New lighting

5. Mechanical - None

6. Misc. - None

Modifications – None

Project # 95-0039A

Contractual Method: SABER (WPAFB)

Project Name: Renovate South Entrance, Lobby, Basement, Canteen Area

Construction Cost: $180,255.24

Project Size: 3218 SF

Project Description

1. Floors

Covering – 2,500 SF of rubber sheet covering

2. Walls

Doors - Installed 7 new doors with frames and closers, demolished 3 existing doors
Coverings – Painted walls 8,400 SF, 2,300 SF of vinyl wall covering
Repair – Patched 1400 SF of existing walls

3. Ceilings

Demolition - Demolished existing ceiling installed
- Installed 3,200 SF lay-in ceiling

4. Electrical

- Installed new lighting
- Installed associated electrical to meet design changes including receptacles, junction boxes and utility boxes

5. Mechanical

- Installed associated HVAC to meet design changes including new ductwork and diffusers

6. Misc.

- Painted stairwell handles and installed countertop

Modifications - None

Project # 96-1035

Contractual Method: SABER (WPAFB)

Project Name: Renovate Room 204 Building 20023

Construction Cost: $13,458

Project Size: 1590 SF

Project Description

1. Floors

Repair - Leveled and filled 360 SF of flooring for future carpet

2. Walls

Demolition - Demolished 560 SF of partition walls, demolished 1200 SF of dry wall.
Construction – Constructed 250 SF of gypsum wall on existing block wall.
Covering - Painted 1200 SF of walls.

3. Ceilings

- Installed 360 SF of lay-in ceiling.

4. Electrical

- Provided two new junction boxes.

5. Mechanical

- Installed associated HVAC to meet design changes including adding a diffusers and ductwork

6. Misc. - None

7. Modifications – 2 modifications

1. No cost change modified contract language change
2. $615 for new requirements to schedule with GFE.

Project # 95-1918

Contractual Method: SABER (WPAFB)

Project Name: Renovate Lobby Facility 2022

Construction Cost: $10,791.34

Project Size: 618 SF

Project Description

1. Floors

Covering - Installed 55 SF of carpet

2. Walls

Windows - Removed and replaced window.
Covering - Painted 830 SF of walls

3. Ceilings

- Installed 618 SF lay in ceiling

4. Electrical - None

5. Mechanical - None

6. Misc.

- Installed various cosmetic/architectural changes
- Installed new counter, magazine rack, and customized plaque

Modifications - None

Project # 97-1945

Contractual Method: SABER (WPAFB)

Project Name: Renovate Restrooms Facility 10893

Construction Cost: $23,786.88

Project Size: 400 SF
Project Description

1. Floors

Demolition – Demolished existing rubber base floor
Covering - Installed 200 SF ceramic floor tiles, Installed 200 SF porcelain floor tiles

2. Walls

Covering – Installed 50 SF of ceramic wall tile, Painted 400 SF of walls
Construction – Constructed100 SF of dry gypsum board wall

3. Ceilings

Installed - 400 SF lay-in ceiling

4. Electrical

- Installed new lighting fixtures

5. Mechanical

- Modified plumbing drains, and plumbing connections for new toilets, sinks, and urinals.

6. Misc.

- Provided 4 new sinks, 2 new mirrors, countertop, 2 new urinals, new toilet partitions, and 4 new water closets

Modifications – 1 modification

1. $3,210.88, change drain line, provide additional wall tiles, demo and replace lights, and demo and replace ceiling. User requested changes.

Project # 95-1874

Contractual Method: SABER (WPAFB)

Project Name: Upgrade Conference Room Building 56

Construction Cost: $35,607.70

Project Size: 1200 SF

Project Description

1. Floors

Covering - Installed 125 SY of carpet
Construction – Constructed 75 SF stage flooring

2. Walls

Construction – Constructed 2200 SF of gypsum walls
Covering - Painted 830 SF of walls
Demolition – Demolished 450 SF of block wall
Doors - Installed 3 new doors and frames

3. Ceilings

- Installed 1200 SF lay in ceiling

4. Electrical

- Installed associated electrical for new design including outlets, receptacles, conduit and wiring to handle conference room equipment
- Installed conference room lighting

5. Mechanical

- Installed associated HVAC for new design including new diffusers and a return air grill
- Installed sprinkler system

6. Misc. - None

Modifications - None

Project #95-0089

Contractual Method: FFP (WPAFB)

Project Name: Repair Convert Digital Memory Lab

Construction Cost: $205,407

Project Size: 1300 SF

Project Description

1. Floors

Covering - Installed 1300 SF of carpet

2. Walls

Covering - Painted 4,000 SF of walls

3. Ceilings

- Installed 1300 SF lay-in ceiling

4. Electrical

- Installed new lights to special computer room standards
- Installed associated electric for new design including receptacles, ceiling trays, conduit, and wiring to meet equipment requirements

5. Mechanical

- Demolished existing ductwork and installed completely new ductwork
- Demolished old sprinkler install completely new sprinkler system
- Installed new variable speed drive on existing AHU

6. Misc.

- Special environmental requirements

Modifications – 2 modifications

1. Contractual changes no change in dollar amount
2. Installed additional carpet, and other finishes $6,097

Project # 96-0076

Contractual Method: FFP (WPAFB)

Project Name: Chapel Care Phase 1 Spirit Hall

Construction Cost: $218,600

Project Size: 6030 SF

Project Description

1. Floors
Covering - Installed 4,000 SF of carpet, 300 SF of ceramic tile, and 2,000 SF of regular tile

2. Walls

Construction – Constructed 2,000 SF of curtain partitions
Wall covering - Painted 8,000 SF of walls, Installed 1,100 SF of wall covering

3. Ceilings - None

4. Electrical - None

5. Mechanical

- Modified ductwork to connect to new AHU, installed in another project

6. Misc.
- Installed two new lavatories
- Removed asbestos removal in floor tile
- Provided new exterior stoops
- Installed 1,800 SF new metal roofing

Modifications

1. $8,743 Modified Ductwork

Project # 92-0245L

Contractual Method: FFP (WPAFB)

Project Name: Upgrade Conference Room for VTC

Construction Cost: $218,188

Project Size: 2125 SF

Project Description

1. Floors

Covering - Installed 1800 SF carpet squares
Construction - Constructed 400 SF of wood flooring

2. Walls

Construction - Constructed 3,000 square feet of block wall
Covering - Painted 4,500 SF of walls, Installed 2,500 SF of vinyl wall covering
Doors - Installed 2 new doors and frames

3. Ceilings - Installed 2,000 SF lay-in ceiling

4. Electrical
- Installed lighting to conference room standards including a dimming system
- Installed associated electrical for design changes including new receptacles, controls for dimming system, and electrical power to meet requirements for video equipment

5. Mechanical

- Installed associated HVAC to meet design changes including new ductwork, diffusers, return air, new sprinkler, and new thermostats

6. Misc. - Performed asbestos abatement in floor tile and joint compound.

Modifications – 5 modifications

1. Federal Acquisition Regulation (FAR) clarification no change in dollar amount
2. Revised construction progress schedule no change in dollar amount
3. Installed additional vinyl wall covering $3,967
4. Modified electrical requirements $5,560
5. Relocated Sprint telephone wires $4,668

Project # 96-8033

Contractual Method: FFP (WPAFB)

Project Name: Repair Construct Dental Clean Room Facility

Construction Cost: $171,253

Project Size: 2800 SF

Project Description

1. Floors

Covering - Installed 1800 SF of carpet

2. Walls

Covering – Painted 4,000 SF of wall, Installed 1000 SF of vinyl wall covering
Construction – Constructed 2500 SF of gypsum wall

3. Ceilings

- Installed 2500 SF lay-in ceiling

4. Electrical

- Installed associated electrical for design changes including receptacles, and routing wiring for equipment relocations

5. Mechanical

Plumbing – Installed new lines to sinks
- Installed associated HVAC for design changes including ductwork, new diffusers and return air grill

6. Misc.

- Installed new customer service countertop

Modifications - None

Project # 96-4008A

Contractual Method: FFP (WPAFB)

Project Name: Repair Officer Housing Kitchen

Construction Cost: $25,500

Project Size: 300 SF

Project Description

1. Floors

Covering – Installed 300 SF of floor tile

2. Walls

Demolition – Demolished existing wall 90 square foot wall

3. Ceilings

- Installed new gypsum ceiling 300 SF

4. Electrical

- Installed associated electrical to meet design changes including new receptacles
- Installed new lighting

5. Mechanical

- Rerouted HVAC to meet design changes including new diffusers and ductwork
- Installed new exhaust hood

6. Misc.

- Performed some asbestos removal

Modifications – 1 modification

1. -$64 deleted contractor equipment using Government Furnished Property (GFP)

Project # 97-5006

Contractual Method: FFP (WPAFB)

Project Name: Upgrade Interior Finishes

Construction Cost: 165,602

Project Size: 31,200

Project Description

1. Floors

Covering – Installed 130,000 of SF carpet

2. Walls

Covering – Installed 450,000 SF vinyl wall covering

3. Ceilings

Covering – Scraped and painted 130,000 SF of ceiling

4. Electrical - None

5. Mechanical - None

6. Misc.

- Performed lead abatement in 960 SF of rooms

Modifications – 2 modifications

1. Materials delay NC
2. Funding Source -$11,098

Project # 99-1001

Contractual Method: FFP (WPAFB)

Project Name: Refurbish Restrooms

Construction Cost: $24,047

Project Size: 420 SF

Project Description

1. Floors

Covering - Installed 420 SF of new floor tile

2. Walls

Construction – Constructed 700 SF of gypsum wall
Covering – Painted 1100 SF of walls

3. Ceilings

- Installed 420 SF lay–in ceiling

4. Electrical

- Installed new lighting

5. Mechanical

- Installed new return air grill, and new diffusers

6. Misc.

- Provided 2 new water closets, 2 new lavatories

Modifications – 1 modification

1. $4,505 replacement of damaged connections and lines

Project # 94-1007

Contractual Method: FFP (WPAFB)

Project Name: Renovate Courtroom facility

Construction Cost: $336,750

Square Footage: 30,400

Project Description

1. Floors

Covering - Installed 3,000 SF of new carpet,
Construction - Installed wood flooring.

2. Walls
Demolition – Demolished 3,500 SF of interior walls.
Wall construction - Constructed 4,000 SF of gypsum walls.
Doors – Installed 6 new doors
Covering – Painted 12,000 SF of walls, Installed 3,000 SF of vinyl wall covering.

3. Ceilings - Installed 4500 SF lay-in ceiling.

4. Electrical

- Installed associated electrical for new design including receptacles, conduit, and junction boxes.
- Installed new lighting over entire courtroom area.

5. Mechanical

- Installed associated HVAC for new design including ductwork, new diffusers, and sprinkler adjustments.

6. Misc.

- Provided some support furniture, Installed extensive architectural finishes.

Modifications – 2 modifications

1. $4,607.50 No description
2. $5,984.00 No description

Project # 94-0076

Contractual Method: FFP (WPAFB)

Project Name: Construct Video Studio Suite

Construction Cost: $182,230

Project Size: 3667 SF

Project Description

1. Floors

Covering – Installed 470 square yards of carpet tile.
Construction – Constructed 1000 SF of studio flooring.

2. Walls

Covering - Painted 980 SF of walls, Installed 520 SF of acoustic wall covering.
Doors – Installed New door frame, and rated door.
Construction – Constructed 2,000 SF of interior walls.

3. Ceilings

- Installed 3,167 SF of new lay-in ceiling.

4. Electrical

- Performed extensive electrical routing for new video equipment.
- Installed new lighting to video studio suite requirements.

5. Mechanical

- Installed associated HVAC to meet design changes including ductwork, diffusers, sprinkler adjustments and controls.

6. Misc.

- Provided sound attenuation for entire facility

Modifications - None

Project # 92-0263

Contractual Method: FFP (WPAFB)

Project Name: Repair restrooms

Construction Cost: $353,399

Project Size: 2753 SF

Project Description

1. Floors

Covering- Installed 3500 SF of ceramic tiles

2. Walls

Covering – Installed 4500 SF ceramic tiles, Painted 10000 SF of gypsum wall
Construction – Constructed 2424 SF of semi-rigid board wall, 1200 SF of gypsum board walls
Repair – Patched 500 SF of walls
Doors - Installed 9 new doors and frames, 24 access panels

3. Ceilings - Installed 3500 SF lay-in ceiling

4. Electrical

- Installed new lighting
- Installed associated electrical for design changes including new receptacles, wiring, and power for hot water heaters

5. Mechanical

- Installed associated HVAC to meet design changes including new ductwork, and 24 new diffusers
- Installed all new plumbing fittings.

6. Misc.

- Installed 28 new water closets, 19 urinals, 40 lavatories, 1 shower, and 3 water coolers

Modifications – 9 Modifications

Descriptions not available for all, total cost of modifications $28,271.92

Project # 92-0101

Contractual Method: FFP (HAFB)

Project Name: Repair VOQ Facility 587

Construction Cost: $999,709

Project Size: 19,920 SF

Project Description

7. Floors
Covering – Installed 2,000 SF of rubber base in laundry rooms, Installed 16000 SF of carpet

8. Walls
Construction – Constructed 65,000 SF wall board
Covering - Painted 78,000 SF of walls

9. Ceilings

- Installed 16,000 SF lay-in ceilings

10. Electrical

- Installed new lighting

11. Mechanical
- Installed new fan coil units
- Installed plumbing from FCU to main chilled water supply run

12. Misc.

- Provided new cook tops

Modifications - None

Project # 97-0031

Contractual Method: FFP (HAFB)

Project Name: Convert Dorm 457

Construction Cost: $795,512

Project Size: 17,654 SF

Project Description

1. Floors
Covering – Installed 15,000 SF of carpet

2. Walls
Demolition – Demolished 24,000 SF walls to enlarge rooms
Construction – Constructed 24,000 SF of new gypsum walls
Coverings – Painted 65,000 SF

3. Ceilings

- Installed 15,000 SF lay-in ceilings

4. Electrical

- Installed new lighting, installed receptacles and power runs to accommodate kitchen appliances

5. Mechanical

- Installed some new piping and plumbing fixtures

6. Misc. - None

Modifications – 1 modification
- Installed additional wall covering

Project # 96-0058

Contractual Method: FFP (HAFB)

Project Name: Repair F4F Weapon Control System Shop

Construction Cost: $410,976

Project Size: 3,000 SF

Project Description

1. Floors

Covering - Sealed 2,400 of concrete flooring

2. Walls

Construction – Constructed 5,800 SF of gypsum walls
Covering – Painted 12,000 SF of walls

3. Ceilings

- Installed 400 SF lay-in ceilings

4. Electrical

- Installed associated electrical changes to meet new design including new outlets, receptacles, wiring for lighting, and wiring for HVAC equipment

5. Mechanical

- Installed a new fan coil unit
- Installed a new 3 ton unit air cooled unit with heat pump along with some new ductwork
- Installed associated HVAC to meet new design

6. Misc. - None

Modifications - None

Project # 90-0002

Contractual Method: FFP (HAFB)

Project Name: Repair VOQ Facility 587

Construction Cost:

Project Size: 5,200 SF

Project Description

1. Floors

Covering – Installed 4,800 SF of carpet

2. Walls

Construction – Constructed 2,800 SF of gypsum board partitions
Doors – Installed new entrance doors with automatic opener

3. Ceilings

- Installed 4,800 SF lay-in ceilings

4. Electrical

- Installed new lighting
- Installed associated electrical for the new design including new outlets, and wiring to lighting.

5. Mechanical

- Installed new ductwork to AHU

6. Misc. - None

Modifications - None

Project # 95-0026

Contractual Method: FFP (HAFB)

Project Name: Repair Dorm 473

Construction Cost: $408,752

Project Size: 16,717 SF

Project Description

1. Floors

Covering - Installed 14000 SF of carpet, Installed 2,000 SF of vinyl base in laundry room and hallway

2. Walls

Covering – Installed 6,000 SF wall covering in common areas, Installed 2,000 SF of vinyl waynes coat in bathrooms

3. Ceilings

- Removed and replaced ceiling as necessary for HVAC replacement

4. Electrical

- Installed new lighting in rooms and common areas

5. Mechanical

- Installed new fan coil units and a new exhaust fan,
- Installed 48 new showers with the associated plumbing to connect showers

6. Misc. - None

Modifications – 1 modification

1. $16,492 added additional wall coverings

Project # 98-0146

Contractual Method: SABER (HAFB)

Project Name: Repair Aerial Target Squadron Facility

Construction Cost: $58,679

Project Size: 2425 SF

Project Description

1. Floors

Covering – Installed 500 SF of floor tile, Installed 50 SY of carpet, Installed 150 SF of padded gym floor

2. Walls

Construction – Constructed 965 SF of gypsum wall
Doors - Installed 2 new doors with frames

3. Ceilings

- Installed 1200 SF lay-in ceiling

4. Electrical

- Installed new light fixtures
- Installed associated electrical for design including outlets, receptacles, and wiring devices for switches

5. Mechanical

- Installed associated mechanical for new design including ductwork and diffusers

6. Misc. - None

Modifications - None

Project # 98-0103

Contractual Method: SABER (HAFB)

Project Name: Repair EOD Facility

Construction Cost: $57,344

Project Size: 1267 SF

Project Description

1. Floors

Covering – Installed 670 SF of ceramic floor tile

2. Walls

Construction - Constructed 150 SF of gypsum wall
Demolition – Demolished 180 SF existing wall
Covering – Installed 1035 SF of ceramic wall tile
Doors- Installed 1 door with frame

3. Ceilings

- Installed 900 SF lay-in ceiling

4. Electrical
- Installed new lighting
- Installed associated electrical for design changes including receptacles, toggle switches, wiring for lighting, and wiring for new exhaust fan

5. Mechanical

- Installed new plumbing fixtures for all bathroom items, washer drain, dryer exhaust
- Installed associated HVAC for design changes including ductwork, diffusers, and exhaust fan

6. Misc.

- Installed 8 lockers, 2 lavatories, 4 showers, 1 laundry sink, 2 urinals, and 2 water closets

Modifications - None

Project # 96-0025

Contractual Method: SABER (HAFB)

Project Name: Repair Dormitory 333

Construction Cost: $151,131

Project Size: 3336 SF

Project Description

1. Floors

Covering - Installed 1064 SY carpet

2. Walls

Construction – Constructed 1932 SF of gypsum walls
Doors – Installed 37 doors with frames

3. Ceilings

- Installed 3000 SF lay-in ceiling

4. Electrical

- Installed lighting, wiring to lighting and exhaust fans

5. Mechanical

- Installed new shower heads, stalls, and mixing valves
- Installed exhaust fans

6. Misc. - None

Modifications None

Project # 98-0142

Contractual Method: SABER (HAFB)

Project Name: Repair Flight Facility 1026

Construction Cost: $47,996

Project Size: 772 SF

Project Description

1. Floors - None

2. Walls

Construction - Constructed 1260 SF gypsum walls
Demolition - Demolished existing interior walls
Covering – Painted 1260 SF of walls

3. Ceilings

- Installed 1260 SF lay-in ceiling
Repair - Repaired roof leaks

4. Electrical

- Installed new lighting, new panel, receptacles, and outlets in new walls
- Installed 400 hz power in new rooms

5. Mechanical

- Installed associated HVAC to meet new design including new ductwork and diffusers

6. Misc.

- Constructed new roof construction for power converter

Modifications – 1 modification

1. $2,614 no description available

Project #95-0046

Contractual Method: SABER (HAFB)

Project Name: Alter Intel Area 811

Construction Cost: $249,371

Project Size: 3106 SF

Project Description

1. Floors

Covering - Installed 2500 SF of carpet, 300 SF of tile in latrine

2. Walls

Doors – Installed 8 doors and frames
Construction - Blocked in 18 existing windows, Constructed 4500 SF gypsum walls
Covering – Painted 8000 SF of walls

3. Ceilings - Installed 3000 SF lay-in ceiling

4. Electrical

- Installed new alarm system and new communication lines
- Installed associated electrical for design changes including receptacles, wiring for lighting, and outlets
- Installed new lighting

5. Mechanical

- Installed new plumbing in bathrooms
- Installed associated HVAC for new design including diffusers in office and latrine, new ductwork in those areas

6. Misc.

- Asbestos abatement included
- Installed 2 water closets, 2 lavatories, a 2 urinals

Modifications 1 modification. $15,600 no description availabe

Project # 96-0043

Contractual Method: SABER (HAFB)

Project Name: Install Electric Building 14

Construction Cost: $117,369

Project Size: 1600 SF

Project Description

1. Floors

Covering - Installed 1200 SF of carpet, Installed 400 SF of floor tile in restrooms

2. Walls

Covering – Installed 1000 SF of wall tile in latrine, Painted 800 SF wall tiles
Construction – Constructed 1800 SF gypsum walls

3. Ceilings

- Installed 1200 SF lay-in ceiling

4. Electrical

- Installed new lighting fixtures
- Installed associated electrical design changes including receptacles, wiring for lighting, junction boxes

5. Mechanical
- Installed plumbing for new latrines
- Installed associated HVAC to meet design changes including new diffusers, and ductwork
- Altered existing fire sprinkler to meet new design

6. Misc.

- Installed 2 new water closets, 2 urinals, 2 lavatories, and stainless steel mirror

Modifications – 1 modification

1. $2,455 no description

Project # 96-0029

Contractual Method: SABER (HAFB)

Project Name: Upgrade Restrooms Bldg. 1087

Project Size: 745 SF

Construction Cost: $57,915

Project Description

1. Floors
Demolition- demolished 275 SF of existing floors
Covering – Installed 745 SF of floor tile

2. Walls

Construction – 1200 SF gypsum board walls
Windows – Installed new windows
Doors – Installed 3 doors and frames

3. Ceilings

- Installed 250 SF lay in ceiling

4. Electrical

- Installed new lighting, receptacles, and wiring to outlets

5. Mechanical

- Installed associated plumbing, exhaust fan, and new drains

6. Misc.

- Installed new countertops, 2 lavatories, 2 showers, 2 urinals, and 2 water closets
- Installed new fire detection system

7. Modifications - None

Project # 97-0022

Contractual Method: SABER (HAFB)

Project Name: Repair Showers Dorm 335

Construction Cost: $85,216

Project Size: 1800 SF

Project Description

1. Floors

Demolition - Demolished 1600 SF of floor tiles
Covering – Installed 1800 SF of ceramic floor tile.

2. Walls

Construction – Constructed 4,800 SF of gypsum board walls
Demolition - Demolished 3000 SF existing walls

3. Ceilings

- Installed 1,800 SF gypsum ceiling

4. Electrical

- Installed new lighting

5. Mechanical

- Installed new showerheads and all other plumbing fixtures necessary to connect new showers

6. Misc.

- Installed 36 showers

7. Modifications - None

Project # 97-0053

Contractual Method: SABER (HAFB)

Project Name: Repair X-34 Program Offices

Construction Cost: $11,764

Project Size: 500 SF

Project Description

1. Floors

Covering - Installed 500 SF carpet pad, Installed 59 of SY carpet

2. Walls
Construction – Installed 1300 SF of gypsum board walls
Covering – Painted 1300 SF of walls
Demolition - Demolished 1200 SF of partition walls

3. Ceilings

- Installed 200 SF lay-in ceilings

4. Electrical

- Provided minor changes to accommodate new design including new receptacles

5. Mechanical - None

6. Misc. - None

7. Modifications - None

Project # 97-0069

Contractual Method: SABER (HAFB)

Project Name: Repair DET 1 Commanders Office

Construction Cost: $28,272

Project Size: 680 SF

Project Description

1. Floors

Covering - Installed 680 SF of carpet

2. Walls

Coverings – Painted 1700 SF of walls
Demolition – Demolished 130 SF of block walls, and 1000 SF of gypsum wall
Construction – Constructed 1700 SF of gypsum wall

3. Ceilings

- Demolished existing 680 SF drywall ceiling
- Installed 680 SF lay-in ceiling

4. Electrical

- Installed associated electrical to meet design changes including receptacles, outlets and wiring to lighting
- Installed new lighting fixtures

5. Mechanical

- Installed associated HVAC to meet design changes including some ductwork changes and new diffusers

6. Misc. - None

Modifications – 2 modifications

1. No dollar amount change contract language modified
2. No dollar amount change added some work deleted other work

Project # 94-0104

Contractual Method: SABER (HAFB)

Project Name: Repair Latrines Bldg. 811

Construction Cost: $39,249

Project Size: 625 SF

Project Description

1. Floors

Covering – Installed 600 SF of ceramic floor tile

2. Walls
Demolition - Demolished existing window and installed a new window
Doors – installed 2 new doors and frames
Construction – Constructed 1200 SF wall partitions

3. Ceilings - None

4. Electrical

- Installed new outlets to meet design changes
- Installed new lighting

5. Mechanical

- Installed associated HVAC to meet design changes including new exhaust fans
- Installed all associated plumbing for new design

6. Misc.

- Installed 3 lavatories, 3 urinals, and 4 water closets

Modifications - None

Project # 98-0150

Contractual Method: SABER (HAFB)

Project Name: Repair 8th and 9th FS

Construction Cost: $21,173

Project Size: 345 SF

Project Description

1. Floors

Covering - Installed 345 SF of floor tile

2. Walls

Doors - Installed 2 doors and frames
Construction – Constructed 550 SF of gypsum walls

3. Ceilings

- Installed 550 SF lay-in ceilings

4. Electrical

- Installed new lighting
- Installed new electric outlets

5. Mechanical

- Installed new sprinkler system
- Installed associated HVAC to meet design changes

6. Misc.

- Installed new alarm system

Modifications - None

Appendix C. Rank Sum Test Results

Appendix C provides computer generated output form the statistical test of sample set differences for each performance metric. Sample sets for the various performance metrics are located in Tables 4 through 7. Abbreviations are the same as those used in Appendix A, Normality Test.

The Wilcoxon Rank and Sum test, run through the computer program Statistix, was used to perform statistical analysis of the sample sets. The test calculates a rank sum for each sample set. The rank sum is calculated by combining all the data points from comparable sample sets, ordering them from 1 to the last data point, the summing the ranks for each sample set. The U-Stat is a measure used in calculating the probability. The Statistix program uses these values and the number of samples to determine the probability of observing values equal to or more extreme than those observed in the sample sets, the one and two-tailed p-values for the sample set comparisons. This research used the one-tailed p-value because the focus was to determine if SABER performance was better than DBB performance. The two-tailed value is used if the focus is to determine if there is a difference between the sample sets in either direction. A one-tailed p-value greater than 0.05 indicates there is no statistically significant difference between the sample set means.

Results from these test were used in Tables 20-25 to determine statistical significance of difference in sample set means. The outputs from the six tests of statistical significance in project performance metrics are shown below.

RANK SUM TWO-SAMPLE TEST FOR WPSC VS WPDC

VARIABLE	RANK SUM	SAMPLE SIZE	U STAT	MEAN RANK
WPSC	259.00	19	69.000	13.6
WPDC	176.00	10	121.00	17.6
TOTAL	435.00	29		

EXACT PROBABILITY OF A RESULT AS or MORE EXTREME
THAN THE OBSERVED RANKS (ONE-TAILED P-VALUE) 0.1341

NORMAL APPROXIMATION WITH CONTINUITY CORRECTION 1.170
TWO-TAILED P-VALUE FOR NORMAL APPROXIMATION 0.2420

TOTAL NUMBER OF VALUES THAT WERE TIED 0
MAXIMUM DIFFERENCE ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 29 MISSING CASES 9

RANK SUM TWO-SAMPLE TEST FOR WPSCG VS WPDCG

VARIABLE	RANK SUM	SAMPLE SIZE	U STAT	MEAN RANK
WPSCG	190.50	15	70.500	10.7
WPDCG	85.500	8	49.500	12.7
TOTAL	276.00	23		

EXACT PROBABILITY OF A RESULT AS or MORE EXTREME
THAN THE OBSERVED RANKS (ONE-TAILED P-VALUE) 0.2621

NORMAL APPROXIMATION WITH CONTINUITY CORRECTION 0.645
TWO-TAILED P-VALUE FOR NORMAL APPROXIMATION 0.5186

TOTAL NUMBER OF VALUES THAT WERE TIED 15
MAXIMUM DIFFERENCE ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 23 MISSING CASES 15

RANK SUM TWO-SAMPLE TEST FOR WPSTG VS WPDTG

VARIABLE	RANK SUM	SAMPLE SIZE	U STAT	MEAN RANK
WPSTG	76.000	11	10.000	6.9
WPDTG	77.000	6	56.000	12.8
TOTAL	153.00	17		

EXACT PROBABILITY OF A RESULT AS or MORE EXTREME
THAN THE OBSERVED RANKS (ONE-TAILED P-VALUE) 0.0101

NORMAL APPROXIMATION WITH CONTINUITY CORRECTION 2.261
TWO-TAILED P-VALUE FOR NORMAL APPROXIMATION 0.0237

TOTAL NUMBER OF VALUES THAT WERE TIED 4
MAXIMUM DIFFERENCE ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 17 MISSING CASES 21

RANK SUM TWO-SAMPLE TEST FOR HDC VS HSC

VARIABLE	RANK SUM	SAMPLE SIZE	U STAT	MEAN RANK
HDC	53.000	5	38.000	10.6
HSC	100.00	12	22.000	8.3
TOTAL	153.00	17		

EXACT PROBABILITY OF A RESULT AS or MORE EXTREME
THAN THE OBSERVED RANKS (ONE-TAILED P-VALUE) 0.2437

NORMAL APPROXIMATION WITH CONTINUITY CORRECTION 0.791
TWO-TAILED P-VALUE FOR NORMAL APPROXIMATION 0.4292

TOTAL NUMBER OF VALUES THAT WERE TIED 0
MAXIMUM DIFFERENCE ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 17 MISSING CASES 7

RANK SUM TWO-SAMPLE TEST FOR HDCG VS HSCG

VARIABLE	RANK SUM	SAMPLE SIZE	U STAT	MEAN RANK
HDCG	49.000	5	34.000	9.8
HSCG	104.00	12	26.000	8.7
TOTAL	153.00	17		

EXACT PROBABILITY OF A RESULT AS or MORE EXTREME
THAN THE OBSERVED RANKS (ONE-TAILED P-VALUE) 0.4321

NORMAL APPROXIMATION WITH CONTINUITY CORRECTION 0.369
TWO-TAILED P-VALUE FOR NORMAL APPROXIMATION 0.7122

TOTAL NUMBER OF VALUES THAT WERE TIED 14
MAXIMUM DIFFERENCE ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 17 MISSING CASES 7

RANK SUM TWO-SAMPLE TEST FOR HDTG VS HSTG

VARIABLE	RANK SUM	SAMPLE SIZE	U STAT	MEAN RANK
HDTG	48.500	5	33.500	9.7
HSTG	87.500	11	21.500	8.0
TOTAL	136.00	16		

EXACT PROBABILITY OF A RESULT AS or MORE EXTREME
THAN THE OBSERVED RANKS (ONE-TAILED P-VALUE) 0.2085

NORMAL APPROXIMATION WITH CONTINUITY CORRECTION 0.623
TWO-TAILED P-VALUE FOR NORMAL APPROXIMATION 0.5332

TOTAL NUMBER OF VALUES THAT WERE TIED 4
MAXIMUM DIFFERENCE ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 16 MISSING CASES 8

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Captain Henry entered active duty on 23 January 96 and took his first assignment in the 17th Civil Engineer Squadron as a Project Engineer at Goodfellow AFB, TX.

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ABSTRACT (*Maximum 200 Words*)

The purpose of this research was to perform a cost analysis between DBB and SABER construction. The research involved traveling to Wright-Patterson and Holloman Air Force Bases to gather project information on comparable projects completed by both methods. There were a total of 46 projects collected from both bases. A methodology was developed to compare the projects completed. Projects were divided into categories containing similar types of construction. Data from the project was then used to calculate a unit cost for the project. Project comparability was demonstrated by showing the projects constructed by each method completed a similar type and scope of work. This consisted of showing commonality in key work elements contained in projects completed by both methods. Time and cost growth were also compared for DBB versus SABER. Statistical test of the means for each method demonstrated that SABER was cheaper but not at a statistically significant level. SABER construction also performed better in cost and time growth for most instances. The research showed that SABER had statistically significant lower time growth that DBB at Wright-Patterson AFB.

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