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A comparison of design-bid-build and design-build project delivery methods on military construction projects

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The US Army Corps of Engineers has adopted the design-build project delivery method as a means to produce military facilities faster and cheaper. An analysis was conducted on 119 military construction projects executed by the US Army Corps of Engineers. While design-build awards may be made earlier in the delivery of military construction projects the design-build project delivery method was shown to have larger contract time growth compared to design-bid-build projects. Military design-build projects experienced a lower total cost of change orders as well as a reduced change order cost associated with field changes.

Finally, statistical analysis demonstrated that no significant difference existed in design-build performance based on the type of facility being constructed. This result indicates that the design-build project delivery method will work equally well on all types of military construction projects.

CHAPTER 1 - INTRODUCTION

The delivery of military construction (MILCON) projects from need identification to beneficial occupancy is a lengthy and lockstep process. The process is outlined in various Army regulations and is intimately tied to Congressional authorizations and appropriations. Authorized construction project delivery methods are specified in various parts of the Federal Acquisition Regulation (FAR).

1.1 - The Medical Military Construction Delivery System

The existing medical MILCON (Med-MILCON) process has been described as cumbersome and slow, often requiring 7 to 12 years from initial planning to facility occupancy. This protracted period of time results from the regulatory, statutory and legislative requirements to plan, approve, fund, design, and construct the medical facility and frequently results in facilities failing to meet timely market needs. The standard plan-design-bid-build delivery process used for many Med-MILCON projects is sequential; with many pauses to conduct progress reviews and obtain approvals before proceed to the next step (Quadrennial, 2006). For instance, the designer is required to provide a block plan submittal, schematic design submittal, design development submittal, 35 percent design submittal, final design submittal, and 100 percent/final submittal. A formal value engineering study is required after the design development submittal which seeks to lower life-cycle costs while still complying with all regulatory requirements. The 35 percent design submittal requires a formal presentation to the Portfolio Planning and Management Division/Tricare Management Agency (TMA) in order to obtain final scope and costs. (Unified, 2003)

The design-bid-build (DBB) project delivery method for Med-MILCON projects is outlined in Army Regulation 415-15, Army Military Construction Program Development and Execution. Acknowledging the shortcomings of the traditional Med-MILCON design-bid-build project delivery method, some individuals and organizations have advocated the use of construction management and/or design-build (DB) project delivery methods. Their justification is based on the premise that projects may be delivered more rapidly if the number of incremental steps may be reduced and/or allowed to overlap. For example, the planning process for a Department of Defense (DoD) medical facility normally takes six years (Uhlik, 1999). Included in this time is the identification of the need for renovation or new construction, estimating of the cost, programming of the funds, and receipt of authorization. Design authorization for Med-MILCON projects is usually received two years prior to the project's programmed fiscal year for construction. The bidding period requires advertisement for a minimum of 30 days, and may be longer depending upon the time of the fiscal year in which the project is advertised and the complexity of the project. At the conclusion of this solicitation period it may take several weeks to award the construction contract and issue notice to proceed. Optimization of this process is possible when design-build is used.

The design-build project delivery method for Med-MILCON projects is outlined in Engineer Regulation 1180-1-9, Design-Build Contracting. This regulation authorizes the use of the design-build project delivery method and requires each district commander within the US Army Corps of Engineers (USACE) to develop formal design-build procedures within their geographic region. (Engineer, 1999) These procedures were then reviewed by the next higher major subordinate command, which would typically be the division. Finally, the regulation goes on to specify project characteristics that should be present in order to effectively utilize the design-build project delivery method.

1.2 - The Changing Face of Medical Military Construction

The US Army Health Facility Planning Agency (USAHFPA) was formed as a key field-operating agency of the Office of the Surgeon General of the Army in 1975 (OTSG, 1975). The Surgeon General has since designated this agency as his representative for the health facility construction program, Med-MILCON. As such, the early role for the USAHFPA centered on design-bid-build project delivery of medical construction projects.

The MILCON program has been instrumental in developing much of the Army's original inpatient medical infrastructure. However, because of the regimented process and bureaucratic inefficiencies it is not uncommon for projects to take as many as 10 years to proceed from programming through completion of construction. (Petersen, 2004) In defense of the USACE, this delay is not the fault of the USACE, rather the delay stem from legislative requirements and prescriptive, military-specific standards.

During the 1990's, military downsizing produced an excess of inpatient capability. Simultaneously, there was a shift in healthcare delivery from inpatient care to a focus on wellness and outpatient care. This paradigm shift in healthcare delivery affected the use and functionality of medical facilities, worldwide. Facilities originally constructed to hold patients in beds for extended periods of time required rapid conversion into outpatient clinical space. The traditional MILCON program was not flexible enough to support this need. Therefore the US Army Medical Command (USAMEDCOM) and the USAHFPA worked with the US Army Corps of Engineers to develop what became known as the renewal program. This program was based on the design-build concept and the much shorter turn around time was a critical feature for meeting the healthcare delivery needs of US Army health care providers. However, funding limitations on this program were such that projects had to be kept below the minimum threshold requirement for MILCON funding, typically $1.5M for new construction or $3M to correct life safety deficiencies. There were other caveats as to what constituted new construction versus what could be considered repair. Therefore, these design-build projects were usually of lower dollar amounts than Med-MILCON projects.

However, it was recognized early that there was a fundamental difference between the traditional design-bid-build project delivery method and the design-build renewal projects.

This led to the creation of a specific type of project manager within the USAHFPA to handle renewal projects and serve as user's representatives to the project delivery process. These project managers became known as project integrators and were responsible for projects from programming through completion and integrating these projects within the framework of the Army Surgeon General's facility priorities.

A study was performed on the effectiveness of project integrators and their impact on renewal projects. The results indicated that project integrators had a strong positive impact in producing project success while balancing scope, time, cost, and quality. It was also determined that "soft" or people skills were important management techniques for project integrators. (Petersen, 2004)

Therefore, the USAHFPA has had success on smaller renewal design-build medical projects and identified that success of design-build projects hinges on approaching the project differently. Design-build project success lies in its team-based collaborative delivery process, however, if an adversarial relationship develops the advantages of design-build are lost . As of this writing, only one design-build hospital construction project above the MILCON threshold has been attempted by the USAHFPA, and is not considered an exemplary success due in part to this adversarial relationship. However, it is expected that design-build usage will increase on future hospital construction projects.

1.3 – Base Realignment and Closure

As part of the Quadrennial Defense Review many recommendations were made to change the existing project delivery method for Military Health System (MHS) construction projects. For example:

> "Current law, 10 U.S.C. § 2851, limits the ability of the MHS to leverage all possible market forces and choose from all possible entities who could potentially perform the direction and supervision of MILCON contracts by prohibiting the use of non-Government entities. According to [Department of Defense Directive (DoDD)] 4270.5 Military Construction, the MHS's MILCON contracts must normally be carried out under the direction and supervision of either the Naval

> Facilities Engineering Command (NAVFAC) or the United States Army Corps of Engineers (USACE). However, the Secretary of Defense has the legal authority to waive this requirement. DoDD 4270.5 Military Construction delegates this authority to the Under Secretary of Defense for Acquisition, Technology, and Logistics. There are several non-DoD construction agents, including the [Department of Veterans Affairs (DVA)], specializing in health care facility development, which may provide insight and experience useful to MHS transformation." (Quadrennial, 16)

However, this restriction on using USACE and NAVFAC has been lifted for Base Realignment and Closure (BRAC) projects. With the authority laid out in DoDD 4270.5, paragraph 4.3.5, the Under Secretary of Defense for Acquisition, Technology, and Logistics has granted a blanket waiver from the required use of the DoD designated construction agents. This waiver is without prejudice from internal DoD construction agents. The intent of the up-front blanket waiver is to allow for a fair and open competition among all Federal agents, including DoD agents, for the MHS medical BRAC projects (excluding the Medical Education and Training Center in San Antonio and the Brooks City Base in San Antonio). (Quadrennial, 18)

The BRAC process placed the following requirements on projects funded with BRAC funds:

- Complete all BRAC medical projects by September 15, 2011.
- Eliminate all internal DoD prescriptive requirements and build to industry standards with performance requirements for anti-terrorism/force protection (ATFP) and life cycle management.
- Solicit industry input as part of the contracting process prior to award for design and construction.
- MHS develops source selection criteria for acquisition needs.
- Designate the Assistant Secretary of Defense (Health Affairs) as the Source Selection Authority, and include both clinical and military facilities personnel on the Source Selection Board.

- Reduce supervision, inspection and overhead costs. (Quadrennial, 19)

In order to comply with these newly-imposed requirements, the Military Health System Office of Transformation (MHS-OT) will oversee the implementation of the following changes to the MHS internal management processes for all medical construction and renovation:

- Transform the current specification-based process into a performance-based standards and criteria driven process.
- Revise existing space and construction criteria to reflect use of accepted industry standards, codes, and best practices for design and construction, keeping specialized requirements only for ATFP and life cycle cost objectives.
- Adopt performance-based contracts versus current prescriptive contracts
- Largely eliminate change orders during construction. (Quadrennial, 18)

From these objectives, the apparent intent is to move toward a design-build project delivery methodology centering on performance specifications and contracts. Furthermore, the current military-specific requirements and prescriptive specifications contained in Military Handbook 1191 or Unified Facilities Criteria 4-510-01 will be adapted to become performance oriented and representative of private-sector medical construction requirements. The most unique objective was the intent to largely eliminate change orders during the construction phase, which will be interesting to determine how successful MHS-OT will be in meeting this objective.

1.4 – MILCON Transformation

A deployment order was issued on March 6, 2007 for Army activities to execute the business transformation principles of Lean Six Sigma. Former Secretary of the Army Francis Harvey’s intent was to apply these principles to more than the Army’s logistics systems. The principles are being applied to administrative services, installations, military construction, recruiting, medical operations, and human resources. The goal of implementing Lean Six Sigma was to “get more output from the same amount of money.” (Burgess, 2006)

As part of this business transformation, the military construction process is being overhauled. The USACE has recognized that the existing MILCON system, with its reliance on design-bid-build project delivery, will not produce quality facilities in the timeframe needed. Therefore, the USACE has embarked on a process known as MILCON Transformation. The USACE has defined that MILCON Transformation will be successful if it is able to reduce project delivery costs by 15% and achieve a 30% time savings while simultaneously meeting Army/DoD requirements (i.e. LEED, small business requirements, etc.). (Temple, 2006)

In order to attain the aggressive cost reduction goals the USACE will make a 20% reduction in cost estimates based on the current design criteria and simultaneously establish this amount as a cost limitation in the project RFP. (Tyler, 2006) MILCON Transformation goals require standardization of the acquisition process by maximizing the use of mandatory template RFP’s. This should streamline the acquisition process and facilitate the proposal process through the application of standardized requirements. Similarly, there will be a standardized set of evaluation and selection criteria. (Temple, 2006) Philosophically, this process will allow faster contract execution while maximizing the offeror’s flexibility and innovation thus attaining the 15% reduction in project delivery costs. During fiscal year (FY) 2006 the USACE has shown that MILCON transformation achieves the 15% cost savings while maintaining 100% project scope on the following projects:

- Aviation barracks at Fort Campbell, KY
- Permanent party barracks at Fort Knox, KY
- Division and brigade headquarters at Fort Riley, KS
- Brigade and battalion headquarters at Fort Carson, CO
- Brigade combat team complex at Fort Bliss, TX (Valine, 2006)

In addition to a standardized RFP, projects will maximize use of the International Building Code (IBC) and/or other civilian code requirements to focus on the end result, not the “how to.” (Temple, 2006) This is a move from military-specific, proscriptive requirements and mirrors recommendations of the Quadrennial Defense Review and BRAC requirements noted above. All of these acquisition changes point toward an initial shift from design-bid-build toward design-build.

Starting in FY07, standardized designs will be developed for standard facility types in order to facilitate the transition from design-build to an “adapt-build” project delivery model. The focus will also shift from site built facilities toward pre-engineered or modular facility solutions. The impact of these changes on medical construction projects could potentially change the way health clinics are developed and constructed. However, hospital requirements are based on the demographic patient populations, which change with location. Therefore, hospitals are usually unique and may not benefit greatly from standardized design efforts. Design-build, rather than adapt-build, may be the future of military hospital construction under MILCON Transformation.

Finally, to further facilitate the goals of MILCON Transformation the USACE is simultaneously implementing an internal reorganization. Divisions remain responsible for projects within their geographical region under this reorganization through their Regional Business Centers (RBC). The business activities of the Districts comprising the Divisional boundaries are regulated by the RBC. The Division RBC’s primary responsibility is to assist in allocation of resources among the subordinate Districts. As such, Districts are expected to share expertise, manpower, and resources within Divisional boundaries. Select Districts have been identified as Centers of Standardization (COS) for a specific facility type (i.e. barracks, dining facilities, vehicle maintenance, etc). The COS will export current request for proposal requirements to any other District for execution, worldwide. The COS will similarly compile lessons learned on projects executed by sister Districts and assimilate them into the RFP requirements for the next project. The goal is to use the design-build project delivery method and rapidly collect lessons learned and prepare standardized designs for each type of facility. Ultimately MILCON Transformation will use the standardized designs and lessons learned to progress beyond design-build to an "adapt-build" project delivery method.

1.5 – The Road Ahead

Dissatisfaction with the performance of traditional, design-bid-build Med-MILCON projects has led to the mandated use of alternative project delivery methods for military medical construction projects. The first step in changing the facility delivery paradigm is the use of design-build project delivery methods on BRAC-funded projects. Simultaneously, the USACE will change the way facilities are delivered, initially increasing the use of the design-build project delivery method. This will eventually change toward the use of standardized designs and a move from design-build toward adapt-build.

In summary, the current paradigm of military medical facility delivery is being influenced by many, external factors. Essentially, the cumulative effect of these factors will shift project delivery methods from design-bid-build toward design-build with the desired end state being an adapt-build delivery method. The only thing that is certain is that future medical construction projects will be delivered differently than they have been in the past.

CHAPTER 2 - LITERATURE REVIEW

2.1 – History of Design and Construction

2.1.1 – Master Builder

Historically, the design-bid-build project delivery method is a relatively recent development. Originally, one individual was charged with both project design and construction and this individual was known as a Master Builder. The Code of Hammurabi specifically addressed the work of the builder in sections 228 through 233 as follows:

228. If a builder build a house for someone and complete it, he shall give him (the builder) a fee of two shekels in money for each sar of surface.
229. If a builder build a house for someone, and does not construct it properly, and the house, which he build fall in and kills its owner, then that builder shall be put to death.
230. If it kill the son of the owner, the son of that builder shall be put to death.
231. If it kill a slave of the owner, then he shall pay slave for slave to the owner of the house.
232. If it ruin goods, he shall make compensation for all that has been ruined, and isasmuch as he did not construct properly this house which he build and it fell, he shall re-erect the house from his own means.
233. If a builder build a house for someone, even though he has not yet completed it; if then the walls seem toppling, the builder must make the walls solid from his own means. (Beard, 2001)

These codes infer that the builder must know the design requirements for a particular structure and then construct the building using traditionally accepted means and methods. Hence, the builder may be considered a design-builder by current terminology.

2.1.2 – Separation of Design and Construction

The sole source responsibility for project design and construction continued until the 1400's. The first known, intentional separation of design and construction occurred in Italy in the mid-fifteenth century when Leon Battista Alberti, a papal secretary, convinced Pope Eugene IV that he could direct the activities of a master mason constructing a new facade on a Gothic church in Florence, Italy. Alberti furnished the plans for his buildings but never supervised their construction. (Beard, 2001)

The Industrial Revolution further divided the fields of design and construction. However, the significant cause of absolute separation of the design professions from the construction trades was the Miller Act of 1935. (Beard, 2001) This law required a contractor on federal projects exceeding $100,000 to post performance and payment bonds. Since bonds are a form of credit to issue a surety bond, the surety must be confident that the contractor possesses the capital assets to reimburse the surety in the event of a default. It is this requirement for capital that has prevented or discouraged all but the largest design firms from acting as construction contractors.

2.1.3 – Resurgence of Integrated Project Delivery

It is believed that the first publicly funded design build project in the United States was awarded in Indiana in 1968. This project utilized performance specifications drafted by the school district for the construction of a school building using the design-build project delivery method. The award was based on a best value determination and, in fact, the contract was not awarded to the low bidder. Apparently, this project met the owner's requirements because the process was repeated in 1970 in an adjoining county again in 1971. (Beard, 2001)

In 1969, Congress and the Secretary of Defense authorized the use of turnkey construction to deliver military housing. The intent was to draw upon the experience of speculative builders and rapidly deliver military housing at a reduced cost. (Molenaar, 1999) Another early application of design-build by the US Army Corps of Engineers (USACE) was the 1976 relocation of the historic Gruber Wagon Works in Berks County Pennsylvania as part of a civil works project. (Gruber, 2006) The success of these early experiments with the design-build project delivery method expanded in the 1980's.

The Brooks Act of 1972 ensured the acquisition of professional design services by the federal government was qualifications based rather than low bid. The Brooks Act did not affect the 6% fee limit for architectural and engineering services on federal construction projects which had been enacted in 1939. (Charles, 1996)

However, in January 1992 the Huntsville District of the USACE issued an innovative RFP for design-build services to construct the John J. Sparkman Center at Redstone Arsenal, Alabama. The RFP identified a maximum bid amount, the minimum acceptable finishes, and the function/purpose of the project. Each prospective bidder was to develop a concept design that would be evaluated and used in the selection of the winning contractor. Since the price of the contract was fixed, contract would be awarded to the proposal which provided the most facility for the money. The independent Government estimate (IGE), prepared before the RFP was issued, estimated that based on the funding limit and specified level of finishes the Government should expect a facility of approximately 543,000 gross square feet.

By September 1992 the contract had been awarded and notice to proceed issued to Centex-Rooney Construction Company from Fort Lauderdale, Florida. Their successful proposal resulted in a 686,790 gross square foot facility for the specified contract amount. (History, 2006) Furthermore, their proposal utilized fast-track construction techniques that resulted in a beneficial occupancy date two years ahead of the contract performance period identified in the RFP.

One item of note regarding the Sparkman Center project was underscored in an article written in Engineering News Record. It was reported that the 15 unsuccessful bidders on the project were upset regarding the amount of design effort and the associated costs that were required as part of the proposal process. Overall, an estimated $4 million was expended to prepare proposals by the 16 firms pursuing the Sparkman Center project. All proposals were required to be developed to a 20-30% level of design completion. (Setzer, 1992) This resulted in the call to reform how design-build projects were solicited and awarded.

In 1996, the Federal Acquisition Reform Act was signed into law and marked the first major change in how federal agencies acquired A/E design services in 20 years. This act required qualifications based selection as established by the Brooks Act and specified procedures for federal agencies to follow when entering into a design-build project. The Federal Acquisition Reform Act authorized a two-phase process for selection of design-build contractors. (Charles, 1996) Presumably, this two-phase process was meant to prevent a Sparkman Center recurrence whereby 16 proposals and preliminary designs had to be prepared and evaluated. However, the 1996 legislation did not go as far as to explicitly authorize a federal agency to pay a stipend to an unsuccessful offeror for the costs of developing and submitting a proposal.

A stipend may reimburse the entire design effort or a percentage thereof to the unsuccessful proposer(s). While not explicitly allowed or disallowed under the requirements of the Federal Acquisition Regulation (FAR) the payment of stipends had been limited. However, in September 2004 the USACE Office of Counsel issued guidance on the payment of stipends in order to encourage competitive bidding on D-B projects. (Use, 2004) Furthermore, the stipends were not intended to offset the entire design effort of the unsuccessful bidder; rather the stipend would be limited to an unnamed percentage. In fact, the legal distinction noted by the Chief Counsel was that the use of a stipend was to increase competition and not simply to pay a contractor’s design costs. (Use, 2004)

The implementation guidance was issued by the USACE on May 19, 2005 and attempted to limit the Government’s financial exposure on stipends by limiting its use to two-phase procurements. (Engineering, 2005) Unlike previous uses of stipend, that required the end-user to "pay the bill," the Corps of Engineers planning and design (P&D) funds were to be used to pay stipends, with pre-approval. (Engineering, 2005)

In an effort to prepare for an increased amount of design-build workload stemming from Army transformation and BRAC requirements a standard medical design-build RFP is currently being drafted. Draft copies propose the usage of stipends on an optional basis and suggest that stipend amounts not exceed 50% of the estimated cost of proposal development. (Model, 2006) Furthermore, the draft RFP specifies a two-phase solicitation process with the maximum number of phase-two offerors capped at four. (Model, 2006)

2.2 – Need for Change

2.2.1 – Historic Cost Overruns

The traditional, design-bid-build project delivery method is perceived as an efficient way to establish the fair market price and eliminate the possibility of favoritism or corruption. (Gordon, 1994) However, in many cases the costs of public design-bid-build projects may be far greater than the contract award amount.

Literature has shown that 9 out of 10 transportation infrastructure projects are underestimated. (Flyvbjerg, 2002) For road projects, actual project costs average 20% more than originally estimated, while rail project costs average 45% over estimates. This same literature also indicates that this cost escalation problem is not any more likely on transportation infrastructure projects than other types of large construction projects. (Flyvbjerg, 2002)

If cost overruns are not exclusive to transportation projects; they are to be expected on building projects. A recent, high profile military construction project experienced problems with cost escalation on traditional, design-bid-build contracts. Part of the $1.222 billion

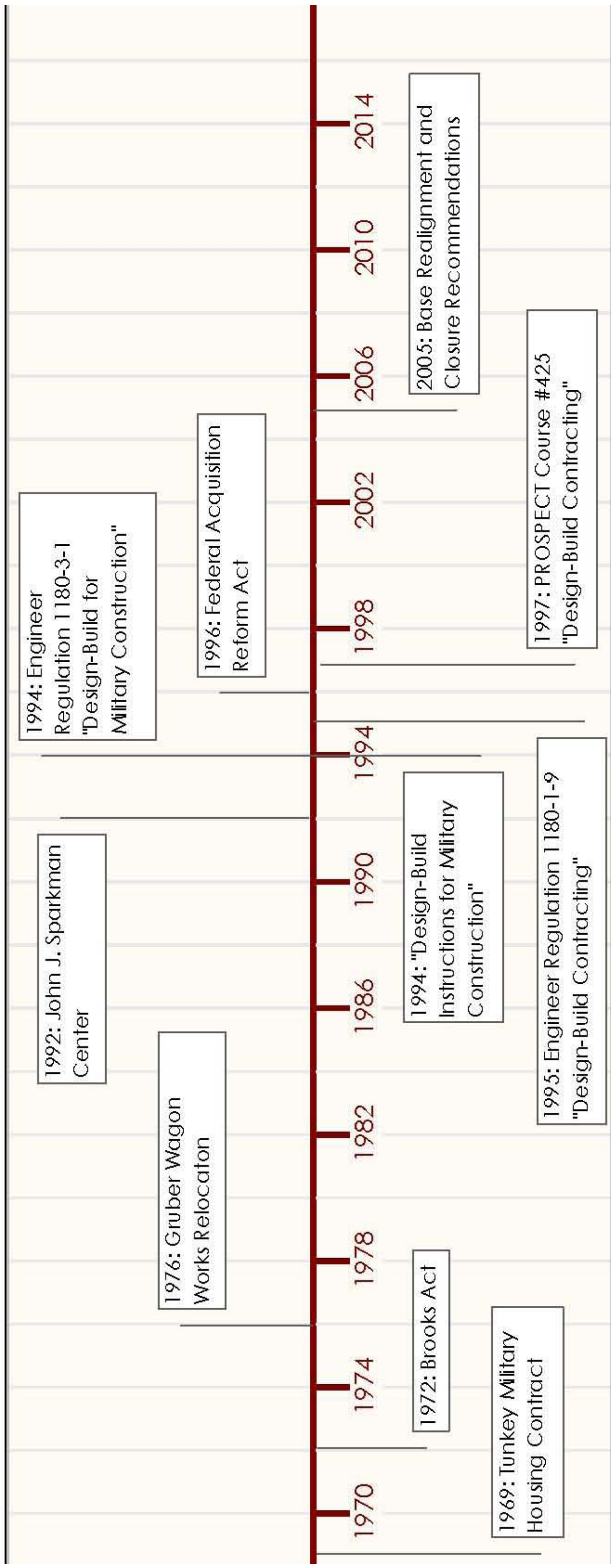

Figure 1. Design-build timeline.

Pentagon renovation ballooned from $50 million to $125 million for one segment of the basement overhaul. (Winston, 2000) This was one of many problems that plagued the early efforts on the Pentagon renovation. Ultimately, it was decided to change from the traditional project delivery methodology to innovative application of the design-build project delivery method.

2.3 – Theoretical Benefits of Different Project Delivery Methods

2.3.1 – Design-Bid-Build

The traditional, design-bid-build project delivery method consists of an owner entering into two separate contracts. On federal projects, one contract is entered into with a designer and the award is qualifications based in accordance with the Brooks Act. A separate contract is awarded to a contractor for construction services. The award of this construction contract is normally arrived at from competitive bidding but may be based on "best value." The project is executed in a linear fashion through the programming, design, bidding, and construction phases.

The owner's advantages of this project delivery method include control over the design of the project, a "known" total price, competition, and impartial selection. (Gordon, 1994) This project delivery method is also well suited when the project is clearly definable and fast tracking is not required.

2.3.2 – Design-Build

According to Part 36.102 of the Federal Acquisition Regulation (FAR) design-build "means combining design and construction in a single contract with one contractor." The FAR goes on to state"[t]wo-phase design-build selection procedures" as a selection method in which a limited number of offerors (normally five or fewer) is selected during phase one to submit detailed proposals for phase two. (FAR, 2007)

Literature outlines potential benefits of using design-build as:

- Shortening the duration of projects by overlapping design and construction (fast-tracking) and/or eliminating bidding time.
- Providing flexibility for changes during construction, without paying a premium for it.
- Creating more designer/contractor teamwork by reducing adversarial relationships.
- Allowing a contractor to participate in the design process and therefore enhance constructability. (Gordon, 1994)

Under the traditional, design-bid-build approach the Government was liable to the construction contractor for design deficiencies. The Government then attempted to recoup the costs associated with these deficiencies through the A/E's errors and omissions insurance. Though the single source of responsibility the design-build delivery method extricates the Government from this litigious process and shifts the risk associated with design errors to the design-builder. In essence the design-build project delivery method assigns this risk of design errors to the party best able to manage the risk.

Other works have further specified the advantages and disadvantages of the design-build project method based on the acquisition strategy employed. Review of Table 1, below reveals a common thread among the disadvantages. Specifically, the use of the design-build project delivery method does not shield the owner from protests from unsuccessful or inadequate offerors. In contrast, anecdotal evidence suggests that a low bid award is seldom protested.

2.4 – Current Research of Design-Build vs. Design-Bid-Build

2.4.1 – Federal Construction Council Design-Build Study (1993)

In 1993 a study was published by the Federal Construction Council outlining experiences federal agencies with the design-build project delivery method. Like the current

Table 1. Advantages and disadvantages of design-build acquisition methods. (Molenaar, 1998)

Form of design-build	**Advantages**	**Disadvantages**
Single-phase	• Allows for award on overall value (price and technical) • Designs that exceed minimum specifications can be realized • Delivers a product that most closely conforms to the user's expectations.	• Burdensome to evaluate multiple proposals • Greatest chance of delays due to protests from inadequate offerors • Costly preparation for offerors • May require the most detail in the RFP, placing a burden on the owner
Two-phase	• Allows for award on overall value (price and technical) • Allows for short-listing, saving owner and offeror time and money • Offers wider range of design solutions • Delivers the best budget and schedule performance	• Technical and design review process can become lengthy • Chance of delays due to protests from inadequate offerors during technical evaluations • If low bid award is chosen, all classic low-bid problems exist
Qualifications-based	• Allows for award solely on qualifications • Can be negotiated in single step • Allows Award with minimum design development • Is the least burdensome on the owner's administration	• Evaluation of technical proposal can be lengthy • Chance of delays from protesting losing offerors • Intensive owner design staff involvement may be required

study, the Federal Construction Council research was restricted to building construction projects, therefore the results of the study are directly applicable to building projects and may not be indicative of experiences with other project types. The results of this study were obtained from information submitted by seven federal agencies on 27 projects. Admittedly, this is a small sample population; however, it was indicative of the small volume of federal design-build work completed prior to the study.

In general, this study deemed the design-build approach to be at least as good as the traditional approach in all aspects except the amount of time required for planning and programming. (Experiences, 1993) This is indicative of the fact that a different type of request for proposal (RFP) process is required for a design-build project compared to that used in the traditional delivery method. A design-build RFP requires greater up-front planning and project definition by the Government.

Prior to this study it had been widely believed that the design-build approach was most appropriate for “simple” projects. However, of the 27 projects reported, only three were characterized as being of low or medium-low complexity. Therefore, the results of this study indicated that the design-build approach may be used successfully on a full spectrum of projects. (Experiences, 1993)

The majority the Federal Construction Council projects were acquired using a single-phase evaluation procedure versus a two-phase procedure. In the single-phase approach, cost is one of several factors that are evaluated simultaneously in order to award the contract. In contrast, the two-phase approach considers cost separately after all proposals have passed other screening factors (usually capacity and experience). This preponderance of single-phase design-build awards was unexpected since federal procurement officers traditionally favor the two-phase approach due to its ability to legally restrict the pool of prospective bidders to those likely to complete the project. (Experiences, 1993)

The sample population in the Federal Construction Council study was stratified based on contract award amounts. This stratification resulted in a group of 11 projects ranging from $1M to $10M, a group of 8 projects ranging from $10M to $20M, and a group of 7 projects costing in excess of $20M. The results indicated that as the contract amount increased the design-build approach would be less successful. (Experiences, 1993) However, the small sample size and wide price ranges for each subgroup were inadequate to specifically determine a dollar amount at which the design-build approach would become less successful than the traditional approach.

This study also attempted to answer the question of how much, if any, design of a proposed facility should be completed prior to issuance of an RFP. Some study respondents believed that prospective bidders should be given a minimum amount of information in order to encourage creative solutions. Other study respondents believed a more developed design should be given to the prospective bidders in order to minimize the number of unresolved issues and potential change orders after award. This dichotomy resulted in a wide distribution of completed designs prior to issuance of the RFP. However, the poorest results were achieved when designs were 15% or less complete prior to award of the design-build contract. Intermediate results were achieved when greater than 35% design was complete prior to design-build contract award. The best project performance was noted when the design was between 15 and 35% complete prior to contract award. (Experiences, 1993)

2.4.2 – Empirical Analysis of the Effectiveness of Design-Build Construction Contracts (1993)

Another early study on the effectiveness of design-build project delivery methods concerned 11 child care centers constructed on multiple Navy installations. The NAVFAC contracted for these projects using traditional, design-bid-build methods for five projects and variations of the design-build project delivery method for the remaining six. Of the design-build projects, two were procured using a single-phase design-build acquisition and the other four projects were procured using the "Newport design/build method." (Mouritsen, 1993)

The "Newport design/build method" was a unique procurement strategy employed by the NAVFAC which combined design-build's single source of responsibility with lump-sum, competitive bids. Under this method, bidders were not required to produce technical proposals. Rather, the Navy would provide a performance specification and fundamental design parameters. The bidders were then expected to perform final detailing of the projects. The contract also contained a clause that allowed it to be closed out if the Navy was not satisfied with the functionality or aesthetics of the facility after the design-builder completed the design. (Mouritsen, 1993)

As part of the evaluation between design-build and design-bid-build project delivery methods, the study calculated the percent increase between the program amount and the final cost of each project. The program amount used for each project was based on the initial parametric cost estimate prepared by professional cost estimators prior to the selection of the project delivery method. Therefore, the program amount was assumed to not favor one project delivery method over the other. The study concluded that design-build project delivery resulted in a substantially smaller cost growth above the program amount than the design-build project delivery method. Of the two design-build methods, the "Newport design/build method" performed better than single-phase acquisition methods. (Mouritsen, 1993)

The small sample size of this study was reflective of the small number of design-build projects which had been completed by the USACE and NAVFAC. In fact, during the period spanning 1985 through 1991 both NAVFAC and the USACE were limited to three design-build project awards per year. (Mouritsen, 1993) However, since the cap was lifted in 1992 there has been an explosion in the number of design-build military construction projects.

2.4.3 – Comparison of Public and Private Owner Perspectives on Design-Build (1996)

Research has shown that design-build selection factors do not drastically differ between public owners and private owners. Six design-build selection factors were identified and are summarized in Table 2, below.

Table 2. Design-build selection factors. (Songer, 1996)

SELECTION FACTOR	DEFINITION
Establish Cost	Secure a project cost before the start of detailed design.
Reduce Cost	Decrease the overall project cost as compared to other procurement methods.
Establish Schedule	Secure a project schedule before the start of detailed design.
Shorten Duration	Decrease the overall project completion time as compared to other procurement methods.
Reduce Claims	Decrease litigation due to separate design and construction entities.
Large Project Size/Complexity	The project's shear magnitude is too complex to be managed through multiple contracts.
Constructability/Innovation	Introduce construction knowledge into design early in the process.

Table 3. Comparison of design-build selection factors. (Songer, 1996)

SELECTION FACTOR	PUBLIC OWNER RANK	PRIVATE OWNER RANK
Shorten Duration	1	1
Establish Cost	2	2
Reduce Cost	3	4
Constructability/Innovation	4	5
Establish Schedule	5	3
Reduce Claims	6	6
Large Project Size/Complexity	7	7

To test whether a difference in opinions existed between the public and private owners the researchers used hypothesis testing. Results shown in Table 3, above, indicated the primary difference in public and owner perspectives were related to the “establish schedule” factor. All other selection factors differed by one ranking between the two populations and indicated general alignment of priorities between the two owner populations. It was concluded that both public and private owners tend to select design-build project delivery in order to shorten project duration. (Songer, 1996)

2.4.4 – Reading University Design-Build Study (1996)

The 1996 University of Reading study was published by the Centre for Strategic Studies in Construction and involved a review of more than 330 building projects in the United Kingdom. The number of projects evaluated yielded statistically significant results and used statistical regression analysis to construct models identifying variables affecting project performance. (Bennett, 1996)

The researchers determined that the construction speed of design-build projects was 12% faster than traditional approaches. Furthermore, overall project delivery speed, including design and construction, was 30% faster than traditional methods. The study also found that the certainty of completion on time increases the earlier the contractor is involved in the design process. (Molenaar, 2003)

Regarding cost performance, the researchers concluded that 75% of design-build projects were completed within 5% of budget, compared with 63% on traditional projects. It was also found that design-build projects were at least 13% cheaper than traditionally procured projects. The greatest cost certainty on design-build projects were realized when the owner provided detailed project requirements. (Molenaar, 2003)

The study also concluded that clients had lower quality expectations when the design-build project delivery method was utilized. This was demonstrated by the fact that 50% of design-build projects met the client's quality expectations, compared to 60% for traditionally delivered projects. Conversely, it was determined that owners paid a higher percentage to repair defects on traditional projects versus design-build projects. Design-build consistently performed better in meeting quality requirements if the project was categorized as complex or innovative, rather than simple, standard or traditional. (Molenaar, 2003)

The report concluded that the design-build project delivery method can deliver projects faster and cheaper than traditional project delivery methods. However, it was also concluded that the design-build project delivery method produced lower quality projects due in large part to the lowered expectations by owners. Finally, the chances of success on design-build projects increased with early involvement of the design-builder.

2.4.5 – Pennsylvania State University Study (1997)

In December 1997 a comprehensive study of project delivery methods was published by Pennsylvania State University and the Construction Industry Institute. This study has been heralded by proponents of the design-build project delivery method as proof-positive of the benefits of design/build and was based on data collected from 351 projects (both public and private). The exact distribution of projects was 43% public to 57% private construction projects, which would indicate a slight skew of the results in favor of private construction projects. However, the size of the sample population allowed for statistically significant results to be obtained.

From this study, the unit cost ($/sf) of design-build projects was shown to be nearly one-third lower than the traditional, design-bid-build project delivery method. Similarly, design-build projects experienced a 2.12% cost growth versus 4.83% cost growth for traditional projects. Finally, the Penn State study revealed that design-build delivery speed was 33% faster than traditional, design-bid-build project delivery. (Konchar, 1997)

A comparison of these two large-scale studies is summarized in Table 4. It is interesting to note how similar the results were despite the geographic separation of the two sample populations.

Table 4. Comparison of results from Penn State and University of Reading studies. (Shane, 2003)

ITEM	PENNSYLVANIA STATE UNIVERSITY	UNIVERSITY OF READING
Construction Speed	DB 12% faster than DBB	DB 12% faster than DBB
Total Speed of Project Delivery	DB 33.5% faster than DBB	DB 30% faster than DBB
Project Cost or Unit Cost ($/Area)	DB 6.1% cheaper than DBB	DB 13% cheaper than DBB
Completion within 5% of budget	DB 58%	DB 75%
	DBB 47%	DBB 65%
Meet Client's Quality Expectations	DB slightly better than DBB	DB 50%
		DBB 60%

2.4.6 – Design Guidelines for Design-Build Projects (1998)

The amount of design completion prior to issuance of the request for proposal (RFP) on design-build projects is a careful balance between articulating the owner's requirements, allowing the design builder flexibility to determine optimized construction methods, controlling costs, and clearly conveying required information to bidders.

The same level of design is performed in both design-build projects and traditional, design-bid-build projects. However, the detail of the design is greater for a design-bid-build project because the designer-of-record assumes that "the least qualified constructor" will be awarded the contract. Therefore, the greater detail in the traditional delivery process is a method by the designer to prevent claims. Furthermore, in the traditional delivery process the designer may have to account for multiple equipment choices which each bidder may use, rather than design for a specific piece of equipment. (Fredrickson, 1998) For these reasons the design of design-build projects will not appear as owners may be accustomed to on design-bid-build projects. The final design will contain only that information required to construct the project and the extra design effort is no longer required.

However, how much design is needed to convey the required information to the prospective bidders about a design-build project? The American Consulting Engineers Council recommends that the design be approximately 35% complete prior to bidding. (Fredrickson, 1998) It is believed that this level of design is adequate to ensure that the owner's requirements are clearly articulated to the bidders. At the opposite extreme is the Design Build Institute of America (DBIA), which advocates very limited design prior to the issuance of the RFP. "Typically, 90 percent of the quality and value impact (financial and other) that a design-build entity can make occurs in the first 10 percent of the design effort." (DBIA, 2007) Clearly DBIA believes that early design should not proceed past 10% if the owner wishes to maximize the benefits of the design-build project delivery method. The Federal Construction Council study discussed above advocated design completion at time of RFP solicitation of 15-35% for best project performance. While projects have been successfully bid and constructed with both an under and overabundance of bidding information this is a decision that is up to owner and will yield differences in the projects.

The minimum designs to be provided to prospective bidders are project definition documents. These documents are approximately equivalent to 5-10% of conventional design effort. If an owner chooses to issue the RFP at this level of design they must be aware of the limitations. For example, the less complete the design the more each bidder will have to assume in preparing their proposals. This lowers the probability that the bids will use similar means and methods and result in a wider distribution of project costs. Likewise, this complicates the bid evaluation process to determine the best value due to the fact that differing elements may have differing value to the owner. (Fredrickson, 1998) In the case of federal project acquisition, the method of determining "best value" has to be clearly articulated in the instructions to bidders and this process opens a project up to potential protests by unsuccessful bidders, if the solicitation is not handled properly. Therefore, on important projects with tight timelines a 5-10% design effort prior to the RFP may result in greater risk of delay due to protest, regardless of the merit of the protest. Conversely, this level of design development makes sense on projects where the owner desires a wide variety of processes and concepts to meet a project requirement.

There is a higher cost in bidding design-build projects at an increased level of design development because each prospective bidder may have a significant design effort to determine realistic schedules and costs as part of their bid. The increased cost of preparing design-build proposals may actually increase costs to the owner over time due to limited personnel and business development budgets of design-build firms. (Fredrickson, 1998) The accumulation of these “sunk” costs in preparing unsuccessful proposals may prevent qualified firms from submitting proposals in the future and driving down competition on a project. As the number of bidders on a project decreases it would be expected that their bid prices would increase. To offset this potential the US Army Corps of Engineers may utilize a two-phase procurement strategy whereby only those potential design builders selected to continue to step two must prepare a proposal. To further increase the likelihood of receiving competitive proposals the Corps of Engineers may pay a stipend to unsuccessful firms to offset some of the proposal development costs. (Engineering, 2005)

Furthermore, the more uncertainty that design-builders have while bidding a project with 5-10% design development may result in increased contingency in their bids. The calculation of contingency is a major concern on competitive bid projects because as contingency increases the lower the probability that the bidder will be awarded the project. Conversely, too little contingency may result in an unsuccessful project for the design-builder. (Fredrickson, 1998)

The primary method of overcoming these challenges is to provide prospective bidders with increased design information during the solicitation period. If an owner has definite requirements for the project these should be provided with the bidding information. In the case of Med-MILCON projects this may include a room listing / program for design (PFD) along with the design criteria for each room. While the PFD is prescriptive in nature this document outlines the minimum requirements for medical construction that meet the defined medical need. The design criteria are currently too prescriptive and contain exclusive DoD requirements not found in private sector medical facilities. A more performance oriented set of design criteria are required if the full potential of the design-build project delivery method is to be realized on Med-MILCON projects.

The next level of design effort concludes with the completion of schematic design which correlates to an approximate conventional design effort of 15-20%. It is important to note that as more information is provided the bidders have reduced flexibility to apply their construction expertise or competitive advantage to a project to obtain the "best value" solution. (Fredrickson, 1998) This relationship is shown in Figure 2, below. This graphic indicates a point where too much design completion may be provided to potential bidders and they may no longer be considered the designer-of-record on the project. At this point it is questionable whether the project is design-build or if it has become design-bid-build.

2.4.7 – Design-Build Selection Model (1998)

Research conducted at the University of Colorado at Boulder has led to the development of a predictive model based on five performance criteria that correlate design-build project characteristics to success. The five performance criteria were budget variance, schedule variance, conformance to expectations, administrative burden, and overall satisfaction. The five performance criteria were further broken down using a total 26 statistically significant variables.

The overall model was based on regression analysis of 122 questionnaires and case studies to obtain specific project data. Of these projects, 104 were utilized to construct the

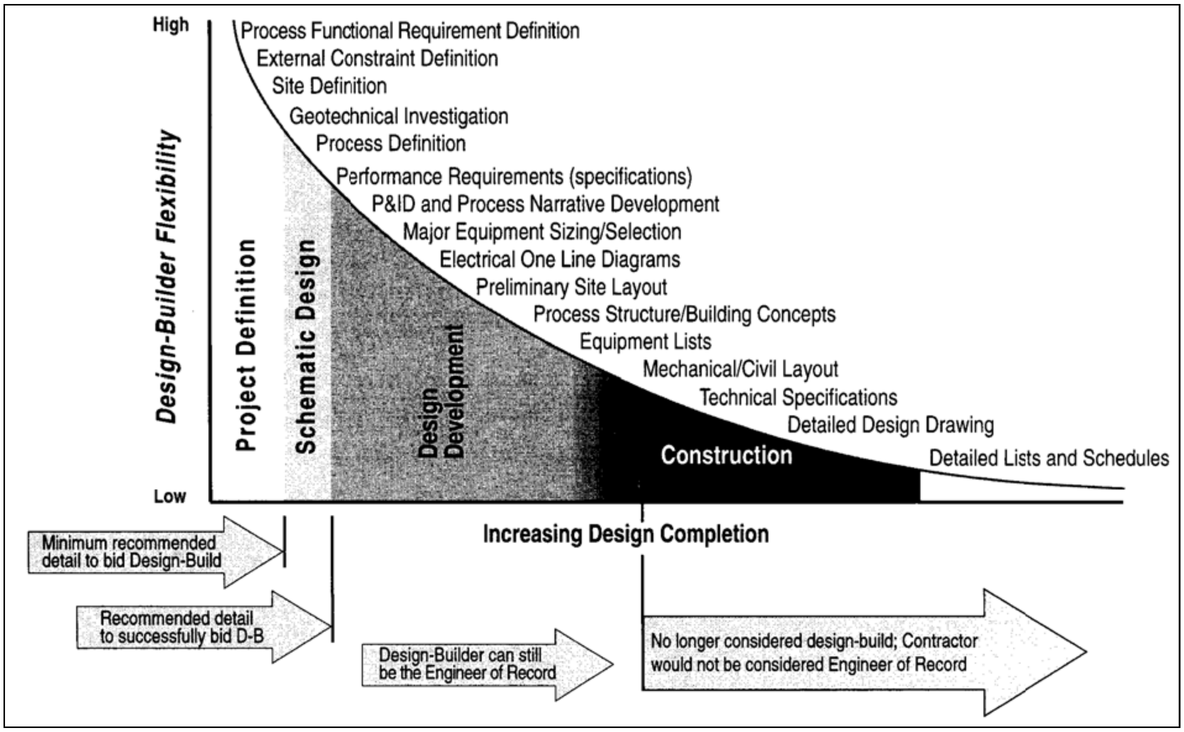

Figure 2. Impact of Design Completion on Design-Builder Flexibility (Fredrickson, 1998)

regression model and the remaining 18 projects were then used to test the model. The model is actually five separate models – one for each of the performance criteria. The definition of success for each model is a comparison to the average result from the 122 case studies. This assumes that each of the 122 studies was a successful application of the design-build project delivery method.

The research has led to the development of the Design Build Selection Tool, which is a web based application based on the regression models from this study. This tool may be accessed at: http://www.Colorado.EDU/engineering/civil/db.

With regard to scope definition, the models indicate that the percent of design completion at the time of the RFP has no statistically significant effect on the success of a design-build project. (Molenaar, 1998) This finding stands in direct conflict with earlier research which emphasized that higher scope definition (or higher percentage of design completion) at the time of RFP leads to lower cost and schedule growth. The belief that greater design is better is explained in an executive summary accompanying the Draft RFP for Medical Military Construction Design-Build Projects:

> "…when the contractor provides the owner a price, the price is on a specific product. The accurate definition of that product and certainty of its not needing to be changed after contract award will determine if the project can be built efficiently and without costly changes. The key to achieving this goal is communication between the users and the design team and between the design team and the contractor/ subcontractors. Design-Bid-Build allows the user to complete this interface with the designer before the contractor begins work.
> Design-Build requires that the user work with the design-builder but entirely within the bounds of the RFP documents. User generated unknowns that are not in the RFP documents are changes. Therefore, the more User information and User input that can go into the RFP preparation, the less of a problem this should be." (Executive, 3)

The regression models indicate that projects were successful despite minimal design completion when the RFP was issued. The explanation lies in the fact that there is a fundamental difference between scope definition and design completion. In completing more design prior to RFP, the owner is constraining the creativity of the design-builder to deliver an acceptable project. If the RFP provides a well-developed scope and clearly conveys the Owner's needs and goals, the project was more likely to be successful regardless of the level of design completion. Furthermore, the scope should be sufficiently flexible to encourage additions or improvements beyond the minimum requirements. The most successful design-build projects will use an RFP that defines the project scope but leaves room for contractor input. (Molenaar, 1998)

With regard to schedule definition the models indicated that schedule driven projects were an appropriate application of the design-build project delivery method. However, as noted above, design-build projects require a high level of owner participation during the RFP preparation and design stages. (Molenaar, 1998)

The models indicate that it is possible to use project budget as a critical factor related to project success and thereby successful design-build projects will experience lower cost growth. However, the cost growth will only be reduced on projects where owners make it a priority early and actively participate in project design in order to keep the project on budget. This also increases the administrative burden on design-build projects as examined previously.

The models determined that the method used to convey the budget to the design-build contractor was statistically significant. However, the researchers only identified and examined three methods of conveying the budget to the contractor as scope constraint, maximum allowable price, or no conveyance. The method of not conveying project budget to the contractor obviously yields the lowest probability of budgetary success. The method of scope constraint will result in project scope being adjusted to fit the available budget. Application of the method of limiting scope to an available budget on a Med-MILCON project, which must support a given patient population, will likely increase the probability of not conforming to the users/patients expectations. Traditionally, the scope of a Med-MILCON project is not locked until the S-4 (35%) Design Submittal. (Unified, 2003) Therefore, in order to exercise scope constraint while simultaneously maximizing the likelihood of meeting user expectations on Med-MILCON design-build projects would require a level of project definition and space requirements equivalent to a 35% design. The method of maximum allowable price method was found to lower owner’s administrative burden while simultaneously lowering the conformance to user expectations.

In regard to project complexity, the predictive model indicates that design-build actually produces greater satisfaction on projects with complex design issues. (Molenaar, 1998) The sources of complexity on a project may stem from design requirements, construction constraints, technology, specialized requirements, or compressed schedule. In these situations the combination of the design and construction expertise by the design builder allows for easier solution to the complex projects. Also, as has been shown by the Penn State and Reading University studies, the speed of delivery advantages of design-build can assist projects with compressed schedules. Finally, by using one contract to turn all of these challenges over to the design-build contractor the risk to the owner is reduced, thus improving project satisfaction.

How the design-builder is selected may also affect the administrative burden to the owner. Researchers stratified the project award methods into three categories: price only; qualifications-only; or a combination of price and qualifications. The models support the premise that owner’s expectations are best met when design-builders are selected through a combination of price and qualifications. (Molenaar, 1998) The two-phase solicitation process may be considered a combination of price and qualifications because it limits potential proposals in the second step based on qualifications and awards the project based on value. Therefore, this finding supports the premise of the Federal Construction Council that federal contracting officers prefer two-phase solicitations. The two-phase solicitation process is also being incorporated into MILCON Transformation Design-Build RFP’s, which further validates this finding.

Research also proposes that the prequalification process for design-build contracts lowers schedule growth and administrative burden. (Molenaar, 1998) Prequalification allows the owner the opportunity to review each perspective bidder’s past performance as well as their capacity to perform the work. Additionally it was discussed that a larger field of prospective bidders does not directly correlate to more competitive bids. It is suggested that by restricting the pool of prospective bidders to no more than four, then more competitive bids may be received. This process is being adopted in the Draft Medical Design-Build RFP being prepared by the USACE. The RFP will use the two-phase procurement method and limit the number of proposals from prospective design builders in the second step to no more than four. (Model, 2006)

Finally, this study acknowledged that a learning curve exists for public agencies attempting design-build for the first time. These agencies experience better project performance if the first design-build project is a typical facility in their portfolio. However, as an agency gains experience with design-build there is an unexpected effect on design-build performance. As design-build experience increases project performance is seen to decrease. These projects exhibit larger cost growth, increased administrative burden, and decreased satisfaction. (Molenaar, 1998) The explanation for this trend was that as owner experience increased they lowered project contingencies and tightened scope requirements, which also affected how they perceived the project.

2.4.8 – Public Sector Design-Build Performance (1999)

The performance of design-build projects were studied using a survey case-study methodology by researchers at the University of Colorado at Boulder. Such a methodology does not allow for refinement of findings, as such, the results are rather general in nature. (Molenaar, 1999) However, this study was based on approximately 79 case studies from multiple government agencies and represents a more robust data set than had been previously collected by the Federal Construction Council.

The results of this study indicated that 59% of design-build projects surveyed were within 2% of the original budget or better. This indicates a similar trend for publicly-funded design-build projects to the Penn State study regarding budget performance. Likewise, 77% of publicly funded, design-build projects were within 2% of the original schedule or better. (Molenaar, 1999) This finding is also in line with general findings of the Penn State study showing an accelerated project delivery for design-build projects.

This study also arrived at the similar conclusions to the Federal Construction Council study regarding administrative burden. The researchers determined that public-sector, design-build projects experienced slightly higher administrative burden than similar projects using different procurement methods. (Molenaar, 1999) This finding is counterintuitive to expectations that the administrative burden would diminish as the number of contracts involved in project is reduced from two to one. The explanation offered for this relationship is that 34% of the owners responding to the survey had never attempted design-build before the project used in the case-study. Therefore, they were observing the project's performance in greater detail than similar projects delivered using traditional methods and this resulted in a perception of increased administrative burden for design-build projects. Also, 69% of respondents had completed less than three design-build projects which would indicate that the respective federal agencies had not achieved a "comfort-level" with the design-build method and were still watching the project's performance in great detail. (Molenaar, 1999) The final explanation for the increased administrative burden is the increased up-front effort required for RFP preparation and initial design for design-build projects. In the case of initial design and project definition for Med-MILCON projects the design effort is usually completed over two-years while other MILCON projects are normally designed over a one-year period. In design-build the design effort will have to be completed in months instead of years, resulting in an increased administrative burden on the federal agency to review designs.

One of the key conclusions of the study further illustrated what had been alluded to in the Federal Construction Council study. Specifically, that design-build methods utilized by different agencies yielded different results. This statement further justifies the decision by the Department of Defense to allow BRAC medical construction projects to potentially use construction agents other than the USACE.

2.4.9 – Design-Build Highway Construction (2003)

An examination of the Federal Highway Administration's Special Experimental Project Number 14 performance was conducted at the University of Colorado at Boulder. As part of this study projects were classified by size based on project costs. The projects were divided into the following classifications:

1. Micro, <$2 million
2. Small, $2 million - $10 million
3. Medium, $10 million - $50 million
4. Large, $50 million - $100 million
5. Mega, >$100 million (Shane, 2003)

As will be shown later, the Micro to Medium categories are used in the current study. However, with the pending MILCON workload there will be project information available for the Large and Mega categories in the future.

2.4.10 – Impact of Design Build Project Delivery on Project Changes (2004)

A study was conducted on 598 change orders on 120 separate construction projects performed by the same mechanical contractor. The sample population was comprised of both design-build and design-bid-build projects and the purpose of the study was to determine if there was a difference in change orders based on the project delivery method. Change orders in this study were categorized as:

1. "Owner-generated" - change orders issued when an adjustment to the project scope, design, or detailing is requested by the owner.
2. "Unforeseen" - often called field-generated change orders which are highly disruptive to labor productivity, as one or more trades are forced to interrupt planned work sequences, and at time, complete rework. (Riley, 2004)

The results noted that while the total number of change orders was close to the same for design-build and design-bid-build projects, there was an 87% decrease in the average number of unforeseen change orders observed on design-build projects vs. design-bid-build projects.

Additionally, the average size of unforeseen change orders was 86% smaller on design-build projects. (Riley, 2004)

Project engineers and/or Resident Engineers classify all change orders on military construction projects as either controllable or uncontrollable changes. The exact definition of what is included in each type is explained in Appendix A. In general, a controllable change would include any engineering change, construction changes necessary to complete the project, and value engineering changes. (RMS, 2.36) The construction contractor or design-builder is best able to control the cost and time impact of controllable changes. An uncontrollable change included any discretionary, user-requested change which would equate to the owner-generated changes noted above.

2.5 – Research Questions

The extensive volume of literature exploring the benefits of the design-build project delivery method coincides with the established goals in MILCON Transformation. Similarly, the directives from the Secretary of the Army as well as the recommendations of the Quadrennial Defense Review are pressing for expanded usage of the design-build project delivery method. However, all of these research studies and the promised benefits of design-build are tempered by the experience of this researcher on a design-build hospital project which did not experience any of the benefits traditionally associated with design-build project delivery. Therefore, it was necessary to determine whether that one project was an anomaly or indicative of the performance of MILCON design-build projects.

To test determine the benefits of the design-build project delivery method on MILCON projects the following questions and hypotheses were developed:

2.5.1 - Time

Is the design-build project delivery method faster than the design-bid-build project delivery method?

H_0: No difference exists between design-build and design-bid-build project delivery methods regarding contract duration.

H_1: Design-build projects will have shorter contract durations than design-bid-build projects.

2.5.2 – Cost

Is a design-build project less expensive than a design-bid-build project

H_0: No difference exists between design-build and design-bid-build project delivery methods regarding contract cost.

H_2: Design-build projects will have lower contract costs than equivalent design-bid-build projects.

2.5.3 - Quality

How does the quality of a design-build project compare with a design-bid-build project?

H_0: No difference exists between design-build and design-bid-build project delivery methods regarding project quality.

H_3: Design-build projects will be of better quality than equivalent design-bid-build projects.

2.5.4 - Facility Type

Is the design-build project delivery method better suited to one type of facility compared with the design-bid-build project delivery method?

H_0: No difference exists between the performance metrics of design-build or design-bid-build projects of a particular facility type.

H_4: Performance metrics for design-build projects will differ from performance metrics for design-bid-build projects of a particular facility type.

Is there a difference in the performance of the design-build project delivery method based on the type of facility?

H_0: No difference exists in the performance of design-build projects of differing facility types.

H_5: Performance of design-build projects differ by facility type.

2.5.5 - Geography

Is the design-build project delivery method better suited to one geographic region compared with the design-bid-build project delivery method?

H_0: No difference exists between the performance metrics of design-build or design-bid-build projects in a particular geographic region.

H_6: Performance metrics for design-build projects will differ from performance metrics for design-bid-build projects in a particular geographic region.

Is the design-build project delivery method better that the design-bid-build project delivery method in a particular USACE district?

H_0: No difference exists between the performance metrics of design-build or design-bid-build projects in a particular district.

H_7: Performance metrics for design-build projects will differ from performance metrics for design-bid-build projects in a particular district.

Does the performance of the design-build project delivery method vary by USACE district?

H_0: No difference exists between the performance metrics of design-build projects in any district.

H_8: Performance metrics for design-build projects in at least one district will differ from performance metrics for design-build projects in other districts.

2.5.6 - Change Orders

Is there a difference between the types of change orders on design-build projects compared to design-bid-build projects?

H_0: No difference exists between change orders of design-build or design-bid-build projects.

H_9: Change order metrics on design-build projects differ from change order metrics on design-bid-build projects.

CHAPTER 3 - RESEARCH METHODOLOGY AND DATA COLLECTION

3.1 – Introduction

The primary purpose of this research was to investigate and explore the questions posed in Chapter 2. To accomplish this, data was collected and analyzed in order to develop answers. The data collection and analysis phase follows the research protocol outlined below.

3.2 – Research Protocol

The research model shown in Figure 3, below, served as a useful guide. The observations which initiated this study arose from the USAHFPA's application of the design-build project delivery method to the Bagram airfield hospital located in Afghanistan (block 1). From this project, many observations were formed that fed into the problem definition and preliminary data gathering steps in the research process (block 3). The literature survey, outlined above, drove the development of a theoretical framework and the identification of variables for analysis (block 4). All of these steps led to the generation of a general hypothesis that there was no difference between design-bid-build and design-build project delivery methods on military construction projects (block 5). The research design (block 6) is explained in section 3.3, below. Data collection and analysis methodologies will be discussed over the remainder of Chapter 3 whereas the analysis and interpretation of results are discussed in Chapter 4 (block 7). Finally, the outcome of the initial hypotheses and deduction regarding the research questions will be discussed in Chapter 5 (block 8).

3.3 – Research Design

The research design was limited by the availability of reliable MILCON project performance data and necessitated an empirical analysis approach. Many authorities on research maintain that empirical analysis provides strong evidence for explaining phenomena. Quantitative research will be able to answer questions of 'how much of a difference?' but not necessarily the 'why?' (Walker, 1997)

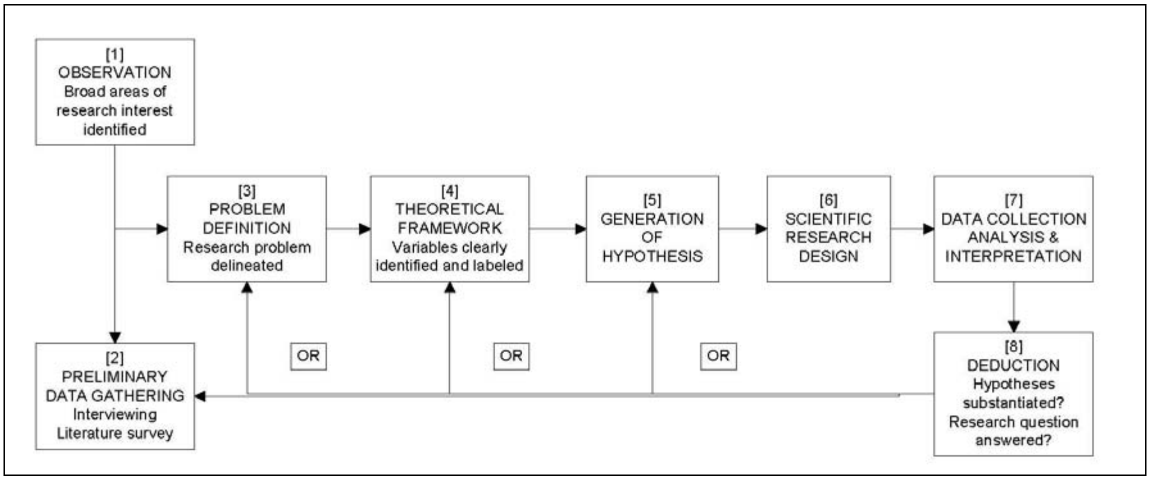

Figure 3. Basic applied research process (Sekaran, 1992)

3.4 – Data Collection

3.4.1 – Web CMI

All data were acquired through the USACE WebCMI on-line application. This tool is made available to USACE customers to monitor the status of their respective construction projects. The application incorporates data from multiple databases and information systems to provide the customer with up-to-date project status. Some of the systems which feed the WebCMI application are:

- Resident Management System (RMS) provides construction phase information.
- Program and Project Management Business Process (P2) provides basic project definition information.
- Corps of Engineers Financial Management System (CEFMS) provides current financial project data.

The information contained in the WebCMI is hierarchical and able to be sorted. Therefore, to obtain the data for this study, a query of projects in each USACE District was conducted. Projects were categorized as civil works, environmental, or military construction within the WebCMI application. In order to achieve a homogenous data set of building projects, the search for project information was limited to military construction projects.

Within the military construction project category were multiple types of projects funded with differing types of federal funds. For example some projects were locally funded with operations and maintenance dollars while others used multi-year military construction funds. To obtain the desired homogenous data set of building projects, only projects funded with military construction funds and governed by the requirements of AR 415-15 were selected. Therefore, projects were limited to the following fund types:

- Military Construction, Army (MCA)
- Minor Military Construction, Army (MMCA)
- Military Construction, Army Reserve (MCAR)
- Military Construction, Army National Guard (MCNG)
- Military Construction, Air Force (MCAF)
- Minor Military Construction, Air Force (MMAF)
- Military Construction, Air Force Reserve (MAFR)
- Department of Defense, Medical (DODM)

Once the WebCMI projects had been sorted by fund type, only completed projects with construction performance information were selected. Therefore, only those projects that had RMS information and an actual construction completion date were selected. In this manner, 100% of all completed projects in the WebCMI application were obtained in the initial data set. It should be noted that projects are constantly being added to and deleted from the WebCMI application, therefore the makeup of the data set will change with time. However, if the data set is sufficiently large and representative of the population the results of the analysis should be reproducible, regardless of when the data set was acquired.

3.4.2 – Data Selection / Screening Criteria

The initial MILCON data set represents 100% of the completed military projects in the WebCMI database during the sampling time, from June to November 2006. This initial data set included 400 project entries from 22 Districts. Therefore, successive screening criteria were used in an effort to reduce measurement error.

3.4.2.1 – Screening for Duplicate Contract Numbers

The first screening criterion was to eliminate duplicate projects based on their contract number. A contract number is a comprised of 13 alphanumeric characters. The first six characters identify the contracting agency and or service component (i.e. Army, Air Force, etc). The seventh and eighth characters specify the fiscal year that the contract was awarded. The ninth character identifies the type of contract (construction, delivery order, etc.) The tenth through thirteenth characters serve as a unique serial number for the contract.

It is possible for contract numbers with the alphanumeric designator “D” as the ninth character to have multiple awards as this is a delivery order contract. However, based on how the WebCMI system handled change order and schedule tracking duplicate contract numbers with the ninth character as anything other than “D” were not allowed. For instance, in WebCMI a delivery order contract will track the changes and schedule as a function of the delivery order keeping this information specific to each delivery order. However, for a construction contract the change and schedule information are tracked as a function of the contract number. Therefore, if the same contract number was assigned to two separate projects in WebCMI any change and schedule data cannot reliably be attributed to the correct project.

Duplicate construction contract numbers may also exist for projects that had phased funding. Normally, the subsequent phases for the project will not contain a contract award amount; rather they were handled as options to the original contract. Therefore, these duplicate entries could be summed to get the entire project record and the subsequent phase entries were removed from the data set. However, if the subsequent phase was handled as a change order then the entries were removed from the data set because this would adversely skew the performance metrics concerning cost. Similarly, if the duplicate construction contract entries were for the same project but contained different schedule information then the entries were removed from the data set. Finally, if two entries had duplicate construction contract numbers but it could not be determined how the entries related to one another then both entries were removed from the data set.

The application of this screening criterion resulted in 30 projects being removed from the data set.

3.4.2.2 – Screening by Contract Award Type

The Federal Business Opportunities (FBO) on-line database was used to validate the project delivery method as traditional or design-build. It was found that some multiple award task order contract (MATOC) awards were for "Construction and Design-Build Construction" services. It was not possible to differentiate which delivery/task orders for the MATOC contract were for construction services and which were for design-build services. Therefore, the five projects with an FBO award of this category was removed from the data set.

3.4.2.3 – Screening by "Design-by" Data

The categorization of the project delivery method into either "Traditional" or "Design-Build" was based in large part on the "Design-by" data. Therefore, the 11 projects that had no "Design-by" data were removed from the data set since this would adversely affect the ability to properly categorize the project's acquisition method.

3.4.2.4 – Accuracy of Categorization of Acquisition Method

Projects were categorized as design-build or traditional, design-bid-build based on the "Design-by" data field, the project description data field, authorized phase data field, and the synopsis data field (if used). For example, the design-by data field may indicate that the project was designed by an architectural engineer, yet the authorized phase may indicate a code 7 (authorization for design-build procurement). An authorized phase identified as a code 9 would indicate final design authorization and a traditional, design-bid-build project delivery method. (AR 415-15, 1998) Similarly, the project description may include the phrase "design and construct" indicating that the design build project delivery method was used or the project synopsis field may name a design-build firm. It is possible to have a conflict between data fields, especially if they are drawn into the WebCMI application from different stand-alone applications. Therefore, if any of the four elements indicated design-build had been utilized then the project was categorized as design-build.

To determine the accuracy of this assignment methodology each project was queried against the FBO on-line database to determine the project delivery method for each project. Unfortunately, the FBO on-line database did not contain records on 100% of the projects extracted from the WebCMI application. The most notable variance between the two databases was regarding projects executed outside of the continental United States (OCONUS). There were other variances and may be a factor of project size and whether alternative public notice was issued for the solicitation. Therefore, for each "Design-by" category those projects with a corresponding record in the FBO database were selected to determine the accuracy of the assignment methodology. If less than 10% of the entries were misclassified then the assignment methodology was deemed adequate and all projects of that "Design-by" code would be included in the final data set. If greater than 10% of the entries were misclassified then only those projects listed in the FBO database were included and the project delivery method on the misclassified projects were corrected.

The first category to be evaluated was projects designed by an A/E which used a construction-type contract (instead of a delivery order contract). There were a total number of 91 projects with a “designed by” code of A/E. However, only 63 had a corresponding record in the FBO online database. Of the 63 projects confirmed in the FBO database, seven were misclassified, which equals 11.1% of the projects. Accordingly, all 91 projects designed by an A/E without a corresponding record in the FBO online database were purged from the data set.

The next category to be evaluated was projects designed by an A/E which used a delivery order-type contract. There were a total number of 12 projects meeting these criteria with a corresponding record in the FBO online database. Of these projects, eight were misclassified which correlates to 66% of the projects. All 17 projects designed by an A/E executed on a delivery order contract without an FBO record were removed from the data set.

The results of the misclassification by project type are shown in Table 5. Checking the accuracy of the classification of project delivery method resulted in 170 projects being removed from the data set. However, the project delivery method classification of the remaining data set is extremely accurate.

3.4.2.5 – Screening for Vertical Construction Projects

In order to determine whether the project delivery method will have a potential impact on Med-MILCON projects the data was restricted to projects with a vertical construction component. Therefore, projects that were airfield paving, security fencing, flood control, utility infrastructure, and water treatment systems were removed from the data set. Similarly, projects with small a small vertical footprint relative to the scope of the project were removed due to the likelihood that they could skew results regarding unit cost calculations. An example of this type of facility is a marksmanship range where a substantial amount of the work is associated with grading, clearing and utilities and results in a facility of just over

Table 5. Project delivery method classification accuracy.

"Design by" Code	Contract Type	# of Projects	# of Projects with FBO confirmation	# of Projects Misclassified	Rate	# of Projects Removed
AE: Architect-Engineer	Construction	91	63	7	11.1%	91
	Delivery Order	17	12	6	66.7%	17
DC: Design-Construct	Construction		27	0	-	-
	Delivery Order		5	0	-	-
HL: Hired Labor	Construction	30	29	5	17.2%	30
	Delivery Order	12	4	2	50.0%	12
ID: Indirect Design	Construction	20	2	1	50.0%	20
	Delivery Order	1	0	0	-	1
US: Using Service	Construction		0	0	-	-
	Delivery Order		2	2	100.0%	0

100 square feet. Application of this screening criterion resulted in 33 projects being removed from the final data set.

3.4.2.6 – Screening for Pending Changes or Unfunded Changes

In the Resident Management System (RMS) data fields it is possible to determine whether a project record had pending, approved changes. Such a balance may indicate that while the construction activities on a project are complete it has not been financially closed out. As the project moves toward financial closure this pending balance may affect the financial performance of the project.

Likewise, the RMS data fields make it possible to determine whether a project has unfunded changes. The resolution of this type of change may take a substantial amount of time if litigation is required and may adversely impact the financial performance of the project.

For these reasons any project with a balance shown as a pending, approved change or an unfunded change were removed from the final data set. The application of this screening criterion resulted in the removal of data for 29 projects.

3.4.2.7 – Impact of Screening Criteria on Final Data Set

The application of the screening criteria outlined above resulted in a smaller, more reliable data set than was initially extracted from the WebCMI application. The impact of the screening criteria on the data set is shown in Table 6, below.

The final data set used in all subsequent analysis was comprised of 119 projects. Of which, 63% were design-build and 37% were design-bid-build. The applied screening criteria affected the North Atlantic Division the greatest with 88.1% of the original projects being screened out of the final data set. At the other extreme is the South Pacific Division which only experienced a screening rate of 60.5%.

3.4.3 – Data Correction

Project data requires correction for project location, size, and time-value-of-money. These adjustments are routine for construction projects and are outlined in RS Means manuals. However, since these projects are exclusively military it was desired to use military adjustment factors as outlined in Army policy. (Programming, 1994)

Table 6. Summary of the impact on the data set by application of screening criteria.

Division	District	Initial Data Set (# of Projects)	Final Data Set (# of Projects)	Screening Rate (%)
North Atlantic Division	New England District	2	-	100.0%
	Baltimore District	20	8	60.0%
	Europe District	32	1	96.9%
	New York District	17	-	100.0%
	Philadelphia District	2	-	100.0%
	Norfolk District	11	1	90.9%
	TOTAL	**84**	**10**	88.1%
South Atlantic Division	Savannah District	73	29	60.3%
	Mobile District	15	5	66.7%
	Charleston District			
	Jacksonville District			
	Wilmington District			
	TOTAL	**88**	**34**	61.4%
Great Lakes and Ohio Rivier Division	Detroit District			
	Buffalo District			
	Chicago District			
	Huntington District			
	Nashville District			
	Pittsburgh District			
	Louisville District	30	9	70.0%
	TOTAL	**30**	**9**	70.0%
Mississippi Valley Division	Rock Island District			
	Memphis District			
	New Orleans District			
	St. Louis District			
	Vicksburg District			
	St. Paul District			
Southwestern Division	Galveston District			
	Fort Worth District	37	13	64.9%
	Little Rock District	4	2	50.0%
	Tulsa District	19	8	57.9%
	TOTAL	**60**	**23**	61.7%
Northwestern Division	Portland District			
	Kansas City District	12	1	91.7%
	Omaha District	19	8	57.9%
	Seattle District	13	3	76.9%
	Walla Walla District			
	TOTAL	**44**	**12**	72.7%
South Pacific Division	Los Angeles District	27	10	63.0%
	Albuquerque District	5	2	60.0%
	Sacramento District	11	5	54.5%
	San Fancisco			
	TOTAL	**43**	**17**	60.5%
Pacific Ocean Division	Far East District	13	-	100.0%
	Alaska District	25	6	76.0%
	Honolulu District	16	8	50.0%
	Japan Engineer District	2	-	100.0%
	TOTAL	**56**	**14**	75.0%

3.4.3.1 – Project Size Adjustment

A larger project may allow a contractor to gain an economy of scale advantage and therefore construct the larger facility at a reduced unit cost. Recognizing this fact the

USACE has a reference facility size for each type of facility. By comparing the project facility size to the reference facility size a size relationship ratio is determined. (Unit, 2006) The size relationship ratio is calculated using the following formula:

$$Size\,\mathrm{Re}\,lationship\ Ratio = \frac{\mathrm{Pr}\,oject\ Building\ Size}{\mathrm{Re}\ ference\ Facility\ Size}$$

The calculated size relationship ratio used to determine the correct size adjustment factor using a lookup table in Appendix A, Unit Costs for Army Facilities – Military Construction. (Unit, 2006) The smallest facilities, as defined by a size relationship ratio <0.05, receive the maximum size adjustment factor of 1.275. The largest facilities, as defined by a size relationship ratio of >3.05, receive the minimum size adjustment factor of 0.920.

This procedure is used on all facility types except for military family housing and barracks/dormitories. For these facility types the size adjustment factor is based off of the number of family housing units in the project or the number of soldiers to be housed. The size adjustment factors are distributed over a similar range as outlined above.

It was necessary adjust the actual project cost data elements to eliminate any potential effects based on project size by dividing the actual project cost data element by the size adjustment factor. Therefore, the costs for small projects, having a size adjustment ratio <1, will be decreased in order to remove the size "penalty." Likewise, the costs for large projects, having a size adjustment ratio >1, will be increased in order to remove the size "advantage." This results in a data set in which projects may be directly compared regardless of project size.

3.4.3.2 – Project Location Adjustment

The USACE multiplies estimated project costs by an area cost factor (ACF) in order to determine an equivalent local value as part of the programming process. The national average cost factor is assumed to be 1.00, determined from 96 Base Cities (two cities per state in the Continental United States). The ACF index is developed based on the local construction costs for a market basket of 8 labor crafts, 17 construction materials, 4 equipment items, and seven other matrix factors that reflect local conditions affecting construction costs, such as weather, climatic (frost zone, wind load), seismic, contractor overhead and profit, life support and mobilization, labor availability and labor productivity compared to the U.S. standard. This market survey is updated biannually. (DoD, 2006)

Therefore, to convert the project financial information into a national average cost the following formula was used:

$$National\ Average\,Cost = \frac{Given\ Cost}{Area\,Cost\ Factor}$$

By converting all projects to an equivalent national average value it is possible to directly compare projects from differing regions.

3.4.3.3 – Project Time Adjustment

All raw data values are expressed in what are termed current dollars which is value of goods and services in terms of the prices and estimated inflation at the time of purchase. The use of current dollars distorts time-series analysis by failing to reflect the greater purchasing power of the dollar in earlier years or the declining purchase power in later years.

Constant dollars are uninflated dollars, which measure the value of purchased goods and services in terms of the price level in a given base year. All cost data from fiscal years prior the base year are inflated to be equal to an equivalent amount in base year dollars; all fiscal years following the base year are deflated so that the amounts are equivalent base year dollars. The same dollar amount is used when both the current and constant values are in the same base year. (Inflation, 2002)

A composite inflation index is a multiplication factor for compounding inflation and is used for converting base year constant/current dollars to current/constant dollars in another year. The inflation rates used in preparation of the Army's budget are based on economic assumptions provided by the Office of Management and Budget (OMB). The rates are published in February in Table S-4 Comparison of Economic Assumptions in the Budget of the United States.

Therefore, all actual project cost data was converted into FY07 constant dollars using the appropriate military construction inflation index. (Inflation, 2002) This will allow for direct comparison of project cost data regardless of project completion date.

3.5 – Data Demographics and Internal Validation

The findings of this study are only as reliable as the data on which it is founded. Through the application of stringent screening criteria and utilization of a second, independent project database it was believed that the data set would be fairly uniform and representative of the population as a whole.

Figures 4 and 5 demonstrate the time variability of the WebCMI data set. Due to the length of construction and settlement of claims it appears that the longer it has been contract award the greater the probability that the project will pass the established screening criteria, regardless of project delivery method. However, the sudden decrease in the number of projects from 2002 to 2001 demonstrate that after a period of time projects are closed out and removed from the WebCMI application. Therefore, to obtain a better picture of the performance of projects executed by the USACE this study would need to be replicated over successive years to fill in the “gaps” in the FY 2003, 2004, and 2005 data.

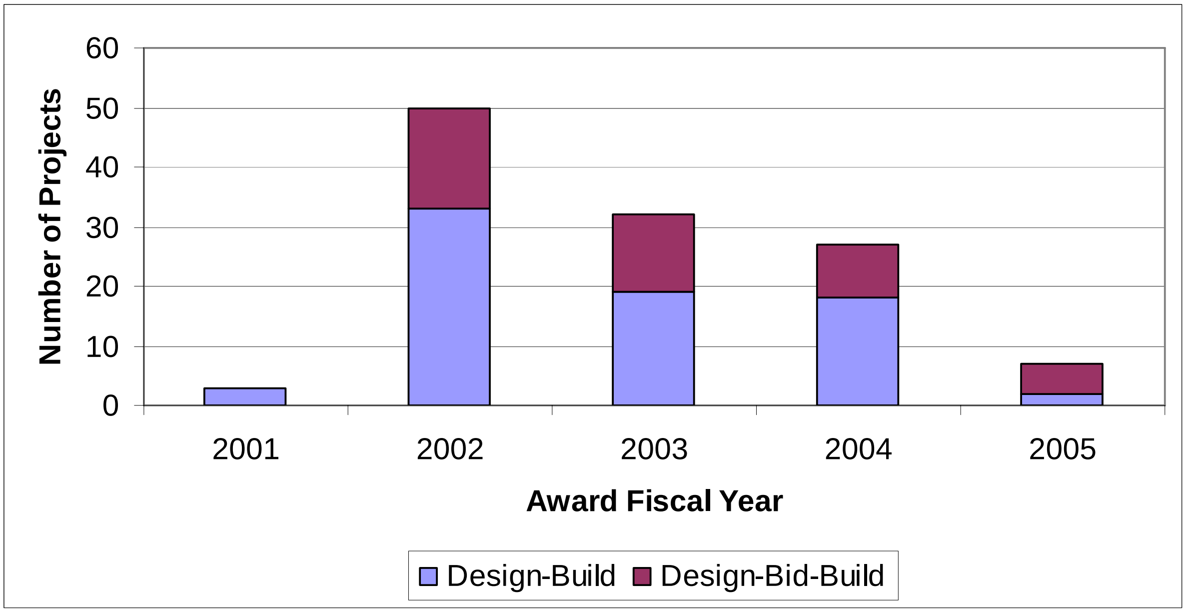

Figure 4. Number of projects by year by project delivery method.

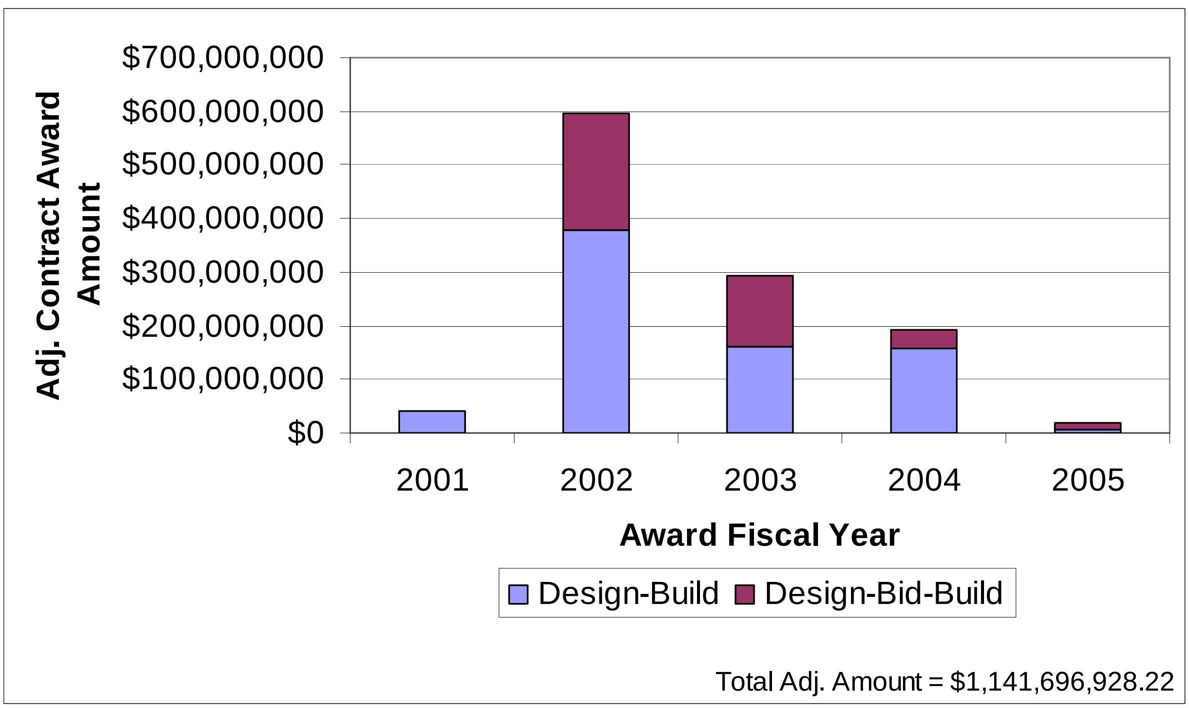

Figure 5. Contract award amount by year by project delivery method.

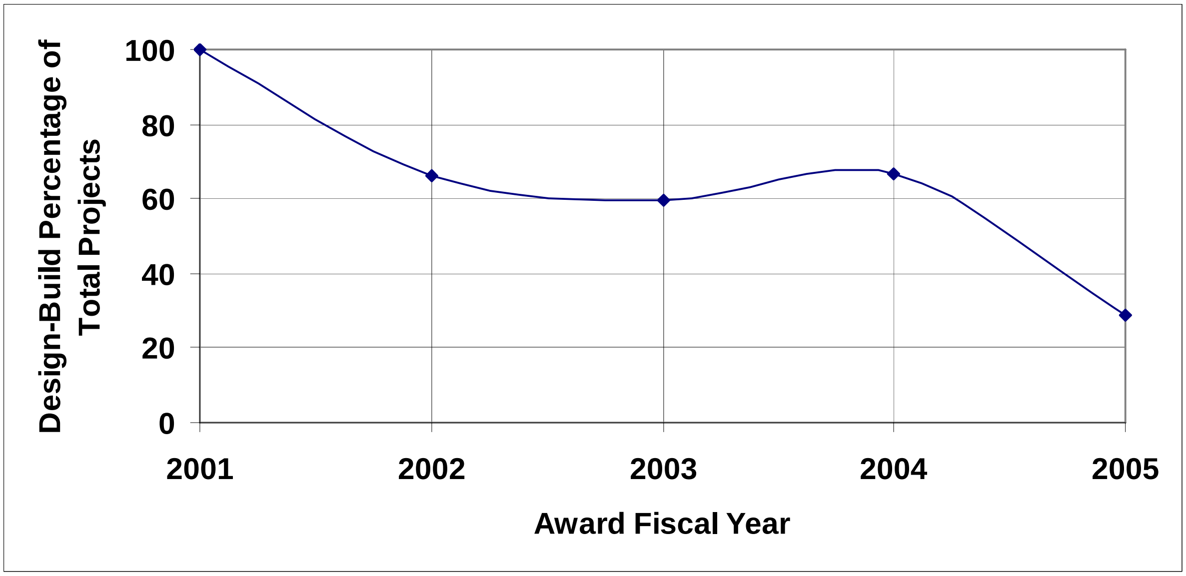

Figure 6. Design-build projects as a percentage of total projects by year.

Taking into account the variability of the number of projects by time and neglecting years 2005 and 2001, Figure 6 shows a fairly steady percentage of USACE projects being awarded design-build. This percentage fluctuates between 59 and 67% and was surprising based on this researcher's experience with Med-MILCON projects. In fact, it would appear that the USACE is well on the way to making design-build the rule, rather than the exception for project delivery.

The definition of project size in this study was based on earlier design-build research focusing on transportation projects and is based on the value of the contract or project. (Shane, 2003) From figures 7 and 8 it is evident that the projects comprising this study were relatively small, as no projects were recorded in the Large or Mega sizes. However, based on upcoming medical construction projects these size classifications are as applicable to facility construction as they are transportation projects.

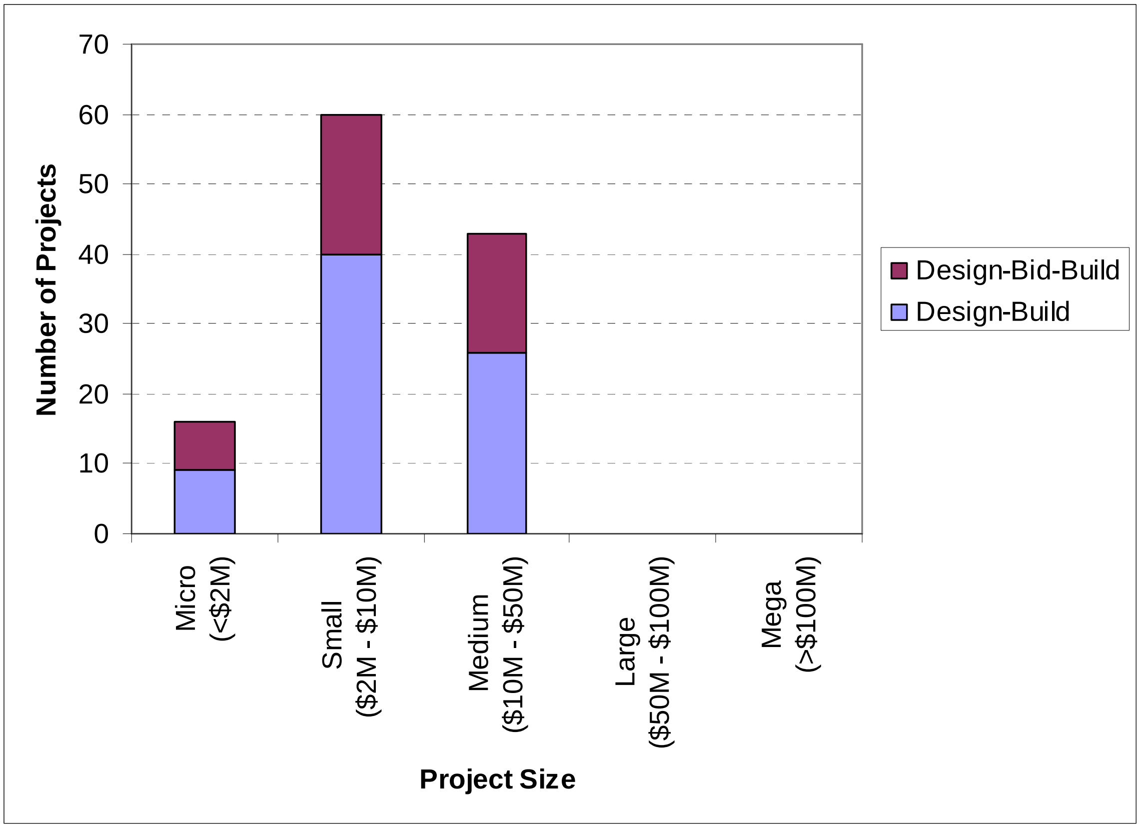

Figure 7. Distribution of projects by size by project delivery method.

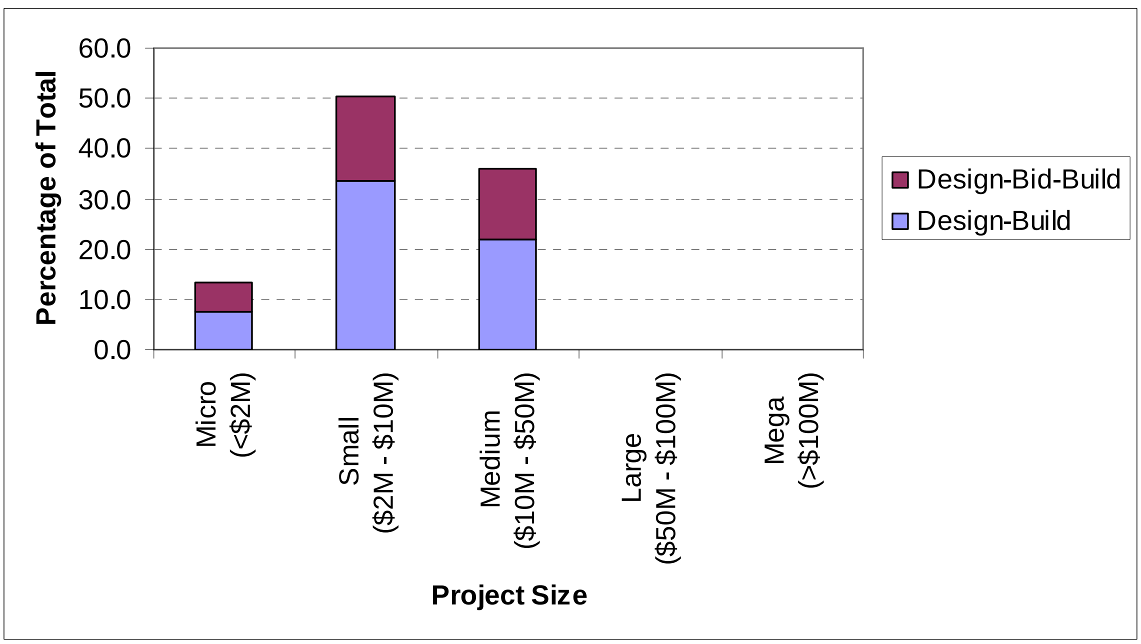

Figure 8. Distribution of project size as a percentage of total award value.

3.6 - Analysis

3.6.1 – Performance Metrics

The preliminary steps of the research methodology outlined in Figure 3 have been discussed above. Therefore, the analysis method must now be addressed. Typical project performance is assessed based on the concepts of time, cost, and quality. The construction industry has traditionally used measures of change from the original contract time and cost as cardinal performance metrics. However literature has revealed that some of the most common metrics are not as valuable in measuring actual construction performance as previously thought. Performance metrics are broken down into three types: relative, static, and dynamic. (Gransberg, 2002)

3.6.1.1 – Relative Metrics

Relative metrics are independent of project size, which allows for direct comparison of small and large project performance. (Gransberg, 2002) Examples of relative metrics include cost, schedule and award growth.

Cost Growth

Literature is rife with the use of cost growth as a metric to evaluate construction project performance. (Jahren, 1991; Konchar, 1998; Gransberg, 2002; Ling, 2004; El Wardani, 2005) The generally accepted formula for calculating cost growth is expressed as:

$$Cost\,Growth = \left[\frac{(Final\,Project\,Cost - Contract\,Cost)}{Contract\,Cost}\right]\cdot 100$$

Where:

Cost Growth (%)

Final Project Cost ($)

Contract Cost ($)

Schedule Growth

Like cost growth, the schedule growth metric is widely utilized to assess construction project performance. (Konchar, 1998; Gransberg, 2002; Ling, 2004; El Wardani, 2005) The generally accepted formula for calculating schedule growth is expressed as:

$$Schedule\,Growth = \left[\frac{(Total\,Time - Total\,\,As\,Planned\,Time)}{Total\,\,As\,Planned\,Time}\right]\cdot 100$$

Where:

Schedule Growth (%)

Total Time (months or calendar days)

Total As Planned Time (months or calendar days)

Award Growth

The final relative metric is award growth and is an assessment of how the difference between the contract award amount and engineer's estimate. (Gransberg, 2002) Award growth may also be a reflection of the bidding environment at the time of solicitation. The formula for this metric is expressed as:

$$Award\,Growth = \left[\frac{(Original\,Contract\,Cost - Engineer's\,Estimate)}{Engineer's\,Estimate}\right]\cdot 100$$

Where:

Award Growth (%)

Original Contract Cost ($)

Engineer's Estimate ($)

3.6.1.2 – Static Metrics

Static metrics are discreet numerical measures that do not change with time. However, these metrics are size dependent and can only be used when comparing projects that are roughly the same size. (Gransberg, 2002) Examples of static metrics include design unit cost, construction unit cost, and design-build unit cost.

A direct comparison of design build unit cost and construction unit cost within this study may be misleading as the construction unit cost does not reflect a design burden. It must be noted that there is a design burden associated with traditional, design-bid-build projects that is not reflected in the standard metrics.

Design Unit Cost (Gransberg, 2002)

Design unit cost determines the average design cost per square-foot of constructed area and may be expressed by the following formula:

$$DesignUnit\,Cost = \frac{Design\,Cost}{Size}$$

Where:

Design Unit Cost ($/SF)

Design Cost ($)

Size (SF)

Construction Unit Cost (Gransberg, 2002)

Construction unit cost determines the average cost per square-foot of constructed area and is expressed by the following formula:

$$ConstructionUnit\,Cost = \frac{Final\,Contruction\,Cost}{Size}$$

Where:

Construction Unit Cost ($/SF)

Final Construction Cost ($)

Size (SF)

Design-Build Unit Cost (Gransberg, 2002)

Design-build unit cost determines the average cost per square-foot of constructed area and is expressed by the following formula:

$$Design\,Build\,Unit\,Cost = \frac{Design\,Build\,Cost}{Size}$$

Where:

Design Build Unit Cost ($/SF)

Design Build Cost ($)

Size (SF)

3.6.1.3 – Dynamic Metrics

Dynamic metrics vary with time and these measures are also dependent on project size.

Design Placement (Gransberg, 2002)

Design placement is the average cost per day of a design contract and is expressed by the following formula:

$$Design\,Placement = \frac{Design\,Contract\,Cost}{Design\,Contract\,Time}$$

Where:

Design Placement ($/day)

Design Contract Cost ($)

Design Contract Time (days)

Construction Placement (Gransberg, 2002)

Effective and efficient construction management is obtained when high values of construction placement are achieved. Construction placement is expressed by the following formula:

$$Construction\,Placement = \frac{Final\,Construction\,Cost}{Final\,Construction\,Time}$$

Where:

Construction Placement ($/day)

Final Construction Cost ($)

Final Construction Time (days)

Design-Build Placement (Gransberg, 2002)

$$Design\,Build\,Placement = \frac{Design\,Build\,Cost}{Design\,Build\,Time}$$

Where:

Design Build Placement ($/days)

Design Build Cost ($)

Design Build Time (days)

Construction Intensity (Gransberg, 2002)

$$Intensity = \frac{\left(\frac{Final\,Construction\,Cost}{Size}\right)}{Final\,Construction\,Time}$$

Where:

Intensity ($/SF/day)

Final Construction Cost ($)

Size (SF)

Final Construction Time (days)

3.6.1.4 – Additional Metrics

Additional performance metrics and/or project characteristics were calculated from the MILCON project data. The metric/characteristics and the corresponding formula are listed in Appendix A.

3.6.1.5 - Analysis

To test the validity of the hypotheses proposed in chapter 2, a two-tail Student's t-test was performed using the analysis tool pack in Microsoft Excel. This software analysis method was chosen over other potential software packages due to the learning curve and the availability of this software on other government computer systems in the future. If this study is to be updated in the future it is better to use software already in use and understood by the intended audience. Furthermore, the Student's t-test used in this study assumed two samples of unequal variance and significance (α) of 0.05, corresponding to a 95% confidence level.

The two-tail Student's t-test function performs a comparison of means and returns the probability whether two samples are likely to have come from the same population. If the probability value was greater than a pre-established threshold then the result was interpreted that the two samples are likely to have come from the same population and no statistical significance existed. For this study, if the probability was less than 15% then the difference between the two samples was interpreted as being statistically significant and this value also serves as the threshold for Type I errors using the Student's t-test The 15% threshold value was selected based on the initial, exploratory nature of this study. In order to gain the widest perspective of potential differences between project delivery methods, it was deemed that the significance threshold had to be expanded to the 15% level. Future research may necessitate narrowing of this significance threshold to either 5 or 10% due to the more focused scope of that work.

Another analysis tool used in this study was the relative value matrix. Typically used to support decision papers or briefings in military operations the relative value matrix is applied to focus the subsequent analysis. For the 23 characteristics assessed using the Student's t-test a relative value was assigned to each characteristic based on the performance relative to the traditional project delivery method. For example, if the design-build characteristic was better than design-bid-build the relative value was "1." If the design-build characteristic was worse than the traditional project delivery method the relative value was "-1." Finally, if there was no statistical difference between the two project delivery methods or if the characteristic is only descriptive in nature the relative value was "0." An example of a descriptive characteristic is the adjusted contract award amount, which simply describes the monetary value of the project and not how that project performed.

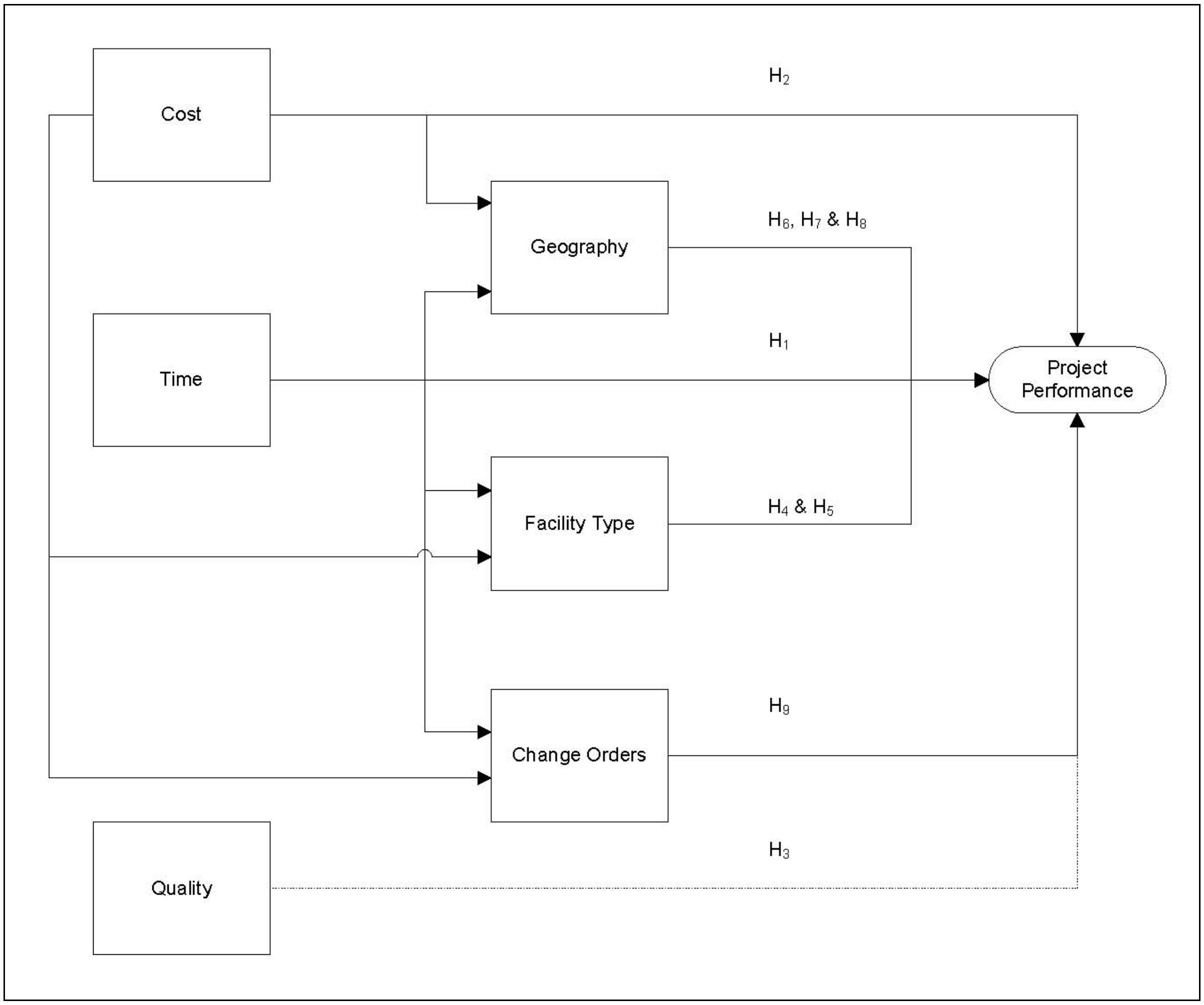

Figure 9. Research model showing interactions between data and research questions.

The final analysis tool used was an analysis of variance (ANOVA), which is an approach to determine if there is a significant difference between numerous groups. As with the Student's t-Test, the ANOVA analysis was conducted using the analysis tool pack in Microsoft Excel. This analysis was a single factor ANOVA test with alpha values (α) of 0.5 and 0.10. The null hypothesis to be tested with this type of test is that the population means are equal, or there is no difference between populations. However, if the probability, or P-value, returned by the ANOVA test is less than the alpha value used in the test the difference between groups is considered statistically significant. Likewise, if the F-value returned by the ANOVA test is greater than the F-critical value then the difference between groups is considered statistically significant. (Newbold, 2007) In general, the ANOVA tests the following hypotheses:

$$H_o : \mu_1 = \mu_2 = \mu_3 = ... = \eta_x$$

$$H_k : \mu_i \neq \mu_j$$ For at least one pair μ_i, μ_j.

CHAPTER 4 – DATA ANALYSIS

4.1 – Introduction

The nature of the military construction system is that total construction needs exceed the available funds and political influences affect the mix of projects. In the case of this study, the data set contains an abundance of projects of one particular type and a dearth of other types. This results in limited conclusions that may be drawn from this data set and trends can only be identified from the available information. These problems are noted where applicable in the following sections.

Factors to consider when analyzing the data include the budgetary restrictions. Military construction funds can only be used to fund military construction and funds left over at the end of a project may be held in reserve for pending claims, be used to fund other projects at financial risk, or allowed to expire in order to return the funds to the Treasury. Therefore, there is a "use it or lose it" mentality tied with federal appropriations. Due to the substantial time period from project need identification/programming to construction award, there is a philosophy among users that this is their only chance to "leave their mark" on the facility.

4.2 – Data Analysis

As discussed in chapter 3, the data will be analyzed primarily through the use of a Student's t-test. This requires the segregation of the sample into two populations so that they may be compared. The hypotheses in chapter 2 focused this study to determine what differences, if any, existed between design-build and design-bid-build projects executed by the USACE. Therefore, all t-tests were performed comparing the design-build population to the design-bid-build population. In the limited cases where an ANOVA test was utilized the samples were segregated differently and will be discussed in more detail in these instances.

4.2.1 – Time

The data set was stratified based on project delivery method and an aggregate comparison of design-build performance to design-bid-build performance was made using a t-test. The results of this test are shown in Table B-1; however the pertinent information related to project time has been extracted and is shown in Table 7. This analysis tested the following hypotheses:

$$H_0 : \mu_{design-build} = \mu_{design-bid-build}$$

$$H_1 : \mu_{design-build} \neq \mu_{design-bid-build}$$

Table 7. T-test summary regarding contract time.

Characteristic	Total Sample Mean	Design-Build Mean (75 Projects)	Design-Bid-Build Mean (44 Projects)	Probability
Controllable Change Duration (days)	48.19			
Controllable Change Duration Ratio	0.34			
Contract Schedule Growth (%)		128.49	110.41	0.14233
BOD Time Growth (days)		87.68	41.66	0.11539
BOD Growth (%)		11.80	6.04	0.13601
Contract Time Growth (%)	31.19			
BOD to Completion Duration (days)	10.21			

Table 7 shows that there were no significant differences between the project delivery methods regarding the controllable change duration and the ratio of the value of controllable changes compared to the total value of changes. There were, on the average, 48 days in approved change orders directly attributable to controllable changes for both project delivery methods. Schedule growth can come from one of two sources, durations attributed to controllable changes and durations attributed to uncontrollable changes. Since the controllable change durations are, on the average, equivalent any difference in schedule growth between the project delivery methods is assumed to arise from the uncontrollable changes.

Near the sensitivity threshold of 15% there is a difference in the contract schedule growth between design-build projects and design-bid-build projects. This finding coupled with the finding that controllable changes are equivalent regardless of project delivery method would seem to indicate that the MILCON design-build projects experience greater uncontrollable cost growth, presumably from user-requested changes.

The contract schedule growth metric is explained in detail in Appendix A, however it is sensitive to changes in the beneficial occupancy date (BOD). Therefore, the statistically, significant difference in BOD growth between project delivery methods carries over into the contract schedule growth metric. Leading to the question of why the BOD increased more for design-build projects than design-bid-build projects?

It was initially thought that the difference in the beneficial occupancy increases was based on the fact that the design-build project had to complete its design in the contract performance period, whereas the design-bid-build project did not. However, there is a conflicting result with this assumption.

The contract time growth is statistically the same between the project delivery methods, and its exact explanation may be found in Appendix A. This metric is calculated based on the actual performance duration and the initial contract duration and the beneficial occupancy date is irrelevant. This finding indicates that based on contract performance period the design-build project delivery method is at least as good as the design-bid-build method.

The result indicating that contract schedule growth for design-build projects was significantly greater may in fact be a symptom of the flexibility of the BOD. If a facility is needed immediately then BOD may be accelerated to the point where early occupancy is provided to the user. Similarly, BOD may coincide with the project completion or may occur shortly afterward. Based on this logic then a project's contract time growth is the better metric to gauge performance.

In summary it appears that based on this analysis that the design-build project delivery model performs as well as design-bid-build project delivery model regarding the *contract performance periods*. This test supports the null hypothesis that the contract time performance of design-build projects is equal to the contract time performance of design-build projects. However, this result should not be construed to mean that a design-build project delivery method takes as long to produce a facility as the design-bid-build method. The design period for MILCON design-bid-build projects will take from one to two years as discussed earlier. The design period is included in the contract performance period of a design-build project, meaning that if similar projects were timed from a common point of reference then the design-build project would be delivered faster on the average.

4.2.2 – Cost

The data set was stratified based on project delivery method and an aggregate comparison of design-build performance to design-bid-build performance was made using a t-test. The results of this test are shown in Table B-1; however the pertinent information related to project cost has been extracted and is shown in Table 8. This analysis tested the following hypotheses:

$$H_0 : \mu_{design-build} = \mu_{design-bid-build}$$

$$H_2 : \mu_{design-build} \neq \mu_{design-bid-build}$$

From Table 8 it is shown that, on the average, contract award amounts for design-build projects do not significantly differ from the contract award amounts of design-bid-build projects. Similarly, the project award amounts, which attempt to adjust the design-bid-build contract costs to include estimated design costs, did not significantly differ between the two project delivery populations. This was expected due to the relatively large distribution of contract award amounts.

Table 8. T-test summary regarding project cost.

Characteristic	Total Sample Mean	Design-Build Mean (75 Projects)	Design-Bid-Build Mean (44 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	9,594,091.83			
Adjusted Initial Project Amount (Constant FY07 $)	9,774,708.78			
Adjusted Final Contract Amount (Constant FY07 $)	10,371,140.55			
Adjusted Final Project Amount (Constant FY07 $)	10,551,757.50			
Contract Cost Growth (%)	6.31			
Project Cost Growth (%)	6.15			
Award Growth (%)	0.65			
Unit Cost ($/sf)	264.33			
Project Placement ($/day)		15,007.29	9,887.68	0.03149
Contract Intensity ($/sf/day)		0.39	0.50	0.13856
Project Intensity ($/sf/day)		0.39	0.27	0.00500

All of the various performance metrics for contract cost growth and project cost growth were not found to significantly differ between the two project delivery populations. Detailed descriptions of these metrics may be found in Appendix A.

Table 8 also reveals a statistically significant difference between the design-build and design-bid-build project delivery methods regarding project placement. According to the literature a larger project placement value is indicative of effective and efficient construction management. (Gransberg, 2002) From this test it appears that the design-build project delivery method provides the owner with a more efficient and effective construction management organization. Due to the team-based delivery and the single point of responsibility feature of the design-build project delivery method this finding is to be expected and is of a benefit to owners.

The results shown for final two characteristics shown in Table 8 are of questionable value. Due to the lack of size data for all projects, any metric that required the project size as part of the calculation is not necessarily representative of the population. The size data element was not as robust as other data elements used in this study.

In summary, contract cost performance did not significantly differ between the project delivery methods substantiating the null hypothesis. However, the fact that the same relationship was seen when estimated design costs were included in design-bid-build projects indicates that as a project delivery method, design-build may be cheaper.

For example, if the design-build project delivery method were used on all Med-MILCON projects there would be a potential net savings equivalent to the planning and design (P&D) funds allocated to traditional Med-MILCON projects. This “savings” is assumed at 6%, based on statutory limits on design and engineering services. These funds could be cost shifted elsewhere within the USACE, Army, or DoD budgets after appropriate reprogramming actions. However, the same amount of MILCON funds will be required, regardless of project delivery method to award the contract. Design liability would be reduced by the very nature of design-build with the single contract for design and construction services.

Explained another way, the data suggests that if a $100 million dollar facility were delivered using the traditional design-bid-build project delivery method and the design-costs would be statutorily capped at 6%, or $6 million. The construction contract would be awarded for $100 million and the total cost to the Government at the time of contract award would be $106 million. However, if the same facility was delivered using the design-build project delivery method then the total cost to the Government at the time of contract award would simply be $100 million, since the design effort is included in the contract amount. Therefore, the design-build project delivery method results in a $6 million or 6% savings over traditionally delivered facilities.

4.2.3 – Quality

The literature review indicates that public owners are pleased with the quality of design-build projects and there are several metrics used to measure the quality of a project. However, the quantitative data used in this study could not be used to assess the quality of projects, regardless of project delivery method. A different approach was explored in an attempt to acquire qualitative data from which to assess the quality of MILCON projects. Many times, a post occupancy evaluation is performed on major Med-MILCON projects with the intent of collecting lessons learned from the project delivery process as well as assessing the overall quality of the facility. However, only one post occupancy evaluation was located for a design-bid-build project, which is insufficient to address the quality of design-build projects compared to design-bid-build projects. Therefore, this research question remains unresolved.

4.2.4 – Facility Type

The individual projects were grouped into fourteen separate types based on classifications utilized by the Corps of Engineers. The primary exception to the USACE classification system was the separation of aviation maintenance facilities from ground maintenance facilities. The separation of maintenance facilities into these categories was justified due to the larger clear span construction methods used in aviation maintenance facilities or hangers. Similarly, the “special” facility type was composed of facilities that did not clearly fit in any of the other facility types, and is composed primarily communication facilities of various sizes and capabilities. The distribution of the various facility types is shown in Figures 10 and 11, below.

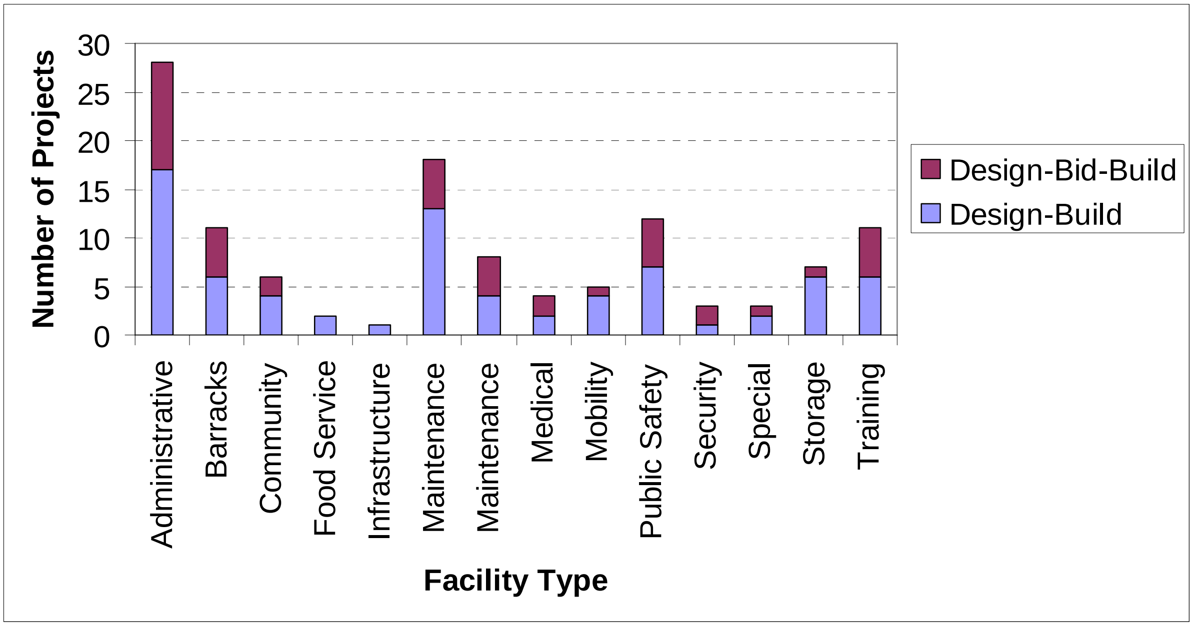

Figure 10. Distribution of projects by facility type and delivery method.

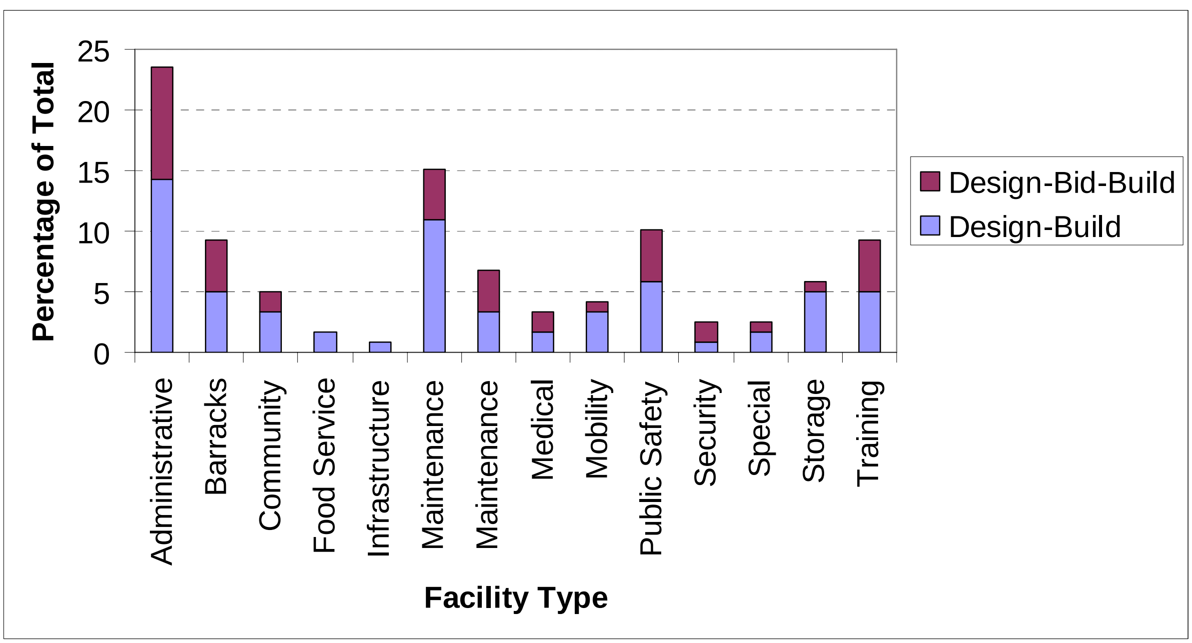

Figure 11. Distribution of percentage of projects by facility type and delivery method.

The data set was stratified by project delivery method and for each facility type design-build projects were compared with design-bid-build projects through the use of a Student's t-test to test the following hypotheses:

$$H_0 : \mu_{design-build} = \mu_{design-bid-build}$$

$$H_4 : \mu_{design-build} \neq \mu_{design-bid-build}$$

Of the facility types used in this study only eight were composed of sufficient numbers of both design-build and design-bid-build projects to perform a t-test. As discussed above a relative value matrix was prepared and is shown in Table 9, below.

Multiple studies have attempted to determine if the design-build project delivery method was suitable for all types of projects regardless of size or complexity. The early belief was that design-build was only suitable for small, uncomplicated projects. However, the Federal Construction Council study determined that the design-build project delivery method could outperform design-bid-build on all types of projects from simple office complexes to complicated industrial and laboratory projects. (Experiences, 1993)

The fairly uniform relative value totals shown indicate that the design-build project delivery method is able to perform as well as the design-bid-build method on facility types included in this study. This indicates that earlier findings are applicable to military construction. It is notable that the four highest ranked projects are types of facilities with a substantial number of repetitive elements, such as exam rooms, classrooms, offices, etc.

The barracks and housing facility type had the undisputable best design-build performance compared to design-bid-build performance. The design-build project delivery method has been used for this facility type since the first DoD design-build housing projects were awarded in 1969. This result would seem to agree with earlier work that as experience levels grow so do the benefits of the design-build project delivery method.

Table 9. Relative value matrix of design-build performance by facility type.

Characteristic	Administrative	Barracks	Community	Maintenance - Aviation	Maintenance - Ground	Medical	Public Safety	Training
Adjusted Contract Award Amount (Constant FY07 $)								
Adjusted Initial Project Amount (Constant FY07 $)								
Adjusted Change Order Value (Constant FY07 $)								
Adjusted Controllable Changes (Constant FY07 $)								
Controllable Change Ratio		1						1
Controllable Change Duration (days)		1	-1					
Controllable Change Duration Ratio		1	-1					
Adjusted Final Contract Amount (Constant FY07 $)								
Adjusted Final Project Amount (Constant FY07 $)								
Contract Cost Growth (%)								
Project Cost Growth (%)								
Contract Controllable Cost Growth (%)		1						
Project Controllable Cost Growth (%)		1						
Contract Schedule Growth (%)						1		
BOD Time Growth (days)						1		
BOD Growth (%)						1		
Contract Time Growth (%)	1					-1		1
BOD to Completion Duration (days)								
Award Growth (%)		1			1			
Unit Cost ($/sf)								
Project Placement ($/day)								1
Contract Intensity ($/sf/day)								
Project Intensity ($/sf/day)	1							
Total	2	6	-2	0	1	2	0	3

4.2.4.1 - Medical Type Facilities

This project type was composed of hospital and medical clinic projects and the results of the Student's t-test for this facility type are summarized in Table B-7. It should be noted that each project delivery method sample population was comprised of two projects, which is the minimum required to perform a t-test. If a data element was lacking in one project then a t-test could not be performed for that particular characteristic/metric. There was only one metric that proved to be significantly different between design-build and design-bid-build medical projects. Contract time growth for design-build projects was determined to be 33.5% compared to -3.47% on traditional medial projects.

On average medical projects contract duration was determined to be 544 days, and did not statistically vary between the two project delivery methods. As discussed earlier, the design time for traditionally delivered medical projects may last up to two years. Therefore, if this two-year design period were factored into the time growth for traditionally delivered projects the difference in time growth may not be significant. It could be argued that while the contract time growth was significantly longer for design-build medical projects the facility end users still received beneficial occupancy of the facility within a similar duration after the completion of project programming.

All other performance measures for medical construction projects were not significantly different between the two project delivery methods. It is interesting to note that the contract cost and cost growth for design-build medical facilities were nearly equivalent to traditionally delivered projects, even with the included design burden.

Based on the findings of this study there is a benefit to selecting design-build over traditional project delivery methods. However, due to the marginal size of the existing data set further research is recommended.

4.2.4.2 - Barracks Type Facilities

This type of facility exhibited better performance regarding controllable changes than design-bid-build barracks and housing projects. This category is composed of unaccompanied enlisted barracks/dormitories, officer barracks, and family housing projects.

On design-build barracks projects the ratio of the value of controllable changes to the value of overall changes was significantly lower than traditional barracks projects. Similarly, design-build barracks projects demonstrated a significantly lower value of controllable changes without a corresponding decrease in total or controllable change order values. This may be a symptom of the fixed appropriation funding system where the Resident Engineer and/or the District Engineer manages a contingency budget and as the likelihood of unforeseen changes diminishes increased user-requested changes may be approved. This "use it or lose it" philosophy would effectively change the distribution of change orders from unforeseen to user-requested without changing the total value of change orders executed.

Therefore, to gain the maximum financial benefit from the design-build project delivery method the owner must intensively manage user-requested changes and approve only those that are mission critical. The literature review shows that the Office of Medical Transformation is implementing this recommendation for BRAC, medical design-build projects.

4.2.4.3 - Training Type Facilities

This facility type included training ranges with a vertical construction component, such as urban warfare training facilities. This facility type also included classroom and hands-on instructional facilities as well as flight simulation facilities. Table B-10 demonstrates that significant differences between design-build and design-bid-build projects of this facility type related to time growth and project placement.

From Table B-10 it is shown that regardless of delivery method training type facilities experienced contract time growth. However, the time growth for design-build projects in this facility type was only 13% compared to 46% for traditionally delivered training facilities. Likewise, the increased project placement for design-build training projects indicates that the more effective and efficient construction management was obtained using the design-build project delivery method. This efficiency and effectiveness may be one of the key reasons that the time growth was substantially reduced on design-build training facilities.

4.2.4.4 – Administrative Type Facilities

As the name suggests this facility type was composed of administrative structures, which are predominantly interchangeable. Meaning, that a military unit can use the facility regardless of that unit's specialized mission requirements due to the flexibility in the facility design. Table B-13 reveals that administrative design-build projects experienced reduced contract time growth and increased placement rates compared with design-bid-build administrative projects.

The increased placement rates may explain a benefit of the ability of the design-build project delivery methodology to successfully leverage the experience of the design-builder. The carry-over effect is the reduced contract time growth on design-build projects relative to the design-bid-build administrative projects.

4.2.4.5 – Community Type Facilities

This facility type includes town halls, libraries, and chapels. Table B-49 clearly shows that the design-build performance regarding controllable change durations trailed design-bid-build performance for this facility type. This finding runs contrary to the expectations outlined in the literature review as well as the results from this study for the other facility types.

The fact that there was not a corresponding difference in the value of controllable changes or a difference in the ratio of the value of controllable changes to the amount of executed changes based on delivery method indicates that time may have been granted on the changes in lieu of money. This, in turn, may indicate that these projects were funding constrained to a greater extent than other facility types.

4.2.4.6 – Hypothesis Testing Results

The results of the hypothesis testing between design-build projects and design-bid-build projects based on the facility type are summarized in Table 10, below. From this table it is summarized that the design-build project delivery method is at least as good as traditional project delivery methods for the majority of facility types. This finding is in general agreement with earlier work performed by the Federal Construction Council regarding design-build project performance in the public-sector.

The primary benefits of the design-build project delivery method were determined to include:

- Reduced value of controllable changes
- Reduced contract time growth
- Reduced planning and design funding

It was also noted that in order to capitalize on the reduced value of controllable changes associated with the design-build project delivery methodology a stringent user-requested change policy must be implemented. Without this policy the project will be subjected to users attempting to "leave their mark" and the "use it or lose it" federal funding philosophy.

4.2.4.7 – ANOVA Test of Design-Build Performance by Facility Type

An analysis of variance test was performed on all design-build projects in an effort to determine whether the project performance for design-build projects was affected by the type of facility being constructed. The ANOVA analysis tested the following hypotheses:

$$H_o : \mu_{ad\min} = \mu_{barracks} = \mu_{community} = \ldots = \mu_{training}$$

$$H_5 : \mu_i \neq \mu_j \text{ For at least one pair } \mu_i, \mu_j.$$

Table 10. Hypothesis test summary between delivery methods based on facility type.

Facility Type	Accepted Hypothesis (H_0 or H_4)	Areas of Difference
Administrative	H_4	Time Growth less on design-build projects Project intensity is greater on design-build projects
Barracks	H_4	Controllable Change Ratio less on design-build projects Controllable Change Duration less on design-build projects Controllable Change Duration Ration less on design-build projects Controllable Cost Growth less on design-build projects
Community	H_4	Controllable Change Duration greater on design-build projects Controllable Change Duration Ratio greater on design-build projects
Food Service		
Infrastructure		
Maintenance - Aviation	H_0	
Maintenance - Ground	H_0	
Medical	H_4	Time Growth greater on design-build projects
Mobility		
Public Safety	H_0	
Security		
Special		
Storage		
Training	H_4	Time Growth less on design-build projects Project placement greater on design-build projects

The results of this analysis are shown in Table B-51. However, the only metric that was determined to significantly differ by facility type (α=0.10) was the award growth, which is a measure of the cost escalation between the architect or engineer's estimate and the contract award. The calculation of this metric requires that the architect or engineer's estimate to be known; which was not the case for the majority of facility types. Only five facility types had at least two projects where the estimated cost was known and these values are shown in Table 11. From that table the Public Safety facility type had only two projects with cost estimates and one cost estimate was significantly greater than the other. This affected the average value for that facility type and indicates that the acceptance of hypothesis H_5 for this metric. The award growth metric is extremely sensitive to market price fluctuations in materials and/or the quality of the architect/engineer's estimate. For example, during the time period of this study there was a rapid escalation in steel and plywood prices that may have affected the accuracy of the estimated cost.

Table 11. Award growth values used in ANOVA analysis.

Award Growth (p = 0.085472) (%)				
Public Safety (Design-Build)	Training (Design-Build)	Maintenance - Aviation (Design-Build)	Administrative (Design-Build)	Storage (Design-Build)
				65.12
8.41				
		-42.80		-33.61
	-45.43			
	-20.12	-36.51		
319.59		-45.86	-51.49	14.52
			-41.15	
		-50.54	170.92	
		6.26		
		4.33		
		-22.66		
		-25.69	-30.58	
			-27.07	

Award growth has been associated with the probability of project success on Navy construction projects falling below the MILCON threshold. (Jahren, 1991) However, the award growth characteristic does not, in and of itself, affect the performance of a construction project. Therefore, if this questionable result is neglected, the ANOVA analysis indicates that the design-build project delivery method may be used on the full range of facility types contained in this study without significant variation in performance.

4.2.5 – Geographical Influence

4.2.5.1 – Major Geographical Region

In earlier work performed by the Federal Construction Council it had been attempted to determine whether design-build performance differed based on geographic region. As such the United States was divided into four regions. This study was unable to determine if such a relationship existed, because each region in their study was dominated by a different federal agency. Therefore, they were unable to determine if any performance difference arose based on geography or if the performance difference was attributed to differing agency policies.

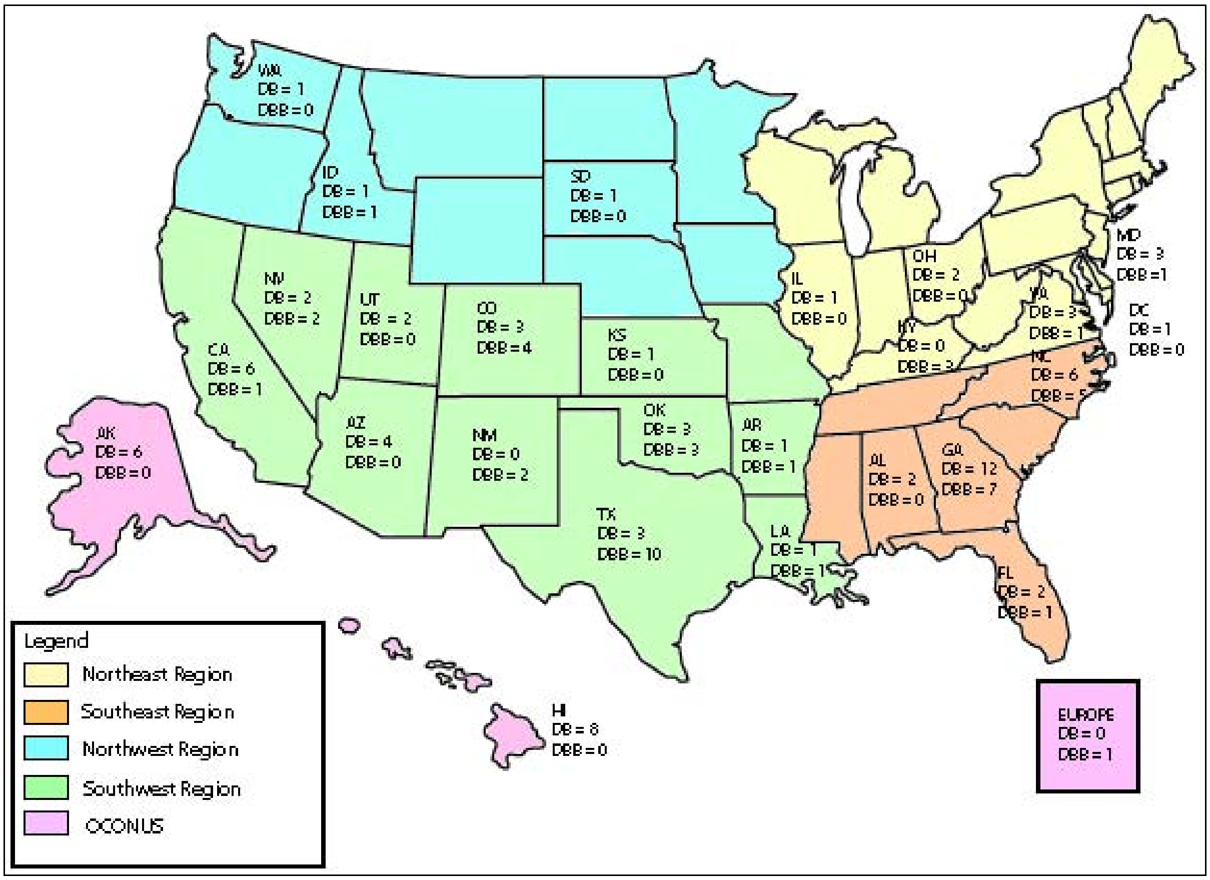

Figure 12. Geographic distribution of projects by project delivery method.

Because this study was comprised of data from only one federal agency, the USACE, the relationship between design-build performance and geography was explored. Figure 12, shows the geographic distribution of projects by type. In addition to the four regions used in the Federal Construction Council study a fifth region was added to account for work occurring outside the continental United States (OCONUS).

The data set was stratified by project delivery method and for each region and design-build projects were compared with design-bid-build projects through the use of a Student's t-test to test the following hypotheses:

$$H_0 : \mu_{design-build} = \mu_{design-bid-build}$$

$$H_6 : \mu_{design-build} \neq \mu_{design-bid-build}$$

Of the five geographic regions it was determined that only three had sufficient populations of both design-build and design-bid-build projects to perform a statistical analysis using the Student's t-test. Interestingly, the two regions with insufficient populations were lacking adequate numbers of traditional, design-bid-build projects. As discussed above a relative value matrix was prepared and is shown in Table 12, below.

The relative value matrix results are mixed as there is only one characteristic common to all three regions. In all regions the controllable changes on design-build projects accounted for a substantially lower portion of the total value of change orders. The rest of the substantial differences between design-build and design-bid-build project delivery methods cannot be grouped together reliably. However, the relative value matrix for the two "southern" regions was substantially positive indicating that the design-build project delivery method is beneficial. The northern region's negative relative value would seem to indicate that design-build projects do not out perform similar, design-bid-build projects. However, the lack of a significantly large data set for the northwest region requires further research or analysis before any definite conclusions regarding relationships between design-build performance and the geographical region may be drawn.

Table 12. Relative value matrix of design-build performance by geographic region.

Characteristic	Northeast Region	Southeast Region	Southwest Region
Adjusted Contract Award Amoun (Constant FY07 $)			
Adjusted Initial Project Amoun (Constant FY07 $)			
Adjusted Change Order Valu((Constant FY07 $)			
Adjusted Controllable Changes (Constant FY07 $)			
Controllable Change Ratic	1	1	1
Controllable Change Duratior (days)			
Controllable Change Duration Ratic		1	
Adjusted Final Contract Amoun (Constant FY07 $)			
Adjusted Final Project Amoun (Constant FY07 $)			
Contract Cost Growth (%)			
Project Cost Growth (%)			
Contract Controllable Cost Growtl (%)		1	
Project Controllable Cost Growth (%)		1	
Contract Schedule Growtl (%)	-1		
BOD Time Growth (days)	-1		
BOD Growth (%)	-1		
Contract Time Growth (%)	-1		1
BOD to Completion Duratior (days)			
Award Growth (%)			
Unit Cost ($/sf)			1
Project Placement ($/day)			1
Contract Intensity ($/sf/day)			1
Project Intensity ($/sf/day)	1		
Total	-2	4	5

4.2.5.2 – USACE District

The seemingly arbitrary nature of the regional boundaries was appropriate for the Federal Construction Council study which had a small data set comprised of four clusters. Since each district of the USACE has a geographic responsibility and the regions shown in Figure 10 do not coincide with these boundaries it was decided that an analysis of design-build performance by district could help answer two of the research questions. First, it may help to further answer whether there is a regional influence on design-build performance and second determine if one district was better at design-build than another district.

A relative value matrix was used to assist with deciding if one Corps district was better at design-build than another. Of the 41 geographical districts in the USACE only 17 are represented in the data set. The unrepresented districts may not have a military construction mission or their projects were screened out as explained earlier. The data set was stratified by project delivery method and for each district and design-build projects were compared with design-bid-build projects through the use of a Student's t-test to test the following hypotheses:

$$H_0 : \mu_{design-build} = \mu_{design-bid-build}$$

$$H_7 : \mu_{design-build} \neq \mu_{design-bid-build}$$

Of the 17 districts in the data set, only seven districts has a large enough population of both design-build and design-bid-build projects for analysis using a Student's t-test. (See Tables B-29 through B-42) As discussed above a relative value matrix was prepared and is shown in Table 9, below.

At this point it is worthy of mention that of the ten districts with populations too small for statistical comparison seven lacked the requisite population of design-bid-build projects. This demonstrates, at least anecdotally, that the USACE is moving toward the design-build project delivery method as the standard of choice.

The relative value matrix shown in Table 9, below, demonstrates that of the seven districts analyzed their application of design-build does not yield standardized project performance. While the project population mix was different for each district, the results of the relative value matrix are beyond question. Those districts with a positive total value were ones where the significant advantages of design-build performance outnumbered the disadvantages. The districts with a negative total value were ones where the significant disadvantages of design-build performance outnumbered the advantages. Districts with a value of zero exhibited no statistical difference in design-build performance as compared to traditional project performance.

The use of this relative value matrix is sensitive to the number of occurrences of an event. When two project characteristics portray the same information in two different ways the district will be rewarded or penalized for both characteristic. For example BOD time growth expressed as a percentage and BOD time growth expressed as a number of days essentially measure the same performance metric two different ways. While the magnitude of the relative value shown in the matrix is sensitive the overall ranking is not.

Figures 13 and 14 demonstrate that within each district of the USACE design-build is used on different types of projects. From these figures it is clearly evident that each district uses the design-build project delivery method is used on different types of projects.

4.2.5.2.1 – Baltimore District

Table 13 has established that using a relative value matrix design-build performance lags behind design-bid-build performance in the Baltimore district. Specifically, change order values are significantly greater on design-build projects which results in greater cost growth compared with design-bid-build projects. To put these results into context, the design-build performance is based on six projects of five different facility types. This means that the Baltimore district has the third largest number of design-build projects in this

Table 13. Relative value matrix of design-build performance by district.

Characteristic	Baltimore District	Savannah District	Louisville District	Fort Worth District	Tulsa District	Omaha District	Los Angeles District
Adjusted Contract Award Amount (Constant FY07 $)							0
Adjusted Initial Project Amount (Constant FY07 $)							0
Adjusted Change Order Value (Constant FY07 $)	-1						-1
Adjusted Controllable Changes (Constant FY07 $)			1				-1
Controllable Change Ratio		1	1				
Controllable Change Duration (days)	-1						
Controllable Change Duration Ratio		1					
Adjusted Final Contract Amount (Constant FY07 $)					0		0
Adjusted Final Project Amount (Constant FY07 $)							0
Contract Cost Growth (%)	-1						-1
Project Cost Growth (%)	-1						-1
Contract Controllable Cost Growth (%)	-1	1	1				-1
Project Controllable Cost Growth (%)	-1	1	1				-1
Contract Schedule Growth (%)		1	-1			-1	-1
BOD Time Growth (days)		1	-1				-1
BOD Growth (%)		1	-1			-1	-1
Contract Time Growth (%)				1			-1
BOD to Completion Duration (days)							
Award Growth (%)							-1
Unit Cost ($/sf)							
Project Placement ($/day)							
Contract Intensity ($/sf/day)							
Project Intensity ($/sf/day)							
Total	-6	7	1	1	0	-2	-11

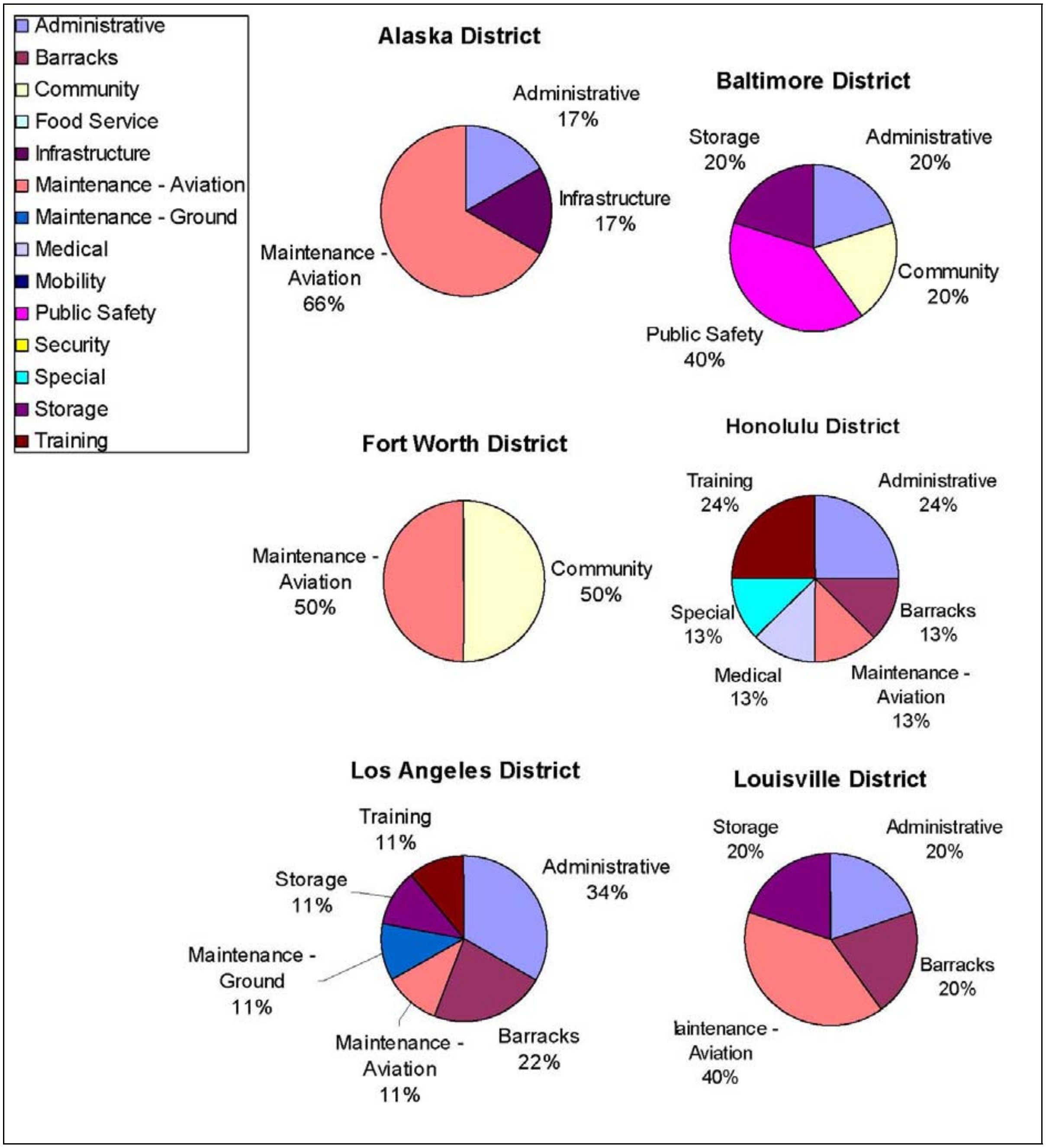

Figure 13. Design-build facility types by district, 1 of 2.

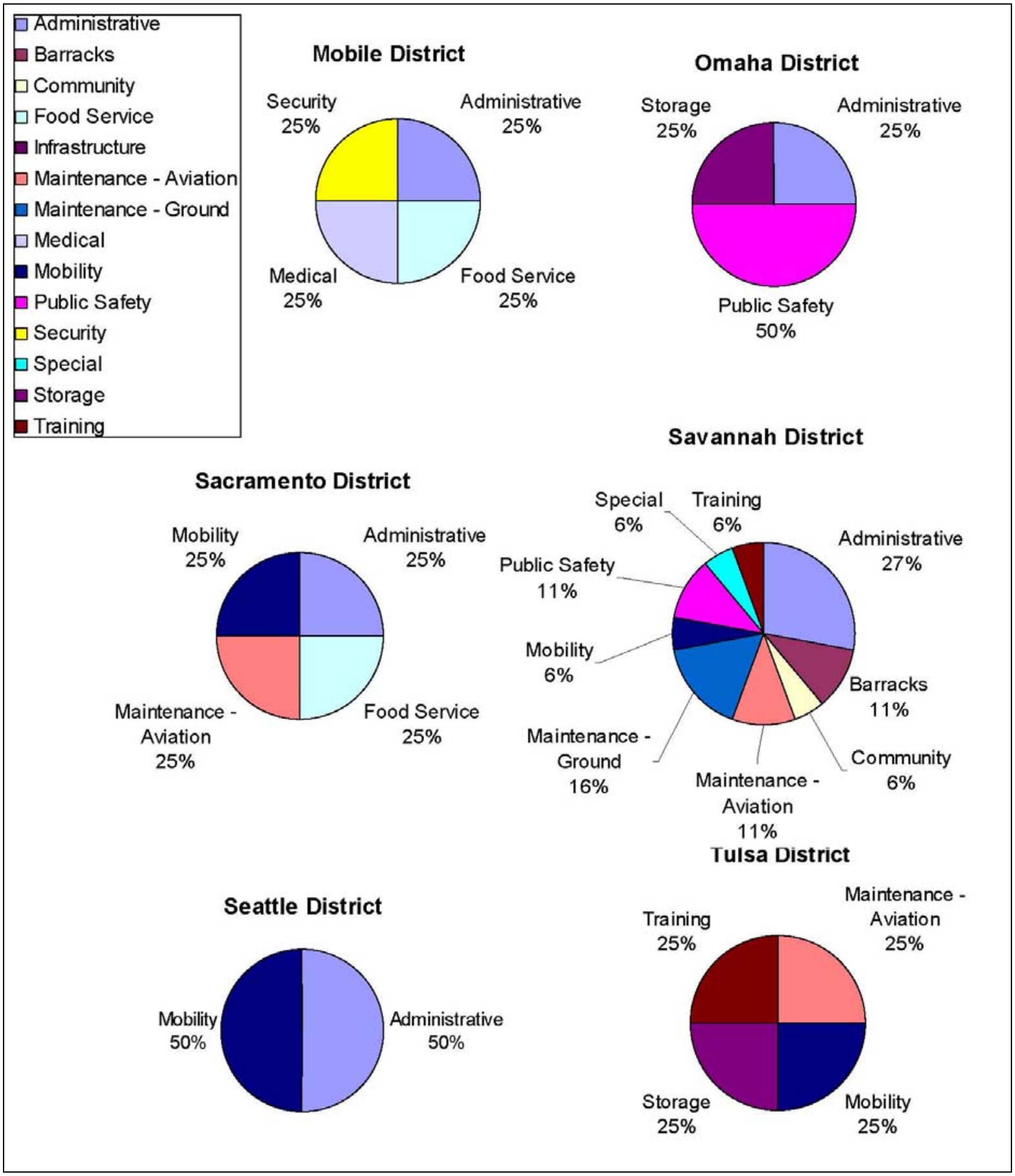

Figure 14. Design-build facility types by district, 2 of 2

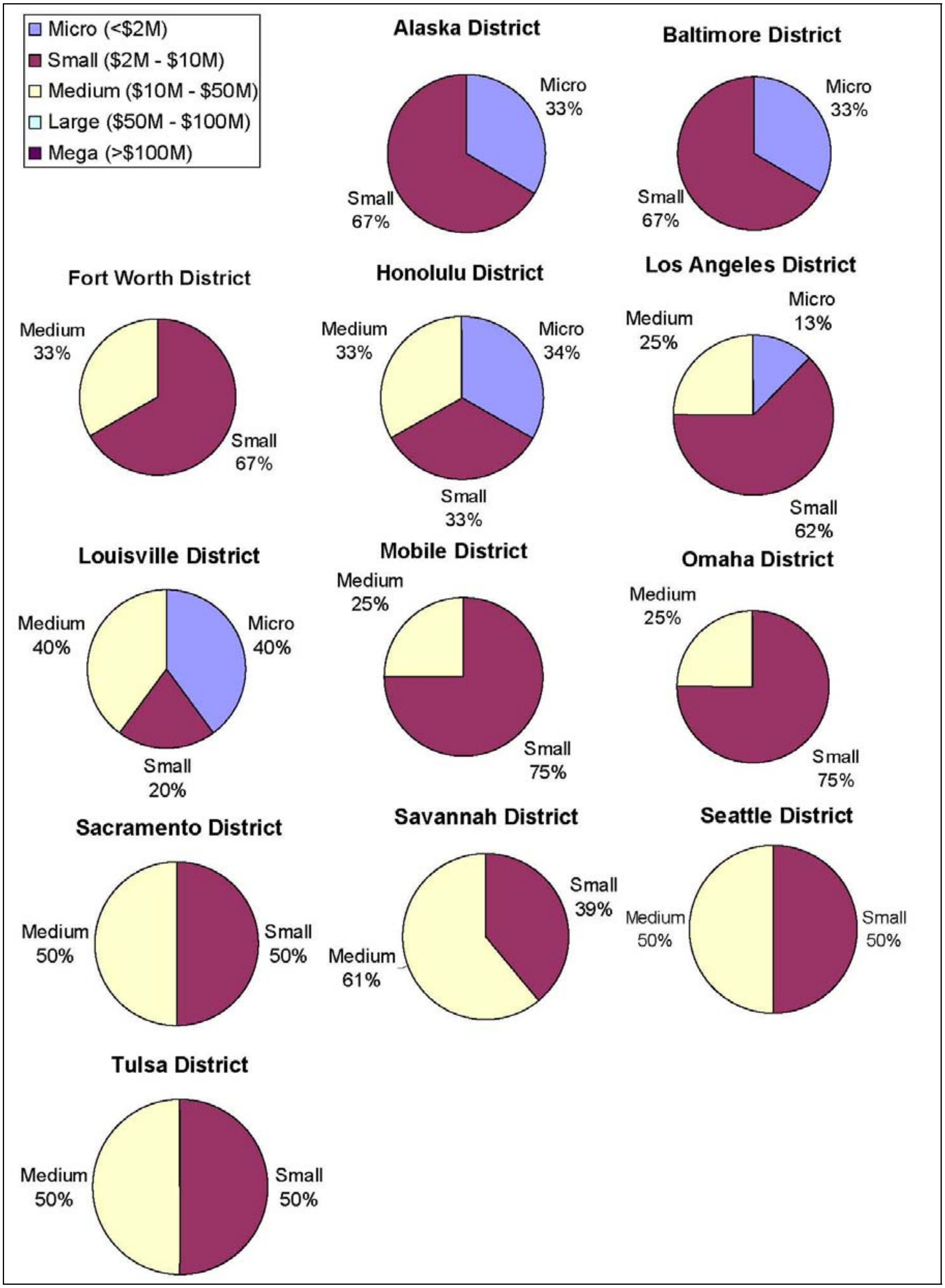

Figure 15. Design-build project sizes by district.

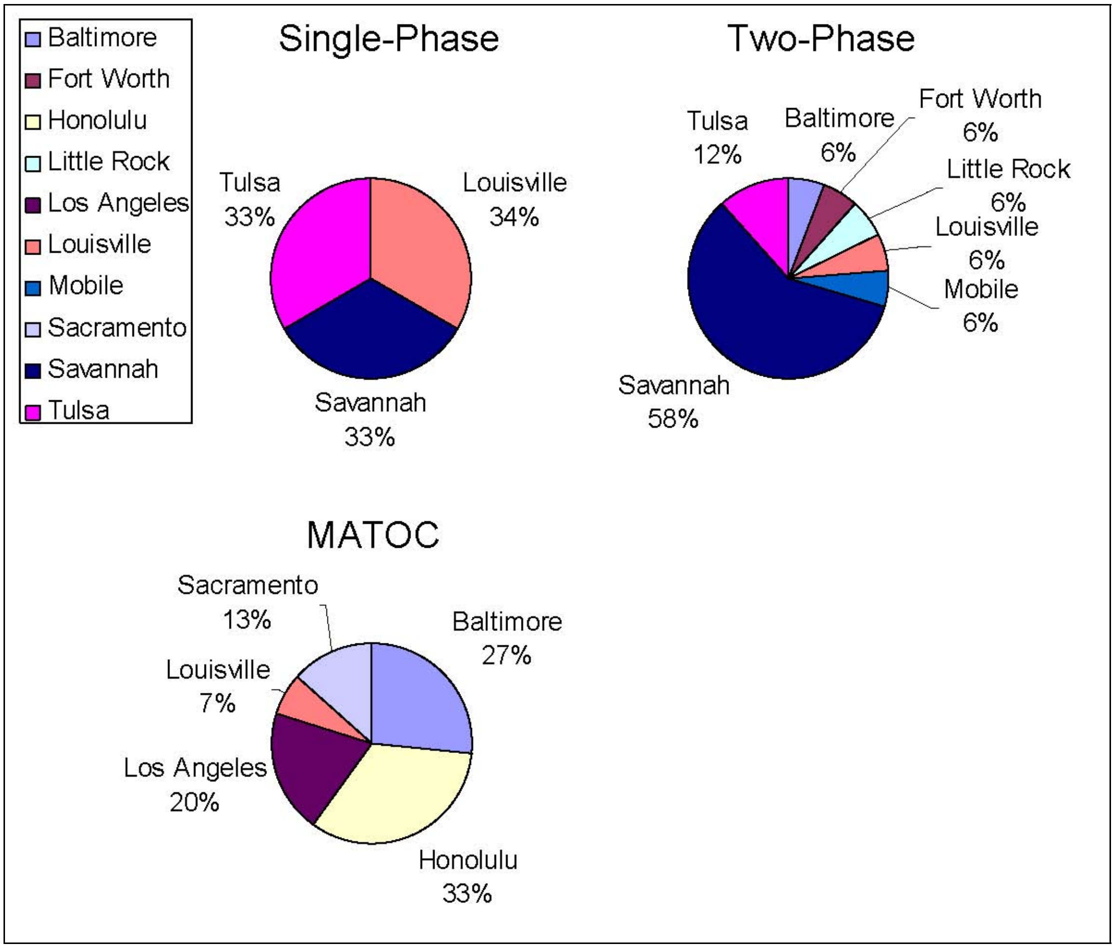

Figure 16. Design-build contracting method by district.

analysis. It was shown earlier that design-build performance does not significantly vary with the type of facility. Figure 15 shows that the majority of the design-build projects awarded in the Baltimore district were categorized as "small" with contract award values ranging from $2-10 million. Figure 16 shows that the district's preferred method of awarding a design-build project was through the use of MATOC contracts.

4.2.5.2.2 – Los Angeles District

The relative value matrix indicates that the performance of design-build projects lag significantly behind design-bid-build projects in the Los Angeles district. The t-test results are shown in detail in Table B-41; however, there was a significant difference in contract values by project delivery method. Larger contracts were awarded using the design-build project delivery method with an average value in excess of $9 million compared to less than $800,000 for design-bid-build projects. Therefore, the value of change orders executed on the design-build projects was significantly greater which in turn affected the rest of the cost growth metrics. Likewise, since larger projects take longer the same trends were noted for schedule growth. It is likely that the lackluster design-build performance may be an result of the difference in average contract values by delivery method.

The design-build performance is based on eight projects of six different facility types, which gives the Los Angeles district the second largest number of design-build projects in this analysis . Figure 15 demonstrates that the majority of the design-build projects are of a small size, ranging from $2-10 million. Figure 16, indicates that all of the design-build projects for this awarded through the use of MATOC contracts.

4.2.5.2.3 –Savannah District

The relative value matrix indicates that design-build performance in the Savannah district is better than the design-bid-build project delivery method. Specifically, lower values of controllable changes were executed with a correspondingly smaller duration associated with controllable changes. Cost growth for design-build projects was, on average, half that associated with design-bid-build projects.

These performance metrics were calculated from 18 projects of nine facility types. According to Figure 15, these projects were predominately medium in size and ranged from $10-50 million. Figure 16, shows that Savannah district awarded these projects through the use of single-phase and two-phase solicitations with no MATOC contracts awarded.

4.2.5.2.4 – Analysis of Variance for Design-Build Performance by District

The overall variation demonstrated in the relative value matrix required the use of an ANOVA analysis to determine if design-build performance varied by district. This analysis tested the following hypotheses:

$$H_o : \mu_{Mobile} = \mu_{Savannah} = \mu_{Baltimore} = ... = \mu_{Seattle}$$

$$H_8 : \mu_i \neq \mu_j \text{ For at least one pair } \mu_i, \mu_j.$$

The results of this analysis are shown in Table B-50 and reveal a difference in design-build performance regarding contract cost growth, controllable cost growth and award growth between districts (when α=0.10). In the case of contract cost growth it would be assumed that the district with the most experience would have the lowest cost growth. However, that finding was not substantiated; rather Seattle district with the fewest design-build projects had an almost equivalent contract cost growth rate as Savannah district with the largest number of design-build projects. A detailed review of Table 14 reveals that Louisville district provides the best probability of a low cost growth on design-build projects with an average cost growth of 2.79% and a variance of only 1.64%.

The analysis of controllable cost growth is summarized in Table 15. As with contract cost growth, the lowest controllable cost growth values do not seem to correlate to the number of completed design-build projects. In this case, the lowest controllable cost growth is achieved by Seattle district with 0.38% and a variance of 0.07%. However, the Seattle district only had two design-build projects in the data set and the fewest of all of the districts in the ANOVA analysis.

Finally, as discussed earlier the award growth metric is extremely sensitive to material price fluctuations and there was limited data regarding the architect/engineer's estimate available to this study. While the award growth does not, by itself, affect design-build performance it has been an indicator of project performance in earlier research. (Jahren, 1991) The results of the analysis are summarized in Table 16 and indicate that for the majority of design-build projects a negative award growth is expected. However, Sacramento district experienced a large, positive award growth on one of two total projects. This one project affected the average award growth for the district and the ANOVA test results.

Table 14. ANOVA analysis summary for design-build contract cost growth by district.

Groups	*Count*	*Sum*	*Average*	*Variance*
Mobile District (Design-Build)	4	20.49767	5.124418	3.005793
Savannah District (Design-Build)	18	70.12533	3.895851	16.00637
Honolulu District (Design-Build)	8	23.44664	2.93083	8.46006
Tulsa District (Design-Build)	4	40.45615	10.11404	80.94837
Alaska District (Design-Build)	6	47.09531	7.849218	22.30601
Sacramento District (Design-Build)	4	21.35472	5.33868	19.34145
Baltimore District (Design-Build)	6	56.78246	9.463743	45.66126
Louisville District (Design-Build)	5	13.96355	2.792711	1.64126
Omaha District (Design-Build)	4	17.14025	4.285063	3.086901
Fort Worth District (Design-Build)	3	4.388899	1.462966	2.19747
Los Angeles District (Design-Build)	8	39.57583	4.946979	30.77548
Seattle District (Design-Build)	2	7.476206	3.738103	4.198895

Table 15. ANOVA summary for design-build controllable cost growth by district.

Groups	*Count*	*Sum*	*Average*	*Variance*
Mobile District (Design-Build)	4	7.01618	1.754045	6.568334
Savannah District (Design-Build)	18	22.71185	1.261769	2.250023
Honolulu District (Design-Build)	8	12.45397	1.556746	1.790725
Tulsa District (Design-Build)	4	21.57797	5.394493	36.43036
Alaska District (Design-Build)	6	22.8773	3.812883	29.1971
Sacramento District (Design-Build)	4	14.88634	3.721584	28.57569
Baltimore District (Design-Build)	6	31.43054	5.238424	23.88338
Louisville District (Design-Build)	5	3.742114	0.748423	1.073337
Omaha District (Design-Build)	4	6.073067	1.518267	2.139013
Fort Worth District (Design-Build)	3	1.521885	0.507295	2.185147
Los Angeles District (Design-Build)	8	6.939618	0.867452	1.616646
Seattle District (Design-Build)	2	0.751605	0.375802	0.065941

Table 16. ANOVA analysis summary for design-build award growth by district.

Groups	*Count*	*Sum*	*Average*	*Variance*
Honolulu District (Design-Build)	5	-239.718	-47.9437	52.67603
Alaska District (Design-Build)	4	-180.521	-45.1302	36.71508
Sacramento District (Design-Build)	2	164.05	82.02501	15804.19
Louisville District (Design-Build)	3	-55.5679	-18.5226	98.18704
Fort Worth District (Design-Build)	3	-10.526	-3.50866	67.90024
Los Angeles District (Design-Build)	4	-78.0496	-19.5124	328.6112

4.2.5.3 – Results

From the t-tests, relative value matrix, and ANOVA analysis it is not possible to comprehensively determine whether design-build performance varies by geographical region. The data set was not large enough to allow for comparison of all major geographical regions. When the data set was parsed by the USACE districts, results indicated that in some districts the design-build project delivery method outperformed the design-bid-build method. Other districts showed the opposite trend. It was then shown that design-build project sizes and contracting methods differed by district.

A district is still composed of multiple installations. It may still be possible for one installation to be very good at design-build and another installation within the same district to not be as well versed in the use of design-build. Any one or all of these unknowns may have influenced the analysis of design-build performance by geographical region. It may prove necessary in the future to collect a larger data set and look at design-build performance by installation. It would also be beneficial to determine how design-build performance varies by acquisition method and by project size. Unfortunately, these tests are currently beyond the scope of this study.

4.2.6 – Change Orders

The data set was stratified based on project delivery method and an aggregate comparison of design-build performance to design-bid-build performance was made using a t-test. The results of this test are shown in Table B-1; however the pertinent information related to project changes have been extracted and are shown in Table 17 This analysis tested the following hypotheses:

$$H_0 : \mu_{design-build} = \mu_{design-bid-build}$$

$$H_9 : \mu_{design-build} \neq \mu_{design-bid-build}$$

Table 17. T-test summary regarding project cost.

Characteristic	Total Sample Mean	Design-Build Mean (75 Projects)	Design-Bid-Build Mean (44 Projects)	Probability
Adjusted Change Order Value (Constant FY07 $)		474,532.70	1,292,701.01	0.10954
Adjusted Controllable Changes (Constant FY07 $)		173,377.10	317,942.56	0.12449
Controllable Change Ratio		0.42	0.66	0.02036
Controllable Change Duration (days)	48.19			
Controllable Change Duration Ratio	0.34			
Contract Controllable Cost Growth (%)	2.07			
Project Controllable Cost Growth (%)	2.03			

The t-test comparison of design-build projects vs. design-bid-build projects reveals significant differences related to change orders. From Table 17, it is noted that on the average the value of change orders on design-build projects was dramatically lower compared to design-bid-build projects. While the probability for this t-test was just over 10%, this finding initially validates other work indicating that the design-build, team based project delivery method will reduce change order value.

Furthermore, Table 17 indicates that design-build projects experience significantly fewer controllable changes compared with design-bid-build projects. As discussed earlier, controllable changes were required/field changes while uncontrollable changes are summarized as user-requested changes. The use of the word "controllable" is related to the fact that the contractor (or design-builder) is best able to control the cost and time impact of these changes. Therefore, it appears that the design-build project delivery method will result in a lower value of controllable changes than the design-bid-build project delivery method.

CHAPTER 5 – CONCLUSIONS AND FUTURE RESEARCH

5.1 – Introduction

All construction projects are different with end result of any military construction project being influenced by the characteristics of the project, the project delivery team, the construction environment, and the political environment. However, the belief which guided this study was that with a sufficiently large and uniform sample population the effects of these unquantifiable influences may be mitigated. Statistical treatment of all data elements was not attempted. For example it may have been possible to look for project performance differences by project delivery method by service component (Army vs. Air Force). It may also have been possible to look for performance differences between new construction and renewal projects.

Based upon the amount of data collected and the results of the analysis performed in Chapter 4 additional, similar studies may explore other possible relationships in the future. This study did showcase many of the benefits of applying the design-build project delivery method to military construction projects.

5.2 – Research Questions

5.2.1 – Time

This study has shown that there design-build MILCON projects may, on the average, experience greater contract schedule growth than design-bid-build projects. It was also demonstrated that delays in BOD were greater for design-build projects than design-bid-build projects. However, it must be noted that these differences are marginally significant. In fact, delays in BOD may be affected more by decisions to take early beneficial occupancy for select projects.

The more important finding was the increased contract schedule growth on design-build projects, which initially seems counter to almost all other published research. However, this is only a measure of the contract performance period increase. As such this includes the design of the facility on design-build projects, which is a separate contract on design-bid-build projects with its own performance period of 1-2 years. What remains unanswered is if the design of design-bid-build projects was included, which project delivery method will complete the facility first? Due to the limited design data available in the WebCMI application this analysis was beyond the scope of this study. A *project delivery time* comparison, rather than a contract delivery time comparison, is required in future work. This project delivery time will be the contract performance duration for design-build projects and the design contract performance duration plus the construction contract performance duration for design-bid-build projects. It is believed that a project delivery time comparison will reveal that the design-build project delivery method provides for more rapid facility delivery to the customer/end-user.

5.2.2 – Cost

This study has demonstrated that among the characteristics related to cost there is not a significant difference between project delivery methods. What was demonstrated was that design-build projects, on the average, have more efficient and effective construction management.

It is important to note that even though there was not a significant difference in the cost performance between project delivery methods the design-build method still enjoys a cost advantage. The example used in section 4.3.2 revealed that by avoiding the use of planning and design funds on design-build projects, estimated at 6% of the project award amount, those funds will be freed up for use elsewhere within the USACE, Army, or DoD. Essentially, the design-build project delivery method provides more value for the money with the inclusion of design services in the contract award amount.

5.2.3 – Quality

The quantitative research methodology of this study and the availability of qualitative data made determination of project quality variation by delivery method impossible. A separate data set specifically compiled to address quality issues would be required in order to answer this research question.

5.2.4 – Facility Type

The analysis of design-build performance compared to design-bid-build performance by facility type revealed that design-build performed at least as well as design-bid-build. In many cases the design-build project delivery method outperformed the design-bid-build method. As further confirmation, an ANOVA analysis revealed that there was no significant variation in design-build performance by facility type.

5.2.5 – Geography

This study showed that design-build performance relative to design-bid-build performance varied by geographical region as well as USACE district. Furthermore, design-build performance varied between USACE districts as well. It is unfortunate that there is no commonality regarding which characteristics varied by geographic location. It is believed that differences in design-build projects, such as size and acquisition method may be affecting this variation. Another possible explanation may lie in the diversity with a district, which is comprised of multiple installations. Since, design-build is predominately a team-based project delivery method and the team and experience level would vary by installation a more apt analysis may be to determine how design-build project performance varies by installation.

Finally, the investigation of design-build performance variance by geographical region may become a moot point. Under MILCON transformation the USACE is transitioning toward centers of expertise for specific facility types. As this process is completed and lessons learned are centralized by specific facility types there should be reduced variation by district by facility type. What may result instead is variation in design-build performance by facility type, which was not observed in the current data set.

5.2.6 – Change Orders

The analysis compared all design-build projects to design-bid-build projects and differences regarding changes were noted between the two project delivery methods. First, on the average, design-build projects experienced a lower total value of changes orders and a lower total value of controllable changes. The probability for these findings was greater than 10%, but less than the 15% significance level used in this study. However, it was also shown that design-build projects experienced significantly fewer controllable changes with the associated probability of 2%, indicating a strong statistical significance.

5.3 – External Validation of Research Results

Scientific and scholarly work must be accurate, verifiable, and reproducible to be of value. In the case of this study, projects are continually being added to and deleted from the WebCMI database. Therefore, it would be expected that the exact value of a metric may vary slightly with time and project mix, however the results should remain the same due to the size of the data set and the relatively constant relationships of cost and compositions shown in Figures 4 and 6.

External validation attempts to relate the findings of this study with other, similar studies in the design and construction industries. For example, the Reading University design-build study concluded that 75% of design-build projects completed within 5% of budget, compared with 63% on traditional projects. (Molenaar, 2003) This study determined that 67% of design-build projects completed within 5% of the initial contract amount, compared to 57% for traditional design-bid-build projects. Therefore, it is concluded that the data set used in this study generally follows trends noted in other works with variations arising from the limitation of the data set to military construction projects executed by a single organization.

Published literature suggested that unforeseen or controllable changes and the overall costs of change orders should be lower on design-build projects. (Riley, 2004) Furthermore, other research related to MILCON projects has concluded that the design-build project delivery method results in fewer and less costly changes. (Robert A. Perkins, unpublished manuscript 2007) The trends noted in this study validated these findings due to the resulting lower value of change orders as well as the reduced value of controllable changes.

5.4 – Research Limitations

It needs to be noted that the results of this study are not necessarily applicable to other types of projects. The sample population was limited to only military construction projects with a vertical construction component. These projects were appropriation funded and therefore projects that require financing may have different delivery speeds and durations based on the availability of funds.

The financial performance of traditional, design-bid-build projects may be different than shown in this study due to the fact that design costs were assumed to be 6% of the base contract award. It was not possible to collect information on the owner's administrative burden for design-build or design-bid-build projects. In the future this information may become, available if activity based costing (ABC) resource management systems continue implementation.

The assignment of risk between the owner and the design builder will affect the administrative burden of the owner. The information to include this aspect of administrative burden was outside of the scope of this study, however, it may be potentially included in future research on a smaller sample size by careful review of the contract using content analysis techniques.

Careful application of screening criteria to the data set was meant to ensure a highly accurate separation of projects into two sub populations of design-build and traditional, design-bid-build. However, since the WebCMI application is secondary data there is still a possibility that projects were misclassified, which can adversely impact the analysis contained in this study.

The metrics used to evaluate project performance in this study assessed only cost and time. The WebCMI application does not contain any information which may be used to assess project quality. Such information would have to be collected from an alternate source using alternative means, such as questionnaires, commissioning reports or post occupancy evaluations.

5.5 – Future Research

5.4.1 – Design-Build Project Quality

Based on the limits of empirical research and the available data set contained in this study the research question the determination of how the project delivery method affects project quality was left unanswered. Future research may be able to better address this question by tapping existing conduits for qualitative information.

Qualitative data may be included in future research as post occupancy evaluations are conducted on major Med-MILCON projects by the USAHFPA. It is envisioned that the post occupancy evaluation process may reveal lessons learned that may be applied to future projects. The existing user satisfaction survey tool, which is completed prior to the post occupancy evaluation, may also provide valuable data. Both the lessons learned and the satisfaction survey will allow for quality assessments to be performed through content analysis. Finally, commissioning reports and maintenance data extracted from the Defense

Medical Logistics System Standard – Facilities Management (DMLSS-FM) may provide valuable empirical data to substantiate subjective quality assessments of completed medical construction projects.

5.4.2 – Required Project Performance Levels

The USACE currently performs a periodic project status review at the district, division and/or program levels. Each project is compared against a standard metric range and those projects falling outside of the range are identified as at-risk. These at-risk projects require detailed explanation in verbal and/or written format during the periodic reviews along with potential follow-up actions. Essentially, this process forces projects to achieve a desired performance level. If this performance level is not set substantially high the process may unfortunately encourage projects to achieve mediocrity. If the level is set too high many projects will fail to achieve the standard resulting in an unwieldy review process. The only performance criteria that could be located at the time of this study related to Air Force projects and were know as "Dirtkicker standards."

As discussed earlier the USACE is changing the performance requirements to achieve a substantial time and cost benefit across all projects, regardless of service. Future research will have to account for the USACE requisite project performance criteria to determine whether the performance objectives have been met. If the future research is limited to only medical projects then a USAHFPA definition for project performance standards may be incorporated to judge project performance in lieu of any USACE criteria.

5.4.3 – Contracting Methodology

Other studies have divided the project delivery method into sub populations based on contract type, which was beyond the capability of this study due to the limited, verifiable contract information. Inclusion of the Standard Form 1442, Solicitation Offer and Award, for each project in a future data set as well as the project advertisement will provide more reliable data concerning the acquisition method utilized. Project acquisition and delivery methodology could be analyzed for potential impact on project performance.

5.4.4 – Project Delivery Cost and Time

This study focused on military construction funded projects and only approximated design costs. Inclusion of design contract information on design-bid-build projects would allow for accurate representation of project delivery time rather than the contract performance durations used in this study. Project–specific activity based costing (ABC) data may be included for both delivery methods to better represent total burdened cost of a project. If this information is factored into a future analysis, then the differences between project delivery methods may better be determined.

Furthermore, in order to assess the shortcomings of the award growth metric a program growth metric may be used as was done with the earlier design-build research of NAVFAC projects. By inclusion of the estimated program amount from the Department of Defense Form 1391 the future work would not be at the mercy of material cost fluctuations associated with the award growth metric. The regimented process in preparing the DD Form 1391 and the program information would allow for a program growth metric to measure the difference between the programmed amount and final contract amount. This program growth metric could then be analyzed by project delivery method and used to determine which resulted in the least growth. A similar metric has shown a tie between project success on smaller Navy projects. (Jahren, 1991, Mouritsen, 1993) Because the DD Form 1391 is completed prior to the selection of a project delivery method it is will not take into account any perceived benefits of any particular delivery method and will serve as a good basis for comparison.

However, due to the effort in obtaining and evaluating this cost information, the data set in future projects may be greatly reduced when compared with the current study. This reduction in sample size would be compensated for with improved quality and reliability of the data.

5.4.5 – Project Size

This study was comprised of projects in the micro to medium size range and therefore performance of the design-build project delivery method may only be extrapolated for larger projects. Based on the currently pending Army Transformation and BRAC workload it is extremely likely that larger projects will be included in future work, thus improving its predictive power.

5.4.6 – Qualitative Data

As noted throughout this study a quantitative study can only answer the question of how much. The solution to the question of why can only be inferred. Therefore, any future work must include a method for acquisition an analysis of both quantitative and qualitative data. This may take the form of surveys solicited from Resident Engineers, Health Facility Project Officers, or similar project expert and analyzed using content analysis and/or Likert scale. The use of case studies may also be implemented in future work to help answer qualitative questions. Only through a combination of the two methods can we determine answers to the pertinent questions of why and by how much.

5.5 – Conclusions

Based on this study it may be concluded that design-build projects executed by the USACE are not meeting the expectations set by published literature. This does not mean that the use of design-build is not advantageous to the federal government, only that there is room for improvement in the application. By its very definition the government enjoys reduced liability for design deficiencies on design-build projects. While there is no statistical difference, on an aggregate basis, between contract cost growth or unit cost, the expense associated with planning and design on traditional design-bid-build projects can be cost shifted elsewhere by the use of design-build. Those funds could be reprogrammed for other use within the Department of Defense thereby freeing up resources.

It will be interesting to note whether the USACE meets their aggressive MILCON transformation goals. Based on the current performance levels it may be possible to achieve the 15% cost savings while simultaneously reducing project delivery time by 30%. While this has been achieved on a handful of projects to date, a concerted effort and fundamental change in the application of the design-build project delivery method is required. An initial step is in place with the Military Health System – Office of Transformation's requirement to largely eliminate change orders during construction. The standard RFP process being implemented by the USACE on MILCON Transformation projects is another important step. By capping the bid amounts and transitioning from prescriptive specifications toward performance-oriented specifications improves the likelihood of attaining reduced project costs.

However, in order to determine the true financial performance difference between project delivery methods may require a change in measurement and reporting of fund expenditures. Currently, the planning and design funds are handled separate from the MILCON funds for construction of traditional, design-bid-build projects. A comparison of MILCON fund expenditures between design-build and design-bid-build projects does not show the whole picture. Only when the planning and design funds are aggregated with the MILCON funds on design-bid-build projects can a true comparison of cost performance be achieved. While this information exists within the various reporting system the "total cost" of a project needs to be articulated to USACE customers and the public to better demonstrate the true cost advantages of the design-build project delivery method.

The most important step to attaining the MILCON Transformation goals will be the shift from the adversarial design-bid-build mentality toward a team-based design-build process. This transition is well underway based upon earlier research conducted on the USAHFPA's renewal program as well as the large percentage of design-build work being awarded by the USACE. Only by capitalizing on past experiences with the design-build project delivery method and successfully leveraging that experience into future projects will the Army truly be able to attain the goals of MILCON Transformation.

APPENDIX A – DATA ELEMENTS

The following data elements were acquired directly from the WebCMI application or were calculated using the formulas shown:

Actual BOD

This is the date on which beneficial occupancy occurred.

Actual Construction Completion

This is the date that the construction was considered complete.

Actual Contract Award

This is the award date of the contract as shown in the RMS information within the WebCMI application.

Actual NTP

This is the date on which NTP was acknowledged by the contractor as shown in the RMS information within the WebCMI application.

Adjusted Change Order Value

$$Adjusted\ Change\ Order\ Value = \frac{Change\ Order\ Value}{[(ACF)(Time\ Adjustment\ Factor)]}$$

The value of approved and completed change orders is adjusted from current dollars to an equivalent FY07 dollar amount. Adjustment factors for location and time were applied to effect this adjustment. No adjustment for size was applied due to the disruptive nature and limited scope of change orders.

Adjusted Contract Award Amount

The contract award amount was adjusted for location, size, and time to convert the current dollar amount to an equivalent constant FY07 dollar amount.

$$Adjusted\ Contract\ Award\ Amount = \frac{Contract\ Award\ Amount}{Total\ Adjustment\ Factor}$$

Where:

$$Total\ Adjustment\ Factor = (ACF)(Time\ Adjustment\ Factor)(Size\ Adjustment\ Factor)$$

Adjusted Controllable Changes

The value of the controllable changes must be adjusted from current dollars to an equivalent constant FY07 dollar amount. As with change orders, this value was only adjusted for location and time using the following equation:

$$Adj.\ Controllable\ Changes = \frac{(Controllable\ Changes)}{[(ACF)(Time\ Adjustment\ Factor)]}$$

Adjusted Construction Budget

The construction budget was only adjusted for time. It was assumed that the original estimate had accounted for regional cost variations (ACF) as well as size variations (economies of scale). The adjusted construction budget was calculated with the following formula:

$$Adjusted\ Construction\ Budget = \frac{Construction\ Budget}{Time\ Adjustment\ Factor}$$

This value may also be described as the engineer's estimate. The Adjusted Construction Budget results in a constant FY07 dollar amount. This value was only adjusted for time because it was assumed that the A/E would already have accounted for project size and location.

Adjusted Estimated Design Cost

The following formula yields the estimated design cost in constant FY07 dollars.

$$Adjusted\ Estimated\ Design\ Cost = \frac{Estimated\ Design\ Cost}{Design\ Time\ Adjusment\ Factor}$$

The Design Time Adjustment Factor was used to convert the estimated design cost into constant FY07 dollars. The Design Time Adjustment Factor assumes that the design contract is awarded one fiscal year before contract award, except for medical projects which will normally begin design two fiscal years prior to construction contract award (Design, 2003). Once assumed fiscal year of design contract award was determined then the Design Time Adjustment Factor was determined using the composite index for military construction funds as published annually by the Army Budget Office.

Adjusted Final Contract Amount

$$Adj.\ Final\ Contract\ Amount = (Adj.\ Contract\ Award\ Amount) + (Adj.\ Change\ Order\ Value)$$

This is the sum of adjusted contract award amount and the adjusted change order value expressed in constant FY07 dollars.

Adjusted Final Project Amount

$$Adj.\ Final\ \mathrm{Pr}oject\ Amount = (Adj.\ Final\ Contract\ Amount) + (Adj.\ Est.\ Design\ Cost)$$

This is the sum of the adjusted final contract amount and adjusted estimated design cost expressed in constant FY07 dollars. This value approximates the cost of project delivery from design through construction completion regardless of project delivery methodology.

Adjusted Initial Project Amount

This is a better representation of the true cost of the project because it attempts to incorporate the design cost in design-bid-build projects. This value is represented in constant FY07 dollars and is calculated using the following formula:

$$Adj.\ Init.\ \mathrm{Pr}oject\ Amount = (Adj.\ Contract\ Award\ Amount) + (Adj.\ Est.\ Design\ Cost)$$

Authorized Year / Program Year

The program year is the fiscal year in which contract award is to be made with design starting on traditional projects one year prior to the program year for all types except medical. Medical projects may start design two years prior to the program year. The authorized year is the year in which authorization was received from Congress. It is normal when the authorized and program years are the same, however, it is not uncommon for the values to differ by up to one year.

Award Growth

$$Award\ Growth = \left\{ \frac{[(Adj.\ Contract\ Award\ Amount) - (Adj.\ Construction\ Budget)]}{(Adj.\ Construction\ Budget)} \right\} \cdot 100$$

This value is expressed as a percentage.

BOD Growth

$$BOD\ Growth = \left[\frac{(BOD\ Time\ Growth)}{(BOD\ Performance\ Duration)} \right] \cdot 100$$

This metric measures how close to the planned beneficial occupancy date the project could accomplish it intended function. A negative value indicates early delivery where a positive value indicates delayed delivery compared to the originally promised delivery date. As such, this metric may indicate how well a particular project delivery method managed customer expectations. This value is expressed as a percentage.

BOD Performance Duration

$$BOD\ Performance\ Duration = (Actual\ BOD) - (Actual\ NTP)$$

This value represents the time from NTP to BOD and is measured in calendar days.

BOD Time Growth

This value represents the time period between the originally projected BOD and the actual BOD. The following equation was derived from the WebCMI application:

$$BOD\ Time\ Growth = (Actual\ BOD) - (Original\ BOD)$$

The beneficial occupancy time growth is measured in calendar days.

BOD to Completion Duration

$$BOD\ to\ Completion\ Duration = (Actual\ Construction\ Completion) - (Actual\ BOD)$$

This value represents the amount of time from BOD to the completion of construction and is predicated on the assumption that most building construction projects will achieve beneficial occupancy prior to or concurrent with construction completion. The most notable exception to this logic is military medical facilities, which often must undergo initial outfitting and/or retrofit prior to occupancy. Therefore, if the BOD occurs after construction completion (as in medical projects) this value will be negative. However, a large value will represent projects that may have had a negotiated phased turn-over or significant punch list issues. This value is expressed in calendar days.

Change Order Time

This is the number of days awarded as part of the approved change orders as shown in the RMS information within the WebCMI application. This value is expressed in calendar days.

Change Order Value

This is the value of all change orders processed and completed as shown in the RMS information within the WebCMI application. This value is expressed in current dollars.

Contract Award Amount

The contract award amount in the sum of the original contract value and the value of any awarded alternates expressed by the following formula:

$$Contract\ Award\ Amount = (Original\ Contract) + (Options\ Exercised)$$

This value represents the obligation that the Government incurs by signing the contract and is in current dollars.

Contract Controllable Cost Growth

This value is expressed as a percentage and does not include any design costs for design-bid-build projects.

$$Contract\ Controllable\ Cost\ Growth = \frac{(Adj.\ Controllable\ Changes)}{(Adj.\ Contract\ Award\ Amount)}$$

Contract Cost Growth

This value is expressed as a percentage. It is important to note that this value does not include any design cost for design-bid-build projects.

$$Contract\ Cost\ Growth = \frac{[(Adj.\ Final\ Contract\ Amount) - (Adj.\ Contract\ Award\ Amount)]}{Adj.\ Contract\ Award\ Amount}$$

Contract Intensity

$$Contract\ Intensity = \frac{\left(\dfrac{Adj.\ Final\ Contract\ Amount}{Scope}\right)}{Contract\ Performance\ Duration}$$

For design-bid-build projects this does not take into account the duration or cost of design services. This value is expressed as $/sf/day.

Contract Number

This data element is a thirteen digit alphanumeric identifier for each project. The first six characters of the contract number identify the service component and/or the contracting office issuing the contract. The next two characters identify the fiscal year in which the contract was awarded. The ninth character indicates the type of contract being awarded, such as “C” for construction type of contract and “D” for a delivery order type of contract. The final four characters serve as a unique serial number. In theory, each contract number should be unique and would serve as a method of identifying duplicate projects from the data set. However, for a delivery order type contract the contract number is identical for each task order awarded under that contract.

Contract Performance Duration

$$Contract\ Performance\ Duration = (Actual\ Construction\ Completion) - (Actual\ NTP)$$

This value represents the time from NTP to construction completion and is measured in calendar days.

Contract Schedule Growth

$$Contract\ Schedule\ Growth = \left[\frac{(BOD\ Performance\ Duration)}{(Original\ Performance\ Duration)}\right] \cdot 100$$

This metric is used by the US Air Force as part of their "Dirt Kicker" criteria and may be used to determine project success. The Air Force attempts to keep schedule growth to less than 10%, therefore any value less than 110% may be viewed as a success in meeting schedule expectations. Any value of 100% or less indicates that the project was delivered to the user ahead of schedule. This value is expressed as a percentage.

Contract Time Growth

$$ContractTimeGrowth = \left\{\frac{[(Contract\ Performance\ Duration) - (Initial\ Contract\ Duration)]}{(Initial\ Contract\ Duration)}\right\} \cdot 100$$

This value is expressed as a percentage.

Controllable Changes

Controllable Changes are defined in Resident Management System (RMS) as changes identified with the following codes:

1 -- Engineering Changes (Includes possible and confirmed A-E Fault)

8 -- Value Engineering Changes

G -- Deficient Government Furnished Property Corrections

S -- Suspension of Work

T -- Termination of Work

V -- Construction Changes Necessary to Complete Contract (RMS, 2.36)

Uncontrollable Changes are defined in the RMS as changes identified with the following codes:

4 -- User Changes (Discretionary)

6 -- Miscellaneous Changes

7 -- Differing Site Conditions not readily identifiable by thorough Site Investigation

9 -- Administrative Changes -- Fund Cite, Paying Station, Address, etc.

A -- Adverse Security Conditions

E -- Excusable Delay for No Fault -- Weather or Act of Nature

Q -- Variations in Estimated Quantities

R -- Revaluation -- Foreign Currency (RMS, 2.36)

The use of the term "controllable change" or "uncontrollable change" seems to be indicative of whether the impact/scope of this change is controllable by the Contractor. A controllable change is similar to the unforeseen change noted in the literature review.

Controllable Change Duration

This is the number of days awarded as part of the approved, controllable change orders as shown in the RMS information within the WebCMI application. This value is expressed in calendar days.

Controllable Change Duration Ratio

$$Controllable\ Change\ Duration\ Portion = \frac{(Controllable\ Change\ Duration)}{(Change\ Order\ Time)}$$

This metric indicates how much of the total change order duration is attributed to controllable changes. Based on the formula the ratios may be interpreted along a range of possible values from 0 to 1. Lower ratios indicate that more of the total change order time was due to uncontrollable changes. Larger ratios indicate that more of the total change order time was attributable to controllable changes.

Controllable Change Ratio

$$Controllable\ Change\ Portion = \frac{(Adj.\ Controllable\ Changes)}{(Adj.\ Change\ Order\ Value)}$$

This metric indicates how much of the total change order value may be attributed to controllable changes. Based on the formula shown the ratio may be interpreted along a range of possible values from 0 to 1. Lower ratios indicate that more of the total value of change orders may be attributed to uncontrollable changes. Larger ratios indicate that more of the total value of change orders may be attributed to controllable changes. If the ratio is greater than 1 then the uncontrollable changes resulted in a net credit. Similarly, if the ratio is less than 0 the controllable changes resulted in a net credit.

Construction Budget

This value was equated to the A/E's estimated cost or the Engineer's estimate.

Construction Placement

$$Construction\ Placement = \frac{(Adj.\ Final\ Contract\ Amount)}{(Contract\ Performance\ Duration)}$$

This metric represents the average rate at which the construction contractor earns value over the contract period. The larger values of construction placement represent effective and efficient construction management. This value is expressed as $/day.

Corps District

This is the Corps of Engineers district office with direct oversight and reporting responsibilities for the project. Typically, districts are organized along geographical boundaries.

Delivery Type

Projects were classified as either “design-build” or “traditional” based on interpretation of the “Design-by” data field, project description, synopsis, or authorized phase values in WebCMI.

Design-Build Placement

$$DB\ Placement = \frac{(Adj.\ Final\ Contract\ Amount)}{(Contract\ Performance\ Duration)}$$

This value is expressed as $/day.

Design-by

The values in the data set are direct reflections of the USACE design-by codes listed in the P2 information management system. The allowable values used in this study are listed in Chapter 3, Table 5.

Design Duration

$$Design\ Duration = (Design\ Completion\ Date) - (Design\ Start\ Date)$$

This value represents the period of time used to complete the bid drawings and specifications. Therefore this duration only applies to design-bid-build projects and is measured in calendar days. For design-build projects the design duration is already included in the contract performance period.

Design Placement

$$Design\ Placement = \frac{(Adj.\ Est.\ Design\ Cost)}{(Design\ Duration)}$$

This metric is the average cost per day of the design contract, however, in this data set it is the estimated cost per day. This value is expressed as $/day.

Design Time Adjustment Factor

This adjustment factor reflects the fact that design costs are paid and executed prior to the award of a construction contract under the traditional project delivery method. It was approximated that design started one year prior to the fiscal year of contract award for all types of facilities, except medical which was approximated at two years. This adjustment factor allows the current dollar amount of the estimated design cost to be converted to an equivalent constant FY07 dollar amount.

Estimated Design Cost

$$Estimated\ \ Design\ Cost = (Original\ \ Contract)(0.06)$$

The Estimated Design Cost is only applicable to design-bid-build projects as the design cost for design-build projects is already included in the contract award amount. A 6% fee limit for architectural and engineering services on federal projects was enacted in 1939 (Charles, 1996). The fee limit for architectural and engineering services on MILCON projects is 6% of the estimated cost of construction. This statutory limit applies only to the “production and delivery of designs, plans, drawings, and specifications for construction. Some non-design services which are exempt from the 6% limit are: project development, feasibility studies, site investigation, construction inspection, shop drawing review, etc (AR 415-15, 1998).

For the purposes of this study it was assumed that the design cost for design-bid-build projects was 6% of the base contract award amount (without additives or options). The A/E’s estimate is used to determine the program amount for a project prior to bid solicitation. If bids come in over the program amount then all bids may be rejected. As such, it would be expected that the bids and contract award amounts are actually lower than the estimated construction cost. Therefore, while the estimated design cost is a good approximation it does not account for all of the design costs for a design-bid-build project.

Initial Contract Duration

This is the sum of the original duration and options duration measured in calendar days.

$$Initial\ Contract\ Duration = (Contract\ Duration) + (Options\ Duration)$$

Installation

This data element identified geographically where the project was executed.

Facility Type – Detailed

The project description field was used to determine the type of facility being constructed based on facility types used in the USACE project programming process. (Unit, 2006; Programming, 1994)

Facility Type – General

The detailed facility type was consolidated to allow for comparison of similar facility projects. In this study there were fifteen general facility classifications.

Final Allowable Contract Duration

$$Final\ Allowable\ Contract\ Duration = (Initial\ Contract\ Duration) + (Change\ Order\ Time)$$

This value is measured in calendar days.

Final Contract Amount

This is the sum of the original contract, options exercised and change order value expressed by the following formula:

$$Final\ Contract\ Amount = (Contract\ Award\ Amount) + (Change\ Order\ Value)$$

The final contract amount is in current dollars.

Fund Type

Different types of funding within the federal government include different restrictions and allowable uses. For example operations and maintenance (O&M) funds may only be used to perform maintenance and repairs, new construction work up to an identified statutory limit, and “expire” at the end of the year of appropriation. Military construction funds are multi-year funds that may be used for the construction of new or renovation/repair of existing facilities. The type of funding used on a project was collected to ensure that all projects were governed by similar regulations.

LEED Rating

This is the LEED rating achieved by the project as part of the effort of the federal government to construct green facilities.

Number of Changes

This is the number of change orders processed and completed as shown in the RMS information within the WebCMI application.

Options Duration

This is the time period allowed for any awarded alternates measured in calendar days.

Options Exercised

This is the value of any alternates awarded.

Original BOD

This is the date originally established for beneficial occupancy by the project delivery team within 30 days of contract award.

Original Construction Completion

This is the date originally established for construction completion as shown in the RMS information within the WebCMI application.

Original Contract

This is the value of the base bid for the project in current dollars.

Original Duration

This is the original performance period for project's base bid measured in calendar days.

Original Performance Duration

$$Original\ Performance\ Duration = (Original\ BOD) - (Actual\ NTP)$$

This value represents the time from NTP to the originally projected BOD, which is established by the project delivery team (PDT) shortly after contract award. This value is expressed in calendar days.

Program Amount

This is the programmed amount that was identified early in the MILCON process.

Project Controllable Cost Growth

This value is expressed as a percentage and includes an approximate value for the design cost on design-bid-build projects.

$$\Pr oject\ Controllable\ Cost\ Growth = \frac{(Adj.\ Controllable\ Changes)}{(Adj.\ Initial\ \Pr oject\ Amount)}$$

Project Cost Growth

This value is expressed as a percentage and includes an approximate value for the design cost on design-bid-build projects.

$$\Pr oject\ Cost\ Growth = \frac{[(Adj.\ Final\ \Pr oject\ Amount) - (Adj.\ Initial\ \Pr oject\ Amount)]}{(Adj.\ Initial\ \Pr oject\ Amount)}$$

Project Description

The project description is a rough description of the project. The contents of this data field were different for each Corps District and may include additional information such as fiscal year, type of funding, contract number, etc.

Project Intensity

$$\Pr oject\ Intensity = \frac{\left(\frac{Adj.\ Final\ \Pr oject\ Amount}{Scope}\right)}{(Contract\ Performance\ Duration + Design\ Duration)}$$

For design-bid-build project this metric estimates the cost of design services and uses known design contract times as reported by webCMI. This value is expressed as $/sf/day.

Project Placement (Design-Bid-Build Projects)

$$\Pr oject\ Placement = \frac{[(Adj.\ Est\ Design\ Cost) + (Adj.\ Final\ Contract\ Amount]}{[(Design\ Duration) + (Contract\ Performance\ Duration)]}$$

This value is expressed as \$/day.

Project Placement (Design-Build Projects)

$$Project\ Placement = DB\ Placement$$

This value is expressed as \$/day.

Project Type

The project type is on multiple fields in the WebCMI project file. The possible values for this data element were limited to “Addition/Alteration” and “New/Replacement” with the later being the default value. This assumes that each construction project is to replace an existing facility or function, which based on current facility inventory ages, energy conservation targets, and the need to dispose of World War II wooden structures is a valid assumption. However, if text in the project description, optional RMS synopsis field, or the Federal Business Opportunities database indicated otherwise, the value was changed to “Addition/Alteration.”

Region

Based on the installation data element the project was assigned to one of five distinct geographical regions as shown in Figure 5. Earlier research on federal design-build projects attempted to determine if a geographic relationship existed and divided the continental US into four regions. With the current data set a fifth region was added to include projects executed outside of the continental US (OCONUS).

Scheduled BOD

This is the date for beneficial occupancy that was updated during the construction process.

Scheduled Contract Award

This is the date originally scheduled to award the contract as shown in the RMS information within the WebCMI application.

Scheduled NTP

This is the date originally scheduled to issue notice-to-proceed (NTP) as shown in the RMS information within the WebCMI application.

Scheduled Construction Completion

This is the construction completion date adjusted to include the approved change order durations as shown in the RMS information within the WebCMI application.

Unit Cost (Design-Bid-Build Projects)

$$Unit\ Cost = \frac{(Adj.\ Est.\ Design\ Cost) + (Adj.\ Final\ Contract\ Amount)}{Scope}$$

This metric indicates the cost per square foot of facility constructed using the design-bid-build project delivery method. By inclusion of the estimated design costs in this metric comparison with design-build projects may be made. This value is expressed in $/sf.

Unit Cost (Design-Build Projects)

$$Unit\ Cost = \frac{(Adj.\ Final\ Contract\ \ Amount)}{Scope}$$

This metric indicates the cost per square foot of the facility using the design-build project delivery method. This value is expressed in $/sf.

APPENDIX B – ANALYSIS SUMMARY SHEETS

Table B-1. Design-build project aggregate vs. design-bid-build project aggregate.

Characteristic	Total Sample Mean	Design-Build Mean (75 Projects)	Design-Bid-Build Mean (44 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	9,594,091.83			
Adjusted Initial Project Amount (Constant FY07 $)	9,774,708.78			
Adjusted Change Order Value (Constant FY07 $)		474,532.70	1,292,701.01	0.10954
Adjusted Controllable Changes (Constant FY07 $)		173,377.10	317,942.56	0.12449
Controllable Change Ratio		0.42	0.66	0.02036
Controllable Change Duration (days)	48.19			
Controllable Change Duration Ratio	0.34			
Adjusted Final Contract Amount (Constant FY07 $)	10,371,140.55			
Adjusted Final Project Amount (Constant FY07 $)	10,551,757.50			
Contract Cost Growth (%)	6.31			
Project Cost Growth (%)	6.15			
Contract Controllable Cost Growth (%)	2.07			
Project Controllable Cost Growth (%)	2.03			
Contract Schedule Growth (%)		128.49	110.41	0.14233
BOD Time Growth (days)		87.68	41.66	0.11539
BOD Growth (%)		11.80	6.04	0.13601
Contract Time Growth (%)	31.19			
BOD to Completion Duration (days)	10.21			
Award Growth (%)	0.65			
Unit Cost ($/sf)	264.33			
Project Placement ($/day)		15,007.29	9,887.68	0.03149
Contract Intensity ($/sf/day)		0.39	0.50	0.13856
Project Intensity ($/sf/day)		0.39	0.27	0.00500

Table B-2. Southeast region DB projects vs. Southeast region DBB projects.

Characteristic	Total Sample Mean	Southeast Region Design-Build Mean (22 Projects)	Southeast Region Design-Bid-Build Mean (13 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	11,310,358.63			
Adjusted Initial Project Amount (Constant FY07 $)	11,490,937.56			
Adjusted Change Order Value (Constant FY07 $)	803,040.90			
Adjusted Controllable Changes (Constant FY07 $)	199,846.80			
Controllable Change Ratio		0.37	0.70	0.07914
Controllable Change Duration (days)	65.77			
Controllable Change Duration Ratio		0.30	0.50	0.05501
Adjusted Final Contract Amount (Constant FY07 $)	12,113,399.53			
Adjusted Final Project Amount (Constant FY07 $)	12,293,978.46			
Contract Cost Growth (%)	6.99			
Project Cost Growth (%)	6.79			
Contract Controllable Cost Growth (%)		1.35	3.03	0.05918
Project Controllable Cost Growth (%)		1.35	2.88	0.07090
Contract Schedule Growth (%)	117.92			
BOD Time Growth (days)	96.07			
BOD Growth (%)	11.64			
Contract Time Growth (%)	28.80			
BOD to Completion Duration (days)	-13.97			
Award Growth (%)	2.20	8.41	0.13	
Unit Cost ($/sf)	347.50			
Project Placement ($/day)	15,671.04			
Contract Intensity ($/sf/day)	0.53			
Project Intensity ($/sf/day)	0.42	0.41	0.51	

Table B-3. Northeast region DB projects vs. Northeast region DBB projects.

Characteristic	Total Sample Mean	Northeast Region Design-Build Mean (10 Projects)	Northeast Region Design-Bid-Build Mean (5 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	9,470,360.88			
Adjusted Initial Project Amount (Constant FY07 $)	9,739,896.76			
Adjusted Change Order Value (Constant FY07 $)	395,780.97			
Adjusted Controllable Changes (Constant FY07 $)	225,518.17			
Controllable Change Ratio		0.49	0.72	0.07757
Controllable Change Duration (days)	40.07			
Controllable Change Duration Ratio	0.29			
Adjusted Final Contract Amount (Constant FY07 $)	9,866,141.85			
Adjusted Final Project Amount (Constant FY07 $)	10,135,677.73			
Contract Cost Growth (%)	5.80			
Project Cost Growth (%)		6.80	3.58	0.14480
Contract Controllable Cost Growth (%)	3.29			
Project Controllable Cost Growth (%)	3.24			
Contract Schedule Growth (%)		124.00	91.41	0.02646
BOD Time Growth (days)		90.90	-104.25	0.07140
BOD Growth (%)		12.57	-11.00	0.07657
Contract Time Growth (%)		36.97	15.36	0.09297
BOD to Completion Duration (days)	-4.33			
Award Growth (%)	-6.59	-6.59		
Unit Cost ($/sf)	228.77			
Project Placement ($/day)	10,624.41			
Contract Intensity ($/sf/day)	0.36			
Project Intensity ($/sf/day)		0.37	0.20	0.01332

Table B-4. Northwest region DB projects vs. Northwest region DBB projects.

Characteristic	Total Sample Mean	Northwest Region Design-Build Mean (3 Projects)	Northwest Region Design-Bid-Build Mean (1 Project)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	15,096,662.94	20,108,010.58	62,620.03	
Adjusted Initial Project Amount (Constant FY07 $)	15,097,589.92	20,108,010.58	66,327.94	
Adjusted Change Order Value (Constant FY07 $)	572,987.30	763,983.07	0.00	
Adjusted Controllable Changes (Constant FY07 $)	73,987.93	98,650.57	0.00	
Controllable Change Ratio	0.15	0.15		
Controllable Change Duration (days)	0.00	0.00	0.00	
Controllable Change Duration Ratio	0.00	0.00		
Adjusted Final Contract Amount (Constant FY07 $)	15,669,650.25	20,871,993.65	62,620.03	
Adjusted Final Project Amount (Constant FY07 $)	15,670,577.23	20,871,993.65	66,327.94	
Contract Cost Growth (%)	2.38	3.18	0.00	
Project Cost Growth (%)	2.38	3.18	0.00	
Contract Controllable Cost Growth (%)	0.32	0.43	0.00	
Project Controllable Cost Growth (%)	0.32	0.43	0.00	
Contract Schedule Growth (%)	108.24	108.24		
BOD Time Growth (days)	50.00	50.00		
BOD Growth (%)	5.20	5.20		
Contract Time Growth (%)	17.00	27.10	-13.33	
BOD to Completion Duration (days)	-42.33	-12.50	-102.00	
Award Growth (%)	-6.45		-6.45	
Unit Cost ($/sf)	290.06	290.06		
Project Placement ($/day)	28,933.05	28,933.05		
Contract Intensity ($/sf/day)	0.44	0.44		
Project Intensity ($/sf/day)	0.44	0.44		

Table B-5. Southwest region DB projects vs. Southwest region DBB projects.

Characteristic	Total Sample Mean	Southwest Region Design-Build Mean (26 Projects)	Southwest Region Design-Bid-Build Mean (24 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	8,551,537.83			
Adjusted Initial Project Amount (Constant FY07 $)	8,764,723.37			
Adjusted Change Order Value (Constant FY07 $)	1,016,937.92			
Adjusted Controllable Changes (Constant FY07 $)	273,590.49			
Controllable Change Ratio		0.39	0.66	0.13072
Controllable Change Duration (days)	49.12			
Controllable Change Duration Ratio	0.31			
Adjusted Final Contract Amount (Constant FY07 $)	9,568,475.76			
Adjusted Final Project Amount (Constant FY07 $)	9,781,661.30			
Contract Cost Growth (%)	6.52			
Project Cost Growth (%)	6.32			
Contract Controllable Cost Growth (%)	1.66			
Project Controllable Cost Growth (%)	1.63			
Contract Schedule Growth (%)	127.80			
BOD Time Growth (days)	61.62			
BOD Growth (%)	9.07			
Contract Time Growth (%)		28.90	50.59	0.06260
BOD to Completion Duration (days)	37.47			
Award Growth (%)	16.68			
Unit Cost ($/sf)		207.67	271.25	0.08249
Project Placement ($/day)		15,112.59	9,210.97	0.09578
Contract Intensity ($/sf/day)		0.35	0.46	0.07568
Project Intensity ($/sf/day)	0.32			

Table B-6. OCONUS DB projects vs. OCONUS DBB projects.

Characteristic	Total Sample Mean	OCONUS Design-Build Mean (14 Projects)	OCONUS Design-Bid-Build Mean (1 Project)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	7,721,027.97	7,817,479.63	6,370,704.76	
Adjusted Initial Project Amount (Constant FY07 $)	7,752,170.04	7,817,479.63	6,837,835.87	
Adjusted Change Order Value (Constant FY07 $)	352,453.70	316,363.97	857,709.99	
Adjusted Controllable Changes (Constant FY07 $)	175,991.26	150,731.76	529,624.24	
Controllable Change Ratio	0.60	0.60	0.62	
Controllable Change Duration (days)	25.07	26.86	0.00	
Controllable Change Duration Ratio	0.58	0.58		
Adjusted Final Contract Amount (Constant FY07 $)	8,073,481.67	8,133,843.60	7,228,414.75	
Adjusted Final Project Amount (Constant FY07 $)	8,104,623.75	8,133,843.60	7,695,545.86	
Contract Cost Growth (%)	5.60	5.04	13.46	
Project Cost Growth (%)	5.54	5.04	12.54	
Contract Controllable Cost Growth (%)	2.91	2.52	8.31	
Project Controllable Cost Growth (%)	2.87	2.52	7.75	
Contract Schedule Growth (%)	120.40	122.24	98.40	
BOD Time Growth (days)	86.38	94.67	-13.00	
BOD Growth (%)	12.24	13.39	-1.63	
Contract Time Growth (%)	14.88	16.06	-1.60	
BOD to Completion Duration (days)	1.00	1.07	0.00	
Award Growth (%)	-46.69	-46.69		
Unit Cost ($/sf)	207.09	207.09		
Project Placement ($/day)	13,126.28	13,611.09	6,339.00	
Contract Intensity ($/sf/day)	0.45	0.45		
Project Intensity ($/sf/day)	0.45	0.45		

Table B-7. Medical type DB projects vs. Medical type DBB projects.

Characteristic	Total Sample Mean	Medical Type Design-Build Mean (2 Projects)	Medical Type Design-Bid-Build Mean (2 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	5,535,132.76			
Adjusted Initial Project Amount (Constant FY07 $)	5,706,328.34			
Adjusted Change Order Value (Constant FY07 $)	199,418.20			
Adjusted Controllable Changes (Constant FY07 $)	25,021.69			
Controllable Change Ratio	20.11			
Controllable Change Duration (days)	14.25			
Controllable Change Duration Ratio	6.54			
Adjusted Final Contract Amount (Constant FY07 $)	5,734,550.96			
Adjusted Final Project Amount (Constant FY07 $)	5,905,746.54			
Contract Cost Growth (%)	4.77			
Project Cost Growth (%)	4.69			
Contract Controllable Cost Growth (%)	0.89			
Project Controllable Cost Growth (%)	0.87			
Contract Schedule Growth (%)	134.03	131.25	139.58	
BOD Time Growth (days)	221.00	209.00	245.00	
BOD Growth (%)	25.15	23.55	28.36	
Contract Time Growth (%)		33.50	-3.47	0.03678
BOD to Completion Duration (days)	-91.50			
Award Growth (%)	-41.89	-58.86	-24.93	
Unit Cost ($/sf)	194.74	182.94	206.54	
Project Placement ($/day)	1,404.41	5,289.79	23,633.66	
Contract Intensity ($/sf/day)	0.34			
Project Intensity ($/sf/day)	0.31	0.23	0.47	

Table B-8. Public safety DB projects vs. Public safety DBB projects.

Characteristic	Total Sample Mean	Public Safety Design-Build Mean (7 Projects)	Public Safety Design-Bid-Build Mean (5 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	6,927,651.34			
Adjusted Initial Project Amount (Constant FY07 $)	7,156,289.75			
Adjusted Change Order Value (Constant FY07 $)	281,250.96			
Adjusted Controllable Changes (Constant FY07 $)	100,168.77			
Controllable Change Ratio	0.50			
Controllable Change Duration (days)	59.00			
Controllable Change Duration Ratio	0.39			
Adjusted Final Contract Amount (Constant FY07 $)	7,208,902.30			
Adjusted Final Project Amount (Constant FY07 $)	7,437,540.71			
Contract Cost Growth (%)	5.27			
Project Cost Growth (%)	5.20			
Contract Controllable Cost Growth (%)	2.55			
Project Controllable Cost Growth (%)	2.52			
Contract Schedule Growth (%)	112.24			
BOD Time Growth (days)	71.18			
BOD Growth (%)	9.94			
Contract Time Growth (%)	22.13			
BOD to Completion Duration (days)	46.00			
Award Growth (%)	89.67			
Unit Cost ($/sf)	311.92			
Project Placement ($/day)	6,512.42			
Contract Intensity ($/sf/day)	0.51			
Project Intensity ($/sf/day)	0.42			

Table B-9. Special type DB projects vs. Special type DBB projects.

Characteristic	Total Sample Mean	Special Type Design-Build Mean (2 Projects)	Special Type Design-Bid-Build Mean (1 Project)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	9,394,511.02	10,441,341.29	7,300,850.47	
Adjusted Initial Project Amount (Constant FY07 $)	9,581,445.77	10,441,341.29	7,861,654.74	
Adjusted Change Order Value (Constant FY07 $)	840,899.77	1,168,744.79	185,209.71	
Adjusted Controllable Changes (Constant FY07 $)	203,989.26	264,296.33	83,375.12	
Controllable Change Ratio	45.70	46.05	45.02	
Controllable Change Duration (days)	6.67	10.00	0.00	
Controllable Change Duration Ratio	14.86	22.29	0.00	
Adjusted Final Contract Amount (Constant FY07 $)	10,235,410.78	11,610,086.08	7,486,060.18	
Adjusted Final Project Amount (Constant FY07 $)	10,422,345.54	11,610,086.08	8,046,864.45	
Contract Cost Growth (%)	8.01	10.75	2.54	
Project Cost Growth (%)	7.95	10.75	2.36	
Contract Controllable Cost Growth (%)	2.17	2.68	1.14	
Project Controllable Cost Growth (%)	2.14	2.68	1.06	
Contract Schedule Growth (%)	98.67	108.05	79.91	
BOD Time Growth (days)	-13.67	43.00	-127.00	
BOD Growth (%)	-3.76	6.94	-25.15	
Contract Time Growth (%)	10.14	9.09	12.22	
BOD to Completion Duration (days)	14.33	21.50	0.00	
Award Growth (%)				
Unit Cost ($/sf)	296.49	296.49		
Project Placement ($/day)	19,068.32	19,068.32		
Contract Intensity ($/sf/day)	0.49	0.49		
Project Intensity ($/sf/day)	0.49	0.49		

Table B-10. Training type DB projects vs. Training type DBB projects.

Characteristic	Total Sample Mean	Training Type Design-Build Mean (5 Projects)	Training Type Design-Bid-Build Mean (5 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	6,967,693.75			
Adjusted Initial Project Amount (Constant FY07 $)	7,098,813.67			
Adjusted Change Order Value (Constant FY07 $)	235,857.17			
Adjusted Controllable Changes (Constant FY07 $)	113,589.50			
Controllable Change Ratio	0.50			
Controllable Change Duration (days)	37.70			
Controllable Change Duration Ratio	0.40			
Adjusted Final Contract Amount (Constant FY07 $)	7,203,550.92			
Adjusted Final Project Amount (Constant FY07 $)	7,334,670.84			
Contract Cost Growth (%)	3.69			
Project Cost Growth (%)	3.54			
Contract Controllable Cost Growth (%)	1.45			
Project Controllable Cost Growth (%)	1.39			
Contract Schedule Growth (%)	112.51			
BOD Time Growth (days)	74.88			
BOD Growth (%)	9.35			
Contract Time Growth (%)		12.14	46.31	0.10599
BOD to Completion Duration (days)	-14.30			
Award Growth (%)	-19.00			
Unit Cost ($/sf)	269.26			
Project Placement ($/day)		14,194.94	3,817.21	0.04864
Contract Intensity ($/sf/day)	0.51			
Project Intensity ($/sf/day)	0.40	0.50	0.21	

Table B-11. Barracks DB projects vs. Barracks DBB projects.

Characteristic	Total Sample Mean	Barracks Design-Build Mean (6 Projects)	Barracks Design-Bid-Build Mean (5 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	16,901,906.43			
Adjusted Initial Project Amount (Constant FY07 $)	17,298,692.22			
Adjusted Change Order Value (Constant FY07 $)	645,345.99			
Adjusted Controllable Changes (Constant FY07 $)	305,645.25			
Controllable Change Ratio		0.30	0.80	0.08022
Controllable Change Duration (days)		2.00	58.60	0.09330
Controllable Change Duration Ratio		0.01	0.41	0.08271
Adjusted Final Contract Amount (Constant FY07 $)	17,547,252.41			
Adjusted Final Project Amount (Constant FY07 $)	17,944,038.20			
Contract Cost Growth (%)	4.38			
Project Cost Growth (%)	4.21			
Contract Controllable Cost Growth (%)		0.84	3.44	0.10666
Project Controllable Cost Growth (%)		0.84	3.23	0.10929
Contract Schedule Growth (%)	121.40			
BOD Time Growth (days)	91.91			
BOD Growth (%)	13.77			
Contract Time Growth (%)	49.61			
BOD to Completion Duration (days)	44.82			
Award Growth (%)	14.90	-7.22	25.96	
Unit Cost ($/sf)	255.71			
Project Placement ($/day)	17,554.27			
Contract Intensity ($/sf/day)	0.30			
Project Intensity ($/sf/day)	0.25			

Table B-12. Maint. - Aviation DB projects vs. Maint. - Aviation DBB projects.

Characteristic	Total Sample Mean	Aviation Maint. Design-Build Mean (13 Projects)	Aviation Maint. Design-Bid-Build Mean (5 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	8,818,013.03			
Adjusted Initial Project Amount (Constant FY07 $)	8,916,050.94			
Adjusted Change Order Value (Constant FY07 $)	1,238,472.88			
Adjusted Controllable Changes (Constant FY07 $)	277,009.93			
Controllable Change Ratio	0.63			
Controllable Change Duration (days)	52.67			
Controllable Change Duration Ratio	0.41			
Adjusted Final Contract Amount (Constant FY07 $)	10,056,485.91			
Adjusted Final Project Amount (Constant FY07 $)	10,154,523.82			
Contract Cost Growth (%)	11.15			
Project Cost Growth (%)	10.86			
Contract Controllable Cost Growth (%)	3.25			
Project Controllable Cost Growth (%)	3.19			
Contract Schedule Growth (%)	122.32			
BOD Time Growth (days)	83.50			
BOD Growth (%)	14.03			
Contract Time Growth (%)	32.86			
BOD to Completion Duration (days)	-5.61			
Award Growth (%)	-26.45	-26.68	-24.55	
Unit Cost ($/sf)	252.07			
Project Placement ($/day)	1,511.91	15,997.11	3,604.35	
Contract Intensity ($/sf/day)	0.50			
Project Intensity ($/sf/day)	0.49	0.51	0.30	

Table B-13. Administrative Type DB projects vs. Administrative Type DBB projects.

Characteristic	Total Sample Mean	Admin. Type Design-Build Mean (17 Projects)	Admin. Type Design-Bid-Build Mean (11 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	9,348,367.95			
Adjusted Initial Project Amount (Constant FY07 $)	9,530,867.59			
Adjusted Change Order Value (Constant FY07 $)	907,170.18			
Adjusted Controllable Changes (Constant FY07 $)	223,014.95			
Controllable Change Ratio	0.48			
Controllable Change Duration (days)	55.36			
Controllable Change Duration Ratio	0.38			
Adjusted Final Contract Amount (Constant FY07 $)	10,255,538.13			
Adjusted Final Project Amount (Constant FY07 $)	10,438,037.77			
Contract Cost Growth (%)	5.38			
Project Cost Growth (%)	5.23			
Contract Controllable Cost Growth (%)	0.87			
Project Controllable Cost Growth (%)	0.88			
Contract Schedule Growth (%)	111.41			
BOD Time Growth (days)	43.00			
BOD Growth (%)	5.11			
Contract Time Growth (%)		21.10	43.41	0.09882
BOD to Completion Duration (days)	15.27			
Award Growth (%)	-1.52			
Unit Cost ($/sf)	224.95			
Project Placement ($/day)	14,235.46			
Contract Intensity ($/sf/day)	0.36			
Project Intensity ($/sf/day)		0.35	0.12	0.00004

Table B-14. Maint. - Ground DB projects vs. Maint. - Ground DBB projects.

Characteristic	Total Sample Mean	Ground Maint. Design-Build Mean (4 Projects)	Ground Maint. Design-Bid-Build Mean (4 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	11,522,086.73			
Adjusted Initial Project Amount (Constant FY07 $)	11,752,790.70			
Adjusted Change Order Value (Constant FY07 $)	505,808.50			
Adjusted Controllable Changes (Constant FY07 $)	283,947.85			
Controllable Change Ratio	0.78			
Controllable Change Duration (days)	67.13			
Controllable Change Duration Ratio	0.56			
Adjusted Final Contract Amount (Constant FY07 $)	12,027,895.23			
Adjusted Final Project Amount (Constant FY07 $)	12,258,599.20			
Contract Cost Growth (%)	3.41			
Project Cost Growth (%)	3.29			
Contract Controllable Cost Growth (%)	1.92			
Project Controllable Cost Growth (%)	1.85			
Contract Schedule Growth (%)	95.73			
BOD Time Growth (days)	-47.43			
BOD Growth (%)	-6.31			
Contract Time Growth (%)	21.49			
BOD to Completion Duration (days)	-6.75			
Award Growth (%)	-5.44	-12.10	-2.11	
Unit Cost ($/sf)	249.46			
Project Placement ($/day)	17,359.45			
Contract Intensity ($/sf/day)	0.34			
Project Intensity ($/sf/day)	0.26			

Table B-15. Mobility type DB projects vs. Mobility type DBB projects.

Characteristic	Total Sample Mean	Mobility Type Design-Build Mean (4 Projects)	Mobility Type Design-Bid-Build Mean (1 Project)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	14,328,476.53	14,708,115.38	12,809,921.11	
Adjusted Initial Project Amount (Constant FY07 $)	14,472,462.37	14,708,115.38	13,529,850.33	
Adjusted Change Order Value (Constant FY07 $)	699,977.45	744,981.50	519,961.25	
Adjusted Controllable Changes (Constant FY07 $)	263,784.19	203,676.04	504,216.76	
Controllable Change Ratio	0.49	0.38	0.97	
Controllable Change Duration (days)	41.40	29.50	89.00	
Controllable Change Duration Ratio	0.31	0.26	0.49	
Adjusted Final Contract Amount (Constant FY07 $)	15,028,453.98	15,453,096.88	13,329,882.36	
Adjusted Final Project Amount (Constant FY07 $)	15,172,439.82	15,453,096.88	14,049,811.57	
Contract Cost Growth (%)	4.83	5.03	4.06	
Project Cost Growth (%)	4.79	5.03	3.84	
Contract Controllable Cost Growth (%)	2.70	2.39	3.94	
Project Controllable Cost Growth (%)	2.66	2.39	3.73	
Contract Schedule Growth (%)	253.22	292.11	97.66	
BOD Time Growth (days)	153.80	196.75	-18.00	
BOD Growth (%)	19.89	25.46	-2.40	
Contract Time Growth (%)	32.33	32.52	31.58	
BOD to Completion Duration (days)	-10.00	-12.25	-1.00	
Award Growth (%)	-6.87	-6.87		
Unit Cost ($/sf)	140.35	111.85	168.85	
Project Placement ($/day)	18,514.89	20,454.14	10,757.90	
Contract Intensity ($/sf/day)	0.21	0.20	0.21	
Project Intensity ($/sf/day)	0.17	0.20	0.13	

Table B-16. Storage type DB projects vs. Storage type DBB projects.

Characteristic	Total Sample Mean	Storage Type Design-Build Mean (6 Projects)	Storage Type Design-Bid-Build Mean (1 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	8,714,932.85	9,878,351.17	1,734,422.90	
Adjusted Initial Project Amount (Constant FY07 $)	8,729,186.71	9,878,351.17	1,834,199.92	
Adjusted Change Order Value (Constant FY07 $)	310,282.41	359,269.74	16,358.42	
Adjusted Controllable Changes (Constant FY07 $)	74,244.74	83,892.46	16,358.42	
Controllable Change Ratio	0.52	0.45	1.00	
Controllable Change Duration (days)	8.71	7.83	14.00	
Controllable Change Duration Ratio	0.12	0.09	0.26	
Adjusted Final Contract Amount (Constant FY07 $)	9,025,215.26	10,237,620.91	1,750,781.32	
Adjusted Final Project Amount (Constant FY07 $)	9,039,469.12	10,237,620.91	1,850,558.34	
Contract Cost Growth (%)	4.06	4.58	0.94	
Project Cost Growth (%)	4.05	4.58	0.89	
Contract Controllable Cost Growth (%)	1.22	1.27	0.94	
Project Controllable Cost Growth (%)	1.21	1.27	0.89	
Contract Schedule Growth (%)	124.70	127.88	105.60	
BOD Time Growth (days)	113.00	128.33	21.00	
BOD Growth (%)	15.79	17.54	5.30	
Contract Time Growth (%)	34.09	36.69	18.48	
BOD to Completion Duration (days)	-5.86	-6.00	-5.00	
Award Growth (%)	10.99	15.34	-2.08	
Unit Cost ($/sf)	194.74	166.32	308.43	
Project Placement ($/day)	13,679.93	15,681.56	1,670.18	
Contract Intensity ($/sf/day)	0.34	0.24	0.75	
Project Intensity ($/sf/day)	0.25	0.24	0.28	

Table B-17. Food service type DB projects vs. Food service type DBB projects.

Characteristic	Total Sample Mean	Food Service Type Design-Build Mean (2 Projects)	Food Service Type Design-Bid-Build Mean (0 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	6,440,383.71	6,440,383.71		
Adjusted Initial Project Amount (Constant FY07 $)	6,440,383.71	6,440,383.71		
Adjusted Change Order Value (Constant FY07 $)	636,835.61	636,835.61		
Adjusted Controllable Changes (Constant FY07 $)	618,333.35	618,333.35		
Controllable Change Ratio	0.97	0.97		
Controllable Change Duration (days)	111.00	111.00		
Controllable Change Duration Ratio	0.71	0.71		
Adjusted Final Contract Amount (Constant FY07 $)	7,077,219.32	7,077,219.32		
Adjusted Final Project Amount (Constant FY07 $)	7,077,219.32	7,077,219.32		
Contract Cost Growth (%)	7.29	7.29		
Project Cost Growth (%)	7.29	7.29		
Contract Controllable Cost Growth (%)	7.08	7.08		
Project Controllable Cost Growth (%)	7.08	7.08		
Contract Schedule Growth (%)	98.65	98.65		
BOD Time Growth (days)	-8.00	-8.00		
BOD Growth (%)	-1.37	-1.37		
Contract Time Growth (%)	45.43	45.43		
BOD to Completion Duration (days)	10.50	10.50		
Award Growth (%)				
Unit Cost ($/sf)	318.72	318.72		
Project Placement ($/day)	13,051.82	13,051.82		
Contract Intensity ($/sf/day)	0.83	0.83		
Project Intensity ($/sf/day)	0.83	0.83		

Table B-18. Security type DB projects vs. Security type DBB projects.

Characteristic	Total Sample Mean	Security Type Design-Build Mean (1 Project)	Security Type Design-Bid-Build Mean (2 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	12,809,783.75	4,174,938.49	17,127,206.39	
Adjusted Initial Project Amount (Constant FY07 $)	13,383,846.32	4,174,938.49	17,988,300.24	
Adjusted Change Order Value (Constant FY07 $)	4,971,786.50	251,463.11	7,331,948.19	
Adjusted Controllable Changes (Constant FY07 $)	1,043,598.17	202,943.04	1,463,925.73	
Controllable Change Ratio	0.59	0.81	0.48	
Controllable Change Duration (days)	150.00	339.00	55.50	
Controllable Change Duration Ratio	0.45	0.75	0.29	
Adjusted Final Contract Amount (Constant FY07 $)	17,781,570.25	4,426,401.60	24,459,154.58	
Adjusted Final Project Amount (Constant FY07 $)	18,355,632.82	4,426,401.60	25,320,248.44	
Contract Cost Growth (%)	23.90	6.02	32.85	
Project Cost Growth (%)	22.84	6.02	31.25	
Contract Controllable Cost Growth (%)	6.90	4.86	7.91	
Project Controllable Cost Growth (%)	6.65	4.86	7.54	
Contract Schedule Growth (%)	139.70	215.26	101.92	
BOD Time Growth (days)	174.67	491.00	16.50	
BOD Growth (%)	19.04	53.54	1.79	
Contract Time Growth (%)	93.09	115.76	81.76	
BOD to Completion Duration (days)	145.33	0.00	218.00	
Award Growth (%)	89.25		89.25	
Unit Cost ($/sf)	2,080.97		2,080.97	
Project Placement ($/day)	18,496.99	4,827.05	32,166.92	
Contract Intensity ($/sf/day)	2.49		2.49	
Project Intensity ($/sf/day)				

Table B-19. Micro DB projects vs. Micro DBB projects.

Characteristic	Total Sample Mean	Micro Design-Build Mean (9 Projects)	Micro Design-Bid-Build Mean (7 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	1,157,173.75			
Adjusted Initial Project Amount (Constant FY07 $)	1,189,361.75			
Adjusted Change Order Value (Constant FY07 $)	59,401.57			
Adjusted Controllable Changes (Constant FY07 $)	36,027.61			
Controllable Change Ratio	0.58			
Controllable Change Duration (days)	20.44			
Controllable Change Duration Ratio	0.32			
Adjusted Final Contract Amount (Constant FY07 $)	1,216,575.32			
Adjusted Final Project Amount (Constant FY07 $)	1,248,763.33			
Contract Cost Growth (%)		6.12	2.40	0.14148
Project Cost Growth (%)		6.12	2.26	0.12436
Contract Controllable Cost Growth (%)	2.77			
Project Controllable Cost Growth (%)	2.74			
Contract Schedule Growth (%)	132.11			
BOD Time Growth (days)		144.75	42.00	0.11207
BOD Growth (%)	19.66			
Contract Time Growth (%)	31.53			
BOD to Completion Duration (days)	-10.25			
Award Growth (%)		-43.43	-20.62	0.02739
Unit Cost ($/sf)		173.91	232.59	0.08135
Project Placement ($/day)	2,646.12	2,754.56	1,670.18	
Contract Intensity ($/sf/day)	0.48			
Project Intensity ($/sf/day)	0.40			

Table B-20. Small DB projects vs. Small DBB projects.

Characteristic	Total Sample Mean	Small Design-Build Mean (40 Projects)	Small Design-Bid-Build Mean (20 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)		6,286,634.27	4,815,280.49	0.01164
Adjusted Initial Project Amount (Constant FY07 $)		6,286,634.27	5,092,548.35	0.04573
Adjusted Change Order Value (Constant FY07 $)	295,143.41			
Adjusted Controllable Changes (Constant FY07 $)	100,009.05			
Controllable Change Ratio		0.40	0.88	0.01628
Controllable Change Duration (days)	51.53			
Controllable Change Duration Ratio	0.38			
Adjusted Final Contract Amount (Constant FY07 $)		6,603,100.61	5,067,778.04	0.01854
Adjusted Final Project Amount (Constant FY07 $)		6,603,100.61	5,345,045.89	0.05907
Contract Cost Growth (%)	4.25			
Project Cost Growth (%)	4.19			
Contract Controllable Cost Growth (%)	1.37			
Project Controllable Cost Growth (%)	1.36			
Contract Schedule Growth (%)	130.13			
BOD Time Growth (days)	80.41			
BOD Growth (%)	10.53			
Contract Time Growth (%)		26.16	47.78	0.05492
BOD to Completion Duration (days)	19.14			
Award Growth (%)	5.26			
Unit Cost ($/sf)	235.79			
Project Placement ($/day)		11,209.67	4,348.75	0.00000
Contract Intensity ($/sf/day)	0.42			
Project Intensity ($/sf/day)		0.40	0.29	0.06570

Table B-21. Medium DB projects vs. Medium DBB projects.

Characteristic	Total Sample Mean	Medium Design-Build Mean (26 Projects)	Medium Design-Bid-Build Mean (17 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	18,032,817.85			
Adjusted Initial Project Amount (Constant FY07 $)	18,391,726.03			
Adjusted Change Order Value (Constant FY07 $)		853,654.90	3,036,161.17	0.08444
Adjusted Controllable Changes (Constant FY07 $)		326,896.38	700,968.52	0.07117
Controllable Change Ratio	0.44			
Controllable Change Duration (days)	53.86			
Controllable Change Duration Ratio	0.30			
Adjusted Final Contract Amount (Constant FY07 $)	19,749,324.07			
Adjusted Final Project Amount (Constant FY07 $)	20,108,232.25			
Contract Cost Growth (%)		5.05	17.22	0.08073
Project Cost Growth (%)		5.05	16.37	0.08758
Contract Controllable Cost Growth (%)		1.97	4.03	0.04178
Project Controllable Cost Growth (%)		1.97	3.83	0.05713
Contract Schedule Growth (%)	109.63			
BOD Time Growth (days)	48.93			
BOD Growth (%)	5.97			
Contract Time Growth (%)	28.01			
BOD to Completion Duration (days)	5.98			
Award Growth (%)	27.00			
Unit Cost ($/sf)	343.62			
Project Placement ($/day)		25,091.10	17,838.54	0.04231
Contract Intensity ($/sf/day)	0.45			
Project Intensity ($/sf/day)		0.37	0.18	0.01309

Table B-22. Northwest region DB projects vs. DB project aggregate.

Characteristic	Total Sample Mean	Northwest Region Design-Build Mean (3 Projects)	Design-Build Mean (75 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	9,954,458.56			
Adjusted Initial Project Amount (Constant FY07 $)	9,954,458.56			
Adjusted Change Order Value (Constant FY07 $)	474,532.70			
Adjusted Controllable Changes (Constant FY07 $)	173,377.10			
Controllable Change Ratio		0.15	0.44	0.00543
Controllable Change Duration (days)		0.00	46.46	0.00001
Controllable Change Duration Ratio		0.00	0.35	0.00000
Adjusted Final Contract Amount (Constant FY07 $)	10,428,991.26			
Adjusted Final Project Amount (Constant FY07 $)	10,428,991.26			
Contract Cost Growth (%)	4.98			
Project Cost Growth (%)	4.98			
Contract Controllable Cost Growth (%)		0.43	2.09	0.00009
Project Controllable Cost Growth (%)		0.43	2.09	0.00009
Contract Schedule Growth (%)	128.49			
BOD Time Growth (days)	87.68			
BOD Growth (%)	11.80			
Contract Time Growth (%)	27.89			
BOD to Completion Duration (days)	8.62			
Award Growth (%)	-0.76		-0.76	
Unit Cost ($/sf)	231.76			
Project Placement ($/day)	15,007.29			
Contract Intensity ($/sf/day)	0.39			
Project Intensity ($/sf/day)	0.39			

Table B-23. Southwest Region DB projects vs. DB project aggregate.

Characteristic	Total Sample Mean	Southwest Region Design-Build Mean (26 Projects)	Design-Build Mean (49 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	9,954,458.56			
Adjusted Initial Project Amount (Constant FY07 $)	9,954,458.56			
Adjusted Change Order Value (Constant FY07 $)	474,532.70			
Adjusted Controllable Changes (Constant FY07 $)	173,377.10			
Controllable Change Ratio	0.43			
Controllable Change Duration (days)	44.60			
Controllable Change Duration Ratio	0.33			
Adjusted Final Contract Amount (Constant FY07 $)	10,428,991.26			
Adjusted Final Project Amount (Constant FY07 $)	10,428,991.26			
Contract Cost Growth (%)	4.98			
Project Cost Growth (%)	4.98			
Contract Controllable Cost Growth (%)	2.02			
Project Controllable Cost Growth (%)	2.02			
Contract Schedule Growth (%)	128.49			
BOD Time Growth (days)	87.68			
BOD Growth (%)	11.80			
Contract Time Growth (%)	27.89			
BOD to Completion Duration (days)		29.54	-2.96	0.11346
Award Growth (%)		31.68	-33.20	0.04437
Unit Cost ($/sf)	231.76			
Project Placement ($/day)	15,007.29			
Contract Intensity ($/sf/day)	0.39			
Project Intensity ($/sf/day)	0.39			

Table B-24. Northeast Region DB projects vs. DB project aggregate.

Characteristic	Total Sample Mean	Northeast Region Design-Build Mean (10 Projects)	Design-Build Mean (65 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	9,954,458.56			
Adjusted Initial Project Amount (Constant FY07 $)	9,954,458.56			
Adjusted Change Order Value (Constant FY07 $)	474,532.70			
Adjusted Controllable Changes (Constant FY07 $)	173,377.10			
Controllable Change Ratio	0.43			
Controllable Change Duration (days)	44.60			
Controllable Change Duration Ratio	0.33			
Adjusted Final Contract Amount (Constant FY07 $)	10,428,991.26			
Adjusted Final Project Amount (Constant FY07 $)	10,428,991.26			
Contract Cost Growth (%)	4.98			
Project Cost Growth (%)	4.98			
Contract Controllable Cost Growth (%)	2.02			
Project Controllable Cost Growth (%)	2.02			
Contract Schedule Growth (%)	128.49			
BOD Time Growth (days)	87.68			
BOD Growth (%)	11.80			
Contract Time Growth (%)	27.89			
BOD to Completion Duration (days)		-3.10	10.48	0.13751
Award Growth (%)	-0.76			
Unit Cost ($/sf)	231.76			
Project Placement ($/day)	15,007.29			
Contract Intensity ($/sf/day)	0.39			
Project Intensity ($/sf/day)	0.39			

Table B-25. Southeast Region DB projects vs. DB aggregate.

Characteristic	Total Sample Mean	Southeast Region Design-Build Mean (22 Projects)	Design-Build Mean (53 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)		12,220,936.09	9,013,656.57	0.12336
Adjusted Initial Project Amount (Constant FY07 $)		12,220,936.09	9,013,656.57	0.12336
Adjusted Change Order Value (Constant FY07 $)	474,532.70			
Adjusted Controllable Changes (Constant FY07 $)	173,377.10			
Controllable Change Ratio	0.43			
Controllable Change Duration (days)	44.60			
Controllable Change Duration Ratio	0.33			
Adjusted Final Contract Amount (Constant FY07 $)		12,735,225.56	9,471,686.46	0.13108
Adjusted Final Project Amount (Constant FY07 $)		12,735,225.56	9,471,686.46	0.13108
Contract Cost Growth (%)	4.98			
Project Cost Growth (%)	4.98			
Contract Controllable Cost Growth (%)		1.35	2.30	0.12375
Project Controllable Cost Growth (%)		1.35	2.30	0.12375
Contract Schedule Growth (%)	128.49			
BOD Time Growth (days)	87.68			
BOD Growth (%)	11.80			
Contract Time Growth (%)	27.89			
BOD to Completion Duration (days)		-4.67	13.98	0.07658
Award Growth (%)	-0.76	8.41	-1.13	
Unit Cost ($/sf)		279.99	216.12	0.04803
Project Placement ($/day)	15,007.29			
Contract Intensity ($/sf/day)	0.39			
Project Intensity ($/sf/day)	0.39			

Table B-26. Micro DB projects vs. Micro DBB projects.

Characteristic	Total Sample Mean	Micro Design-Build Mean (9 Projects)	Micro Design-Bid-Build Mean (7 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	1,157,173.75			
Adjusted Initial Project Amount (Constant FY07 $)	1,189,361.75			
Adjusted Change Order Value (Constant FY07 $)	59,401.57			
Adjusted Controllable Changes (Constant FY07 $)	36,027.61			
Controllable Change Ratio	0.58			
Controllable Change Duration (days)	20.44			
Controllable Change Duration Ratio	0.32			
Adjusted Final Contract Amount (Constant FY07 $)	1,216,575.32			
Adjusted Final Project Amount (Constant FY07 $)	1,248,763.33			
Contract Cost Growth (%)		6.12	2.40	0.14148
Project Cost Growth (%)		6.12	2.26	0.12436
Contract Controllable Cost Growth (%)	2.77			
Project Controllable Cost Growth (%)	2.74			
Contract Schedule Growth (%)	132.11			
BOD Time Growth (days)		144.75	42.00	0.11207
BOD Growth (%)	19.66			
Contract Time Growth (%)	31.53			
BOD to Completion Duration (days)	-10.25			
Award Growth (%)		-43.43	-20.62	0.02739
Unit Cost ($/sf)		173.91	232.59	0.08135
Project Placement ($/day)	2,646.12	2,754.56	1,670.18	
Contract Intensity ($/sf/day)	0.48			
Project Intensity ($/sf/day)	0.40			

Table B-27. Small DB projects vs. Small DBB projects.

Characteristic	Total Sample Mean	Small Design-Build Mean (40 Projects)	Small Design-Bid-Build Mean (20 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)		6,286,634.27	4,815,280.49	0.01164
Adjusted Initial Project Amount (Constant FY07 $)		6,286,634.27	5,092,548.35	0.04573
Adjusted Change Order Value (Constant FY07 $)	295,143.41			
Adjusted Controllable Changes (Constant FY07 $)	100,009.05			
Controllable Change Ratio		0.40	0.88	0.01628
Controllable Change Duration (days)	51.53			
Controllable Change Duration Ratio	0.38			
Adjusted Final Contract Amount (Constant FY07 $)		6,603,100.61	5,067,778.04	0.01854
Adjusted Final Project Amount (Constant FY07 $)		6,603,100.61	5,345,045.89	0.05907
Contract Cost Growth (%)	4.25			
Project Cost Growth (%)	4.19			
Contract Controllable Cost Growth (%)	1.37			
Project Controllable Cost Growth (%)	1.36			
Contract Schedule Growth (%)	130.13			
BOD Time Growth (days)	80.41			
BOD Growth (%)	10.53			
Contract Time Growth (%)		26.16	47.78	0.05492
BOD to Completion Duration (days)	19.14			
Award Growth (%)	5.26			
Unit Cost ($/sf)	235.79			
Project Placement ($/day)		11,209.67	4,348.75	0.00000
Contract Intensity ($/sf/day)	0.42			
Project Intensity ($/sf/day)		0.40	0.29	0.06570

Table B-28. Medium DB projects vs. Medium DBB projects

Characteristic	Total Sample Mean	Medium Design-Build Mean (26 Projects)	Medium Design-Bid-Build Mean (17 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	18,032,817.85			
Adjusted Initial Project Amount (Constant FY07 $)	18,391,726.03			
Adjusted Change Order Value (Constant FY07 $)		853,654.90	3,036,161.17	0.08444
Adjusted Controllable Changes (Constant FY07 $)		326,896.38	700,968.52	0.07117
Controllable Change Ratio	0.44			
Controllable Change Duration (days)	53.86			
Controllable Change Duration Ratio	0.30			
Adjusted Final Contract Amount (Constant FY07 $)	19,749,324.07			
Adjusted Final Project Amount (Constant FY07 $)	20,108,232.25			
Contract Cost Growth (%)		5.05	17.22	0.08073
Project Cost Growth (%)		5.05	16.37	0.08758
Contract Controllable Cost Growth (%)		1.97	4.03	0.04178
Project Controllable Cost Growth (%)		1.97	3.83	0.05713
Contract Schedule Growth (%)	109.63			
BOD Time Growth (days)	48.93			
BOD Growth (%)	5.97			
Contract Time Growth (%)	28.01			
BOD to Completion Duration (days)	5.98			
Award Growth (%)	27.00			
Unit Cost ($/sf)	343.62			
Project Placement ($/day)		25,091.10	17,838.54	0.04231
Contract Intensity ($/sf/day)	0.45			
Project Intensity ($/sf/day)		0.37	0.18	0.01309

Table B-29. Mobile district DB projects vs. Mobile district DBB projects.

Characteristic	Total Sample Mean	Mobile District Design-Build Mean (4 Projects)	Mobile District Design-Bid-Build Mean (1 Project)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	8,631,288.27	7,738,849.40	12,201,043.75	
Adjusted Initial Project Amount (Constant FY07 $)	8,747,472.24	7,738,849.40	12,781,963.59	
Adjusted Change Order Value (Constant FY07 $)	2,705,530.70	449,567.96	11,729,381.67	
Adjusted Controllable Changes (Constant FY07 $)	196,439.90	40,610.20	819,758.70	
Controllable Change Ratio	0.36	0.43	0.07	
Controllable Change Duration (days)	106.60	112.25	84.00	
Controllable Change Duration Ratio	0.43	0.40	0.55	
Adjusted Final Contract Amount (Constant FY07 $)	11,336,818.97	8,188,417.36	23,930,425.41	
Adjusted Final Project Amount (Constant FY07 $)	11,453,002.94	8,188,417.36	24,511,345.25	
Contract Cost Growth (%)	23.33	5.12	96.13	
Project Cost Growth (%)	22.45	5.12	91.77	
Contract Controllable Cost Growth (%)	2.75	1.75	6.72	
Project Controllable Cost Growth (%)	2.69	1.75	6.41	
Contract Schedule Growth (%)	142.24	157.54	96.34	
BOD Time Growth (days)	226.50	309.67	-23.00	
BOD Growth (%)	23.34	32.38	-3.80	
Contract Time Growth (%)	50.52	56.59	26.25	
BOD to Completion Duration (days)	-0.20	-0.25	0.00	
Award Growth (%)				
Unit Cost ($/sf)	294.91	242.75	451.41	
Project Placement ($/day)	9,447.71	9,447.71		
Contract Intensity ($/sf/day)	0.49	0.41	0.73	
Project Intensity ($/sf/day)	0.41	0.41		

Table B-30. Savannah district DB projects vs. Savannah district DBB projects.

Characteristic	Total Sample Mean	Savannah District Design-Build Mean (18 Projects)	Savannah District Design-Bid-Build Mean (11 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	12,049,401.78			
Adjusted Initial Project Amount (Constant FY07 $)	12,242,116.20			
Adjusted Change Order Value (Constant FY07 $)	501,268.63			
Adjusted Controllable Changes (Constant FY07 $)	206,372.12			
Controllable Change Ratio		0.35	0.76	0.05668
Controllable Change Duration (days)	61.00			
Controllable Change Duration Ratio		0.28	0.54	0.01496
Adjusted Final Contract Amount (Constant FY07 $)	12,550,670.41			
Adjusted Final Project Amount (Constant FY07 $)	12,743,384.83			
Contract Cost Growth (%)	4.37			
Project Cost Growth (%)	4.28			
Contract Controllable Cost Growth (%)		1.26	2.89	0.08171
Project Controllable Cost Growth (%)		1.26	2.75	0.09478
Contract Schedule Growth (%)		110.53	122.99	0.12527
BOD Time Growth (days)		52.44	129.11	0.07330
BOD Growth (%)		6.60	17.53	0.04621
Contract Time Growth (%)	25.98			
BOD to Completion Duration (days)	-16.93			
Award Growth (%)	-7.02	8.41	-14.73	
Unit Cost ($/sf)	363.87			
Project Placement ($/day)	17,471.90	17,129.58	23,633.66	
Contract Intensity ($/sf/day)	0.52			
Project Intensity ($/sf/day)	0.41	0.41		

Table B-31. Kansas City district DB projects vs. Kansas City DBB projects.

Characteristic	Total Sample Mean	Kansas City District Design-Build Mean (1 Projects)	Kansas City District Design-Bid-Build Mean (0 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	5,695,751.56	5,695,751.56		
Adjusted Initial Project Amount (Constant FY07 $)	5,695,751.56	5,695,751.56		
Adjusted Change Order Value (Constant FY07 $)	98,846.45	98,846.45		
Adjusted Controllable Changes (Constant FY07 $)	-46,276.50	-46,276.50		
Controllable Change Ratio	-0.47	-0.47		
Controllable Change Duration (days)	18.00	18.00		
Controllable Change Duration Ratio	0.37	0.37		
Adjusted Final Contract Amount (Constant FY07 $)	5,794,598.01	5,794,598.01		
Adjusted Final Project Amount (Constant FY07 $)	5,794,598.01	5,794,598.01		
Contract Cost Growth (%)	1.74	1.74		
Project Cost Growth (%)	1.74	1.74		
Contract Controllable Cost Growth (%)	-0.81	-0.81		
Project Controllable Cost Growth (%)	-0.81	-0.81		
Contract Schedule Growth (%)	97.22	97.22		
BOD Time Growth (days)	-16.00	-16.00		
BOD Growth (%)	-2.86	-2.86		
Contract Time Growth (%)	16.67	16.67		
BOD to Completion Duration (days)	0.00	0.00		
Award Growth (%)				
Unit Cost ($/sf)	111.33	111.33		
Project Placement ($/day)	10,347.50	10,347.50		
Contract Intensity ($/sf/day)	0.20	0.20		
Project Intensity ($/sf/day)	0.20	0.20		

Table B-32. Little Rock district DB projects vs. Little Rock district DBB projects.

Characteristic	Total Sample Mean	Little Rock District Design-Build Mean (1 Project)	Little Rock District Design-Bid-Build Mean (1 Project)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	6,101,213.23	9,304,807.88	2,897,618.58	
Adjusted Initial Project Amount (Constant FY07 $)	6,180,323.50	9,304,807.88	3,055,839.13	
Adjusted Change Order Value (Constant FY07 $)	417,963.31	820,858.09	15,068.53	
Adjusted Controllable Changes (Constant FY07 $)	44,580.40	38,051.52	51,109.28	
Controllable Change Ratio	1.72	0.05	3.39	
Controllable Change Duration (days)	28.00	12.00	44.00	
Controllable Change Duration Ratio	0.20	0.07	0.33	
Adjusted Final Contract Amount (Constant FY07 $)	6,519,176.54	10,125,665.97	2,912,687.11	
Adjusted Final Project Amount (Constant FY07 $)	6,598,286.82	10,125,665.97	3,070,907.66	
Contract Cost Growth (%)	4.67	8.82	0.52	
Project Cost Growth (%)	4.66	8.82	0.49	
Contract Controllable Cost Growth (%)	1.09	0.41	1.76	
Project Controllable Cost Growth (%)	1.04	0.41	1.67	
Contract Schedule Growth (%)	114.21	114.27	114.16	
BOD Time Growth (days)	87.50	113.00	62.00	
BOD Growth (%)	12.44	12.49	12.40	
Contract Time Growth (%)	55.45	22.22	88.68	
BOD to Completion Duration (days)	37.00	74.00	0.00	
Award Growth (%)				
Unit Cost ($/sf)	280.21	303.44	256.98	
Project Placement ($/day)	6,973.61	10,342.87	3,604.35	
Contract Intensity ($/sf/day)	0.40	0.31	0.49	
Project Intensity ($/sf/day)	0.31	0.31	0.30	

Table B-33. Honolulu district DB projects vs. Honolulu district DBB projects.

Characteristic	Total Sample Mean	Honolulu District Design-Build Mean (8 Projects)	Honolulu District Design-Bid-Build Mean (0 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	9,439,581.78	9,439,581.78		
Adjusted Initial Project Amount (Constant FY07 $)	9,439,581.78	9,439,581.78		
Adjusted Change Order Value (Constant FY07 $)	203,898.02	203,898.02		
Adjusted Controllable Changes (Constant FY07 $)	141,985.42	141,985.42		
Controllable Change Ratio	0.64	0.64		
Controllable Change Duration (days)	41.50	41.50		
Controllable Change Duration Ratio	0.61	0.61		
Adjusted Final Contract Amount (Constant FY07 $)	9,643,479.80	9,643,479.80		
Adjusted Final Project Amount (Constant FY07 $)	9,643,479.80	9,643,479.80		
Contract Cost Growth (%)	2.93	2.93		
Project Cost Growth (%)	2.93	2.93		
Contract Controllable Cost Growth (%)	1.56	1.56		
Project Controllable Cost Growth (%)	1.56	1.56		
Contract Schedule Growth (%)	122.78	122.78		
BOD Time Growth (days)	126.50	126.50		
BOD Growth (%)	15.27	15.27		
Contract Time Growth (%)	22.73	22.73		
BOD to Completion Duration (days)	2.50	2.50		
Award Growth (%)	-47.94	-47.94		
Unit Cost ($/sf)	239.14	239.14		
Project Placement ($/day)	15,668.40	15,668.40		
Contract Intensity ($/sf/day)	0.47	0.47		
Project Intensity ($/sf/day)	0.47	0.47		

Table B-34. Tulsa district DB projects vs. Tulsa District DBB projects.

Characteristic	Total Sample Mean	Tulsa District Design-Build Mean (4 Projects)	Tulsa District Design-Bid-Build Mean (4 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	8,211,884.98			
Adjusted Initial Project Amount (Constant FY07 $)	8,362,077.06			
Adjusted Change Order Value (Constant FY07 $)	643,280.94			
Adjusted Controllable Changes (Constant FY07 $)	347,548.27			
Controllable Change Ratio	0.54			
Controllable Change Duration (days)	46.50			
Controllable Change Duration Ratio	0.26			
Adjusted Final Contract Amount (Constant FY07 $)		12,221,265.37	5,489,066.47	0.13194
Adjusted Final Project Amount (Constant FY07 $)	9,005,358.00			
Contract Cost Growth (%)	6.91			
Project Cost Growth (%)	6.81			
Contract Controllable Cost Growth (%)	3.53			
Project Controllable Cost Growth (%)	3.49			
Contract Schedule Growth (%)	206.50			
BOD Time Growth (days)	144.88			
BOD Growth (%)	20.33			
Contract Time Growth (%)	45.35			
BOD to Completion Duration (days)	-5.25			
Award Growth (%)	18.50	65.12	-4.82	
Unit Cost ($/sf)	238.58	208.65	248.56	
Project Placement ($/day)	15,062.08	18,175.52	2,608.32	
Contract Intensity ($/sf/day)	0.45	0.34	0.49	
Project Intensity ($/sf/day)	0.34	0.34		

Table B-35. Alaska district DB projects vs. Alaska district DBB projects.

Characteristic	Total Sample Mean	Alaska District Design-Build Mean (6 Projects)	Alaska District Design-Bid-Build Mean (0 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	5,654,676.75	5,654,676.75		
Adjusted Initial Project Amount (Constant FY07 $)	5,654,676.75	5,654,676.75		
Adjusted Change Order Value (Constant FY07 $)	466,318.57	466,318.57		
Adjusted Controllable Changes (Constant FY07 $)	162,393.55	162,393.55		
Controllable Change Ratio	0.55	0.55		
Controllable Change Duration (days)	7.33	7.33		
Controllable Change Duration Ratio	0.50	0.50		
Adjusted Final Contract Amount (Constant FY07 $)	6,120,995.32	6,120,995.32		
Adjusted Final Project Amount (Constant FY07 $)	6,120,995.32	6,120,995.32		
Contract Cost Growth (%)	7.85	7.85		
Project Cost Growth (%)	7.85	7.85		
Contract Controllable Cost Growth (%)	3.81	3.81		
Project Controllable Cost Growth (%)	3.81	3.81		
Contract Schedule Growth (%)	121.69	121.69		
BOD Time Growth (days)	62.83	62.83		
BOD Growth (%)	11.52	11.52		
Contract Time Growth (%)	7.16	7.16		
BOD to Completion Duration (days)	-0.83	-0.83		
Award Growth (%)	-45.13	-45.13		
Unit Cost ($/sf)	168.64	168.64		
Project Placement ($/day)	10,868.00	10,868.00		
Contract Intensity ($/sf/day)	0.44	0.44		
Project Intensity ($/sf/day)	0.44	0.44		

Table B-36. Sacramento district DB projects vs. Sacramento district DBB projects.

Characteristic	Total Sample Mean	Sacramento District Design-Build Mean (4 Projects)	Sacramento District Design-Bid-Build Mean (1 Project)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	11,535,230.27	12,593,825.21	7,300,850.47	
Adjusted Initial Project Amount (Constant FY07 $)	11,647,391.12	12,593,825.21	7,861,654.74	
Adjusted Change Order Value (Constant FY07 $)	585,859.97	686,022.54	185,209.71	
Adjusted Controllable Changes (Constant FY07 $)	185,209.71	514,440.09	83,375.12	
Controllable Change Ratio	0.45	0.45	0.45	
Controllable Change Duration (days)	25.80	32.25	0.00	
Controllable Change Duration Ratio	0.17	0.22	0.00	
Adjusted Final Contract Amount (Constant FY07 $)	12,121,090.24	13,279,847.75	7,486,060.18	
Adjusted Final Project Amount (Constant FY07 $)	12,233,251.09	13,279,847.75	8,046,864.45	
Contract Cost Growth (%)	4.78	5.34	2.54	
Project Cost Growth (%)	4.74	5.34	2.36	
Contract Controllable Cost Growth (%)	3.21	3.72	1.14	
Project Controllable Cost Growth (%)	3.19	3.72	1.06	
Contract Schedule Growth (%)	96.70	100.90	79.91	
BOD Time Growth (days)	-17.40	10.00	-127.00	
BOD Growth (%)	-5.38	-0.43	-25.15	
Contract Time Growth (%)	19.83	21.73	12.22	
BOD to Completion Duration (days)	4.20	5.25	0.00	
Award Growth (%)	82.03	82.03		
Unit Cost ($/sf)	292.38	292.38		
Project Placement ($/day)	19,282.34	19,282.34		
Contract Intensity ($/sf/day)	0.42	0.42		
Project Intensity ($/sf/day)	0.42	0.42		

Table B-37. Baltimore district DB projects vs. Baltimore district DBB projects.

Characteristic	Total Sample Mean	Baltimore District Design-Build Mean (6 Projects)	Baltimore District Design-Bid-Build Mean (2 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	3,311,984.41			
Adjusted Initial Project Amount (Constant FY07 $)	3,357,724.19			
Adjusted Change Order Value (Constant FY07 $)		333,631.20	91,140.08	0.11255
Adjusted Controllable Changes (Constant FY07 $)	128,810.97			
Controllable Change Ratio	0.57			
Controllable Change Duration (days)		53.17	11.00	0.11315
Controllable Change Duration Ratio	0.35			
Adjusted Final Contract Amount (Constant FY07 $)	3,584,992.83			
Adjusted Final Project Amount (Constant FY07 $)	3,630,732.61			
Contract Cost Growth (%)		9.46	3.03	0.08300
Project Cost Growth (%)		9.46	2.84	0.07298
Contract Controllable Cost Growth (%)		5.24	1.67	0.13938
Project Controllable Cost Growth (%)		5.24	1.57	0.12935
Contract Schedule Growth (%)	123.08	126.14	104.68	
BOD Time Growth (days)	73.29	82.17	20.00	
BOD Growth (%)	9.07	9.84	4.47	
Contract Time Growth (%)	36.76			
BOD to Completion Duration (days)	-0.88			
Award Growth (%)	-27.07	-27.07		
Unit Cost ($/sf)	255.93			
Project Placement ($/day)	5,452.57			
Contract Intensity ($/sf/day)	0.47			
Project Intensity ($/sf/day)		0.45	0.28	0.14386

Table B-38. Louisville district DB projects vs. Louisville district DBB projects.

Characteristic	Total Sample Mean	Louisville District Design-Build Mean (5 Projects)	Louisville District Design-Bid-Build Mean (4 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	11,551,174.15			
Adjusted Initial Project Amount (Constant FY07 $)	11,976,479.10			
Adjusted Change Order Value (Constant FY07 $)	416,212.44			
Adjusted Controllable Changes (Constant FY07 $)		78,276.99	482,267.77	0.08796
Controllable Change Ratio		0.21	0.77	0.00816
Controllable Change Duration (days)	28.89			
Controllable Change Duration Ratio	0.20			
Adjusted Final Contract Amount (Constant FY07 $)	11,967,386.59			
Adjusted Final Project Amount (Constant FY07 $)	12,392,691.53			
Contract Cost Growth (%)	3.13			
Project Cost Growth (%)	3.04			
Contract Controllable Cost Growth (%)		0.75	2.85	0.07993
Project Controllable Cost Growth (%)		0.75	2.70	0.08481
Contract Schedule Growth (%)		128.25	88.51	0.03558
BOD Time Growth (days)		92.20	-115.50	0.04312
BOD Growth (%)		18.88	-13.98	0.01424
Contract Time Growth (%)	21.20			
BOD to Completion Duration (days)	-1.00			
Award Growth (%)	-6.43	-18.52	29.85	
Unit Cost ($/sf)	215.22			
Project Placement ($/day)	12,972.69			
Contract Intensity ($/sf/day)	0.42			
Project Intensity ($/sf/day)	0.35			

Table B-39. Omaha district DB projects vs. Omaha district DBB projects.

Characteristic	Total Sample Mean	Omaha District Design-Build Mean (4 Projects)	Omaha District Design-Bid-Build Mean (4 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	9,766,080.68			
Adjusted Initial Project Amount (Constant FY07 $)	10,080,353.41			
Adjusted Change Order Value (Constant FY07 $)	2,124,602.55			
Adjusted Controllable Changes (Constant FY07 $)	467,720.33			
Controllable Change Ratio	0.35			
Controllable Change Duration (days)	40.63			
Controllable Change Duration Ratio	0.30			
Adjusted Final Contract Amount (Constant FY07 $)	11,890,683.23			
Adjusted Final Project Amount (Constant FY07 $)	12,204,955.96			
Contract Cost Growth (%)	12.11			
Project Cost Growth (%)	11.55			
Contract Controllable Cost Growth (%)	3.11			
Project Controllable Cost Growth (%)	2.98			
Contract Schedule Growth (%)		108.94	96.09	0.12335
BOD Time Growth (days)	14.43			
BOD Growth (%)		7.23	-4.15	0.14296
Contract Time Growth (%)	20.12			
BOD to Completion Duration (days)	23.63			
Award Growth (%)	100.83	319.59	27.91	
Unit Cost ($/sf)	284.26			
Project Placement ($/day)	14,679.60	14,679.60		
Contract Intensity ($/sf/day)	0.48			
Project Intensity ($/sf/day)	0.42	0.40	0.47	

Table B-40. Fort Worth district DB projects vs. Fort Worth district DBB projects.

Characteristic	Total Sample Mean	Fort Worth District Design-Build Mean (3 Projects)	Fort Worth District Design-Bid-Build Mean (10 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	10,000,479.39			
Adjusted Initial Project Amount (Constant FY07 $)	10,416,572.22			
Adjusted Change Order Value (Constant FY07 $)	1,561,124.63			
Adjusted Controllable Changes (Constant FY07 $)	335,196.91			
Controllable Change Ratio	0.64			
Controllable Change Duration (days)	58.38			
Controllable Change Duration Ratio	0.35			
Adjusted Final Contract Amount (Constant FY07 $)	11,561,604.02			
Adjusted Final Project Amount (Constant FY07 $)	11,977,696.85			
Contract Cost Growth (%)	7.24			
Project Cost Growth (%)	6.92			
Contract Controllable Cost Growth (%)	0.23			
Project Controllable Cost Growth (%)	0.24			
Contract Schedule Growth (%)	116.11			
BOD Time Growth (days)	68.83			
BOD Growth (%)	9.16			
Contract Time Growth (%)		25.43	78.35	0.01378
BOD to Completion Duration (days)	64.33			
Award Growth (%)	4.46			
Unit Cost ($/sf)	246.44			
Project Placement ($/day)	12,910.31			
Contract Intensity ($/sf/day)	0.35			
Project Intensity ($/sf/day)	0.24			

Table B-41. Los Angeles district DB projects vs. Los Angeles district DBB projects.

Characteristic	Total Sample Mean	Los Angeles District Design-Build Mean (8 Projects)	Los Angeles District Design-Bid-Build Mean (2 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)		9,396,341.77	792,079.39	0.01952
Adjusted Initial Project Amount (Constant FY07 $)		9,396,341.77	865,728.33	0.02024
Adjusted Change Order Value (Constant FY07 $)		575,008.13	601.40	0.04628
Adjusted Controllable Changes (Constant FY07 $)		62,983.63	-1,123.28	0.08406
Controllable Change Ratio	0.35			
Controllable Change Duration (days)	55.50			
Controllable Change Duration Ratio	0.30	0.30		
Adjusted Final Contract Amount (Constant FY07 $)		9,971,349.90	792,680.79	0.01918
Adjusted Final Project Amount (Constant FY07 $)		9,971,349.90	866,329.73	0.01985
Contract Cost Growth (%)		4.95	0.05	0.04184
Project Cost Growth (%)		4.95	0.05	0.04158
Contract Controllable Cost Growth (%)		0.87	-0.15	0.06404
Project Controllable Cost Growth (%)		0.87	-0.14	0.06528
Contract Schedule Growth (%)		116.86	99.44	0.05451
BOD Time Growth (days)		76.40	-2.00	0.05704
BOD Growth (%)		13.32	-0.56	0.05119
Contract Time Growth (%)		35.54	-0.56	0.12512
BOD to Completion Duration (days)	69.90			
Award Growth (%)		-19.51	-39.20	0.11817
Unit Cost ($/sf)	189.82			
Project Placement ($/day)	14,210.30	14,210.30		
Contract Intensity ($/sf/day)	0.35			
Project Intensity ($/sf/day)	0.24	0.24		

Table B-42. Seattle district DB projects vs. Seattle district DBB projects.

Characteristic	Total Sample Mean	Seattle District Design-Build Mean (2 Projects)	Seattle District Design-Bid-Build Mean (1 Project)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	14,174,393.93	21,230,280.88	62,620.03	
Adjusted Initial Project Amount (Constant FY07 $)	14,175,629.90	21,230,280.88	66,327.94	
Adjusted Change Order Value (Constant FY07 $)	641,158.17	961,737.26	0.00	
Adjusted Controllable Changes (Constant FY07 $)	67,235.43	100,853.14	0.00	
Controllable Change Ratio	0.10	0.10		
Controllable Change Duration (days)	0.00	0.00	0.00	
Controllable Change Duration Ratio	0.00	0.00		
Adjusted Final Contract Amount (Constant FY07 $)	14,815,552.10	22,192,018.13	62,620.03	
Adjusted Final Project Amount (Constant FY07 $)	14,816,788.07	22,192,018.13	66,327.94	
Contract Cost Growth (%)	2.49	3.74	0.00	
Project Cost Growth (%)	2.49	3.74	0.00	
Contract Controllable Cost Growth (%)	0.25	0.38	0.00	
Project Controllable Cost Growth (%)	0.25	0.38	0.00	
Contract Schedule Growth (%)	125.50	125.50		
BOD Time Growth (days)	165.00	165.00		
BOD Growth (%)	20.32	20.32		
Contract Time Growth (%)	19.60	36.07	-13.33	
BOD to Completion Duration (days)	-63.50	-25.00	-102.00	
Award Growth (%)	-6.45		-6.45	
Unit Cost ($/sf)	265.78	265.78		
Project Placement ($/day)	29,482.05	29,482.05		
Contract Intensity ($/sf/day)	0.41	0.41		
Project Intensity ($/sf/day)	0.41	0.41		

Table B-43. Norfolk district DB projects vs. Norfolk DBB projects.

Characteristic	Total Sample Mean	Norfolk District Design-Build Mean (1 Project)	Norfolk District Design-Bid-Build Mean (0 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	22,286,276.33	22,286,276.33		
Adjusted Initial Project Amount (Constant FY07 $)	22,286,276.33	22,286,276.33		
Adjusted Change Order Value (Constant FY07 $)	131,333.35	131,333.35		
Adjusted Controllable Changes (Constant FY07 $)	59,475.84	59,475.84		
Controllable Change Ratio	0.45	0.45		
Controllable Change Duration (days)	0.00	0.00		
Controllable Change Duration Ratio	0.00	0.00		
Adjusted Final Contract Amount (Constant FY07 $)	22,417,609.68	22,417,609.68		
Adjusted Final Project Amount (Constant FY07 $)	22,417,609.68	22,417,609.68		
Contract Cost Growth (%)	0.59	0.59		
Project Cost Growth (%)	0.59	0.59		
Contract Controllable Cost Growth (%)	0.27	0.27		
Project Controllable Cost Growth (%)	0.27	0.27		
Contract Schedule Growth (%)	109.44	109.44		
BOD Time Growth (days)	68.00	68.00		
BOD Growth (%)	8.63	8.63		
Contract Time Growth (%)	5.14	5.14		
BOD to Completion Duration (days)	-31.00	-31.00		
Award Growth (%)	14.52	14.52		
Unit Cost ($/sf)	215.55	215.55		
Project Placement ($/day)	29,613.75	29,613.75		
Contract Intensity ($/sf/day)	0.28	0.28		
Project Intensity ($/sf/day)	0.28	0.28		

Table B-44. European district DB projects vs. European district DBB projects.

Characteristic	Total Sample Mean	Europe District Design-Build Mean (0 Projects)	Europe District Design-Bid-Build Mean (1 Project)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	6,370,704.76		6,370,704.76	
Adjusted Initial Project Amount (Constant FY07 $)	6,837,835.87		6,837,835.87	
Adjusted Change Order Value (Constant FY07 $)	857,709.99		857,709.99	
Adjusted Controllable Changes (Constant FY07 $)	529,624.24		529,624.24	
Controllable Change Ratio	0.62		0.62	
Controllable Change Duration (days)	0.00		0.00	
Controllable Change Duration Ratio				
Adjusted Final Contract Amount (Constant FY07 $)	7,228,414.75		7,228,414.75	
Adjusted Final Project Amount (Constant FY07 $)	7,695,545.86		7,695,545.86	
Contract Cost Growth (%)	13.46		13.46	
Project Cost Growth (%)	12.54		12.54	
Contract Controllable Cost Growth (%)	8.31		8.31	
Project Controllable Cost Growth (%)	7.75		7.75	
Contract Schedule Growth (%)	98.40		98.40	
BOD Time Growth (days)	-13.00		-13.00	
BOD Growth (%)	-1.63		-1.63	
Contract Time Growth (%)	-1.60		-1.60	
BOD to Completion Duration (days)	0.00		0.00	
Award Growth (%)				
Unit Cost ($/sf)				
Project Placement ($/day)	6,339.00		6,339.00	
Contract Intensity ($/sf/day)				
Project Intensity ($/sf/day)				

Table B-45. Albuquerque district DB projects vs. Albuquerque DBB projects.

Characteristic	Total Sample Mean	Albuquerque District Design-Build Mean (0 Projects)	Albuquerque District Design-Bid-Build Mean (2 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	5,933,667.69		5,933,667.69	
Adjusted Initial Project Amount (Constant FY07 $)	6,267,682.17		6,267,682.17	
Adjusted Change Order Value (Constant FY07 $)	114,865.81		114,865.81	
Adjusted Controllable Changes (Constant FY07 $)	104,209.45		104,209.45	
Controllable Change Ratio	0.92		0.92	
Controllable Change Duration (days)	121.00		121.00	
Controllable Change Duration Ratio	0.77		0.77	
Adjusted Final Contract Amount (Constant FY07 $)	6,048,533.50		6,048,533.50	
Adjusted Final Project Amount (Constant FY07 $)	6,382,547.99		6,382,547.99	
Contract Cost Growth (%)	1.93		1.93	
Project Cost Growth (%)	1.83		1.83	
Contract Controllable Cost Growth (%)	1.75		1.75	
Project Controllable Cost Growth (%)	1.66		1.66	
Contract Schedule Growth (%)	106.44		106.44	
BOD Time Growth (days)	29.50		29.50	
BOD Growth (%)	5.95		5.95	
Contract Time Growth (%)	19.79		19.79	
BOD to Completion Duration (days)	52.50		52.50	
Award Growth (%)				
Unit Cost ($/sf)	288.06		288.06	
Project Placement ($/day)	6,660.00		6,660.00	
Contract Intensity ($/sf/day)	0.48		0.48	
Project Intensity ($/sf/day)	0.33		0.33	

Table B-46. Two-phase DB projects vs. DBB project aggregate.

Characteristic	Total Sample Mean	Two-Phase Design-Build Mean (17 Projects)	Design-Bid-Build Mean (44 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)		14,044,778.29	8,979,830.36	0.01469
Adjusted Initial Project Amount (Constant FY07 $)		14,044,778.29	9,468,317.11	0.02969
Adjusted Change Order Value (Constant FY07 $)	1,145,129.04			
Adjusted Controllable Changes (Constant FY07 $)	295,944.07			
Controllable Change Ratio		0.30	0.68	0.00344
Controllable Change Duration (days)	54.20			
Controllable Change Duration Ratio	0.34			
Adjusted Final Contract Amount (Constant FY07 $)		14,807,956.34	10,272,531.38	0.04760
Adjusted Final Project Amount (Constant FY07 $)		14,807,956.34	10,761,018.12	0.08202
Contract Cost Growth (%)	7.72			
Project Cost Growth (%)	7.41			
Contract Controllable Cost Growth (%)	1.99			
Project Controllable Cost Growth (%)	1.91			
Contract Schedule Growth (%)	111.15			
BOD Time Growth (days)	51.15			
BOD Growth (%)	6.82			
Contract Time Growth (%)	34.38			
BOD to Completion Duration (days)	9.50			
Award Growth (%)	4.74			
Unit Cost ($/sf)	300.30			
Project Placement ($/day)		19,274.07	9,887.68	0.00220
Contract Intensity ($/sf/day)		0.35	0.50	0.04801
Project Intensity ($/sf/day)		0.35	0.27	0.09967

Table B-47. Single-phase DB projects vs. DBB project aggregate.

Characteristic	Total Sample Mean	One-Phase Design-Build Mean (3 Projects)	Design-Bid-Build Mean (44 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	9,134,063.02			
Adjusted Initial Project Amount (Constant FY07 $)	9,591,369.76			
Adjusted Change Order Value (Constant FY07 $)	1,244,941.22			
Adjusted Controllable Changes (Constant FY07 $)	303,577.67			
Controllable Change Ratio		0.01	0.68	0.12171
Controllable Change Duration (days)	54.85			
Controllable Change Duration Ratio	0.37			
Adjusted Final Contract Amount (Constant FY07 $)	10,379,004.24			
Adjusted Final Project Amount (Constant FY07 $)	10,836,310.98			
Contract Cost Growth (%)	8.36			
Project Cost Growth (%)	7.96			
Contract Controllable Cost Growth (%)	2.03			
Project Controllable Cost Growth (%)	1.93			
Contract Schedule Growth (%)	110.36			
BOD Time Growth (days)	43.00			
BOD Growth (%)	6.23			
Contract Time Growth (%)		22.90	36.81	0.07398
BOD to Completion Duration (days)	12.07			
Award Growth (%)	2.59		2.59	
Unit Cost ($/sf)	304.26			
Project Placement ($/day)	10,897.21			
Contract Intensity ($/sf/day)		0.35	0.50	0.07912
Project Intensity ($/sf/day)	0.28			

Table B-48. MATOC DB projects vs. DBB project aggregate.

Characteristic	Total Sample Mean	MATOC Design-Build Mean (14 Projects)	Design-Bid-Build Mean (44 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	8,447,964.04			
Adjusted Initial Project Amount (Constant FY07 $)		6,776,384.18	9,468,317.11	0.10956
Adjusted Change Order Value (Constant FY07 $)		357,644.42	1,292,701.01	0.07154
Adjusted Controllable Changes (Constant FY07 $)	293,422.22			
Controllable Change Ratio	0.66			
Controllable Change Duration (days)	61.45			
Controllable Change Duration Ratio		0.61	0.36	0.06778
Adjusted Final Contract Amount (Constant FY07 $)		7,134,028.61	10,272,531.38	0.09700
Adjusted Final Project Amount (Constant FY07 $)		7,134,028.61	10,761,018.12	0.06379
Contract Cost Growth (%)	7.79			
Project Cost Growth (%)	7.46			
Contract Controllable Cost Growth (%)	2.33			
Project Controllable Cost Growth (%)	2.25			
Contract Schedule Growth (%)	109.41			
BOD Time Growth (days)	34.00			
BOD Growth (%)	4.88			
Contract Time Growth (%)	35.03			
BOD to Completion Duration (days)	22.39			
Award Growth (%)	1.64			
Unit Cost ($/sf)	293.85			
Project Placement ($/day)	11,284.07			
Contract Intensity ($/sf/day)	0.50			
Project Intensity ($/sf/day)		0.49	0.27	0.02836

Table B-49. Community type DB projects vs. Community DBB projects.

Characteristic	Total Sample Mean	Community Type Design-Build Mean (4 Projects)	Community Type Design-Bid-Build Mean (2 Projects)	Probability
Adjusted Contract Award Amount (Constant FY07 $)	6,818,270.16			
Adjusted Initial Project Amount (Constant FY07 $)	6,912,624.93			
Adjusted Change Order Value (Constant FY07 $)	337,541.64			
Adjusted Controllable Changes (Constant FY07 $)	142,498.53			
Controllable Change Ratio	0.36			
Controllable Change Duration (days)		67.00	12.50	0.05079
Controllable Change Duration Ratio		0.47	0.18	0.14938
Adjusted Final Contract Amount (Constant FY07 $)	7,155,811.80			
Adjusted Final Project Amount (Constant FY07 $)	7,250,166.57			
Contract Cost Growth (%)	5.60			
Project Cost Growth (%)	5.49			
Contract Controllable Cost Growth (%)	2.31			
Project Controllable Cost Growth (%)	2.26			
Contract Schedule Growth (%)	114.23	117.79	100.00	
BOD Time Growth (days)	63.40	79.25	0.00	
BOD Growth (%)	9.72	12.15	0.00	
Contract Time Growth (%)	27.22			
BOD to Completion Duration (days)	0.00	0.00	0.00	
Award Growth (%)	-2.76	-2.76		
Unit Cost ($/sf)	247.18			
Project Placement ($/day)	11,304.72	12,953.72	4,708.74	
Contract Intensity ($/sf/day)	0.46			
Project Intensity ($/sf/day)	0.36	0.40	0.24	

Table B-50. Analysis of Variance for design-build projects by district.

Variable Name	P-value	F-value	Alpha = 0.05 F-critical	Alpha = 0.10 F-critical
Adjusted Contract Award Amount (Constant FY07 $)	0.19741	1.40	1.95	1.68
Adjusted Initial Project Amount (Constant FY07 $)	0.19741	1.40	1.95	1.68
Adjusted Change Order Value (Constant FY07 $)	0.33036	1.16	1.95	1.68
Adjusted Controllable Changes (Constant FY07 $)	0.16335	1.48	1.95	1.68
Controllable Change Ratio	0.55354	0.89	1.96	1.68
Controllable Change Duration (days)	0.88959	0.51	1.95	1.68
Controllable Change Duration Ratio	0.74359	0.69	1.98	1.70
Adjusted Final Contract Amount (Constant FY07 $)	0.20608	1.38	1.95	1.68
Adjusted Final Project Amount (Constant FY07 $)	0.20608	1.38	1.95	1.68
Contract Cost Growth (%)	0.07941	1.77	1.95	1.68
Project Cost Growth (%)	0.07941	1.77	1.95	1.68
Contract Controllable Cost Growth (%)	0.07703	1.78	1.95	1.68
Project Controllable Cost Growth (%)	0.07703	1.78	1.95	1.68
Contract Schedule Growth (%)	0.20881	1.40	2.02	1.73
BOD Time Growth (days)	0.23084	1.35	2.02	1.73
BOD Growth (%)	0.63119	0.80	2.02	1.73
Contract Time Growth (%)	0.70938	0.73	1.95	1.68
BOD to Completion Duration (days)	0.15381	1.53	2.00	1.71
Award Growth (%)	0.00790	4.82	2.90	2.27
Unit Cost ($/sf)	0.24493	1.36	2.17	1.82
Project Placement ($/day)	0.24733	1.32	2.07	1.75
Contract Intensity ($/sf/day)	0.88853	0.46	2.17	1.82
Project Intensity ($/sf/day)	0.88853	0.46	2.17	1.82

Table B-51. Analysis of variance for design-build projects by facility type.

Variable Name	P-value	F-value	Alpha = 0.05 F-critical	Alpha = 0.10 F-critical
Adjusted Contract Award Amount (Constant FY07 $)	0.24091	1.31	1.95	1.68
Adjusted Initial Project Amount (Constant FY07 $)	0.24091	1.31	1.95	1.68
Adjusted Change Order Value (Constant FY07 $)	0.46697	0.99	1.95	1.68
Adjusted Controllable Changes (Constant FY07 $)	0.79073	0.64	1.95	1.68
Controllable Change Ratio	0.68083	0.76	1.96	1.68
Controllable Change Duration (days)	0.67185	0.77	1.95	1.68
Controllable Change Duration Ratio	0.11508	1.64	1.97	1.70
Adjusted Final Contract Amount (Constant FY07 $)	0.27937	1.24	1.95	1.68
Adjusted Final Project Amount (Constant FY07 $)	0.27937	1.24	1.95	1.68
Contract Cost Growth (%)	0.33670	1.16	1.95	1.68
Project Cost Growth (%)	0.33670	1.16	1.95	1.68
Contract Controllable Cost Growth (%)	0.53295	0.91	1.95	1.68
Project Controllable Cost Growth (%)	0.53295	0.91	1.95	1.68
Contract Schedule Growth (%)	0.23483	1.34	2.02	1.73
BOD Time Growth (days)	0.69255	0.73	2.02	1.73
BOD Growth (%)	0.66512	0.76	2.02	1.73
Contract Time Growth (%)	0.65706	0.78	1.95	1.68
BOD to Completion Duration (days)	0.43145	1.03	1.96	1.68
Award Growth (%)	0.08547	2.51	3.06	2.36
Unit Cost ($/sf)	0.74989	0.65	2.15	1.81
Project Placement ($/day)	0.41671	1.05	1.95	1.68
Contract Intensity ($/sf/day)	0.20541	1.45	2.15	1.81
Project Intensity ($/sf/day)	0.20541	1.45	2.15	1.81

REFERENCES CITED

"Army Regulation 415-15, Army Military Construction Program Development and Execution." Headquarters, Department of the Army. Washington, D.C. September 4, 1998.

Beard, Jeffrey L., Loulakis, Michael C., and Wundram, Edward C. (2001) *Design Build: Planning through Development*. McGraw Hill Publishers. Boston, Massachusetts.

Bennett, J., Pothecary, E., Robinson, G., (1996) The Industry Today. Designing and Building a World-Class Industry, Centre for Strategic Studies in Construction, United Kingdom.

Burgess, Carmen L. (2006) "SecArmy Orders Army-Wide Business Transformation." Army News Service, March 7, 2006. Washington DC.

Charles, Michael. (1996) "Congress Approves New Design-Build Law." *Civil Engineering* 66(33).

"Design: Military Medical Facilities." *Unified Facilities Criteria 4-510-01*. Department of Defense. October 16, 2003.

Design Build Institute of America (DBIA) – Industry Information. http://www.dbia.org/fr_industryin.html, viewed February 14, 2007.

"DoD Area Cost Factors." PAX Newsletter No. 3.2.1, US Army Corps of Engineers, Washington, D.C. February 13, 2006.

El Wardani, Marwa A., Messner, John I., and Horman, Michael J. (2005) "Comparing Procurement Methods for Design-Build Projects." *Journal of Construction Engineering and Management*. ASCE, 132(3), 230-238.

"Engineering and Construction Bulletin No. 2005-7." (2005) US Army Corps of Engineers, Washington D.C. May 19, 2005.

"Engineer Regulation 1180-1-9, Design-Build Contracting." Department of the Army, US Army Corps of Engineers. Washington, D.C. July 31, 1999.

"Executive Summary - Model Request for Proposal for Medical Design-Build (D-B) Projects – DRAFT COPY." (2006) Department of Defense. Project Number: W912 HN-05-D-003. March 14, 2006.

"Experiences of Federal Agencies with the Design-Build Approach to Construction." Federal Construction Council Consulting Committee on Cost Engineering. National Academy Press. Washington, D.C. 1993.

Federal Acquisition Regulation (FAR). http://www.acquisition.gov/far/current/html/Subpart%2036_1.html#wp1076344, viewed February 14, 2007.

Flyvbjerg, Bent; Holm, Mette Skamris; and Buhl Soren. (2002) "Underestimating Costs in Public Works Projects: Error or Lie?" *Journal of the American Planning Association*, American Planning Association. 68(3). 279-295.

Fredrickson, Ken. (1998) "Design Guidelines for Design-Build Projects." *Journal of Management in Engineering*, ASCE. 14(1). 77-80.

Gordon, Christopher M. (1994) "Choosing Appropriate Construction Contracting Method." *Journal of Construction Engineering*, ASCE. 120(1). 196-210.

Gransberg, Douglas D. and Villarreal-Buitrago, Monica E. (2002) "Construction Project Performance Metrics." *2002 AACE International Transactions.* AACE International, Morgantown, West Virgina.

"The Gruber Wagon Works." Berks County Heritage Center. http://www.fieldtrip.com/pa/03748839.htm, viewed April 16, 2006.

"History of the John J. Sparkman Center." Redstone Arsenal. http://www.redstone.army.mil/history/sparkman/welcome.html, viewed March 30, 2006.

"Inflation and Real Growth Handbook." Army Budget Office, Budget Formulation Division. Washington D.C. April 2002.

Jahren, Charles T., and Ashe, Andrew M. (1991) "Predictors of Cost-Overrun Rates." *Journal of Construction Engineering and Management*. ASCE, 116(3), 548-552.

Konchar, Mark. (1997) "A Comparison of United States Project Delivery Systems." Technical Report No. 38, Computer Integrated Construction Research Program. Pennsylvania State University.

Konchar, Mark, and Sanvido, Victor. (1998) "Comparison of U.S. Project Delivery Systems." *Journal of Construction Engineering and Management*. ASCE, 124(6), 435-444.

Ling, Florence Y. Y., Chan, Swee Lean, Chong, Edwin, and Ee, Lee Ping. (2004) "Predicting Performance of Design-Build and Design-Bid-Build Projects." *Journal of Construction Engineering and Management*. ASCE, 130(1), 75-83.

Loulakis, Michael C. (2004) Design-Build Lessons Learned: Case Studies from 2003. Wickwire Gavin, P.C. Vienna, Virginia, USA.

"Model Request for Proposal for Medical Design-Build (D-B) Projects – DRAFT COPY." (2006) Department of Defense, Project Number: W912HN-05-D-003. March 14, 2006.

Molenaar, Keith R., and Songer, Anthony D. (1998) "Model for Public Sector Design-Build Project Selection." *Journal of Construction Engineering and Management*, ASCE. 124(6). 467-479.

Molenaar, Keith R., Songer, Anthony D., and Barash, Mouji. (1999) "Public-Sector Design/Build Evolution and Performance." *Journal of Management in Engineering*, ASCE. 15(2). 54-62.

Molenaar, K.R., and Scott, S. (2003). Examining the Performance of Design-Build in the Public Sector. Public Sector Design-Build, Aspen Law and Business.

Mouritsen, John W. (1993) "An Empirical Analysis of the Effectiveness of Design-Build Construction Contracts." MS Thesis, Purdue University, West Lafayette, Indiana.

Newbold, Paul; Carlson, William L.; Thorne, Betty. (2007) Statistics for Business and Economics, 6th edition. Prentice Hall, Upper Saddle River, New Jersey. 984 pages.

Office of the Surgeon General (OTSG). (1975) Department of the Army. General Orders Number 29. Organization of Unit – United States Army Health Facility Planning Agency. Washington, DC.

Petersen, Denis R. and Murphree, E Lile. (2004) "The Impact of Owner Representatives in a Design-Build Construction Environment." *Project Management Journal*. September 2004. 27-38.

"Programming Cost Estimates for Military Construction." Technical Manual 5-800-4. Department of the Army. May 1994.

"Quadrennial Defense Review – Roadmap for Medical Transformation." Military Health System Office of Transformation. 3 April 2006.

Riley, David R., Diller, Brenton E., and Kerr, Daniel. (2004) "Effects of Delivery Systems on Change Order Size and Frequency in Mechanical Construciton." *Journal of Construction Engineering and Management*, ASCE. 131(9). 953-962.

"RMS Users Guide – Software Version 2.36." US Army Corps of Engineers, RMS Center. http://216.86.193.60/guides.aspx viewed February 10, 2007

Sekaran, U. (1992) Research Methods for Business – A Skill Building Approach, 2nd edition. Wiley, New York.

Setzer, Steven, W. (1992) “Design-build Job Stokes Tempers.” *Engineering News Record*. 229(13). 8

Shane, Jennifer S. (2003) “Design-Build Highway Construction: An Examination of Special Experimental Project Number 14 Performance.” MS Thesis, University of Colorado, Boulder, Colo.

Songer, Anthony D., and Molenaar, Keith R. (1996) “Selecting Design-Build: Public Private Sector Owner Attitudes.” *Journal of Management in Engineering*, ASCE. 12(6). 47-53.

Temple, Meredith W.B. “MILCON Transformation Update.” Presentation to the Garrison Commanders Conference. October 31, 2006.

Tyler, J. Joseph. “MILCON Process Reinvention and MILCON Transformation” Presentation to the US Army Corps of Engineers. May 3, 2006.

Uhlik, Felix T, and Eller, Michael D. (1999) “Alternative Deliver Approaches for Military Medical Construction Projects.” *Journal of Architectural Engineering*. ASCE 5(4). 149-155.

“Unified Facilities Criteria 4-510-01, Design: Medical Military Facilities.” Department of Defense. Washington, D.C. October 16, 2003.

“Unit Costs for Army Facilities – Military Construction.” PAX Newsletter No. 3.2.2. US Army Corps of Engineers. Washington, D.C. March 30, 2006.

“Use of Stipends in Military Construction-Funded Two-Phase Design Build Projects.” U.S. Army Corps of Engineers, CECC-C. Washington, D.C. September 30, 2004.

Valine, Debra. “Tyler discusses MILCON Transformation at Small Business Conference.” US Army Engineering and Support Center, Huntsville. http://www.hq.usace.army.mil/cemp/milcontrans/tyler.htm, viewed February 9, 2007

Walker, Derek H.T. (1997) “Choosing an Appropriate Research Methodology.” *Construction Management and Economics*. 15. 149-159.

Winston, Sherie. (2000) “Pentagon Contractors Divide and Conquer.” *Engineering News Record*. 245(9). 58.