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An Empirical Analysis of Air Force Military Construction Project Delivery Method Performance in the United States

Erich C. Kramer

AN EMPIRICAL ANALYSIS OF AIR FORCE MILITARY CONSTRUCTION

PROJECT DELIVERY METHOD PERFORMANCE IN THE UNITED STATES

THESIS

Erich C. Kramer, Captain, USAF

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Erich C. Kramer, BS

Captain, USAF

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Erich C. Kramer, BS
Captain, USAF

Approved:

Chris M. Stoppel, Lt Col, PhD, P.E. (Chairman)	Date
Alfred E. Thal, Jr., PhD (Member)	Date
Diedrich Prigge V, PhD (Member)	Date

Abstract

The objective of this study is to investigate the performance of the design-bid-build and design-build project delivery methods in Air Force military construction (MILCON). Project delivery performance is measured through quantitative cost, schedule, and change order metrics for 264 design-bid-build and 316 design-build MILCON projects from 2003-2014. The average response measures were statistically compared within each delivery method using three independent variables: time, facility type, and major command (MAJCOM).

The historical analysis revealed that the current working estimate – programmed amount ratios improved over time for design-build projects, and an overall consistency in schedule growth and project duration performance occurred across both delivery methods. The facility type analysis revealed that design-bid-build airfield pavement projects had significantly lower average unit costs and fewer modifications than other facility types. Dormitories, officer quarters, and dining halls were constructed (design-bid-build) and delivered (design-build) more rapidly than other facility types. While the study revealed significant differences across individual performance measures, no overall trend in project delivery performance was identified in the MAJCOM analysis.

Finally, the current methods used by Air Force project managers to gather project data does not allow for meaningful project delivery performance comparisons. This study recommends the following eight key performance indicators be tracked to effectively compare the performance of project delivery methods: cost growth, unit cost, award growth, project duration, schedule growth, project delivery speed, modifications per million dollars of project scope, and percent modifications due to deficiencies.

Acknowledgments

I would not have been able to complete this work without the love and grace of my Lord and Redeemer, Jesus Christ. His steadfast wisdom, strength and blessings were abundant throughout the entire thesis process. I express my genuine appreciation and respect to my advisor, Lt. Col Chris Stoppel, and my committee for their unwavering guidance and vision. Your professional insights heightened the quality of my thesis and your flexibility and patience enabled the successful completion of this research. Most importantly, I am extremely grateful for the love and support of my family. I owe my eternal love, gratitude and devotion to my incredible wife and Son. Your unending sacrifices, understanding, patience and encouragement carried me through this process. I love you and am excited to see what God has in store for us in the future.

Erich C. Kramer

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AN EMPIRICAL ANALYSIS OF AIR FORCE MILITARY CONSTRUCTION PROJECT DELIVERY METHOD PERFORMANCE IN THE UNITED STATES

I. Introduction

The 2015 Air Force Strategic Master Plan (SMP) calls for its managers to "aggressively pursue a path that leads to institutional strategic agility," in all planning and programmatic decisions (Department of the Air Force, 2015). Specifically, the service's 30-year SMP highlights the need for its senior leaders to adopt cost-conscious mindsets, while remaining focused on achieving quality mission effectiveness. This approach is inevitably challenging while operating in today's increasingly dynamic and resource-constrained environment, which is characterized by sequestered funding levels, an increased number of overseas contingency operations, force reductions, recapitalization and modernization of the Air Force aircraft inventory, and a shifted corporate focus toward space and cyberspace security.

Nonetheless, implementation of this core strategic approach must permeate across service-wide activities within both the operational and support arenas. Of its approximate 9.5 billion dollars in 2016 Military Construction (MILCON) appropriations, the 114th Congress funded over 1.5 billion dollars toward Air Force, Air National Guard and Air Force Reserve MILCON requirements (Office of the Under Secretary of Defense, Comptroller, 2015). To remain aligned with the streamlined guidance in the SMP, leadership within the Air Force Facility Engineering Directorate must champion substantial cost savings throughout its business practices, while remaining focused on providing "superior, customer-focused support to the warfighter," thus enabling the effective and timely accomplishment of his mission (Office of the Assistant Secretary of the Air Force, Installations, Environment and Energy, 2016).

Background

A project delivery method is a system characterized by contractual relations, as well as roles and responsibilities, designed to achieve satisfactory execution of a construction project from initial conception to the point of completion and customer utilization. This process directly defines the framework for interaction between all individuals associated with the project and includes requirement scope definition; organization of the designers; constructors and consultants; and the definition, sequencing, and execution of all design and construction operations to include start-up and closeout procedures (Touran et al., 2009). The most commonly used project delivery method throughout recent construction history is the traditional design-bid-build (DBB) method. However, during the latter half of the twentieth century, an alternative form of project delivery known as design-build (DB) has become increasingly popular. While several different types of project delivery methods are available to today's project owners, system selection is often driven by organizational goals, as well as financial and time constraints of the customer (CMAA, 2012).

Motivation

The use of alternative project delivery methods has seen a rapid increase over the past 25 years in the construction industry. Dissatisfaction with the performance of the traditional design-bid-build project delivery approach has caused both private and public owners to demand more of their project delivery teams including higher quality, more cost-effective design processes, less litigation, fewer delays, and more expeditious project delivery (American Society of Civil Engineers, 1992). Since then, numerous quantitative and qualitative analyses comparing the performance of design-bid-build and design build delivery methods have further underlined the benefits of using alternative approaches (Konchar and Sanvido, 1993; Songer and Molenaar, 1997; Ibbs et al., 2003; Ling et al., 2004; Shrestha et al., 2012).

Following the industry's lead, the military has shifted away from the exclusive use of design-bid-build and has aggressively incorporated design-build project delivery into its construction projects (Air Force Civil Engineer Center Integration Cell, 2015). However, few in-depth studies have quantitatively validated this rapid shift toward the alternate approach. Initial reports have been predominantly qualitative in nature (Mouritsen, 1993; Allen, 2001) while others have lacked sufficient scope to definitively substantiate the claim that design-build is superior to the traditional design-bid-build delivery method for military construction (Roth, 1995; Webster, 1997; Garner et al., 2008; Hale, 2009).

A previous study conducted by Rosner et al. (2009) was the first empirical attempt to validate the increased use of design-build project delivery in Air Force MILCON projects using large sample sizes. Still, design-build use was limited to approximately one-third of the total number of projects completed during the time of the study, indicating that widespread use of the alternative project delivery approach was limited by the experience of many Air Force project managers with the new process (Rosner et al., 2009). Ultimately, the researchers found design-build performance superior to design-bid-build in six of the eight performance metrics. However, several significant limitations within the Air Force's ACES-PM database have prompted recent criticisms regarding the validity of the study's results.

Therefore, the question arises whether the current MILCON project metrics tracked by Air Force project managers are appropriate for the comparison of project delivery method performance. Or is there a better framework for project delivery method performance analysis available to Air Force planners? Additionally, has the increased use of the design-build project delivery method shown a change in performance over time? How has the performance of the traditional design-bid-build approach changed with this increased use of design-build? Does the performance of each method align with the strategic goals of the Air Force Civil Engineer Center (AFCEC)?

Problem Statement

The Air Force does not currently utilize a formal decision-making model for MILCON project delivery method selection. Instead, construction planners have historically selected delivery strategies based primarily on the project manager's familiarity with and experience using specific delivery methods, the level of risk deemed acceptable by the contracting officer, and the expertise of local contractors (Kindt, 2016). There is no official DoD or Air Force mandate driving project delivery method selection. However, in 2010 the AFCEC Integration Cell established a goal for Air Force project managers to execute 75% of its projects using the design-build approach (Winslow, 2017). This decision was based solely on its perceived benefits and not through empirical analysis of the performance of each method (Kindt, 2016).

The following research is a performance-based empirical investigation of two project delivery systems, traditional design-bid-build (DBB) and design-build, within the U.S. Air Force MILCON arena. The relative performance of project delivery systems is measured through key quantitative cost, schedule, and change order performance indicators recognized across the construction industry. This study will propose a new foundation of key performance indicators the Air Force should use to better understand relative project delivery method performance. An examination of Air Force project delivery performance and the comparison of findings from a previous research effort will help determine whether the service has improved in the execution of each approach over time.

Investigative Questions

A thorough analysis of current Air Force MILCON project data and an extensive literature review will focus on answering the following seven questions.

1. What framework of key performance indicators should the Air Force track to effectively compare the relative performance of AF MILCON project delivery methods?

2. Using current cost, schedule and change order project measures, has the performance of Air Force MILCON design-build project delivery improved at a statistically significant level over time?

3. Using these performance measures, does a specific facility type outperform other facility types in Air Force design-build project delivery?

4. Using these performance measures, does a specific Major Command outperform its peers in Air Force design-build project delivery?

5. Using current cost, schedule and change order project measures, has the performance of Air Force MILCON design-bid-build project delivery improved at a statistically significant level over time?

6. Using these performance measures, does a specific facility type outperform other facility types in Air Force design-bid-build project delivery?

7. Using these performance measures, does a specific Major Command outperform its peers in Air Force design-bid-build project delivery?

Methodology

An investigation of past research identified common project performance metrics germane to both project delivery methods mentioned above. The literature review provided a basis for determining a possible framework of key performance metrics that the Air Force can use to effectively compare the relative performance of project delivery methods. This research also determined if the Air Force's execution of each delivery strategy has improved over time using statistical analysis of individual project schedule, cost and change order data currently tracked in ACES-PM. These performance success criteria are broken down into eight performance metrics: cost growth, current working estimate – programmed amount (CWE/PA) ratio, schedule growth, unit cost, modifications per million dollars of project scope, project duration, construction speed, and delivery speed. A random sampling of Air Force MILCON project performance data from fiscal year (FY) 2003 to 2016 was collected and analyzed using the ACES-PM database. Projects were selected based on the following criteria: projects classified as standard MILCON, projects with 100% completion status; projects with costs exceeding the minimum MILCON spending level of $1M, and projects in the United States.

Finally, statistical tests were conducted to determine if these performance metrics were significantly different from other projects within the same delivery system over time. Additionally, these measures will be tested against specific facility and major command (MAJCOM) categories to provide a better understanding of Air Force MILCON project delivery method performance. This study will use a statistical comparison between the eight response variables and the previously mentioned three independent variables. The Air Force MILCON data will be analyzed using Tukey's Honest Significant Difference (HSD) test, the Student's t-test for unequal variance, Levine's test for sample homogeneity of variance, and Shapiro-Wilk's test for normality.

Assumptions/Limitations

The primary limitations of this research stem from the ACES-PM data source and are consistent with many of the limitations faced by Rosner et al. (2009). The foundation of the statistical analysis is based on the notion that the data in ACES-PM are regularly scrutinized by installation project managers, MAJCOM and Headquarters Air Force staffs, as well as Congress, and that the resulting data are both current and accurate.

The ACES-PM module was developed to track design-bid-build projects and fails to capture specific project cost and schedule fields that are unique to design-build delivery (Winslow, 2017). This causes some cost and schedule metrics calculated from

ACES-PM fields to be automatically "skewed…in favor of traditional projects" (Rosner et al., 2009). Therefore, to make an unbiased assessment of project delivery method performance, this research will not directly compare key performance indicators across opposing project delivery methods. Instead, only the time-based performance of projects within each delivery method will be analyzed using key project cost, schedule and change order metrics.

Additionally, this analysis is strictly empirical in nature and does not investigate causal relationships between factors of interest within this study. The reasons for contract modifications are also not universally tracked within ACES-PM; therefore, an assumption is made that considers all modifications to be results of factors with detrimental impact to the project and its timeline. Performance measure analysis is also limited by the extent of the data fields tracked within ACES-PM.

Research Implications

The results of this study will provide Air Force MILCON project delivery teams a lens through which to analyze the benefits and disadvantages of each project delivery method based on past project execution. Results within this research will help AFCEC decision-makers identify performance-based trends for each delivery approach with respect to time, facility type, and managing command. Ideally, the results of this research will also provide a foundation for the future application of a project delivery performance assessment framework, thus providing Air Force planners with concrete means to adequately compare Air Force MILCON project delivery strategies.

Document Overview

This thesis follows a traditional five-chapter format. Chapter I presented a brief overview of the topic, introduced the investigative questions, and described the methodology. Chapter II illustrates a literature review that describes each project delivery method and provides an overview, history, and the benefits and disadvantages of each delivery method approach. Chapter II then explores the literature review consisting of research within the public sector of the construction industry and highlights past studies related to project delivery performance within military construction; an introduction to the Air Force's Ribbon Cutter Criteria will provide the proper context to this discussion. Chapter II also identifies common and recurring key performance indicators used across public and MILCON sectors; it also identifies gaps within the literature review that ultimately provide a foundation for the methodology used to address these gaps. Chapter III discusses the methodology used within this study – focusing on the detailed description of key project performance indicators and the statistical time-based performance analysis of each project delivery approach. This will be accomplished through the identification, description, and statistical comparison of key performance metrics originating from the ACES-PM data source. Chapter IV provides a foundation for the final analyses by introducing a framework of key performance measures for future Air Force project delivery comparisons and presenting the statistical results of the study. Finally, Chapter V provides an analysis and conclusion, as well as opportunities for future research.

II. Literature Review

This chapter begins by investigating the current research conducted on project delivery methods in the construction industry, including a history and description of the different delivery methods, as well as their respective advantages and disadvantages of each. Several key success measures specific to the Air Force military construction (MILCON) program are also explored through a review of the service's Ribbon Cutter Criteria. This section details past research measuring delivery method performance in both the public and MILCON arenas by analyzing common key performance indicators used across the industry. Ultimately, the gaps identified in this literature review serve as the foundation for the study's methodology section, which includes a time-based statistical performance test of each Air Force MILCON project delivery method and the aggregation of key project performance indicators that are laced throughout this literature review.

History of Design and Construction

Throughout history, the nature of design and construction has evolved significantly. While initial roles of designer and builder were initially executed by one entity, advancements in technology, knowledge, and task specialization caused a separation of these roles to occur over time. However, with an increased emphasis on professional skillsets, project schedule, budgets and quality began to suffer, resulting in a search for alternative approach to project delivery. The following sections provide further detail the history of design and construction.

The Master Builder

Although design-bid-build is commonly referred to as the traditional project delivery system, the earliest forms of project delivery were characterized by the concept of a single entity responsible for both design and construction with no distinguishable separation between phases. Beard et al. (2001) describe this "master builder" as both architect/engineer and builder who designed every element of a project and oversaw all aspects of the construction of which he was exclusively familiar. These master builders found their origin in ancient civilizations like Egypt and Mesopotamia and were the first in a long history of design-builders who developed infrastructure and building projects such as "pyramids, temples, aqueducts, cathedrals, and major public buildings" (U.S. Department of Transportation Federal Highway Administration, 2006). Without scientifically-based engineering principles, standards, and specifications, the craftsmen master builder was the only individual with the necessary engineering and design experience to complete construction projects (Cushman and Loulakis, 2001).

Separation of Design and Construction

The European Renaissance was characterized by the higher degrees of specialization, knowledge, and skillsets needed to challenge the concept of a master builder. Through improved forms of documentation and scientific discovery, designs became more specialized and complex, and the need for accountability and functional responsibility for various construction elements emerged (Beard et al., 2001). However, despite its first major challenge, the master builder remained the project delivery method-of-choice through much of recorded history until the dawn of the Industrial Revolution (Beard et al., 2001).

The technological advances in manufacturing and production that characterized the Industrial Revolution shifted the world away from the master builder and made the distinction between design and construction even more obvious. Beard et al. (2001) argue that task specialization, standardization of design drawings and specifications, and the formal division of labor contributed to the further distinction between project phases. Risk management also became a concern as builders became more willing to assume risk to grow their business, while designers remained risk-averse. Finally, a growing labor force and the need for highly specialized machinery required builders to partner with stockholders or venture capitalists while designers saw such partnerships as a threat to their professional desire to remain uninfluenced by others (Beard et al., 2001). During the 1850s, the emerging reality of increased specialization caused several societies to form to recognize the need to formally separate professional designers and building contractors. Several of these professional societies are still in existence today, including the American Society of Civil Engineers (ASCE) and the Institute of Architects (AIA) (Beard et al., 2001).

Several key legislative events further led to the formal separation of the design and construction phases of projects in the U.S. Capital projects became the first target. In 1893, the 53rd United States Congress formally separated the design and construction phases of a capital construction project. Thirty years later, the 1926 Omnibus Public Buildings Act required the plans and specifications of all capital projects to be completed prior to the beginning of the project's construction phase (U.S. Department of Transportation Federal Highway Administration, 2006). Congress protected the federal government from contractors in default of contract by passing the Miller Act of 1935.

Under this act, prime contractors were required to post performance and payment bonds that guaranteed their performance and payment of subcontractors on federal construction projects (Beard et al., 2001).

The Armed Services Procurement Act of 1947 specifically directed that design services be procured on a negotiated basis, while construction services would continue to be procured through a formal, low-bid selection process (U.S. Department of Transportation Federal Highway Administration, 2006). Similarly, the Federal Property and Administrative Procedures Act extended the requirements of the Armed Services Procurement Act requirements to all federal civilian agencies (Loulakis, 2003). Additional regulation was seen in the 1972 Brooks Architect-Engineers Act which required all federal capital design contracts to be awarded based on the qualifications and competence of the design firm, as opposed to the competitively bid construction contracts. After becoming institutionalized through numerous laws and regulations over time, design-bid-build became the traditional method for delivering government projects. Finally, there existed a delivery method that reduced favoritism in the procurement process but also spurred competition among builders (U.S. Department of Transportation Federal Highway Administration, 2006).

Re-Emergence of Public Design-Build

The benefits of design-bid-build soon became more difficult to appreciate as construction complexity advanced in the second half of the twentieth century. Significant levels of scrutiny were placed on traditional project delivery throughout the 1960s and 1970s as construction was characterized by an increase in claims, disputes, and project delays resulting from a lack of integration between design and construction entities

(Cushman and Loulakis, 2001). Public owners experienced significant project cost and schedule growth during this time as they assumed a role as referee between design and construction entities. Their desire for a single point of contact responsible for all communication across project phases emerged. Correspondingly, the metaphoric pendulum shifted back toward the development of a new master builder (Beard et al., 2001). The private sector of the U.S. construction industry remained immune to most of the regulations passed in the mid-twentieth century. In fact, private owners benefited from a new form of project delivery known as design-build, in which a project owner has a contractual relationship with a singular entity responsible for design and construction (Beard et al., 2001).

Design-Build in Military Construction (MILCON)

One of the earliest documented uses of design-build in the U.S. public sector was in 1968 across school districts within the Midwest. Shortly thereafter, select federal agencies also began limited experimentation with similar alternative approaches. The year 1969 marked the first use of an alternative delivery method in military construction as Congress and the Secretary of Defense authorized the use of turnkey construction for military housing to benefit from the knowledge of speculative builders and rapidly deliver military housing at a reduced cost. The successes of this program and other early experiments with the design-build delivery method expanded in the 1980s (Molenaar et al., 1999).

In 1986 Congress passed the Military Construction Authorization Act, authorizing the use of design-build for military construction (MILCON), Military Family Housing, and Operations and Maintenance (O&M) programs (Beard et al., 2001). This authorization allowed each service to use design-build procedures for the execution of a maximum of three annual pilot projects with the goal of assessing whether design-build was a fair and effective means to delivery MILCON projects (Webster, 1997). However, the widespread use of the design-build project delivery method did not begin until the 1996 Federal Acquisitions Reform Act (Clinger-Cohen Act) which finally allowed federal agencies to engage in design-build projects using a two-step design-build procurement process (Beard et al., 2001; Loulakis, 2003). The unrestricted use of design-build began to grow within the military after 1996. Today, federal agencies that use the design-build delivery strategy include the DoD, Veterans Affairs (VA), State Department, General Services Administration (GSA), Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), Federal Highway Administration (FHWA), Federal Bureau of Prisons (FBP), United States Postal Service (USPS) and the Department of Energy (DOE) (Beard et al., 2001).

Delivery Method Overview

The two most common project delivery methods throughout the history of the construction industry are traditional design-bid-build and the alterative design-build. Each method has its advantages and disadvantages, and provides a unique approach to delivering the final product to the project owner. The following sections provide a brief description of each method and detail common advantages and disadvantages of each.

Design-Bid-Build (DBB)

The most widely-accepted and time-tested project delivery method is the traditional design-bid-build delivery method. This method is customarily characterized by three sequential project phases: design, procurement, and construction. It is defined as a method where:

> [A]n owner retains a designer to furnish complete design services and then advertises and awards a separate construction contract that is based on the designer's completed construction documents. (Touran et al., 2009)

Theoretical Advantages and Disadvantages of Design-Bid-Build

Design-bid-build is often the preferred method for well-developed, detailed requirements to allow for maximum owner input and control (Cushman and Loulakis, 2001). The detailed scope communicated in design-bid-build solicitations often promotes a more competitive bidding process and the selection of a contractor based on lowest bid. Additionally, the sequential nature of design-bid-build project delivery usually leads to a sealed bid, fixed-price contract. The design-bid-build method's competitive low-bid and firm-fixed nature have historically made it the most appealing method for public agency owners, who remain accountable to taxpayers and must ensure transparency in the contractor selection process (Construction Management Association of America, 2012).

The U.S. military has historically used the design-bid-build delivery method in its MILCON programs (Department of the Air Force, 2015a). Prior to 2007, the clear majority of Air Force MILCON projects were accomplished using the design-bid-build delivery method. As Rosner et al. (2009) discussed within their research, the traditional delivery approach is "well understood by project managers because of all the steps, processes, requirements, and roles have been codified by professional societies, the government, designers and contractors." Table 1 further outlines the benefits of the design-bid-build delivery method identified through extensive studies and literature review.

However, despite the many arguments in favor of design-bid-build, this approach is often criticized for its lengthy project timeline and an increased risk of contract modifications driven by the lack of the contractor's constructability feedback present in the design stage (Design-Build Institute of America, 2016). In fact, it has been common for Air Force MILCON project managers to find themselves "managing by change order" when lowest bid contractors work to increase profit margins by searching for design errors and resulting change orders (Kindt, 2016; Winslow, 2017). Table 2 identifies several disadvantages found in traditional design-bid-build project delivery.

Table 1 - Advantages of Design-Bid-Build Delivery (adapted from Rosner, 2008)

Advantages	Description	Source
Well-Known, Established Project Execution Method	Proven historical use, well-established legal and contractual precedents	5, 9, 11
Most Appropriate for Competitive Bidding	Competitive bidding on 100% design ensures lowest price for construction	2, 5, 7, 8, 10
Control Over Design	Owner has maximum input throughout design stages	2, 3, 8, 9, 11
Low Price Award	Award given to contractor with lowest bid price	2, 3, 5, 7, 8, 10
A/E Works Directly for Owner	A/E gives professional advice to owner in not-at-risk relationship	5, 7, 10, 11
No Legal Barriers to Procurement/Licensing	Risk allocation and responsibility are pre-established with many legal findings. Established licensning procedure for A/Es and construction firms in all U.S. states	5, 10
Contractor Assumes all Construction Risks	Absorbs weather costs, labor disputes, material cost increases, and external factors	7, 10
Fully Defined Project	Design phase produces 100% complete drawings, specifications and cost estimates	2, 6, 7, 8, 10
Objective Contract Award	Sealed bid packages ensures award is based on price and not subjective metrics	2, 10

Key:
1. Mouritsen (1993)
2. Gordon (1994)
3. Webster (1997)
4. Molenaar et al. (1999)
5. Beard et al. (2001)
6. Cushman & Loulakis (2001)
7. US DOT FHWA (2006)
8. Department of the Air Force (2007)
9. Garner et al. (2008)
10. Touran et al. (2009)
11. DBIA (2016)

Table 2 - Disadvantages of Design-Bid-Build Delivery (adapted from Rosner, 2008)

Disadvantages	Description	Source
Owner Acts as Arbiter Between Design and Constructor	Owner bears risk for adequacy of design. Disagreements between designer-builder must be resolved by owner.	5, 6, 10, 11
Owner Pays for Changes	Owner funds change orders to overcome design conflicts. Litigation may result from depleted contingency funds caused by increased costs.	2, 6, 7, 8, 10, 11
Lack of Overall Integration/Shared Vision	Adversarial relationship causes each party to solely focus on direct element of their responsibility. Designer focuses on accuracy/quality of physical produces. Constructor focuses on cost and schedule management. Ultimate goals of the project and its owner ignored.	2, 5, 6, 8 9, 10
Initial Low Bid May Not Necessarily Result in Final Best Value	Factors like past performance, good environmental practices, attention to life cycle performance and other best-value selection criteria are often ignored when owner is preoccupied with low first cost.	5, 6
Uncertainty in Price Prior to Bid	Over-budget bids are problematic for owners. Cost is known only when the 100% design is bid on. Chance for redesign and project descoping likely if bids exceed owner's budget.	5, 7, 10
Lack of Constructability Input in Design	Separation of roles and responsibilities across two distinct phases is detrimental to constructability due to lack of construction design input.	2, 5, 6, 7, 8, 9, 10, 11
Lengthy Project Duration	Sequential phasing structure cause DBB to be slower than alternates. By definition construction cannot start until design is 100%.	2, 5, 6, 7, 9, 10, 11
History of Litigation	Increased disputes between builder and designer over ambiguity in design, errors, omissions, in-place construction quality, time delays, etc.	7, 8, 11
Change Orders	Contractors can easily low-bid to win award, and recover profits by generating change orders resulting from design omissions and errors. Occurs at owner's cost	2, 7, 10, 11

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5. Beard et al. (2001)
6. Cushman & Loulakis (2001)
7. US DOT FHWA (2006)
8. Department of the Air Force (2007)
9. Garner et al. (2008)
10. Touran et al. (2009)
11. DBIA (2016)

Design-Build (DB)

The inefficiencies of the design-bid-build delivery method led to the creation of alternate delivery methods (Beard et al., 2001). The design-build method of project delivery:

> Includes one entity (design-builder) and a single contract with the owner to provide both architectural/engineering design services and construction. (Design-Build Institute of America, 2016)

Theoretical Advantages and Disadvantages of Design-Build

The alternative design-build approach is often the preferred method for projects characterized by fewer detailed design requirements or initial owner design input. In such projects, the owner turns to a single point of contact accountable and liable for design and construction progress and therefore remove themselves as the referee between designer and builder (Design-Build Institute of America, 2016; Touran et al., 2009; Cushman and Loulakis, 2001). Use of this method has resulted in an increase in schedule and cost savings, reduction of contract burden placed on the owner, reduction of contract litigation and construction claims, and the generation of higher-quality products to the customer (Cushman and Loulakis, 2001; Beard et al., 2001). Table 3 highlights the advantages recognized throughout the literature.

Table 3 - Advantages of Design-Build Delivery (adapted from Rosner, 2008)

Advantages	Description	Source
Single Entity for Design & Construction	Design-Builder assumes all responsibility for errors/omissions, faulty performance, internal coordination	1, 2, 4, 5, 6, 7, 9, 10, 11
Time Savings	Design-build eliminates bidding and possible redesign periods. Material/equipment procurement, mobilization and early construction can begin prior to 100% design	1, 2, 4, 5, 6, 7, 9, 10, 11
Early Knowledge of Firm Costs	Guaranteed project costs are known at time of proposal selection; Inter-entity coordination of cost estimates for construction also increases cost savings	5, 6, 7, 8, 9, 10
Increased Quality	Design-builder responsible for the entire project. Constructability input included throughout the design phase. Design errors, omissions and defects are identified and resolved quickly.	2, 3, 4, 5, 6, 7, 9, 11
Cost-effectiveness	Value engineering and constructability are ongoing throughout design process resulting in lower cost to owner	1, 2, 4, 5, 6, 7, 8, 10, 11
Encourages Innovation	Design-build is a performance-based system as opposed to one focused solely on specifications. The RFP outlines the owner's performance requirements and proposers are encouraged to find alternative solutions to meet owner's goals.	1, 2, 4, 5, 7, 8, 11
Lower Claims & Litigation	Owners avoid majority of claims and litigation as sole risk is assumed by design-builder. The number of disputes in far fewer with absence of adversarial relationships.	1, 2, 5, 7, 8, 9, 10, 11
Reduced Administrative Burden	Owner not required to have individual contracts with A/E and construction inspectors. Personnel required to administer conflicts between contractors is drastically reduced.	1, 2, 4, 6, 7, 8, 10

Key:
1. Mouritsen (1993)
2. Gordon (1994)
3. Webster (1997)
4. Molenaar et al. (1999)
5. Beard et al. (2001)
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10. Touran et al. (2009)
11. DBIA (2016)

While considered the more flexible and timely method, the inherent lack of checks and balances between the design and construction stages can lead to expensive contract modifications and potential conflict with the owner (Construction Management Association of America, 2012). When agreeing to a design-build contract, the owner also assumes a lack of design control throughout the process. Instead of benefiting from the professional advice of an individually contracted architect-engineer, the owner should understand that the design-builder is likely to take a financially biased approach when discussing in-place construction quality (Touran et al., 2009). The proclaimed disadvantages associated with design-build project delivery method can be found in Table 4. Despite these disadvantages, the use of the design-build method has become increasingly prevalent over the past two decades not only in the private sector but also in federal construction projects. Since the Federal Acquisitions Reform Act of 1996 lifted previous limitations established by the mid-century U.S. legislation and allowed for the unlimited use of the traditional method, the design-build approach has become increasingly popular across federal projects to include those in the Air Force MILCON arena (Department of the Air Force, 2015a).

Table 4 - Disadvantages of Design-Build Delivery (adapted from Rosner, 2008)

Disadvantages	Description	Source
Unfamiliarity with the Process	Owners new to the design-build approach often must rely on third-party professional to act as owner's representative	4, 5, 6, 10
Robust RFP Development is Primary Way to Communicate Needs	Owners, reliant on specifications and comfortable with traditional method will struggle with qualifications-based proposals for the RFP instead of simply awarding based on low cost bid. A significant amount of owner's time/money can be spent in RFP development; The owner's performance requirements must be outlined as criteria for design and not detailed specifications.	4, 5, 7, 8, 9, 10
Diminished quality control	Strikes at the foundation of traditional quality assurance/quality control roles through commination of engineering and construction	5, 7, 9, 10
Availability of Insurance & Bonding Products for Design-Build	Industry still wary of providing same coverage to design-build firms as traditional construction firms resulting in higher premiums for insurance and bonding.	1, 5, 10
Loss of Design Input and Control	Both the designer and constructor are in the business to generate profit. The designer's interest are no longer directly tied to the owner's requirements as with the traditional method. Therefore there is a loss of the owner's design advocate with this method.	1, 7, 10
Subjective Contract Award	The process may bypass the competitive bidding process, possibly not affording the owner the lowest cost. Lack of competition provides an opportunity for favoritism to inter into contract award process by including non-price factors in basis for selection; Likewise, the number of qualified bidders may be significantly reduced, leaving the owner susceptible to inflated bids.	2, 4, 7, 9, 10

Key:

1. Mouritsen (1993)
2. Gordon (1994)
3. Webster (1997)
4. Molenaar et al. (1999)
5. Beard et al. (2001)
6. Cushman & Loulakis (2001)
7. US DOT FHWA (2006)
8. Department of the Air Force (2007)
9. Garner et al. (2008)
10. Touran et al. (2009)
11. DBIA (2016)

MILCON Program Overview

The MILCON program is the process used by the Department of Defense (DoD) to provide new facilities, major developments, conversions, or extensions on military installations that cost $1M or greater. In September 2015, the lower-level threshold for MILCON funding increased from $750K to $1M in total project cost. These projects generally take four to five years to progress from user-defined requirements to completed products (Department of the Air Force, 2015a). Every year, Congress funds the MILCON program through the Military Construction Appropriations Act and requires each newly-funded project to be completed within a five-year appropriations expiration period. Air Force MILCON program managers use a service-wide database known as the Automated Civil Engineering System – Project Management (ACES-PM) Module to track and record project information throughout a project planning and execution. Project information and status updates are then gathered at Air Force Headquarters staff and reported to Congress as part of the President's annual budget (Department of the Air Force, 2015a).

The MILCON Process

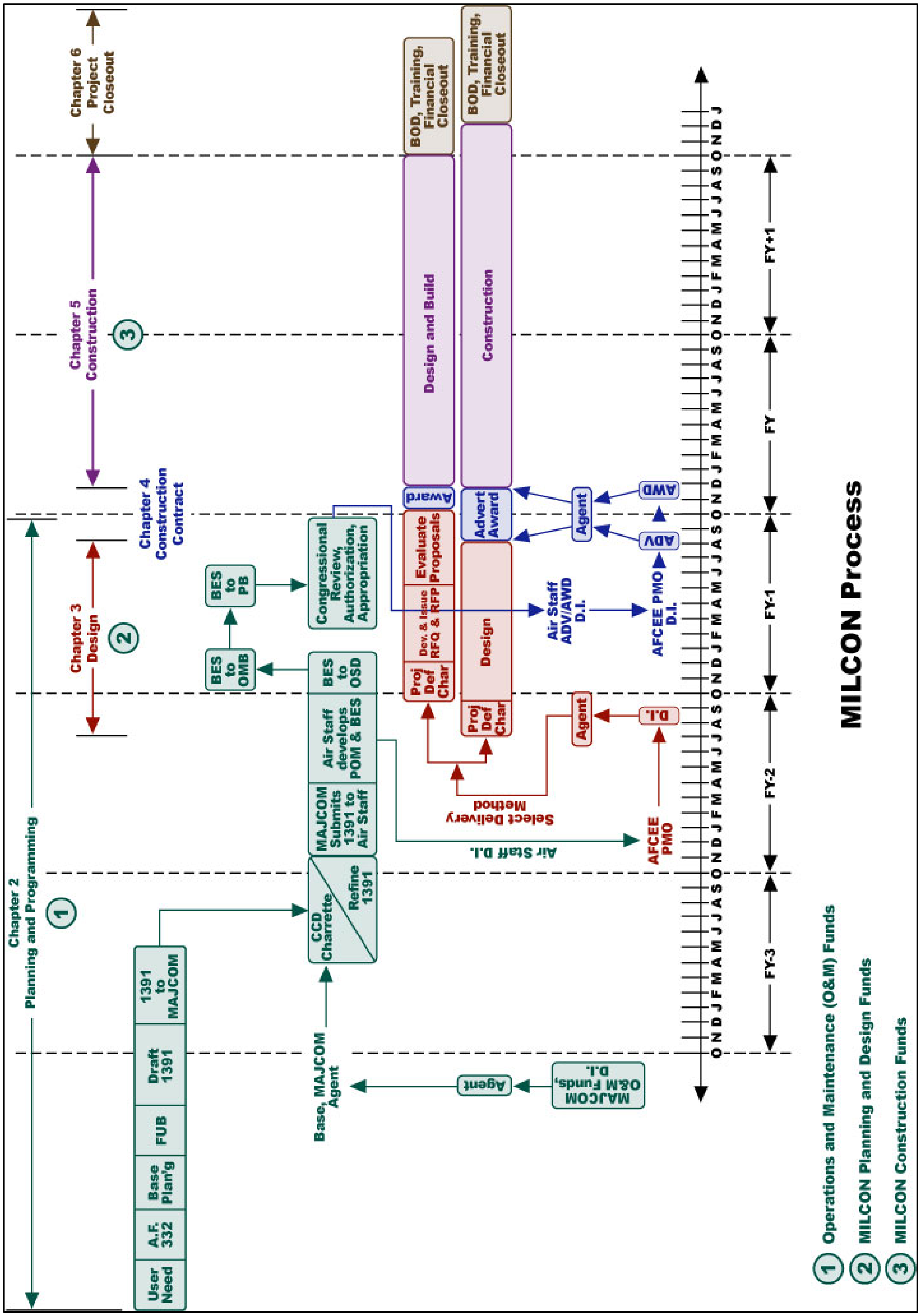
The following is brief overview of the Air Force MILCON process. The primary purpose of the MILCON program is to provide major construction exceeding the minor construction authority of $1M in scope on DoD installations by "Building quality facilities…on time and on budget" to meet mission requirements (Department of the Air Force, 2007). Project types include but are not limited to anything from airfield pavements and roads to utility systems and all other types of buildings (Department of the Air Force, 2015a). *The U.S. Air Force Project Managers' Guide for Design and*

Construction (Department of the Air Force, 2007) illustrates the general MILCON process in Figure 1.

Planning and Programming

Effective MILCON planning establishes infrastructure and facility requirements critical to mission accomplishment and proposes the most effective and economical means of meeting those requirements. The major Air Force MILCON planning and programming actions include: requirements determination, evaluation of alternative solutions, initiation of programming actions, a request for funds, and finally the authorization of funds (Department of the Air Force, 2016).

Figure 1 - The MILCON Process (Department of the Air Force, 2007)



The determination of requirements is a fundamental activity in the planning stage of any construction project. After receiving a formalized request from an installation user, the Base Civil Engineer (BCE) and staff will work with the user to develop facility requirements to accomplish the mission. This includes referencing a *Facility Requirements Handbook* (AFH 32-1084) which provides general requirements for a given facility type and assists in determining a preliminary project scope based on project description; functional, architectural and technical requirements; and project site information (Department of the Air Force, 2007). From there, the BCE and staff will evaluate existing assets and determine if MILCON is the most appropriate means for satisfying the requirement or if the user's needs can be met by using an existing facility.

If MILCON is selected as the most appropriate course of action, a DD Form 1391, *Military Construction Project Data* document, is developed to justify and formally request a user's need. The DD Form 1391 is then approved and submitted to the Major Command (MAJCOM) as an installation MILCON priority (Department of the Air Force, 2016). The initial DD Form 1391 is a significant programming action, as it not only defines the requirement scope, but it also details the programmed amount (PA). The PA is used for budgeting strategies at the installation, MAJCOM, and Air Staff, and it is ultimately forwarded to Congress as a part of the DoD budget request (Department of the Air Force, 2007). Additionally, a Project Management Plan (PMP) is also developed and submitted along with the DD Form 1391. The PMP details key strategic decisions for the project, to include project delivery method selection, procurement type selection, in-house or architect-engineer (AE) design, list of all project team members and their organizations, and finally the project risk and schedule analyses (Rosner et al., 2009).

Ultimately, congressional approval of a specific MILCON requirement is based on the project scope and PA included on the DD Form 1391 (Department of the Air Force, 2007).

Design or Request for Proposal (RFP) Development

The design or Request for Proposal (RFP) development process is initiated after funding authorization has been presented by Congress. Air Staff directs the MAJCOM to send a design instruction (DI) to direct the project design manager/construction manager (DM/CM) to initiate design for a traditional design-bid-build project or RFP preparation for a design-build project (Department of the Air Force, 2007). In response, the DM/CM issues a field DI to a selected design agent (DA) authorizing immediate design commencement or RFP preparation. The Air Force does not generally manage the MILCON project as a DA. Instead, the U.S. Army Corps of Engineers (USACE) or the Naval Facilities Engineering Command (NAVFAC) serves as the design and construction agent for the Air Force (Air Force Civil Engineer Center Integration Cell, 2015).

This process will include the creation of extensive drawings and the identification of all applicable specifications for traditional design-bid-build delivery. RFP development for design-build project delivery clearly describes the technical requirements of the project and explains the criteria used for evaluating proposals (Department of the Air Force, 2007). Design criteria, performance specifications, program requirements, site-specific information, proposal requirements, and deliverable and contractual relationship details between the U.S. government and contractor are all contained within the RFP (Beard et al., 2001). The final steps in the design-build RFP process are the evaluation of proposals and the award. Ultimately, the MILCON design phase produces the facility's RFP or drawings and specifications, and refines the cost and scope of the project (Department of the Air Force, 2007).

Construction

Design-bid-build and design-build delivered projects differ a great deal within the construction phase of a MILCON project. The construction phases in projects delivered via design-build include award, design, and construction (Air Force Civil Engineer Center Integration Cell, 2015). The notice to proceed (NTP) begins the final phase of the project. NTP is the formal directive given to the awardee to begin the design of design-build projects (Air Force Civil Engineer Center Integration Cell, 2015). Design work and construction are often overlapped when using the alternative delivery approach (Department of the Air Force, 2007).

The construction phase for design-bid-build projects includes bid solicitation from construction contractors, contract award, contract document development, NTP instruction, and the effective project management during construction activities. The NTP is considered the formal instruction from the contracting officer, which authorizes the contractor to begin work on the project. In design-build projects, this milestone marks the start of design activity by the design-build contractor. Conversely, in design-bid-build projects, this milestone marks the start of construction activity. Regular and effective project management is characterized by the "successful management of cost, schedule, and quality in a manner compatible with user satisfaction" (Department of the Air Force, 2007). This includes conducting quality assurance/quality control inspections as well as the tracking and management of construction change orders. Construction work for projects within each delivery method progresses until completion of all construction tasks as detailed within the contract agreements. Lastly, the beneficial occupancy date (BOD) marks final government acceptance of the facility (Department of the Air Force, 2007).

Project Closeout

Approximately 60 days prior to the anticipated BOD, the project delivery team (PDT) conducts "Red Zone" (RZ) meetings to discuss the final project closeout process. RZ meetings include final consensus on elements of remaining construction that remain to be executed, notification and support of user occupancy, and preparation of fiscal closeout documents for the project in the real property records (Air Force Civil Engineer Center Integration Cell, 2015). Final acceptance inspections and documentation of project completion is conducted by the DA in the project closeout phase. A project becomes physically complete only when the agent certifies that all elements of the delivered product are complete and contractual obligations are met by signing the final DD Form 1354 *Transfer and Acceptance of Military Real Property* (Department of the Air Force, 2007).

Measuring Project Performance

The identification of a project's success criteria is necessary for a thorough analysis of project delivery method performance. Numerous empirical studies have been conducted to examine the impact of various project success factors on project performance. The following discusses the available literature regarding project delivery method success criteria and the respective measures that have been developed. Strategic goals related to Air Force MILCON execution are identified through the introduction of the Service's Ribbon Cutter Criteria. Similarities and differences between Air Force and industry performance measures are also discussed.

Project Success Criteria

Project success is defined as "the degree to which project goals and expectations are met" (Chan et al., 2002). Cost, time, and quality have long been the three fundamental success criteria used to evaluate the performance of a construction project (Chan et al., 2002; Beard et al., 2001; Konchar and Sanvido, 1998; Songer et al., 1997). However, these broad success measures often encompass a multitude of factors that define success differently for every project and, in some cases, may not fully capture all elements of success. The end-state goals of a project are achieved by various measurements of these criteria throughout the life of the construction project (Chan et al., 2001). The degrees to which these factors influence project success also change throughout the course of a project (Chan et al., 2002).

Industry Performance Metrics

Chan et al. (2002) conducted an in-depth review of past studies to identify relevant measures of success for a construction project and established a comprehensive assessment framework for project success in design-build projects. This framework encompasses both objective and subjective measures that significantly influence the success of a project. Time, profitability, cost, and health and safety were identified as the objective measures. Subjective measures included quality, technical performance, productivity, functionality, satisfaction, and environmental sustainability (Rosner et al., 2009).

These measures are consistent with those previously identified in other related studies (Songer and Molenaar, 1997). Songer and Molenaar (1997) also recognized a projects ability to stay "on schedule" and "on budget" as measures of success. Likewise, Molenaar et al. (1999) considered three separate criteria that measure quality in design-build projects. These include conformity with expectations, administrative burden, and overall owner satisfaction. They also identified "meeting specifications" as a success measure that is consistent with the technical performance identified later by Chan et al. (2002). The subjective "functionality" factor also closely relates to Songer and Molenaar's (1997) "conformance to expectation of project team members."

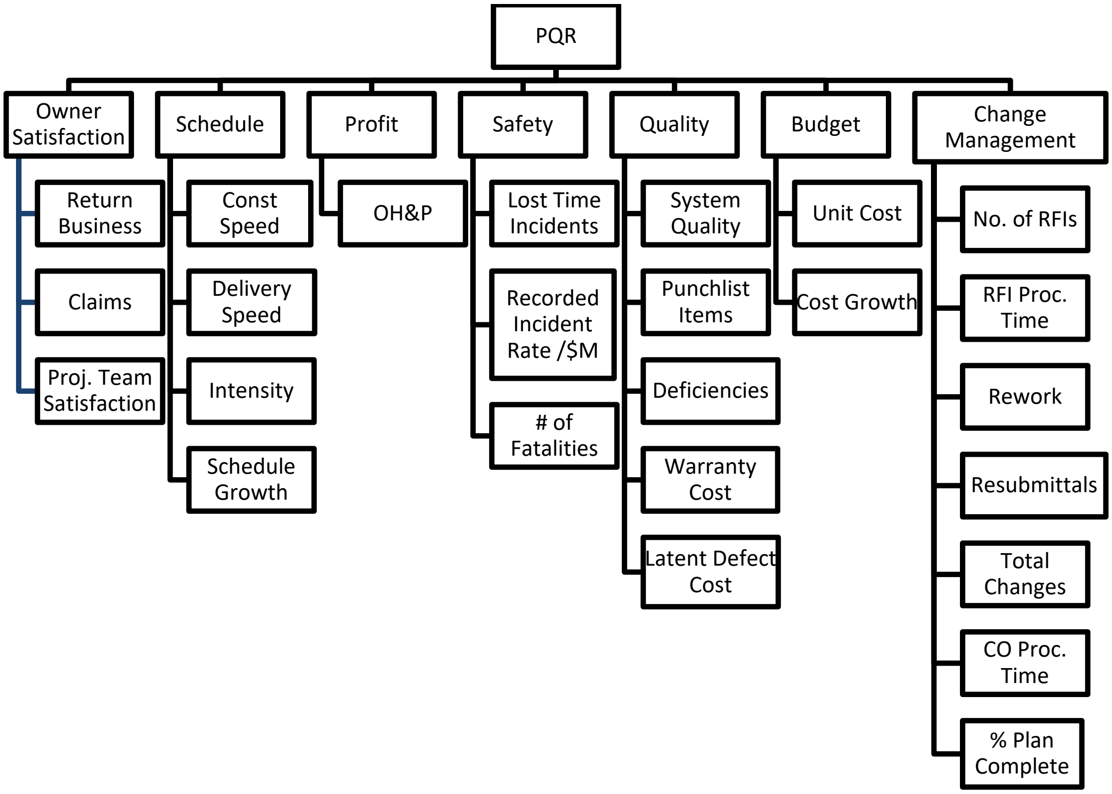
Project Performance Prediction Modeling

Benchmark studies conducted by Songer and Molenaar (1997) and Chan et al. (2002) laid the foundation for numerous studies comparing project delivery system performance. Many of these comparisons will be discussed in subsequent sections. The identification of these success criteria led to the natural progression and development of construction project performance prediction models. Ling et al. (2004) performed research that further investigated design-bid-build and design-build projects and identified several explanatory variables that significantly affect project performance. Performance metrics included unit cost ($/SM), cost growth (%), intensity (unit cost/month), construction speed (SM/month), delivery speed (SM/month), schedule growth (%), turnover quality, system quality, equipment quality, owner satisfaction, and owner's administrative burden. These variables were then incorporated into the model's design to predict project performance across different delivery methods. Using project-specific data collected from 87 building projects in Singapore, Ling et al. (2004) used multivariate regression and multiple linear regression analysis to determine the statistical relationship between the performance metrics (Konchar and Sanvido, 1998; Molenaar and Songer, 1998) and 59 explanatory variables gathered through surveys of past project delivery team members.

Some of the same performance measures were used in subsequent research efforts. El Wardani et al. (2006) quantitatively analyzed the correlation between the design-build procurement method and common performance metrics related to cost, time, and quality success measures. These correlations helped determine recommended procurement strategies for the owner. The researchers considered similar variables analyzed by Ling et al. (2004): unit cost, cost growth, intensity, construction speed, delivery speed and schedule growth. The study found superior cost growth performance to significantly correlate to qualifications-based design-build procurement strategies (El Wardani et al., 2006).

A recent study, conducted by Hanna et al. (2014) introduced a new framework to assess construction project performance. Modeled after the National Football League's Quarterback Rating, Hanna et al. (2014) created the Project Quarterback Rating (PQR) to give each construction project a specific score based on a set of "key variables that affected project performance and outcome." Using an extensive literature review, the researchers combined key performance indicators into a three-tiered model that combines measures into an overall score to help assess project performance (Hanna, 2016). Figure 2 depicts the breakdown of these key performance indicators.

Figure 2 - Project Quarterback Rating (adapted from Hanna, 2016)



Air Force Ribbon Cutter Criteria

The Air Force has incorporated its own list of performance measures into a MILCON project management tool developed to communicate and summarize a project delivery team's performance (Air Force Civil Engineer Center Integration Cell, 2015). The Ribbon Cutter Criteria was created by the AFCEC Integration Cell to evaluate how well the Air Force and its USACE and NAVFAC partners achieve their strategic goals to provide the Air Force with the "best possible facilities on time and within budget" (Air Force Civil Engineer Center Integration Cell, 2015).

Ribbon Cutter evaluates a project across its four primary phases: design, award, construction, and closeout. Within each category, AFCEC leaders have identified characteristics and milestones as performance measures that impact the success of the subsequent activity in a MILCON project. An overall score is given to each installation's project delivery team for their ability to achieve these specific goals (Air Force Civil Engineer Center Integration Cell, 2015). The Ribbon Cutter Criteria framework is the successor to a previous project evaluation tool known as the Dirtkicker Criteria. Results from Rosner's study (2008) were directly compared to the Dirtkicker Criteria to determine if Air Force goals had been achieved. Details of the Ribbon Cutter Criteria will be further discussed in Chapter III.

Public Sector Project Delivery Method Performance

The widespread public use of the design-build delivery method in the late twentieth century has caused many industry professionals to compare project delivery methods using many of the objective and subjective project measures discussed in the previous sections. The following is a consolidation of these studies. Recurring project success criteria and key performance indicators are further identified through the aggregation of the research results in the literature review.

Konchar and Sanvido (1998)

Konchar and Sanvido (1998) conducted a study that is considered by many to be a benchmark for the construction industry with respect to project cost, schedule and quality performance (Cushman and Loulakis, 2001; Loulakis, 2003; Beard et al., 2001; Ling et al., 2004; El Wardani et al., 2006; Shrestha et al., 2012). The researchers gathered data for 351 private and public projects from the Construction Industry Institute (CII) database to compare design-build, design-bid-build, and construction manager at risk (CMAR) delivery methods. The study quantitatively compared unit cost, percent cost growth, design-construction intensity, construction speed, delivery speed, and schedule growth. Additionally, the delivery methods were compared over six facility types: light industrial, multi-story dwelling, simple office, complex office, heavy manufacturing, and high technology.

Two structured surveys were combined to identify and compare quality performance of the project delivery methods. These quality measures included difficulty of facility start-up, number and magnitude of call-backs, O&M costs, system quality, and process equipment quality (Konchar and Sanvido, 1998). Univariate analyses were conducted for all quantitative and qualitative metrics using a significance level of 0.05. Finally, the researchers built a multivariate linear regression model to effectively compare nearly 100 interacting variables with project delivery systems across the cost and schedule metrics (Konchar and Sanvido, 1998).

Konchar and Sanvido's (1998) research revealed that design-build projects experienced less cost and schedule growth on average. The univariate analysis of the quality performance indicators also suggested that the design-build project delivery method resulted in better facility start-up quality, fewer call-backs, and improved O&M capability (El Wardani et al., 2006). However, the usefulness of their research was somewhat limiting because the regression equations, coefficients of variables, and R-squared values were only referenced and not fully detailed in the report.

Moore (1998)

Moore (1998) analyzed the same 273 complete private, public, and federal construction projects that were used by Konchar and Sanvido (1998) to directly compare objective cost, schedule, and quality performance between design-bid-build and design-build project delivery methods across various facility types and performance measures. Using an extensive literature review, the researcher also developed a questionnaire to objectively collect new cost, schedule, and quality data across 88 federal construction projects to compare projects by delivery system based on an equivalent project delivery start at zero percent time complete (Moore, 1998). This allowed for the investigation of objective metrics to equally measure each delivery system's performance. He also sought to identify project characteristics which explain the largest degree of variation in a metric called delivery speed performance. The study included univariate statistical testing of 15 performance measures across private, public, and federal projects facility types for each delivery method (four cost metrics, four schedule metrics, and seven quality measures). Additionally, the researcher used multiple linear regression modeling of the delivery speed measure to test the influence of several variables for the new 88 projects surveyed (Moore, 1998).

Overall, design-build performed better than design-bid-build projects through the direct, objective comparisons of the 273 completed private, public, and federal projects in the CII database. However, using a 95% confidence level, schedule growth remained the only characteristic where design-build outperformed design-bid-build at a significant level (p-value of 0.005). The delivery speed performance of design-build was found to be equal to that of design-bid-build when measured from zero percent design start for the 88 federal construction projects. Facility size, facility type, and delivery system accounted for the greatest proportion of project delivery speed variation. While the study provides evidence that design-build was superior to design-bid-build across several metrics, Moore's (1998) results were limited to a period from design start to construction completion and failed to successfully capture pre-planning and programming cost and schedule metrics as well as design procurement schedule metrics due to limitations in the data source.

Construction Industry Institute (2002)

Research conducted by the Construction Industry Institute (CII) in 2002 sought to measure the effect of project delivery system on industrial building project performance. Using the CII's Benchmarking and Metrics database, 326 owner-submitted projects and 291contractor-submitted projects were used to compare delivery method performance over various cost, schedule, safety, changes, and rework measures (CII and NIST, 2002). The research revealed that, on average, design-build projects were approximately four times larger than design-bid-build projects in total project cost. The study also found that owner-submitted design-build projects significantly outperformed projects delivered by its traditional counterpart in schedule, changes, rework and practice use performance measures.

Ibbs et al. (2003)

Ibbs et al. (2003) compared the performance of design-build and design-bid-build delivery projects across cost growth, schedule growth, and productivity ratio measures. The researchers collected data for 67 projects found within the CII's database and used a survey questionnaire as the source for the productivity measure. Performance metrics for each delivery method were compared using individual linear regression equations. Ibbs et al. (2003) concluded that design-build delivery outperformed its traditional competitor with respect to schedule growth. However, the study's results for cost growth were not nearly as convincing. Additionally, the researchers admitted to difficulty in explaining the effects of project delivery method selection on productivity, as design-bid-build seemingly outperformed design-build (Ibbs et al., 2003). Overall, their work contrasted other studies by presenting a case in which design-build failed to perform significantly better than design-bid-build. Their research was limited by comparisons of relatively heterogenous facility types and a disproporionate number of projects (30 of 67) with a project cost of at least $50M. Very few MILCON projects exceed this project value; therefore, meaningful conclusions from their research may not be as easily drawn for MILCON project delivery performance (Hale et al., 2009).

Federal Highway Administration (2006)

In 2006, the Federal Highway Administration (FHWA) conducted research to evaluate the effects of design-build contracting on project cost, schedule, and quality measures. Data was collected using a project survey distributed to various state transportation agencies. These metrics were then analyzed for equal parings of like-scope design-build and design-bid-build projects. The main findings of the report revealed that design-bid-build projects have significantly higher project durations than their design-build counterparts. The research also found that design-build projects experienced on average, lower schedule growth but higher cost growth than design-bid-build projects. Finally, design-build achieved significantly less project cost per change order than the design-bid-build method, while the average number of change orders for design-build were fewer than that of design-bid-build. Their research failed to report the statistical significance levels for any its results, and it applies more to public transportation project delivery method selection and performance than it does to MILCON projects.

Shrestha et al. (2012)

Shrestha, O'Connor, and Gibson (2012) conducted a study comparing the relationship of the two project delivery methods with the performance of large highway projects with costs exceeding $50M. Two of the researchers had previously worked with Hale et al. (2009) to compare project delivery method performance in the construction of U.S. Navy Bachelor Enlisted Quarters (BEQ) projects. The study measured project performance in cost, schedule, and change orders for both forms of project delivery systems and also investigated associations between project characteristics (22 input variables) and project performance (7 output variables) experienced on 22 large highway projects (Shrestha et al., 2012). The performance output variables included contract award cost gowth, total cost growth, actual cost per lane distance (constructed), total schedule growth, project delivery speed, construction speed, and cost per change order. Using questionnaires, telephone interviews, and internet searches, Shrestha et al. (2012) identified critical information regarding the input variables and gathered key performance output variables relating to cost, schedule, safety, change orders, quality and claims.

The study analyzed the data using a single factor ANOVA test and t-test assuming unequal variance at an industry-accepted 95% confidence level. Additionally, correlations were made between input and output variables to determine if they interacted at a statistically significant level. Results showed that no statistical difference in mean cost-related metrics between project delivery methods existed. However, the mean project delivery speed per land distance and construction speed per lane distance for the design-build projects was significantly faster than that for design-bid-build. The researchers concluded that design-build projects are delivered and constucted faster than their traditional counterparts (Shrestha et al., 2012). Mean schedule growth in traditional design-bid-build projects was not significantly different than that of design-build projects. Additionally, there was no significant difference found between cost per change order when comparing the two delivery methods. Finally, the research found that 14 of 21 input variables have statistically significant associations with one or more or the seven outputs for these projects (Shrestha et al., 2012).

Their study used a very small sample size due to the limited number of large highway projects constructed by state departments of transportation that exceed $50M in project cost, thus causing the statistical findings from the research to be somewhat limited. Additionally, not all six design-build projects were constructed in Texas, while all 16 of the design-bid-build projects were products of the Texas Department of Transportation (TXDOT). Therefore, conclusions from their study should not necessarily be extended to other geographic locations of the country. The large scale population that was targeted for their study does not correspond well to the scope of most MILCON proejcts.

Public-Sector Studies Summary

While these public-sector studies vary in the significance of their findings, recurring project success criteria and key performance metrics have emerged as common threads in the review of these studies. These performance indicators have been identified as prevalent in the military sector as well. The following section includes related discussions germane to the analysis and comparison of MILCON project delivery systems execution.

U.S. Naval MILCON Studies

Following the industry's lead, the military has shifted away from the exclusive use of the design-bid-build project delivery method and has aggressively incorporated design-build project delivery into its construction projects. The following section is an aggregation of past research related to U.S. Naval MILCON project delivery method performance.

Mouritsen (1993)

Mouritsen (1993) conducted one of the first quantitative comparisons of design-build and design-bid-build performance for U.S. Navy MILCON projects. His research examined eleven Navy child care centers, to include five traditionally delivered and six using the alternative approach. The design-build projects were further broken down into procurement method type, either single-phase design-build acquisition or the Newport design-build method. Newport design-build projects were unique in that the Naval contracting agency combined design-build's single source of responsibility with competitive lump sum bids (Mouritsen, 1993). Under this method, the Navy would provide performance specifications and general design parameters instead of requiring the bidders to submit technical proposals.

The study's performance evaluation between design-build and design-bid-build delivery strategies included the calculation of percentage increase in the final cost of the project from the programmed amount. Mouritsen (1993) concluded that design-build project delivery resulted in substantially smaller cost growth above the programmed amount relative to the competing design-bid-build delivery method. Additionally, his research determined that the Newport design-build procurement strategy outperformed the single-phase acquisition method in cost savings with 21.9% and 15.5% cost savings respectively. Finally, project delivery time was determined to be reduced by 50%, without much explanation as to why the reduction occurred.

While his study was the first empirical comparison between MILCON delivery method execution, it lacked overall statistical analysis and adequate sample size to substantiate its general recommendation that design-build should be used for all MILCON projects (Mouritsen, 1993). It was only after the 1996 Federal Acquisitions Reform Act that the DoD began seeing benefits of using an alternative delivery approach (Cushman and Loulakis, 2001). Until that time, studies like Mouritsen's (1993) were affected by limitations in project data availability and project delivery team experience, ultimately making them less comprehensive.

Roth (1995)

Roth (1995) conducted an empirical analysis of twelve U.S. Navy MILCON capital contracts from FY 1987 to 1994 found within the NAVFAC database. Comparisons of design, construction, administrative costs, cost growth, contract modifications, and the procurement time frame were conducted across six design-build and six design-bid-build Naval childcare projects; this data population was much like that investigated by Mouritsen (1993). Ultimately, the study concluded that the use of design-build drastically reduced costs associated with design and construction in comparison to design-bid-build. The unit cost savings associated with using the design-build delivery method was the only characteristic that yielded significantly superior performance over its design-bid-build counterpart (p-value = 0.083). Additional results indicated that cost growth decreased with the use of design-build projects (Roth, 1995).

However, Roth's study (1995) was very limited from a statistical perspective due to the investigation of a relatively small sample size. While a comparison was made between several key performance characteristics found in the construction industry, the statistical comparison of design-build delivery for U.S. Naval MILCON projects was limited by federal law to three design-build pilot projects per year (Webster, 1997). These limitations were like those experienced by Mouritsen (1993). Therefore, the study's statistical results lacked robustness and convincing results.

Allen (2001)

Allen (2001) compared delivery method performance for 110 design-build and traditionally delivered MILCON projects; data was retrieved from the Navy Financial Information System (FIS) ranging from FY 1996 to 2000. Project delivery method performance was compared across several facility type categories, including BEQ, homogenous facilities (BEQ, Family Fitness Centers, and Child Care Centers), and horizontal-vertical construction. Direct comparisons of FIS data measured the average performance in percent cost growth, percent contract award growth, percent construction growth, and percentage total schedule growth characteristics for design-build and design-bid-build projects. Additionally, a survey questionnaire captured delivery method quality performance in characteristics that included total number of call backs, facility start-up costs, O&M costs, system quality, equipment quality, and environmental quality (Allen, 2001).

The study concluded that the design-build delivery approach largely outperformed its design-bid-build counterpart in percent cost, award, schedule, and construction growth. Design-build also largely outperformed design-bid-build in five of six quality performance metrics with the exception of O&M costs (Allen, 2001). Although the research provided a thorough analysis of MILCON facility types, the study lacked statistical analysis to determine significance levels. Moreover, the investigated projects were some of the first managed by Southwest Division (SWDIV) of NAVFAC; it would therefore benefit the command for a subsequent research effort to determine if delivery method performance has changed over time as familiarity with design-build has developed.

Hale et al. (2009)

A similar, yet unrelated, study of Navy BEQ was conducted by Hale et al. (2009) to further investigate project delivery method performance across a homogenous sample of MILCON projects. Widespread regionalized project data gathered across 18 states was retrieved from FIS for 38 design-build and 39 design-bid-build projects delivered between FY 1995 and 2004. Data was selected for projects that ranged from $4.7M to $41.5M in total project cost. Using time and location adjustments, these samples were then statistically compared through the following cost and schedule performance metrics to test the hypothesis that the performance of design-build is superior to design-bid-build: project duration, project duration per bed, construction start duration, project time growth, cost growth, and cost per bed (Hale et al., 2009).

The researchers conducted a single factor analysis of variance (ANOVA) using an industry standard 95% confidence level to identify statistically significant performance comparisons between delivery methods. The authors found that design-build significantly outperformed the design-bid-build delivery strategy (with varying levels) in all metrics except for cost per bed; the average cost per bed for design-build projects were still less than that of design-bid-build (Hale et al., 2009).

Overall the study revealed that projects delivered using a design-build strategy took less time, had less cost growth and were less expensive than those delivered using design-bid-build. However, Hale et al. (2009) only considered the construction phase when comparing total project time and failed to represent the design phase. A greater comprehensive approach would include milestones throughout the entire MILCON process. The primary limitation of the study existed in the comparison of a relatively small sample size. While each of the compared samples consisted of more than 30 projects, a future analysis should build on the research and use larger sample sizes.

Other MILCON Studies

The following is a consolidation of previous research related to project delivery method comparison in other MILCON studies. Recurring project success criteria and key performance measures used by the USACE are further examined through the aggregation of the results of these studies.

Pocock (1996)

Pocock (1996) was the first to investigate MILCON project delivery method performance using a statistical approach across an adequately large sample size (Rosner, 2008). The researcher compared three alternative delivery methods (partnered, design-build, and combination) to the performance of design-bid-build using the following performance indicators: cost growth, schedule growth, quantity of modifications per unit scope, and quantity of modifications due to design deficiencies (Pocock, 1996). The study's data set was retrieved from the USACE Automated Management and Progress Reporting System (AMPRS) and included 90 traditional design-bid-build, 63 partnering, 40 design-build, and 16 combination projects. Constructed projects from FY 1988 to 1995 were compared to determine relative project performance using two-sample Student's t-tests. Pocock (1996) also introduced a method called the Degree of Interaction (DOI) to capture the amount of interaction between project delivery team members throughout the planning, design, construction and start-up phases of a project. Data contributing to DOI was collected via survey questionnaire. The objective was to determine the impact of project interaction on delivery method performance. This was accomplished through the calculation of DOI scores for 38 different projects and subsequently correlating the score to the projects' delivery method performance.

Using a significance level of 0.1, Pocock (1996) did not find a statistically significant difference in delivery method performance using cost growth, schedule growth, and modification count per unit scope metrics. However, when considering the percent modifications due to design deficiencies, he found that design-build significantly outperformed its traditional counterpart. Overall, the results of the study showed that alternative approaches generally performed better than design-bid-build across all performance indicators. Additionally, Pocock (1996) determined that the increased levels of interaction experienced with alternative delivery approaches contribute to significantly higher average DOI scores than those achieved using design-bid-build.

The study was extremely comprehensive, yet it fell victim to the lower overall population of MILCON design-build projects, which resulted from the limited use of design-build project deliveries prior to 1996. Future related research would benefit from increased MILCON project delivery team experience using the design-build project delivery approach.

Webster (1997)

As a continuation of Pocock's study (1996), Webster (1997) further investigated the relative project delivery performance for MILCON projects by comparing design-build and design-bid-build projects across the same four metrics: cost growth, schedule growth, quantity of contract modifications per unit scope, and the percentage modifications due to design deficiencies. This was the first attempt to empirically determine whether the performance of design-build MILCON projects improved over time. Webster (1997) examined 29 design-build projects in AMPRS from FY 1991 to 1996 with the goal of verifying and validating Pocock's analysis. Subjective indicators, including user satisfaction, project management satisfaction, and design-build experience, were also gathered from interviews.

Using the same two-sample Student's t-test and a significance level of 0.05, the researcher found that design-build significantly outperformed its traditional competitor in schedule growth, modifications quantity per million dollars of project scope, and percent modifications due to design deficiencies. However, only the schedule growth indicator showed significant improvement over time. Additionally, design-build projects failed to be statistically superior to the alternative combination projects. Despite this fact, the study succeeded in its validation of Pocock's conclusions.

Several limitations exist within Webster's (1997) study. First, the comparisons suffered from a small sample size of the new 29 design-build projects. The analysis was also conducted only one year after its predecessor, limiting its ability to truly capture time-based performance data related to schedule growth. Finally, the subjective user satisfaction characteristic was not statistically compared, thus preventing any significant conclusions to be drawn from that element of the study.

Air Force MILCON Studies

Considering the limited presence of MILCON research related to project delivery method performance within the past 20 years, there is little wonder why no previously discussed study has strictly analyzed Air Force MILCON project delivery method comparisons. However, the following two research efforts have been the only academic attempts to investigate whether the alternative design-build approach outperformed the design-bid-build method in Air Force MILCON projects.

Garner et, al. (2008)

Garner et al. (2008) collected data for 332 Air Force MILCON projects from FY 2002 to 2006 from the ACES-PM database. Direct comparisons of the mean schedule and cost growths were made between design-build and design-bid-build delivered projects across three PA categories: projects less than $5M, projects between $5M and $10M, and projects greater than $10M. The same metrics were compared across horizontal and vertical construction groupings of projects.

The study found that there was a slight difference between delivery approaches when comparing cost growth to the PA categories in favor of design-build. Design-bid-build delivery schedule growth comparisons of the lower two PA categories exceeded that of the design-build method. Additionally, cost growth comparisons between delivery method and construction type groupings yielded results in favor of design-build. Results varied for the schedule growth comparison (Garner, et. al, 2008). While the sample size was adequate, the study lacked both scope and statistical analysis, thus making only direct means comparisons across two major parameters (PA category and construction type). While general conclusions were drawn as to identifying the design-build project delivery method as the superior method, it is difficult to definitively make this statement with any statistical certainty.

Rosner et al. (2009)

Rosner et al. (2009) sought to fill a dearth in academic literature regarding Air Force MILCON project delivery method studies by comparing the relative performances of design-build and design-bid-build delivery approaches. Specifically, their goal was to determine if the design-build delivery method outperformed design-bid-build across cost, schedule and change order metrics. The study also included delivery method comparisons over time and across several Air Force facility types (Rosner et al., 2009).

<u>Overview</u>

The researchers collected data for 278 design-build and 557 design-bid-build MILCON projects from the ACES-PM database constructed from FY 1996 to 2005. Project selection criteria included geographic location, data range, minimum project value, completion status, funding categories, and facility type exclusions. Rosner et al. (2009) narrowed the project samples to those conducted in the CONUS so that cost effects driven by overseas economic and political conditions would be eliminated. The project years were selected based on previous MILCON studies and the widespread authorization given by Congress in 1996 to use the two-phase design-build method for federal construction. The minimum project value used for screening reflected the past minimum MILCON spending level of $500K for FY 1996 to 2002 and the minimum spending level of $750K at the time of the study. Projects were also removed for having other than 100% completion status as reported by ACES-PM. Emergency MILCON funding categories and a specific facility type (i.e., housing) were also screened to eliminate the impact of funding and contracting policies unique to "Emergency 341 MILCON" or military family housing (MFH) projects (Rosner et al., 2009).

Eight key performance metrics were used to compare relative delivery method performance. Informal interviews with Air Force project managers helped validate the study's selection of the most impactful characteristics effecting project performance (Rosner et al., 2009). These performance metrics included: unit cost, percent cost growth, percent schedule growth, construction speed, modifications per million dollars (in project scope), construction timeline, and total project time. No justification was given for the selection of these specific metrics. Statistical differences that achieved a p-value of less than 0.05 were significant, and those that achieved a p-value of less than 0.01 were considered highly significant (Rosner et al., 2009).

Unit Cost Results

Rosner et al. (2009) found that although the average design-bid-build unit cost was less than that of design-build, the difference was not significant. However, the traditional approach significantly outperformed design-build in the FY00-01 year group. The study also found that unit cost performance worsened over time. Firm conclusions were not able to be made from the unit cost analysis of all project types. Airfield pavements and fitness centers constructed by design-build were characterized by significantly lower unit cost than those delivered via design-bid-build (Rosner et al., 2009).

<u>Cost Growth Results</u>

The study's cost growth analysis showed that the design-build delivery method outperformed the design-bid-build method at a highly significant level. While not statistically significant, design-build consistently outperformed design-bid-build for each year group. Rosner et al. (2009) concluded that the performance of design-build improved over time with several year significant year group comparisons. Similarly, the design-bid-build method saw improvement of cost growth over time with one year group comparison yielding highly significant differences in mean cost growths. The facility analysis showed that the cost growth for design-build was on average significantly lower than design-bid-build cost growth, yielding highly significant and significant levels across several facility types (Rosner et al., 2009).

<u>Schedule Growth Results</u>

Mean schedule growth comparisons between the two delivery methods yielded non-statistically significant results. The historical trends showed an increase in average schedule growth over time for both delivery methods, with design-build experiencing statistically significant average schedule growth increase in one year group comparison (Rosner et al., 2009).

Construction Speed Results

The average construction speed of design-bid-build projects was faster than that of design-build, although not at a significant level. Additionally, the average construction speed over time analysis did not yield any statistically significant results. Because of these analyses, a firm conclusion could not be drawn for the combined facility type grouping. After filtering the results by facility type, Rosner et al. (2009) concluded that the average construction speed of design-build was faster than that of design-bid-build.

Modifications per Million Dollars (of scope) Results

This analysis yielded highly significant results in favor of design-build. The historical analysis of both delivery methods produced highly significant findings. While the average number of modifications per million dollars for both delivery methods generally decreased, design-build outperformed design-bid-build projects at a highly significant level for all but one year group, where design-build proved to be superior at a significant level. Results of the facility analysis proved to be very consistent with these findings. Design-build was found to significantly outperform the design-bid-build method across seven of the nine facility types (Rosner et al., 2009).

CWE/PA Ratio Results

Little difference was found between the CWE/PA ratio performances of each delivery method. Likewise, the historical analysis of each method over time failed to yield significant results or even a performance trend. While not significant, general direct comparisons of average CWE/PA ratios across facility types favored the design-build delivery method (Rosner et al., 2009).

Construction Timeline Results

The researchers measured the construction timeline metric across three PA groupings: PA < $5M, $5M < PA < $20M, and PA > $20M. Results measuring differences across delivery methods within the lowest and highest PA categories were not significant. However, when considering the middle PA category, the average construction timeline of the design-bid-build method was less than that of design-build at a highly significant level. Several year group comparisons showed statistically significant improvement in the use of design-build over time. While traditional methods improved, the differences between year groups were not significant. Traditionally constructed maintenance facilities were the only facility types across all three PA groupings that yielded highly significant results. Rosner et al. (2009) concluded that the construction timelines for design-bid-build projects were generally faster than those of the design-build projects.

Total Project Time

A highly significant difference in average total project time was observed in favor of design-bid-build projects. The historical analysis showed that on average, the total design-build project duration had improved over time at a highly significant level. Additionally, the mean design-bid-build project durations outperformed its design-build counterpart in three of the five-year group comparisons. No conclusions were drawn for the historical trend of design-bid-build projects. Traditionally constructed corrosion control facilities exhibited highly significant lower average project duration than those constructed using the alternative approach (Rosner et al., 2009).

Limitations

The current research has identified several major limitations with methodology of Rosner et al.'s (2008) study. Most of these limitations stem from the data fields captured in ACES-PM. The ACES-PM module was developed to track traditionally delivered projects and fails to capture specific project cost fields and schedule milestones that are unique to design-build delivery. Air Force project managers are directed to track MILCON project timelines based on two distinct dates, from NTP to the BOD (Air Force Civil Engineer Center Integration Cell, 2015). However, while the period from NTP to BOD for design-bid-build projects reflects the construction timeline, this period represents both the design and construction timelines for projects delivered by design-build. Thus, performance metrics such as schedule growth that use these fields in ACES-PM are automatically "skewed…in favor of traditional projects" (Rosner et al., 2009).

Despite this limitation, Rosner et al. (2009) allowed "equitable" comparisons to be made of skewed data for schedule growth, construction timeline, and construction speed. The period from NTP to BOD is used to calculate these three measures, thereby skewing the relative performance of each in favor of design-bid-build. This initial skew was not enough to make design-bid-build projects outperform design-build at a statistically significant level in any of the three metrics. Instead, the overall analysis found that design-bid-build projects performed modestly better in the construction timeline and construction speed measures. Additionally, the results showed that through direct comparison of the mean schedule growths, design-build projects performed better than design-bid-build.

Finally, the reasons for contract modifications are also not universally tracked within ACES-PM. Therefore, Rosner et al. (2009) assumed that all modifications were results of factors with detrimental impact to the project and its timeline. Industry professionals have found increased change orders to be characteristic of design-bid-build projects (Gordon, 1994; Touran et al., 2009; Design-Build Institute of America, 2016). Rosner et al. (2009) found this to be the case as the average number of design-build modifications was fewer than that of traditional modifications by a highly significant degree.

The limitations identified above have called into question the soundness of Rosner et al.'s (2009) study. While many elements of his analysis remain unbiased, direct delivery method performance comparisons cannot be made across measures that are not equitably tracked in the ACES-PM database.

Summary

The use of the design-build project delivery method has seen a rapid increase over the past 25 years in the construction industry. Over that time, numerous key performance measures related to a project's budget, schedule, and quality have emerged as useful tools for comparing relative project delivery method performance across different sectors of the construction industry. Many public-sector analyses have used these measures to compare the relative performance of traditional and alternative project delivery strategies with varying degrees of success. Others have developed comprehensive models to help predict and improve project delivery performance using these indicators. Although the U.S. military is no stranger to design-build project delivery, few academic studies have focused on its performance, and even fewer have definitively revealed it to be the superior approach for MILCON project execution. As a result of reviewing the delivery method performance literature, the following research gaps have been identified.

- Academic studies related to MILCON project delivery method performance are lacking in scope.
- Of the eight previous MILCON studies examined above, only three statistically compared the performance of project delivery methods through significance testing of large sample sizes (Pocock, 1996; Rosner et al., 2009; Hale et al., 2009).
- All but two of the past MILCON studies were conducted before an established track record of design-build project performance existed.
- While the most recent MILCON study found the overall performance of design-build to be significantly superior across almost every performance indicator, the results were limited to a single facility type (Hale et. al, 2009).
- The only in-depth study of Air Force MILCON delivery method performance was conducted in 2008, and its findings were largely hampered by the functionality of its data source (Rosner, 2008).
- The historical performance of Air Force MILCON project delivery has not been sufficiently analyzed beyond 2005 (Rosner, 2008).

- No formal Air Force research has identified an industry-proven list of key measures used to effectively analyze project delivery method performance.

This research will attempt to address these literature gaps. Chapter III presents a methodology used to answer the investigative questions of this research. Chapter IV then presents a framework of industry-proven key performance measures for consideration of future Air Force delivery method performance comparison analyses. And finally, Chapter V provides an analysis, conclusion, and present opportunities for future research.

III. Methodology

This chapter presents the method used to aggregate a list of industry-proven key performance indicators that can be used to analyze the performance of Air Force construction projects. Detailed descriptions of these performance indicators are made so that parallels can be drawn between these and similar measures currently being tracked by the Air Force Civil Engineer Center (AFCEC). Additionally, this chapter describes the statistical approach used to analyze the performance of Air Force MILCON projects by delivery method over time and by facility type using applicable cost, schedule and change order project data from the ACES-PM database.

Investigative Question #1

This chapter begins by addressing the methodology used to address Investigative Question #1:

1. What framework of key performance indicators should the Air Force track to effectively compare the relative performance of AF MILCON project delivery methods?

The process for collecting industry-proven project delivery performance indicators is addressed through the discussion of selection criteria for key performance indicators, the description of the indicator aggregation and screening processes, the definition of each performance measure, and the in-depth examination of the Air Force Ribbon Cutter Criteria.

Key Performance Indicators

This research conducted a comprehensive review of previously published studies related to project delivery method performance. The purpose of the review was to identify commonly examined key performance indicators that have been used to analyze or predict project delivery method performance.

Conditions for Research Selection

Studies spanning from 1993 to 2016 were examined to provide a comprehensive understanding of critical variables impacting project delivery performance over time. Twenty-four peer-reviewed journal articles, theses, dissertations and reports were selected as the foundation for this research. One of the goals of this study was to avoid unnecessary gaps in the relevant discussion. The first gap in study frequency occurred between the 1993 and 1995 MILCON studies (Mouritsen, 1993; Roth, 1995). As previously discussed, widespread public use of alternative project delivery methods did not begin until after 1996 (Beard et al., 2001; Cushman and Loulakis, 2003). Subsequent gaps that exceeded one year between studies occurred between 1999 and 2001(Molenaar et al., 1999; Allen, 2001), 2004 and 2006 (Ling et al., 2004; El Wardani et al., 2006) and 2014 to 2016 (Goftar et al, 2014; Hanna, 2016). Aside from these instances, the sample studies were well spread across the 24-year period averaging almost one every per year.

Data for these studies were predominantly gathered through private, public or military project databases, telephone interview, or by distribution of survey questionnaires to project owners and contractors. Key performance indicators generally fell into one of the following categories: budget (cost), schedule (time), or quality.

Quality measures were frequently further characterized as objective or subjective in nature.

Indicator Aggregation and Screening

Using the selection criteria outlined above, an aggregated list of key performance measures was developed in a Microsoft Excel spreadsheet to identify variables pertinent to project delivery performance or projected success for each study and summarize any related findings. MILCON studies were then separated from non-MILCON studies to more easily identify trends or commonalities between variables across military studies. Key performance variables were then identified across each study, highlighting any indicator results that were statistically significant. Additionally, both statistically superior and average superior delivery methods were separately designated. Statistical findings from small sample sizes were also uniquely identified.

After collecting each study's results and key performance measures, the compiled data were examined for outliers, similarities, and trends. Screening of outliers included the removal of performance measures that were unique to less than five projects. Performance measures that were found to be statistically significant were exempt from outlier removal regardless of whether five or more studies shared the indicator. Measures were then grouped by like cost, schedule and quality attributes.

Key Performance Indicator Definitions

The following key performance indicators emerged as common variables examined throughout the literature. This section provides a brief overview of each measure based on a consensus of the researchers. From a list of the following measures, Chapter IV constructs a framework of key performance indicators for Air Force civil engineers to use when comparing relative project delivery method performance.

Cost Growth

Cost growth is the resultant percentage of project cost growth throughout the project's design and construction phases. Usually, cost growth is a result of contract modifications made through various stages of the project. This is measured using a project's final cost and contracted costs (Konchar and Sanvido, 1998). The generally accepted formula for cost growth is as follows.

$$\text{Cost Growth (\%)} = \left[\frac{\text{(Final Project Cost-Contracted Project Cost)}}{\text{Contracted Project Cost}}\right] * 100 \qquad (1)$$

Unit Cost

The unit cost measure is the relative cost per unit area of a constructed facility and allows for the equitable comparison of construction projects in the U.S by normalizing project-specific data. The funding for many state, federal, and military projects is often planned for a unit cost value. An historical cost index is also commonly applied using construction planning standards like Means (1995) to correct for the effects of time and location on the variable (Konchar and Sanvido, 1998). The generally accepted formula for unit cost is presented below.

$$\text{Unit Cost}\left(\frac{\$}{m^2}\right) = \frac{\left(\frac{\text{Final Design Cost+Final Construction Cost}}{\text{Project Area}}\right)}{\text{Index}} \qquad (2)$$

Award Growth

The award growth measure assesses the difference between contract award amounts and the current working estimates which often reflects the bidding environment at the time of the award (Gransberg, 2002). This metric was found most commonly throughout the literature as a percent growth metric; however, other researchers have used a ratio to represent this measure. The following is the most commonly accepted formula for award growth.

$$\text{Award Growth (\%)}=\left[\frac{(\text{Original Contract Cost-Engineer's Estimate})}{\text{Engineer's Estimate}}\right]*100 \qquad (3)$$

Intensity

Project intensity is the unit cost of design and construction work for a facility per unit of time (Konchar and Sanvido, 1998). Project intensity is commonly defined by the following formula.

$$\text{Intensity}\left(\frac{\frac{\$}{m^2}}{\text{month}}\right)=\frac{\text{Unit Cost}}{\text{Total Project Time}} \qquad (4)$$

Schedule Growth

Like cost growth, a project's schedule growth is a widely-accepted measure for project performance (Konchar and Sanvido, 1998; Ling et al., 2004; El Wardani et al., 2006; McWhirt, 2007). Schedule growth measures the percent by which the combined design and construction duration grows over the project life. This metric is determined using the total as-built and as-planned project durations and is expressed by the following formula.

$$\text{Schedule Growth (\%)} = \left[\frac{(\text{Total As Built Time} - \text{Total As Planned Time})}{\text{Total As Planned Time}}\right] * 100 \qquad (5)$$

Construction Speed

Construction speed is the rate at which the builder constructs a facility beginning from the NTP and ending on the BOD. This measure is represented by area of facility constructed over time (Konchar and Sanvido, 1998). The following is a generally accepted formula for construction speed.

$$\text{Construction Speed}\left(\frac{\text{S.F.}}{\text{month}}\right) = \left[\frac{\text{Area}}{\frac{\text{Total As Built Construction Time}}{30}}\right] \qquad (6)$$

Delivery Speed

Like construction speed, the delivery speed of a project is the rate at which a facility's gross square footage is designed and constructed each month (Moore, 1998; Shrestha et al., 2012). Delivery speed is commonly expressed using the following formula.

$$\text{Delivery Speed}\left(\frac{\text{S.F.}}{\text{month}}\right) = \left[\frac{\text{Area}}{\frac{\text{Total As Built Time}}{30}}\right] \qquad (7)$$

Total Project Duration

Total project duration is simply the time from the start of design to the moment the occupants enter the facility (Rosner et al., 2009; Hale et al., 2009). Total project duration is expressed using the following formula.

$$\text{Total Project Duration (days)} = \text{Beneficial Occupancy Date} - \text{Design Start Date} \qquad (8)$$

Construction Duration

Like total project duration, construction duration is simply the time from the start of construction beginning from the NTP until the moment the occupant enters the facility for beneficial occupancy (Rosner et al., 2009; Hale et al., 2009). Construction duration is expressed using the following formula.

$$\text{Construction Duration (days)} = \text{BOD} - \text{NTP} \qquad (9)$$

Design Duration

Simply put, design duration is the amount of time it takes to design a project. This metric marks the difference between the 100% design complete date and the design start date (Construction Industry Institute (CII) and National Institute of Standards and Technology (NIST), 2002). A project's design duration is expressed using the following formula.

$$\text{Design Duration (days)} = \text{100\% Design Complete Date} - \text{Design Start Date} \qquad (10)$$

Modifications per Million Dollars (scope)

Change order management is a critical factor to delivering a quality product on time and within budget. Construction contract modifications are generally effective indicators for determining the project's overall status. Contracts characterized by many modifications are often indicative of poorly performing projects. Therefore, it is important to consider the number of contract changes in a normalized manner when comparing multiple projects to ensure a fair and balanced comparison (Rosner et al., 2009). The following formula expresses the modification count per million dollars of project scope.

$$\text{Modifications per Millon Dollars}\left(\frac{\#\text{ Mods}}{\$\text{M}}\right)=\frac{\text{Modification Count}}{\left(\frac{\text{Contract Amounnt}+\text{Design Amount}}{\$1{,}000{,}000}\right)} \quad 11)$$

Percent Modifications due to Deficiencies

One form of limiting controllable scope change is ensuring the accuracy of design. Percent modifications due to design deficiencies captures the undesirable amount of change orders that are caused from errors in the design (Pocock, 1996).

Operations & Maintenance Costs

Quality was a common thread throughout many of the sample research studies. Operations and maintenance costs are the amount of the owner's financial resources required to utilize the facility daily. Poorly designed or constructed facilities can become a greater financial burden on the owner (Konchar and Sanvido, 1998).

Quantity of Call-Backs

Another form of quality identified throughout the literature review was the number and magnitude of call-backs. Poorly constructed facilities will inevitably have more warranty calls than those that are properly constructed. Maintaining excellent quality control and quality assurance throughout the project's duration will minimize the number of initial warranty calls (Konchar and Sanvido, 1998).

Facility Start-up Difficulty

This qualitative measure captures the amount of frustration an owner experiences when he or she experiences roadblocks to reaching their normal operating capacity (Konchar and Sanvido, 1998).

System Quality and Process Equipment Quality

System quality of a project reflects the performance of building elements, the interior space and the environment. Process equipment quality reflects the performance of the installed equipment within the facility (Ling, et al. 2004). These two measures were used interchangeably throughout the literature in multiple studies (Konchar and Sanvido, 1998; Chan et al., 2002).

Owner Satisfaction

This measure captures the degree to which the owner is pleased about the entire project, from the planning phase to project closeout and owner occupancy. While difficult to measure, this qualitative indicator was captured by many surveys and is generally considered an important predictor for project performance (Molenaar et al., 1999).

Owner's Administrative Burden

Another subjective performance measure that emerged throughout the review of the sample studies was the amount of administrative burden that is experienced by the owner throughout the course of the project. Projects that constantly require an owner's attention and resources can quickly become frustrating (Ling et al., 2004). Other researchers argue that the administrative burden felt by the owner is directly related to the type of project delivery used to execute the project (Songer and Molenaar, 1996; Molenaar et al., 1999).

Air Force Ribbon Cutter Criteria

The Air Force has incorporated its own list of 20 performance measures into a MILCON project management tool developed to communicate and summarize a project delivery team's performance (Air Force Civil Engineer Center Integration Cell, 2015). The Ribbon Cutter Criteria was created by the AFCEC Integration Cell to evaluate how well the Air Force and its USACE and NAVFAC agent partners achieve their strategic goals of MILCON execution. Figure 3 illustrates the Ribbon Cutter scoring summary developed by AFCEC.

The tool focuses on four distinct phases of the MILCON project execution process: design, award, construction, and closeout. These primary phases are further broken down into subcategories that evaluate specific milestones of interest, or pivotal elements of the MILCON project process that impact the overall success of the project's execution. Members of the AFCEC Integration Cell established these characteristic and milestone goals "based on the historical data, negotiations, personal experience, and government, Department of Defense and Air Force policies" (Air Force Civil Engineer Center Integration Cell, 2015). Several of these pivotal metrics share similarities with previously discussed industry-proven key performance indicators, while others remain unique to the MILCON process.

Overview of Ribbon Cutter Scoring

The Ribbon Cutter scoring process allows the AFCEC to recognize superior performance across the Air Force on a quarterly basis (Air Force Civil Engineer Center Integration Cell, 2015). The current application of the Ribbon Cutter metric includes the comparison of MILCON project delivery team performances across all Air Force installations by using a weighted mean to calculate final scores.

Figure 3 - Ribbon Cutter Criteria (AFCEC Integration Cell, 2015)

Note: Highlighted = Agent Metric	OPR	Goal	Weight
Design			**3.0**
Asset Management (Design)	AF PM	Confirm inclusion of Asset Mgnt elements in project DSG	0.4
LEED Silver Certified	AF PM	100%	0.6
HAF DI Issue Time (Air Staff to AFCEC)	HAF	18 months prior to FY CONUS 24 months prior to FY OCONUS	0.5
AF DI Issue Time (AF to Agent)	AF PM	7 days	0.25
Agent Design Start Turnaround	Agent	90 days	0.25
Design Build/Adapt Build	AF PM	75% of All Projects	0.5
Design/RFP Completion	Agent	Ready to Advertise within 540 days (CONUS) or 720 days (OCONUS) from Agent DI Notification	0.5
Award			**3.0**
Time to Award After Bids/Proposals Received	Agent	90 days	0.75
HAF Notification/Funds Processing Time	HAF	10 days	0.5
Construction Timeline	Agent	Construction timeline goals vary with project PA; metric based on contract performance period at time of award	0.25
Project Award	Agent	Award NLT 30 Jun FY (PB) Award NLT 30 Sep FY (Late Adds)	1.0
Award CWE/PA Ratio	Agent	Less than or equal to 97%	0.5
Construction			**1.5**
Asset Management (Construction)	AF PM	Demolition completed if required	0.5
Cost Growth (Non-Mandatory Changes, e.g. Customer Requested)	AF PM	2% Growth or less	0.25
Cost Growth (Mandatory Changes)	Agent	3% Growth or less	0.25
Time Growth (Non-Mandatory Changes, e.g. Customer Requested)	AF PM	10% growth or less	0.25
Time Growth (Mandatory Changes)	Agent	10% growth or less	0.25
Project Closure			**2.5**
Red Zone	Agent	Conduct meeting at least 75 days prior to BOD	.75
Contract Physical Completion	Agent	Within 85 days of BOD	1.0
Project Financial Closeout	Agent	Within 18 months of BOD (CONUS) and 24 months (OCONUS)	0.75
	Total Weight		**10**

A scaled point system is used to measure the performance for each of the 20 key project measures. Individual performance point values are integers ranging from "zero" to "three" that together create a four-point system defining standard thresholds displayed in Table 5. A project delivery team receives a raw individual performance measure score for each project managed in the installation's MILCON project portfolio. For example, a team with five MILCON projects will be assigned five raw scores for each of the 20 Ribbon Cutter performance measures. Weighted mean scores are then calculated for each performance measure by multiplying the team's average measure score by a specific weight shown in Table 5. The applied weights indicate the "relative importance [of each metric] to the Air Force" (Air Force Civil Engineer Center Integration Cell, 2015).

Table 5 - Ribbon Cutter Goal Scoring

Point Value	Description
0	"Does Not Meet Goal"
1	"Below Goal"
2	"Meets Goal"
3	"Exceeds Goal"

The team's weighted mean performance scores are then added within their corresponding project phase categories (design, award, construction and closeout) to create a total weighted category score. These values are then "normalized" by dividing by the category's overall weight to determine a total score (0-3) achieved in that project category. These final category scores indicate the project delivery team's performance in that category across its project portfolio. All four categories are assessed the same way and then combined and normalized to create a team's overall total Ribbon Cutter score.

Ribbon Cutter Limitations

There are, however, shortcomings associated with the Air Force Ribbon Cutter Criteria. To begin, several metrics are considered either "meets" or "does not meet" and are often associated with project manager bookkeeping in ACES-PM more than true project performance. Additionally, the evaluation tool is inherently biased toward the design-build project delivery method as five percent of the overall score is dependent on whether the project was delivered using design-build (Air Force Civil Engineer Center Integration Cell, 2015). Finally, many of the milestones within the Ribbon Cutter Criteria are limited by the available data fields within ACES-PM. This ultimately makes it difficult to equally compare project delivery method performances using this project evaluation tool across many meaningful performance measures used throughout the construction industry.

While these shortcomings exist, the tool succeeds in identifying key milestones or performance values specific to Air Force MILCON projects. Additionally, future analyses can glean value from the weights assigned to each milestone. During the presentation of results in Chapter IV, parallels will be drawn with respect to direct results from the statistical analysis and some of the goals listed in the Air Force Ribbon Cutter Criteria to assess whether the Air Force is achieving its advertised goals.

Investigative Questions #2-7

This chapter now address the methodology used to address Investigative Questions #2 through #7:

2. Using current cost, schedule and change order project measures, has the performance of Air Force MILCON design-build project delivery improved at a statistically significant level over time?

3. Using these performance measures, does a specific facility type outperform other facility types in Air Force design-build project delivery?

4. Using these performance measures, does a specific Major Command outperform its peers in Air Force design-build project delivery?

5. Using current cost, schedule and change order project measures, has the performance of Air Force MILCON design-bid-build project delivery improved at a statistically significant level over time?

6. Using these performance measures, does a specific facility type outperform other facility types in Air Force design-bid-build project delivery?

7. Using these performance measures, does a specific Major Command outperform its peers in Air Force design-bid-build project delivery?

The following section describes the process for answering these investigative questions through the analysis of MILCON metrics currently tracked by AFCEC. This will be addressed through the description of the data source, the collection and preparation of data, the selection of relevant performance measures and independent variables, and the explanation of the statistical analysis testing used in this study.

Data Source

Air Force civil engineers use the ACES-PM module as the universal MILCON project-planning database to track a wide variety of project information through the planning, programming, and construction phases of military construction. Specific information managed within this database includes general project information, critical project cost data, and schedule milestones across each phase of a MILCON project, as well as project scope characteristics. These variables provide useful measures for measuring the historical performance of the design-build and design-bid-build project delivery methods. Air Force regulations dictate that all MILCON project data be kept up to date within ACES-PM to accurately reflect real-time cost and schedule data (Department of the Air Force, 2016). Therefore, this universal Air Force MILCON data repository will be used as the sole source to retrieve project information for this research.

Data Collection and Preparation

The primary goal of this research is to determine if the Air Force's execution of each project delivery approach has improved over time using statistical analysis of individual project schedule, cost, and change order data from the ACES-PM database. Project information was collected from ACES-PM through the help and guidance of the AFCEC Integration Cell. A data report-writing software extracted an initial data report from ACES-PM into a Microsoft Excel spreadsheet (Winslow, 2017). This report included information for all past and present Air Force MILCON projects ranging from FY 2003 to 2018. Before any analysis would be conducted, project selection criteria were established to ensure the projects remained in keeping with the scope of this research. Additionally, individual fields pertaining to a project's physical scope, cost, and schedule were identified.

Project Selection Criteria

This research used the following criteria to select projects from ACES-PM:

- Project Type: Only standard MILCON projects were selected for analysis to ensure a relative homogenous dataset. The report retrieved from ACES-PM not only included MILCON projects, but it also contained non-standard construction projects categorized as one of the following: Overseas Contingency Operations (OCO), Defense Logistics Agency (DLA), Base Realignment and Closure (BRAC), Medical (MED), Military Family Housing (MFH), Numbered Air Force (NAF), Unspecified Minor Military Construction (UMMC) or (P-341), and Special Operations Command (SOCOM). Due to unique differences in funding and contracting policies, this analysis only considered standard MILCON projects.

- Construction Completion Percentage: ACES-PM tracks data throughout all phases of a construction project. To ensure equivalent comparison of project data, only projects listed with a completion level of 100% were selected.

- Minimum MILCON Funding Threshold: The minimum funding level for construction projects classified as MILCON has changed over time. Prior to FY 2003, the minimum funding level for MILCON projects was $500,000. From FY

2003 to 2014, this threshold was raised to $750,000. Yet another increase to this funding threshold occurred in FY 2015, elevating the MILCON minimum to $1,000,000 (Department of the Air Force, 2015a). Thus, only projects exceeding $750,000 were considered for this study.

- Project Fiscal Year (FY) Range: Projects ranging from FY 2003 to 2016 were analyzed in this research. Rosner et al. (2009) analyzed projects ranging from FY 1996 to 2005 (Rosner et al., 2009). Thus, by using a two-year overlap in project data this research should sufficiently capture unfinished projects at the time of Rosner's study (2008).

- United States: MILCON projects constructed overseas are subject to possible socio-economic and political factors not easily recognized within the scope of this research. The more homogenous U.S. project classification was used as the final screening rule for this study.

- Data Retrieval Date: The report used for the analysis portion of this research was retrieved from ACES-PM on January 13th, 2017. Only projects satisfying the above criteria on this date were selected for analysis.

Performance Measure Selection

The preliminary steps of this research methodology have been outlined above. The following steps address the analysis method of this study. As observed through the extensive literature review of key performance indicators at the beginning of the chapter, and as expressed within the Air Force's Ribbon Cutter Criteria, typical project performance is assessed using the concepts of cost, time and quality. Gransberg et al. (2002) further categorized these measures into the following three types: relative, static, and dynamic. These performance measures will be used to determine whether the Air Force's execution of each MILCON project delivery method has improved over time.

Gransberg et al. (2002) classified relative metrics separately because they are independent of project size, which ultimately allows for the direct performance comparison of any project, regardless of scope size. The following relative metrics will be used in this analysis: cost growth, CWE/PA ratio, and schedule growth. Static metrics are discreet numerical measures that do not change over time (Gransberg et al., 2002). Unit cost and modifications per million dollars will be used as static metrics in this analysis. Finally, dynamic metrics vary with time (Gransberg et al., 2002). Overall project duration, construction speed, and delivery speed are dynamic metrics that were also analyzed in this research.

Cost Growth

As previously discussed, cost growth is the resultant percentage of project cost growth throughout the project's design and construction phases. Usually, cost growth is a result of contract modifications made through various stages of the project. The Air Force tracks consolidated costs associated with all project contract modifications using the ACES-PM data field called "Contract Mod. Amount." The overall change in a project cost over its duration was defined as the percentage ratio between the project's compiled modified contract amount (in dollars) and the original amount of the contract (dollars). This can be seen in the cost growth formula below.

$$\text{Cost Growth (\%)} = \left(\frac{\text{Contract Modification Amount (\$)}}{\text{Contract Original Amount (\$)}} \right) * 100 \qquad (12)$$

The use of the cost growth metric presents challenges to Air Force project managers when they attempt to compare project delivery method performance. The ACES-PM database includes these two fields to reflect the compiled sum of all original contracts within the construction phase as well as a total cost associated with all changes. The database does not specifically capture any costs that occur during the design phase for traditionally constructed projects. However, modification and contract costs associated with both design and construction phases of design-build projects are included within this field of ACES-PM. This is a departure from the methodology used by Rosner et al. (2009), who directly compared the different delivery methods using this metric. The manner in which project information is tracked within the ACES-PM database does not allow for an equivalent comparison of cost growth metrics between the two delivery methods evaluated in this study. Instead, the cost growth performance of each delivery method will be individually analyzed with respect to time with the understanding of this limitation.

CWE/PA Ratio

Project programming and planning are key to the success of a project. Comprehensive and effective cost estimates conducted early in the project generally result in fewer modifications and higher overall performance (DBIA, 2007). In Air Force applications, when the occurrence of modifications causes the project's costs to exceed 25% of the amount appropriated for the project, the project is delayed for reprogramming – incurring additional cost to the U.S. government (Department of the Air Force, 2016).

For this reason, the CWE/PA ratio is used by both design and construction managers to gauge the engineer's estimate with the congressionally approved programmed amount of the project (Air Force Civil Engineer Center Integration Cell, 2015). Therefore, the CWE/PA ratio is an effective measure for quantifying the effectiveness of a project delivery method in meeting a MILCON project's initial programmed amount. This study uses the following formula to define the CWE/PA ratio.

$$CWE/PA = \frac{\text{Total Current Working Estimate (\$)}}{\text{Programmed Amount (\$)}} \tag{13}$$

Schedule Growth

Construction delays often contribute to significant cost increases and delayed occupancy by the end user. Therefore, schedule change is an important factor to consider when determining the overall performance of a project. This research study defined schedule change and use ACES-PM data in the following formula,

$$\text{Schedule Growth (\%)} = \left[\left(\frac{\text{NTP to Act BOD}}{\text{NTP to Est BOD}}\right) \text{-1}\right] * 100 \tag{14}$$

where "NTP to Act BOD" is the notice to proceed to actual beneficial occupancy date and "NTP to Est BOD" is the notice to proceed to estimated beneficial occupancy date.

As Rosner et al. (2009) discovered in his earlier study, ACES-PM data were stored uniquely for different project delivery methods. When considering design-bid-build projects, NTP to BOD represents the construction phase of the project. Conversely, ACES-PM also assigns design and construction phase attributes to projects utilizing the design-build method. Therefore, when analyzing data from ACES-PM, equivalent comparisons cannot be made using this metric. Instead, the performance of each project delivery method was analyzed individually, with the understanding that schedule growth is measured differently across each delivery approach.

Unit Cost

Unit cost is a normalized comparison metric for determining the dollar amount per unit of area of the project cost. However, there are many types of costs defined throughout the programming, design, and construction phases of a project. Therefore, the most appropriate definition for determining the full impact of project delivery method performance includes the Current Working Estimate (CWE) when calculating unit cost. This research defines unit cost in the following formula,

$$\text{Unit Cost}\left(\frac{\$}{\text{SM}}\right) = \frac{\text{Total CWE Amnt} * \text{Index}}{\text{Scope}} \quad (15)$$

where "Total CWE Amnt" is the Total Current Working Estimate Amount ($), "Index" is the location adjustment factor * time adjustment factor, and "Scope" is the quantity of units constructed in square meters (SM). During project execution, the CWE is a running total of expected costs associated with all phases of the project. Upon project completion, the CWE serves as the final funds expensed for these project phases.

Modifications per Million Dollars

Construction contract modifications are generally effective indicators for determining the project's overall status. Contracts characterized by many change orders are often indicative of poorly performing projects. Therefore, it is important to consider the number of contract modifications in a normalized manner when comparing multiple projects to ensure a fair and balanced comparison. The formula below defines the modifications per million dollars,

$$\frac{\text{Modifications}}{\text{Million Dollars}} = \frac{\text{Mod Count Qty}}{\left(\frac{\text{Contract Orig Amnt} + \text{Des Amnt}}{\$1{,}000{,}000}\right)} \qquad (16)$$

where "Mod Count Qty" is the number of modifications, "Contract Orig Amnt" is the original contract amount ($), and "Des Amnt" is the design amount ($).

Project Duration

Project duration is a dynamic metric used to capture the total amount of time expended during the design and construction phases of a project. However, due to the previously discussed limitations of the data residing in ACES-PM, this measure must include a universal commencement date for design activity and a final construction completion date. Therefore, this research measures project duration from the time the field design instruction (DI) is issued to the agent to the completion of construction marked by the beneficial occupancy of the owners. The design phase for both forms of Air Force project delivery begin at the issuance of the field DI. For design-build projects, the issuance of the field DI initiates the agent's development of the request for proposal (RFP), which details the government's requirements prior to solicitation, while the field DI initiates the actual start of design activity within a traditionally delivered project (Department of the Air Force, 2007). In both instances, initial design activity commences with the issuance of the field DI. Likewise, the end of construction is commonly marked by the occupancy of the facility's end user. The following formula was used to calculate the total project duration.

$$\text{Project Duration (Days)} = \text{BOD} - \text{DI Notification to Agent} \qquad (17)$$

While there are many differences between the way design and construction phases are executed across both delivery methods, a project's overall duration can be used to make a direct comparison between delivery methods. The project duration measure captures not only design and construction activities, but it also captures all contracting actions associated with the project. This limitation must be understood when using the project duration measure.

Construction & Delivery Speeds

Speed is an indicator commonly used to determine how quickly a project delivery team delivered the final constructed facility (Konchar and Sanvido, 1998). Both the facility size (area) and time are factors that determine the speed. The notice to proceed date marks the start of the construction phase for design-bid-build projects. Air Force project managers use the same data field to track the date the design-builder is instructed to begin design work (Air Force Civil Engineer Center Integration Cell, 2015). For this reason, a separate formula was used to characterize speed for each delivery method. Ultimately, the construction speed of a traditionally delivered project was expressed using the following formula,

$$\text{Construction Speed}\left(\frac{\text{SM}}{\text{Month}}\right) = \frac{\text{Scope}}{\left(\frac{\text{NTP to Act BOD}}{30}\right)} \tag{18}$$

where "Scope" is the quantity of constructed units (SM) and "NTP to Act BOD" is the notice to proceed to actual beneficial occupancy date. Likewise, the speed of a design-build project was expressed using the following formula,

$$\text{Delivery Speed}\left(\frac{\text{SM}}{\text{Month}}\right) = \frac{\text{Scope}}{\left(\frac{\text{NTP to Act BOD}}{30}\right)} \tag{19}$$

where “Scope” is the quantity of designed and constructed units (SM) and “NTP to Act BOD” is the notice to proceed to actual beneficial occupancy date. Due to the previously discussed limitations with data availability in the ACES-PM module, no direct and equivalent comparison was made between delivery method performances using this measure. Instead, these measures were used to analyze the individual performance of each delivery method over time.

Independent Variables

The final six research questions were addressed by analyzing the eight previously discussed performance measures as dependent outputs, or responses, to the following three key independent variables: time, facility type, and major command (MAJCOM).

Historical Delivery Method Performance

One of the primary goals of this research is to determine whether the Air Force’s execution of each delivery method has improved over time. ACES-PM project data and the eight response measures allow for such analyses. Specifically, this study grouped and compared project data within each delivery method using six two-year categories determined by the project’s fiscal year (FY). Based on the limiting number of Air Force MILCON projects, year groupings were necessary to capture sufficient sample sizes of representative project data. Whereas Rosner et al. (2009) analyzed MILCON project data from 1996-2005, this study analyzed similar project data beginning in FY 2003-2004. Additionally, only three FY 2015 or FY 2016 MILCON projects were completed during the time of this study; therefore, the most recent MILCON data was from the FY03-14 category.

Facility Type

Throughout much of the literature review, researchers have analyzed delivery method performance across many facility types to determine if one approach is decidedly more advantageous to a project's physical characteristics (Konchar and Sanvido, 1998; El Wardani, 2006). In the same manner, it would benefit Air Force project managers to know key performance characteristics of project delivery strategies across the service's facility inventory. The Air Force uses a six-digit number, or category code (CATCODE), to represent the function of a facility or project area (Department of the Air Force, 2016). Numeric pairings within the code identify functional characteristics of the facility. The overarching facility classification is designated with the first two digits, and the subsequent number pairings describe specific functional characteristics of the facility (Department of the Air Force, 2016).

ACES-PM project data available from FY 2003 to 2014 included 19 different CATCODEs. However, the use of each CATCODE varied a great deal across the MILCON project data; this resulted in several relatively small sample sizes across several categories. Therefore, the total list of facility types was narrowed down to the top eight most frequently constructed facilities during the FY03-14 category, capturing at least 15 projects utilizing each delivery method execution by facility type. This study analyzed project delivery method performance using the response measures across the eight facility types shown in Table 6.

Table 6 - Facility Category Codes (Department of the Air Force, 2016)

CATCODE PREFIX	DESCRIPTION	ANNOTATION
11	Airfield Pavements	AIRFIELD PAVEMENTS (11XXXX)
14	Land Operations Facilities	OPERATIONS (14XXXX)
17	Training Facilities	TRAINING (17XXXX)
21	Maintenance Facilities	MAINTENANCE (21XXXX)
61	Administrative Facilities	ADMINISTRATIVE (610XXX)
72	Dormitories, Officer Quarters, and Dining Halls	DORMS, QUARTERS, DINING HALLS (72XXXX)
73	Personnel Support Facilities	PERSONNEL SUPPORT (73XXXX)
74	Community Support Facilities	COMMUNITY SUPPORT (74XXXX)

Major Command

The major command (MAJCOM) category was the final independent variable used to measure the response of the performance metrics. MAJCOMs are major subdivisions of the Air Force and are characterized by unique mission specializations. Installations associated with each MAJCOM generate the formal requirements for MILCON projects and oversee the performance of the agent and project contractors (Department of the Air Force, 2015a). The complete list of MAJCOM categories will be established to reflect the top eight MAJCOMs most prevalently involved with MILCON projects between FY 2003-2014. The narrowed list will ensure a sample size of at least 5 projects executed by each delivery method for MILCON projects analyzed in this research. Table 7 lists the MAJCOMs that will be used within this study to analyze project delivery method performance.

Table 7 - Air Force Major Commands (MAJCOM)

MAJCOM Designation	Formal Title
ACC	Air Combat Command
AETC	Air Education and Training Command
AMC	Air Mobility Command
AFMC	Air Force Material Command
AFGSC	Air Force Global Strike Command
AFSOC	Air Force Special Operations Command
AFSPC	Air Force Space Command
PACAF	Pacific Air Forces

Statistical Analysis

Finally, statistical tests were conducted to determine if these performance metrics were significantly different from other projects within the same delivery system over time. This study used a statistical comparison between the eight response variables and the previously mentioned three independent variables. The Air Force MILCON data were analyzed using Tukey's Honest Significant Difference (HSD) test, the Student's t-test for unequal variance, Levine's test for sample homogeneity of variance, and Shapiro-Wilk's test for normality.

Use of Tukey's HSD test requires the following three assumptions to be met: 1) the sample should be randomly selected or by means of a convenient random sampling, 2) the dependent variables should be normally distributed, and 3) the variances between the two groups should be equal (Levine et al., 2007). A precondition test for the Tukey HSD test is the homogeneity of variance between compared groups, which is measured by Levine's test. If the significance of a Levine's test is less than 0.05, the variance between groups is said to be significantly different and Tukey's test cannot be used. Shapiro-Wilk's test determines the normality of statistically compared groupings by applying a "goodness of fit" curve to their distributions. Data with a Shapiro-Wilk's significance value of less than 0.5 is said to be non-normal. If either test violates the assumptions of the Tukey HSD test, a Student's t-test must be used to compare the means between two samples of unequal variances or non-normal distributions (Levine et al., 2007).

If, however, all assumptions are maintained, Tukey's HSD test can be used to compare the means of each pair. Tukey's HSD test is a single-step multiple comparison procedure for comparing the means across multiple samples. It is very similar to Student's t-test, but it corrects for family-wise error rates, or the errors resulting from false positives when comparing the means between two samples. For this reason, Tukey's test is considered superior to the Student's t-test of each pair which does not correct for the increased chance of type I error associated with multiple comparisons (Levine et al., 2007). While this study will primarily attempted to use Tukey's HSD test, either procedure will provide a means comparison with varying levels of confidence.

Each of the previously discussed statistical tests were conducted using the JMP® statistical software package courtesy of the Suite of Analytics Software (SAS) Institute. ACES-PM data collected from a Microsoft Excel report were entered into JMP® and analyzed to draw statistical conclusions for this study.

Study Hypotheses

The investigative questions focus on the time-based performance of each Air Force project delivery strategy using previously introduced cost, schedule, and change order project measures. However, this study also included performance comparisons with respect to facility type and MAJCOM. Individual time-based performance characteristics were compared using eight specific project measures (dependent response variables) across FY groups, facility categories, and MAJCOM categories. Throughout each comparison, the null hypothesis always assumes that the means of the two groups are equal. Additionally, except for project duration, no direct performance comparisons were made between project delivery methods. Only performance comparisons within each delivery method will be examined.

Study Significance Levels

The level of significance in statistical research is designated by the character, α, and is used to represent the Type I error of the null hypothesis being incorrectly rejected (Levine et al., 2007). In each of the two means comparison tests, a test static produces an observed level of significance for a specific comparison. This level of significance, or p-value, is compared to the α selected at the beginning of the study. If the p-value is less than the determined α, the null hypothesis is rejected and the means between two groups are considered statistically different. An α of 0.05 was selected for this study to remain consistent with other related industry studies. Therefore, for the purposes of this research, any one-tailed test statistic that produces a p-value of less than 0.05 will reject the corresponding null hypothesis and be considered statistically significant.

Summary

This chapter presented the method used to aggregate a list of industry-proven key performance indicators that can be used to benefit Air Force project managers. Detailed descriptions of these performance indicators were made so that parallels could be drawn between these and similar measures currently tracked by the AFCEC. Additionally, this chapter discussed the statistical approach used to analyze the performance of each Air Force MILCON project delivery method over time using applicable cost, schedule, and change order project data from the ACES-PM database and a selection of fiscal year groupings. Additional comparisons were made between individual delivery method performances in these measures against facility type and MAJCOM groupings.

Chapter IV, the Results section, will present, analyze, and discuss the data to test the research hypotheses and answer the research questions.

IV. Analysis and Results

This chapter begins by presenting a list of key performance indicators recommended for use by Air Force project managers. This list is extracted from the larger group of industry-proven key performance indicators presented in Chapter III and filtered for Air Force MILCON application. Raw results from the procedures described in Chapter III are also presented through the presentation of graphs, tables, and the statistical analysis of Air Force MILCON project delivery method performance using associated cost, schedule and change order project data. Individual time-based delivery performance was analyzed by presenting the test results of each statistical comparison of year groupings with each of the following eight performance measures: cost growth, CWE/PA ratio, schedule growth, unit cost, modifications per million dollars of project scope, project duration, construction speed, and delivery speed. Similarly, the comparative results between each of these measures and Air Force facility types are also examined. Finally, this chapter also includes the analysis of resulting comparisons between the eight performance measures across MAJCOM groupings. Complete tables used to summarize this study's statistical analysis are provided in Appendices A-AQ.

Key Performance Indicators for Air Force Application

Chapter III discussed the process used to aggregate a list of industry-proven performance measures base on an extensive literature review. Table 8 illustrates a comprehensive view of aggregated industry-proven key performance indicators.

Table 8 - Industry-Proven Key Performance Indicators (KPI)

	SUCCESS CRITERIA:	BUDGET				SCHEDULE						QUALITY (OBJECTIVE)				QUALITY (SUBJECTIVE)				
	KEY PERFORMANCE INDICATORS	Cost Growth (%)	Unit Cost ($/SF)	Award Growth (% or Ratio)	Intensity ($/SM/Months)	Schedule Growth (%)	Construction Speed (SF/Month)	Delivery Speed (SF/Month)	Total Project Duration (Days)	Construction Duration (Days)	Design Duration (Days)	Modifications per Million Dollars of Scope (Qty/$M)	Modifications Due to Deficiencies (%)	O&M Costs	# of Call-Backs	Facility Start-up Quality	System Quality	Process Equipment Quality	Owner Satisfaction	Owner's Administrative Burden
PAST PUBLIC-SECTOR RESEARCH	Konchar & Sanvido (1998)	X	X		X	X	X	X							X	X	X	X		
	Moore (1998)	X	X			X	X	X						X	X	X	X	X		X
	Molenaar et al. (1999)	X				X													X	X
	Chan et al. (2002)	X	X	X	X	X													X	
	CII & NIST (2002)	X		X		X			X	X	X									
	Ibbs et al. (2003)	X				X														X
	Ling et. Al. (2004)	X	X		X	X	X	X					X		X	X	X	X	X	
	El Wardani et al. (2006)	X	X		X	X	X	X												
	Debella & Ries (2006)	X	X			X	X	X												
	US DOT FHWA (2006)	X	X	X		X			X										X	X
	McWhirt (2007)	X	X	X	X	X														
	Mostafavi & Karamouz (2010)	X	X		X	X														
	Fernane (2011)	X	X	X	X	X	X	X				X								
	Shrestha et al. (2012)	X	X	X		X	X	X								X				
	Goftar et al. (2014)~	X	X			X		X												X
	Hanna (2016)	X	X		X	X	X	X				X	X		X		X		X	X
PAST MILCON RESEARCH	Mouritsen (1993)	X							X											
	Roth (1995)	X	X									X								
	Pocock (1996)	X				X						X	X							
	Webster (1997)	X				X						X	X							
	Allen (2001)	X				X								X	X	X	X	X		X
	Garner et al. (2008)	X				X														
	Rosner et al. (2009)	X	X	X		X	X		X	X		X								
	Hale et al. (2009)	X	X			X	X		X	X										

~Meta-Analysis of Literature Review Comparing DB vs DBB in Performance Measures

The primary goal in the development of this list was to identify key measures as framework components that will enable the Air Force to effectively compare the relative performance of its MILCON project delivery methods. Ultimately, universal performance measures utilized across the private and public sectors of the construction industry serve as highly impactful factors that affect project success. These factors must be studied by the Air Force to improve its project delivery business practices in the MILCON arena.

While the Air Force's recognition of some of these performance indicators can be seen in the establishment of certain Ribbon Cutter goals, very few of these measures are effectively used to analyze Air Force MILCON project delivery performance. Limitations associated with the ACES-PM database inhibit a project manager's ability to compare and select the most effective project delivery system. The following sections describe how each of the eight recommended key performance indicators will improve the ability of Air Force project managers to analyze MILCON project delivery performance.

Cost Growth

While cost growth is already recognized as a performance indicator in MILCON projects, the Air Force must ensure all costs associated with modifications from both the design and construction phases of a project are distinctly tracked in ACES-PM. Currently, Air Force project managers are only able to analyze costs associated with the construction phase of a project, as the data fields in ACES-PM fail to capture costs associated with design modifications. To fully benefit from the use of the cost growth performance measure, modification costs associated with each phase of the construction project must be specifically tracked to provide a basis for equivalent comparisons of project delivery performance.

Unit Cost

Unit cost is not a metric that is universally tracked in the Air Force's project database. However, experts in the construction industry have identified unit cost as a key measure to analyze project performance. This study encourages the Air Force to incorporate unit cost as a specific field in the ACES-PM database. Specifically tracking a project's unit cost will provide a basis for Air Force project managers to identify unique performance trends associated with certain project facility types and delivery method selection.

Award Growth

The AFCEC Integration Cell directs Air Force project managers to track the CWE/PA ratio of each project. This metric is considered a key metric in the Ribbon Cutter Criteria because it provides a real-time status of a project's expected budget with respect to congressional appropriation levels. While useful in MILCON project management, the CWE/PA ratio reflects a project planner's cost estimating ability more than it provides useful information about contract cost growth. By specifically relating original contract cost details to final engineering estimates, Air Force project managers will be able to asses which project delivery method performs better in specific bidding locations and environments. It is recommended that the Air Force begin tracking award growth within ACES-PM so that each project delivery method can be analyzed with respect to contract growth performance.

Project Duration

The construction timeline of a MILCON project is currently emphasized as a key performance metric in the Air Force's Ribbon Cutter Criteria. However, because ACES-PM calculates the construction timeline based on the difference between the NTP and BOD dates, both design and construction activities are included in this analysis for design-build projects, while only construction activities are included in this metric for traditionally delivered projects. This creates an inability for project managers to equally compare the performance of each delivery method.

A project's overall duration provides an equivalent baseline for assessing how long it takes to deliver a project from the first design activity to owner occupancy. The milestones used to calculate project duration are already tracked in ACES-PM (Date Design Instruction (DI) is sent to Agent and BOD). Therefore, it is recommended that the AFCEC begin tracking this new measure in its MILCON program.

Schedule Growth

Air Force project managers have already adopted schedule growth as an important performance indicator to monitor throughout its MILCON program. However, the previously identified limitations with the NTP data field in ACES-PM do not allow for equivalent comparison of delivery method performance using this metric. Therefore, it is recommended that project managers maintain higher degrees of communication with design-build contractors to identify specific design completion and construction start milestones. By tracking the initiation and completion of specific design and construction activities, project managers will be able to make an equivalent comparisons of schedule growth between delivery methods.

Delivery Speed

The Air Force Ribbon Cutter currently recognizes construction speed as a critical measure for determining project success. This measure represents the relationship between project scope and the amount of time it takes to construct the facility. However, because no distinction is made in ACES-PM between design and construction activities for design-build projects, design-bid-build projects are given an unfair advantage using this metric. Therefore, instead of tracking a project's construction speed, it is recommended that Air Force project managers track the total amount of design and construction time it takes to deliver a unit of project scope (project scope divided by overall project duration). This will provide an equivalent basis for comparing project delivery method performance.

Modifications

The construction industry has recognized the importance of monitoring the effects of contract modifications on a construction project. However, Air Force project managers do not directly measure the impact of unplanned changes on a project's performance. Using two key measures commonly identified in the construction industry, it is recommended that Air Force project managers begin separately monitoring costs of change orders that negatively impact a project's budget. This will provide means for monitoring the number of detrimental change orders per million dollars of project scope and will also allow a project delivery team to actively monitor the number of modifications that are caused by design deficiencies. Air Force project managers will be able to identify which delivery method achieves the most desirable change order performance.

Summary

Data collection is critical to the overall improvement of Air Force business practices, and is especially applicable to Air Force project management program. In order for many of these key performance indicators to be effectively used by Air Force project managers to improve project delivery, the proper data must be adequately tracked in ACES-PM. This study recommends that the Air Force use the following eight key performance indicators when analyzing the relative performance of project delivery methods: cost growth, unit cost, award growth, project duration, schedule growth, delivery speed, modifications per million dollars of unit scope, and percent modifications due to design deficiencies. While some of these indicators are currently used to analyze project delivery method performance for Air Force MILCON projects, limitations with the ACES-PM database will not allow for true equivalent comparisons to be made. It is recommended that the Air Force consider tracking additional project characteristics and milestones as data fields that are unique to each type of delivery method. This will allow for more accurate and useful analyses to be made as Air Force project managers seek to improve future project delivery performance

General Observations

A raw set of Air Force MILCON project data from FY 2003 to 2018 was initially extracted from the ACES-PM module and transferred into a Microsoft Excel spreadsheet. General observations related to Air Force MILCON project delivery use were noted and then compared to those identified in the previous research effort. Figure 4 illustrates the percent delivery method use within Air Force MILCON projects ranging from FY 1990 to 2009. This figure was adopted from the previous study conducted by Rosner et al. (2009) indicating the use of the design-build project delivery method rapidly increased after the Clinger-Cohen Act of 1996 authorized the unrestricted used of design-build for MILCON projects. At the time of their study, Rosner et al. (2009) predicted the continual increased used of design-build project delivery in the MILCON sector.

In comparison, Figure 5 illustrates the percent delivery method use within Air Force MILCON projects ranging from FY 2003 to 2015. The overall increased trend in design-build project delivery from FY 2004 to 2012 generally matches that which was observed in the 2008 study (Rosner et al., 2009). However, since FY 2013, the majority delivery approach has fluctuated, experiencing up to 33% change for each method. If the goals expressed within Air Force Ribbon Cutter Criteria remain the target for future Air Force MILCON execution, it is anticipated that the use of design-build will continue to steadily increase in the following years.

Figure 4 - MILCON Delivery Method Use (FY1990-2009) (adopted from Rosner, 2008)

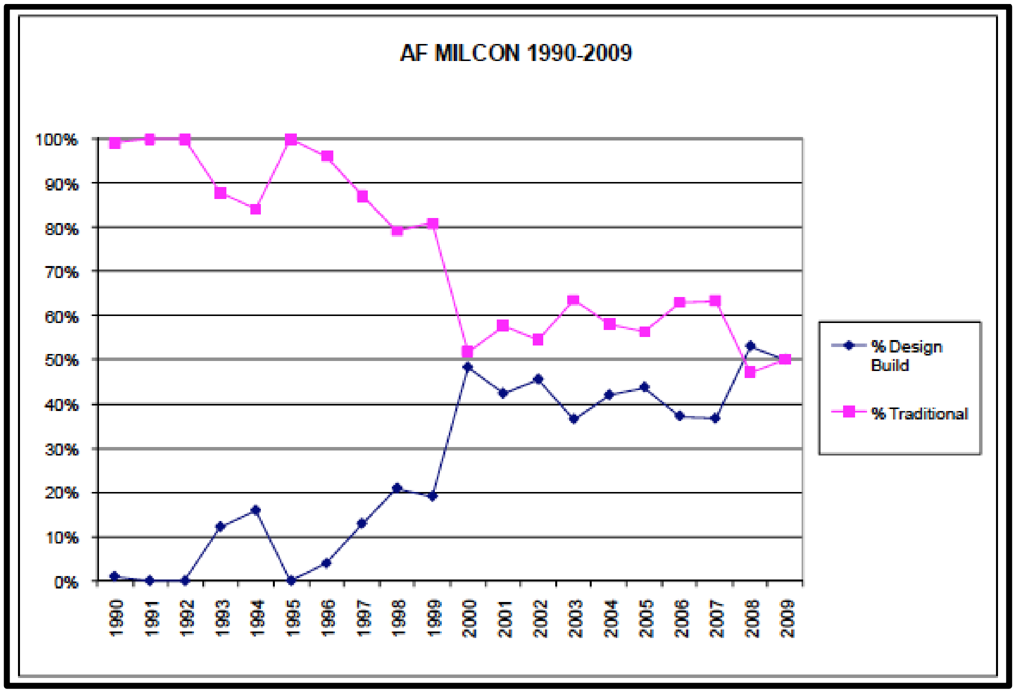
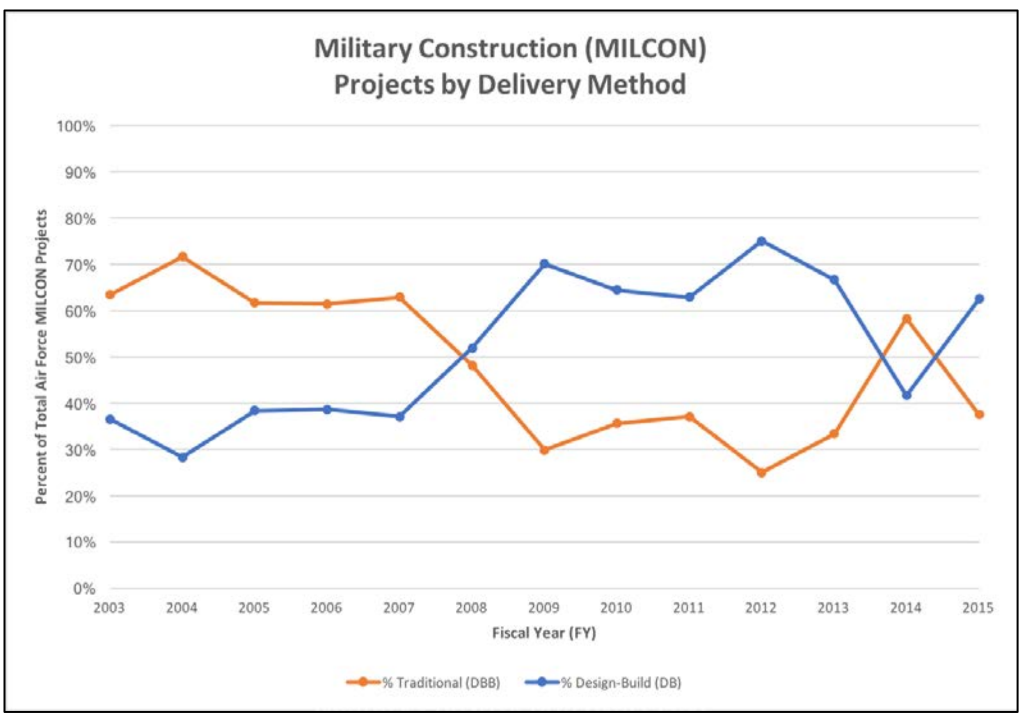


Figure 5 - Air Force MILCON Delivery Method Use (FY 2003-2015)



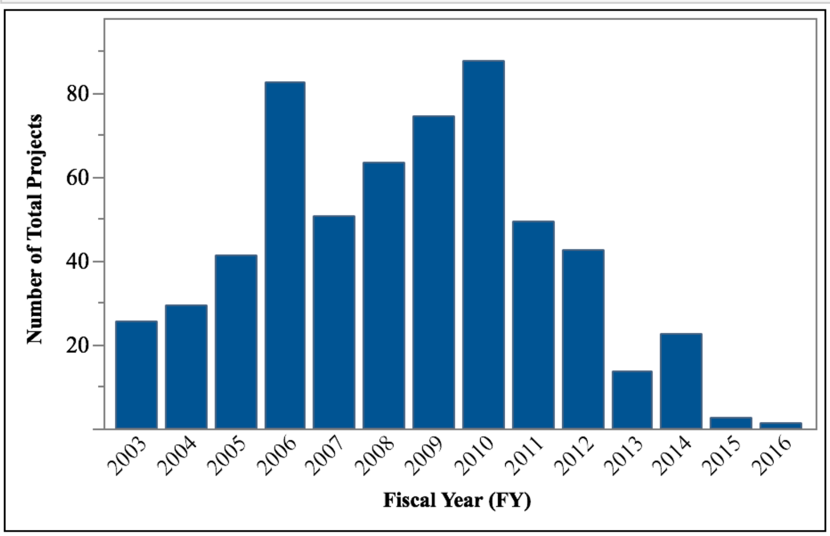
Overall Data Description

The raw ACES-PM data was then refined using the project selection criteria discussed in Chapter III as preparation for subsequent statistical procedures. Filters for project type, construction completion percentage, minimum MILCON funding thresholds, fiscal year range, and overseas locations were implemented to prepare the data in accordance with the study's methodology. After refinement, a total number of 580 projects met the required analysis criteria. This total consisted of 264 (45.5%) design-bid-build projects and 316 (54.4%) design-build projects. The total distribution of Air Force MILCON projects over time is depicted in Figure 6.

Figure 6 - Total Number of Air Force MILCON Projects by Fiscal Year

Distributions

Fiscal Year (FY)



Frequencies

Level	*Count*	*Prob*
2003	25	0.04310
2004	29	0.05000
2005	41	0.07069
2006	82	0.14138
2007	50	0.08621
2008	63	0.10862
2009	74	0.12759
2010	87	0.15000
2011	49	0.08448
2012	42	0.07241
2013	13	0.02241
2014	22	0.03793
2015	2	0.00345
2016	1	0.00172
Total	580	1.00000

N Missing 0
14 Levels

Upon initial inspection of this total project distribution, it was determined that the three projects occurring in FY15-16 would be removed due to the lack of overall sample size in the FY15-16 category. Therefore, all fiscal year statistical comparisons were made using six major fiscal year groupings: FY03-04, FY05-06, FY07-08, FY09-10, FY11-12 and FY13-14.

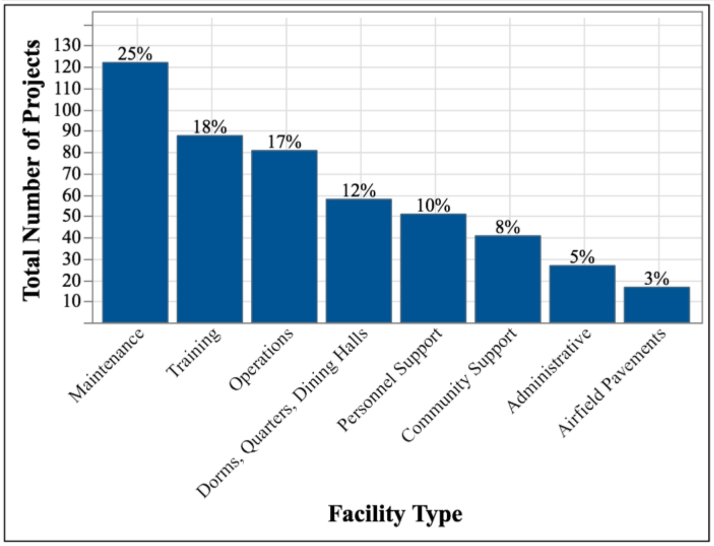
As discussed previously in Chapter III, the complete list of 19 facility types was narrowed down to the top eight most frequently constructed facilities between both delivery methods during FY 2003-2014. This filtering was intended to establish a minimum number of instances that each delivery method executed each facility type. After studying the overall facility type distributions, the lower frequency threshold of 15 instances was selected, which limited the overall study to the following eight most frequently constructed facility types: maintenance; operations; training; personnel support; administrative; community support; dormitories, officer quarters, and dining halls; and airfield pavements. The total distribution of Air Force MILCON projects by facility type is depicted in Figure 7.

A similar refinement of project data occurred when the MAJCOM groupings were statistically prepared. As previously discussed, the eight most prominent MAJCOMs in delivery method use were determined using a minimum threshold of five projects executed for each method. The total distribution of Air Force MILCON projects by MAJCOM is depicted in Figure 8.

Figure 7 - Total Number of Air Force MILCON Projects by Facility Type

Distributions

Facility Type



Frequencies

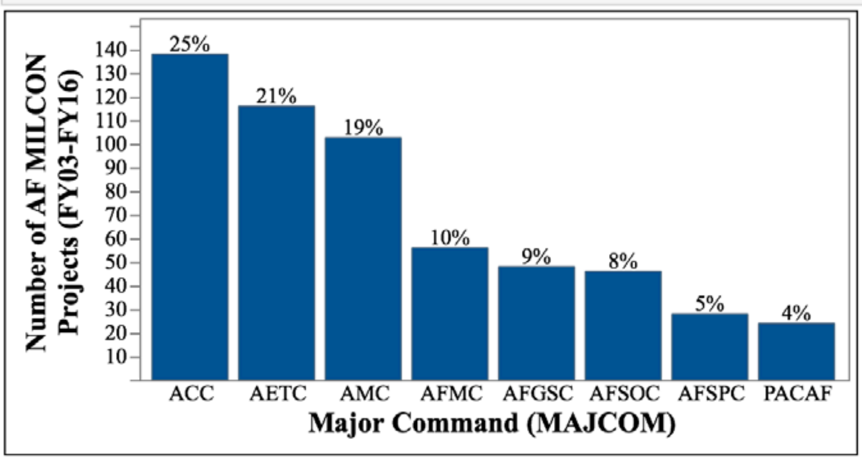
Level	*Count*	*Prob*
Maintenance	121	0.25367
Training	87	0.18239
Operations	80	0.16771
Dorms, Quarters, Dining Halls	57	0.11950
Personnel Support	50	0.10482
Community Support	40	0.08386
Administrative	26	0.05451
Airfield Pavements	16	0.03354
Total	477	1.00000

N Missing 103
8 Levels

Figure 8 - Total Number of Air Force MILCON Projects by MAJCOM

Distributions

MAJCOM



Frequencies

Level	*Count*	*Prob*
ACC	137	0.24864
AETC	115	0.20871
AMC	102	0.18512
AFMC	55	0.09982
AFGSC	47	0.08530
AFSOC	45	0.08167
AFSPC	27	0.04900
PACAF	23	0.04174
Total	551	1.00000

N Missing 29
8 Levels

Performance Metric Analyses

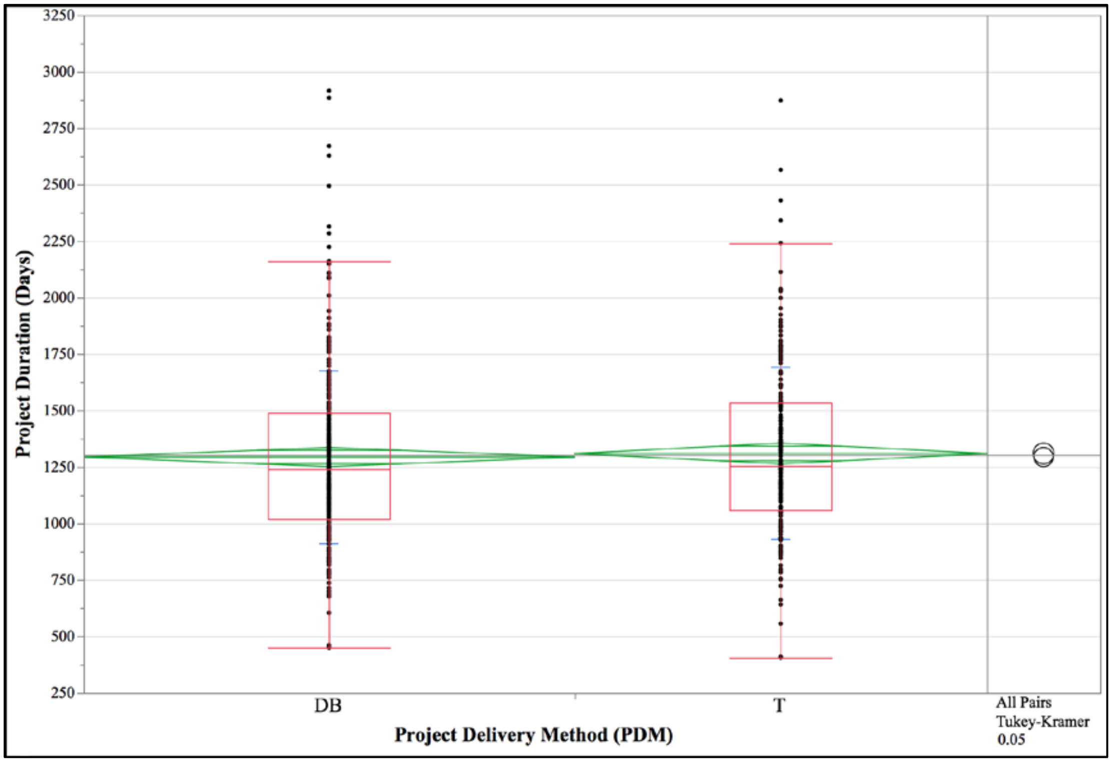
After general observations and final data refinements were made, each performance measure was statistically measured across FY groupings, facility types and MAJCOM categories to determine if a significant difference in means existed amongst each of these performance measures. As outlined in the methodology, significant differences in means were defined by a p-value of less than 0.05. Ultimately, the p-value indicates the level at which the null hypothesis of equivalent means is rejected.

The impacts from fiscal year, facility type, and MAJCOM on cost growth performance were determined using statistical analysis of the JMP® software reports. The first step for each analysis was to determine the most appropriate method of statistical comparison by testing for normality and variance homogeneity. All sample distributions were examined for normality using the Shapiro-Wilks goodness of fit test. Levine's test was then used to determine whether variances between groups were significantly different. If each grouping was determined to be normal with homogenous variances, Tukey's HSD test was used for the means comparison within the performance measure. Sample groupings that failed either, or both initial tests were analyzed using Student's t-test for pairwise comparison. The following sections detail the findings for the Air Force's historical use of each delivery method with respect to each performance measure. Complete statistical results for each of the following tests can be found in Appendices A-AQ.

Project Duration Analysis

As discussed in Chapter III, the milestones used to calculate a project's overall design and construction activity duration are common to both design-build and design-bid-build projects. Therefore, a direct comparison of mean project durations was conducted to determine which delivery method performed better using this metric. After removing two outlier projects with missing data in the NTP field of ACES-PM, a total of 314 design-build and 264 design-bid-build projects were compared using this measure. As seen in Figure 9 the overall direct comparison of mean project durations between delivery methods yielded insignificant results. The average project duration for design-bid-build projects (1,309 days) was only 16 days longer than the average design-build project duration (1,293 days). Ultimately these results indicate that despite which delivery method is chosen to execute MILCON projects, there is no significant difference in the average duration between initial design instruction issuance to beneficial occupancy.

Figure 9 - Project Duration By Project Delivery Method



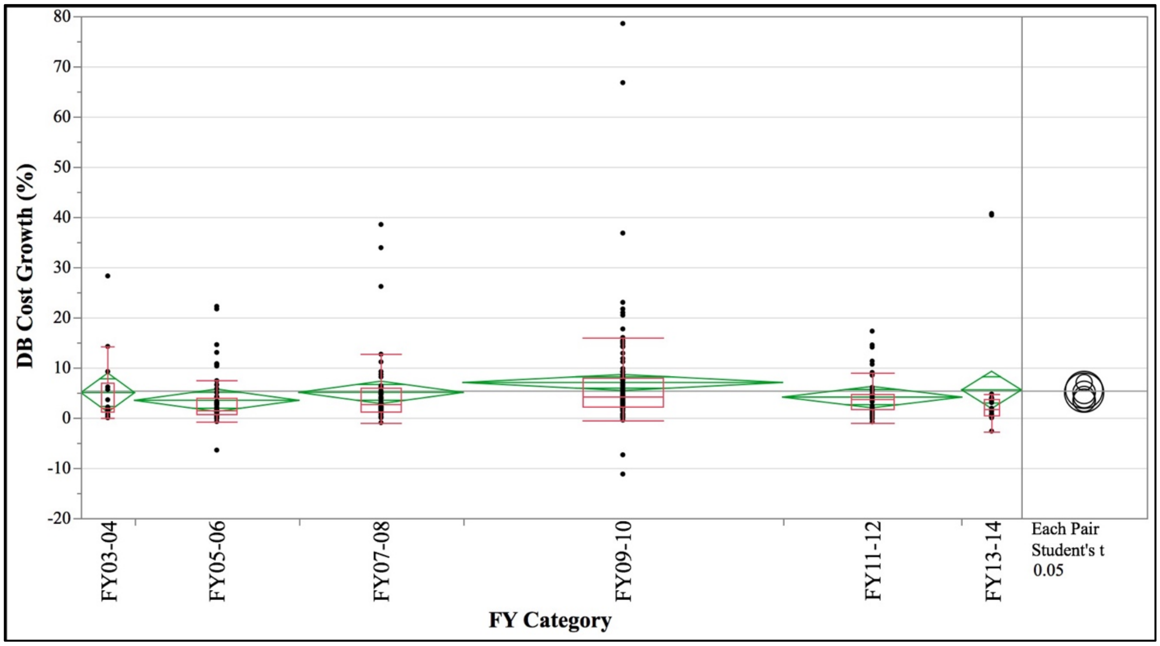
Delivery Method Performance Over Time

Cost Growth

<u>Design-Build (DB) Cost Growth Results</u>

After Levine's test identified unequal variances across sample groups, Student's t-test was used to compare cost growth means for 315 design-build projects across fiscal year categories. The mean percent cost growth for design-build projects in the FY09-10 category was found to be 7.03%, which was significantly higher than the cost growth means of 3.48% experienced in FY05-06 (p-value = 0.0115) and 4.11% experienced in FY11-12 (p-value = 0.0327). No other significant differences in design-build cost growths were found between fiscal year categories. Aside from the FY05-06 year grouping, overall results indicate consistent cost growth performance in the Air Force's use of design-build over time. Results of this analysis are displayed in Figure 10.

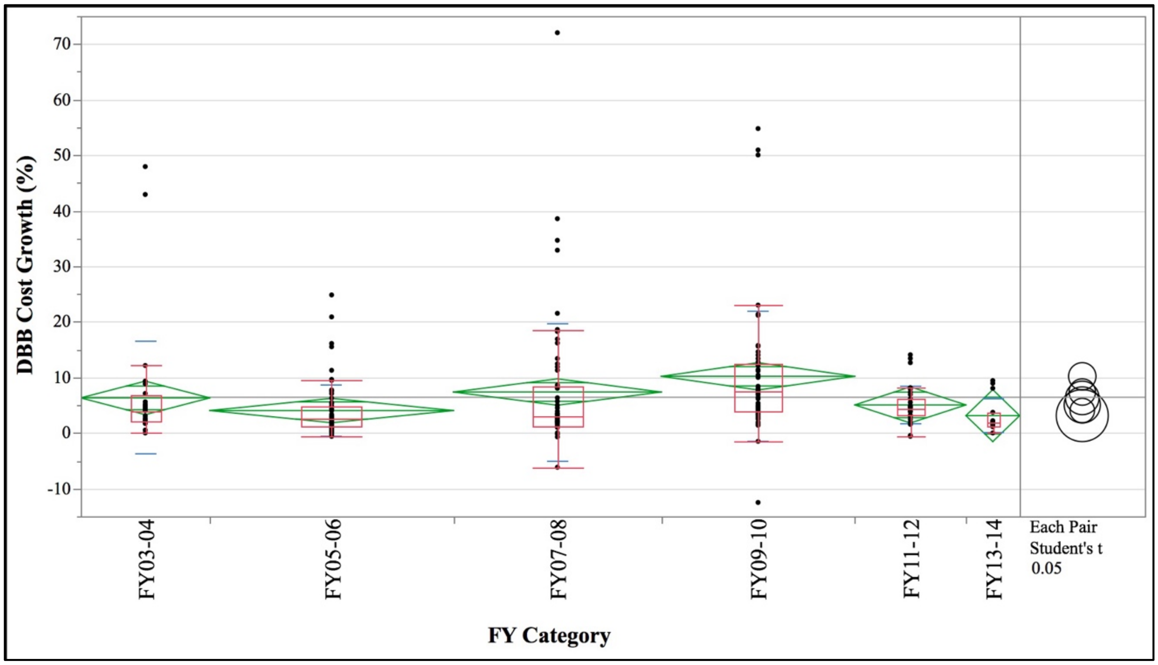
Figure 10 - Design-Build (DB) Cost Growth (%) by FY Category



Design-Bid-Build (DBB) Cost Growth Results

After the identification of unequal variances across fiscal year groups, means comparisons within each pair of year groupings were conducted using the Student's t-test method. Overall, 262 design-bid-build projects were included in this analysis, after the removal of two extreme outliers. A noticeable increase in mean traditional cost growths was found between FY05-06 (4.03%) and FY07-08 (7.37%) at a significance level of 0.0434. Similarly, the increase of mean cost growths between FY05-06 and FY09-10 (10.19%) was significant, yielding a p-value of 0.0003. However, after FY09-10, decreases in means were found in FY11-12 (5.04%) and FY13-14 (3.12%). The findings were found to be significant at p-values of 0.0135 and 0.0089 respectively. While the Air Force certainly experienced increased cost growth in traditionally delivered projects in FY09-10, its performance improved at a significant level in the following years.

Figure 11 - Design-Bid-Build (DBB) Cost Growth (%) by FY Category

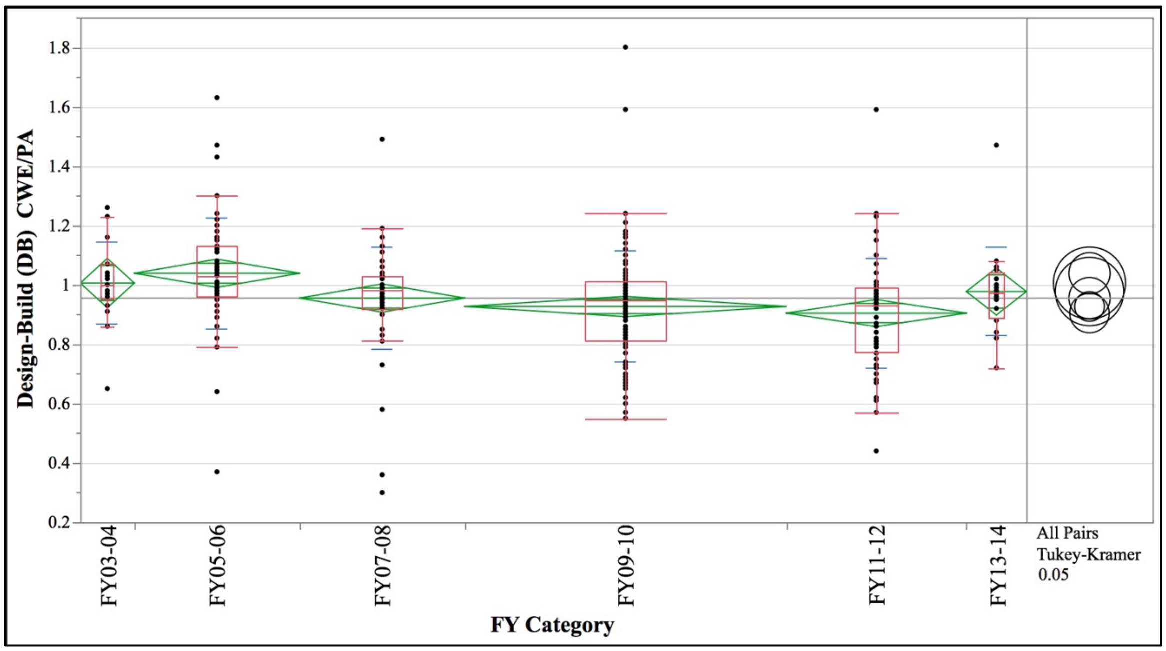


CWE/PA Ratio

<u>Design-Build (DB) CWE/PA Ratio Results</u>

Upon initial testing for variances between year groupings, Tukey's HSD test was used to compare the means of 315 design-build projects across the six year groups. Figure 12 illustrates these findings. A significant average CWE/PA ratio decrease occurred between from FY05-06 (1.04) and FY09-10 (0.93) with a p-value of 0.0028. Likewise, a similar decrease in average CWE/PA ratio was identified between FY05-06 and FY11-12 (0.90) at a significance level of 0.0011. The Ribbon Cutter Criteria challenges Air Force program managers to maintain a CWE/PA ration of 0.97 or less (Air Force Civil Engineer Center Integration Cell, 2015). Correspondingly, the Air Force experienced an overall improvement in CWE/PA Ratio performance over time as the average FY07-08, FY09-10 and FY11-12 CWE/PA values decreased from FY05-06.

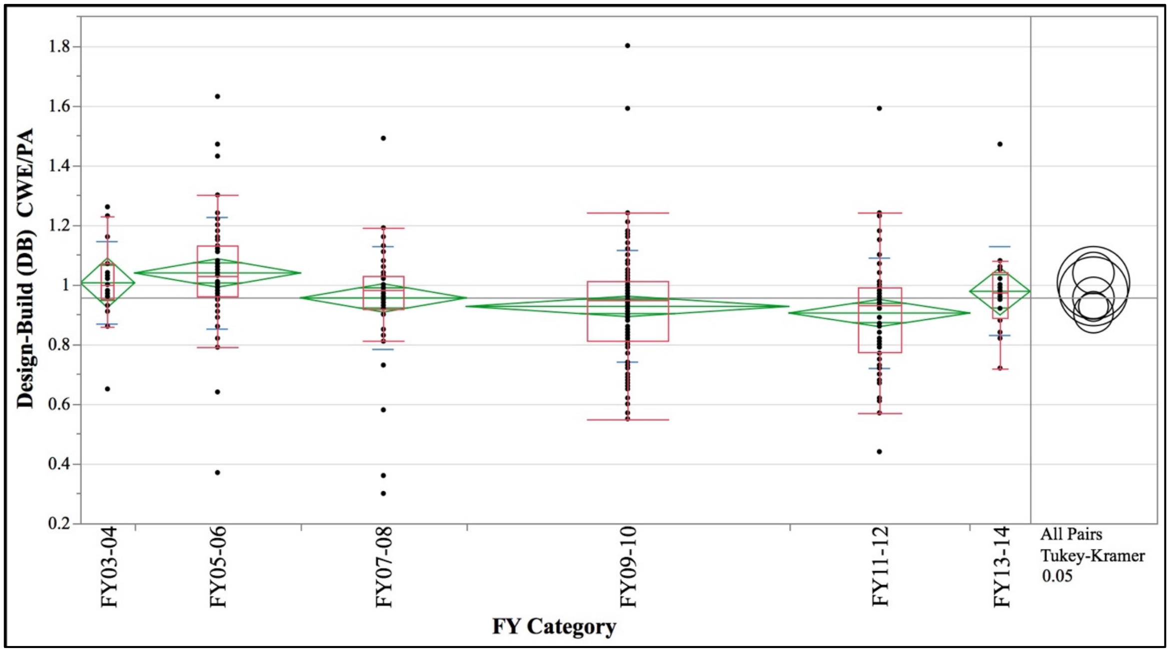
Figure 12 - Design-Build (DB) CWE/PA Ratios by FY Category



Design-Bid-Build (DBB) CWE/PA Ratio Results

Average CWE/PA ratios of 262 traditionally delivered MILCON projects were compared across fiscal year categories using Tukey's HSD test. A trend similar to that seen in design-build projects was observed in comparisons of design-bid-build projects over time. Figure 13 displays these findings.

Figure 13 - Design-Bid-Build (DBB) CWE/PA Ratios by FY Category



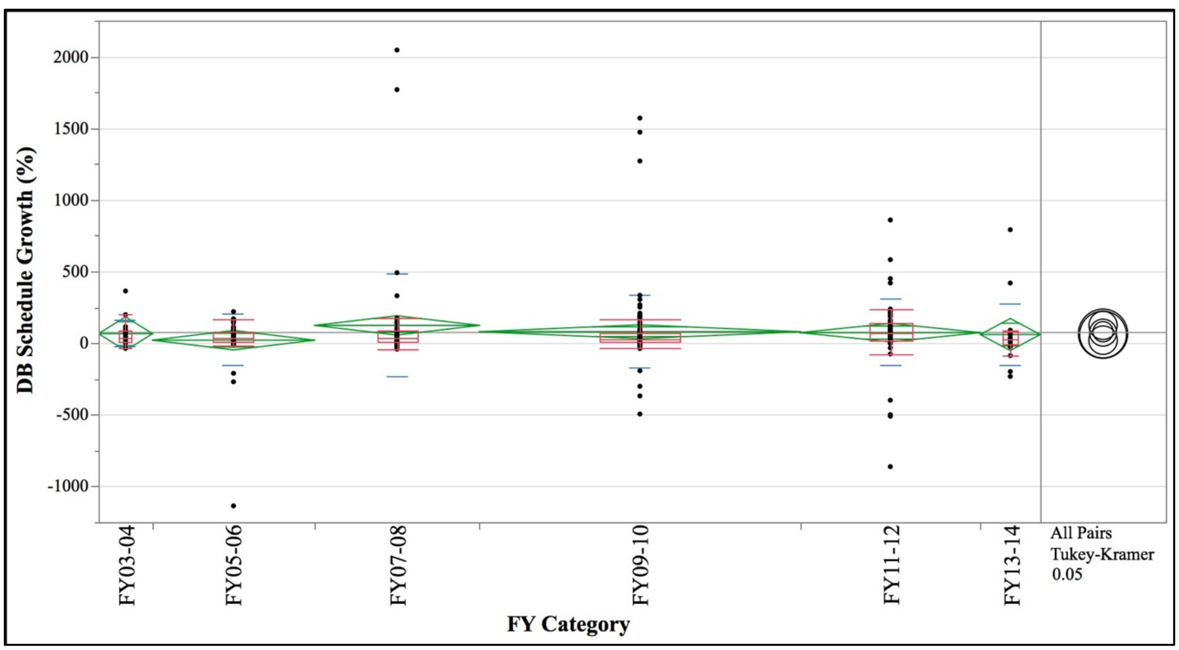
A significant decrease in CWE/PA ratio means occurred between FY05-06 (1.02) and FY09-10 (0.89) with a p-value below 0.0001. Another mean CWE/PA value of 0.89 was also observed in FY11-12, again marking a significant difference in means when compared to FY05-06 (p-value = 0.0017). While this decrease in mean CWE/PA values initially appeared to mark an improvement in performance after FY05-06, a significant increase in mean values was then found within FY13-14 (1.03). This marks a significant increase when compared to the mean of 0.89 in FY09-10 (p-value = 0.0302). The significant fluctuations in these values over time makes it difficult to provide an overall determination of CWE/PA performance trends in traditional design-bid-build projects. This performance metric will be further explored across facility types and MAJCOMs later in this chapter.

Schedule Growth

<u>Design-Build (DB) Schedule Growth Results</u>

A schedule growth analysis for the same sample of design-build projects was conducted using the Tukey's HSD test for groups of equal variances. These projects experienced the highest mean level of schedule growth in FY07-08 at 123% while the mean schedule growth during other year groups ranged from 20.5% in FY03-04 to 79.4% in FY09-10. However, despite this range in average values, no significant differences were found when comparing each pair of year groups for design-build schedule growth. Figure 14 depicts these results. The overall mean performance across the combined year groups leveled off around 60%, which ultimately indicates consistent schedule growth performance in the Air Force's design-build projects.

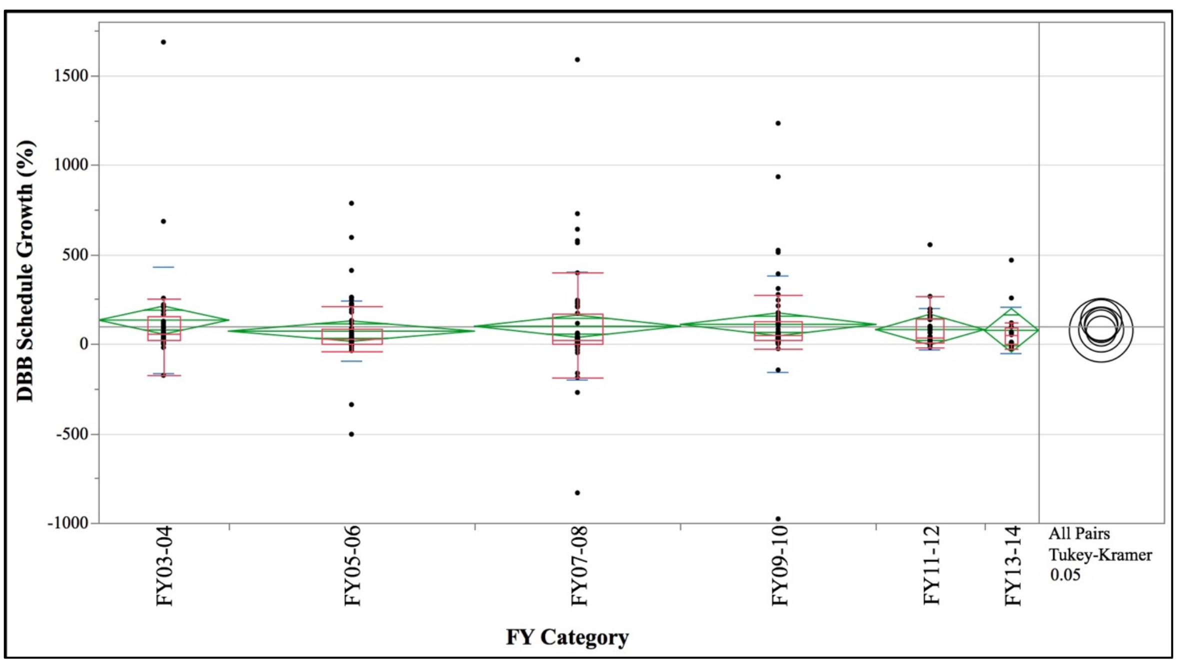
Figure 14 - Design-Build (DB) Schedule Growth (%) by FY Category



Design-Bid-Build (DBB) Schedule Growth Results

Tukey's HSD test was also used to compare mean schedule growths between different year groups for traditionally delivered projects. While these values ranged from 71.1% in FY05-06 to 132.6% in FY03-04, no pairwise comparison was found to be statistically significant. Two project were removed as outliers in this analysis due to incomplete information in the NTP field of ACES-PM. Figure 15 reflects this consistency in mean schedule growths between FY03-14. The Air Force's schedule growth performance has been consistent over time using both types of delivery methods. Further conclusions will be drawn from these findings in Chapter V.

Figure 15 - Design-Bid-Build (DBB) Schedule Growth (%) by FY Category

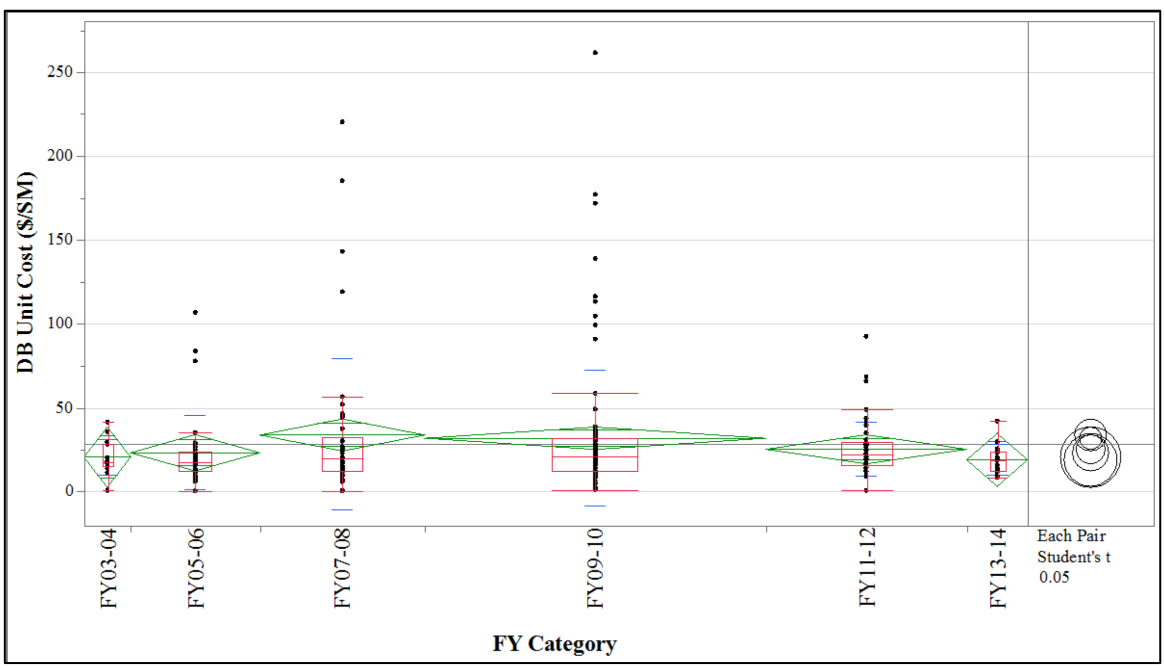


Unit Cost

<u>Design-Build (DB) Unit Cost Results</u>

Levine's test for homogeneity of variance resulted in significant differences between fiscal year groups when studying unit cost of design-build projects. Therefore, Student's t-test was used to compare each pair of year groups. Ultimately, only 263 design-build projects with a "SM" listing in the "units of measure" data field were analyzed for this performance measure. The mean unit costs across these groups ranged from $19.00/SM in FY13-14 to $33.80/SM in FY07-08. While FY07-08 and FY09-10 both saw, on average, slightly higher unit costs than other year groups, the results for these comparisons yielded no significant differences between design-build projects over time.

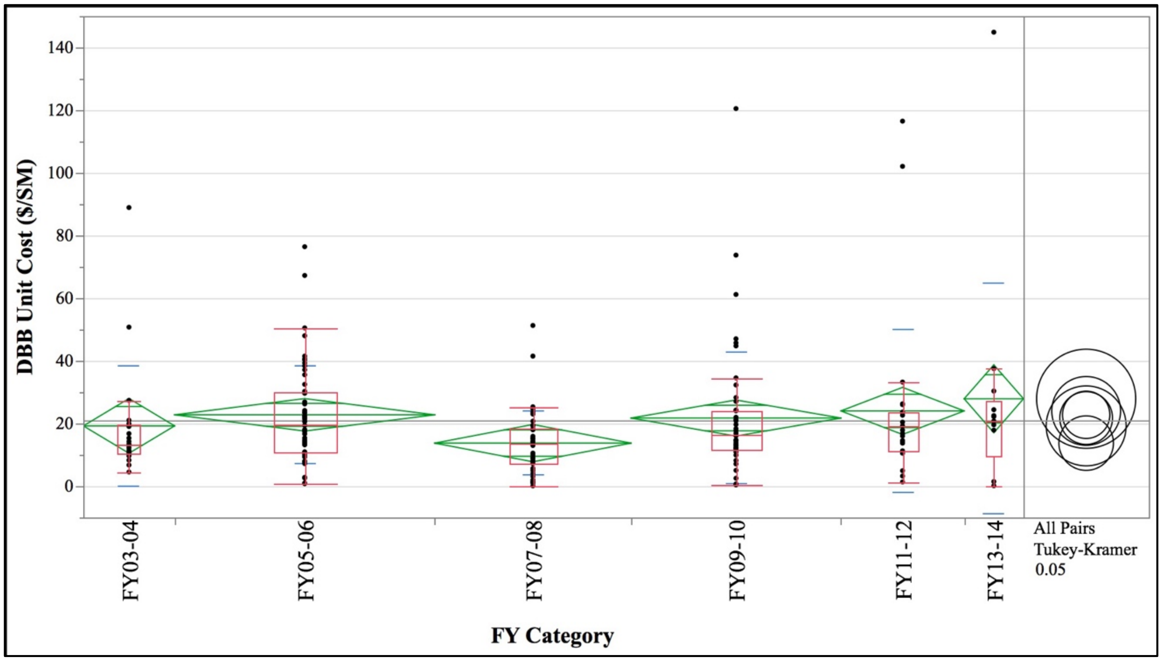
Figure 16 - Design-Build (DB) Unit Cost ($/SM) by FY Category



Design-Bid-Build (DBB) Unit Cost Results

After no significant differences in variances were determined between year groups, Tukey's HSD test was used to compare mean unit costs for 206 traditional design-bid-build projects measured in "SM." These projects experienced a similar range in unit cost over time. After FY03-04 saw a unit cost of $19.24/SM, the mean unit cost fluctuated in subsequent year groups ranging from $13.74/SM in FY07-08 to the highest unit cost experienced in FY13-14 ($27.89/SM). Despite this range, results from Tukey's comparison of all pairs resulted in no significant differences between groups. However, as depicted in Figure 17, the overall range of mean unit costs for design-bid-build projects was slightly less than the range found for design-build projects. Further analysis of unit cost will be measured across different facility types and MAJCOMs to identify any discernable differences in delivery method performance.

Figure 17 - Design-Bid-Build (DBB) Unit Cost ($/SM) by FY Category

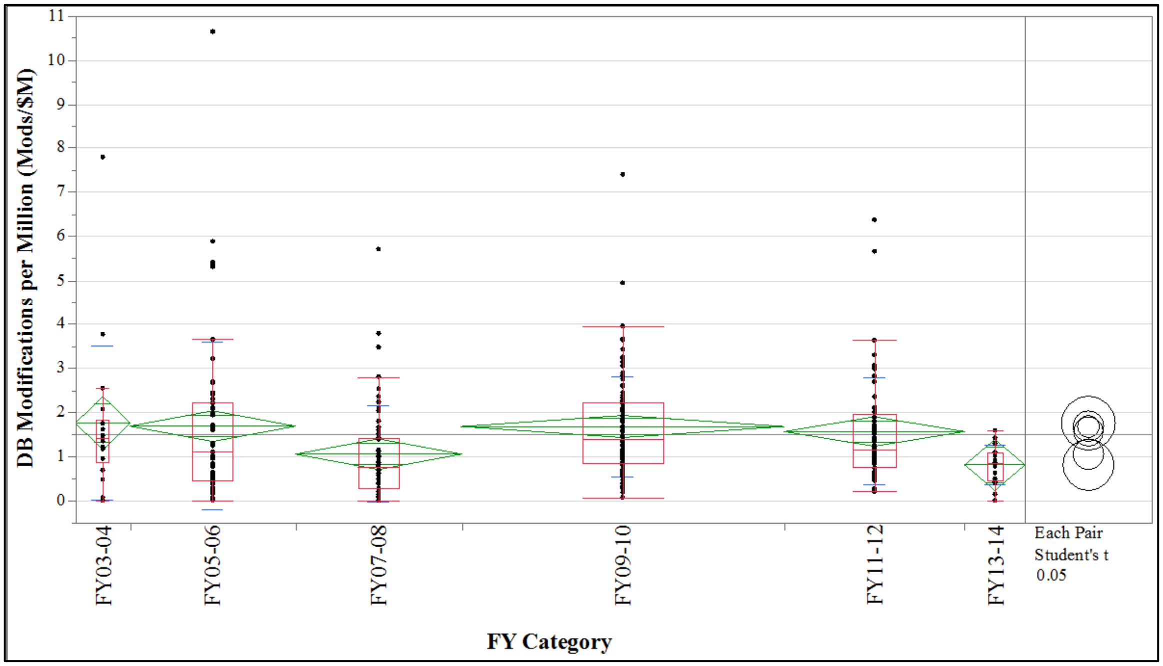


Modifications per Million Dollars

<u>Design-Build (DB) Results for Modifications per Million Dollars</u>

Significant differences in year group variances were identified using Levine's test, thus limiting comparisons of each group to Student's t-test. A total of 315 design-build projects were analyzed across the six year groups. Figure 18 summarizes the findings of this test and shows that the mean quantity of modifications per million dollars of contract cost was significantly lower in FY07-08 (1.05) and FY13-14 (0.81) compared to all other year groups. Significance levels for differences found in FY07-08 ranged from 0.0489 to 0.0043, while p-values representing similar differences between FY13-14 ranged from 0.0269 to 0.0068. While fluctuations in average modification counts over time make it difficult to identify historical trends, the Air Force's change order management performance was significantly superior in FY07-08 and FY13-14.

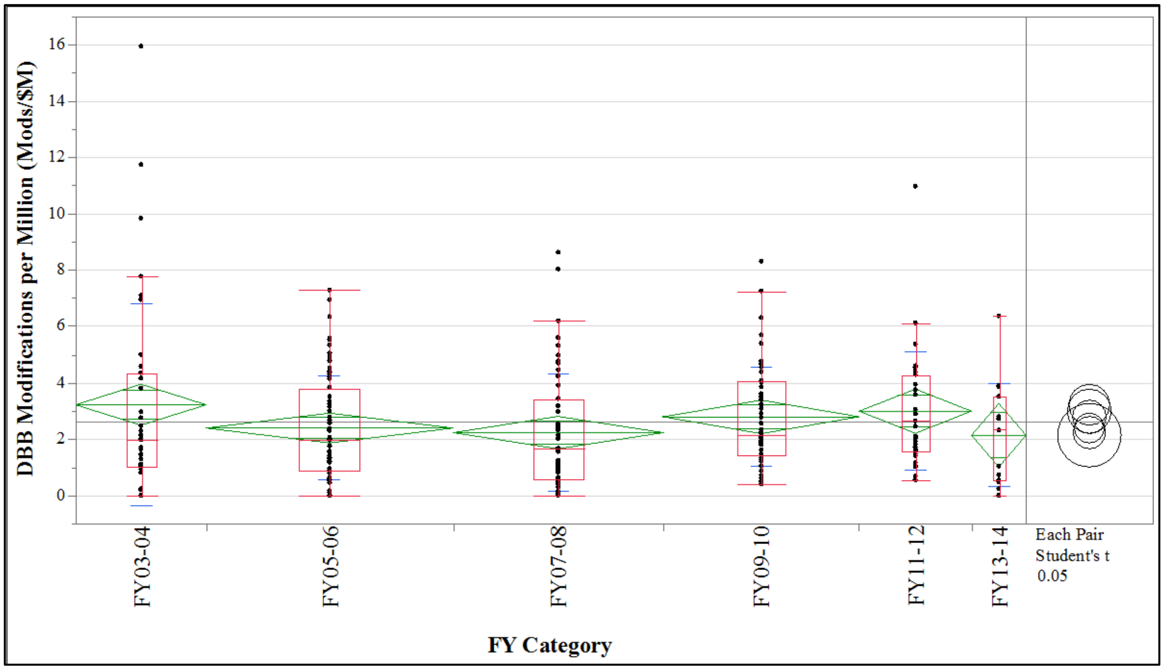
Figure 18 - Design-Build (DB) Modifications (Mods/$M) by FY Category



<u>Design-Bid-Build (DBB) Results for Modifications per Million Dollars</u>

The variances for modifications within design-bid-build projects were found to be significant. Therefore, Student's t-test was used for comparing the mean number of modifications experienced per million dollars of project scope over time. The average number of modifications per million dollars ranged from 3.21 in FY03-04 to 2.12 in FY13-14. The only significant difference in these values was found when comparing FY03-04 with an average 2.22 modifications per million dollars in FY07-08 (p-value = 0.0366). The lowest average modification count in FY13-14 was likely a result of the relatively small sample size of 15 design-build projects. It is quite possible that as more FY13-14 projects are completed, the average modification count per million dollars of project scope may increase in a manner consistent with previous years. Figure 19 depicts the change order performance results of design-bid-build projects described above.

Figure 19 - Design-Bid-Build (DBB) Modifications (Mods/$M) by FY Category



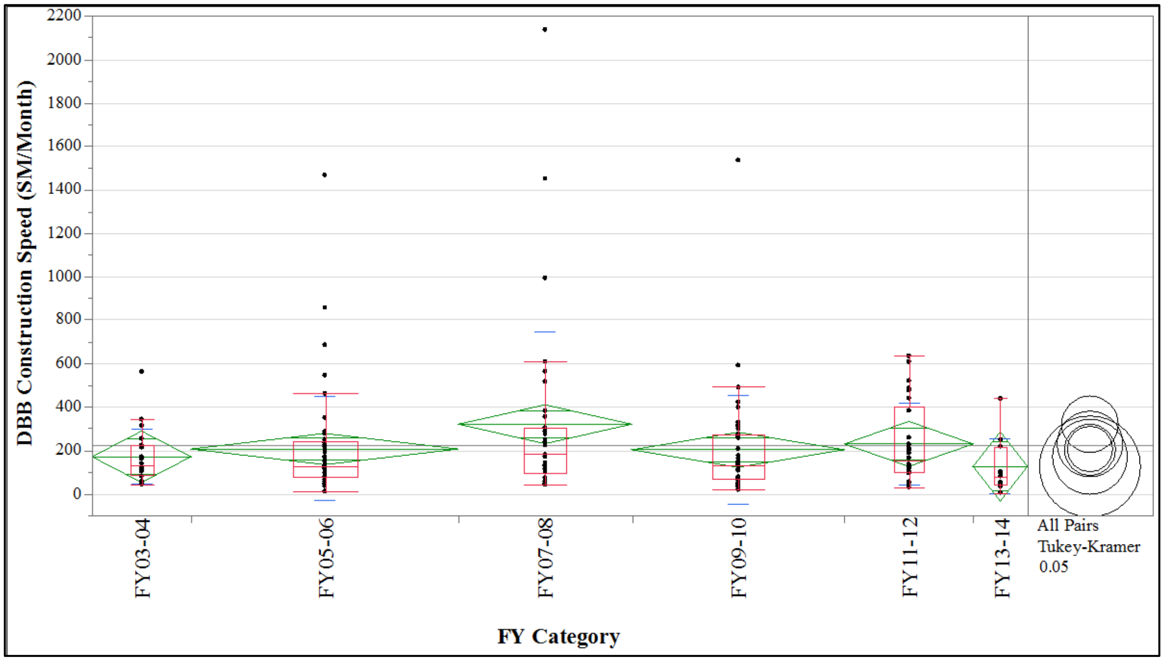
Design-Bid-Build (DBB) Construction Speed Results

One of the first steps in analyzing construction speed for traditional design-bid-build projects was to filter out horizontal construction projects that included airfield pavements, roadways, and electrical line distributions. These facility types were removed to provide a more equivalent comparison of vertical construction activity across fiscal years. Overall, 189 design-bid-build projects were analyzed using the construction speed performance measure.

The initial Levine's test found no significant difference in variances between year groups, thus allowing the study to apply Tukey's HSD test to compare mean construction speed values over pairs of year groups. While the average construction speed ranged from 124.6 SM/month in FY13-14 to 318.9 SM/month in FY07-08, there was no significant difference detected when each year group was compared. As illustrated in Figure 20, FY03-04 and FY13-14 marked the time periods of slowest average construction speeds. Yet again, the relatively small sample size (20 projects in FY03-04, 11 projects in FY13-14) of each year group may have contributed to the lower average construction speed experienced during these time periods. Overall however, there were no discernable trends in construction speed performance for design-bid-build projects.

As previously discussed in Chapter III, the construction speed performance measure is unique to traditionally delivered projects because it captures only construction progress from the NTP to the BOD. Limitations in the way data is tracked within the ACES-PM module prevented an equivalent performance measurement from being made with design-build projects. Instead the following section presents the results of design-build delivery speed, which captures design and construction activity of alternatively delivered projects using the same milestones in ACES-PM.

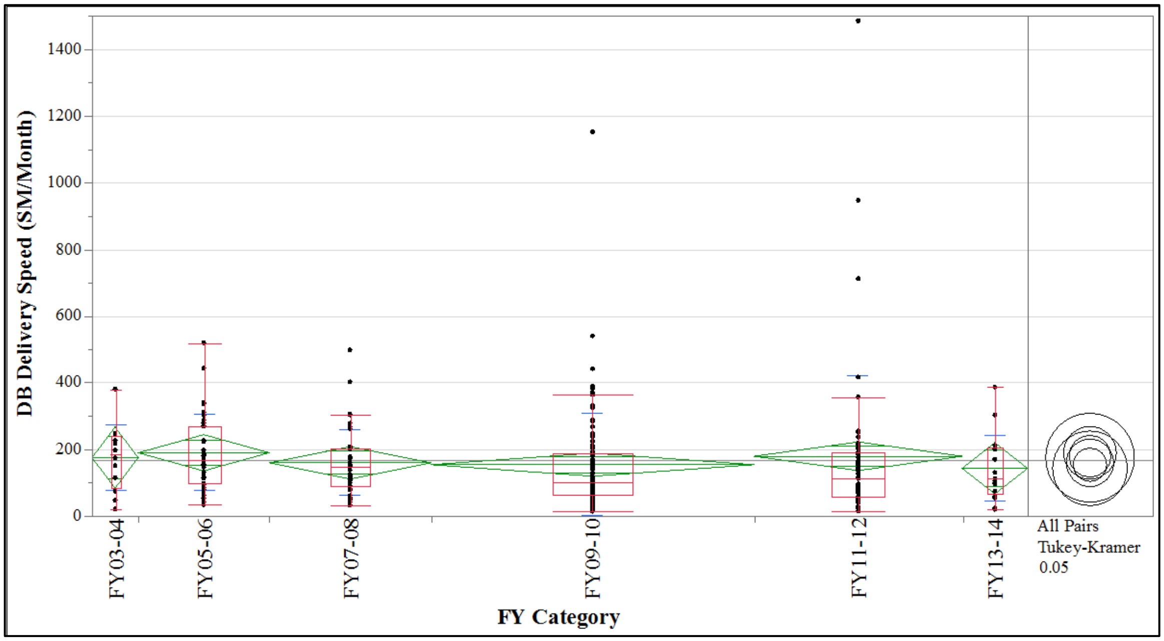
Figure 20 - Design-Bid-Build (DBB) Construction Speed (SM/Month) by FY Category



Design-Build (DB) Delivery Speed Results

Tukey's HSD test provided the analysis used to compare mean delivery speeds for design-build projects over time. Just as horizontal projects were filtered from the construction speed and unit cost analyses, horizontal projects were similarly removed from this analysis to create a more homogenous sample of design-build projects. Project delivery speeds ranged from 142.2 SM/month in FY13-14 to 188.8 SM/month in FY05-06. As seen in Figure 21, no significant differences were found when comparing average delivery speeds for design-build projects over time. Ultimately, the results from this test are evidence of the overall consistency in the Air Force's speed of delivery for design-build MILCON projects over time.

Figure 21 - Design-Build (DB) Delivery Speed (SM/Month) by FY Category

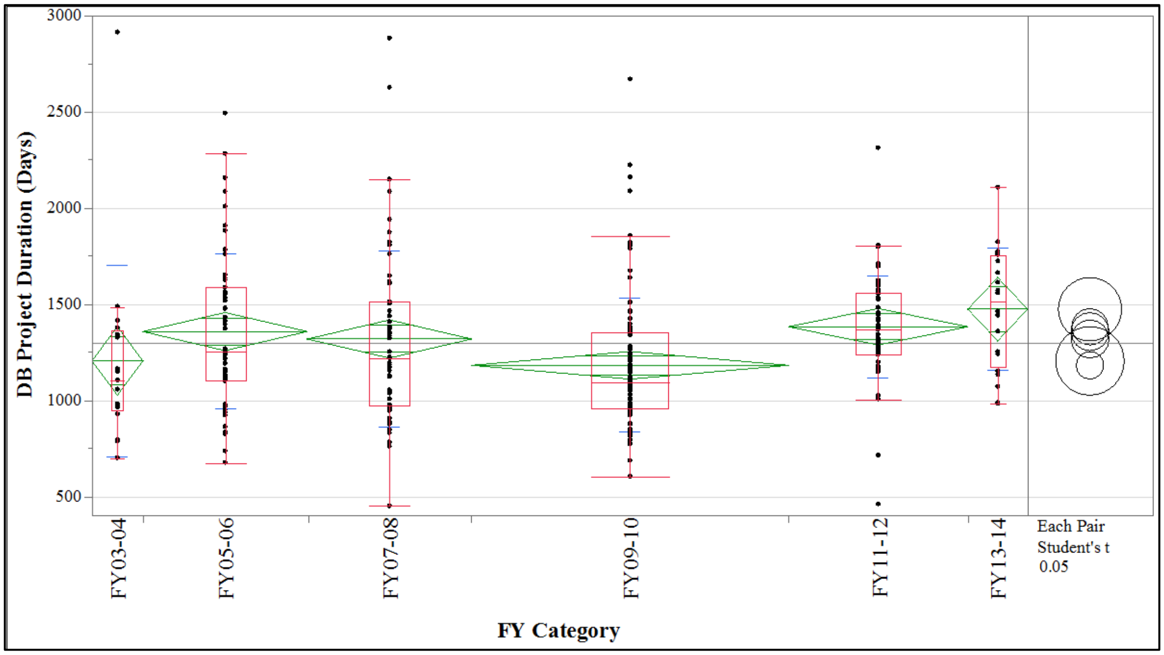


Project Duration Results

Design-Build (DB) Project Duration Results

After testing for variance homogeneity within year groups using Levine's test, Student's t-test was used to compare the mean project duration for design-build projects over time. Figure 22 illustrates significant differences in mean project durations that existed between several year groups. Design-build projects constructed in FY09-10 were characterized by an average 1,181 days of project duration. Conversely, projects delivered in FY11-12 experienced average project durations of 1,382 days, while FY13-14 projects saw an average project duration of 1,473 days. Significance levels for each of these comparisons with the FY09-10 category resulted in p-values of 0.001 and 0.0015, respectively.

Figure 22 - Design-Build (DB) Project Duration (Days) by FY Category

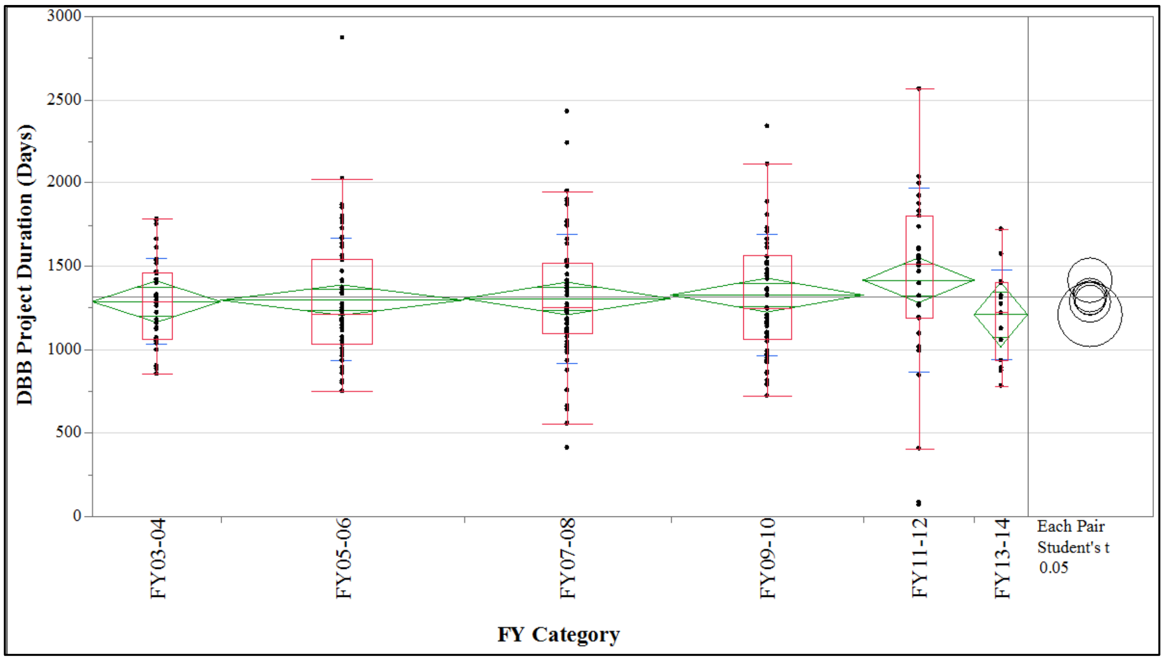


Other significant differences in average project durations were observed when comparing FY05-06 (1,357 days) and FY07-08 (1,318 days) with FY09-10 at significance levels of 0.005 and 0.0283, respectively. Finally, a significant p-value of 0.0302 was also found when comparing the mean project duration of FY03-04 (1,204 days) with that of FY13-14 (1,473 days). Once again, this difference may have been disproportionately caused by the relatively small samples sizes within the FY03-04 category (17 projects) and FY13-14 category (20 projects).

Design-Bid-Build (DBB) Project Duration Results

Student's t-test was used to compare each pair of mean project durations for traditionally delivered projects over time. Overall, there were no significant differences identified between year group comparisons with respect to total project duration. As depicted in Figure 23, these mean values ranged from 1,208 days in FY13-14 to 1,414 days in FY11-12, indicating an overall consistency in project duration performance within traditionally delivered MILCON projects. While the only direct comparison of project duration across delivery methods yielded insignificant results, the significant fluctuation seen in average design-build project durations directly contrasts the consistency seen in average design-bid-build project durations over the same period of time.

Figure 23 - Design-Bid-Build (DBB) Project Duration (Days) by FY Category



Delivery Method Performance by Facility Type

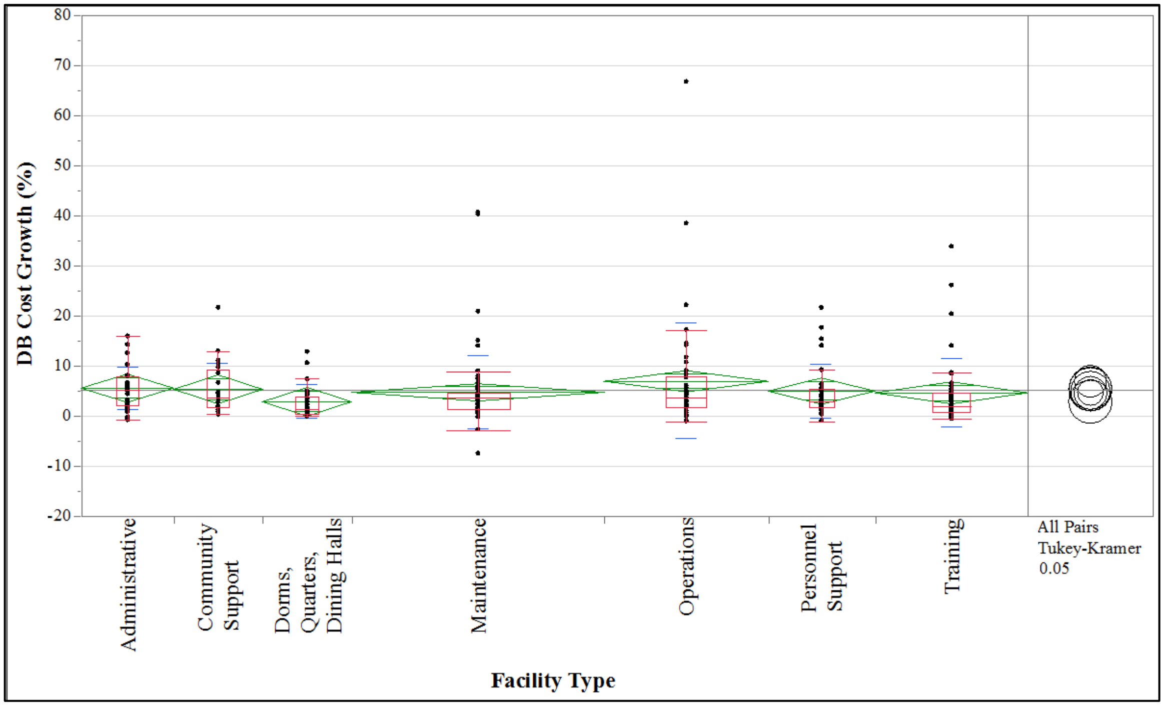
The second independent variable used to compare project delivery performance was facility type. The top seven most frequently used facility types by project delivery method were used for analyzing each performance measure. Administrative facilities were unique to design-build projects, while airfield pavements remained unique to traditionally constructed projects. The six facility types that each delivery method shared were community support facilities; dormitories, quarters and dining halls; maintenance facilities; land operations facilities; personnel support facilities; and training facilities.

Cost Growth

Design-Build (DB) Cost Growth Results

A total of 266 design-build projects were analyzed across the seven facility categories to identify significant differences in mean cost growths. Overall, comparisons made by using Tukey's HSD test yielded insignificant results. Average cost growths ranged from 2.8% for dorms, quarters, and dining halls to 6.9% for operations facilities. All other mean values fell between 4.6% and 5.5%, indicating an overall consistency in percent cost growth performance for the seven most frequently constructed design-build facility types. Figure 24 illustrates the graphical results of this analysis.

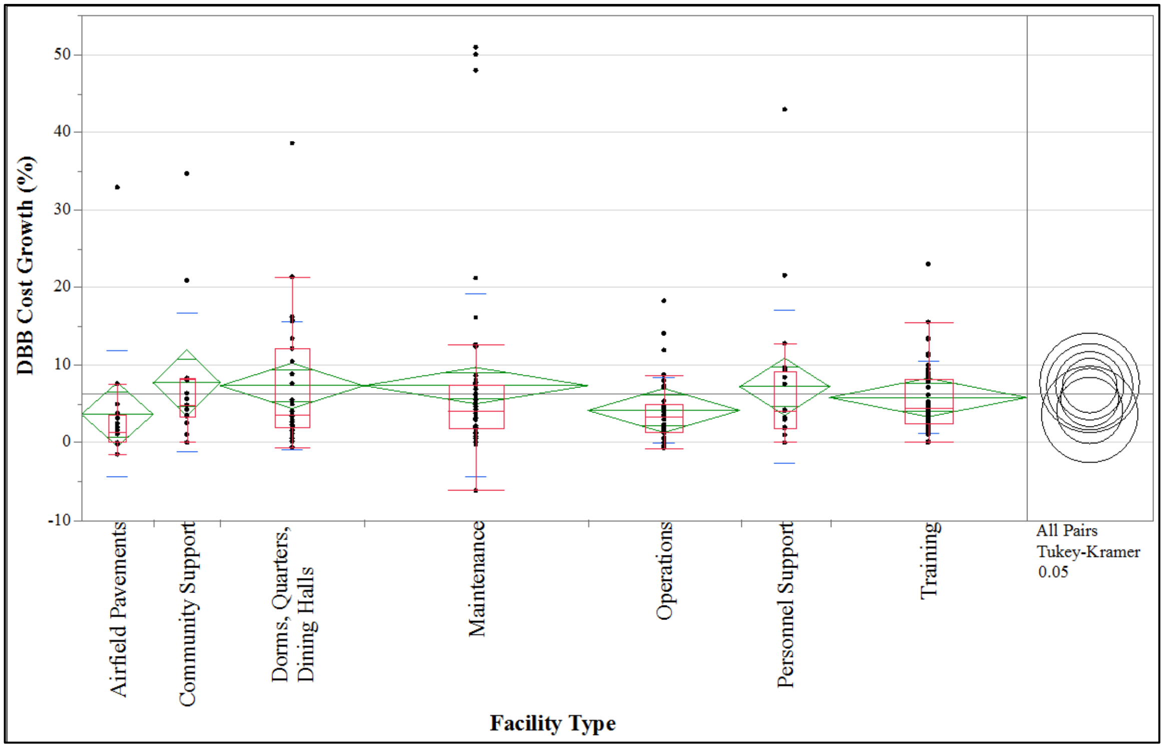
Figure 24 - Design-Build (DB) Cost Growth (%) by Facility Type



Design-Bid-Build (DBB) Cost Growth Results

Of the 264 total design-bid-build projects, 211 were constructed using the method's top seven facility types. The mean cost growth performances for these top facility types were compared using Tukey's HSD test. Overall, the comparisons of average cost growths of traditionally delivered projects were also found to be statistically insignificant. Design-bid-build projects shared a similar range in average cost growths values as design-build. As shown in Figure 25, airfield pavements were found to have a mean cost growth of 3.6%, while community support facilities averaged 7.7%. Once again, it appears that there is an overall consistency in cost growth performances of design-bid-build projects regardless of facility type.

Figure 25 - Design-Bid-Build (DBB) Cost Growth (%) by Facility Type

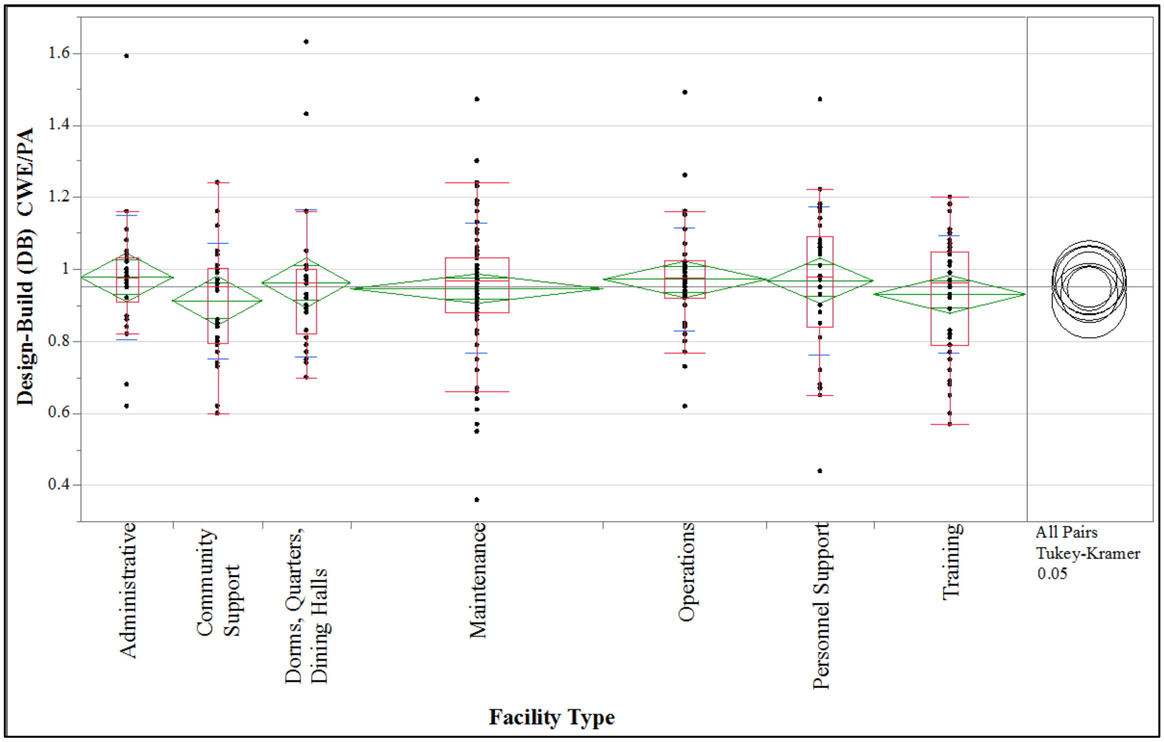


CWE/PA Ratio

<u>Design-Build (DB) CWE/PA Ratio Results</u>

The average CWE/PA ratios for the 266 design-build projects were also compared using Tukey's HSD. While these mean ratio values ranged from 0.91 for community support facilities to 0.98 for administrative facilities, there was an overall lack of significant findings resulting from this analysis. Ultimately, this lack of significant results indicates consistent cost estimating performance across design-build projects.

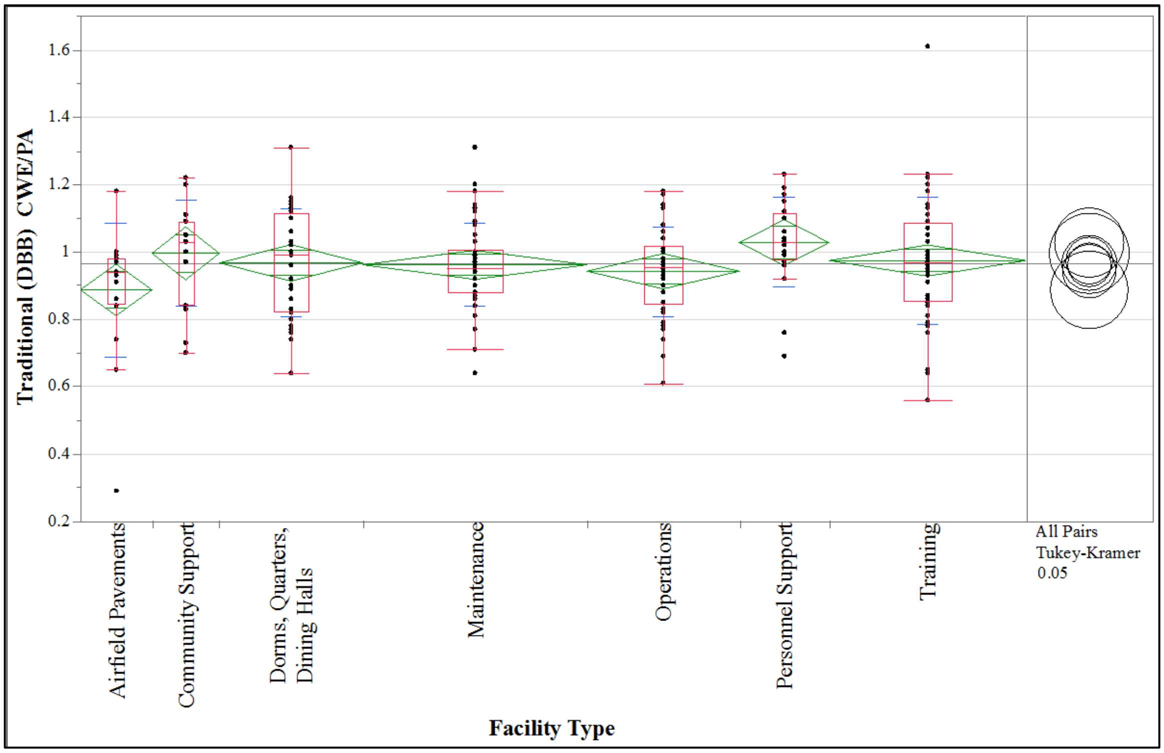
Figure 26 - Design-Build (DB) CWE/PA Ratios by Facility Type



<u>Design-Bid-Build (DBB) CWE/PA Ratio Results</u>

Tukey's HSD test yielded similar results for the seven most frequently constructed facility types in the 211 traditionally delivered projects. While a wider range of average CWE/PA ratios were seen between airfield pavements (0.87) and personnel support (1.03), there were no significant differences in the comparison of means between facility types. The findings remain consistent with the performance of design-build using this performance measure.

Figure 27 - Design-Bid-Build (DBB) CWE/PA Ratios by Facility Type

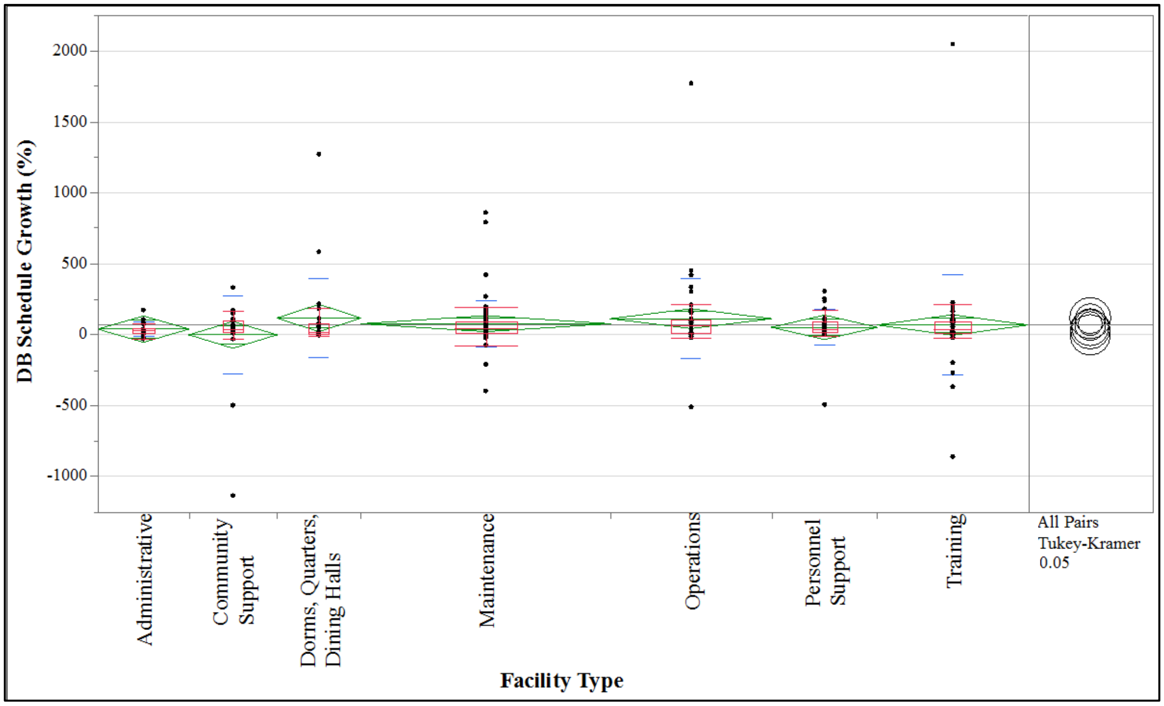


Schedule Growth

Design-Build (DB) Schedule Growth Results

Insignificant results were also found when using Tukey's HSD test for average design-build schedule growth comparisons. While community support facilities experienced a negative average schedule growth (-3.7%), the average dormitory, quarters, or dining hall project saw 114.7% schedule growth. This seemingly wide range of average schedule growths may have been impacted by the relatively small sample sizes of dormitories, quarters, and dining halls (24 projects) and community support facilities (25 projects). Despite these considerations, the study found similar average schedule growths across all facility types.

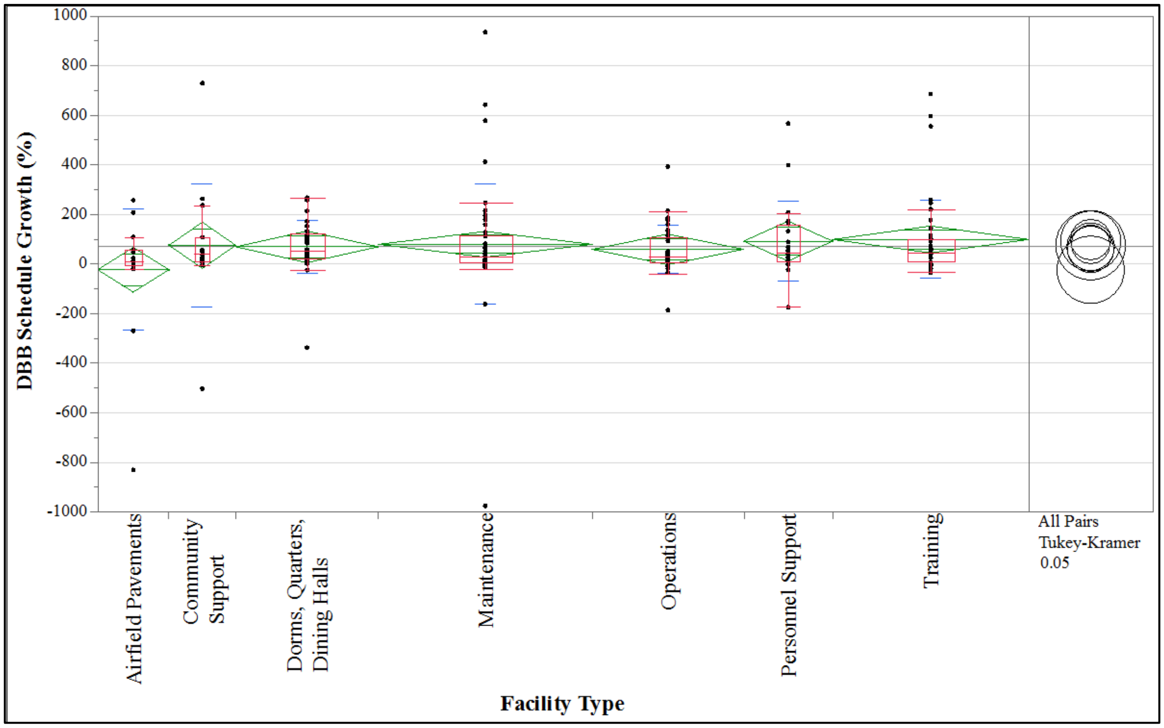
Figure 28 - Design-Build (DB) Schedule Growth (%) by Facility Type



Design-Bid-Build (DBB) Schedule Growth Results

The average schedule growths of the 211 design-bid-build projects were also compared across facility types using Tukey's HSD test. While the average training facility saw 96.6% schedule growth in traditionally delivered projects, the 16 airfield pavement projects yielded the most desirable results with an average schedule growth of -25.0%. Despite any discrepancy in samples sizes between facility types, there was no significant difference found in any of the paired comparisons. These results remain consistent with the average design-build project. Regardless of the choice in delivery method, a project's facility type failed to significantly influence its average schedule growth performance.

Figure 29 - Design-Bid-Build (DBB) Schedule Growth (%) by Facility Type

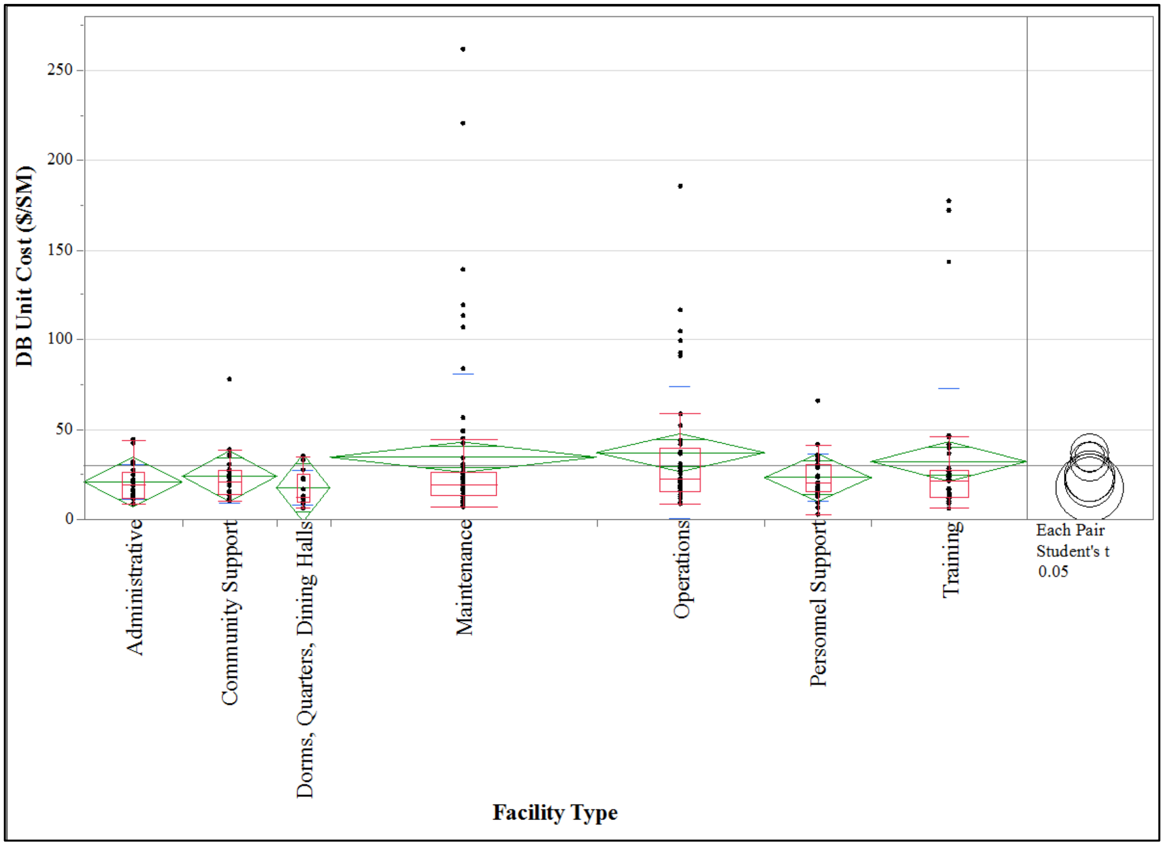


Unit Cost

<u>Design-Build (DB) Unit Cost Results</u>

Thirty-six projects were removed from the 266 design-build project total to conduct a unit cost analysis using "square meters" as the common unit of measure. Student's t-test revealed insignificant results when comparing mean unit cost performance across these facility types. The range of average unit costs ranged from $17.41/SM for dorms, quarters, and dining halls to $36.95/SM for operations facilities.

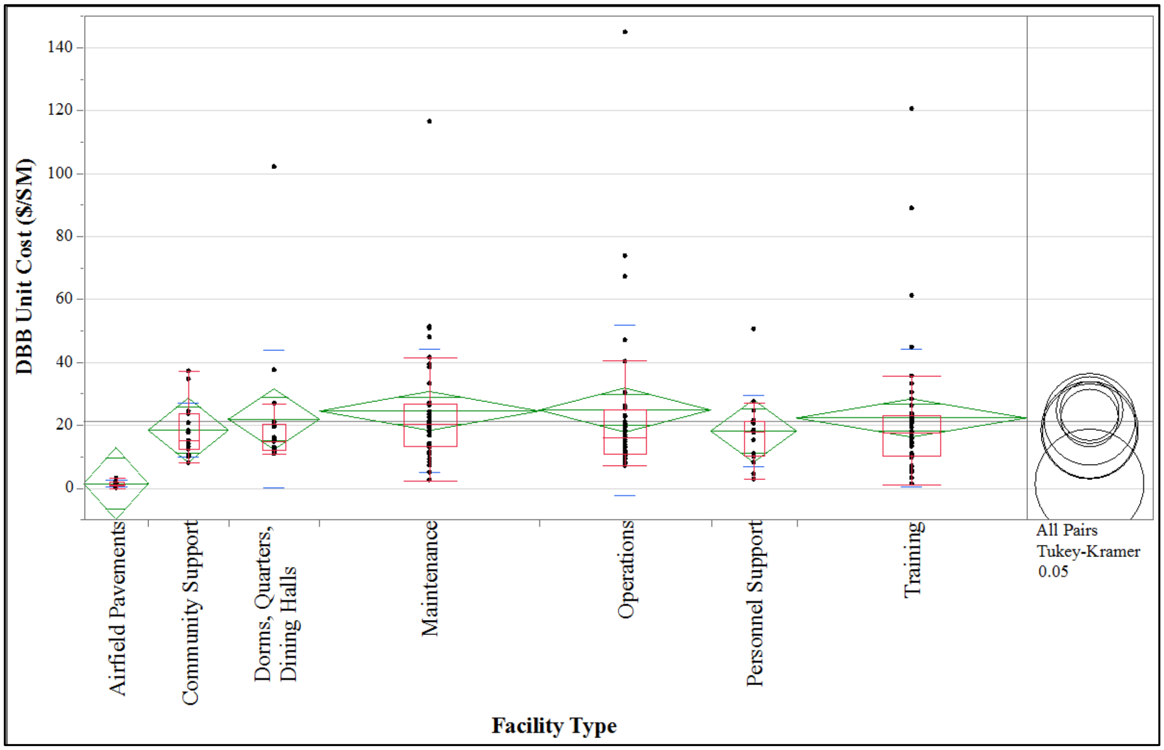
Figure 30 - Design-Build (DB) Unit Cost ($/SM) by Facility Type



Design-Bid-Build (DBB) Unit Cost Results

Of the 211 design-bid-build projects used in the facility type analyses, 176 were compared to determine whether the mean unit cost performance varied significantly by facility type. Tukey's HSD test produced significant results when comparing the mean unit cost of airfield pavement projects with that of three other project types. The average unit cost of the 12 traditionally constructed airfield pavement projects was $1.33/SM, while the average unit costs of operations, maintenance, and training facilities was found to be $24.70/SM, $24.40/SM, and $22.19/SM, respectively. Each of these average differences were characterized by significance levels of less than 0.029. The relatively small sample size of 12 airfield pavement projects likely contributed a great deal of the differences in these mean unit costs.

Figure 31 - Design-Bid-Build (DBB) Unit Cost ($/SM) by Facility Type

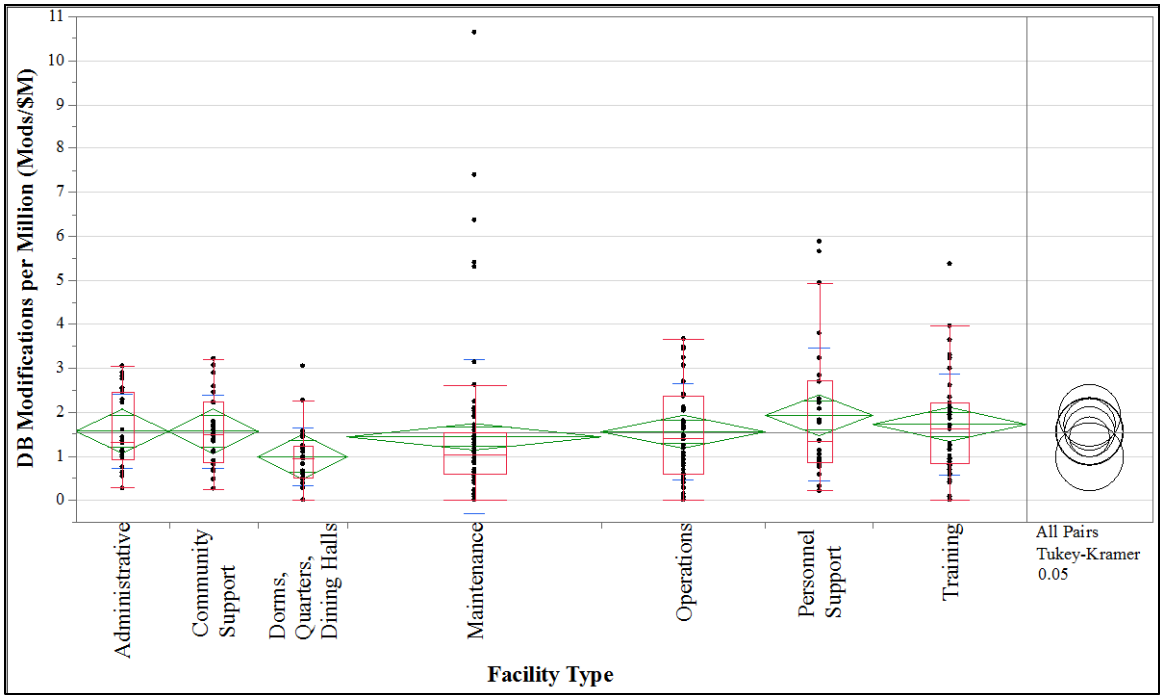


Modifications per Million Dollars

Design-Build (DB) Results for Modifications per Million Dollars

Tukey's HSD test was used to compare the mean number of modifications per million dollars of project scope across design-build facility types. Average numbers of change orders per million dollars ranged from 0.97 for dorms, quarters and dining halls to 1.92 for personnel support. Despite this discrepancy, there were no significant differences found between facility types when considering the mean change order performance metric.

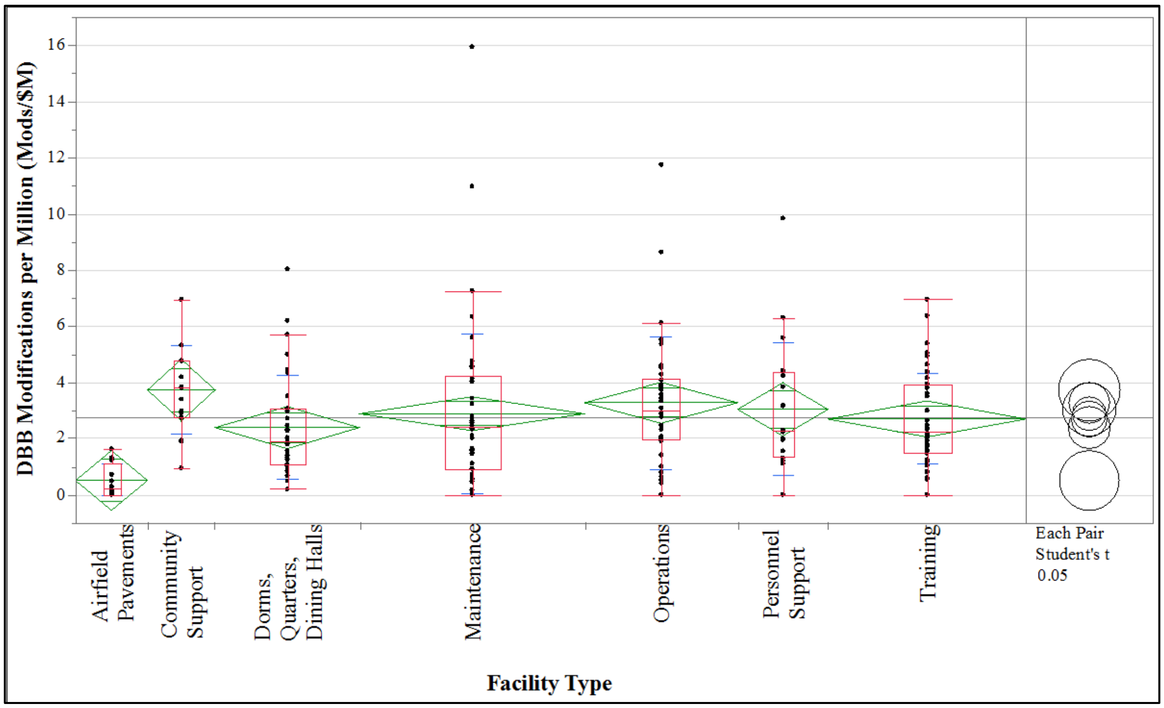
Figure 32 - Design-Build (DB) Modifications (Mods/$M) by Facility Type



Design-Bid-Build (DBB) Results for Modifications per Million Dollars

Student's t-test produced significant findings in the comparison of mean modifications per million dollars between facility types. The 16 airfield pavements experienced an average of 0.5 change orders per million dollars of project scope. This proved significantly lower than the average change order performance of all other facility types at significance values of less than 0.0048. Once again, the relatively small sample size of design-bid-build airfield pavements is a potential factor that influenced these comparisons. However, another significant difference in mean modification counts per million dollars was identified in this analysis. Dormitories, quarters, and dining halls experienced an average of 2.38 modifications per million dollars compared to the 3.71 modifications seen by community support facilities. While the p-value of 0.0485 found in this comparison barely satisfied the study's statistical definition of significant, the average change order performance of dormitories, quarters, and dining halls is noticeably superior to all other facility types (with exception to airfield pavements).

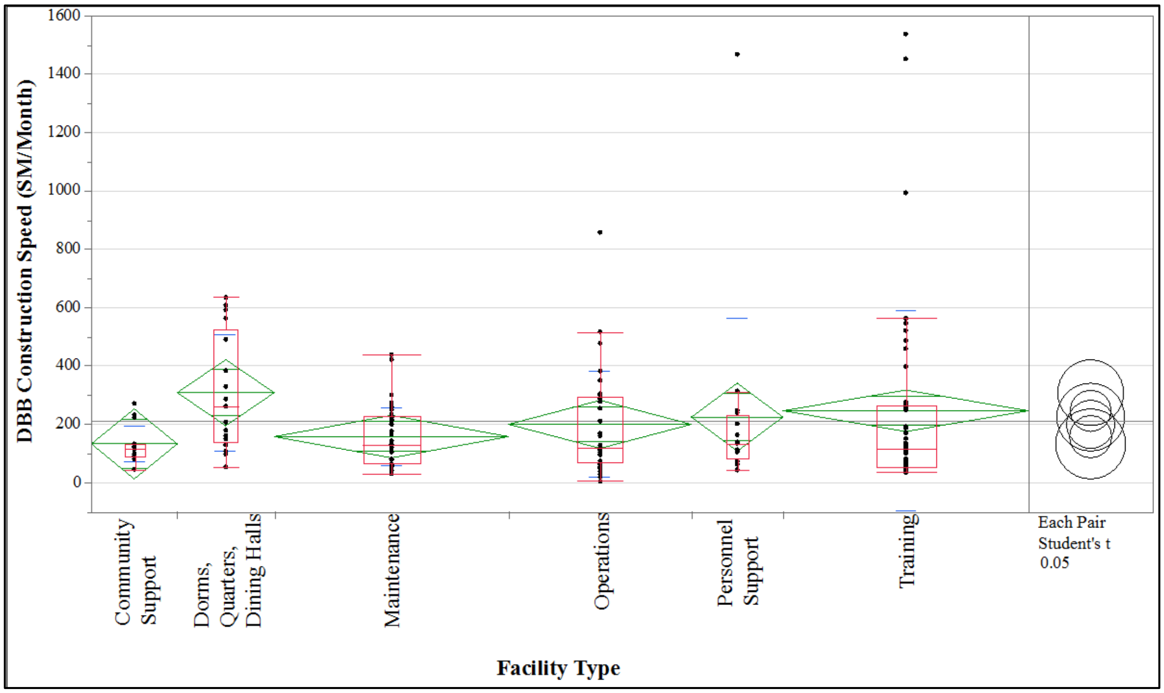
Figure 33 - Design-Bid-Build (DBB) Modifications (Mods/$M) by Facility Type



Design-Bid-Build (DBB) Construction Speed Results

Levine's test identified unequal variances between facility types, causing the mean construction speed performance of 164 design-bid-build projects to be compared using Student's t-test. Significant differences in mean construction speeds were found between dormitories, quarters, and dining halls (307.78 SM/month) and that of maintenance facilities (157.31 SM/month; p-value = 0.0281) and community support facilities (132.35 SM/month; p-value = 0.0370). The relatively small sample sizes of community support facilities and dorms, quarters, and dining halls may have contributed to these significant findings. However, aside from these comparisons, there were no other discernable differences in construction speed performance between facility types.

Figure 34 - Design-Bid-Build (DBB) Construction Speed (SM/Month) by Facility Type



Design-Build (DB) Delivery Speed Results

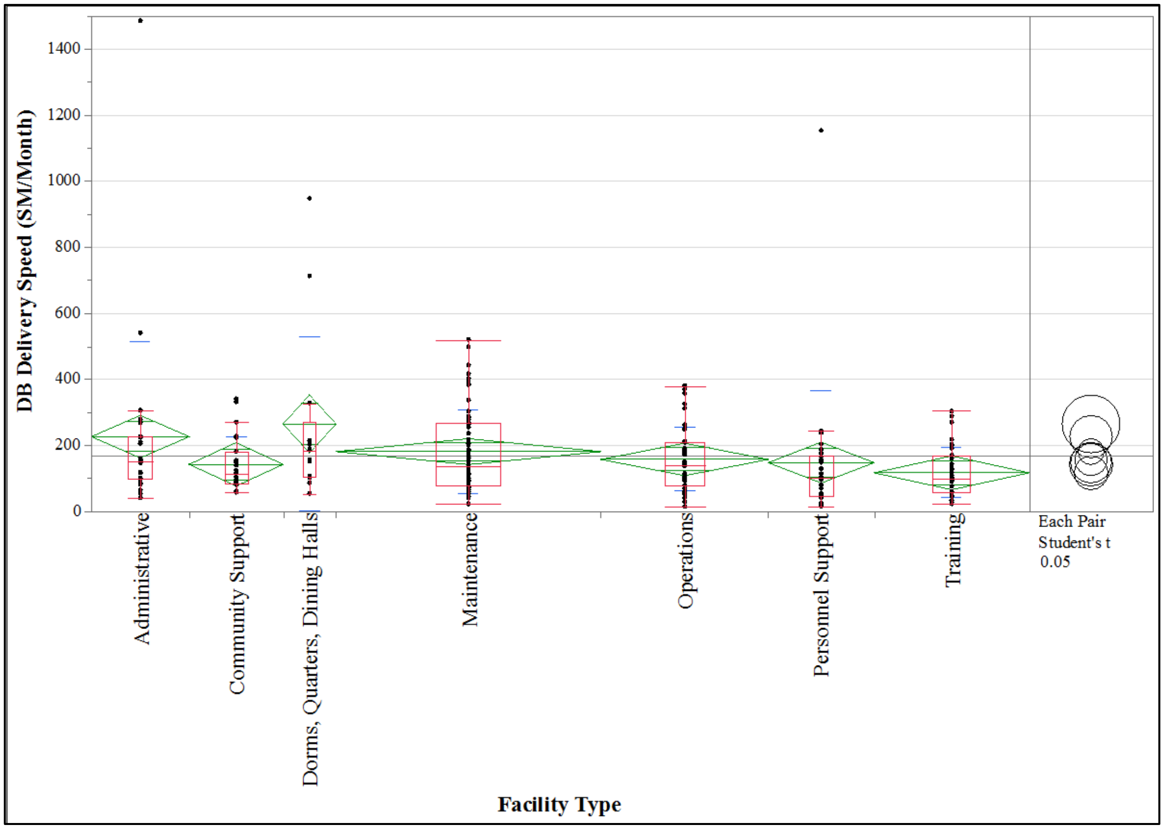
Student's t-test produced significant findings in the comparison of average design-build delivery speeds across facility types. As similarly found with the average construction speed of design-bid-build projects, dormitories, quarters, and dining halls

(263.6 SM/month) experienced significantly faster delivery speeds than four other facility types resulting in p-values of less than 0.0362 for each comparison. Another significant difference in mean delivery speed performance was seen between administrative facilities (225.12 SM/month) and training facilities (115.53 SM/month) at a significance level of 0.0093. It is unclear what contributed to this difference. Once again though, a sample size of 13 projects in this facility category likely contributed to the extreme differences observed amongst these facility types.

Project Duration

Tukey's HSD test was used for both the design-build and design-bid-build comparisons across facility types. Neither instance of testing resulted in significant differences in project duration performance between facility types. Therefore, it is difficult to draw a definitive conclusion with regards to the impact of facility type on project duration performance.

Figure 35 - Design-Build (DB) Delivery Speed (SM/Month) by Facility Type



Delivery Method Performance by MAJCOM

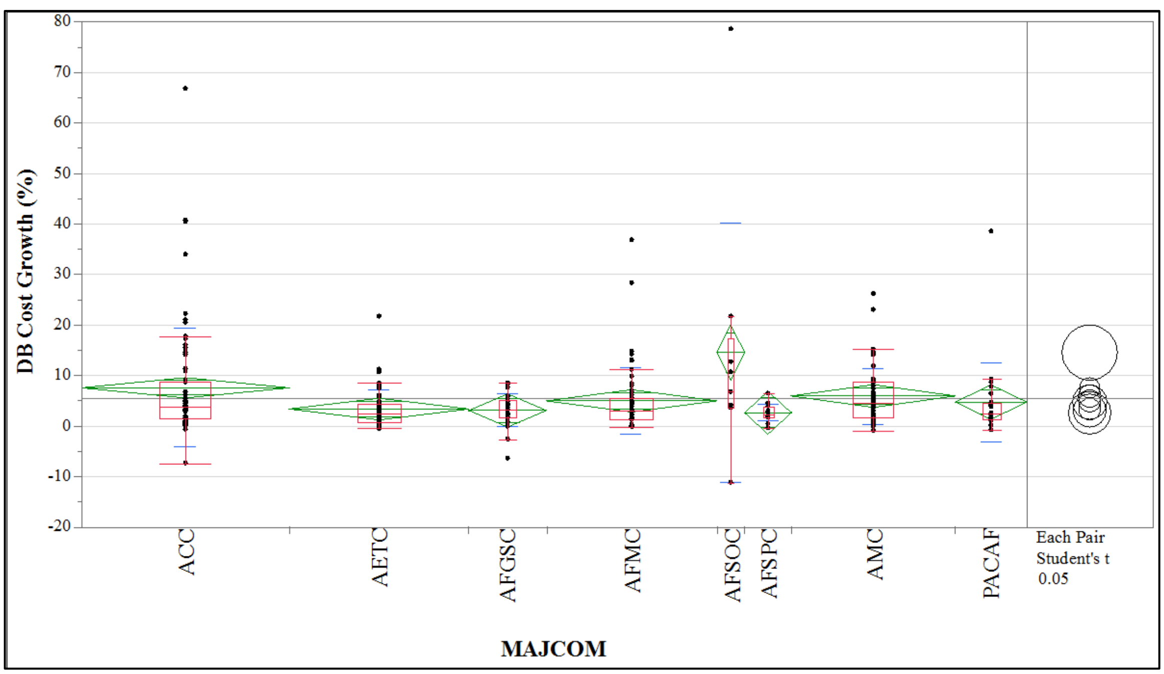
The final independent variable used to compare project delivery performance was MAJCOM. The top eight most MAJCOMs by project delivery method were used for analyzing each performance measure. Air Force Material Command (AFMC) and Pacific Air Forces (PACAF) were unique to design-build projects. The six common MAJCOMs that each delivery method shared were ACC, AETC, AFGSC, AFSOC, AFSPC, and AMC.

Cost Growth

Design-Build (DB) Cost Growth Results

After conducting Levine's test, Student's t-test for each pair of MAJCOM groups was conducted to compare the mean cost growth performances of 305 design-build MILCON projects. Mean cost growth performance ranged between 2.54% for AFSPC to 14.45% for AFSOC. The most significant findings were the differences observed between the higher average cost growths experienced by AFSOC compared to those achieved by every other MAJCOM. The levels of significance for each of these findings was at, or below, a p-value of 0.019. However, these results may be disproportionally impacted by the small sample size of nine AFSOC projects used in this analysis. Figure 36 illustrates the findings of the Student's t-test.

Figure 36 - Design-Build (DB) Cost Growth (%) by MAJCOM

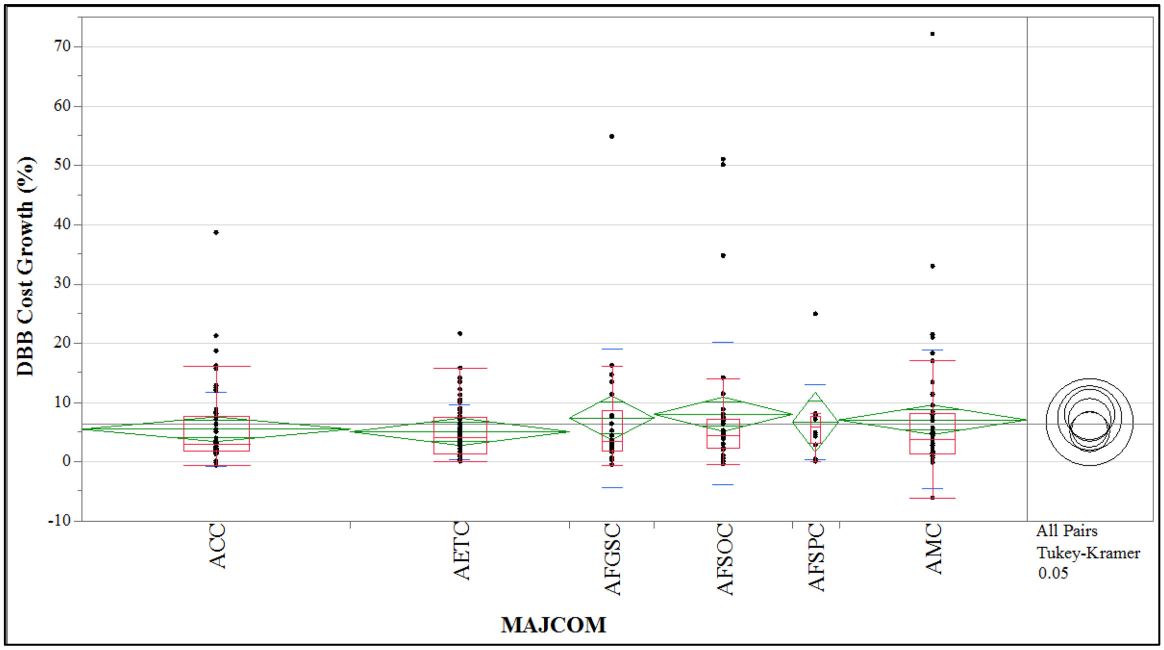


There was also another significant finding between several pairs of MAJCOM comparisons. The mean cost growth achieved by ACC (7.47%) was found to be statistically higher than those experienced in AETC (3.26%), AFGSC (2.98%), and AFSPC (2.54%), at significance levels of 0.0051, 0.0222, and 0.0392, respectively. Most MAJCOMs experienced little difference in average cost growths in design-build projects, while both ACC and AFSOC performed worse in this performance area.

Design-Bid-Build (DBB) Cost Growth Results

Levine's identification of equal variances allowed the researcher to use Tukey's HSD for comparing mean cost growth performances of 246 design-bid-build MILCON projects by MAJCOM category. As illustrated in Figure 37, average cost growths ranged from 4.96% in AETC projects to 7.91% in AFSOC projects. This range indicates that design-bid-build projects generally performed much more consistently that design-build projects. Ultimately, there were no significant differences identified in mean cost growth performance across MAJCOMs.

Figure 37 - Design-Bid-Build (DBB) Cost Growth (%) by MAJCOM

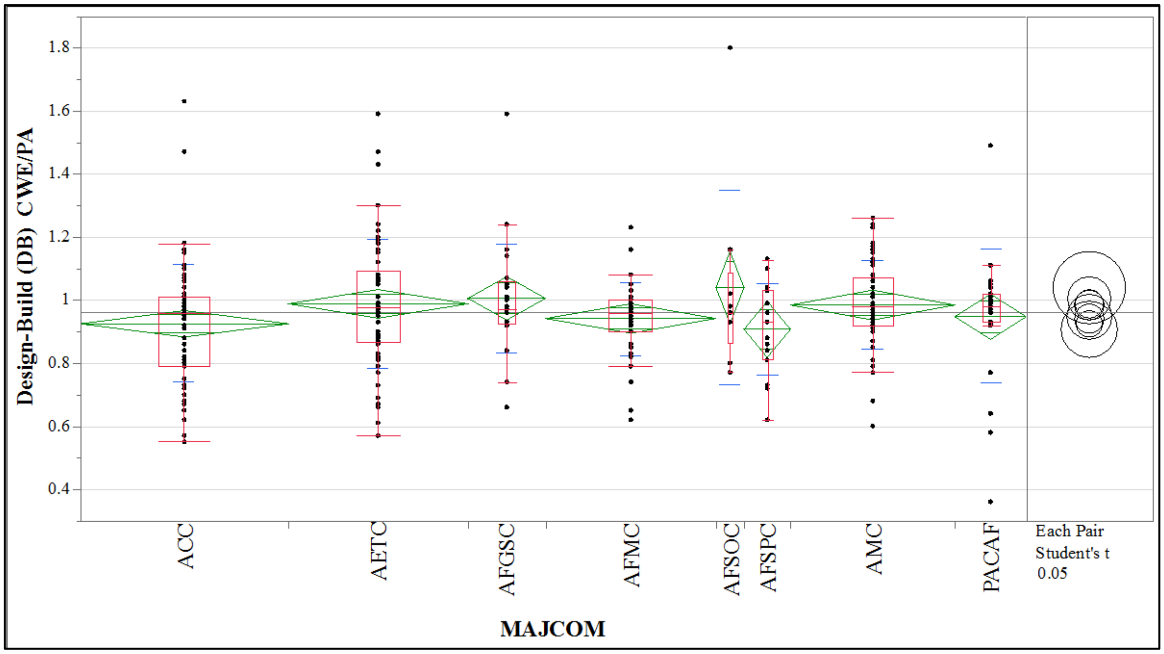


CWE/PA Ratio

Design-Build (DB) CWE/PA Ratio Results

Student's t-test was used for mean CWE/PA ratio comparisons between each pair of MAJCOMs. The test results revealed a significant difference between the mean CWE/PA ratio for ACC design-build projects (0.92) and that of AETC projects (0.99) at a significance level of 0.0448. However, this was the only significant finding from this analysis, indicating a general cost estimating consistency across MAJCOMs throughout design-build MILCON projects. Figure 38 illustrates the results from this CWE/PA ratio comparison across 305 design-build projects.

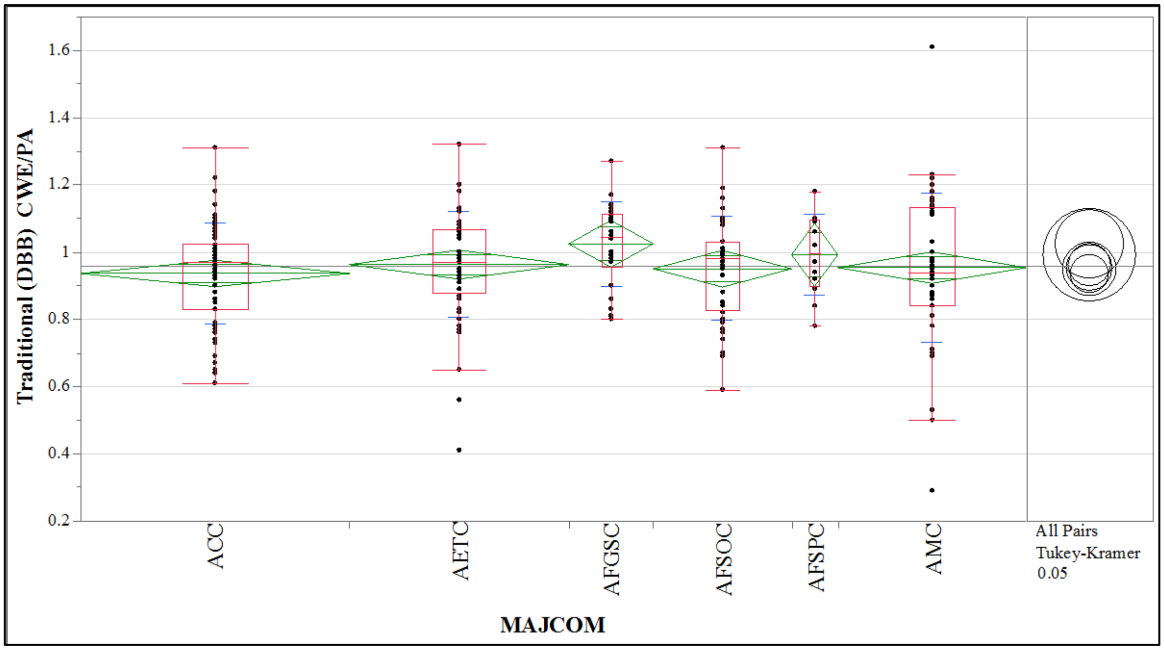
Figure 38 - Design-Build (DB) CWE/PA Ratios by MAJCOM



Design-Bid-Build (DBB) CWE/PA Ratio Results

A similar comparison was conducted using Tukey's HSD test for comparing mean CWE/PA ratios between 246 design-bid-build MAJCOM projects. Figure 39 shows that the mean ratio values ranged from 0.93 for ACC projects to 1.02 for AFGSC projects; it also shows that no significant differences were identified in CWE/PA ratios across MAJCOMs. However, the range of CWE/PA ratios for design-build projects was wider than that of design-bid-build projects when comparing MAJCOM performances. This indicates a greater level of consistency in cost estimating achieved in traditional projects when compared to design-build projects across MAJCOM categories.

Figure 39 - Design-Bid-Build (DBB) CWE/PA Ratios by MAJCOM

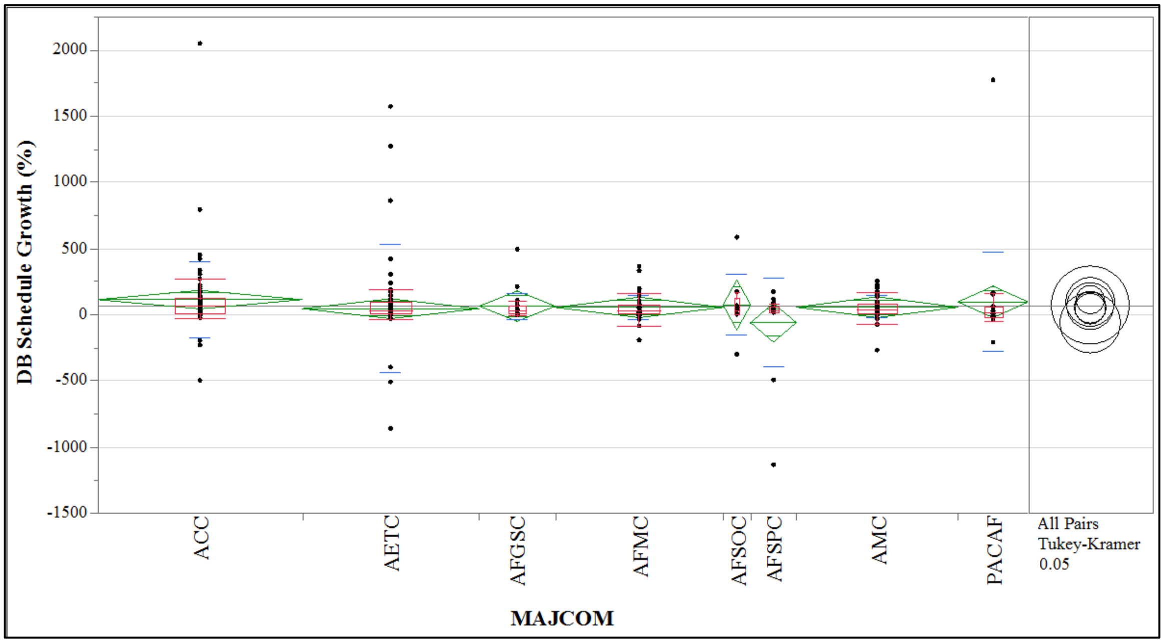


Schedule Growth

<u>Design-Build (DB) Schedule Growth Results</u>

A comparison between mean schedule growth performances of 305 design-build projects was conducted using Tukey's HSD test. The results from this procedure are shown in Figure 40. While the mean schedule growths ranged between -63.10% for AFSPC projects to 110.44% for ACC projects, there was no significant difference found between means when using this procedure. However, ACC design projects generally suffered from higher schedule growths when compared to the average performance of most other MAJCOMs.

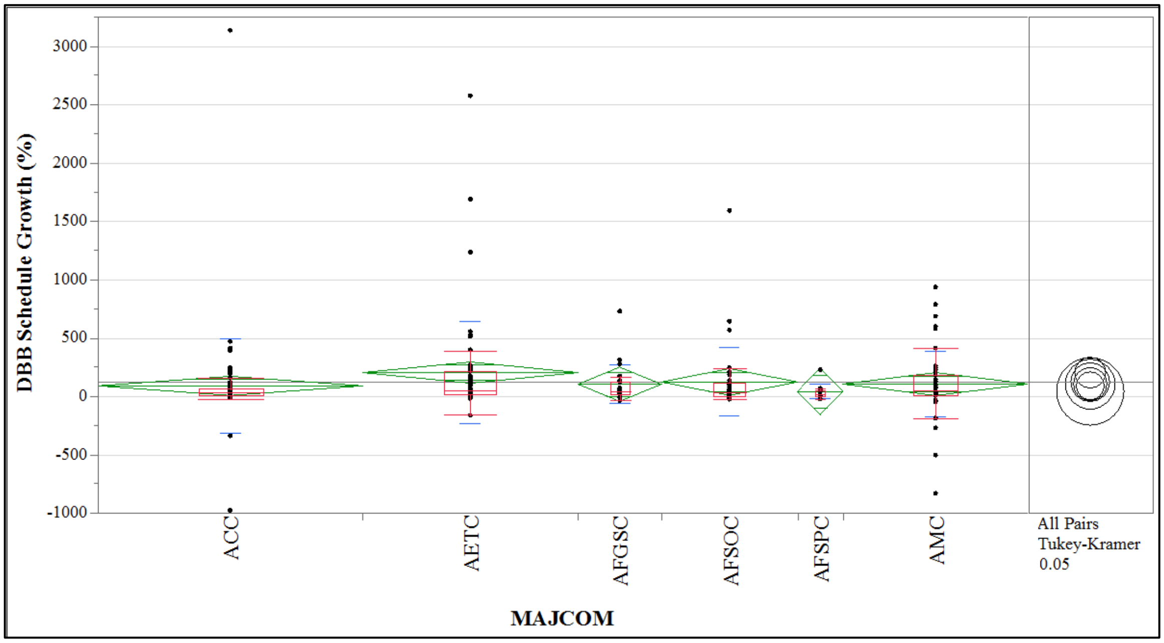
Figure 40 - Design-Build (DB) Schedule Growth (%) by MAJCOM



Design-Bid-Build (DBB) Schedule Growth Results

Tukey's HSD test was also used to make a similar comparison between mean schedule growths across MAJCOMs for 246 design-bid-build projects. Average schedule growth values ranged from 39.70% for AFSPC projects to 200.52% for traditional AETC projects. While the mean schedule growth range for traditional projects was higher than that of design-build MILCON projects, there was no significant difference in schedule growth performance found between MAJCOMs. General results do indicate, however, that AETC performs worse in this metric when compared to the average performance of other MAJCOMs. Figure 41 illustrates the results from this test.

Figure 41 - Design-Bid-Build (DBB) Schedule Growth (%) by MAJCOM

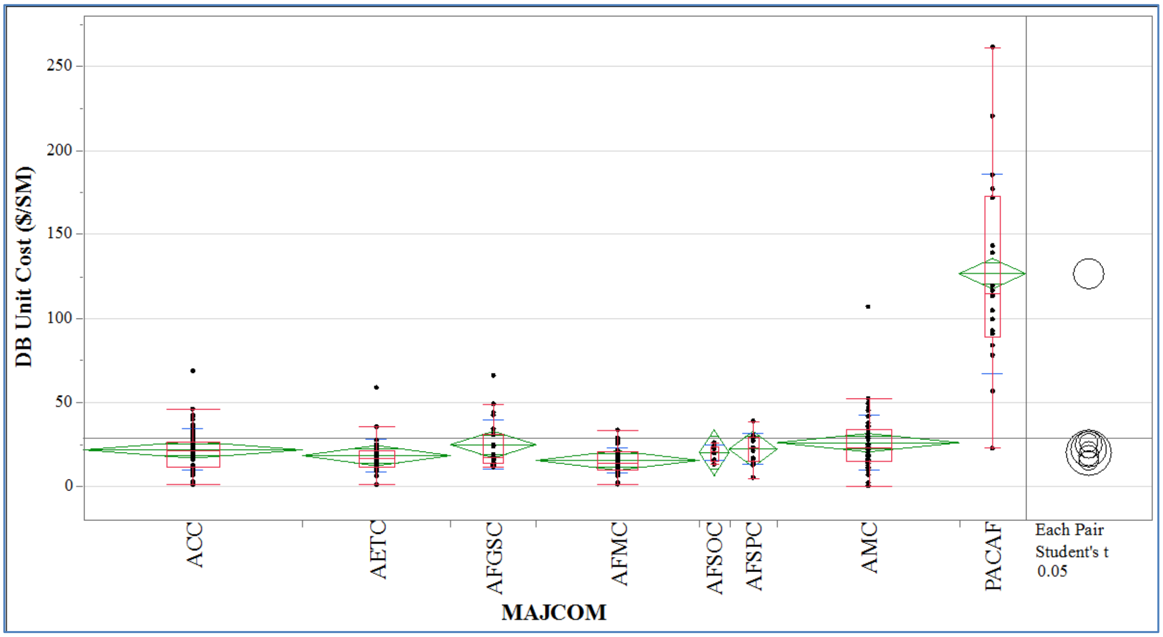


Unit Cost

<u>Design-Build (DB) Unit Cost Results</u>

Results from Student's t-test comparing each MAJCOM pair of mean unit cost measures for 254 design-build projects revealed several interesting results. Some of the most obvious findings were the significant differences in mean cost growth performances of $126.37/SM for PACAF projects and the mean range of $15.18/SM to $25.73/SM for all other MAJCOMs. Significance levels for these comparisons were all below 0.0001, indicating a high level of significance. Figure 42 illustrates this wide discrepancy in mean unit cost across MAJCOMs.

Figure 42 - Design-Build (DB) Unit Cost ($/SM) by MAJCOM

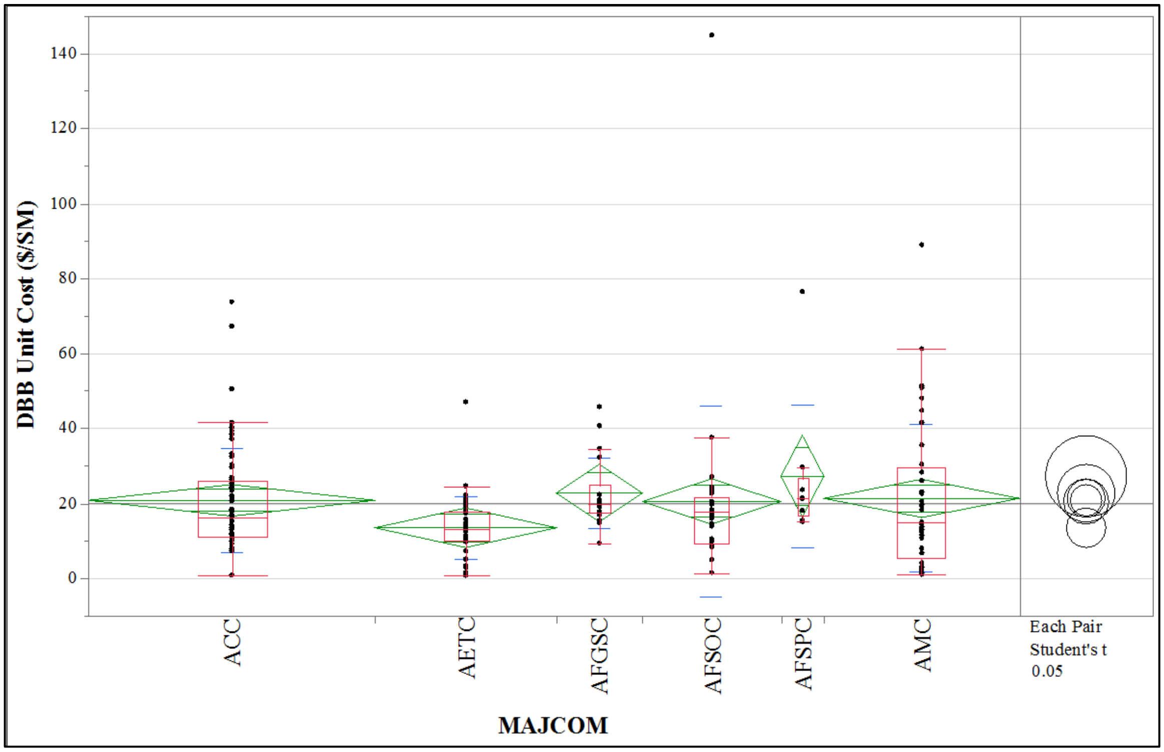


Student's t-test also revealed another significant difference in average unit cost performance across MAJCOMs. The mean unit cost for AMC ($25.73/SM) was significantly higher than that of AFMC ($15.18/SM) at a significance level of 0.0097. The reason for this discrepancy is also unclear as the sample sizes for both MAJCOMs were relatively equal and considered adequately large for statistical comparisons (49 AMC projects vs. 44 AFMC projects). Further examination of unit cost performance across MAJCOMs will be discussed for design-bid-build MILCON projects in the next section.

Design-Bid-Build (DBB) Unit Cost Results

Student's t-test was also used to conduct a comparison between unit cost performances by MAJCOM for 195 design-bid-build projects. Results from this analysis reveal that the mean unit cost experienced by AETC projects was significantly less than those of three other MAJCOMs. AETC's average unit cost was $13.39/SM while the mean values of AFSPC, AMC, and ACC fell within a range of $20.71/SM to $27.15/SM of constructed facility. The significance levels for each of these comparisons ranged from 0.0362 to 0.0258. It is unclear why the average AETC project experienced such a low unit cost compared to other MAJCOMs. Figure 43 displays the results of this comparison.

Figure 43 - Design-Bid-Build (DBB) Unit Cost ($/SM) by MAJCOM

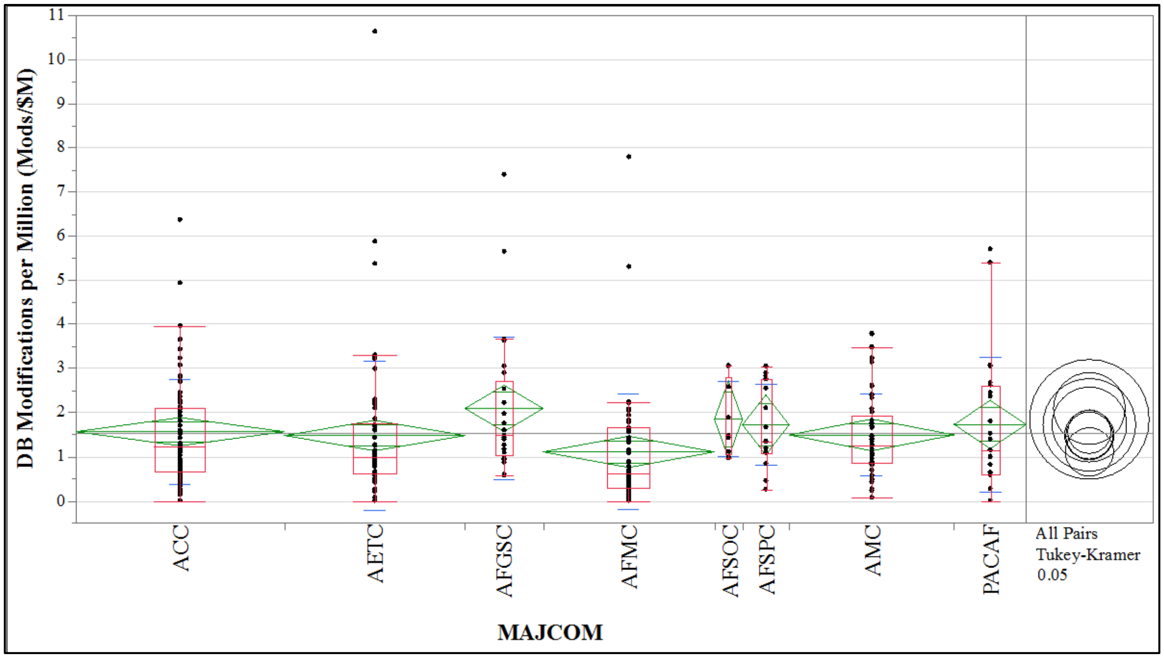


Modifications per Million Dollars

<u>Design-Build (DB) Results for Modifications per Million Dollars</u>

Levine's test resulted in the failure to reject the null hypothesis of equal variances. Therefore, Tukey's HSD test was used to compare the average number of modifications per million dollars for 305 design-build projects across MAJCOM categories. Average values ranged between 1.10 modifications for AFMC projects to 2.08 modifications for AFGSC design-build projects. This comparison marked a significant discrepancy in mean change order performance and was characterized by a p-value of 0.0486. Except for this comparison, the overall range of modifications indicated relatively consistent change order performance across MAJCOMs.

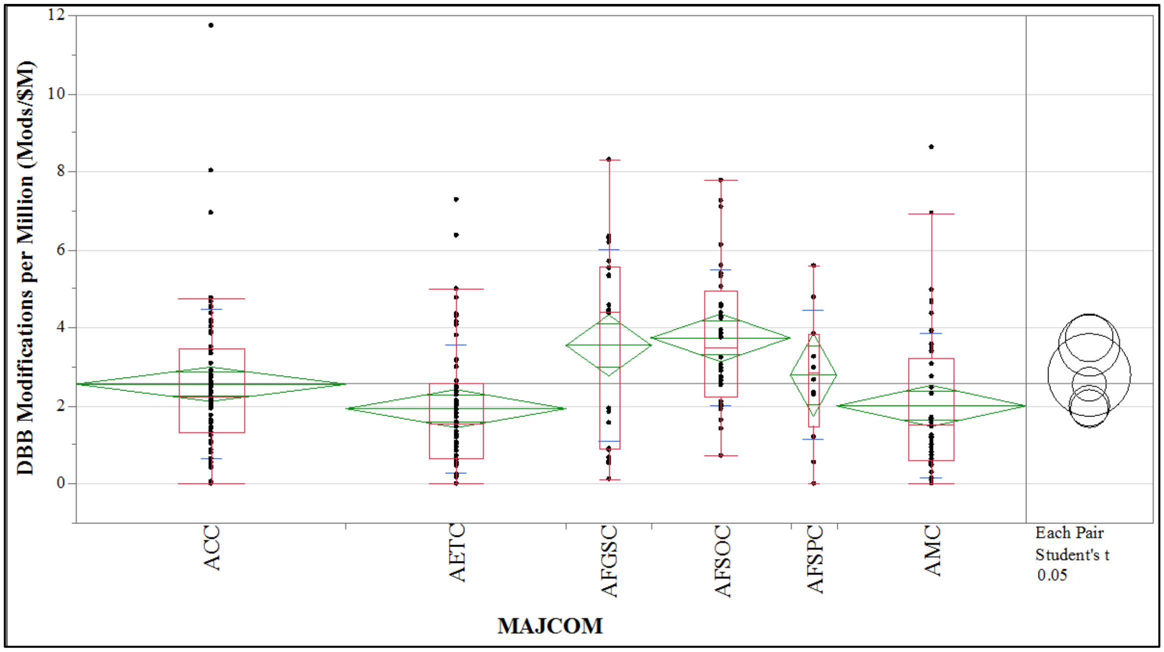
Figure 44 - Design-Build (DB) Modifications (Mods/$M) by MAJCOM



Design-Bid-Build (DBB) Results for Modifications per Million Dollars

Levine's identification of unequal variances resulted in the use of Student's t-test to compare mean change order performances of 246 design-bid-build MILCON projects across MAJCOM categories. As shown in Figure 45, the average number of modifications per million dollars of project scope ranged from 1.91 for AETC projects to 3.73 for AFSOC projects. When compared to design-build projects, the range of change order performance for traditional projects was generally lower and more consistent. Noticeable differences were observed in some areas though. The average number of modifications experienced by AFSOC was significantly higher than ACC (2.58), AMC (1.98) and AETC (1.91) at significance levels of 0.0021, below 0.0001, and below 0.0001, respectively. Similarly, the mean number of modifications for AFGSC (3.53) was significantly higher than the same three MAJCOMs. These differences were marked by significance levels ranging from 0.0301 and 0.0006. Ultimately, the reason for these differences is unclear. However, both AFSOC and AFGSC generally perform worse than other MAJCOMs when comparing this change order performance measure across design-bid-build projects.

Figure 45 - Design-Bid-Build (DBB) Modifications (Mods/$M) by MAJCOM

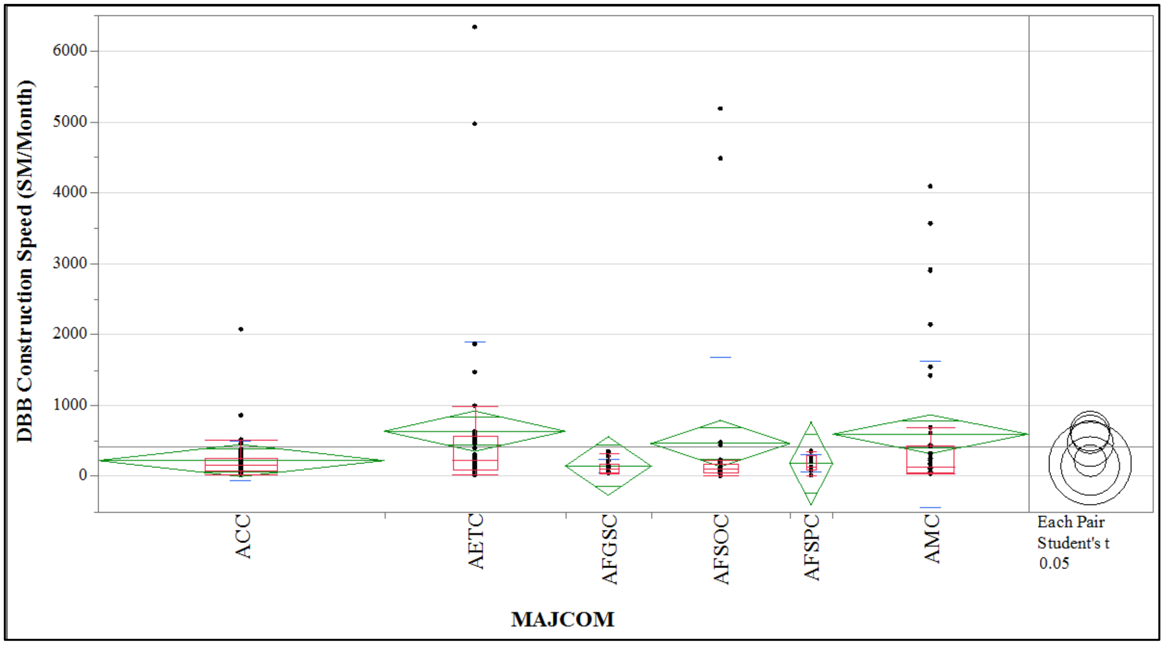


Design-Bid-Build (DBB) Construction Speed Results

After Levine's test was used to identify unequal variances across traditional MAJCOM groups, Student's t-test was used to compare the mean construction speed performance of 195 design-bid-build projects using MAJCOM categories. As indicated in Figure 46, average construction speed values ranged between 142.40 SM/month for AFGSC projects and 633.34 SM/month for traditional AETC projects. Specifically, the average construction speed achieved by ACC (219.32 SM/month) was significantly lower than those achieved by AETC and AMC (590.72 SM/month) at p-values of 0.0256 and 0.0403, respectively. While the average construction speeds achieved by AFSPC (177.86 SM/month) and AFGSC were slower than ACC, the relatively small sample sizes of these

MAJCOM categories likely prevented significant findings from being identified in Student's t-test.

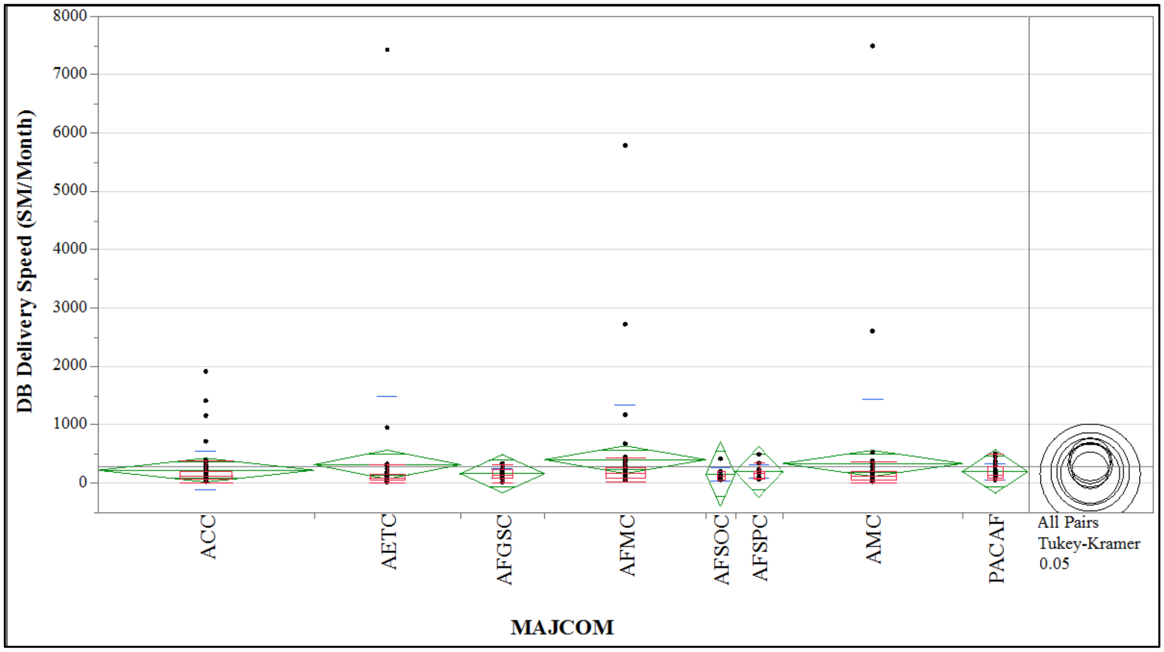
Figure 46 - Design-Bid-Build (DBB) Construction Speed (SM/Month) by MAJCOM



Design-Build (DB) Delivery Speed Results

Tukey's HSD test was used to compare the mean delivery speed performance of 254 design-build projects between MAJCOMs categories. Average delivery speeds ranged from 151.07 SM/month for AFSOC projects to 397.26 SM/month for AFMC design-build projects. No significant differences were found between MAJCOM categories using Tukey's HSD test procedure. Therefore, the overall average construction speed achieved by each MAJCOM was generally consistent across design-build projects. Figure 47 displays the results of the design-build delivery speed comparison across Air Force MAJCOMs.

Figure 47 - Design-Build (DB) Delivery Speed (SM/Month) by MAJCOM

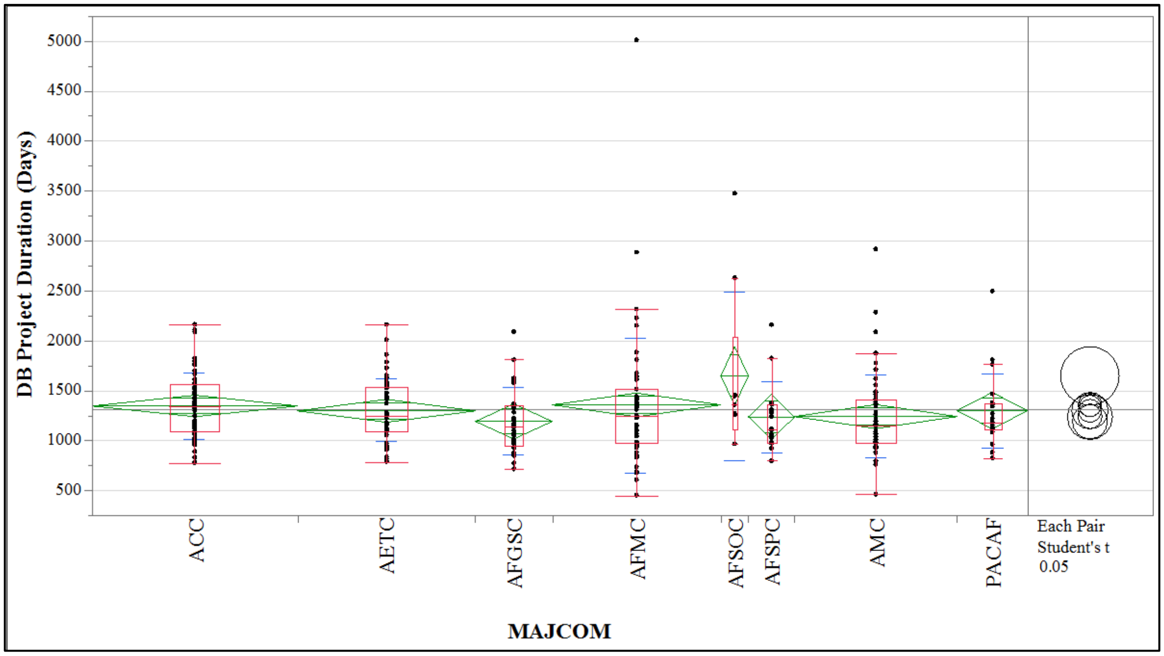


Project Duration Results

<u>Design-Build (DB) Project Duration Results</u>

Unequal variances identified within MAJCOM categories resulted in the use of a Student's t-test to compare the mean project durations of 305 design-build projects. The average project durations ranged from 1,189 days for AFGSC projects to 1,646 days for AFSOC design-build projects. While the overall average project durations were consistent across seven of the eight MAJCOM categories, all except for ACC and AFMC were found to be significantly shorter than the average project duration experienced in an AFSOC project. The significance levels of these comparisons ranged from 0.0473 to 0.0089. The relatively small sample size of nine AFSOC projects is most likely the cause of these significant findings. Figure 48 provides an illustration of the average project duration analysis.

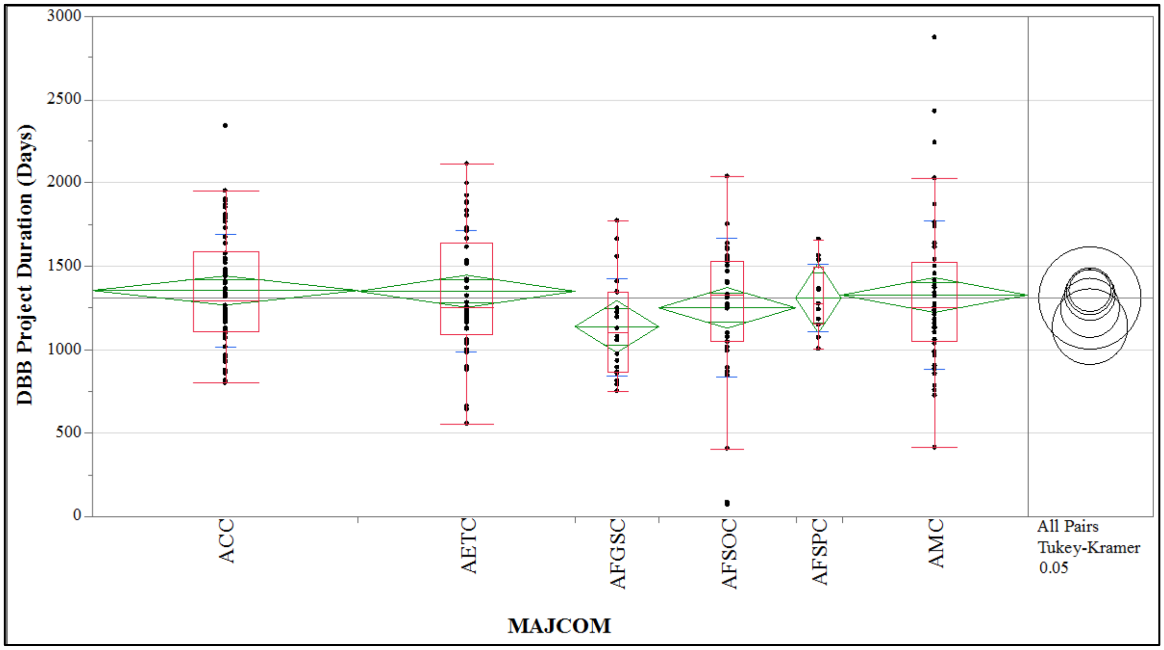
Figure 48 - Design-Build (DB) Project Duration (Days) by MAJCOM



Design-Bid-Build (DBB) Project Duration Results

The final performance indicator was analyzed using Tukey’s HSD test. Mean project durations of 246 design-bid-build projects were compared across the six MAJCOM groups to determine if any one MAJCOM performed significantly different than others in this metric. Average project durations ranged from 1,135 days for AFGSC projects to 1,352 days for traditional ACC projects. While no significant differences were identified in mean project durations, the general average AFGSC project once again outperformed projects from other MAJCOMs using this metric. Figure 49 illustrates these results.

Figure 49 - Design-Bid-Build (DBB) Project Duration (Days) by MAJCOM



Summary

Statistical results of this study included the gathering of 580 (264 design-bid-build, 316 design-build) MILCON projects from the ACES-PM module to quantitatively measure the performance of each delivery method over time, within specific facility types, and across MAJCOM categories. Additionally, this study proposed a list of eight key performance indicators that the Air Force should use to measure the relative performance of project delivery methods. These key performance indicators were derived from a larger aggregated list of performance measures that have been successfully tracked and used in related industry studies. While some of these indicators are currently used to analyze project delivery method performance for Air Force MILCON projects, limitations with the ACES-PM database do not allow for true equivalent comparisons to be made. By actively monitoring and measuring additional project performance data, Air Force project managers will be able to more effectively analyze MILCON project delivery performance. Appendices A-H summarize the significant findings of these variables with respect to each of the eight performance measures.

V. Conclusions and Recommendations

This chapter summarizes the study's results and answers the investigative questions of this research effort. In Chapter IV, a recommended list of industry-proven key performance indicators was presented for future application by Air Force project managers. Additionally, the previous chapter presented the results of raw data used to statistically analyze the performance of design-build and design-bid-build project delivery methods with respect to time, constructed facility type, and MAJCOM execution of Air Force MILCON projects. Chapter V presents conclusions from these research findings that answer the research questions. Finally, it discusses the significance and limitations of this research effort, which provide a course of recommended business improvement actions and a basis for future research opportunities.

Problem Statement

The first goal of this study was to identify a group of key project performance indicators that have been successfully utilized by experts in the construction industry to measure project delivery performance. This list would then be filtered for Air Force application, thus enabling the service to effectively analyze its project delivery performance and ultimately improve its execution of future MILCON projects. The other goals of this thesis were to explore whether Air Force execution of the design-build and design-bid-build project delivery methods has improved over time and to identify trends in MILCON project delivery with respect to the project's facility type and managing MAJCOM. The following sections summarize the study's findings in the context of these investigative goals. While this research was strictly empirical in nature, additional observations are presented to offer context and possible explanations for the study's statistical findings.

Investigative Question #1

1. **What framework of key performance indicators should the Air Force track to effectively compare the relative performance of AF MILCON project delivery methods?**

An extensive review of past research facilitated the compilation of key performance measures that have been successfully used by construction industry experts to measure and predict relative project delivery performance. This study recommends that the Air Force use a list of the following eight key performance indicators when analyzing the relative performance of project delivery methods: cost growth, unit cost, award growth, project duration, schedule growth, project delivery speed, modifications counts per million dollars of project scope, and percent modifications due to deficiencies. While some of these indicators are currently used to analyze project delivery method performance for Air Force MILCON projects, limitations with the ACES-PM database do not allow for accurate and equivalent comparisons to be made. It is recommended that the Air Force consider tracking additional project characteristics and milestones as data fields that are unique to each type of delivery method. This framework of key performance indicators will allow for more accurate and useful analyses to be conducted as Air Force project managers seek to improve future project delivery performance.

Investigative Questions #2-4

2. **Using current cost, schedule and change order project measures, has the performance of Air Force MILCON design-build project delivery improved at a statistically significant level when viewed over time, by facility type, and by MAJCOM?**

3. **Using these performance measures, does a specific facility type outperform other facility types in Air Force design-build project delivery?**

4. **Using these performance measures, does a specific Major Command outperform its peers in Air Force design-build project delivery?**

Responses from seven cost, schedule, and change order project characteristics were measured across three major categories (fiscal year groups, facility types, and managing MAJCOM) to identify significant performance trends in Air Force design-build MILCON projects.

Cost Growth

Average cost growth performances of design-build projects fluctuated a great deal from 2003 to 2014. The Air Force experienced a significant increase in cost growth from FY05-06 to FY09-10, yet subsequently saw a similar degree of decreased cost growth from FY09-10 to FY11-12. While the most recent year groups have been characterized by an improved cost growth trend, it is difficult to definitively state the cost growth performance of Air Force design-build project delivery has improved over time. No significant performance findings were identified when design-build projects were examined across the most commonly constructed facility types. This ultimately reveals a consistency in average cost growth performance for Air Force projects regardless of the project's facility type. On average, AFSOC and ACC design-build projects were shown to underperform by having significantly higher cost growths than other MAJOCMs. While the relatively poor average cost growth performance of ACC was unmistakable, this analysis may have fallen victim to the small sample size of AFSOC projects.

CWE/PA Ratio

The historical analysis of CWE/PA ratio identified an overall trend of improvement in Air Force design-build project planning and cost estimating after FY05-06. Additionally, insignificant findings in the facility type analysis indicate a general level of consistency in project planning and monitoring for all project types. Additionally, while AETC was found to perform significantly worse than ACC in this metric, the other seven MAJCOMs shared relatively consistent CWE/PA ratio performance.

Schedule Growth

There were ultimately no significant trends in design-build schedule growth performance found between 2003-2014, which indicates a level of overall consistency in the ability of Air Force project managers to accurately plan design-build project schedules during that time. A lack of significant results from the facility type and managing MAJCOM analyses also provide little definitive proof of varying levels of average design-build performance across these categories.

Unit Cost

The historical analysis of the average unit cost of design-build projects failed to present any noticeable trends in performance. Likewise, there was no noticeable difference in the unit costs of various design-build facility types. When considering the managing MAJCOM, the average PACAF project emerged as having a significantly higher unit cost than those of its peers. The nature of PACAF projects may simply cause an escalated unit cost for design-build MILCON projects. Additionally, regional influences may have contributed to this vast difference. Of the 18 PACAF design-build projects examined in this study, 17 were constructed at Joint Base Elmendorf-Richardson, AK and the remaining project was constructed in Hawaii. However, because the formula for unit cost incorporates a location index extracted from 2016 DoD area cost factors, it is unclear why these projects experienced such escalated unit costs. Additionally, this study found that most of these projects were constructed in support of the F-22 mission beddown and C-17 operations. Perhaps specialized project requirements unique to the missions of this installation drove the average unit cost to be significantly higher than those experienced by other MAJCOMs.

Modifications per Million Dollars

While general fluctuations in average modification counts make it difficult to identify historical trends, the Air Force's change order management performance in design-build projects was significantly superior in FY07-08 and FY13-14 compared to other year groups. Additionally, no single facility type was found to significantly outperform other project types in this change order metric. However, AFMC significantly outperformed AFGSC with fewer average modifications per million dollars of project scope. While not at a statistically significant level, AFGSC design-build projects experienced an increased average number of modifications when compared to other MAJCOMs. Therefore, the significant difference found when comparing AFMC and AFGSC design-build projects was likely impacted more by the relatively higher AFGSC performance values.

Delivery Speed

The historical analysis of average design-build project delivery speed failed to yield significant results. Additionally, the test did not reveal any significant differences in MAJCOM delivery speed performance, indicating a general consistency in the speed at which all MAJCOMs delivery design-build projects. However, noticeable differences were observed in the facility analysis. Dormitories, officer quarters, and dining halls were delivered at significantly faster rates than four other facility types. While these findings was likely impacted by the small sample size of 13 projects, the homogenous design of dormitories, quarters, and dining halls may also provide an advantage in their speed of project delivery compared to other less-uniform facility types. A similar theme was also observed in the comparison of administrative and training design-build facilities. The former facility type was delivered at significantly higher rates than the later. While new Air Force administrative facilities have standard designs, training facilities are often highly specialized to accommodate the unique mission of its occupants.

Project Duration

There was also a lack of significant findings when comparing mean design-build project durations of various facility types. This ultimately points to a general consistency in a design-build project's timeline regardless of facility type. The historical analysis of average design-build project durations revealed fluctuating trends across fiscal year groups. Easily characterized with the largest sample size amongst fiscal year groups, FY09-10 was observed to have significantly shorter average project timelines than four of the five other groups. Comprised of only 17 projects, FY03-04 was observed to have a significantly shorter average project duration than that of the FY13-14 year group. These contrasting findings present a strange paradox when considering sample size.

The mean project duration of one MAJCOM was also found to be quite different than many of its peers. The average design-build AFSOC project timeline was significantly longer than those of five other MAJCOMs. This finding may be a result of the small sample size of nine projects, but it also may be impacted by the fact that there were only two installations responsible for managing AFSOC design-build projects from FY 2003-2014.

Investigative Questions #5-7

5. **Using current cost, schedule and change order project measures, has the performance of Air Force MILCON design-bid-build project delivery improved at a statistically significant level when viewed over time, by facility type, and by MAJCOM?**

6. **Using current cost, schedule and change order project measures, has the performance of Air Force MILCON design-bid-build project delivery improved at a statistically significant level over time?**

7. **Using these performance measures, does a specific facility type outperform other facility types in Air Force project design-bid-build delivery?**

Responses from seven cost, schedule, and change order project characteristics were measured across the same three major categories to identify significant performance trends in traditionally delivered Air Force MILCON projects.

Cost Growth

Average cost growth performances of design-bid-build projects fluctuated a great deal from 2003 to 2014. Design-bid-build MILCON projects experienced a significant increase in average cost growths from FY05-06 to FY07-08 and FY09-10, yet subsequently saw a similar degree of decreased cost growth from FY09-10 to FY11-12 and FY13-14. This fluctuation matches the trend seen in design-build project cost growths. While the historical trends of design-bid-build cost growth performance were significant, no such findings were observed in the facility type or managing MAJCOM analyses. Ultimately this points to a general consistency in the degree of cost growths regardless of project type and managing command from FY 2003-2014.

CWE/PA Ratio

The historical trend seen in the design-build CWE/PA ratio performance was also observed in design-bid-build project delivery. A significant decrease in mean CWE/PA ratios was observed from FY05-06 to FY09-10 and FY11-12, ultimately demonstrating a trend of improved cost estimating during those periods of time. However, traditionally delivered projects saw a noteworthy increase again between FY09-10 and FY13-14, marking a more recent shift away from the Air Force's CWE/PA ratio goal of 0.97 (Air Force Civil Engineer Center Integration Cell, 2015). While this shift is significant, the degree of CWE/PA ratio increase between FY09-10 and FY13-14 may be due to the limited sample size in FY13-14 (15 design-bid-build projects). The facility type and managing MAJCOM analyses failed to identify any significant findings, which ultimately marks a general level of consistency in cost estimating performance from FY 2003-2014, regardless of project type or managing command.

Schedule Growth

There were ultimately no significant historical trends in design-bid-build schedule growth performance found between 2003-2014, which indicates a level of overall consistency in the ability of Air Force project managers to accurately plan project schedules during that time. The facility type and managing MAJCOM analyses also provide little definitive proof of varying levels of average design-bid-build performance as no noticeable findings were observed across these categories. The lack of significant historical trends for schedule growth in design-bid-build projects mirrors findings found in design-build projects. MILCON schedule growth levels remained very consistent from FY 2003 to 2014, regardless of delivery method selection.

Unit Cost

No significant historical trends were identified when examining traditionally delivered projects from FY 2003 to 2014. Instead, average unit costs fluctuated with a slight relative increased shift in the more recent fiscal year categories. Another analysis found the average airfield pavement project to have significantly lower unit costs than three of the five other facility types. Airfield pavement projects have relatively simple designs when compared to many forms of vertical construction; therefore, it is not surprising that this facility type had a more desirable average unit cost than its peers. Finally, design-bid-build projects managed by AETC had significantly lower average unit costs than those managed within three other MAJCOMs. It is unclear why the average AETC project experienced such a low unit cost compared to those managed within other MAJCOMs, as there were no anomalies found in specific AETC installations or project types.

Modifications per Million Dollars

Ultimately, the average number of modifications in design-bid-build projects was greater than those seen in design-build projects over time. However, historical trends in design-bid-build projects were less apparent, as FY07-08 was the only year group found to experience a significantly lower average number of modifications per million dollars than that of the average FY03-04 project. Another noteworthy trend in airfield pavement projects was identified when comparing the change order performance of various facility types. The average airfield pavement project was characterized by far fewer modifications than every other facility type in FY 2003-2014. Once again, this is not overly surprising because the relatively simple designs of airfield pavement projects do not warrant as many modifications as the more complex designs of other project types. Dormitories, officer quarters, and dining halls were also found to have a significantly increased average number of modifications when compared to community support facilities. However, this comparison was identified at a relatively high p-value, thus indicating a lower degree of significance. The sample size of community support facilities was also less than half that of dormitories, officer quarters and dining halls.

Finally, the average projects managed within AFSOC and AFGSC experienced significantly more modifications than those managed within three other MAJCOMs. As seen in the design-build comparison, AFGSC was observed to have generally increased modifications counts compared to most other MAJCOMs.

Construction Speed

The average construction speed of design-bid-build projects was found to be statistically consistent during FY2003-2014, as indicated by a lack of significant findings during the year group comparisons. However, dormitories, officer quarters, and dining halls were constructed at a much faster average rate than maintenance and community support facilities. Once again, the homogenous designs of dormitories, quarters, and dining halls may also provide an advantage over less-uniform facility types, thus allowing for more expedient construction processes and overall shortened timelines. These findings mirror that of the delivery speed comparison for design-build facility types. Finally, while the average construction speed of projects managed within ACC was not the lowest among MAJCOMs, it was found to be significantly slower than the average rates of projects constructed within AETC and AMC. This anomaly may be explained by the relatively small sample size of traditional AETC and AMC projects included in this analysis.

Project Duration

The investigation of design-bid-build project duration over time failed to produce significant findings. Likewise, no noticeable differences were discovered between project durations of different facility types and managing MAJCOMs. The lack of findings in each of these three variables reveals a consistency in the overall performance of design-bid-build projects.

Project Duration: A Comparison of Delivery Method Performance

Because the milestones used to calculate a project's overall design and construction activity duration are common to both design-build and design-bid-build projects, an equivalent comparison of the average project duration of each delivery method was conducted in this study. The primary intent of this comparison was to determine which delivery method performed better using this metric. As discussed in Chapter IV, the overall direct comparison of mean project durations between delivery methods yielded insignificant results, suggesting that despite the delivery method selection, there is no significant difference in the average MILCON project duration from the date of initial design instruction to beneficial occupancy. While design-build is often hailed by many industry experts as a more expedient method for project delivery, the analysis of Air Force project data from FY2003 to 2014 failed to support a similar claim in the military construction sector. The concrete planning, programming, and funding milestones that are unique to the beginning of the MILCON process prevent the expected benefits of design-build delivery from coming to fruition. Although the development of a design-build RFP does not consume as much time as a traditional design, the awards of both delivery types are still initiated at the start of the new fiscal year in October.

Significance of Research

The examination of 580 MILCON projects (264 design-bid-build and 316 design-build) provides Air Force MILCON project delivery teams a lens through which to analyze the benefits and disadvantages of each project delivery method based on past project execution. Results within this research will help AFCEC decision-makers identify performance-based trends for each delivery approach with respect to time, facility type and managing command. This research also presents a list of key performance indicators as a foundation for a project delivery performance assessment framework. Air Force planners now have concrete means to adequately compare Air Force MILCON project delivery strategies.

Research Limitations

There were several specific limitations associated with this thesis. Most of these limitations stem from the reliance on project data from the Air Force's ACES-PM MILCON database. The foundation of this statistical analysis was based on the notion that the data in ACES-PM are regularly scrutinized by multiple levels of management and that the resulting data are both current and accurate.

More importantly the ACES-PM module was developed to track traditionally delivered projects and fails to capture specific project cost fields and schedule milestones that are unique to design-build delivery. Air Force project managers are directed to track MILCON project timelines based on two distinct dates, from NTP to the BOD (Air Force Civil Engineer Center Integration Cell, 2015). However, while the period from NTP to BOD for design-bid-build projects reflects the construction timeline, this period represents both the design and construction timelines for projects delivered by design-build. Therefore, to make an unbiased assessment of project delivery method performance, this research did not directly compare most key performance indicators across opposing project delivery methods. Instead, the only measure used to equivalently compare project delivery strategies was project duration.

Another limitation associated with this research was the limited amount of Air Force MILCON projects across the three chosen independent variables. Some of the facility and MAJCOM categories investigated in this study were considered statistically small sample sizes. Therefore, the significant findings presented in this research must be interpreted with this limitation in mind.

Additionally, this analysis is strictly empirical in nature. While explanatory suggestions were offered, this thesis did not investigate causal relationships between factors of interest. The reasons for contract modifications are also not universally tracked within ACES-PM; therefore, an assumption is made that considers all modifications to be results of factors with detrimental impact to the project and its timeline. Performance measure analysis may also be limited by the extent of the data fields tracked within ACES-PM.

Finally, the aggregated list of industry-proven key performance measures was gathered through an extensive literature review of past research related to project delivery methods. The extracted indicators were based on a convenient random sampling and a consensus of industry experts. Moreover, the causal impacts of these measures were not statistically verified in the current thesis.

Recommendations for Action

The extent of MILCON project data tracked by the ACES-PM module considerably limits the ability of Air Force project managers to effectively measure project delivery performance. While this study included an investigation of the performance of each individual delivery approach, direct comparisons of delivery strategies cannot currently be made. This research revealed eight key performance indicators that will benefit Air Force project managers in future project delivery performance evaluations. However, the value in using these indicators will always be limited by the robustness of the data that they measure.

To conduct effective project delivery comparisons that are beneficial to MILCON delivery method selection, Air Force project managers must develop a way to capture key schedule milestones, cost attributes and change order characteristics that are representative of both delivery approaches. In other words, improving the current business operations of Air Force MILCON project management requires an information technology (IT) system that tracks project data fields that are much more robust than the current ACES-PM interfaces allows. Such fields should include specific design completion and construction start schedule milestones for design-build projects. This would allow for equivalent comparative analyses of design-build project delivery schedule performance with that of traditional design-bid build projects. Additionally, detailed cost attributes that are specific to the design and construction phases of a MILCON project would enable project managers to directly compare cost performance measures across both delivery methods. Likewise, Air Force project managers must also track MILCON project change orders in much greater detail than what is currently monitored. Specifying the positive or negative financial impact of project modifications and detailing the project phase in which they occur will provide a means for equivalent project delivery performance comparisons.

On November 2nd, 2015, the Air Force Office of the Civil Engineer launched NexGen IT/TRIRIGA, the service's enterprise wide civil engineering IT solution (AFCEC Public Affairs, 2015) that will eventually replace the ACES-PM module for MILCON project data management. While widespread implementation of TRIRIGA has yet to take place, the inevitable departure from the ACES-PM module is imminent. Before its complete implementation, the AFCEC should ensure the NexGen IT/TRIRIGA system effectively tracks these key schedule, cost and change order attributes; this will ensure that only truly valuable information is captured and stored in this system.

Additionally, Air Force project managers must begin including specific data tracking line items in design and construction contracts. In requiring a design-build contractor to particularly track cost, schedule and change order characteristics that are specific to one project phase can be examined independently from other phases. Tracking design costs in design-build projects will allow for equivalent performance comparisons with the traditional design-bid-build method. The same is true for design-build schedule milestones and modifications that occur in the design phase of a MILCON project. The inclusion of these elements in design-build MILCON contracts will provide a higher confidence in the quality of the project data than what is currently enjoyed. Additionally, these elements will provide a basis for effective comparisons of project delivery performance across delivery approaches.

Topics for Future Research

Several topics for future research emerge from this study that would benefit the Air Force civil engineering community.

1. Overseas Project Delivery Method Performance Analysis: There have been several studies that have compared MILCON project delivery methods for CONUS projects, yet there has never been a study that has examined overseas project data. Future research that explores Air Force MILCON project delivery method performance outside of the United States would benefit commands like PACAF and United States Air Forces in Europe-Air Forces Africa (USAFE-AFAFRICA).

2. Quality Performance Measures: The findings of this study were limited by statistical analysis of quantitative MILCON project data. However, project delivery performance has also been investigated by industry experts using qualitative measures. Future research that explores quality measures as they apply to Air Force MILCON project performance using surveys or interviews of facility owners will capture critical data not previously studied in a MILCON setting.

3. Project Size Analysis: While many past industry and MILCON studies have focused on a variety of project performance measures, few have examined the effect of scope size on project performance. Future research that examines the responses of project performance measures across a distinct array of project sizes

will aid Air Force project managers in improving their delivery of MILCON projects at each scope level.

4. Project Delivery Performance Based on Air Force Ribbon Cutter Criteria: The Air Force's required project performance levels are currently expressed in its Ribbon Cutter Criteria. This project evaluation tool presents key milestones and project characteristics that Air Force civil engineers have recognized as key elements to MILCON project success. Future research that uses the Ribbon Cutter to calculate performance scores based on the weighted importance of each milestone will allow Air Force project managers to determine which delivery method best achieves their MILCON program goals.

5. Project Delivery Method Selection Tool: The development of a decision support systems for selecting the proper project delivery method has been recently explored throughout the construction industry. Future research that investigates the use of Value Focused Thinking (VFT), the Analytical Hierarchy Process (AHP), or other frameworks for delivery method selection will benefit Air Force project managers by proposing a selection tool tailored to Air Force project delivery goals.

Summary

This chapter presented the conclusions of this research based off the investigative questions introduced in Chapter I of this thesis. The study's significance and limitations were also thoroughly discussed. Finally, recommendations for future research were proposed as means to improve the Air Force's execution of MILCON project delivery.

Appendix A: Cost Growth Results Summary

Performance Measure	PDM	Fiscal Year (FY)				Facility Type				Major Command (MAJCOM)			
		Level		-Level	P-Value	Level		-Level	P-Value	Level		-Level	P-Value
Cost Growth (%)	Design-Build (DB)	FY09-10	>	FY05-06	0.0115	No Signficant Findings				AFSOC	>	ACC	0.0190
												AETC	0.0002
												AFGSC	0.0005
												AFMC	0.0016
												AFSPC	0.0008
				FY11-12	0.0327							AMC	0.0045
												PACAF	0.0030
										ACC	>	AETC	0.0051
												AFGSC	0.0222
												AFSPC	0.0392
	Trends:	N/A				Consistency Across Facility Type				AFSOC: Small Sample Size (9)			
	Design-Bid-Build (DBB)	FY07-08	>	FY05-06	0.0434	No Signficant Findings				No Signficant Findings			
		FY09-10	>	FY05-06	0.0003								
				FY11-12	0.0135								
				FY13-14	0.0089								
	Trends:	N/A				Consistency Across Facility Type				N/A			

Appendix B: CWE/PA Ratio Results Summary

Performance Measure	PDM	Fiscal Year (FY)				Facility Type				Major Command (MAJCOM)			
		Level		-Level	P-Value	Level		-Level	P-Value	Level		-Level	P-Value
CWE/PA Ratio	Design-Build (DB)	FY05-06	>	FY09-10	0.0028	No Signficant Findings				AETC	>	ACC	0.0448
				FY11-12	0.0011								
	Trends:	Ratio Improves After FY05-06				Consistency Across Facility Type				Consistency Across MAJCOMs			
	Design-Bid-Build (DBB)	FY05-06	>	FY09-10	<.0001	No Signficant Findings				No Signficant Findings			
				FY11-12	0.0017								
		FY13-14	>	FY09-10	0.0302								
	Trends:	N/A				Consistency Across Facility Type				Consistency Across MAJCOMs			

Appendix C: Schedule Growth Results Summary

Performance Measure	PDM	Fiscal Year (FY)				Facility Type				Major Command (MAJCOM)			
		Level		-Level	P-Value	Level		-Level	P-Value	Level		-Level	P-Value
Schedule Growth (%)	Design-Build (DB)	No Signficant Findings				No Signficant Findings				No Signficant Findings			
	Trends:	Consistent Performance Over Time				Consistency Across Facility Type				Generally ACC Performs Worse Than Others			
	Design-Bid-Build (DBB)	No Signficant Findings				No Signficant Findings				No Signficant Findings			
	Trends:	Consistent Performance Over Time				Consistency Across Facility Type				Generally AETC Performs Worse Than Others			

Appendix D: Unit Cost Results Summary

Performance Measure	PDM	Fiscal Year (FY)				Facility Type				Major Command (MAJCOM)			
		Level		-Level	P-Value	Level		-Level	P-Value	Level		-Level	P-Value
Unit Cost ($/SM)	**Design-Build (DB)**	No Signficant Findings				No Signficant Findings				PACAF	>	ACC	<.0001
												AETC	<.0001
												AFGSC	<.0001
												AFMC	<.0001
												AFSOC	<.0001
												AFSPC	<.0001
												AMC	<.0001
										AMC	>	AFMC	0.0097
	Trends:	N/A				N/A				PACAF Performed Poorer Than All MAJCOMs			
	Design-Bid-Build (DBB)	No Signficant Findings				Airfield Pavements	<	Operations	0.0131	AETC	<	ACC	0.0339
								Maintenance	0.0107			AFSPC	0.0258
								Training	0.0289			AMC	0.0362
	Trends:	General Improvement Over Time				Airfield Pavements: Small Sample Size (12)				N/A			

Appendix E: Modifications per Million Dollars Results Summary

Performance Measure	PDM	Fiscal Year (FY) Level		Fiscal Year (FY) -Level	Fiscal Year (FY) P-Value	Facility Type Level		Facility Type -Level	Facility Type P-Value	Major Command (MAJCOM) Level		Major Command (MAJCOM) -Level	Major Command (MAJCOM) P-Value
Modifications Per Million (Mods/$M)	**Design-Build (DB)**	FY07-08	<	FY03-04	0.0489	No Signficant Findings				AFGSC	>	AFMC	0.0486
				FY05-06	0.0117								
				FY09-10	0.0043								
				FY11-12	0.0367								
		FY13-14	<	FY03-04	0.0269								
				FY05-06	0.0109								
				FY09-10	0.0068								
				FY11-12	0.0261								
	Trends:	N/A				N/A				N/A			
	Design-Bid-Build (DBB)	FY03-04	>	FY07-08	0.0366	Airfield Pavements	<	Community Support	<.0001	AFSOC	>	ACC	0.0021
								Dorms, Qrts, Dining	0.0047			AETC	<.0001
								Maintenance	0.0002			AMC	<.0001
								Operations	<.0001	AFGSC	>	ACC	0.0301
								Personnel Support	0.0006			AETC	0.0006
								Training	0.0006			AMC	0.0014
						Dorms, Qrts, Dining	<	Community Support	0.0485				
	Trends:	N/A				Airfield Pavements: Small Sample Size (16)				N/A			

Appendix F: Construction Speed Results Summary

Performance Measure	PDM	Fiscal Year (FY)				Facility Type				Major Command (MAJCOM)			
		Level		-Level	P-Value	Level		-Level	P-Value	Level		-Level	P-Value
Construction Speed (SM/Month)	Design-Bid-Build (DBB)	No Signficant Findings				Dorms, Quarters, Dining	>	Community Support	0.0370	ACC	<	AETC	0.0256
								Maintenance	0.0281			AMC	0.0403
	Trends:	N/A				Dorms, Quarters, Dining: Small Sample Size (17)				N/A			

Appendix G: Delivery Speed Results Summary

Performance Measure	PDM	Fiscal Year (FY)				Facility Type				Major Command (MAJCOM)			
		Level		-Level	P-Value	Level		-Level	P-Value	Level		-Level	P-Value
Delivery Speed (SM/Month)	Design-Build (DB)	No Signficant Findings				Dorms, Quarters, Dining	>	Community Support	0.0287	No Signficant Findings			
								Operations	0.0362				
								Personnel Support	0.0326				
								Training	0.0044				
						Administrative	>	Training	0.0093				
	Trends:	Consistent Performance Over Time				Dorms, Quarters, Dining: Small Sample Size (13)				Consistency Across MAJCOMs			

Appendix H: Project Duration Results Summary

Performance Measure	PDM	Fiscal Year (FY)				Facility Type				Major Command (MAJCOM)			
		Level		-Level	P-Value	Level		-Level	P-Value	Level		-Level	P-Value
Project Duration (Days)	Design-Build (DB)	FY09-10	<	FY05-06	0.0050	No Signficant Findings				AFSOC	>	AETC	0.0291
				FY07-08	0.0283							AFGSC	0.0089
				FY11-12	0.0010							AFSPC	0.0293
				FY13-14	0.0015							AMC	0.0117
		FY03-04	<	FY13-14	0.0302							PACAF	0.0473
	Trends:	N/A				N/A				AFSOC: Small Sample Size (9)			
	Design-Bid-Build (DBB)	No Signficant Findings				No Signficant Findings				No Signficant Findings			
	Trends:	Consistent Performance Over Time				N/A				Generally AFGSC Performs Better Than Others			

Appendix I: Design-Build (DB) Cost Growth by Fiscal Year

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
FY 03-04	FY 05-06	18	55	1.532	2.286	-2.965	6.030	0.503
	FY 07-08		55	0.046	2.286	-4.452	4.543	0.984
	FY 09-10		107	2.017	2.144	-2.202	6.237	0.348
	FY 11-12		60	0.896	2.262	-3.555	5.347	0.692
	FY 13-14		20	0.541	2.735	-4.840	5.922	0.843
FY 05-06	FY 03-04	55	18	1.532	2.286	-2.965	6.030	0.503
	FY 07-08		55	1.578	1.605	-1.580	4.737	0.326
	FY 09-10		107	3.550	1.397	0.802	6.298	0.0115*
	FY 11-12		60	0.637	1.571	-2.455	3.729	0.686
	FY 13-14		20	2.073	2.198	-2.251	6.398	0.346
FY 07-08	FY 03-04	55	18	0.046	2.286	-4.452	4.543	0.984
	FY 05-06		55	1.578	1.605	-1.580	4.737	0.326
	FY 09-10		107	1.972	1.397	-0.776	4.720	0.159
	FY 11-12		60	0.941	1.571	-2.150	4.033	0.550
	FY 13-14		20	0.495	2.198	-3.829	4.820	0.822
FY 09-10	FY 03-04	107	18	2.017	2.144	-2.202	6.237	0.348
	FY 05-06		55	3.550	1.397	0.802	6.298	0.0115*
	FY 07-08		55	1.972	1.397	-0.776	4.720	0.159
	FY 11-12		60	2.913	1.358	0.242	5.584	0.0327*
	FY 13-14		20	1.476	2.051	-2.558	5.511	0.472
FY 11-12	FY 03-04	60	18	0.896	2.262	-3.555	5.347	0.692
	FY 05-06		55	0.637	1.571	-2.455	3.729	0.686
	FY 07-08		55	0.941	1.571	-2.150	4.033	0.550
	FY 09-10		107	2.913	1.358	0.242	5.584	0.0327*
	FY 13-14		20	1.437	2.173	-2.840	5.713	0.509
FY 13-14	FY 03-04	20	18	0.541	2.735	-4.840	5.922	0.843
	FY 05-06		55	2.073	2.198	-2.251	6.398	0.346
	FY 07-08		55	0.495	2.198	-3.829	4.820	0.822
	FY 09-10		107	1.476	2.051	-2.558	5.511	0.472
	FY 11-12		60	1.437	2.173	-2.840	5.713	0.509

Appendix J: Design-Bid-Build (DBB) Cost Growth by Fiscal Year

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
FY 03-04	FY 05-06	36	68	2.276	1.894	-1.453	6.006	0.231
	FY 07-08		58	1.057	1.949	-2.782	4.896	0.588
	FY 09-10		54	3.884	1.977	-0.009	7.777	0.051
	FY 11-12		31	1.263	2.251	-3.170	5.697	0.575
	FY 13-14		15	3.190	2.824	-2.371	8.750	0.260
FY 05-06	FY 03-04	68	36	2.276	1.894	-1.453	6.006	0.231
	FY 07-08		58	3.333	1.642	0.099	6.568	0.0434*
	FY 09-10		54	6.161	1.675	2.862	9.459	0.0003*
	FY 11-12		31	1.013	1.991	-2.908	4.934	0.611
	FY 13-14		15	0.913	2.621	-4.248	6.075	0.728
FY 07-08	FY 03-04	58	36	1.057	1.949	-2.782	4.896	0.588
	FY 05-06		68	3.333	1.642	0.099	6.568	0.0434*
	FY 09-10		54	2.827	1.737	-0.595	6.249	0.105
	FY 11-12		31	2.320	2.044	-1.705	6.346	0.257
	FY 13-14		15	4.247	2.661	-0.994	9.488	0.112
FY 09-10	FY 03-04	54	36	3.884	1.977	-0.009	7.777	0.051
	FY 05-06		68	6.161	1.675	2.862	9.459	0.0003*
	FY 07-08		58	2.827	1.737	-0.595	6.249	0.105
	FY 11-12		31	5.147	2.070	1.070	9.225	0.0135*
	FY 13-14		15	7.074	2.682	1.793	12.355	0.0089*
FY 11-12	FY 03-04	31	36	1.263	2.251	-3.170	5.697	0.575
	FY 05-06		68	1.013	1.991	-2.908	4.934	0.611
	FY 07-08		58	2.320	2.044	-1.705	6.346	0.257
	FY 09-10		54	5.147	2.070	1.071	9.225	0.0135*
	FY 13-14		15	1.926	2.890	-3.764	7.617	0.506
FY 13-14	FY 03-04	15	36	3.190	2.824	-2.371	8.750	0.260
	FY 05-06		68	0.913	2.621	-4.248	6.075	0.728
	FY 07-08		58	4.247	2.661	-0.994	9.488	0.112
	FY 09-10		54	7.074	2.682	1.793	12.355	0.0089*
	FY 11-12		31	1.926	2.890	-3.765	7.617	0.506

Appendix K: Design-Build (DB) Cost Growth by Facility Type

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
ADMINISTRATIVE	COMMUNITY SUPPORT	26	25	0.231	2.047	-5.853	6.315	1.000
	DORMS, QUARTERS, DINING HALLS		25	2.715	2.047	-3.369	8.799	0.839
	MAINTENANCE		71	0.839	1.675	-4.140	5.818	0.999
	OPERATIONS		46	1.374	1.793	-3.955	6.703	0.988
	PERSONNEL SUPPORT		30	0.588	1.958	-5.232	6.408	1.000
	TRAINING		43	0.938	1.816	-4.458	6.334	0.999
COMMUNITY SUPPORT	ADMINISTRATIVE	25	26	0.231	2.047	-5.853	6.315	1.000
	DORMS, QUARTERS, DINING HALLS		25	2.484	2.067	-3.660	8.628	0.893
	MAINTENANCE		71	0.608	1.700	-4.443	5.659	1.000
	OPERATIONS		46	1.605	1.816	-3.792	7.002	0.975
	PERSONNEL SUPPORT		30	0.357	1.979	-5.525	6.239	1.000
	TRAINING		43	0.707	1.838	-4.756	6.170	1.000
DORMS, QUARTERS, DINING HALLS	ADMINISTRATIVE	25	26	2.715	2.047	-3.369	8.799	0.839
	COMMUNITY SUPPORT		25	2.484	2.067	-3.660	8.628	0.893
	MAINTENANCE		71	1.876	1.700	-3.175	6.927	0.927
	OPERATIONS		46	4.089	1.816	-1.308	9.486	0.272
	PERSONNEL SUPPORT		30	2.127	1.979	-3.755	8.009	0.935
	TRAINING		43	1.777	1.838	-3.686	7.240	0.961
MAINTENANCE	ADMINISTRATIVE	71	26	0.839	1.675	-4.140	5.818	0.999
	COMMUNITY SUPPORT		25	0.608	1.700	-4.443	5.659	1.000
	DORMS, QUARTERS, DINING HALLS		25	1.876	1.700	-3.175	6.927	0.927
	OPERATIONS		46	2.213	1.383	-1.898	6.324	0.683
	PERSONNEL SUPPORT		30	0.251	1.592	-4.479	4.981	1.000
	TRAINING		43	0.099	1.412	-4.098	4.296	1.000
OPERATIONS	ADMINISTRATIVE	46	26	1.374	1.793	-3.955	6.703	0.988
	COMMUNITY SUPPORT		25	1.605	1.816	-3.792	7.002	0.975
	DORMS, QUARTERS, DINING HALLS		25	4.089	1.816	-1.308	9.486	0.272
	MAINTENANCE		71	2.213	1.383	-1.898	6.324	0.683
	PERSONNEL SUPPORT		30	1.962	1.715	-3.136	7.059	0.914
	TRAINING		43	2.312	1.550	-2.296	6.919	0.750
PERSONNEL SUPPORT	ADMINISTRATIVE	30	26	0.588	1.958	-5.232	6.408	1.000
	COMMUNITY SUPPORT		25	0.357	1.979	-5.525	6.239	1.000
	DORMS, QUARTERS, DINING HALLS		25	2.127	1.979	-3.755	8.009	0.935
	MAINTENANCE		71	0.251	1.592	-4.479	4.981	1.000
	OPERATIONS		46	1.962	1.715	-3.136	7.059	0.914
	TRAINING		43	0.350	1.739	-4.817	5.517	1.000
TRAINING	ADMINISTRATIVE	43	26	0.938	1.816	-4.458	6.334	0.999
	COMMUNITY SUPPORT		25	0.707	1.838	-4.756	6.170	1.000
	DORMS, QUARTERS, DINING HALLS		25	1.777	1.838	-3.686	7.240	0.961
	MAINTENANCE		71	0.099	1.412	-4.098	4.296	1.000
	OPERATIONS		46	2.312	1.550	-2.296	6.919	0.750
	PERSONNEL SUPPORT		30	0.350	1.739	-4.817	5.517	1.000

Appendix L: Design-Bid-Build (DBB) Cost Growth by Facility Type

Level	- Level	Observations		Mean	Std Error	95% Confidence Interval		Significance
		Level	- Level	Difference		Lower Bound	Upper Bound	(p-value)
AIRFIELD PAVEMENTS	COMMUNITY SUPPORT	16	15	4.064	3.003	-4.878	13.007	0.826
	DORMS, QUARTERS, DINING HALLS		32	3.691	2.558	-3.927	11.309	0.778
	MAINTENANCE		50	3.703	2.400	-3.443	10.850	0.718
	OPERATIONS		34	0.502	2.533	-7.041	8.045	1.000
	PERSONNEL SUPPORT		20	3.560	2.802	-4.785	11.906	0.865
	TRAINING		44	2.175	2.439	-5.089	9.438	0.974
COMMUNITY SUPPORT	AIRFIELD PAVEMENTS	15	16	4.064	3.003	-4.878	13.007	0.826
	DORMS, QUARTERS, DINING HALLS		32	0.373	2.614	-7.412	8.159	1.000
	MAINTENANCE		50	0.361	2.460	-6.963	7.686	1.000
	OPERATIONS		34	3.563	2.590	-4.150	11.275	0.814
	PERSONNEL SUPPORT		20	0.504	2.854	-7.994	9.003	1.000
	TRAINING		44	1.890	2.498	-5.549	9.329	0.989
DORMS, QUARTERS, DINING HALLS	AIRFIELD PAVEMENTS	32	16	3.691	2.558	-3.927	11.309	0.778
	COMMUNITY SUPPORT		15	0.373	2.614	-7.412	8.159	1.000
	MAINTENANCE		50	0.012	1.891	-5.620	5.645	1.000
	OPERATIONS		34	3.189	2.058	-2.939	9.317	0.714
	PERSONNEL SUPPORT		20	0.131	2.381	-6.961	7.223	1.000
	TRAINING		44	1.516	1.941	-4.264	7.297	0.987
MAINTENANCE	AIRFIELD PAVEMENTS	50	16	3.703	2.400	-3.443	10.850	0.718
	COMMUNITY SUPPORT		15	0.361	2.460	-6.963	7.686	1.000
	DORMS, QUARTERS, DINING HALLS		32	0.012	1.891	-5.620	5.645	1.000
	OPERATIONS		34	3.201	1.857	-2.329	8.732	0.601
	PERSONNEL SUPPORT		20	0.143	2.210	-6.440	6.726	1.000
	TRAINING		44	1.529	1.727	-3.614	6.672	0.975
OPERATIONS	AIRFIELD PAVEMENTS	34	16	0.502	2.533	-7.041	8.045	1.000
	COMMUNITY SUPPORT		15	3.563	2.590	-4.150	11.275	0.814
	DORMS, QUARTERS, DINING HALLS		32	3.189	2.058	-2.939	9.317	0.714
	MAINTENANCE		50	3.201	1.857	-2.329	8.732	0.601
	PERSONNEL SUPPORT		20	3.058	2.354	-3.953	10.070	0.852
	TRAINING		44	1.673	1.908	-4.009	7.354	0.976
PERSONNEL SUPPORT	AIRFIELD PAVEMENTS	20	16	3.560	2.802	-4.785	11.906	0.865
	COMMUNITY SUPPORT		15	0.504	2.854	-7.994	9.003	1.000
	DORMS, QUARTERS, DINING HALLS		32	0.131	2.381	-6.961	7.223	1.000
	MAINTENANCE		50	0.143	2.210	-6.440	6.726	1.000
	OPERATIONS		34	3.058	2.354	-3.953	10.070	0.852
	TRAINING		44	1.386	2.253	-5.324	8.095	0.996
TRAINING	AIRFIELD PAVEMENTS	44	16	2.175	2.439	-5.089	9.438	0.974
	COMMUNITY SUPPORT		15	0.504	2.854	-7.994	9.003	1.000
	DORMS, QUARTERS, DINING HALLS		32	0.131	2.381	-6.961	7.223	1.000
	MAINTENANCE		50	0.143	2.210	-6.440	6.726	1.000
	OPERATIONS		34	1.673	1.908	-4.009	7.354	0.976
	PERSONNEL SUPPORT		20	1.386	2.253	-5.324	8.095	0.996

Appendix M: Design-Build (DB) Cost Growth by MAJCOM

Level	- Level	Observations		Mean	Std Error	95% Confidence Interval		Significance
		Level	- Level	Difference		Lower Bound	Upper Bound	(p-value)
	AETC		58	4.215	1.495	1.273	7.158	0.0051*
	AFGSC		25	4.493	1.954	0.648	8.338	0.0222*
	AFMC		55	2.590	1.517	-0.395	5.575	0.089
ACC	AFSOC	67	9	6.980	2.960	1.155	12.805	0.0190*
	AFSPC		15	4.933	2.381	0.246	9.619	0.0392*
	AMC		53	1.628	1.533	-1.388	4.644	0.289
	PACAF		23	2.827	2.015	-1.138	6.792	0.162
	ACC		67	4.215	1.495	1.273	7.158	0.0051*
	AFGSC		25	0.278	1.995	-3.648	4.203	0.889
	AFMC		55	1.625	1.569	-1.463	4.713	0.301
AETC	AFSOC	58	9	11.195	2.987	5.317	17.073	0.0002*
	AFSPC		15	0.717	2.415	-4.035	5.470	0.767
	AMC		53	2.587	1.584	-0.531	5.705	0.104
	PACAF		23	1.388	2.054	-2.655	5.431	0.500
	ACC		67	4.493	1.954	0.648	8.338	0.0222*
	AETC		58	0.278	1.995	-3.648	4.203	0.889
	AFMC		55	1.903	2.011	-2.055	5.860	0.345
AFGSC	AFSOC	25	9	11.473	3.241	5.095	17.851	0.0005*
	AFSPC		15	0.440	2.723	-4.919	5.798	0.872
	AMC		53	2.865	2.023	-1.116	6.845	0.158
	PACAF		23	1.666	2.409	-3.075	6.406	0.490
	ACC		67	2.590	1.517	-0.395	5.575	0.089
	AETC		58	1.625	1.569	-1.463	4.713	0.301
	AFGSC		25	1.903	2.011	-2.055	5.860	0.345
AFMC	AFSOC	55	9	9.570	2.998	3.670	15.469	0.0016*
	AFSPC		15	2.343	2.428	-2.436	7.122	0.336
	AMC		53	0.962	1.605	-2.196	4.120	0.549
	PACAF		23	0.237	2.070	-3.837	4.311	0.909
	ACC		67	6.980	2.960	1.155	12.805	0.0190*
	AETC		58	11.195	2.987	5.317	17.073	0.0002*
	AFGSC		25	11.473	3.241	5.095	17.851	0.0005*
AFSOC	AFMC	9	55	9.570	2.998	3.670	15.469	0.0016*
	AFSPC		15	11.913	3.515	4.995	18.830	0.0008*
	AMC		53	8.608	3.006	2.693	14.523	0.0045*
	PACAF		23	9.807	3.278	3.356	16.258	0.0030*
	ACC		67	4.933	2.381	0.246	9.619	0.0392*
	AETC		58	0.717	2.415	-4.035	5.470	0.767
	AFGSC		25	0.440	2.723	-4.919	5.798	0.872
AFSPC	AFMC	15	55	2.343	2.428	-2.436	7.122	0.336
	AFSOC		9	11.913	3.515	4.995	18.830	0.0008*
	AMC		53	3.304	2.438	-1.494	8.103	0.176
	PACAF		23	2.106	2.767	-3.340	7.551	0.447
	ACC		67	1.628	1.533	-1.388	4.644	0.289
	AETC		58	2.587	1.584	-0.531	5.705	0.104
	AFGSC		25	2.865	2.023	-1.116	6.845	0.158
AMC	AFMC	53	55	0.962	1.605	-2.196	4.120	0.549
	AFSOC		9	8.608	3.006	2.693	14.523	0.0045*
	AFSPC		15	3.304	2.438	-1.494	8.103	0.176
	PACAF		23	1.199	2.082	-2.898	5.296	0.565
	ACC		67	2.827	2.015	-1.138	6.792	0.162
	AETC		58	1.388	2.054	-2.655	5.431	0.500
	AFGSC		25	1.666	2.409	-3.075	6.406	0.490
PACAF	AFMC	15	55	0.237	2.070	-3.837	4.311	0.909
	AFSOC		9	9.807	3.278	3.356	16.258	0.0030*
	AFSPC		15	2.106	2.767	-3.340	7.551	0.447
	AMC		53	1.199	2.082	-2.898	5.296	0.565

Appendix N: Design-Bid-Build (DBB) Cost Growth by MAJCOM

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
ACC	AETC	70	57	0.427	1.580	-4.111	4.965	1.000
	AFGSC		22	1.912	2.164	-4.305	8.128	0.950
	AFSOC		36	2.516	1.816	-2.700	7.733	0.736
	AFSPC		12	1.194	2.766	-6.753	9.141	0.998
	AMC		49	1.575	1.649	-3.163	6.312	0.932
AETC	ACC	57	70	0.427	1.580	-4.111	4.965	1.000
	AFGSC		22	2.339	2.222	-4.045	8.723	0.899
	AFSOC		36	2.943	1.885	-2.471	8.358	0.625
	AFSPC		12	1.621	2.812	-6.458	9.699	0.993
	AMC		49	2.002	1.725	-2.953	6.957	0.855
AFGSC	ACC	22	70	1.912	2.164	-4.305	8.128	0.950
	AETC		57	2.339	2.222	-4.045	8.723	0.899
	AFSOC		36	0.605	2.396	-6.278	7.488	1.000
	AFSPC		12	0.718	3.177	-8.410	9.846	1.000
	AMC		49	0.337	2.272	-6.191	6.865	1.000
AFSOC	ACC	36	70	2.516	1.816	-2.700	7.733	0.736
	AETC		57	2.943	1.885	-2.471	8.358	0.625
	AFGSC		22	0.605	2.396	-6.278	7.488	1.000
	AFSPC		12	1.323	2.951	-7.156	9.801	0.998
	AMC		49	0.942	1.943	-4.641	6.525	0.997
AFSPC	ACC	12	70	1.194	2.766	-6.753	9.141	0.998
	AETC		57	1.621	2.812	-6.458	9.699	0.993
	AFGSC		22	0.718	3.177	-8.410	9.846	1.000
	AFSOC		36	1.323	2.951	-7.156	9.801	0.998
	AMC		49	0.381	2.852	-7.811	8.573	1.000
AMC	ACC	49	70	1.575	1.649	-3.163	6.312	0.932
	AETC		57	2.002	1.725	-2.953	6.957	0.855
	AFGSC		22	0.337	2.272	-6.191	6.865	1.000
	AFSOC		36	0.942	1.943	-4.641	6.525	0.997
	AFSPC		12	0.381	2.852	-7.811	8.573	1.000

Appendix O: Design-Build (DB) CWE/PA Ratio by Fiscal Year

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
FY 03-04	FY 05-06	18	55	0.033	0.049	-0.107	0.173	0.984
	FY 07-08		55	0.051	0.049	-0.089	0.190	0.905
	FY 09-10		107	0.079	0.046	-0.052	0.210	0.515
	FY 11-12		60	0.101	0.048	-0.037	0.240	0.291
	FY 13-14		20	0.029	0.058	-0.139	0.196	0.997
FY 05-06	FY 03-04	55	18	0.033	0.049	-0.107	0.173	0.984
	FY 07-08		55	0.084	0.034	-0.015	0.182	0.145
	FY 09-10		107	0.112	0.030	0.027	0.197	0.0028*
	FY 11-12		60	0.134	0.034	0.038	0.230	0.0011*
	FY 13-14		20	0.062	0.047	-0.073	0.196	0.778
FY 07-08	FY 03-04	55	18	0.051	0.049	-0.089	0.190	0.905
	FY 05-06		55	0.084	0.034	-0.015	0.182	0.145
	FY 09-10		107	0.028	0.030	-0.057	0.114	0.932
	FY 11-12		60	0.051	0.034	-0.046	0.147	0.659
	FY 13-14		20	0.022	0.047	-0.112	0.157	0.997
FY 09-10	FY 03-04	107	18	0.079	0.046	-0.052	0.210	0.515
	FY 05-06		55	0.112	0.030	0.027	0.197	0.0028*
	FY 07-08		55	0.028	0.030	-0.057	0.114	0.932
	FY 11-12		60	0.022	0.029	-0.061	0.105	0.973
	FY 13-14		20	0.050	0.044	-0.075	0.176	0.858
FY 11-12	FY 03-04	60	18	0.101	0.048	-0.037	0.240	0.291
	FY 05-06		55	0.134	0.034	0.038	0.230	0.0011*
	FY 07-08		55	0.051	0.034	-0.046	0.147	0.659
	FY 09-10		107	0.022	0.029	-0.061	0.105	0.973
	FY 13-14		20	0.073	0.046	-0.060	0.206	0.621
FY 13-14	FY 03-04	20	18	0.029	0.058	-0.139	0.196	0.997
	FY 05-06		55	0.062	0.047	-0.073	0.196	0.778
	FY 07-08		55	0.022	0.047	-0.112	0.157	0.997
	FY 09-10		107	0.050	0.044	-0.075	0.176	0.858
	FY 11-12		60	0.073	0.046	-0.060	0.206	0.621

Appendix P: Design-Bid-Build (DBB) CWE/PA Ratio by Fiscal Year

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
FY 03-04	FY 05-06	36	68	0.061	0.032	-0.032	0.154	0.417
	FY 07-08		58	0.008	0.033	-0.088	0.104	1.000
	FY 09-10		54	0.072	0.034	-0.025	0.170	0.273
	FY 11-12		31	0.072	0.039	-0.039	0.183	0.425
	FY 13-14		15	0.068	0.048	-0.071	0.207	0.726
FY 05-06	FY 03-04	68	36	0.061	0.032	-0.032	0.154	0.417
	FY 07-08		58	0.053	0.028	-0.028	0.134	0.419
	FY 09-10		54	0.133	0.029	0.051	0.216	<.0001*
	FY 11-12		31	0.133	0.034	0.035	0.231	0.0017*
	FY 13-14		15	0.060	0.046	-0.071	0.191	0.781
FY 07-08	FY 03-04	58	36	0.008	0.033	-0.088	0.104	1.000
	FY 05-06		68	0.053	0.028	-0.028	0.134	0.419
	FY 09-10		54	0.081	0.030	-0.005	0.166	0.078
	FY 11-12		31	0.080	0.035	-0.020	0.181	0.202
	FY 13-14		15	0.060	0.046	-0.071	0.191	0.781
FY 09-10	FY 03-04	54	36	0.072	0.034	-0.025	0.170	0.273
	FY 05-06		68	0.133	0.029	0.051	0.216	<.0001*
	FY 07-08		58	0.081	0.030	-0.005	0.166	0.078
	FY 11-12		31	0.000	0.035	-0.102	0.102	1.000
	FY 13-14		15	0.140	0.046	0.008	0.272	0.0302*
FY 11-12	FY 03-04	31	36	0.072	0.039	-0.039	0.183	0.425
	FY 05-06		68	0.133	0.034	0.035	0.231	0.0017*
	FY 07-08		58	0.080	0.035	-0.020	0.181	0.202
	FY 09-10		54	0.000	0.035	-0.102	0.102	1.000
	FY 13-14		15	0.140	0.050	-0.002	0.282	0.057
FY 13-14	FY 03-04	15	36	0.068	0.048	-0.071	0.207	0.726
	FY 05-06		68	0.007	0.045	-0.122	0.136	1.000
	FY 07-08		58	0.060	0.046	-0.071	0.191	0.781
	FY 09-10		54	0.140	0.046	0.008	0.272	0.0302*
	FY 11-12		31	0.140	0.050	-0.002	0.282	0.057

Appendix Q: Design-Build (DB) CWE/PA Ratio by Facility Type

Level	- Level	Observations		Mean	Std Error	95% Confidence Interval		Significance
		Level	- Level	Difference		Lower Bound	Upper Bound	(p-value)
ADMINISTRATIVE	COMMUNITY SUPPORT	26	25	0.065	0.049	-0.081	0.210	0.842
	DORMS, QUARTERS, DINING HALLS		25	0.015	0.049	-0.130	0.161	1.000
	MAINTENANCE		71	0.031	0.040	-0.087	0.150	0.986
	OPERATIONS		46	0.006	0.043	-0.121	0.133	1.000
	PERSONNEL SUPPORT		30	0.009	0.047	-0.130	0.148	1.000
	TRAINING		43	0.047	0.043	-0.082	0.176	0.933
COMMUNITY SUPPORT	ADMINISTRATIVE	25	26	0.065	0.049	-0.081	0.210	0.842
	DORMS, QUARTERS, DINING HALLS		25	0.049	0.049	-0.097	0.196	0.954
	MAINTENANCE		71	0.033	0.041	-0.087	0.154	0.983
	OPERATIONS		46	0.059	0.043	-0.070	0.188	0.824
	PERSONNEL SUPPORT		30	0.055	0.047	-0.085	0.196	0.904
	TRAINING		43	0.018	0.044	-0.113	0.148	1.000
DORMS, QUARTERS, DINING HALLS	ADMINISTRATIVE	25	26	0.015	0.049	-0.130	0.161	1.000
	COMMUNITY SUPPORT		25	0.049	0.049	-0.097	0.196	0.954
	MAINTENANCE		71	0.016	0.041	-0.105	0.137	1.000
	OPERATIONS		46	0.010	0.043	-0.119	0.138	1.000
	PERSONNEL SUPPORT		30	0.006	0.047	-0.134	0.147	1.000
	TRAINING		43	0.031	0.044	-0.099	0.162	0.991
MAINTENANCE	ADMINISTRATIVE	71	26	0.031	0.040	-0.087	0.150	0.986
	COMMUNITY SUPPORT		25	0.033	0.041	-0.087	0.154	0.983
	DORMS, QUARTERS, DINING HALLS		25	0.016	0.041	-0.105	0.137	1.000
	OPERATIONS		46	0.026	0.033	-0.072	0.124	0.987
	PERSONNEL SUPPORT		30	0.022	0.038	-0.091	0.135	0.997
	TRAINING		43	0.015	0.034	-0.085	0.116	0.999
OPERATIONS	ADMINISTRATIVE	46	26	0.006	0.043	-0.121	0.133	1.000
	COMMUNITY SUPPORT		25	0.059	0.043	-0.070	0.188	0.824
	DORMS, QUARTERS, DINING HALLS		25	0.010	0.043	-0.119	0.138	1.000
	MAINTENANCE		71	0.026	0.033	-0.072	0.124	0.987
	PERSONNEL SUPPORT		30	0.003	0.041	-0.118	0.125	1.000
	TRAINING		43	0.041	0.037	-0.069	0.151	0.924
PERSONNEL SUPPORT	ADMINISTRATIVE	30	26	0.009	0.047	-0.130	0.148	1.000
	COMMUNITY SUPPORT		25	0.055	0.047	-0.085	0.196	0.904
	DORMS, QUARTERS, DINING HALLS		25	0.006	0.047	-0.134	0.147	1.000
	MAINTENANCE		71	0.022	0.038	-0.091	0.135	0.997
	OPERATIONS		46	0.003	0.041	-0.118	0.125	1.000
	TRAINING		43	0.038	0.041	-0.086	0.161	0.971
TRAINING	ADMINISTRATIVE	43	26	0.047	0.043	-0.082	0.176	0.933
	COMMUNITY SUPPORT		25	0.018	0.044	-0.113	0.148	1.000
	DORMS, QUARTERS, DINING HALLS		25	0.031	0.044	-0.099	0.162	0.991
	MAINTENANCE		71	0.015	0.034	-0.085	0.116	0.999
	OPERATIONS		46	0.041	0.037	-0.069	0.151	0.924
	PERSONNEL SUPPORT		30	0.038	0.041	-0.086	0.161	0.971

Appendix R: Design-Bid-Build (DBB) CWE/PA Ratio by Facility Type

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
AIRFIELD PAVEMENTS	COMMUNITY SUPPORT	16	15	0.108	0.056	-0.057	0.274	0.450
	DORMS, QUARTERS, DINING HALLS		32	0.080	0.047	-0.061	0.221	0.625
	MAINTENANCE		50	0.074	0.044	-0.058	0.207	0.635
	OPERATIONS		34	0.055	0.047	-0.085	0.195	0.902
	PERSONNEL SUPPORT		20	0.140	0.052	-0.014	0.295	0.103
	TRAINING		44	0.087	0.045	-0.048	0.221	0.467
COMMUNITY SUPPORT	AIRFIELD PAVEMENTS	15	16	0.108	0.056	-0.057	0.274	0.450
	DORMS, QUARTERS, DINING HALLS		32	0.028	0.048	-0.116	0.173	0.997
	MAINTENANCE		50	0.034	0.046	-0.102	0.170	0.989
	OPERATIONS		34	0.053	0.048	-0.090	0.196	0.925
	PERSONNEL SUPPORT		20	0.032	0.053	-0.126	0.189	0.997
	TRAINING		44	0.021	0.046	-0.116	0.159	0.999
DORMS, QUARTERS, DINING HALLS	AIRFIELD PAVEMENTS	32	16	0.080	0.047	-0.061	0.221	0.625
	COMMUNITY SUPPORT		15	0.028	0.048	-0.116	0.173	0.997
	MAINTENANCE		50	0.006	0.035	-0.099	0.110	1.000
	OPERATIONS		34	0.025	0.038	-0.089	0.138	0.995
	PERSONNEL SUPPORT		20	0.060	0.044	-0.071	0.192	0.819
	TRAINING		44	0.007	0.036	-0.100	0.114	1.000
MAINTENANCE	AIRFIELD PAVEMENTS	50	16	0.074	0.044	-0.058	0.207	0.635
	COMMUNITY SUPPORT		15	0.034	0.046	-0.102	0.170	0.989
	DORMS, QUARTERS, DINING HALLS		32	0.006	0.035	-0.099	0.110	1.000
	OPERATIONS		34	0.019	0.034	-0.083	0.122	0.998
	PERSONNEL SUPPORT		20	0.066	0.041	-0.056	0.188	0.676
	TRAINING		44	0.013	0.032	-0.083	0.108	1.000
OPERATIONS	AIRFIELD PAVEMENTS	34	16	0.055	0.047	-0.085	0.195	0.902
	COMMUNITY SUPPORT		15	0.053	0.048	-0.090	0.196	0.925
	DORMS, QUARTERS, DINING HALLS		32	0.025	0.038	-0.089	0.138	0.995
	MAINTENANCE		50	0.019	0.034	-0.083	0.122	0.998
	PERSONNEL SUPPORT		20	0.085	0.044	-0.045	0.215	0.450
	TRAINING		44	0.032	0.035	-0.074	0.137	0.973
PERSONNEL SUPPORT	AIRFIELD PAVEMENTS	20	16	0.140	0.052	-0.014	0.295	0.103
	COMMUNITY SUPPORT		15	0.032	0.053	-0.126	0.189	0.997
	DORMS, QUARTERS, DINING HALLS		32	0.060	0.044	-0.071	0.192	0.819
	MAINTENANCE		50	0.066	0.041	-0.056	0.188	0.676
	OPERATIONS		34	0.085	0.044	-0.045	0.215	0.450
	TRAINING		44	0.053	0.042	-0.071	0.178	0.862
TRAINING	AIRFIELD PAVEMENTS	44	16	0.087	0.045	-0.048	0.221	0.467
	COMMUNITY SUPPORT		15	0.021	0.046	-0.116	0.159	0.999
	DORMS, QUARTERS, DINING HALLS		32	0.007	0.036	-0.100	0.114	1.000
	MAINTENANCE		50	0.013	0.032	-0.083	0.108	1.000
	OPERATIONS		34	0.032	0.035	-0.074	0.137	0.973
	PERSONNEL SUPPORT		20	0.053	0.042	-0.071	0.178	0.862

Appendix S: Design-Build (DB) CWE/PA Ratio by MAJCOM

Level	- Level	Observations		Mean	Std Error	95% Confidence Interval		Significance
		Level	- Level	Difference		Lower Bound	Upper Bound	(p-value)
ACC	AETC	67	58	0.063	0.031	0.001	0.125	0.0448*
	AFGSC		25	0.081	0.041	0.000	0.161	0.050
	AFMC		55	0.017	0.032	-0.046	0.079	0.600
	AFSOC		9	0.115	0.062	-0.008	0.237	0.066
	AFSPC		15	0.018	0.050	-0.081	0.116	0.726
	AMC		53	0.059	0.032	-0.004	0.123	0.066
	PACAF		23	0.022	0.042	-0.062	0.106	0.598
AETC	ACC	58	67	0.063	0.031	0.001	0.125	0.0448*
	AFGSC		25	0.017	0.042	-0.065	0.100	0.678
	AFMC		55	0.047	0.033	-0.018	0.111	0.159
	AFSOC		9	0.051	0.063	-0.072	0.175	0.412
	AFSPC		15	0.081	0.051	-0.019	0.180	0.112
	AMC		53	0.004	0.033	-0.062	0.069	0.908
	PACAF		23	0.041	0.043	-0.044	0.126	0.344
AFGSC	ACC	25	67	0.081	0.041	0.000	0.161	0.050
	AETC		58	0.017	0.042	-0.065	0.100	0.678
	AFMC		55	0.064	0.042	-0.019	0.147	0.131
	AFSOC		9	0.034	0.068	-0.100	0.168	0.617
	AFSPC		15	0.098	0.057	-0.014	0.211	0.087
	AMC		53	0.021	0.042	-0.062	0.105	0.618
	PACAF		23	0.058	0.051	-0.041	0.158	0.250
AFMC	ACC	55	67	0.017	0.032	-0.046	0.079	0.600
	AETC		58	0.047	0.033	-0.018	0.111	0.159
	AFGSC		25	0.064	0.042	-0.019	0.147	0.131
	AFSOC		9	0.098	0.063	-0.026	0.222	0.121
	AFSPC		15	0.034	0.051	-0.066	0.135	0.502
	AMC		53	0.043	0.034	-0.024	0.109	0.206
	PACAF		23	0.006	0.043	-0.080	0.091	0.897
AFSOC	ACC	9	67	0.115	0.062	-0.008	0.237	0.066
	AETC		58	0.051	0.063	-0.072	0.175	0.412
	AFGSC		25	0.034	0.068	-0.100	0.168	0.617
	AFMC		55	0.098	0.063	-0.026	0.222	0.121
	AFSPC		15	0.132	0.074	-0.013	0.277	0.074
	AMC		53	0.055	0.063	-0.069	0.179	0.381
	PACAF		23	0.092	0.069	-0.043	0.228	0.180
AFSPC	ACC	15	67	0.018	0.050	-0.081	0.116	0.726
	AETC		58	0.081	0.051	-0.019	0.180	0.112
	AFGSC		25	0.098	0.057	-0.014	0.211	0.087
	AFMC		55	0.034	0.051	-0.066	0.135	0.502
	AFSOC		9	0.132	0.074	-0.013	0.277	0.074
	AMC		53	0.077	0.051	-0.024	0.178	0.134
	PACAF		23	0.040	0.058	-0.074	0.154	0.493
AMC	ACC	53	67	0.059	0.032	-0.004	0.123	0.066
	AETC		58	0.004	0.033	-0.062	0.069	0.908
	AFGSC		25	0.021	0.042	-0.062	0.105	0.618
	AFMC		55	0.043	0.034	-0.024	0.109	0.206
	AFSOC		9	0.055	0.063	-0.069	0.179	0.381
	AFSPC		15	0.077	0.051	-0.024	0.178	0.134
	PACAF		23	0.037	0.044	-0.049	0.123	0.397
PACAF	ACC	15	67	0.022	0.042	-0.061	0.106	0.598
	AETC		58	0.041	0.043	-0.044	0.126	0.344
	AFGSC		25	0.058	0.051	-0.041	0.158	0.250
	AFMC		55	0.006	0.043	-0.080	0.091	0.897
	AFSOC		9	0.092	0.069	-0.043	0.228	0.180
	AFSPC		15	0.040	0.058	-0.074	0.154	0.493
	AMC		53	0.037	0.044	-0.049	0.123	0.397

Appendix T: Design-Bid-Build (DBB) CWE/PA Ratio by MAJCOM

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
ACC	AETC	70	57	0.026	0.030	-0.059	0.112	0.949
	AFGSC		22	0.088	0.041	-0.028	0.205	0.253
	AFSOC		36	0.014	0.034	-0.084	0.112	0.999
	AFSPC		12	0.056	0.052	-0.093	0.205	0.890
	AMC		49	0.017	0.031	-0.072	0.106	0.993
AETC	ACC	57	70	0.026	0.030	-0.059	0.112	0.949
	AFGSC		22	0.062	0.042	-0.058	0.182	0.674
	AFSOC		36	0.012	0.035	-0.089	0.114	0.999
	AFSPC		12	0.030	0.053	-0.122	0.181	0.993
	AMC		49	0.009	0.032	-0.084	0.102	1.000
AFGSC	ACC	22	70	0.088	0.041	-0.028	0.205	0.253
	AETC		57	0.062	0.042	-0.058	0.182	0.674
	AFSOC		36	0.074	0.045	-0.055	0.203	0.565
	AFSPC		12	0.032	0.060	-0.139	0.204	0.994
	AMC		49	0.071	0.043	-0.052	0.193	0.557
AFSOC	ACC	36	70	0.014	0.034	-0.084	0.112	0.999
	AETC		57	0.012	0.035	-0.089	0.114	0.999
	AFGSC		22	0.074	0.045	-0.055	0.203	0.565
	AFSPC		12	0.042	0.055	-0.117	0.201	0.974
	AMC		49	0.003	0.036	-0.101	0.108	1.000
AFSPC	ACC	12	70	0.056	0.052	-0.093	0.205	0.890
	AETC		57	0.030	0.053	-0.122	0.181	0.993
	AFGSC		22	0.032	0.060	-0.139	0.204	0.994
	AFSOC		36	0.042	0.055	-0.117	0.201	0.974
	AMC		49	0.039	0.054	-0.115	0.192	0.979
AMC	ACC	49	70	0.017	0.031	-0.072	0.106	0.993
	AETC		57	0.009	0.032	-0.084	0.102	1.000
	AFGSC		22	0.071	0.043	-0.052	0.193	0.557
	AFSOC		36	0.003	0.036	-0.101	0.108	1.000
	AFSPC		12	0.039	0.054	-0.115	0.192	0.979

Appendix U: Design-Build (DB) Schedule Growth by Fiscal Year

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
FY 03-04	FY 05-06	18	54	45.084	69.172	-153.285	243.453	0.987
	FY 07-08		55	58.004	69.015	-139.914	255.921	0.960
	FY 09-10		107	13.784	64.748	-171.898	199.465	1.000
	FY 11-12		60	7.414	68.302	-188.460	203.288	1.000
	FY 13-14		20	5.896	82.573	-230.904	242.695	1.000
FY 05-06	FY 03-04	54	18	45.084	69.172	-153.285	243.453	0.987
	FY 07-08		55	103.088	48.689	-36.541	242.717	0.281
	FY 09-10		107	58.868	42.425	-62.797	180.533	0.735
	FY 11-12		60	52.498	47.674	-84.218	189.215	0.881
	FY 13-14		20	39.189	66.528	-151.597	229.974	0.992
FY 07-08	FY 03-04	55	18	58.004	69.015	-139.914	255.921	0.960
	FY 05-06		54	103.088	48.689	-36.541	242.717	0.281
	FY 09-10		107	44.220	42.168	-76.708	165.147	0.901
	FY 11-12		60	50.589	47.445	-85.471	186.650	0.894
	FY 13-14		20	63.899	66.364	-126.417	254.215	0.929
FY 09-10	FY 03-04	107	18	13.784	64.748	-171.898	199.465	1.000
	FY 05-06		54	58.868	42.425	-62.797	180.533	0.735
	FY 07-08		55	44.220	42.168	-76.708	165.147	0.901
	FY 11-12		60	6.369	40.991	-111.183	123.922	1.000
	FY 13-14		20	19.679	61.915	-157.877	197.235	1.000
FY 11-12	FY 03-04	60	18	7.414	68.302	-188.460	203.288	1.000
	FY 05-06		54	52.498	47.674	-84.218	189.215	0.881
	FY 07-08		55	50.589	47.445	-85.471	186.650	0.894
	FY 09-10		107	6.369	40.991	-111.183	123.922	1.000
	FY 13-14		20	13.310	65.623	-174.880	201.499	1.000
FY 13-14	FY 03-04	20	18	5.896	82.573	-230.904	242.695	1.000
	FY 05-06		54	39.189	66.528	-151.597	229.974	0.992
	FY 07-08		55	63.899	66.364	-126.417	254.215	0.929
	FY 09-10		107	19.679	61.915	-157.877	197.235	1.000
	FY 11-12		60	13.310	65.623	-174.880	201.499	1.000

Appendix V: Design-Bid-Build (DBB) Schedule Growth by Fiscal Year

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
FY 03-04	FY 05-06	36	68	61.455	49.289	-80.083	202.994	0.813
	FY 07-08		57	34.348	50.908	-111.841	180.537	0.985
	FY 09-10		54	23.773	51.453	-123.979	171.526	0.997
	FY 11-12		30	52.867	59.115	-116.888	222.622	0.948
	FY 13-14		15	57.134	73.489	-153.899	268.167	0.971
FY 05-06	FY 03-04	68	36	61.455	49.289	-80.083	202.994	0.813
	FY 07-08		57	27.107	42.944	-96.210	150.425	0.989
	FY 09-10		54	37.682	43.588	-87.485	162.849	0.955
	FY 11-12		30	8.588	52.413	-141.920	159.097	1.000
	FY 13-14		15	4.322	68.214	-191.563	200.207	1.000
FY 07-08	FY 03-04	57	36	34.348	50.908	-111.841	180.537	0.985
	FY 05-06		68	27.107	42.944	-96.210	150.425	0.989
	FY 09-10		54	10.575	45.411	-119.829	140.978	1.000
	FY 11-12		30	18.519	53.938	-136.371	173.409	0.999
	FY 13-14		15	22.786	69.394	-176.486	222.057	1.000
FY 09-10	FY 03-04	54	36	23.773	51.453	-123.979	171.526	0.997
	FY 05-06		68	37.682	43.588	-87.485	162.849	0.955
	FY 07-08		57	10.575	45.411	-119.829	140.978	1.000
	FY 11-12		30	29.094	54.453	-127.273	185.461	0.995
	FY 13-14		15	33.360	69.794	-167.061	233.782	0.997
FY 11-12	FY 03-04	30	36	52.867	59.115	-116.888	222.622	0.948
	FY 05-06		68	8.588	52.413	-141.920	159.097	1.000
	FY 07-08		57	18.519	53.938	-136.371	173.409	0.999
	FY 09-10		54	29.094	54.453	-127.273	185.461	0.995
	FY 13-14		15	4.267	75.620	-212.885	221.418	1.000
FY 13-14	FY 03-04	15	36	57.134	73.489	-153.899	268.167	0.971
	FY 05-06		68	4.322	68.214	-191.563	200.207	1.000
	FY 07-08		57	22.786	69.394	-176.486	222.057	1.000
	FY 09-10		54	33.360	69.794	-167.061	233.782	0.997
	FY 11-12		30	4.267	75.620	-212.885	221.418	1.000

Appendix W: Design-Build (DB) Schedule Growth by Facility Type

Level	- Level	Observations		Mean	Std Error	95% Confidence Interval		Significance
		Level	- Level	Difference		Lower Bound	Upper Bound	(p-value)
ADMINISTRATIVE	COMMUNITY SUPPORT	26	25	40.326	67.282	-159.621	240.273	0.997
	DORMS, QUARTERS, DINING HALLS		24	78.126	67.993	-123.934	280.185	0.912
	MAINTENANCE		71	38.497	55.061	-125.131	202.124	0.993
	OPERATIONS		46	73.569	58.935	-101.571	248.710	0.874
	PERSONNEL SUPPORT		30	13.144	64.360	-178.120	204.408	1.000
	TRAINING		43	28.860	59.673	-148.473	206.194	0.999
COMMUNITY SUPPORT	ADMINISTRATIVE	25	26	40.326	67.282	-159.621	240.273	0.997
	DORMS, QUARTERS, DINING HALLS		24	118.452	68.643	-85.538	322.442	0.600
	MAINTENANCE		71	78.822	55.861	-87.183	244.828	0.796
	OPERATIONS		46	113.895	59.683	-63.470	291.260	0.477
	PERSONNEL SUPPORT		30	53.469	65.046	-139.833	246.772	0.983
	TRAINING		43	69.186	60.412	-110.344	248.716	0.913
DORMS, QUARTERS, DINING HALLS	ADMINISTRATIVE	24	26	78.126	67.993	-123.934	280.185	0.912
	COMMUNITY SUPPORT		25	118.452	68.643	-85.538	322.442	0.600
	MAINTENANCE		71	39.629	56.715	-128.915	208.173	0.993
	OPERATIONS		46	4.557	60.484	-175.186	184.299	1.000
	PERSONNEL SUPPORT		30	64.982	65.781	-130.504	260.469	0.956
	TRAINING		43	49.266	61.203	-132.614	231.145	0.984
MAINTENANCE	ADMINISTRATIVE	71	26	38.497	55.061	-125.131	202.124	0.993
	COMMUNITY SUPPORT		25	78.822	55.861	-87.183	244.828	0.796
	DORMS, QUARTERS, DINING HALLS		24	39.629	56.715	-128.915	208.173	0.993
	OPERATIONS		46	35.073	45.463	-100.032	170.178	0.987
	PERSONNEL SUPPORT		30	25.353	52.305	-130.085	180.791	0.999
	TRAINING		43	9.636	46.415	-128.299	147.572	1.000
OPERATIONS	ADMINISTRATIVE	46	26	73.569	58.935	-101.571	248.710	0.874
	COMMUNITY SUPPORT		25	113.895	59.683	-63.470	291.260	0.477
	DORMS, QUARTERS, DINING HALLS		24	4.557	60.484	-175.186	184.299	1.000
	MAINTENANCE		71	35.073	45.463	-100.032	170.178	0.987
	PERSONNEL SUPPORT		30	60.426	56.369	-107.089	227.941	0.936
	TRAINING		43	44.709	50.951	-106.706	196.124	0.976
PERSONNEL SUPPORT	ADMINISTRATIVE	30	26	13.144	64.360	-178.120	204.408	1.000
	COMMUNITY SUPPORT		25	53.469	65.046	-139.833	246.772	0.983
	DORMS, QUARTERS, DINING HALLS		24	64.982	65.781	-130.504	260.469	0.956
	MAINTENANCE		71	25.353	52.305	-130.085	180.791	0.999
	OPERATIONS		46	60.426	56.369	-107.089	227.941	0.936
	TRAINING		43	15.717	57.140	-154.089	185.523	1.000
TRAINING	ADMINISTRATIVE	43	26	28.860	59.673	-148.473	206.194	0.999
	COMMUNITY SUPPORT		25	69.186	60.412	-110.344	248.716	0.913
	DORMS, QUARTERS, DINING HALLS		24	49.266	61.203	-132.614	231.145	0.984
	MAINTENANCE		71	9.636	46.415	-128.299	147.572	1.000
	OPERATIONS		46	44.709	50.951	-106.706	196.124	0.976
	PERSONNEL SUPPORT		30	15.717	57.140	-154.089	185.523	1.000

Appendix X: Design-Bid-Build (DBB) Schedule Growth by Facility Type

Level	- Level	Observations		Mean	Std Error	95% Confidence Interval		Significance
		Level	- Level	Difference		Lower Bound	Upper Bound	(p-value)
AIRFIELD PAVEMENTS	COMMUNITY SUPPORT	16	15	98.566	65.618	-96.865	293.996	0.743
	DORMS, QUARTERS, DINING HALLS		32	92.112	55.903	-74.384	258.608	0.652
	MAINTENANCE		48	102.337	52.706	-54.636	259.311	0.455
	OPERATIONS		34	81.878	55.352	-82.978	246.733	0.757
	PERSONNEL SUPPORT		20	115.101	61.239	-67.286	297.488	0.496
	TRAINING		44	121.654	53.301	-37.094	280.401	0.258
COMMUNITY SUPPORT	AIRFIELD PAVEMENTS	15	16	98.566	65.618	-96.865	293.996	0.743
	DORMS, QUARTERS, DINING HALLS		32	6.454	57.132	-163.702	176.609	1.000
	MAINTENANCE		48	3.772	54.007	-157.079	164.622	1.000
	OPERATIONS		34	16.688	56.593	-151.863	185.239	1.000
	PERSONNEL SUPPORT		20	16.536	62.362	-169.198	202.270	1.000
	TRAINING		44	23.088	54.589	-139.494	185.670	1.000
DORMS, QUARTERS, DINING HALLS	AIRFIELD PAVEMENTS	32	16	92.112	55.903	-74.384	258.608	0.652
	COMMUNITY SUPPORT		15	6.454	57.132	-163.702	176.609	1.000
	MAINTENANCE		48	10.226	41.668	-113.873	134.324	1.000
	OPERATIONS		34	10.234	44.968	-123.695	144.163	1.000
	PERSONNEL SUPPORT		20	22.990	52.043	-132.010	177.989	0.999
	TRAINING		44	29.542	42.418	-96.793	155.877	0.993
MAINTENANCE	AIRFIELD PAVEMENTS	48	16	102.337	52.706	-54.636	259.311	0.455
	COMMUNITY SUPPORT		15	3.772	54.007	-157.079	164.622	1.000
	DORMS, QUARTERS, DINING HALLS		32	10.226	41.668	-113.873	134.324	1.000
	OPERATIONS		34	20.460	40.926	-101.429	142.349	0.999
	PERSONNEL SUPPORT		20	12.764	48.592	-131.959	157.487	1.000
	TRAINING		44	19.316	38.106	-94.175	132.808	0.999
OPERATIONS	AIRFIELD PAVEMENTS	34	16	81.878	55.352	-82.978	246.733	0.757
	COMMUNITY SUPPORT		15	16.688	56.593	-151.863	185.239	1.000
	DORMS, QUARTERS, DINING HALLS		32	10.234	44.968	-123.695	144.163	1.000
	MAINTENANCE		48	20.460	40.926	-101.429	142.349	0.999
	PERSONNEL SUPPORT		20	33.224	51.451	-120.012	186.460	0.995
	TRAINING		44	39.776	41.690	-84.389	163.941	0.963
PERSONNEL SUPPORT	AIRFIELD PAVEMENTS	20	16	115.101	61.239	-67.286	297.488	0.496
	COMMUNITY SUPPORT		15	16.536	62.362	-169.198	202.270	1.000
	DORMS, QUARTERS, DINING HALLS		32	22.990	52.043	-132.010	177.989	0.999
	MAINTENANCE		48	12.764	48.592	-131.959	157.487	1.000
	OPERATIONS		34	33.224	51.451	-120.012	186.460	0.995
	TRAINING		44	6.552	49.238	-140.092	153.197	1.000
TRAINING	AIRFIELD PAVEMENTS	44	16	121.654	53.301	-37.094	280.401	0.258
	COMMUNITY SUPPORT		15	23.088	54.589	-139.494	185.670	1.000
	DORMS, QUARTERS, DINING HALLS		32	29.542	42.418	-96.793	155.877	0.993
	MAINTENANCE		48	19.316	38.106	-94.175	132.808	0.999
	OPERATIONS		34	39.776	41.690	-84.389	163.941	0.963
	PERSONNEL SUPPORT		20	6.552	49.238	-140.092	153.197	1.000

Appendix Y: Design-Build (DB) Schedule Growth by MAJCOM

Level	- Level	Observations		Mean	Std Error	95% Confidence Interval		Significance
		Level	- Level	Difference		Lower Bound	Upper Bound	(p-value)
	AETC		58	67.978	51.925	-90.528	226.485	0.895
	AFGSC		25	48.865	67.851	-158.259	255.989	0.996
	AFMC		55	58.489	52.678	-102.319	219.296	0.954
ACC	AFSOC	67	9	39.833	102.782	-273.923	353.589	1.000
	AFSPC		15	173.533	82.698	-78.913	425.979	0.418
	AMC		53	57.022	53.221	-105.443	219.487	0.962
	PACAF		23	16.970	69.966	-196.611	230.552	1.000
	ACC		67	67.978	51.925	-90.528	226.485	0.895
	AFGSC		25	19.114	69.267	-192.332	230.559	1.000
	AFMC		55	9.490	54.490	-156.847	175.826	1.000
AETC	AFSOC	58	9	28.145	103.722	-288.480	344.771	1.000
	AFSPC		15	105.555	83.863	-150.449	361.558	0.913
	AMC		53	10.956	55.015	-156.983	178.896	1.000
	PACAF		23	51.008	71.340	-166.767	268.783	0.997
	ACC		67	48.865	67.851	-158.259	255.989	0.996
	AETC		58	19.114	69.267	-192.332	230.559	1.000
	AFMC		55	9.624	69.833	-203.552	222.800	1.000
AFGSC	AFSOC	25	9	9.032	112.543	-334.520	352.584	1.000
	AFSPC		15	124.668	94.555	-163.973	413.309	0.891
	AMC		53	8.157	70.244	-206.272	222.586	1.000
	PACAF		23	31.894	83.648	-223.453	287.241	1.000
	ACC		67	58.489	52.678	-102.319	219.296	0.954
	AETC		58	9.490	54.490	-156.847	175.826	1.000
	AFGSC		25	9.624	69.833	-203.552	222.800	1.000
AFMC	AFSOC	55	9	18.656	104.101	-299.128	336.439	1.000
	AFSPC		15	115.044	84.332	-142.390	372.478	0.873
	AMC		53	1.467	55.727	-168.646	171.579	1.000
	PACAF		23	41.518	71.891	-177.937	260.973	0.999
	ACC		67	39.833	102.782	-273.923	353.589	1.000
	AETC		58	28.145	103.722	-288.480	344.771	1.000
	AFGSC		25	9.032	112.543	-334.520	352.584	1.000
AFSOC	AFMC	9	55	18.656	104.101	-299.128	336.439	1.000
	AFSPC		15	133.700	122.070	-238.934	506.334	0.958
	AMC		53	17.189	104.377	-301.437	335.815	1.000
	PACAF		23	22.862	113.831	-324.621	370.346	1.000
	ACC		67	173.533	82.698	-78.913	425.979	0.418
	AETC		58	10.956	55.015	-156.983	178.896	1.000
	AFGSC		25	124.668	94.555	-163.973	413.309	0.891
AFSPC	AFMC	15	55	115.044	84.332	-142.390	372.478	0.873
	AFSOC		9	133.700	122.070	-238.934	506.334	0.958
	AMC		53	116.511	84.672	-141.962	374.984	0.868
	PACAF		23	156.562	96.084	-136.747	449.872	0.732
	ACC		67	57.022	53.221	-105.443	219.487	0.962
	AETC		58	10.956	55.015	-156.983	178.896	1.000
	AFGSC		25	8.157	70.244	-206.272	222.586	1.000
AMC	AFMC	53	55	1.467	55.727	-168.646	171.579	1.000
	AFSOC		9	17.189	104.377	-301.437	335.815	1.000
	AFSPC		15	116.511	84.672	-141.962	374.984	0.868
	PACAF		23	40.052	72.289	-180.621	260.724	0.999
	ACC		67	16.970	69.966	-196.611	230.552	1.000
	AETC		58	51.008	71.340	-166.767	268.783	0.997
	AFGSC		25	31.894	83.648	-223.453	287.241	1.000
PACAF	AFMC	15	55	41.518	71.891	-177.937	260.973	0.999
	AFSOC		9	22.862	113.831	-324.621	370.346	1.000
	AFSPC		15	156.562	96.084	-136.747	449.872	0.732
	AMC		53	40.052	72.289	-180.621	260.724	0.999

Appendix Z: Design-Bid-Build (DBB) Schedule Growth by MAJCOM

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
ACC	AETC	70	57	0.427	1.580	-4.111	4.965	1.000
	AFGSC		22	1.912	2.164	-4.305	8.128	0.950
	AFSOC		36	2.516	1.816	-2.700	7.733	0.736
	AFSPC		12	1.194	2.766	-6.753	9.141	0.998
	AMC		49	1.575	1.649	-3.163	6.312	0.932
AETC	ACC	57	70	0.427	1.580	-4.111	4.965	1.000
	AFGSC		22	2.339	2.222	-4.045	8.723	0.899
	AFSOC		36	2.943	1.885	-2.471	8.358	0.625
	AFSPC		12	1.621	2.812	-6.458	9.699	0.993
	AMC		49	2.002	1.725	-2.953	6.957	0.855
AFGSC	ACC	22	70	1.912	2.164	-4.305	8.128	0.950
	AETC		57	2.339	2.222	-4.045	8.723	0.899
	AFSOC		36	0.605	2.396	-6.278	7.488	1.000
	AFSPC		12	0.718	3.177	-8.410	9.846	1.000
	AMC		49	0.337	2.272	-6.191	6.865	1.000
AFSOC	ACC	36	70	2.516	1.816	-2.700	7.733	0.736
	AETC		57	2.943	1.885	-2.471	8.358	0.625
	AFGSC		22	0.605	2.396	-6.278	7.488	1.000
	AFSPC		12	1.323	2.951	-7.156	9.801	0.998
	AMC		49	0.942	1.943	-4.641	6.525	0.997
AFSPC	ACC	12	70	1.194	2.766	-6.753	9.141	0.998
	AETC		57	1.621	2.812	-6.458	9.699	0.993
	AFGSC		22	0.718	3.177	-8.410	9.846	1.000
	AFSOC		36	1.323	2.951	-7.156	9.801	0.998
	AMC		49	0.381	2.852	-7.811	8.573	1.000
AMC	ACC	49	70	1.575	1.649	-3.163	6.312	0.932
	AETC		57	2.002	1.725	-2.953	6.957	0.855
	AFGSC		22	0.337	2.272	-6.191	6.865	1.000
	AFSOC		36	0.942	1.943	-4.641	6.525	0.997
	AFSPC		12	0.381	2.852	-7.811	8.573	1.000

Appendix AA: Design-Build (DB) Unit Cost by Fiscal Year

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
FY 03-04	FY 05-06	13	36	2.564	10.647	-18.402	23.531	0.810
	FY 07-08		46	13.191	10.335	-7.162	33.543	0.203
	FY 09-10		95	11.237	9.730	-7.924	30.398	0.249
	FY 11-12		56	4.677	10.130	-15.271	24.625	0.645
	FY 13-14		17	1.637	12.123	-22.236	25.510	0.893
FY 05-06	FY 03-04	36	13	2.564	10.647	-18.402	23.531	0.810
	FY 07-08		46	10.626	7.322	-3.792	25.045	0.148
	FY 09-10		95	8.673	6.440	-4.009	21.354	0.179
	FY 11-12		56	2.113	7.029	-11.729	15.954	0.764
	FY 13-14		17	4.202	9.683	-14.866	23.270	0.665
FY 07-08	FY 03-04	46	13	13.191	10.335	-7.162	33.543	0.203
	FY 05-06		36	10.626	7.322	-3.792	25.045	0.148
	FY 09-10		95	1.954	5.910	-9.685	13.592	0.741
	FY 11-12		56	8.514	6.547	-4.380	21.407	0.195
	FY 13-14		17	14.828	9.339	-3.563	33.219	0.114
FY 09-10	FY 03-04	95	13	11.237	9.730	-7.924	30.398	0.249
	FY 05-06		36	8.673	6.440	-4.009	21.354	0.179
	FY 07-08		46	1.954	5.910	-9.685	13.592	0.741
	FY 11-12		56	6.560	5.543	-4.356	17.476	0.238
	FY 13-14		17	12.874	8.665	-4.189	29.938	0.139
FY 11-12	FY 03-04	56	13	4.677	10.130	-15.271	24.625	0.645
	FY 05-06		36	2.113	7.029	-11.729	15.954	0.764
	FY 07-08		46	8.514	6.547	-4.380	21.407	0.195
	FY 09-10		95	6.560	5.543	-4.356	17.476	0.238
	FY 13-14		17	6.314	9.111	-11.628	24.257	0.489
FY 13-14	FY 03-04	17	13	1.637	12.123	-22.236	25.510	0.893
	FY 05-06		36	4.202	9.683	-14.866	23.270	0.665
	FY 07-08		46	14.828	9.339	-3.563	33.219	0.114
	FY 09-10		95	12.874	8.665	-4.189	29.938	0.139
	FY 11-12		56	6.314	9.111	-11.628	24.257	0.489

Appendix AB: Design-Bid-Build (DBB) Unit Cost by Fiscal Year

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
FY 03-04	FY 05-06	20	57	3.535	5.150	-11.286	18.356	0.983
	FY 07-08		43	5.501	5.364	-9.934	20.936	0.909
	FY 09-10		46	2.505	5.308	-12.769	17.779	0.997
	FY 11-12		27	4.775	5.847	-12.049	21.599	0.964
	FY 13-14		13	8.654	7.060	-11.662	28.970	0.824
FY 05-06	FY 03-04	57	20	3.535	5.150	-11.286	18.356	0.983
	FY 07-08		43	9.036	4.003	-2.482	20.555	0.217
	FY 09-10		46	1.030	3.928	-10.273	12.332	1.000
	FY 11-12		27	1.239	4.630	-12.083	14.562	1.000
	FY 13-14		13	5.119	6.091	-12.409	22.646	0.960
FY 07-08	FY 03-04	43	20	5.501	5.364	-9.934	20.936	0.909
	FY 05-06		57	9.036	4.003	-2.482	20.555	0.217
	FY 09-10		46	8.007	4.204	-4.090	20.103	0.402
	FY 11-12		27	10.276	4.866	-3.727	24.278	0.286
	FY 13-14		13	14.155	6.272	-3.894	32.205	0.217
FY 09-10	FY 03-04	46	20	2.505	5.308	-12.769	17.779	0.997
	FY 05-06		57	1.030	3.928	-10.273	12.332	1.000
	FY 07-08		43	8.007	4.204	-4.090	20.103	0.402
	FY 11-12		27	2.269	4.805	-11.556	16.095	0.997
	FY 13-14		13	6.149	6.225	-11.764	24.061	0.921
FY 11-12	FY 03-04	27	20	4.775	5.847	-12.049	21.599	0.964
	FY 05-06		57	1.239	4.630	-12.083	14.562	1.000
	FY 07-08		43	10.276	4.866	-3.727	24.278	0.286
	FY 09-10		46	2.269	4.805	-11.556	16.095	0.997
	FY 13-14		13	3.879	6.690	-15.372	23.130	0.992
FY 13-14	FY 03-04	13	20	8.654	7.060	-11.662	28.970	0.824
	FY 05-06		57	5.119	6.091	-12.409	22.646	0.960
	FY 07-08		43	14.155	6.272	-3.894	32.205	0.217
	FY 09-10		46	6.149	6.225	-11.764	24.061	0.921
	FY 11-12		27	3.879	6.690	-15.372	23.130	0.992

Appendix AC: Design-Build (DB) Unit Cost by Facility Type

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
ADMINISTRATIVE	COMMUNITY SUPPORT	24	23	3.179	10.028	-16.583	22.941	0.752
	DORMS, QUARTERS, DINING HALLS		13	3.270	11.835	-20.053	26.593	0.783
	MAINTENANCE		65	13.762	8.209	-2.414	29.939	0.095
	OPERATIONS		41	16.266	8.833	-1.141	33.672	0.067
	PERSONNEL SUPPORT		26	2.392	9.728	-16.779	21.563	0.806
	TRAINING		38	11.386	8.961	-6.272	29.045	0.205
COMMUNITY SUPPORT	ADMINISTRATIVE	23	24	3.179	10.028	-16.583	22.941	0.752
	DORMS, QUARTERS, DINING HALLS		13	6.449	11.925	-17.051	29.949	0.589
	MAINTENANCE		65	10.583	8.338	-5.848	27.015	0.206
	OPERATIONS		41	13.087	8.953	-4.557	30.730	0.145
	PERSONNEL SUPPORT		26	0.787	9.838	-18.600	20.173	0.936
	TRAINING		38	8.208	9.079	-9.685	26.100	0.367
DORMS, QUARTERS, DINING HALLS	ADMINISTRATIVE	13	24	3.270	11.835	-20.053	26.593	0.783
	COMMUNITY SUPPORT		23	6.449	11.925	-17.051	29.949	0.589
	MAINTENANCE		65	17.032	10.441	-3.544	37.609	0.104
	OPERATIONS		41	19.536	10.939	-2.021	41.093	0.076
	PERSONNEL SUPPORT		26	5.662	11.674	-17.343	28.668	0.628
	TRAINING		38	14.657	11.042	-7.104	36.417	0.186
MAINTENANCE	ADMINISTRATIVE	65	24	13.762	8.209	-2.414	29.939	0.095
	COMMUNITY SUPPORT		23	10.583	8.338	-5.848	27.015	0.206
	DORMS, QUARTERS, DINING HALLS		13	17.032	10.441	-3.544	37.609	0.104
	OPERATIONS		41	2.504	6.854	-11.004	16.011	0.715
	PERSONNEL SUPPORT		26	11.370	7.975	-4.346	27.086	0.155
	TRAINING		38	2.376	7.018	-11.454	16.206	0.735
OPERATIONS	ADMINISTRATIVE	41	24	16.266	8.833	-1.141	33.672	0.067
	COMMUNITY SUPPORT		23	13.087	8.953	-4.557	30.730	0.145
	DORMS, QUARTERS, DINING HALLS		13	19.536	10.939	-2.021	41.093	0.076
	MAINTENANCE		65	2.504	6.854	-11.004	16.011	0.715
	PERSONNEL SUPPORT		26	13.873	8.616	-3.106	30.852	0.109
	TRAINING		38	4.879	7.739	-10.371	20.130	0.529
PERSONNEL SUPPORT	ADMINISTRATIVE	26	24	2.392	9.728	-16.779	21.563	0.806
	COMMUNITY SUPPORT		23	0.787	9.838	-18.600	20.173	0.936
	DORMS, QUARTERS, DINING HALLS		13	5.662	11.674	-17.343	28.668	0.628
	MAINTENANCE		65	11.370	7.975	-4.346	27.086	0.155
	OPERATIONS		41	13.873	8.616	-3.106	30.852	0.109
	TRAINING		38	8.994	8.747	-8.243	26.231	0.305
TRAINING	ADMINISTRATIVE	38	24	11.386	8.961	-6.272	29.045	0.205
	COMMUNITY SUPPORT		23	8.208	9.079	-9.685	26.100	0.367
	DORMS, QUARTERS, DINING HALLS		13	14.657	11.042	-7.104	36.417	0.186
	MAINTENANCE		65	2.376	7.018	-11.454	16.206	0.735
	OPERATIONS		41	4.879	7.739	-10.371	20.130	0.529
	PERSONNEL SUPPORT		26	8.994	8.747	-8.243	26.231	0.305

Appendix AD: Design-Bid-Build (DBB) Unit Cost by Facility Type

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
AIRFIELD PAVEMENTS	COMMUNITY SUPPORT	12	15	16.963	7.791	-6.286	40.211	0.313
	DORMS, QUARTERS, DINING HALLS		17	20.445	7.584	-2.188	43.078	0.106
	MAINTENANCE		41	23.070	6.602	3.368	42.772	0.0107*
	OPERATIONS		32	23.365	6.809	3.046	43.685	0.0131*
	PERSONNEL SUPPORT		16	16.707	7.682	-6.216	39.631	0.315
	TRAINING		43	20.855	6.567	1.257	40.453	0.0289*
COMMUNITY SUPPORT	AIRFIELD PAVEMENTS	15	12	16.963	7.791	-6.286	40.211	0.313
	DORMS, QUARTERS, DINING HALLS		17	3.482	7.126	-17.783	24.747	0.999
	MAINTENANCE		41	6.107	6.070	-12.007	24.221	0.952
	OPERATIONS		32	6.403	6.294	-12.381	25.186	0.950
	PERSONNEL SUPPORT		16	0.255	7.229	-21.319	21.829	1.000
	TRAINING		43	3.892	6.032	-14.109	21.893	0.995
DORMS, QUARTERS, DINING HALLS	AIRFIELD PAVEMENTS	17	12	20.445	7.584	-2.188	43.078	0.106
	COMMUNITY SUPPORT		15	3.482	7.126	-17.783	24.747	0.999
	MAINTENANCE		41	2.625	5.803	-14.691	19.941	0.999
	OPERATIONS		32	2.920	6.037	-15.095	20.936	0.999
	PERSONNEL SUPPORT		16	3.738	7.006	-17.171	24.646	0.998
	TRAINING		43	0.410	5.763	-16.788	17.608	1.000
MAINTENANCE	AIRFIELD PAVEMENTS	41	12	23.070	6.602	3.368	42.772	0.0107*
	COMMUNITY SUPPORT		15	6.107	6.070	-12.007	24.221	0.952
	DORMS, QUARTERS, DINING HALLS		17	2.625	5.803	-14.691	19.941	0.999
	OPERATIONS		32	0.296	4.745	-13.864	14.455	1.000
	PERSONNEL SUPPORT		16	6.362	5.929	-11.332	24.057	0.935
	TRAINING		43	2.215	4.391	-10.888	15.318	0.999
OPERATIONS	AIRFIELD PAVEMENTS	32	12	23.365	6.809	3.046	43.685	0.0131*
	COMMUNITY SUPPORT		15	6.403	6.294	-12.381	25.186	0.950
	DORMS, QUARTERS, DINING HALLS		17	2.920	6.037	-15.095	20.936	0.999
	MAINTENANCE		41	0.296	4.745	-13.864	14.455	1.000
	PERSONNEL SUPPORT		16	6.658	6.159	-11.722	25.038	0.933
	TRAINING		43	2.511	4.696	-11.504	16.525	0.998
PERSONNEL SUPPORT	AIRFIELD PAVEMENTS	16	12	16.707	7.682	-6.216	39.631	0.315
	COMMUNITY SUPPORT		15	0.255	7.229	-21.319	21.829	1.000
	DORMS, QUARTERS, DINING HALLS		17	3.738	7.006	-17.171	24.646	0.998
	MAINTENANCE		41	6.362	5.929	-11.332	24.057	0.935
	OPERATIONS		32	6.658	6.159	-11.722	25.038	0.933
	TRAINING		43	4.147	5.891	-13.431	21.726	0.992
TRAINING	AIRFIELD PAVEMENTS	43	12	20.855	6.567	1.257	40.453	0.0289*
	COMMUNITY SUPPORT		15	3.892	6.032	-14.109	21.893	0.995
	DORMS, QUARTERS, DINING HALLS		17	0.410	5.763	-16.788	17.608	1.000
	MAINTENANCE		41	2.215	4.391	-10.888	15.318	0.999
	OPERATIONS		32	2.511	4.696	-11.504	16.525	0.998
	PERSONNEL SUPPORT		16	4.147	5.891	-13.431	21.726	0.992

Appendix AE: Design-Build (DB) Unit Cost by MAJCOM

Level	- Level	Observations Level	Observations - Level	Mean Difference	Std Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Significance (p-value)
ACC	AETC	59	40	3.473	3.991	-4.389	11.334	0.385
	AFGSC		23	3.075	4.790	-6.361	12.510	0.522
	AFMC		44	6.326	3.882	-1.320	13.971	0.105
	AFSOC		8	1.674	7.342	-12.787	16.136	0.820
	AFSPC		13	0.388	5.971	-11.373	12.148	0.948
	AMC		49	4.224	3.767	-3.195	11.642	0.263
	PACAF		18	104.857	5.247	94.522	115.193	<.0001*
AETC	ACC	40	59	3.473	3.991	-4.389	11.334	0.385
	AFGSC		23	6.547	5.100	-3.497	16.592	0.200
	AFMC		44	2.853	4.257	-5.532	11.239	0.503
	AFSOC		8	1.799	7.547	-13.067	16.664	0.812
	AFSPC		13	3.860	6.221	-8.394	16.114	0.536
	AMC		49	7.696	4.153	-0.483	15.875	0.065
	PACAF		18	108.330	5.531	97.436	119.224	<.0001*
AFGSC	ACC	23	59	3.075	4.790	-6.361	12.510	0.522
	AETC		40	6.547	5.100	-3.497	16.592	0.200
	AFMC		44	9.401	5.014	-0.476	19.277	0.062
	AFSOC		8	4.749	7.999	-11.006	20.504	0.553
	AFSPC		13	2.687	6.762	-10.632	16.006	0.691
	AMC		49	1.149	4.926	-8.553	10.851	0.816
	PACAF		18	101.783	6.133	89.704	113.862	<.0001*
AFMC	ACC	44	59	6.326	3.882	-1.320	13.971	0.105
	AETC		40	2.853	4.257	-5.532	11.239	0.503
	AFGSC		23	9.401	5.014	-0.476	19.277	0.062
	AFSOC		8	4.652	7.490	-10.101	19.405	0.535
	AFSPC		13	6.713	6.152	-5.403	18.830	0.276
	AMC		49	10.549	4.047	2.578	18.521	0.0097*
	PACAF		18	111.183	5.452	100.444	121.923	<.0001*
AFSOC	ACC	8	59	1.674	7.342	-12.787	16.136	0.820
	AETC		40	1.799	7.547	-13.067	16.664	0.812
	AFGSC		23	4.749	7.999	-11.006	20.504	0.553
	AFMC		44	4.652	7.490	-10.101	19.405	0.535
	AFSPC		13	2.062	8.757	-15.186	19.310	0.814
	AMC		49	5.898	7.431	-8.739	20.534	0.428
	PACAF		18	106.532	8.281	90.222	122.841	<.0001*
AFSPC	ACC	13	59	0.388	5.971	-11.373	12.148	0.948
	AETC		40	3.860	6.221	-8.394	16.114	0.536
	AFGSC		23	2.687	6.762	-10.632	16.006	0.691
	AFMC		44	6.713	6.152	-5.403	18.830	0.276
	AFSOC		8	2.062	8.757	-15.186	19.310	0.814
	AMC		49	3.836	6.080	-8.139	15.811	0.529
	PACAF		18	104.470	7.093	90.499	118.441	<.0001*
AMC	ACC	49	59	4.224	3.767	-3.195	11.642	0.263
	AETC		40	7.696	4.153	-0.483	15.875	0.065
	AFGSC		23	1.149	4.926	-8.553	10.851	0.816
	AFMC		44	10.549	4.047	2.578	18.521	0.0097*
	AFSOC		8	5.898	7.431	-8.739	20.534	0.428
	AFSPC		13	3.836	6.080	-8.139	15.811	0.529
	PACAF		18	100.634	5.371	90.055	111.213	<.0001*
PACAF	ACC	13	59	104.857	5.247	94.522	115.193	<.0001*
	AETC		40	108.330	5.531	97.436	119.224	<.0001*
	AFGSC		23	101.783	6.133	89.704	113.862	<.0001*
	AFMC		44	111.183	5.452	100.444	121.923	<.0001*
	AFSOC		8	106.532	8.281	90.222	122.841	<.0001*
	AFSPC		13	104.470	7.093	90.499	118.441	<.0001*
	AMC		49	100.634	5.371	90.055	111.213	<.0001*

Appendix AF: Design-Bid-Build (DBB) Unit Cost by MAJCOM

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
ACC	AETC	60	38	7.315	3.424	0.561	14.070	0.0339*
	AFGSC		18	1.952	4.438	-6.803	10.708	0.661
	AFSOC		29	0.295	3.735	-7.073	7.663	0.937
	AFSPC		9	6.440	5.904	-5.205	18.086	0.277
	AMC		41	0.532	3.346	-6.069	7.134	0.874
AETC	ACC	38	60	7.315	3.424	0.561	14.070	0.0339*
	AFGSC		18	9.268	4.726	-0.054	18.589	0.051
	AFSOC		29	7.020	4.072	-1.013	15.053	0.086
	AFSPC		9	13.756	6.123	1.678	25.833	0.0258*
	AMC		41	7.848	3.719	0.511	15.184	0.0362*
AFGSC	ACC	18	60	1.952	4.438	-6.803	10.708	0.661
	AETC		38	9.268	4.726	-0.054	18.589	0.051
	AFSOC		29	2.248	4.956	-7.528	12.023	0.651
	AFSPC		9	4.488	6.743	-8.812	17.788	0.507
	AMC		41	1.420	4.670	-7.792	10.632	0.761
AFSOC	ACC	29	60	0.295	3.735	-7.073	7.663	0.937
	AETC		38	7.020	4.072	-1.013	15.053	0.086
	AFGSC		18	2.248	4.956	-7.528	12.023	0.651
	AFSPC		9	6.736	6.302	-5.695	19.167	0.287
	AMC		41	0.828	4.007	-7.077	8.733	0.837
AFSPC	ACC	9	60	6.440	5.904	-5.205	18.086	0.277
	AETC		38	13.756	6.123	1.678	25.833	0.0258*
	AFGSC		18	4.488	6.743	-8.812	17.788	0.507
	AFSOC		29	6.736	6.302	-5.695	19.167	0.287
	AMC		41	5.908	6.080	-6.084	17.901	0.332
AMC	ACC	41	60	0.532	3.346	-6.069	7.134	0.874
	AETC		38	7.848	3.719	0.511	15.184	0.0362*
	AFGSC		18	1.420	4.670	-7.792	10.632	0.761
	AFSOC		29	0.828	4.007	-7.077	8.733	0.837
	AFSPC		9	5.908	6.080	-6.084	17.901	0.332

Appendix AG: Design-Build (DB) Modifications per Million by Fiscal Year

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
FY 03-04	FY 05-06	18	55	0.070	0.356	-0.631	0.771	0.845
	FY 07-08		55	0.705	0.356	0.003	1.406	0.0489*
	FY 09-10		107	0.077	0.334	-0.580	0.735	0.817
	FY 11-12		60	0.191	0.353	-0.503	0.885	0.589
	FY 13-14		20	0.948	0.426	0.109	1.787	0.0269*
FY 05-06	FY 03-04	55	18	0.070	0.356	-0.631	0.771	0.845
	FY 07-08		55	0.635	0.250	0.142	1.127	0.0117*
	FY 09-10		107	0.008	0.218	-0.421	0.436	0.972
	FY 11-12		60	0.121	0.245	-0.361	0.603	0.622
	FY 13-14		20	0.878	0.343	0.204	1.552	0.0109*
FY 07-08	FY 03-04	55	18	0.705	0.356	0.003	1.406	0.0489*
	FY 05-06		55	0.635	0.250	0.142	1.127	0.0117*
	FY 09-10		107	0.627	0.218	0.199	1.055	0.0043*
	FY 11-12		60	0.514	0.245	0.032	0.996	0.0367*
	FY 13-14		20	0.243	0.343	-0.431	0.918	0.478
FY 09-10	FY 03-04	107	18	0.077	0.334	-0.580	0.735	0.817
	FY 05-06		55	0.008	0.218	-0.421	0.436	0.972
	FY 07-08		55	0.627	0.218	0.199	1.055	0.0043*
	FY 11-12		60	0.113	0.212	-0.303	0.530	0.593
	FY 13-14		20	0.870	0.320	0.241	1.499	0.0068*
FY 11-12	FY 03-04	60	18	0.191	0.353	-0.503	0.885	0.589
	FY 05-06		55	0.121	0.245	-0.361	0.603	0.622
	FY 07-08		55	0.514	0.245	0.032	0.996	0.0367*
	FY 09-10		107	0.113	0.212	-0.303	0.530	0.593
	FY 13-14		20	0.757	0.339	0.091	1.424	0.0261*
FY 13-14	FY 03-04	20	18	0.948	0.426	0.109	1.787	0.0269*
	FY 05-06		55	0.878	0.343	0.204	1.552	0.0109*
	FY 07-08		55	0.243	0.343	-0.431	0.918	0.478
	FY 09-10		107	0.870	0.320	0.241	1.499	0.0068*
	FY 11-12		60	0.757	0.339	0.091	1.424	0.0261*

Appendix AH: Design-Bid-Build (DBB) Modifications per Million by Fiscal Year

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
FY 03-04	FY 05-06	36	68	0.828	0.457	-0.072	1.728	0.071
	FY 07-08		58	0.989	0.471	0.062	1.916	0.037*
	FY 09-10		54	0.431	0.477	-0.509	1.371	0.367
	FY 11-12		31	0.227	0.543	-0.843	1.298	0.676
	FY 13-14		15	1.083	0.682	-0.259	2.426	0.113
FY 05-06	FY 03-04	68	36	0.828	0.457	-0.072	1.728	0.071
	FY 07-08		58	0.161	0.396	-0.620	0.942	0.685
	FY 09-10		54	0.397	0.404	-0.399	1.193	0.327
	FY 11-12		31	0.601	0.481	-0.346	1.547	0.213
	FY 13-14		15	0.255	0.633	-0.991	1.501	0.687
FY 07-08	FY 03-04	58	36	0.989	0.471	0.062	1.916	0.037*
	FY 05-06		68	0.161	0.396	-0.612	0.942	0.685
	FY 09-10		54	0.558	0.419	-0.268	1.384	0.185
	FY 11-12		31	0.761	0.493	-0.210	1.733	0.124
	FY 13-14		15	0.094	0.643	-1.171	1.360	0.883
FY 09-10	FY 03-04	54	36	0.431	0.477	-0.509	1.371	0.367
	FY 05-06		68	0.397	0.404	-0.399	1.193	0.327
	FY 07-08		58	0.558	0.419	-0.268	1.384	0.185
	FY 11-12		31	0.204	0.500	-0.781	1.188	0.684
	FY 13-14		15	0.652	0.647	-0.623	1.927	0.315
FY 11-12	FY 03-04	31	36	0.227	0.543	-0.843	1.298	0.676
	FY 05-06		68	0.601	0.481	-0.346	1.547	0.213
	FY 07-08		58	0.761	0.493	-0.210	1.733	0.124
	FY 09-10		54	0.204	0.500	-0.781	1.188	0.684
	FY 13-14		15	0.856	0.698	-0.518	2.230	0.221
FY 13-14	FY 03-04	15	36	1.083	0.682	-0.259	2.426	0.113
	FY 05-06		68	0.255	0.633	-0.991	1.501	0.687
	FY 07-08		58	0.094	0.643	-1.171	1.360	0.883
	FY 09-10		54	0.652	0.647	-0.623	1.927	0.315
	FY 11-12		31	0.856	0.698	-0.518	2.230	0.221

Appendix AI: Design-Build (DB) Modifications per Million by Facility Type

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
ADMINISTRATIVE	COMMUNITY SUPPORT	26	25	0.003	0.363	-1.077	1.082	1.000
	DORMS, QUARTERS, DINING HALLS		25	0.581	0.363	-0.499	1.660	0.684
	MAINTENANCE		71	0.128	0.297	-0.755	1.011	1.000
	OPERATIONS		46	0.012	0.318	-0.933	0.958	1.000
	PERSONNEL SUPPORT		30	0.363	0.347	-0.670	1.395	0.943
	TRAINING		43	0.157	0.322	-0.801	1.114	0.999
COMMUNITY SUPPORT	ADMINISTRATIVE	25	26	0.003	0.363	-1.077	1.082	1.000
	DORMS, QUARTERS, DINING HALLS		25	0.125	0.302	-0.771	1.021	1.000
	MAINTENANCE		71	0.010	0.322	-0.948	0.967	1.000
	OPERATIONS		46	0.010	0.322	-0.948	0.967	1.000
	PERSONNEL SUPPORT		30	0.366	0.351	-0.678	1.409	0.944
	TRAINING		43	0.159	0.326	-0.810	1.128	0.999
DORMS, QUARTERS, DINING HALLS	ADMINISTRATIVE	25	26	0.581	0.363	-0.499	1.660	0.684
	COMMUNITY SUPPORT		25	0.578	0.367	-0.512	1.668	0.698
	MAINTENANCE		71	0.453	0.302	-0.444	1.349	0.744
	OPERATIONS		46	0.568	0.322	-0.389	1.526	0.574
	PERSONNEL SUPPORT		30	0.944	0.351	-0.100	1.987	0.106
	TRAINING		43	0.737	0.326	-0.232	1.706	0.268
MAINTENANCE	ADMINISTRATIVE	71	26	0.128	0.297	-0.755	1.011	1.000
	COMMUNITY SUPPORT		25	0.125	0.302	-0.771	1.021	1.000
	DORMS, QUARTERS, DINING HALLS		25	0.453	0.302	-0.444	1.349	0.744
	OPERATIONS		46	0.116	0.245	-0.614	0.845	0.999
	PERSONNEL SUPPORT		30	0.491	0.282	-0.348	1.330	0.591
	TRAINING		43	0.284	0.251	-0.460	1.029	0.917
OPERATIONS	ADMINISTRATIVE	46	26	0.012	0.318	-0.933	0.958	1.000
	COMMUNITY SUPPORT		25	0.010	0.322	-0.948	0.967	1.000
	DORMS, QUARTERS, DINING HALLS		25	0.568	0.322	-0.389	1.526	0.574
	MAINTENANCE		71	0.116	0.245	-0.614	0.845	0.999
	PERSONNEL SUPPORT		30	0.375	0.304	-0.529	1.280	0.881
	TRAINING		43	0.169	0.275	-0.649	0.986	0.996
PERSONNEL SUPPORT	ADMINISTRATIVE	30	26	0.363	0.347	-0.670	1.395	0.943
	COMMUNITY SUPPORT		25	0.366	0.351	-0.678	1.409	0.944
	DORMS, QUARTERS, DINING HALLS		25	0.944	0.351	-0.100	1.987	0.106
	MAINTENANCE		71	0.491	0.282	-0.348	1.330	0.591
	OPERATIONS		46	0.375	0.304	-0.529	1.280	0.881
	TRAINING		43	0.206	0.308	-0.710	1.123	0.994
TRAINING	ADMINISTRATIVE	43	26	0.157	0.322	-0.801	1.114	0.999
	COMMUNITY SUPPORT		25	0.159	0.326	-0.810	1.128	0.999
	DORMS, QUARTERS, DINING HALLS		25	0.737	0.326	-0.232	1.706	0.268
	MAINTENANCE		71	0.284	0.251	-0.460	1.029	0.917
	OPERATIONS		46	0.169	0.275	-0.649	0.986	0.996
	PERSONNEL SUPPORT		30	0.206	0.308	-0.710	1.123	0.994

Appendix AJ: Design-Bid-Build (DBB) Modifications per Million by Facility Type

Level	- Level	Observations Level	Observations - Level	Mean Difference	Std Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Significance (p-value)
AIRFIELD PAVEMENTS	COMMUNITY SUPPORT	16	15	3.219	0.774	1.693	4.744	<.0001*
	DORMS, QUARTERS, DINING HALLS		32	1.882	0.659	0.582	3.181	0.0047*
	MAINTENANCE		50	2.375	0.618	1.156	3.594	0.0002*
	OPERATIONS		34	2.765	0.653	1.479	4.052	<.0001*
	PERSONNEL SUPPORT		20	2.530	0.722	1.107	3.954	0.0006*
	TRAINING		44	2.187	0.628	0.948	3.426	0.0006*
COMMUNITY SUPPORT	AIRFIELD PAVEMENTS	15	16	3.219	0.774	1.693	4.744	<.0001*
	DORMS, QUARTERS, DINING HALLS		32	1.337	0.673	0.009	2.665	0.0485*
	MAINTENANCE		50	0.844	0.634	-0.405	2.093	0.184
	OPERATIONS		34	0.453	0.667	-0.862	1.769	0.498
	PERSONNEL SUPPORT		20	0.688	0.735	-0.761	2.138	0.350
	TRAINING		44	1.032	0.644	-0.237	2.300	0.110
DORMS, QUARTERS, DINING HALLS	AIRFIELD PAVEMENTS	32	16	2.375	0.618	1.156	3.594	0.0002*
	COMMUNITY SUPPORT		15	1.337	0.673	0.009	2.665	0.0485*
	MAINTENANCE		50	0.493	0.487	-0.468	1.454	0.313
	OPERATIONS		34	0.883	0.530	-0.162	1.929	0.097
	PERSONNEL SUPPORT		20	0.649	0.613	-0.561	1.858	0.292
	TRAINING		44	0.305	0.500	-0.681	1.291	0.543
MAINTENANCE	AIRFIELD PAVEMENTS	50	16	2.375	0.618	1.156	3.594	0.0002*
	COMMUNITY SUPPORT		15	0.844	0.634	-0.405	2.093	0.184
	DORMS, QUARTERS, DINING HALLS		32	0.493	0.487	-0.468	1.454	0.313
	OPERATIONS		34	0.391	0.478	-0.553	1.334	0.415
	PERSONNEL SUPPORT		20	0.156	0.569	-0.967	1.279	0.785
	TRAINING		44	0.188	0.445	-0.689	1.065	0.673
OPERATIONS	AIRFIELD PAVEMENTS	34	16	2.765	0.653	1.479	4.052	<.0001*
	COMMUNITY SUPPORT		15	0.453	0.667	-0.862	1.769	0.498
	DORMS, QUARTERS, DINING HALLS		32	0.883	0.530	-0.162	1.929	0.097
	MAINTENANCE		50	0.391	0.478	-0.553	1.334	0.415
	PERSONNEL SUPPORT		20	0.235	0.607	-0.961	1.431	0.699
	TRAINING		44	0.578	0.491	-0.391	1.547	0.241
PERSONNEL SUPPORT	AIRFIELD PAVEMENTS	20	16	2.530	0.722	1.107	3.954	0.0006*
	COMMUNITY SUPPORT		15	0.688	0.735	-0.761	2.138	0.350
	DORMS, QUARTERS, DINING HALLS		32	0.649	0.613	-0.561	1.858	0.292
	MAINTENANCE		50	0.156	0.569	-0.967	1.279	0.785
	OPERATIONS		34	0.235	0.607	-0.961	1.431	0.699
	TRAINING		44	0.344	0.580	-0.801	1.488	0.554
TRAINING	AIRFIELD PAVEMENTS	44	16	2.187	0.628	0.948	3.426	0.0006*
	COMMUNITY SUPPORT		15	1.032	0.644	-0.237	2.300	0.110
	DORMS, QUARTERS, DINING HALLS		32	0.305	0.500	-0.681	1.291	0.543
	MAINTENANCE		50	0.188	0.445	-0.689	1.065	0.673
	OPERATIONS		34	0.578	0.491	-0.391	1.547	0.241
	PERSONNEL SUPPORT		20	0.344	0.580	-0.801	1.488	0.554

Appendix AK: Design-Build (DB) Modifications per Million by MAJCOM

Level	- Level	Observations		Mean	Std Error	95% Confidence Interval		Significance
		Level	- Level	Difference		Lower Bound	Upper Bound	(p-value)
ACC	AETC	67	58	0.087	0.239	-0.644	0.817	1.000
	AFGSC		25	0.527	0.313	-0.427	1.481	0.696
	AFMC		55	0.458	0.243	-0.283	1.199	0.560
	AFSOC		9	0.281	0.473	-1.164	1.726	0.999
	AFSPC		15	0.156	0.381	-1.007	1.319	1.000
	AMC		53	0.074	0.245	-0.674	0.823	1.000
	PACAF		23	0.163	0.322	-0.821	1.147	1.000
AETC	ACC	58	67	0.087	0.239	-0.644	0.817	1.000
	AFGSC		25	0.614	0.319	-0.360	1.588	0.536
	AFMC		55	0.371	0.251	-0.395	1.138	0.818
	AFSOC		9	0.368	0.478	-1.091	1.826	0.995
	AFSPC		15	0.242	0.386	-0.937	1.422	0.999
	AMC		53	0.012	0.253	-0.761	0.786	1.000
	PACAF		23	0.250	0.329	-0.754	1.253	0.995
AFGSC	ACC	25	67	0.527	0.313	-0.427	1.481	0.696
	AETC		58	0.614	0.319	-0.360	1.588	0.536
	AFMC		55	0.985	0.322	0.003	1.967	0.0486*
	AFSOC		9	0.246	0.518	-1.337	1.829	1.000
	AFSPC		15	0.371	0.436	-0.958	1.701	0.990
	AMC		53	0.601	0.324	-0.386	1.589	0.580
	PACAF		23	0.364	0.385	-0.812	1.540	0.981
AFMC	ACC	55	67	0.458	0.243	-0.283	1.199	0.560
	AETC		58	0.371	0.251	-0.395	1.138	0.818
	AFGSC		25	0.985	0.322	0.003	1.967	0.0486*
	AFSOC		9	0.739	0.480	-0.725	2.203	0.785
	AFSPC		15	0.614	0.388	-0.572	1.800	0.762
	AMC		53	0.384	0.257	-0.400	1.167	0.810
	PACAF		23	0.621	0.331	-0.390	1.632	0.569
AFSOC	ACC	9	67	0.281	0.473	-1.164	1.726	0.999
	AETC		58	0.368	0.478	-1.091	1.826	0.995
	AFGSC		25	0.246	0.518	-1.337	1.829	1.000
	AFMC		55	0.739	0.480	-0.725	2.203	0.785
	AFSPC		15	0.125	0.562	-1.591	1.842	1.000
	AMC		53	0.355	0.481	-1.112	1.823	0.996
	PACAF		23	0.118	0.524	-1.483	1.719	1.000
AFSPC	ACC	15	67	0.156	0.381	-1.007	1.319	1.000
	AETC		58	0.242	0.386	-0.937	1.422	0.999
	AFGSC		25	0.371	0.436	-0.958	1.701	0.990
	AFMC		55	0.614	0.388	-0.572	1.800	0.762
	AFSOC		9	0.125	0.562	-1.591	1.842	1.000
	AMC		53	0.230	0.390	-0.960	1.421	0.999
	PACAF		23	0.007	0.443	-1.344	1.358	1.000
AMC	ACC	53	67	0.074	0.245	-0.674	0.823	1.000
	AETC		58	0.012	0.253	-0.761	0.786	1.000
	AFGSC		25	0.601	0.324	-0.386	1.589	0.580
	AFMC		55	0.384	0.257	-0.400	1.167	0.810
	AFSOC		9	0.355	0.481	-1.112	1.823	0.996
	AFSPC		15	0.230	0.390	-0.960	1.421	0.999
	PACAF		23	0.237	0.333	-0.779	1.254	0.997
PACAF	ACC	15	67	0.163	0.322	-0.821	1.147	1.000
	AETC		58	0.250	0.329	-0.754	1.253	0.995
	AFGSC		25	0.364	0.385	-0.812	1.540	0.981
	AFMC		55	0.621	0.331	-0.390	1.632	0.569
	AFSOC		9	0.118	0.524	-1.483	1.719	1.000
	AFSPC		15	0.007	0.443	-1.344	1.358	1.000
	AMC		53	0.237	0.333	-0.779	1.254	0.997

Appendix AL: Design-Bid-Build (DBB) Modifications per Million by MAJCOM

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
ACC	AETC	70	57	0.625	0.333	-0.031	1.281	0.062
	AFGSC		22	0.996	0.456	0.097	1.895	0.0301*
	AFSOC		36	1.190	0.383	0.436	1.944	0.0021*
	AFSPC		12	0.237	0.583	-0.912	1.386	0.684
	AMC		49	0.555	0.348	-0.130	1.240	0.112
AETC	ACC	57	70	0.625	0.333	-0.031	1.281	0.062
	AFGSC		22	1.621	0.469	0.698	2.544	0.0006*
	AFSOC		36	1.815	0.397	1.032	2.598	<.0001*
	AFSPC		12	0.863	0.593	-0.305	2.031	0.147
	AMC		49	0.070	0.364	-0.646	0.787	0.847
AFGSC	ACC	22	70	0.996	0.456	0.097	1.895	0.0301*
	AETC		57	1.621	0.469	0.698	2.544	0.0006*
	AFSOC		36	0.194	0.505	-0.801	1.189	0.701
	AFSPC		12	0.758	0.670	-0.561	2.078	0.259
	AMC		49	1.551	0.479	0.607	2.495	0.0014*
AFSOC	ACC	36	70	1.190	0.383	0.436	1.944	0.0021*
	AETC		57	1.815	0.397	1.032	2.598	<.0001*
	AFGSC		22	0.194	0.505	-0.801	1.189	0.701
	AFSPC		12	0.953	0.622	-0.273	2.178	0.127
	AMC		49	1.745	0.410	0.938	2.552	<.0001*
AFSPC	ACC	12	70	0.237	0.583	-0.912	1.386	0.684
	AETC		57	0.863	0.593	-0.305	2.031	0.147
	AFGSC		22	0.758	0.670	-0.561	2.078	0.259
	AFSOC		36	0.953	0.622	-0.273	2.178	0.127
	AMC		49	0.792	0.601	-0.392	1.977	0.189
AMC	ACC	49	70	0.555	0.348	-0.130	1.240	0.112
	AETC		57	0.070	0.364	-0.646	0.787	0.847
	AFGSC		22	1.551	0.479	0.607	2.495	0.0014*
	AFSOC		36	1.745	0.410	0.938	2.552	<.0001*
	AFSPC		12	0.792	0.601	-0.392	1.977	0.189

Appendix AM: Design-Bid-Build (DBB) Construction Speed by Fiscal Year

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
FY 03-04	FY 05-06	20	54	35.550	70.163	-166.531	237.630	0.996
	FY 07-08		35	149.647	75.134	-66.751	366.044	0.351
	FY 09-10		43	31.994	72.548	-176.955	240.944	0.998
	FY 11-12		26	58.883	79.723	-170.731	288.497	0.977
	FY 13-14		11	44.697	100.618	-245.098	334.491	0.998
FY 05-06	FY 03-04	54	20	35.550	70.163	-166.531	237.630	0.996
	FY 07-08		35	114.097	58.166	-53.430	281.624	0.369
	FY 09-10		43	3.555	54.785	-154.233	161.344	1.000
	FY 11-12		26	23.333	63.983	-160.948	207.615	0.999
	FY 13-14		11	80.246	88.668	-175.132	335.624	0.945
FY 07-08	FY 03-04	35	20	149.647	75.134	-66.751	366.044	0.351
	FY 05-06		54	114.097	58.166	-53.430	281.624	0.369
	FY 09-10		43	117.652	61.022	-58.099	293.404	0.389
	FY 11-12		26	90.764	69.398	-109.114	290.641	0.780
	FY 13-14		11	194.343	92.652	-72.508	461.194	0.293
FY 09-10	FY 03-04	43	20	31.994	72.548	-176.955	240.944	0.998
	FY 05-06		54	3.555	54.785	-154.233	161.344	1.000
	FY 07-08		35	117.652	61.022	-58.099	293.404	0.389
	FY 11-12		26	26.889	66.590	-164.900	218.678	0.999
	FY 13-14		11	76.691	90.567	-184.157	337.538	0.958
FY 11-12	FY 03-04	26	20	58.883	79.723	-170.731	288.497	0.977
	FY 05-06		54	23.333	63.983	-160.948	207.615	0.999
	FY 07-08		35	90.764	69.398	-109.114	290.641	0.780
	FY 09-10		43	26.889	66.590	-164.900	218.678	0.999
	FY 13-14		11	103.579	96.410	-174.096	381.255	0.891
FY 13-14	FY 03-04	11	20	44.697	100.618	-245.098	334.491	0.998
	FY 05-06		54	80.246	88.668	-175.132	335.624	0.945
	FY 07-08		35	194.343	92.652	-72.508	461.194	0.293
	FY 09-10		43	76.691	90.567	-184.157	337.538	0.958
	FY 11-12		26	103.579	96.410	-174.096	381.255	0.891

Appendix AN: Design-Bid-Build (DBB) Construction Speed by Facility Type

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
COMMUNITY SUPPORT	DORMS, QUARTERS, DINING HALLS	15	17	175.423	83.390	10.719	340.126	0.0370*
	MAINTENANCE		41	24.960	71.034	-115.339	165.259	0.726
	OPERATIONS		32	67.090	73.661	-78.397	212.578	0.364
	PERSONNEL SUPPORT		16	91.807	84.603	-75.292	258.906	0.280
	TRAINING		43	113.443	70.590	-25.979	252.866	0.110
DORMS, QUARTERS, DINING HALLS	COMMUNITY SUPPORT	17	15	175.423	83.390	10.719	340.126	0.0370*
	MAINTENANCE		41	150.463	67.906	16.342	284.583	0.0281*
	OPERATIONS		32	108.332	70.650	-31.207	247.872	0.127
	PERSONNEL SUPPORT		16	83.616	81.994	-78.331	245.562	0.309
	TRAINING		43	61.980	67.442	-71.224	195.183	0.360
MAINTENANCE	COMMUNITY SUPPORT	41	15	24.960	71.034	-115.339	165.259	0.726
	DORMS, QUARTERS, DINING HALLS		17	150.463	67.906	16.342	284.583	0.0281*
	OPERATIONS		32	42.130	55.527	-67.541	151.801	0.449
	PERSONNEL SUPPORT		16	66.847	69.390	-70.204	203.899	0.337
	TRAINING		43	88.483	51.384	-13.004	189.970	0.087
OPERATIONS	COMMUNITY SUPPORT	32	15	67.090	73.661	-78.397	212.578	0.364
	DORMS, QUARTERS, DINING HALLS		17	108.332	70.650	-31.207	247.872	0.127
	MAINTENANCE		41	42.130	55.527	-67.541	151.801	0.449
	PERSONNEL SUPPORT		16	24.717	72.077	-117.642	167.076	0.732
	TRAINING		43	46.353	54.958	-62.195	154.900	0.400
PERSONNEL SUPPORT	COMMUNITY SUPPORT	16	15	91.807	84.603	-75.292	258.906	0.280
	DORMS, QUARTERS, DINING HALLS		17	83.616	81.994	-78.331	245.562	0.309
	MAINTENANCE		41	66.847	69.390	-70.204	203.899	0.337
	OPERATIONS		32	24.717	72.077	-117.642	167.076	0.732
	TRAINING		43	21.636	68.935	-114.518	157.790	0.754
TRAINING	COMMUNITY SUPPORT	43	15	113.443	70.590	-25.979	252.866	0.110
	DORMS, QUARTERS, DINING HALLS		17	61.980	67.442	-71.224	195.183	0.360
	MAINTENANCE		41	88.483	51.384	-13.004	189.970	0.087
	OPERATIONS		32	46.353	54.958	-62.195	154.900	0.400
	PERSONNEL SUPPORT		16	21.636	68.935	-114.518	157.790	0.754

Appendix AO: Design-Bid-Build (DBB) Construction Speed by MAJCOM

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
ACC	AETC	60	38	414.021	184.018	51.028	777.014	0.0256*
	AFGSC		18	76.925	238.534	-393.606	547.455	0.747
	AFSOC		29	239.820	200.740	-156.159	635.800	0.234
	AFSPC		9	41.464	317.280	-584.400	667.329	0.896
	AMC		41	371.401	179.849	16.632	726.170	0.0403*
AETC	ACC	38	60	414.021	184.018	51.028	777.014	0.0256*
	AFGSC		18	490.946	253.969	-10.032	991.923	0.055
	AFSOC		29	174.201	218.857	-257.516	605.917	0.427
	AFSPC		9	455.485	329.041	-193.580	1104.550	0.168
	AMC		41	42.620	199.869	-351.640	436.879	0.831
AFGSC	ACC	18	60	76.925	238.534	-393.606	547.455	0.747
	AETC		38	490.946	253.969	-10.032	991.923	0.055
	AFSOC		29	316.745	266.335	-208.626	842.116	0.236
	AFSPC		9	35.460	362.359	-679.327	750.248	0.922
	AMC		41	448.326	250.965	-46.725	943.377	0.076
AFSOC	ACC	29	60	239.820	200.740	-156.159	635.800	0.234
	AETC		38	174.201	218.857	-257.516	605.917	0.427
	AFGSC		18	316.745	266.335	-208.626	842.116	0.236
	AFSPC		9	281.285	338.677	-386.788	949.358	0.407
	AMC		41	131.581	215.364	-293.244	556.407	0.542
AFSPC	ACC	9	60	41.464	317.280	-584.400	667.329	0.896
	AETC		38	455.485	329.041	-193.580	1104.550	0.168
	AFGSC		18	35.460	362.359	-679.327	750.248	0.922
	AFSOC		29	281.285	338.677	-386.788	949.358	0.407
	AMC		41	412.866	326.728	-231.636	1057.368	0.208
AMC	ACC	41	60	371.401	179.849	16.632	726.170	0.0403*
	AETC		38	42.620	199.869	-351.640	436.879	0.831
	AFGSC		18	448.326	250.965	-46.725	943.377	0.076
	AFSOC		29	131.581	215.364	-293.244	556.407	0.542
	AFSPC		9	412.866	326.728	-231.636	1057.368	0.208

Appendix AP: Design-Build (DB) Delivery Speed by Fiscal Year

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
FY 03-04	FY 05-06	12	34	14.724	54.030	-140.514	169.962	1.000
	FY 07-08		42	15.512	52.670	-135.819	166.844	1.000
	FY 09-10		84	20.976	49.658	-121.701	163.653	0.998
	FY 11-12		54	4.268	51.353	-143.280	151.816	1.000
	FY 13-14		17	31.892	60.669	-142.422	206.206	0.995
FY 05-06	FY 03-04	34	12	14.724	54.030	-140.514	169.962	1.000
	FY 07-08		42	30.236	37.122	-76.421	136.894	0.965
	FY 09-10		84	35.700	32.707	-58.275	129.674	0.884
	FY 11-12		54	10.456	35.228	-90.761	111.673	1.000
	FY 13-14		17	46.615	47.798	-90.716	183.947	0.925
FY 07-08	FY 03-04	42	12	15.512	52.670	-135.819	166.844	1.000
	FY 05-06		34	30.236	37.122	-76.421	136.894	0.965
	FY 09-10		84	5.464	30.409	-81.908	92.835	1.000
	FY 11-12		54	19.780	33.105	-75.338	114.898	0.991
	FY 13-14		17	16.379	46.255	-116.521	149.279	0.999
FY 09-10	FY 03-04	84	12	20.976	49.658	-121.701	163.653	0.998
	FY 05-06		34	35.700	32.707	-58.275	129.674	0.884
	FY 07-08		42	5.464	30.409	-81.908	92.835	1.000
	FY 11-12		54	25.244	28.066	-55.396	105.884	0.946
	FY 13-14		17	10.916	42.794	-112.039	133.870	1.000
FY 11-12	FY 03-04	54	12	4.268	51.353	-143.280	151.816	1.000
	FY 05-06		34	10.456	35.228	-90.761	111.673	1.000
	FY 07-08		42	19.780	33.105	-75.338	114.898	0.991
	FY 09-10		84	25.244	28.066	-55.396	105.884	0.946
	FY 13-14		17	36.159	44.750	-92.416	164.734	0.966
FY 13-14	FY 03-04	17	12	31.892	60.669	-142.422	206.206	0.995
	FY 05-06		34	46.615	47.798	-90.716	183.947	0.925
	FY 07-08		42	16.379	46.255	-116.521	149.279	0.999
	FY 09-10		84	10.916	42.794	-112.039	133.870	1.000
	FY 11-12		54	36.159	44.750	-92.416	164.734	0.966

Appendix AQ: Design-Build (DB) Delivery Speed by Facility Type

Level	- Level	Observations		Mean	Std Error	95% Confidence Interval		Significance
		Level	- Level	Difference		Lower Bound	Upper Bound	(p-value)
ADMINISTRATIVE	COMMUNITY SUPPORT	24	23	83.881	46.727	-8.202	175.965	0.074
	DORMS, QUARTERS, DINING HALLS		13	38.474	55.146	-70.201	147.148	0.486
	MAINTENANCE		65	45.370	38.249	-30.006	120.747	0.237
	OPERATIONS		41	68.956	41.158	-12.152	150.063	0.095
	PERSONNEL SUPPORT		26	78.488	45.330	-10.842	167.818	0.085
	TRAINING		38	109.596	41.753	27.315	191.877	0.0093*
COMMUNITY SUPPORT	ADMINISTRATIVE	23	24	83.881	46.727	-8.202	175.965	0.074
	DORMS, QUARTERS, DINING HALLS		13	122.355	55.566	12.854	231.856	0.0287*
	MAINTENANCE		65	38.511	38.852	-38.053	115.075	0.323
	OPERATIONS		41	14.926	41.718	-67.287	97.138	0.721
	PERSONNEL SUPPORT		26	5.394	45.839	-84.940	95.727	0.906
	TRAINING		38	25.715	42.306	-57.656	109.085	0.544
DORMS, QUARTERS, DINING HALLS	ADMINISTRATIVE	13	24	38.474	55.146	-70.201	147.148	0.486
	COMMUNITY SUPPORT		23	122.355	55.566	12.854	231.856	0.0287*
	MAINTENANCE		65	83.844	48.653	-12.035	179.722	0.086
	OPERATIONS		41	107.429	50.971	6.982	207.876	0.0362*
	PERSONNEL SUPPORT		26	116.961	54.396	9.766	224.157	0.0326*
	TRAINING		38	148.070	51.453	46.673	249.466	0.0044*
MAINTENANCE	ADMINISTRATIVE	65	24	45.370	38.249	-30.006	120.747	0.237
	COMMUNITY SUPPORT		23	38.511	38.852	-38.053	115.075	0.323
	DORMS, QUARTERS, DINING HALLS		13	83.844	48.653	-12.035	179.722	0.086
	OPERATIONS		41	23.585	31.937	-39.352	86.523	0.461
	PERSONNEL SUPPORT		26	33.118	37.159	-40.111	106.346	0.374
	TRAINING		38	64.226	32.701	-0.217	128.668	0.051
OPERATIONS	ADMINISTRATIVE	41	24	68.956	41.158	-12.152	150.063	0.095
	COMMUNITY SUPPORT		23	14.926	41.718	-67.287	97.138	0.721
	DORMS, QUARTERS, DINING HALLS		13	107.429	50.971	6.982	207.876	0.0362*
	MAINTENANCE		65	23.585	31.937	-39.352	86.523	0.461
	PERSONNEL SUPPORT		26	9.532	40.147	-69.583	88.648	0.813
	TRAINING		38	40.640	36.060	-30.421	111.702	0.261
PERSONNEL SUPPORT	ADMINISTRATIVE	26	24	78.488	45.330	-10.842	167.818	0.085
	COMMUNITY SUPPORT		23	5.394	45.839	-84.940	95.727	0.906
	DORMS, QUARTERS, DINING HALLS		13	116.961	54.396	9.766	224.157	0.0326*
	MAINTENANCE		65	33.118	37.159	-40.111	106.346	0.374
	OPERATIONS		41	9.532	40.147	-69.583	88.648	0.813
	TRAINING		38	31.108	40.757	-49.210	111.427	0.446
TRAINING	ADMINISTRATIVE	38	24	109.596	41.753	27.315	191.877	0.0093*
	COMMUNITY SUPPORT		23	25.715	42.306	-57.656	109.085	0.544
	DORMS, QUARTERS, DINING HALLS		13	148.070	51.453	46.673	249.466	0.0044*
	MAINTENANCE		65	64.226	32.701	-0.217	128.668	0.051
	OPERATIONS		41	40.640	36.060	-30.421	111.702	0.261
	PERSONNEL SUPPORT		26	31.108	40.757	-49.210	111.427	0.446

Appendix: AR Design-Build (DB) Delivery Speed by MAJCOM

Level	- Level	Observations		Mean	Std Error	95% Confidence Interval		Significance
		Level	- Level	Difference		Lower Bound	Upper Bound	(p-value)
ACC	AETC	59	40	94.419	162.857	-403.47	592.307	0.999
	AFGSC		23	60.469	195.461	-537.10	658.037	1.000
	AFMC		44	179.978	158.384	-304.24	664.191	0.948
	AFSOC		8	66.212	299.578	-849.66	982.088	1.000
	AFSPC		13	28.852	243.620	-715.95	773.651	1.000
	AMC		49	115.387	153.685	-354.46	585.235	0.995
	PACAF		18	23.389	214.105	-631.18	677.955	1.000
AETC	ACC	40	59	94.419	162.857	-403.47	592.307	0.999
	AFGSC		23	154.887	208.075	-481.24	791.018	0.996
	AFMC		44	85.559	173.711	-445.51	616.631	1.000
	AFSOC		8	160.631	307.957	-780.86	1102.121	1.000
	AFSPC		13	123.271	253.852	-652.81	899.351	1.000
	AMC		49	20.968	169.438	-497.04	538.977	1.000
	PACAF		18	117.807	225.679	-572.14	807.758	1.000
AFGSC	ACC	23	59	60.469	195.461	-537.10	658.037	1.000
	AETC		40	154.887	208.075	-481.24	791.018	0.996
	AFMC		44	240.447	204.593	-385.04	865.932	0.938
	AFSOC		8	5.743	326.374	-992.05	1003.540	1.000
	AFSPC		13	31.617	275.905	-811.88	875.118	1.000
	AMC		49	175.856	200.978	-438.58	790.288	0.988
	PACAF		18	37.080	250.228	-727.92	802.081	1.000
AFMC	ACC	44	59	179.978	158.384	-304.24	664.191	0.948
	AETC		40	85.559	173.711	-445.51	616.631	1.000
	AFGSC		23	240.447	204.593	-385.04	865.932	0.938
	AFSOC		8	246.190	305.615	-688.14	1180.521	0.993
	AFSPC		13	208.830	251.006	-558.55	976.209	0.991
	AMC		49	64.591	165.143	-440.29	569.470	1.000
	PACAF		18	203.367	222.473	-476.78	883.515	0.985
AFSOC	ACC	8	59	66.212	299.578	-849.66	982.088	1.000
	AETC		40	160.631	307.957	-780.86	1102.121	1.000
	AFGSC		23	5.743	326.374	-992.05	1003.540	1.000
	AFMC		44	246.190	305.615	-688.14	1180.521	0.993
	AFSPC		13	37.360	357.303	-1054.99	1129.713	1.000
	AMC		49	181.599	303.206	-745.37	1108.566	0.999
	PACAF		18	42.823	337.870	-990.12	1075.764	1.000
AFSPC	ACC	13	59	28.852	243.620	-715.95	773.651	1.000
	AETC		40	123.271	253.852	-652.81	899.351	1.000
	AFGSC		23	31.617	275.905	-811.88	875.118	1.000
	AFMC		44	208.830	251.006	-558.55	976.209	0.991
	AFSOC		8	37.360	357.303	-1054.99	1129.713	1.000
	AMC		49	144.239	248.068	-614.16	902.635	0.999
	PACAF		18	5.463	289.412	-879.33	890.259	1.000
AMC	ACC	49	59	115.387	153.685	-354.46	585.235	0.995
	AETC		40	20.968	169.438	-497.04	538.977	1.000
	AFGSC		23	175.856	200.978	-438.58	790.288	0.988
	AFMC		44	64.591	165.143	-440.29	569.470	1.000
	AFSOC		8	181.599	303.206	-745.37	1108.566	0.999
	AFSPC		13	144.239	248.068	-614.16	902.635	0.999
	PACAF		18	138.776	219.153	-531.22	808.773	0.998
PACAF	ACC	13	59	23.389	214.105	-631.18	677.955	1.000
	AETC		40	117.807	225.679	-572.14	807.758	1.000
	AFGSC		23	37.080	250.228	-727.92	802.081	1.000
	AFMC		44	203.367	222.473	-476.78	883.515	0.985
	AFSOC		8	42.823	337.870	-990.12	1075.764	1.000
	AFSPC		13	5.463	289.412	-879.33	890.259	1.000
	AMC		49	138.776	219.153	-531.22	808.773	0.998

Appendix AS: Design-Build (DB) Project Duration by Fiscal Year

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
FY 03-04	FY 05-06	17	55	152.736	103.826	-51.565	357.036	0.142
	FY 07-08		55	113.936	103.826	-90.365	318.236	0.273
	FY 09-10		106	23.109	97.751	-169.238	215.455	0.813
	FY 11-12		60	177.818	102.799	-24.463	380.098	0.085
	FY 13-14		20	268.818	123.426	25.950	511.686	0.0302*
FY 05-06	FY 03-04	55	17	152.736	103.826	-51.565	357.036	0.142
	FY 07-08		55	38.800	71.348	-101.592	179.192	0.587
	FY 09-10		106	175.845	62.176	53.499	298.190	0.0050*
	FY 11-12		60	25.082	69.845	-112.354	162.518	0.720
	FY 13-14		20	116.082	97.697	-76.158	308.322	0.236
FY 07-08	FY 03-04	55	17	113.936	103.826	-90.365	318.236	0.273
	FY 05-06		55	38.800	71.348	-101.592	179.192	0.587
	FY 09-10		106	137.045	62.176	14.699	259.390	0.0283*
	FY 11-12		60	63.882	69.845	-73.554	201.318	0.361
	FY 13-14		20	154.882	97.697	-37.358	347.122	0.114
FY 09-10	FY 03-04	106	17	23.109	97.751	-169.238	215.455	0.813
	FY 05-06		55	175.845	62.176	53.499	298.190	0.0050*
	FY 07-08		55	137.045	62.176	14.699	259.390	0.0283*
	FY 11-12		60	200.926	60.446	81.985	319.868	0.0010*
	FY 13-14		20	291.926	91.214	112.442	471.411	0.0015*
FY 11-12	FY 03-04	60	17	177.818	102.799	-24.463	380.098	0.085
	FY 05-06		55	25.082	69.845	-112.354	162.518	0.720
	FY 07-08		55	63.882	69.845	-73.554	201.318	0.361
	FY 09-10		106	200.926	60.446	81.985	319.868	0.0010*
	FY 13-14		20	91.000	96.605	-99.092	281.092	0.347
FY 13-14	FY 03-04	20	17	268.818	123.426	25.950	511.686	0.0302*
	FY 05-06		55	116.082	97.697	-76.158	308.322	0.236
	FY 07-08		55	154.882	97.697	-37.358	347.122	0.114
	FY 09-10		106	291.926	91.214	112.442	471.411	0.0015*
	FY 11-12		60	91.000	96.605	-99.092	281.092	0.347

Appendix AT: Design-Bid-Build (DBB) Project Duration by Fiscal Year

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
FY 03-04	FY 05-06	36	68	9.114	78.293	-215.699	233.927	1.000
	FY 07-08		58	18.668	80.595	-212.757	250.092	1.000
	FY 09-10		54	39.176	81.731	-195.508	273.860	0.997
	FY 11-12		31	128.564	93.071	-138.685	395.812	0.738
	FY 13-14		15	86.876	108.355	-224.260	398.011	0.967
FY 05-06	FY 03-04	68	36	9.114	78.293	-215.699	233.927	1.000
	FY 07-08		58	9.553	67.893	-185.399	204.505	1.000
	FY 09-10		54	30.062	69.237	-168.749	228.872	0.998
	FY 11-12		31	119.449	82.318	-116.921	355.819	0.696
	FY 13-14		15	86.876	108.355	-224.260	398.011	0.967
FY 07-08	FY 03-04	58	36	18.668	80.595	-212.757	250.092	1.000
	FY 05-06		68	9.553	67.893	-185.399	204.505	1.000
	FY 09-10		54	20.508	71.831	-185.749	226.765	1.000
	FY 11-12		31	109.896	84.511	-132.771	352.563	0.785
	FY 13-14		15	96.429	110.030	-219.517	412.374	0.952
FY 09-10	FY 03-04	54	36	39.176	81.731	-195.508	273.860	0.997
	FY 05-06		68	30.062	69.237	-168.749	228.872	0.998
	FY 07-08		58	20.508	71.831	-185.749	226.765	1.000
	FY 11-12		31	89.388	85.594	-156.390	335.165	0.902
	FY 13-14		15	116.937	110.865	-201.404	435.278	0.899
FY 11-12	FY 03-04	31	36	128.564	93.071	-138.685	395.812	0.738
	FY 05-06		68	119.449	82.318	-116.921	355.819	0.696
	FY 07-08		58	109.896	84.511	-132.771	352.563	0.785
	FY 09-10		54	89.388	85.594	-156.390	335.165	0.902
	FY 13-14		15	206.325	119.471	-136.729	549.379	0.515
FY 13-14	FY 03-04	15	36	77.761	116.735	-257.435	412.957	0.985
	FY 05-06		68	86.876	108.355	-224.260	398.011	0.967
	FY 07-08		58	96.429	110.030	-219.517	412.374	0.952
	FY 09-10		54	116.937	110.865	-201.404	435.278	0.899
	FY 11-12		31	206.325	119.471	-136.729	549.379	0.515

Appendix AU: Design-Build (DB) Project Duration by Facility Type

Level	- Level	Observations		Mean	Std Error	95% Confidence Interval		Significance
		Level	- Level	Difference		Lower Bound	Upper Bound	(p-value)
ADMINISTRATIVE	COMMUNITY SUPPORT	26	25	21.692	106.183	-293.848	337.233	1.000
	DORMS, QUARTERS, DINING HALLS		25	17.132	106.183	-298.408	332.673	1.000
	MAINTENANCE		71	112.580	86.895	-145.645	370.804	0.854
	OPERATIONS		46	166.627	93.009	-109.766	443.021	0.555
	PERSONNEL SUPPORT		30	55.708	101.572	-246.130	357.546	0.998
	TRAINING		43	2.819	94.174	-277.034	282.673	1.000
COMMUNITY SUPPORT	ADMINISTRATIVE	25	26	21.692	106.183	-293.848	337.233	1.000
	DORMS, QUARTERS, DINING HALLS		25	4.560	107.219	-314.059	323.179	1.000
	MAINTENANCE		71	90.887	88.158	-171.090	352.865	0.947
	OPERATIONS		46	144.935	94.190	-134.968	424.838	0.721
	PERSONNEL SUPPORT		30	77.400	102.654	-227.655	382.455	0.989
	TRAINING		43	24.512	95.340	-258.808	307.832	1.000
DORMS, QUARTERS, DINING HALLS	ADMINISTRATIVE	25	26	17.132	106.183	-298.408	332.673	1.000
	COMMUNITY SUPPORT		25	4.560	107.219	-314.059	323.179	1.000
	MAINTENANCE		71	95.447	88.158	-166.530	357.425	0.933
	OPERATIONS		46	149.495	94.190	-130.408	429.398	0.691
	PERSONNEL SUPPORT		30	72.840	102.654	-232.215	377.895	0.992
	TRAINING		43	19.952	95.340	-263.368	303.272	1.000
MAINTENANCE	ADMINISTRATIVE	71	26	112.580	86.895	-145.645	370.804	0.854
	COMMUNITY SUPPORT		25	90.887	88.158	-171.090	352.865	0.947
	DORMS, QUARTERS, DINING HALLS		25	95.447	88.158	-166.530	357.425	0.933
	OPERATIONS		46	54.048	71.748	-159.165	267.260	0.989
	PERSONNEL SUPPORT		30	168.287	82.546	-77.013	413.588	0.393
	TRAINING		43	115.399	73.251	-102.280	333.078	0.698
OPERATIONS	ADMINISTRATIVE	46	26	166.627	93.009	-109.766	443.021	0.555
	COMMUNITY SUPPORT		25	144.935	94.190	-134.968	424.838	0.721
	DORMS, QUARTERS, DINING HALLS		25	149.495	94.190	-130.408	429.398	0.691
	MAINTENANCE		71	54.048	71.748	-159.165	267.260	0.989
	PERSONNEL SUPPORT		30	222.335	88.960	-42.024	486.694	0.164
	TRAINING		43	169.446	80.410	-69.505	408.398	0.352
PERSONNEL SUPPORT	ADMINISTRATIVE	30	26	55.708	101.572	-246.130	357.546	0.998
	COMMUNITY SUPPORT		25	77.400	102.654	-227.655	382.455	0.989
	DORMS, QUARTERS, DINING HALLS		25	72.840	102.654	-232.215	377.895	0.992
	MAINTENANCE		71	168.287	82.546	-77.013	413.588	0.393
	OPERATIONS		46	222.335	88.960	-42.024	486.694	0.164
	TRAINING		43	52.888	90.176	-215.086	320.863	0.997
TRAINING	ADMINISTRATIVE	43	26	2.819	94.174	-277.034	282.673	1.000
	COMMUNITY SUPPORT		25	24.512	95.340	-258.808	307.832	1.000
	DORMS, QUARTERS, DINING HALLS		25	19.952	95.340	-263.368	303.272	1.000
	MAINTENANCE		71	115.399	73.251	-102.280	333.078	0.698
	OPERATIONS		46	169.446	80.410	-69.505	408.398	0.352
	PERSONNEL SUPPORT		30	52.888	90.176	-215.086	320.863	0.997

Appendix AV: Design-Bid-Build (DBB) Project Duration by Facility Type

Level	- Level	Observations		Mean	Std Error	95% Confidence Interval		Significance
		Level	- Level	Difference		Lower Bound	Upper Bound	(p-value)
AIRFIELD PAVEMENTS	COMMUNITY SUPPORT	16	15	82.638	132.143	-310.884	476.159	0.996
	DORMS, QUARTERS, DINING HALLS		32	238.813	112.578	-96.446	574.071	0.344
	MAINTENANCE		50	41.198	105.608	-273.302	355.697	1.000
	OPERATIONS		34	129.143	111.469	-202.812	461.098	0.909
	PERSONNEL SUPPORT		20	103.588	123.323	-263.669	470.844	0.980
	TRAINING		44	118.097	107.339	-201.559	437.753	0.928
COMMUNITY SUPPORT	AIRFIELD PAVEMENTS	15	16	82.638	132.143	-310.884	476.159	0.996
	DORMS, QUARTERS, DINING HALLS		32	156.175	115.053	-186.452	498.802	0.824
	MAINTENANCE		50	41.440	108.242	-280.904	363.784	1.000
	OPERATIONS		34	46.506	113.968	-292.890	385.902	1.000
	PERSONNEL SUPPORT		20	20.950	125.586	-353.046	394.946	1.000
	TRAINING		44	35.459	109.932	-291.917	362.836	1.000
DORMS, QUARTERS, DINING HALLS	AIRFIELD PAVEMENTS	32	16	238.813	112.578	-96.446	574.071	0.344
	COMMUNITY SUPPORT		15	156.175	115.053	-186.452	498.802	0.824
	MAINTENANCE		50	197.615	83.237	-50.264	445.494	0.215
	OPERATIONS		34	109.669	90.558	-160.012	379.351	0.889
	PERSONNEL SUPPORT		20	135.225	104.805	-176.883	447.333	0.856
	TRAINING		44	120.716	85.423	-133.674	375.105	0.794
MAINTENANCE	AIRFIELD PAVEMENTS	50	16	41.198	105.608	-273.302	355.697	1.000
	COMMUNITY SUPPORT		15	41.440	108.242	-280.904	363.784	1.000
	DORMS, QUARTERS, DINING HALLS		32	197.615	83.237	-50.264	445.494	0.215
	OPERATIONS		34	87.946	81.731	-155.447	331.339	0.935
	PERSONNEL SUPPORT		20	62.390	97.279	-227.306	352.086	0.995
	TRAINING		44	76.899	76.001	-149.433	303.231	0.951
OPERATIONS	AIRFIELD PAVEMENTS	34	16	129.143	111.469	-202.812	461.098	0.909
	COMMUNITY SUPPORT		15	46.506	113.968	-292.890	385.902	1.000
	DORMS, QUARTERS, DINING HALLS		32	109.669	90.558	-160.012	379.351	0.889
	MAINTENANCE		50	87.946	81.731	-155.447	331.339	0.935
	PERSONNEL SUPPORT		20	25.556	103.612	-283.002	334.113	1.000
	TRAINING		44	11.047	83.956	-238.973	261.067	1.000
PERSONNEL SUPPORT	AIRFIELD PAVEMENTS	20	16	103.588	123.323	-263.669	470.844	0.980
	COMMUNITY SUPPORT		15	20.950	125.586	-353.046	394.946	1.000
	DORMS, QUARTERS, DINING HALLS		32	135.225	104.805	-176.883	447.333	0.856
	MAINTENANCE		50	62.390	97.279	-227.306	352.086	0.995
	OPERATIONS		34	25.556	103.612	-283.002	334.113	1.000
	TRAINING		44	14.509	99.156	-280.776	309.795	1.000
TRAINING	AIRFIELD PAVEMENTS	44	16	118.097	107.339	-201.559	437.753	0.928
	COMMUNITY SUPPORT		15	35.459	109.932	-291.917	362.836	1.000
	DORMS, QUARTERS, DINING HALLS		32	120.716	85.423	-133.674	375.105	0.794
	MAINTENANCE		50	76.899	76.001	-149.433	303.231	0.951
	OPERATIONS		34	11.047	83.956	-238.973	261.067	1.000
	PERSONNEL SUPPORT		20	14.509	99.156	-280.776	309.795	1.000

Appendix AW: Design-Build (DB) Project Duration by MAJCOM

Level	- Level	Observations		Mean	Std Error	95% Confidence Interval		Significance
		Level	- Level	Difference		Lower Bound	Upper Bound	(p-value)
ACC	AETC	67	58	48.612	79.987	-108.801	206.025	0.544
	AFGSC		25	154.812	104.521	-50.883	360.507	0.140
	AFMC		55	10.643	81.148	-149.055	170.340	0.896
	AFSOC		9	301.833	158.330	-9.759	613.424	0.058
	AFSPC		15	109.879	127.391	-140.825	360.583	0.389
	AMC		53	105.838	81.984	-55.506	267.182	0.198
	PACAF		23	47.438	107.779	-164.670	259.546	0.660
AETC	ACC	58	67	48.612	79.987	-108.801	206.025	0.544
	AFGSC		25	106.200	106.702	-103.787	316.187	0.320
	AFMC		55	59.255	83.938	-105.934	224.444	0.481
	AFSOC		9	350.444	159.778	36.003	664.886	0.0291*
	AFSPC		15	61.267	129.187	-192.970	315.504	0.636
	AMC		53	57.226	84.747	-109.555	224.008	0.500
	PACAF		23	1.174	109.896	-215.099	217.447	0.992
AFGSC	ACC	25	67	154.812	104.521	-50.883	360.507	0.140
	AETC		58	106.200	106.702	-103.787	316.187	0.320
	AFMC		55	165.455	107.575	-46.250	377.159	0.125
	AFSOC		9	456.644	173.366	115.463	797.826	0.0089*
	AFSPC		15	44.933	145.657	-241.716	331.583	0.758
	AMC		53	48.974	108.207	-163.976	261.923	0.651
	PACAF		23	107.374	128.855	-146.211	360.959	0.405
AFMC	ACC	55	67	10.643	81.148	-149.055	170.340	0.896
	AETC		58	59.255	83.938	-105.934	224.444	0.481
	AFGSC		25	165.455	107.575	-46.250	377.159	0.125
	AFSOC		9	291.190	160.363	-24.401	606.781	0.070
	AFSPC		15	120.521	129.909	-135.137	376.179	0.354
	AMC		53	116.481	85.844	-52.458	285.420	0.176
	PACAF		23	58.081	110.743	-159.861	276.022	0.600
AFSOC	ACC	9	67	301.833	158.330	-9.759	613.424	0.058
	AETC		58	350.444	159.778	36.003	664.886	0.0291*
	AFGSC		25	456.644	173.366	115.463	797.826	0.0089*
	AFMC		55	291.190	160.363	-24.401	606.781	0.070
	AFSPC		15	411.711	188.042	41.648	781.774	0.0293*
	AMC		53	407.671	160.788	91.244	724.098	0.0117*
	PACAF		23	349.271	175.350	4.185	694.356	0.0473*
AFSPC	ACC	15	67	109.879	127.391	-140.825	360.583	0.389
	AETC		58	61.267	129.187	-192.970	315.504	0.636
	AFGSC		25	44.933	145.657	-241.716	331.583	0.758
	AFMC		55	120.521	129.909	-135.137	376.179	0.354
	AFSOC		9	411.711	188.042	41.648	781.774	0.0293*
	AMC		53	4.040	130.433	-252.649	260.730	0.975
	PACAF		23	62.441	148.012	-228.845	353.726	0.673
AMC	ACC	53	67	105.838	81.984	-55.506	267.182	0.198
	AETC		58	57.226	84.747	-109.555	224.008	0.500
	AFGSC		25	48.974	108.207	-163.976	261.923	0.651
	AFMC		55	116.481	85.844	-52.458	285.420	0.176
	AFSOC		9	407.671	160.788	91.244	724.098	0.0117*
	AFSPC		15	4.040	130.433	-252.649	260.730	0.975
	PACAF		23	58.400	111.358	-160.750	277.551	0.600
PACAF	ACC	15	67	47.438	107.779	-164.670	259.546	0.660
	AETC		58	1.174	109.896	-215.099	217.447	0.992
	AFGSC		25	107.374	128.855	-146.211	360.959	0.405
	AFMC		55	58.081	110.743	-159.861	276.022	0.600
	AFSOC		9	349.271	175.350	4.185	694.356	0.0473*
	AFSPC		15	62.441	148.012	-228.845	353.726	0.673
	AMC		53	58.400	111.358	-160.750	277.551	0.600

Appendix AX: Design-Bid-Build (DBB) Project Duration by MAJCOM

Level	- Level	Observations		Mean Difference	Std Error	95% Confidence Interval		Significance (p-value)
		Level	- Level			Lower Bound	Upper Bound	
ACC	AETC	70	57	4.867	66.201	-185.321	195.055	1.000
	AFGSC		22	216.656	90.695	-43.900	477.212	0.164
	AFSOC		36	104.040	76.103	-114.596	322.675	0.747
	AFSPC		12	44.929	115.935	-288.141	377.998	0.999
	AMC		49	27.143	69.115	-171.418	225.704	0.999
AETC	ACC	57	70	211.789	93.135	-55.778	479.356	0.209
	AFGSC		22	99.173	78.995	-127.773	326.118	0.809
	AFSOC		36	40.061	117.854	-298.521	378.644	0.999
	AFSPC		12	22.276	72.288	-185.400	229.951	1.000
	AMC		49	22.276	72.288	-185.400	229.951	1.000
AFGSC	ACC	22	70	216.656	90.695	-43.900	477.212	0.164
	AETC		57	211.789	93.135	-55.778	479.356	0.209
	AFSOC		36	112.616	100.415	-175.866	401.099	0.872
	AFSPC		12	171.727	133.164	-210.838	554.293	0.791
	AMC		49	189.513	95.229	-84.069	463.095	0.351
AFSOC	ACC	36	70	104.040	76.103	-114.596	322.675	0.747
	AETC		57	99.173	78.995	-127.773	326.118	0.809
	AFGSC		22	112.616	100.415	-175.866	401.099	0.872
	AFSPC		12	59.111	123.688	-296.231	414.453	0.997
	AMC		49	76.897	81.453	-157.110	310.903	0.935
AFSPC	ACC	12	70	44.929	115.935	-288.141	377.998	0.999
	AETC		57	40.061	117.854	-298.521	378.644	0.999
	AFGSC		22	171.727	133.164	-210.838	554.293	0.791
	AFSOC		36	59.111	123.688	-296.231	414.453	0.997
	AMC		49	17.786	119.516	-325.570	361.141	1.000
AMC	ACC	49	70	27.143	69.115	-171.418	225.704	0.999
	AETC		57	22.276	72.288	-185.400	229.951	1.000
	AFGSC		22	189.513	95.229	-84.069	463.095	0.351
	AFSOC		36	76.897	81.453	-157.110	310.903	0.935
	AFSPC		12	17.786	119.516	-325.570	361.141	1.000

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Kramer, Erich C., Capt, USAF

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Air Force Institute of Technology
Graduate School of Engineering and Management (AFIT/ENV)
2950 Hobson Way, Building 640
WPAFB OH 45433-8865

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9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Civil Engineer Center
Attn: Mr. Benjamin Kindt (AFCEC/CFTP)
2261 Hughes Ave, Joint Base San Antonio, TX 78236
210-395-8524, (DSN 969-8524), benjamin.kindt.1@us.af.mil

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14. ABSTRACT
The objective of this study is to investigate the performance of the design-bid-build and design-build project delivery methods in Air Force military construction (MILCON). Project delivery performance is measured through quantitative cost, schedule, and change order metrics for 264 design-bid-build and 316 design-build MILCON projects from 2003-2014. The average response measures were statistically compared within each delivery method using three independent variables: time, facility type, and major command (MAJCOM). The historical analysis revealed that the current working estimate – programmed amount ratios improved over time for design-build projects, and an overall consistency in schedule growth and project duration performance occurred across both delivery methods. The facility type analysis revealed that design-bid-build airfield pavement projects had significantly lower average unit costs and fewer modifications than other facility types. Dormitories, officer quarters, and dining halls were constructed (design-bid-build) and delivered (design-build) more rapidly than other facility types. While the study revealed significant differences across individual performance measures, no overall trend in project delivery performance was identified in the MAJCOM analysis. Finally, the current methods used by Air Force project managers to gather project data does not allow for meaningful project delivery performance comparisons. This study recommends the following eight key performance indicators be tracked to effectively compare the performance of project delivery methods: cost growth, unit cost, award growth, project duration, schedule growth, project delivery speed, modifications per million dollars of project scope, and percent modifications due to deficiencies.

15. SUBJECT TERMS
Air Force Military Construction; Project Delivery Method Performance; Design-Bid-Build; Design-Build; Measures

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U	U	U	UU	241	937-255-3636 x4645 Christopher.stoppel@afit.edu

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