NPS-AM-23-230

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Defense Acquisition Best Practices: The Knowledge-Based Approach

March 2022

LT Charles D. Heard, USN

Thesis Advisors: Raymond D. Jones, Professor
Dr. Robert F. Mortlock, Professor

Department of Defense Management

Naval Postgraduate School

Prepared for the Naval Postgraduate School, Monterey, CA 93943

The research presented in this report was supported by the Acquisition Research Program of the Department of Defense Management at the Naval Postgraduate School.

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ABSTRACT

Over the last decade, several response plans and methods have been established to reduce schedule and budget overruns in the Department of Defense's (DOD) procurement programs. The Government Accountability Office (GAO) chose to revisit this issue in a recent study. They discovered that leveraging mature technology, having complete product designs, and having control over manufacturing processes were key to the successful development of new products. The GAO merged these principles into a single acquisition strategy known as the Knowledge-Based Approach (KBA). They assert that Major Defense Acquisition Programs (MDAP) that implement the KBA principles will have better program outcomes. The purpose of this research is to determine if MDAPs that meet the three basic KBA criteria outperform those that do not. MDAPs that adhered to KBA knowledge points were predicted to have lower percentages of schedule and budget overruns than those that did not. This thesis demonstrated a clear link between the KBA and program performance by using inferential testing to compare the KBA to the most recent MDAPs, thus validating the GAO's approach, validating the research hypothesis, and promoting wider adoption of the KBA within the DOD's acquisition community.

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ACKNOWLEDGMENTS

Despite the fact that this process has been demanding and challenging, I am grateful for the experience. I want to express my gratitude to my wife for her patience and understanding over the time it took to complete my research. I would not have been able to finish this thesis without her support throughout the most trying periods. I also want to thank my advisors, Professor Robert Mortlock and Professor Raymond Jones, for the many hours they spent leading me through my research. I would like to thank the professors who supported the 816 curricula, which provided me with the information I needed to finish this thesis. Additionally, I would like to express my heartfelt appreciation to Ms. Alison Scharmota, who worked tirelessly with me on my writing style, and without whom this thesis would not have been published. Finally, I'd like to thank my classmates for their contributions to my academic achievement at Naval Postgraduate School.

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LIST OF ACRONYMS AND ABBREVIATIONS

APB	Acquisition Program Baseline
DA	Decisions Authority
DBS	Defense Budget System
DCC	Development Cost Change
DOD	Department of Defense
GAO	Government Accountability Office
H0	Null Hypothesis
Ha	Alternative Hypothesis
KAT	Knowledge-Based Acquisition Theory
KBA	Knowledge-Based Approach
KP	Knowledge Point
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MTA	Middle Tier Acquisition
PCC	Procurement Cost Change
PM	Program Manager
QCP	Quantity Change Percent
SIP	Schedule Increase Percentage
TRL	Technology Readiness Level
UCC	Unit Cost Change

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I. INTRODUCTION

The Government Accountability Office (GAO) has published yearly reports on the cost, schedule, and performance of the Department of Defense's (DOD) procurement projects for almost two decades (Government Accountability Office [GAO], 2021b). Since the initial GAO reports, the GAO has regularly maintained that many of the DOD's programs had unnecessary budget overruns and schedule delays. In fact, the GAO reported in its most recent annual weapon systems assessment that the "DOD's 84 major defense acquisition programs (MDAP) accumulated over $615.4 billion (or 52 percent) in total cost growth since program start, about 60 percent of which was unrelated to the increase in quantities purchased" (GAO, 2021a, p. 3). According to the GAO, "over the same period, the time required to deliver initial capabilities increased by about 35%, resulting in an average delay of more than 2 years" (GAO, 2021a).

According to a previous report published in fiscal year 2020, cost overruns and schedule delays in a large number of critical military weapon programs are directly related to poor judgment on the part of program managers due to a lack of knowledge in sound business practices (GAO, 2020). The GAO substantiated this determination by stressing the impact of bad business procedures on the Zumwalt-class destroyer program's outcomes (GAO, 2020). According to the analysis, the Navy's weak business procedures drove it to spend more on only three ships than it anticipated spending on the first 21 ships. To compound things, the ships did not meet all anticipated specifications, resulting in a large loss for the Department of Defense (GAO, 2020).

In their efforts to address these issues over the last decade, the GAO examined successful DOD and commercial procurement processes for answers and identified many best practices (GAO, 2002). The GAO combined these best practices into a cohesive approach to acquisition dubbed Knowledge-Based Acquisition Theory (KAT), later called the Knowledge-Based Approach (KBA) (GAO, 2004).

Simply said, the KBA is designed around three critical decision points that help program managers to make the best choices possible when selecting whether to continue with a program (GAO, 1998a). The first critical decision point is planned to occur prior to the start of product development (GAO, 2004). At this phase, the program manager is responsible to guarantee that appropriate resources, finance, and technical competence are available to create a successful product, depending on the customer's requirements (GAO, 2004). The second critical decision point is anticipated to occur around halfway through the development stage. The program manager is expected to make a judgment at this time on the product's ability to fulfill the customer's specified performance criteria (GAO, 2004). Prior to production, the third critical decision point needs the project manager to determine if the developer can build the product within the budget, time, and performance constraints (GAO, 2004). The KBA recommends that if poor findings are discovered at any of these critical decision points, the program should be halted (GAO, 1998a). Recent research indicates that MDAPs that incorporate these KBA decision points into their overall program strategy have less budget and schedule growth (GAO, 2021a).

The motivation to complete this thesis stems from Dana C. Wyman II's 2010 study, which sought to better understand the link between the KBA and DOD program performance at the time (Wyman, 2010). The purpose of this thesis is to examine the most current MDAPs in order to determine if recent GAO statements that KBA compliance resulted in improved program outcomes for the most critical DOD programs are credible. This thesis is structured similarly to Dana C. Wyman's in that a similar research methodology was employed. This thesis is structured as follows: Chapter II is devoted to a review of the available literature. Chapter III summarizes the research methodology and data findings. Chapter IV is an analysis of the important findings this research, and Chapter V discusses the impact to the acquisition community and provides constructive insight the DOD might use regarding the KBA principles, as well as ideas for future research.

A. PROBLEM STATEMENT

The issue is, despite repeated GAO recommendations for DOD acquisition programs to adopt KBA principles, there appears to be continued skepticism about the approach's actual impact on program success, potentially resulting in avoidable budget overruns and schedule delays in MDAPs. As a result, crucial capabilities for the warfighter are delayed, eroding global military superiority.

B. PURPOSE AND SCOPE

The purpose of this study is to determine if MDAPs that comply to the three primary KBA criteria outperform those that do not. By comparing the KBA to the most recent MDAPs, we can establish a link between the KBA and program performance, therefore validating the GAO's approach and promoting wider adoption within the acquisition community.

To eliminate as many independent variables as possible, 84 major defense weapons programs detailed in the GAO's 2021 report were analyzed. This guarantees that reviewed programs have comparable budget allocations, employ a comparable adaptive acquisition pathway framework, and are similarly relevant to the DOD. The goal of this study is to identify and examine programs that adhered to the knowledge points (KPs) of the KBA, as well as programs that did not, and to compare program outcomes. As previously noted, this thesis' research methodology is based on Dana C Wyman II's 2010 study. Similarly, to his work, three initial hypotheses were utilized to provide the basis for disproving the null hypothesis via a series of inferential statistical tests. The following hypotheses based on GAO claims provide a strategy for accomplishing the objective:

Hypothesis 1: MDAPs that ensure that they meet a Technology Readiness Level 7 (TRL7) prior to Milestone B as per KBA's knowledge point (KP) 1, would have better program outcomes than MDAPs that do not

Hypothesis 2: MDAPs that complete at minimum 90 percent of their engineering drawings prior to the critical design review, as required by KBA's KP 2, would have better program outcomes than MDAPs that do not.

Hypothesis 3: MDAPs that demonstrate their critical processes are in statistical control by Milestone C, as required by KBA's KP 3, will experience better program outcomes than MDAPS that do not

C. RELEVANCE OF RESEARCH

This research assists the defense acquisition community in its development. The findings have the potential to assist program managers in comprehending the implications of their choices regarding the GAO's KBA. Additionally, by focusing on the critical factors of program success, decision-makers have a better knowledge of the trade space in which their choices are made.

According to the GAO, the KBA is the solution for reducing budget overruns and schedule delays within the acquisition community. The GAO concluded in June 2020 on their 18th annual review that there is a direct association between implementing the KPs associated with the KBA strategy and improving cost and schedule performance (see Table 1). I anticipate that the findings in this thesis will substantiate the GAO's assertion and will persuade program managers to adopt the GAO's KBA.

Table 1. Statistically Significant Knowledge-Based Acquisition Practices and Their Corresponding Unit Cost and Schedule Outcomes. Source: GAO (2020).

Knowledge practice	Programs that implemented the practice	Programs that did not implement the practice	Net performance difference
Complete a system-level preliminary design review prior to system development	• −13.1% unit cost growth • 11.6% schedule growth	• 33.6% unit cost growth • 46.3% schedule growth	• 46.7% less unit cost growth • 34.7% less schedule growth
Release at least 90% of design drawings by critical design review	• 5.5% unit cost growth • 10.3% schedule growth	• 45.1% unit cost growth • 50.3% schedule growth	• 50.6% less unit cost growth • 40.0% less schedule growth
Test a system-level integrated prototype by critical design review	• 13.3% schedule growth	• 43.2% schedule growth	• 29.9% less schedule growth

II. LITERATURE REVIEW

Despite the fact that the U.S. military has grown to be one of the world's most formidable forces, the DOD has not always had the best track record when it comes to MDAPs. Numerous programs have seen substantial budget overruns and costly schedule delays during the last two decades, resulting in the inability to provide critical capabilities to warfighters. This is significant, particularly for bigger initiatives like MDAPs, which may cost tens to hundreds of billions of dollars over decades (Baldwin & Cook, 2015). The GAO claims that after decades of study and program analysis, they have identified an effective method for the DOD to enhance acquisition program outcomes: the KBA (GAO, 1998a). The KBA approach has gained increasing support at the highest levels of the acquisition community, to the point where several of its principles influenced the recent redesign of the DOD 5000 Series acquisition policies (Office of the Under Secretary of Defense for Acquisition and Sustainment [OUSD(A&S)], 2020b). What's interesting is that, despite support from higher-level acquisition officials and the impact the GAO's KBA has had on policy, it appears the GAO's approach has not been readily adopted by front-line program managers (OUSD(A&S)], 2020).

The data demonstrate that for almost two decades, the DOD's MDAPs have been beset by both cost and deadline overruns that jeopardize military readiness (Edwards & Kaeding, 2015; Johnson, 2018). Taxpayer resources have been spent attempting to advance initiatives, sometimes at the expense of taxpayer returns (Edwards & Kaeding, 2015). This regrettable reality has raised congressional and public concern, resulting in an urgent push for more efficient acquisition processes (2021a, GAO). According to the GAO, they feel they have responded to that call (GAO, 2021a).

A. BACKGROUND

Since the late 1980s, Congress and the Department of Defense have made it a priority to maintain a collaborative effort to constantly improve the acquisition process (Hanks et al., 2005). Both congress and the DOD hoped to make the acquisition process more efficient and flexible for the acquisition workforce with each successive reform

(Hanks et al., 2005). The first significant changes, implemented in the late 1980s, focused largely on defense management (Hanks et al., 2005). The primary criticism leveled against the acquisition process in 1985 was that it needed to be more responsive and efficient. President Reagan acted by appointing David Packard as chairman of the President's Blue-Ribbon Commission on Defense Management. David Packard and his team spent a year analyzing both government and private sector businesses in order to uncover effective business practices that may be used to improve the DOD's acquisition management system (Hanks et al., 2005). David Packard's results were highly regarded and laid the groundwork for what became known as the GAO's Knowledge Acquisition Theory, which was recently renamed the KBA, as discussed later in the chapter (Wyman, 2010).

Nearly a decade later, President Bill Clinton's administration confronted similar problems with the defense acquisition process as the Reagan administration did (Fox et al., 2015, p. 151). The Clinton administration, inspired by new technologies of the decade, popularized the slogan "reinventing government" (Fox et al., 2015, p. 151). This slogan called for the improvement of acquisition processes by deploying advanced technologies (Fox et al., 2015, p. 151). President Clinton named William J. Perry as chairman of the initiative (Fox et al., 2015, p. 151).

As a previous member of the David Packard-led team during the Reagan administration, Perry came to the helm with several ideas about how to effectively incorporate modern technologies to enhance acquisition procedures (Fox et al., 2015, p. 151). His proposals culminated in an 18-page report titled *Acquisition Reform: A Mandate for Change* (Fox et al., 2015, p. 153). According to Perry's report, in order for the DOD to successfully integrate cutting-edge technology, not only to revamp the acquisition process, but also to produce more technologically advanced products for warfighters, the DOD would need to find a way to acquire items "faster, better, and cheaper" (Fox et al., 2015, pp. 153–154). Throughout his tenure, Perry pushed to improve acquisition procedures in order to shorten the acquisition cycle, boost product performance, and reduce acquisition expenses. An endeavor that was widely regarded as successful.

B. GAO'S KNOWLEDGE ACQUISITION THEORY

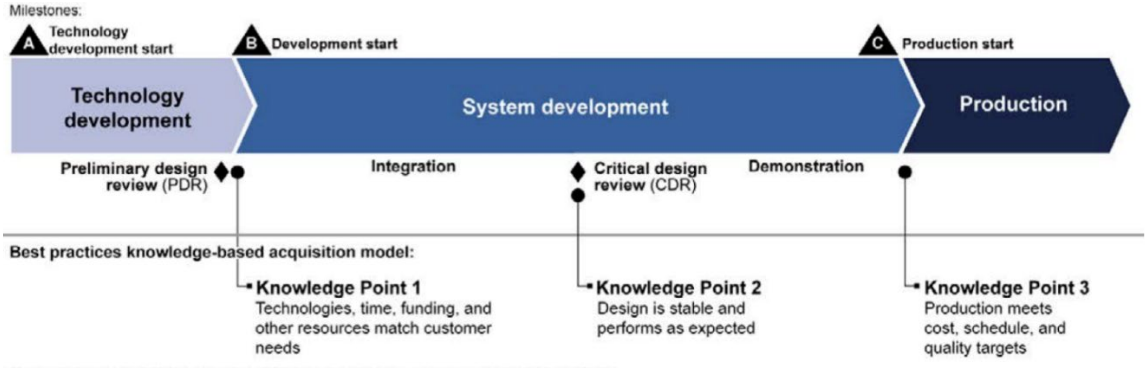
As previously stated, David Packard's efforts to identify effective business practices for use in improving the DOD's acquisition management system during the administration of President Ronald Reagan laid the groundwork for what became known as KAT, which was recently renamed KBA (Wyman, 2010). Packard based many of his recommendations on commercial principles that he felt could be applied to government acquisition initiatives (Hanks et al., 2005). Since 1998, when the Packard Commission issued its report, the GAO has researched best business practices in private companies that deal with acquisition programs comparable to those used by the DOD and established what they have dubbed a knowledge-based methodology (GAO, 1998a, 2002). Despite the GAO assertions, it appears as though many program managers have not fully integrated the GAO's KBA into their management process (GAO, 2021a; Wyman, 2010). Some scholars on the subject have claimed that DOD programs are so different from private initiatives that they are incapable of applying the exact same practices as commercial firms (GAO, 2005; Wyman, 2010).

C. CORRELATION OF COMMERCIAL ORGANIZATIONS AND THE DOD

While both private enterprises and government entities strive to develop innovative products, their motivations are somewhat different. Typically, the DOD's purpose is to equip combat troops with the capabilities necessary to successfully carry out the Nation's defense strategy. The majority of enterprises in the private sector develop new products in order to retain clients and increase earnings. What's notable about this discovery is that, despite their differing motives, commercial enterprises and the DOD both strive to build systems centered on a similar principle. The premise is that it is preferable to generate or acquire the best possible product at the lowest feasible price. The DOD is driven to cut costs because of a restricted budget, while many commercial firms are motivated to cut expenses in order to maximize profit. Both the DOD and private firms seek to reduce the cost and time necessary to produce a new product, making the private sector's business practices relevant to the government acquisition community's search for new viable business practices.

D. THE GAO'S KNOWLEDGE-BASED ACQUISITION APPROACH

The Knowledge-Based Acquisition Approach (KBA) is inextricably linked to the three critical milestones for best results, as seen in Figure 1.



Source: GAO analysis of DOD-provided data, DOD Instruction 5000.02, and best practices. | GAO-19-336SP

Figure 1. The Knowledge-Based Acquisition Approach. Source: GAO (2021b).

1. Knowledge Point 1: Resources and Needs

The GAO's Knowledge Point (KP) 1 is the first of three KBA criteria that the GAO predicts will result in better program outcomes. KP1 is scheduled for completion at Milestone B (GAO, 1998a, 2004). KP1 occurs when the program manager determines that the necessary knowledge, time, and resources are available to satisfy the customer's needs (GAO, 2004). Additionally, the GAO determined that a product must have a TRL7 at or before KP1 in order to fulfill the requirement (GAO, 1998a, 2004; Wyman, 2010).

2. Knowledge Point 2: Product Design Is Stable

According to the GAO, KP2 is satisfied when the program manager ensures that a product's design fulfills all user expectations, financial restrictions, and schedule constraints (GAO, 2004). As per the GAO, this KP should be finished midway through the development cycle (GAO, 2004). Additionally, to fulfill KP2, at least 90% of engineering drawings must be prepared during the critical design review to assure the "design's stability" (GAO, 2004).

3. Knowledge Point 3: Production Processes Are Mature

KP3 is the final KP in the KBA that must be met. When the program manager determines that the product can be built within the stated cost, time, and quality standards, this KP is satisfied (GAO, 2004). According to the GAO, "a best practice is to provide statistical control over all essential production processes" (GAO, 2002,, p. 13; GAO 2004) Simply put, this implies that manufacturers are capable of regularly manufacturing parts within the defined quality standards for the product (GAO, 2004). This KP must be satisfied prior to manufacturing in order to meet this KBA requirement (GAO, 2004).

E. MAJOR DEFENSE WEAPON ACQUISITIONS

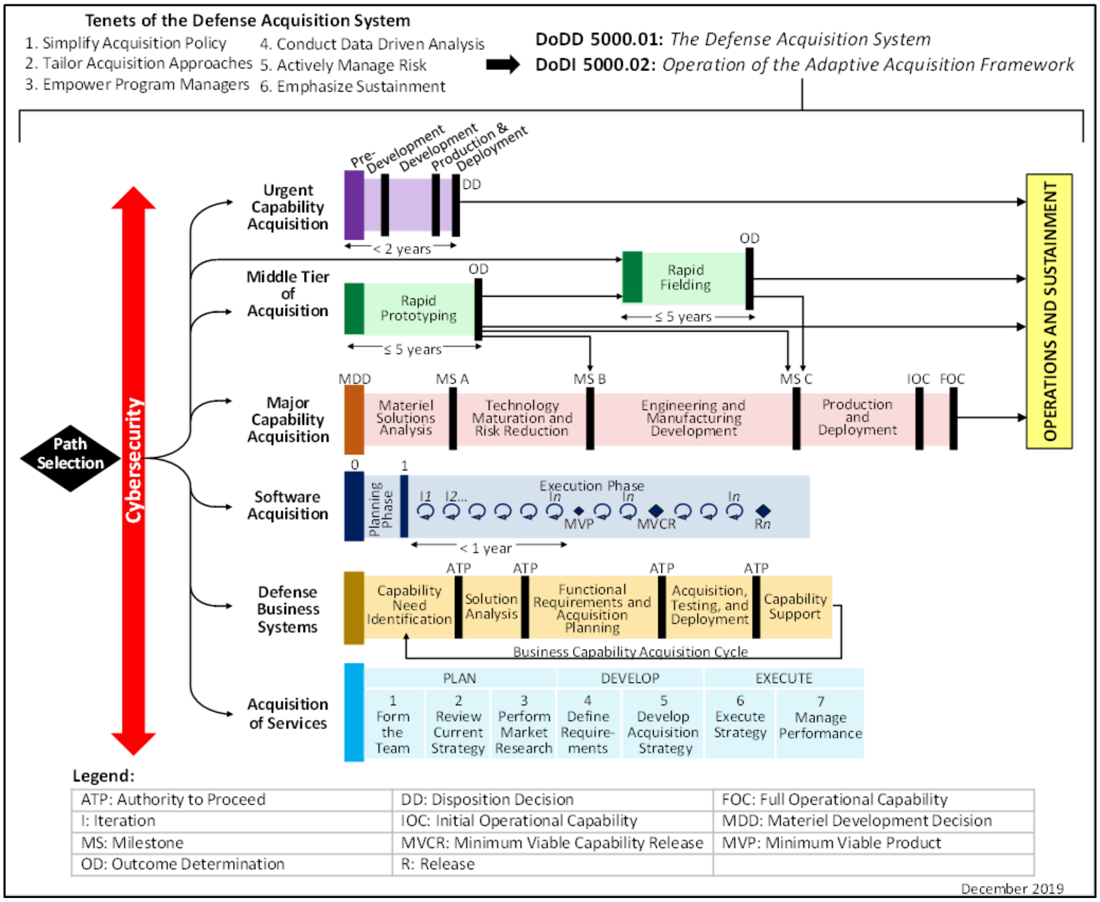
Weapon acquisitions are among the DOD's most expensive MDAPs (GAO, 1992). The Department of Defense Weapon Portfolio for Fiscal Year 2021 estimates that it will spend at least $1.8 trillion on 107 of its most expensive weapon projects, 84 of which are MDAPS (GAO, 2021b). This evidence backs up the notion that decisions to develop weapon systems programs will potentially cost the country tens of billions of dollars (GAO, 1992). The GAO has made evaluating the acquisition process of weapon systems a priority for nearly six decades, with the first report issued in 1971 (GAO, 1992, 2021b). Since then, more than 900 weapon acquisition projects have been audited, providing the Office of the Secretary of Defense with data trends on the most important aspects of significant defense weapon acquisition programs' successes and failures (GAO, 1992). The Department of Defense's Office of the Secretary of Defense has taken steps to improve the weapon system acquisition process based on that data (GAO, 1992). While they have been successful in many areas, they still have a number of issues to deal with, the most serious of which are budget overruns, schedule delays, and performance deficiencies (GAO, 1992). The GAO has been making recommendations on how to address some of these concerns, yet many of the problems perpetuate (GAO, 1992). Many stakeholders are now wondering if there are any other underlying factors that aren't being addressed (GAO,1992).

F. RECENT ACQUISITION REFORM

One of the most notable initiatives contributing to reforms in the weapon acquisition process is the Weapon Systems Acquisition Reform Act of 2009 (GAO, 2012).

In terms of requirements, cost, schedule, testing, and reliability, the reform act has resulted in substantial progress. Because weapon systems make up the majority of MDAPs, the improvements have resulted in a significant rise in overall MDAP success rates (GAO, 2012). Similar to the KBA, the Weapon Systems Acquisition reform Act emphasizes the importance of "early problem solving and requires programs to put much more effort toward considering trade-offs among cost, schedule, and performance requirements prior to Milestone B" (GAO, 2012, p. 15). Many of the reform's provisions provided the groundwork for future policy modifications in the acquisition framework.

One of the most recent acquisition programs aimed at improving the Department of Defense's ability to rapidly deploy capabilities to warfighters is the Adaptive Acquisition Framework (AAF) (GAO, 2021a). Some of the problems it aims to solve include those faced by programs attempting to combine advanced software and technologies, many of which are MDAPs (GAO, 2021a). The AAF was designed to address these issues by giving program managers (PMs) and other decision authorities (DAs) more flexibility when establishing program strategies (see Figure 2) (OUSD[A&S], 2020).



ATP: Authority to Proceed	DD: Disposition Decision	FOC: Full Operational Capability
I: Iteration	IOC: Initial Operational Capability	MDD: Materiel Development Decision
MS: Milestone	MVCR: Minimum Viable Capability Release	MVP: Minimum Viable Product
OD: Outcome Determination	R: Release	

Figure 2. Adaptive Acquisition Framework: Six Pathways. Source: OUSD(A&S, 2020).

G. ADAPTIVE ACQUISITION FRAMEWORK PATHWAYS

The six pathways of the AAF are designed to give PMs an option of six different ways to approach their acquisition program (OUSD[A&S], 2020). Each pathway is intended to offer PMs with a unique strategy for achieving their program’s objectives (OUSD[A&S], 2020). The purposes of each of the six pathways are summarized below.

1. Urgent Capability Acquisition

The urgent capability pathway is designed to fill emergent capabilities in less than 2 years (OUSD[A&S], 2020). As illustrated in Figure 3 the urgent capability acquisition pathway is a streamlined acquisition process characterized by 4 stages, which are Pre-development, Development, Production & Deployment and Operations and Sustainment

(OUSD[A&S], 2020). During the Pre-development stage the management team is responsible for developing the courses of action within their approach to field their specific “quick reaction capabilities” (OUSD [A&S, 2020a]). The Development Stage is the time allotted to identify any shortfalls in terms of performance, safety, suitability, and survivability. This stage is also where the major stakeholders, namely the PM, Milestone Decision Authority (MDA), and end user determine which shortfalls must be corrected before proceeding and what risks they are willing to accept (DOD 5000 series acquisition policy transformation handbook, 2020). During the Production & Deployment stage the user is provided with the capability, training, reserve equipment and logistical support necessary for operation (DOD 5000 series acquisition policy transformation handbook, 2020). Finally, the Operations and Sustainment phase is where the management team ensures that the chosen strategy for supportability is implemented correctly (DOD 5000 series acquisition policy transformation handbook, 2020).

Figure 3. Urgent Capability Pathway. Source: OUSD(A&S, 2020).

2. Middle Tier Acquisition

Simply explained, the middle tier acquisition (MTA) approach is intended to facilitate “rapid prototyping” and “rapid fielding.” To satisfy the “rapid prototyping” objectives of this pathway, the PM must be able to deliver a prototype that satisfies all requirements in an operating setting within five years of initiating the MTA program (OUSD[A&S], 2020). To meet the “rapid fielding” objectives, the PM must be capable of initiating production within six months after the program start date and completing “rapid fielding” within five years. 2020 [OUSD[A&S]]. The MTA pathway is depicted in Figure 4.

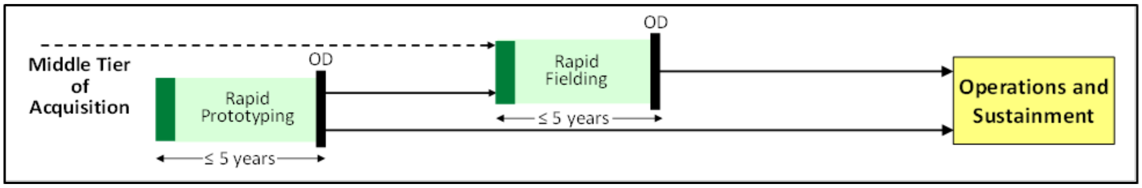


Figure 4. Middle Tier Acquisition Pathway. Source: OUSD(A&S, 2020).

3. Major Capability Acquisition

Programs that tend to follow the major capability acquisitions pathway are typically larger more complex programs in need of a more structured approach (OUSD[A&S], 2020). Management teams overseeing MDAPs generally model their acquisition approach after this pathway (OUSD[A&S], 2020). As Figure 5 illustrates this pathway is characterized by the more traditional acquisition checkpoints to include a Material Development Decision (MDD), Milestone A (MS A), Milestone B (MS B), Milestone C (MS C), Initial operational capability (IOC), and Final Operational Capability (FOC) followed by Operations and Sustainment (OUSD[A&S], 2020).

Figure 5. Major Capability Acquisition Pathway. Source: OUSD(A&S, 2020).

4. Software Acquisition

The software acquisition strategy is typically utilized by management teams with the goal of providing users with rapid access to software capabilities (DOD 5000 series acquisition policy transformation handbook, 2020). This approach leverages existing incremental software development approaches to enable management teams to rapidly deploy sophisticated software capabilities (Handbook for transforming the acquisition policy of the Department of Defense’s 5000-series acquisitions, 2020). As seen in Figure

6, this pathway is divided into two phases: planning and execution (DOD 5000 series acquisition policy transformation handbook, 2020).

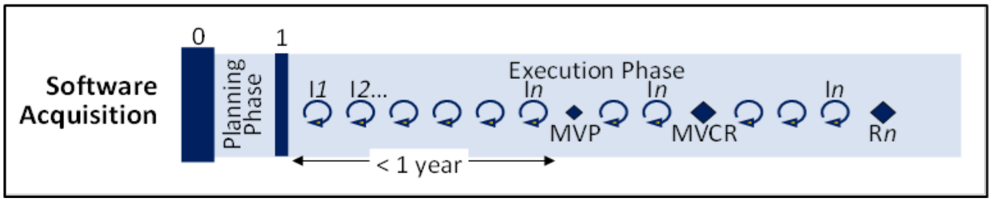


Figure 6. Software Acquisition Pathway. Source: OUSD(A&S, 2020).

5. Defense Business System Acquisition

The defense business system (DBS) acquisition pathway is primarily used to "acquire information systems that support DOD business operations" (DOD 5000 series acquisition policy transformation handbook, 2020). Additionally, this pathway is utilized to acquire "software-intensive programs" that are not classified as business systems but are nevertheless capable of supporting business activities (DOD 5000 series acquisition policy transformation handbook, 2020). This pathway, as demonstrated in Figure 7, consist of five phases.

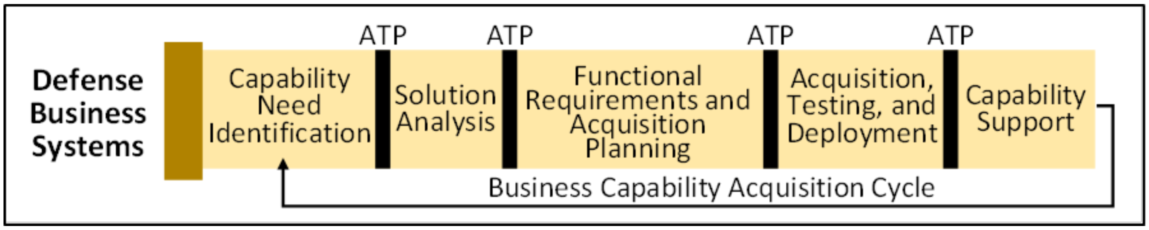


Figure 7. DBS Acquisition Pathway. Source: OUSD(A&S, 2020).

6. Defense Acquisition of Services

The DOD's acquisition community uses the defense acquisition of services. As depicted in Figure 8, the seven steps of this pathway are separated into three stages: plan, develop, and execute.

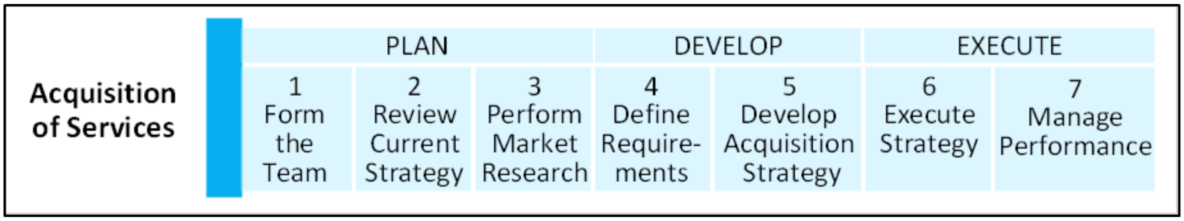


Figure 8. Defense Acquisition of Services Pathway. Source: OUSD(A&S, 2020).

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III. DATA COLLECTION AND METHODOLOGY

This thesis' methodology is based on Dana C Wyman II's thesis, *Best practices in government acquisition: A test of the Government Accountability Office's knowledge-based acquisition theory* (Wyman, 2010). Wyman reviewed over 107 acquisition programs with varied levels of ACAT to discover if there was a link between the Knowledge Acquisition Theory (KAT) and the performance statistics for acquisition programs (Wyman, 2010). The data came from GAO evaluations conducted and released between 2003 and 2009. Wyman tested assumptions using inferential statistics and other techniques (Wyman, 2010).

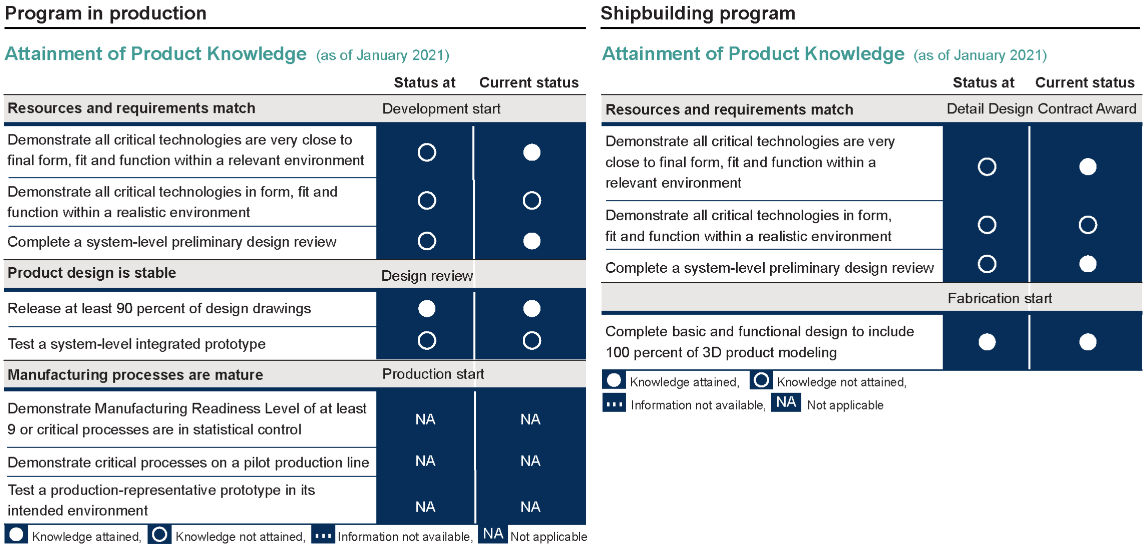
As with Wyman's study, the goal of this thesis was to examine whether there was a link between the KBA, formerly known as the Knowledge Acquisition Theory (KAT), and the most recently analyzed MDAPs acquisition program performance statistics (Wyman, 2010). Unlike Wyman's study, this one analyzed only programs having an ACAT level 1, resulting in an initial sample size of 84 programs. Both this analysis and the Wyman study revealed the need of accounting for program age (Wyman, 2010). This is critical because the GAO tested the success of the programs in a variety of ways. In some cases, the GAO measured the programs immediately after they achieved a KP (Wyman, 2010). In other situations, the GAO measured the programs years after they reached the same KP (Wyman, 2010). Wyman used linear regression models to account for program age in their model; but for this study, I limited the sample size to MDAPs with a similar timeline, which means that all the programs in the sample were in the early stages of development or production at the time of the program's June 2021 Selected Acquisition Report (GAO, 2021b, p. 71). Additionally, I ensured that the knowledge points were acquired within 12–18 months of one another to guarantee that the period the programs were required to incur additional costs or encounter schedule modifications was generally consistent (GAO, 2021b, p. 71; Wyman, 2010). As a result, the sample size was decreased to 34 programs.

As previously indicated, my research modeled Wyman's in that I also tested my hypotheses using data on program performance from GAO reports. As they did a decade ago during Wyman's research, the GAO claims that if a program does not match the KP requirements at predetermined points in time, it will provide worse outcomes in comparison to those that do (Wyman, 2010). To validate these findings, I modeled my independent variables (IVs) and dependent variables (DVs) following Wyman's study approach. As a result, I defined the KPs as independent variables and compared the outcomes of KP-compliant programs to those that were not. To test I developed my "null hypothesis (Ho)" and "alternative hypothesis (Ha)" based on Wyman's approach (LaMorte, 2017; Wyman, 2010)

$$\begin{aligned} Ho&: \mu\ outcome\ of\ Group\ 0 \geq \mu\ outcome\ of\ Group\ 1 \\ \mathrm{Ha}&: \mu\ outcome\ of\ Group\ 0 < \mu\ outcome\ of\ Group\ 1 \end{aligned}$$

where Group 0 did not meet KP criteria and Group 1 Met KP criteria and Dependent Variables/Outcomes measured: QCP, DCC, PCC, SIP, UCC

In each report, the GAO examined whether a program satisfied KP1, KP2, and KP3 requirements at the KBA's defined knowledge points (Figure 9). Modeling Wyman's approach, I assigned a value of "0" to each independent variable if the program failed to fulfill the KBA criteria on time, and a value of "1" to programs that did achieve the KBA criteria on time (Wyman, 2010).



Program in production

Attainment of Product Knowledge (as of January 2021)

	Status at	Current status
Resources and requirements match	Development start	
Demonstrate all critical technologies are very close to final form, fit and function within a relevant environment	○	●
Demonstrate all critical technologies in form, fit and function within a realistic environment	○	○
Complete a system-level preliminary design review	○	●
Product design is stable	Design review	
Release at least 90 percent of design drawings	●	●
Test a system-level integrated prototype	○	○
Manufacturing processes are mature	Production start	
Demonstrate Manufacturing Readiness Level of at least 9 or critical processes are in statistical control	NA	NA
Demonstrate critical processes on a pilot production line	NA	NA
Test a production-representative prototype in its intended environment	NA	NA

● Knowledge attained, ○ Knowledge not attained, ⋯ Information not available, NA Not applicable

Shipbuilding program

Attainment of Product Knowledge (as of January 2021)

	Status at	Current status
Resources and requirements match	Detail Design Contract Award	
Demonstrate all critical technologies are very close to final form, fit and function within a relevant environment	○	●
Demonstrate all critical technologies in form, fit and function within a realistic environment	○	○
Complete a system-level preliminary design review	○	●
	Fabrication start	
Complete basic and functional design to include 100 percent of 3D product modeling	●	●

● Knowledge attained, ○ Knowledge not attained, ⋯ Information not available, NA Not applicable

Source: GAO analysis of DOD data. I GAO-21-222

Figure 9. Knowledge Point Attainment. Source: GAO (2021b).

A. DATA LIMITATIONS

There were several external factors that limited the results of this thesis. For example, unanticipated schedule changes caused by elements beyond the program office's control, such as COVID-19, might have jeopardize program performance outcomes (GAO, 1992; GAO, 2021b). These exogenous variables may limit the model's analytical value, as it focused exclusively on whether a program matched the KP requirements.

The complete sample size of 34 programs was sufficient to test my hypothesis on the KP criteria for KP1 and KP2, but not sufficient to perform an extensive analysis of KP3. Additionally, the GAO encountered situations where it lacked data for particular KPs and instances where programs met the requirements for some KPs but not others. After reviewing the sample, it was determined that the GAO provided comprehensive data for KP1 for 34 programs, KP2 for 31 programs, and KP3 for 34 programs. Additionally, for this study, only 20 programs with complete data fulfilled the KP1 requirements, 10 programs met the KP2 requirements, and none met the KP3 requirements. Wyman's research team identified comparable shortcomings, demonstrating that nearly a decade later, the GAO is still having difficulty analyzing programs and that certain programs continue to violate all three KPs (Wyman, 2010). To account for the data gaps, I conducted independent KP analyses to maximize the value of each data point similar to that of Wyman’s study in 2010 (Wyman, 2010).

B. DEPENDENT VARIABLES

I collected data on DVs using the same GAO report that included information on IVs. Given that the GAO reports have utilized the same performance criteria for the last decade, Wyman and I both focused on certain program performance characteristics such as quantity, schedule, and cost (Wyman, 2010). I considered the Quantity Change Percentage (QCP), the Development Cost Change Percentage (DCC), the Schedule Increase Percentage (SIP), the Procurement Cost Change Percentage (PCC), and the Unit Cost Change Percentage (UCC) as performance metrics in this study. Because the GAO associates each of the KPs with these measures, I utilized them as my DVs, similar to Wyman’s approach (Wyman, 2010). Figure 10 illustrates how the GAO reports the QCP, DCC, SIP, PCC, UCC.

Program Performance (fiscal year 2021 dollars in millions)

	First Full Estimate (4/2020)	Latest (6/2020)	Percentage change
Development	$1,174.21	$1,174.21	+0.0%
Procurement	$19,382.9	$19,382.9	+0.0%
Unit cost	$1,062.81	$1,062.81	+0.0%
Acquisition cycle time (months)	139	139	+0.0%
Total quantities	20	20	+0.0%

Total quantities comprise zero development quantities and 20 procurement quantities.

Figure 10. Program Performance with Respect to Program Baseline. Source: GAO (2021).

C. DEPENDENT VARIABLE DESCRIPTION

SIP, UCC, QCP, DCC, and PCC were the five DVs (see Table 2). The Schedule Increase Percentage (SIP) is used to show how the schedule of a program has altered from the initial prediction (Wyman, 2010). I examined whether programs that adhered to the KP saw a lower percentage schedule variation than ones that did not (Wyman, 2010). The following dependent variable that I examined was unit cost changes (UCC) (Wyman, 2010). UCC is a variable that is used to describe changes in the unit cost in percent terms compared to the initial unit cost estimate (Wyman, 2010). Reduced unit cost percentages were considered to indicate a more favorable program outcome for this variable (Wyman, 2010). Additionally, I examined the Quantity Change Percentage (QCP). The QCP is used to indicate changes in the quantity of output produced by a program (Wyman, 2010). I looked at whether programs that met the KP requirements could produce or exceeding the quantity specified in the program's baseline. Next, I examined changes in procurement costs, or Changes in Procurement Costs (PCC). I examined changes in PCC to see if programs that met the KP criteria had a lower increase in procurement costs than those that did not. Finally, I examined Development Cost Change (DCC), which is a percentage change in the development costs of a program. I was curious as to whether projects that did not meet the KPs would incur additional development costs (Wyman, 2010).

Table 2. Variable List. Adapted from Wyman (2010, Table 3).

Dependent Variables	**Description**	**Nomenclature**
Unit Cost Change	The percentage change in cost of each production unit relative to the initial estimate	UCC
Procurement Cost Change	The percentage change in Procurement Costs relative to the initial estimate	PCC
Schedule Increase Percentage	The percentage of schedule increase relative to the initial estimate (Percentage)	SIP
Development Cost Change	The percentage change in Development costs relative to the initial estimate (Percentage)	DCC
Quantity Change Percentage	The percentage change in number of units produced relative to the initial estimate	QCP
Independent Variables	**Description**	**Nomenclature**
Knowledge Point 1	Program reached TRL7 prior to Milestone B	KP1
Knowledge Point 2	Program had 90% of its engineering drawings by Critical Design Review	KP2
Knowledge Point 3	Program's manufacturing processes were in statistical control by Milestone C	KP3

D. METHODOLOGY

I based my testing method after Wyman's 2010 work, in which he used the Independent T-test and Welch test to evaluate his hypotheses, as well as the Levene test for added precision (Wyman, 2010). As in his work, I used the conventional t-test with "pooled variance" to evaluate if the mean performance of programs that fulfilled the KP requirements was superior than the mean performance of programs that did not meet the KP criteria (Kutner et al., 2004, pp. 1309–1310; Wyman, 2010). One disadvantage of this test is that it presupposes that the variances of both test groups are equal. To check this assumption, I utilized the ANOVA single factor test, which is equivalent to the Levene test used by Wyman (McClave et al., 2008, p. 455; Wyman, 2010). The ANOVA single factor test computes the p-value to determine whether or not the variances between the two test groups are negligible. If the p-value was less than 0.05, the variances were statistically significant, and the standard T-test was ineffective at determining the correlation between the two groups' mean performance. In these circumstances, I, like Wyman, utilized the Welch test since it compensates for the fact that test groups may have significant variances (Montgomery, 1999, p. 392: Wyman, 2010). I used both the standard T-test and the Welch test to get the resulting P-value for significant correlations (Wyman, 2010).

E. TYPE I AND TYPE II ERROR

To test my hypotheses about the effect of KPs on program outcomes, I created a "Ho." There are two types of errors that can arise when testing for the "Ho" (LaMorte, 2017). The first sort of error is referred to as a "Type I error," and it occurs when researchers reject "Ho" incorrectly when it is true, resulting in a false positive result (LaMorte, 2017). When this occurs, researchers wrongly conclude that the research hypothesis is true when, in fact, it is not (LaMorte, 2017).

To avoid this error the rule of thumb is to select a small value to represent the testing level of significance (LaMorte, 2017). By choosing a small value it reduces the chance of researchers committing a Type I Error (LaMorte, 2017). For this research, I chose a level of significance of 0.05. By selecting 0.05, I minimized the likelihood of committing a "Type I error" to 5% (LaMorte, 2017). Most researchers are comfortable with 5% as their margin of probability to commit a "Type I error" (LaMorte, 2017). This fact leaves me confident that the test is true if it tells me to reject "Ho" (LaMorte, 2017).

On the other hand, when researchers test a hypothesis and decide not to reject "H0," then either they make a correct decision, or they commit a "Type II error" (LaMorte, 2017). The rule of thumb to minimize the probability of committing a Type II error is to have a sample size of at least 30 (LaMorte, 2017). For my research we had a final sample size of 34. Table 3 summarizes the various conclusions.

Table 3. Type I and Type II Error. Source: LaMorte (2017).

	Do Not Reject H_0	**Reject H_0**
H_0 is True	Correct Decision	Type I Error
H_0 is False	Type II Error	Correct Decision

F. VISUAL TEST

Along with statistical analysis of the correlations between KP criteria compliance and program performance, I visually inspected the recorded dependent variables to see whether programs that regularly met two or more KP criteria had a decrease in QCP, UCC, DCC, PCC, or SIP. It was evident that meeting two or more KPs resulted in a decrease in UCC. The QCP, DCC, and PCC did not show any significant visual correlation with the completion of two or more KPs, implying that there may be additional underlying factors for these variables. I also visually analyzed whether certain DOD agencies were more efficient in applying the KPs and found that the Air Force was the most efficient, with the Army coming in second.

IV. ANALYSIS AND RESULTS

It was observed that not meeting the KP requirements had no obvious influence on most dependent variables. While inferential testing revealed a connection between SIP and KP2, inferential testing revealed no association between the other four variables and the KPs. A visual analysis revealed connections between the KPs and UCC. There was insufficient data to evaluate hypotheses regarding KP3.

A. TEST HYPOTHESIS

The analyses are summarized in Table 4. According to the t-test results, if a program manager follows the KBA, their Schedule Increase Percentage is likely to decrease. Most variables were determined to be insignificant statistically. In my opinion, PCC, DCC, UCC, and QCP lacked statistical significance due to the inherent variability of acquisition programs and the presence of other uncontrolled variables. Regrettably, the sample size was insufficient to conduct an inferential statistics test to determine the truth of the Null Hypothesis for KP3, rendering the study inconclusive. Nonetheless, it was visually determined that programs that implemented more than one KP consistently had a smaller UCC. The KPs had a statistically significant effect on only one dependent variable, SIP. According to what has been discovered visually and statistically, and because they are easily comparable across programs of various types, I propose that UCC and SIP are the two best measures of program performance.

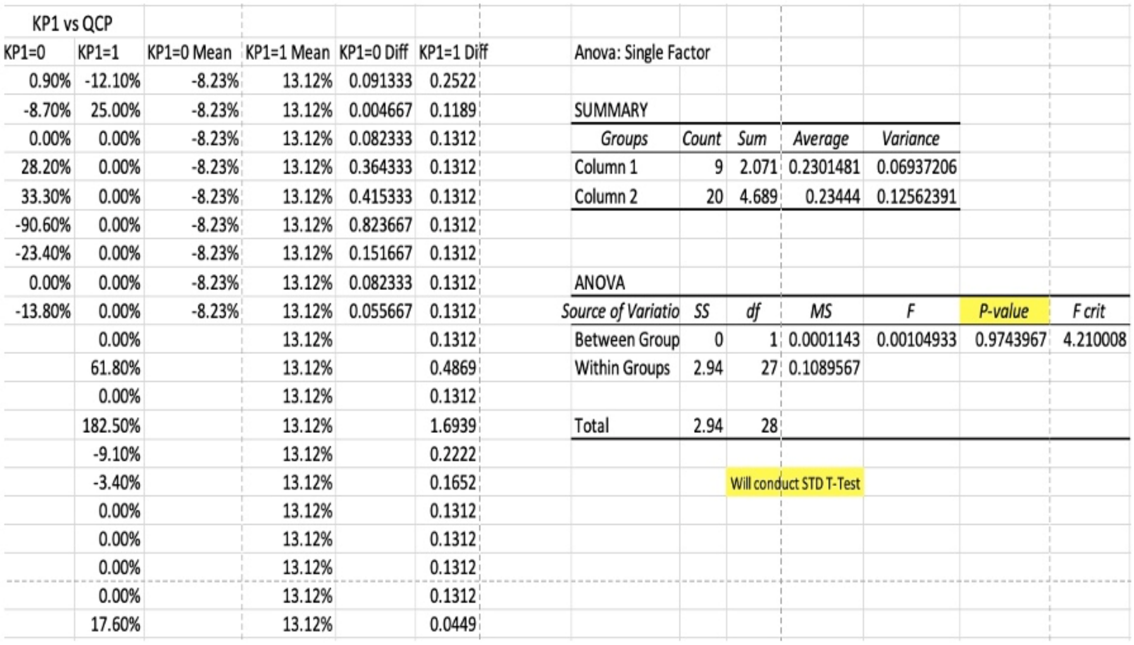
Table 4. Results of Analyses

	Hypothesis 1 KP1	**Hypothesis 2 KP2**	**Hypothesis 3 KP3**
QCP	0.204512258	0.21437665	Insufficient Data
PCC	0.627804344	0.10480831	Insufficient Data
UCC	0.306665232	0.37928286	Insufficient Data

	Hypothesis 1 KP1	**Hypothesis 2 KP2**	**Hypothesis 3 KP3**
DCC	0.174050088	0.08376491	Insufficient Data
SIP	0.589339665	0.02652126	Insufficient Data
P-Value < 0.05; Reject Null Hypothesis **If P-Value > 0.05; do not have significant evidence to show that the Alternative Hypothesis (HA) is true.**			

B. DATA VARIABILITY RESULTS

In most cases, the KP data did not have statistically different variances (KP1=0= Missed KP; KP1=1 = Met KP). This could be due to the small sample size or other uncontrollable variables. Figures 11–20 show the results of the Anova: Single Factor Test, which highlights variances for each variable with respect to the testable KPs. In cases where KPs had statistically different variances, a Welch test was conducted. Figures 21 – 25 show the results of group "0" and group "1" for KP3 that led to inconclusive results.



KP1 vs QCP

KP1=0	KP1=1	KP1=0 Mean	KP1=1 Mean	KP1=0 Diff	KP1=1 Diff
0.90%	-12.10%	-8.23%	13.12%	0.091333	0.2522
-8.70%	25.00%	-8.23%	13.12%	0.004667	0.1189
0.00%	0.00%	-8.23%	13.12%	0.082333	0.1312
28.20%	0.00%	-8.23%	13.12%	0.364333	0.1312
33.30%	0.00%	-8.23%	13.12%	0.415333	0.1312
-90.60%	0.00%	-8.23%	13.12%	0.823667	0.1312
-23.40%	0.00%	-8.23%	13.12%	0.151667	0.1312
0.00%	0.00%	-8.23%	13.12%	0.082333	0.1312
-13.80%	0.00%	-8.23%	13.12%	0.055667	0.1312
	0.00%		13.12%		0.1312
	61.80%		13.12%		0.4869
	0.00%		13.12%		0.1312
	182.50%		13.12%		1.6939
	-9.10%		13.12%		0.2222
	-3.40%		13.12%		0.1652
	0.00%		13.12%		0.1312
	0.00%		13.12%		0.1312
	0.00%		13.12%		0.1312
	0.00%		13.12%		0.1312
	17.60%		13.12%		0.0449

Anova: Single Factor

SUMMARY

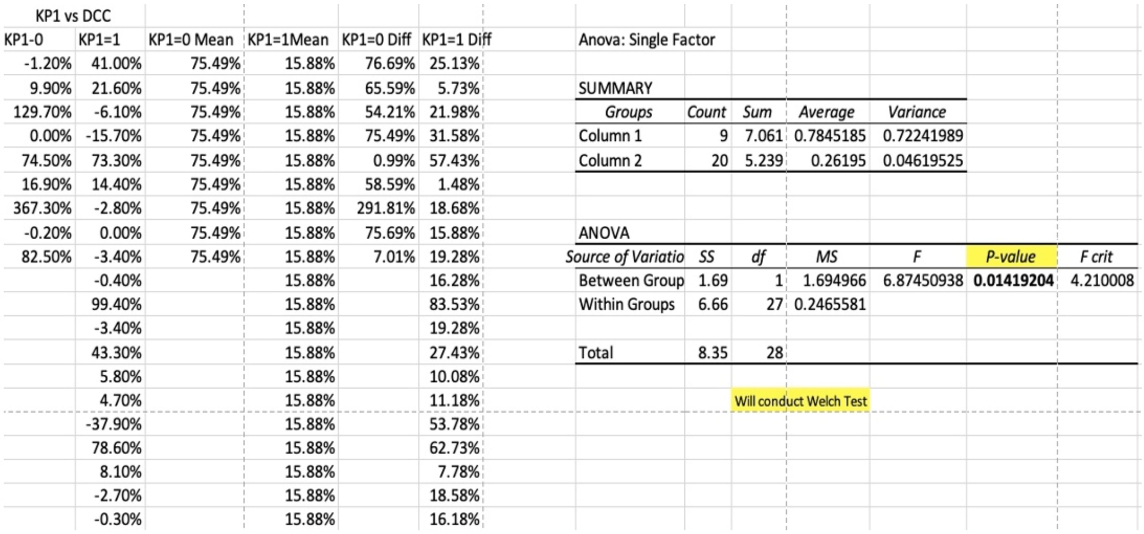
Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	2.071	0.2301481	0.06937206
Column 2	20	4.689	0.23444	0.12562391

ANOVA

Source of Variatio	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Group	0	1	0.0001143	0.00104933	0.9743967	4.210008
Within Groups	2.94	27	0.1089567			
Total	2.94	28				

Will conduct STD T-Test

Figure 11. KP1 vs. QCP



KP1 vs DCC

KP1-0	KP1=1	KP1=0 Mean	KP1=1Mean	KP1=0 Diff	KP1=1 Diff
-1.20%	41.00%	75.49%	15.88%	76.69%	25.13%
9.90%	21.60%	75.49%	15.88%	65.59%	5.73%
129.70%	-6.10%	75.49%	15.88%	54.21%	21.98%
0.00%	-15.70%	75.49%	15.88%	75.49%	31.58%
74.50%	73.30%	75.49%	15.88%	0.99%	57.43%
16.90%	14.40%	75.49%	15.88%	58.59%	1.48%
367.30%	-2.80%	75.49%	15.88%	291.81%	18.68%
-0.20%	0.00%	75.49%	15.88%	75.69%	15.88%
82.50%	-3.40%	75.49%	15.88%	7.01%	19.28%
	-0.40%		15.88%		16.28%
	99.40%		15.88%		83.53%
	-3.40%		15.88%		19.28%
	43.30%		15.88%		27.43%
	5.80%		15.88%		10.08%
	4.70%		15.88%		11.18%
	-37.90%		15.88%		53.78%
	78.60%		15.88%		62.73%
	8.10%		15.88%		7.78%
	-2.70%		15.88%		18.58%
	-0.30%		15.88%		16.18%

Anova: Single Factor

SUMMARY

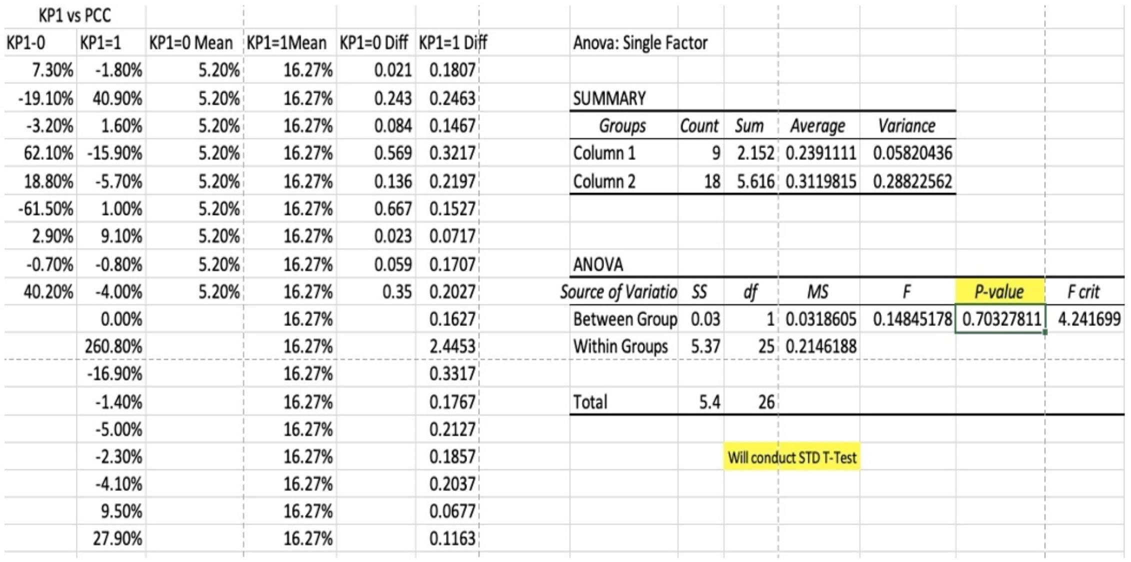
Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	7.061	0.7845185	0.72241989
Column 2	20	5.239	0.26195	0.04619525

ANOVA

Source of Variatio	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Group	1.69	1	1.694966	6.87450938	**0.01419204**	4.210008
Within Groups	6.66	27	0.2465581			
Total	8.35	28				

Will conduct Welch Test

Figure 12. KP1 vs. DCC



KP1 vs PCC

KP1-0	KP1=1	KP1=0 Mean	KP1=1Mean	KP1=0 Diff	KP1=1 Diff
7.30%	-1.80%	5.20%	16.27%	0.021	0.1807
-19.10%	40.90%	5.20%	16.27%	0.243	0.2463
-3.20%	1.60%	5.20%	16.27%	0.084	0.1467
62.10%	-15.90%	5.20%	16.27%	0.569	0.3217
18.80%	-5.70%	5.20%	16.27%	0.136	0.2197
-61.50%	1.00%	5.20%	16.27%	0.667	0.1527
2.90%	9.10%	5.20%	16.27%	0.023	0.0717
-0.70%	-0.80%	5.20%	16.27%	0.059	0.1707
40.20%	-4.00%	5.20%	16.27%	0.35	0.2027
	0.00%		16.27%		0.1627
	260.80%		16.27%		2.4453
	-16.90%		16.27%		0.3317
	-1.40%		16.27%		0.1767
	-5.00%		16.27%		0.2127
	-2.30%		16.27%		0.1857
	-4.10%		16.27%		0.2037
	9.50%		16.27%		0.0677
	27.90%		16.27%		0.1163

Anova: Single Factor

SUMMARY

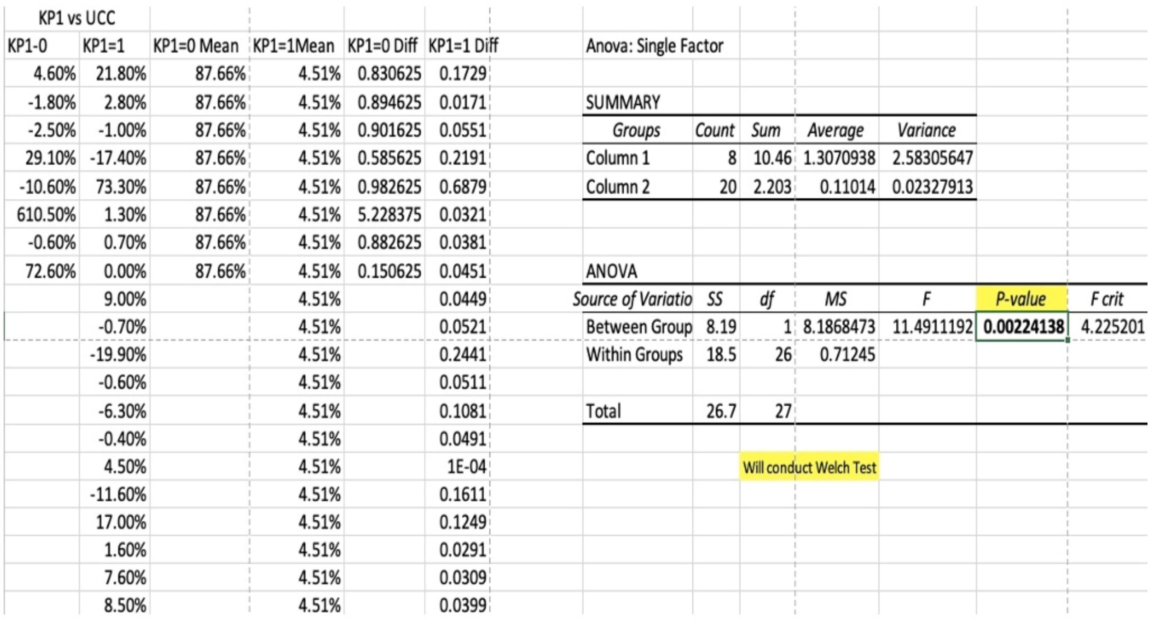
Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	2.152	0.2391111	0.05820436
Column 2	18	5.616	0.3119815	0.28822562

ANOVA

Source of Variatio	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Group	0.03	1	0.0318605	0.14845178	0.70327811	4.241699
Within Groups	5.37	25	0.2146188			
Total	5.4	26				

Will conduct STD T-Test

Figure 13. KP1 vs. PCC



KP1 vs UCC

KP1-0	KP1=1	KP1=0 Mean	KP1=1Mean	KP1=0 Diff	KP1=1 Diff
4.60%	21.80%	87.66%	4.51%	0.830625	0.1729
-1.80%	2.80%	87.66%	4.51%	0.894625	0.0171
-2.50%	-1.00%	87.66%	4.51%	0.901625	0.0551
29.10%	-17.40%	87.66%	4.51%	0.585625	0.2191
-10.60%	73.30%	87.66%	4.51%	0.982625	0.6879
610.50%	1.30%	87.66%	4.51%	5.228375	0.0321
-0.60%	0.70%	87.66%	4.51%	0.882625	0.0381
72.60%	0.00%	87.66%	4.51%	0.150625	0.0451
	9.00%		4.51%		0.0449
	-0.70%		4.51%		0.0521
	-19.90%		4.51%		0.2441
	-0.60%		4.51%		0.0511
	-6.30%		4.51%		0.1081
	-0.40%		4.51%		0.0491
	4.50%		4.51%		1E-04
	-11.60%		4.51%		0.1611
	17.00%		4.51%		0.1249
	1.60%		4.51%		0.0291
	7.60%		4.51%		0.0309
	8.50%		4.51%		0.0399

Anova: Single Factor

SUMMARY

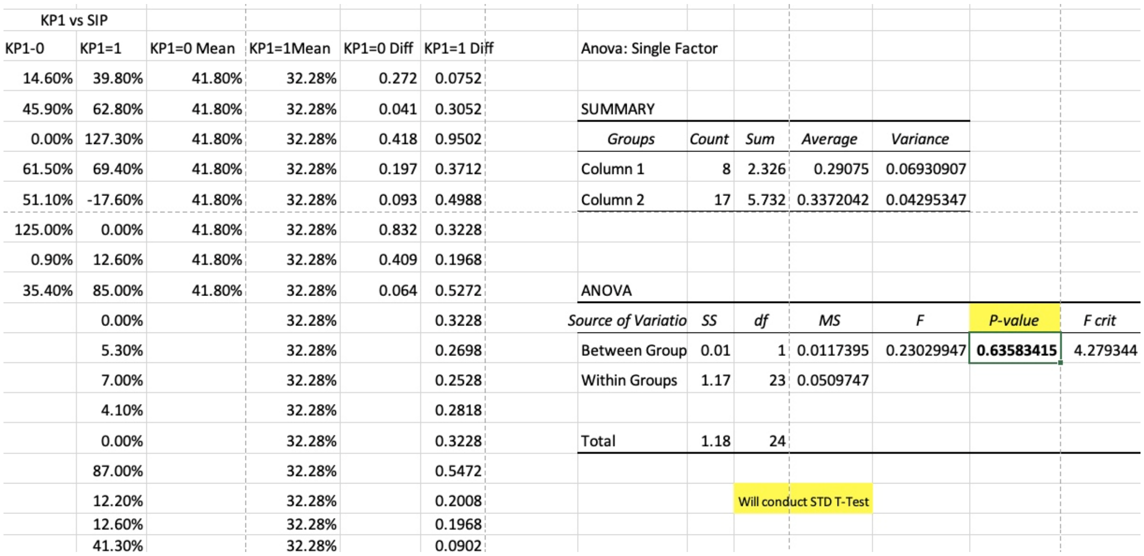
Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	8	10.46	1.3070938	2.58305647
Column 2	20	2.203	0.11014	0.02327913

ANOVA

Source of Variatio	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Group	8.19	1	8.1868473	11.4911192	**0.00224138**	4.225201
Within Groups	18.5	26	0.71245			
Total	26.7	27				

Will conduct Welch Test

Figure 14. KP1 vs. UCC



KP1 vs SIP

KP1-0	KP1=1	KP1=0 Mean	KP1=1Mean	KP1=0 Diff	KP1=1 Diff
14.60%	39.80%	41.80%	32.28%	0.272	0.0752
45.90%	62.80%	41.80%	32.28%	0.041	0.3052
0.00%	127.30%	41.80%	32.28%	0.418	0.9502
61.50%	69.40%	41.80%	32.28%	0.197	0.3712
51.10%	-17.60%	41.80%	32.28%	0.093	0.4988
125.00%	0.00%	41.80%	32.28%	0.832	0.3228
0.90%	12.60%	41.80%	32.28%	0.409	0.1968
35.40%	85.00%	41.80%	32.28%	0.064	0.5272
	0.00%		32.28%		0.3228
	5.30%		32.28%		0.2698
	7.00%		32.28%		0.2528
	4.10%		32.28%		0.2818
	0.00%		32.28%		0.3228
	87.00%		32.28%		0.5472
	12.20%		32.28%		0.2008
	12.60%		32.28%		0.1968
	41.30%		32.28%		0.0902

Anova: Single Factor

SUMMARY

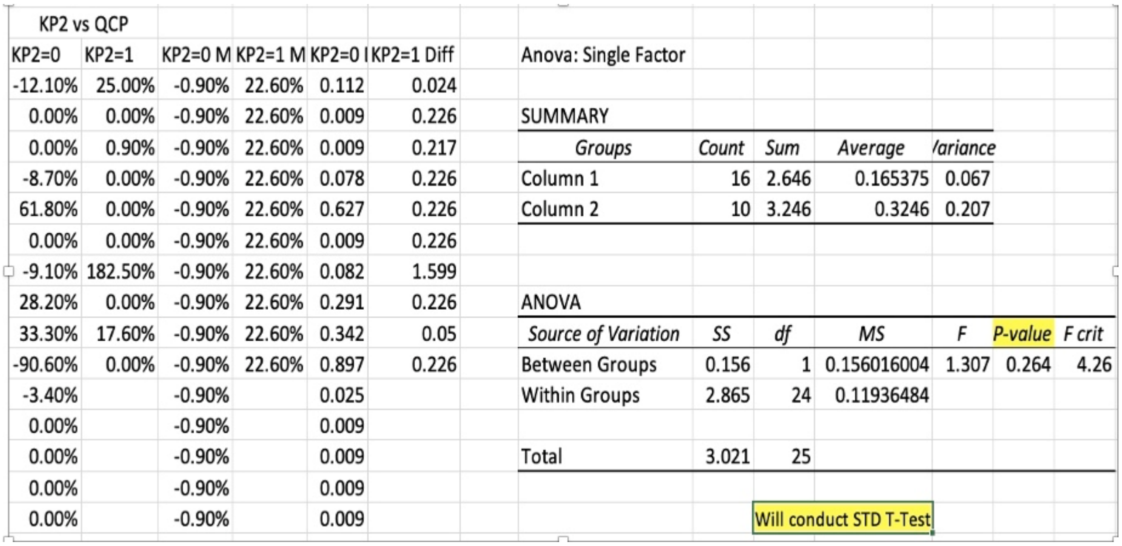
Groups	Count	Sum	Average	Variance
Column 1	8	2.326	0.29075	0.06930907
Column 2	17	5.732	0.3372042	0.04295347

ANOVA

Source of Variatio	SS	df	MS	F	P-value	F crit
Between Group	0.01	1	0.0117395	0.23029947	**0.63583415**	4.279344
Within Groups	1.17	23	0.0509747			
Total	1.18	24				

Will conduct STD T-Test

Figure 15. KP1 vs. SIP



KP2 vs QCP

KP2=0	KP2=1	KP2=0 M	KP2=1 M	KP2=0	KP2=1 Diff
-12.10%	25.00%	-0.90%	22.60%	0.112	0.024
0.00%	0.00%	-0.90%	22.60%	0.009	0.226
0.00%	0.90%	-0.90%	22.60%	0.009	0.217
-8.70%	0.00%	-0.90%	22.60%	0.078	0.226
61.80%	0.00%	-0.90%	22.60%	0.627	0.226
0.00%	0.00%	-0.90%	22.60%	0.009	0.226
-9.10%	182.50%	-0.90%	22.60%	0.082	1.599
28.20%	0.00%	-0.90%	22.60%	0.291	0.226
33.30%	17.60%	-0.90%	22.60%	0.342	0.05
-90.60%	0.00%	-0.90%	22.60%	0.897	0.226
-3.40%		-0.90%		0.025	
0.00%		-0.90%		0.009	
0.00%		-0.90%		0.009	
0.00%		-0.90%		0.009	
0.00%		-0.90%		0.009	

Anova: Single Factor

SUMMARY

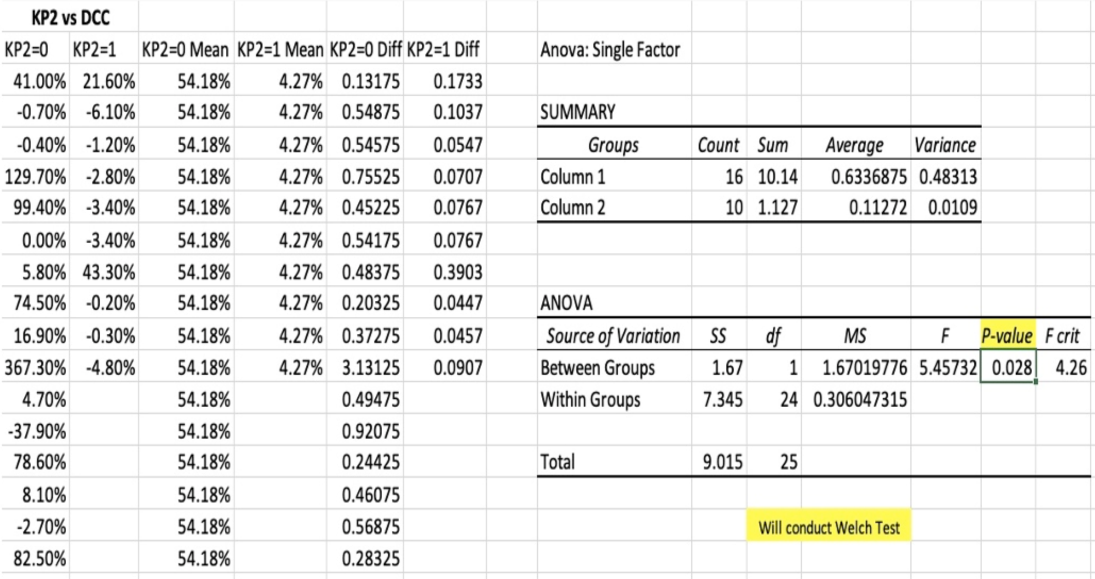
Groups	Count	Sum	Average	ariance
Column 1	16	2.646	0.165375	0.067
Column 2	10	3.246	0.3246	0.207

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.156	1	0.156016004	1.307	0.264	4.26
Within Groups	2.865	24	0.11936484			
Total	3.021	25				

Will conduct STD T-Test

Figure 16. KP2 vs. QCP



KP2 vs DCC

KP2=0	KP2=1	KP2=0 Mean	KP2=1 Mean	KP2=0 Diff	KP2=1 Diff
41.00%	21.60%	54.18%	4.27%	0.13175	0.1733
-0.70%	-6.10%	54.18%	4.27%	0.54875	0.1037
-0.40%	-1.20%	54.18%	4.27%	0.54575	0.0547
129.70%	-2.80%	54.18%	4.27%	0.75525	0.0707
99.40%	-3.40%	54.18%	4.27%	0.45225	0.0767
0.00%	-3.40%	54.18%	4.27%	0.54175	0.0767
5.80%	43.30%	54.18%	4.27%	0.48375	0.3903
74.50%	-0.20%	54.18%	4.27%	0.20325	0.0447
16.90%	-0.30%	54.18%	4.27%	0.37275	0.0457
367.30%	-4.80%	54.18%	4.27%	3.13125	0.0907
4.70%		54.18%		0.49475	
-37.90%		54.18%		0.92075	
78.60%		54.18%		0.24425	
8.10%		54.18%		0.46075	
-2.70%		54.18%		0.56875	
82.50%		54.18%		0.28325	

Anova: Single Factor

SUMMARY

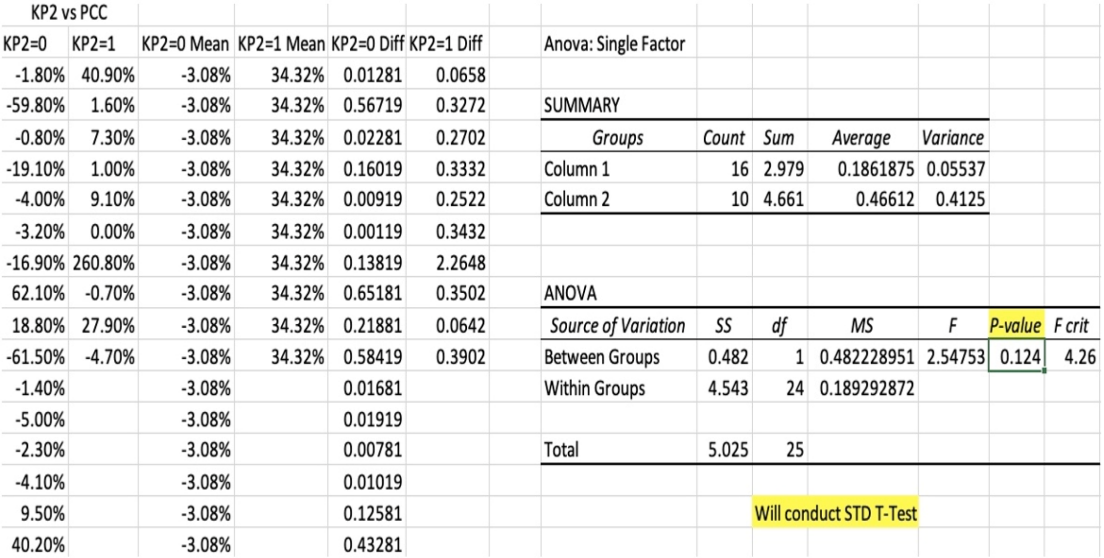
Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	16	10.14	0.6336875	0.48313
Column 2	10	1.127	0.11272	0.0109

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.67	1	1.67019776	5.45732	0.028	4.26
Within Groups	7.345	24	0.306047315			
Total	9.015	25				

Will conduct Welch Test

Figure 17. KP2 vs. DCC



KP2 vs PCC

KP2=0	KP2=1	KP2=0 Mean	KP2=1 Mean	KP2=0 Diff	KP2=1 Diff
-1.80%	40.90%	-3.08%	34.32%	0.01281	0.0658
-59.80%	1.60%	-3.08%	34.32%	0.56719	0.3272
-0.80%	7.30%	-3.08%	34.32%	0.02281	0.2702
-19.10%	1.00%	-3.08%	34.32%	0.16019	0.3332
-4.00%	9.10%	-3.08%	34.32%	0.00919	0.2522
-3.20%	0.00%	-3.08%	34.32%	0.00119	0.3432
-16.90%	260.80%	-3.08%	34.32%	0.13819	2.2648
62.10%	-0.70%	-3.08%	34.32%	0.65181	0.3502
18.80%	27.90%	-3.08%	34.32%	0.21881	0.0642
-61.50%	-4.70%	-3.08%	34.32%	0.58419	0.3902
-1.40%		-3.08%		0.01681	
-5.00%		-3.08%		0.01919	
-2.30%		-3.08%		0.00781	
-4.10%		-3.08%		0.01019	
9.50%		-3.08%		0.12581	
40.20%		-3.08%		0.43281	

Anova: Single Factor

SUMMARY

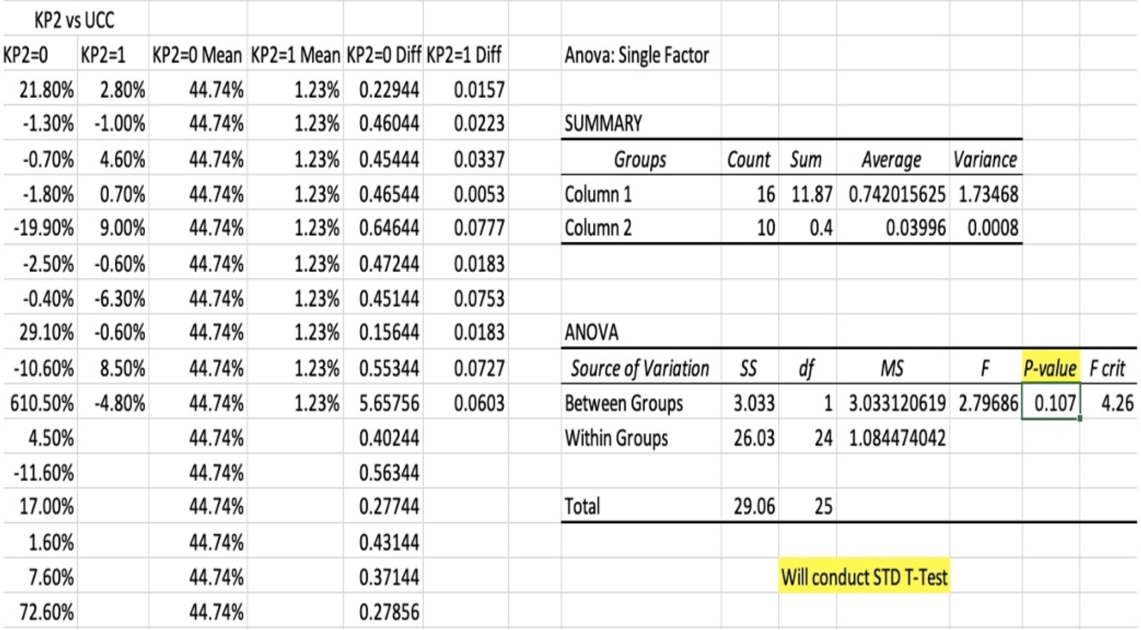
Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	16	2.979	0.1861875	0.05537
Column 2	10	4.661	0.46612	0.4125

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.482	1	0.482228951	2.54753	0.124	4.26
Within Groups	4.543	24	0.189292872			
Total	5.025	25				

Will conduct STD T-Test

Figure 18. KP2 vs. PCC



KP2 vs UCC

KP2=0	KP2=1	KP2=0 Mean	KP2=1 Mean	KP2=0 Diff	KP2=1 Diff
21.80%	2.80%	44.74%	1.23%	0.22944	0.0157
-1.30%	-1.00%	44.74%	1.23%	0.46044	0.0223
-0.70%	4.60%	44.74%	1.23%	0.45444	0.0337
-1.80%	0.70%	44.74%	1.23%	0.46544	0.0053
-19.90%	9.00%	44.74%	1.23%	0.64644	0.0777
-2.50%	-0.60%	44.74%	1.23%	0.47244	0.0183
-0.40%	-6.30%	44.74%	1.23%	0.45144	0.0753
29.10%	-0.60%	44.74%	1.23%	0.15644	0.0183
-10.60%	8.50%	44.74%	1.23%	0.55344	0.0727
610.50%	-4.80%	44.74%	1.23%	5.65756	0.0603
4.50%		44.74%		0.40244	
-11.60%		44.74%		0.56344	
17.00%		44.74%		0.27744	
1.60%		44.74%		0.43144	
7.60%		44.74%		0.37144	
72.60%		44.74%		0.27856	

Anova: Single Factor

SUMMARY

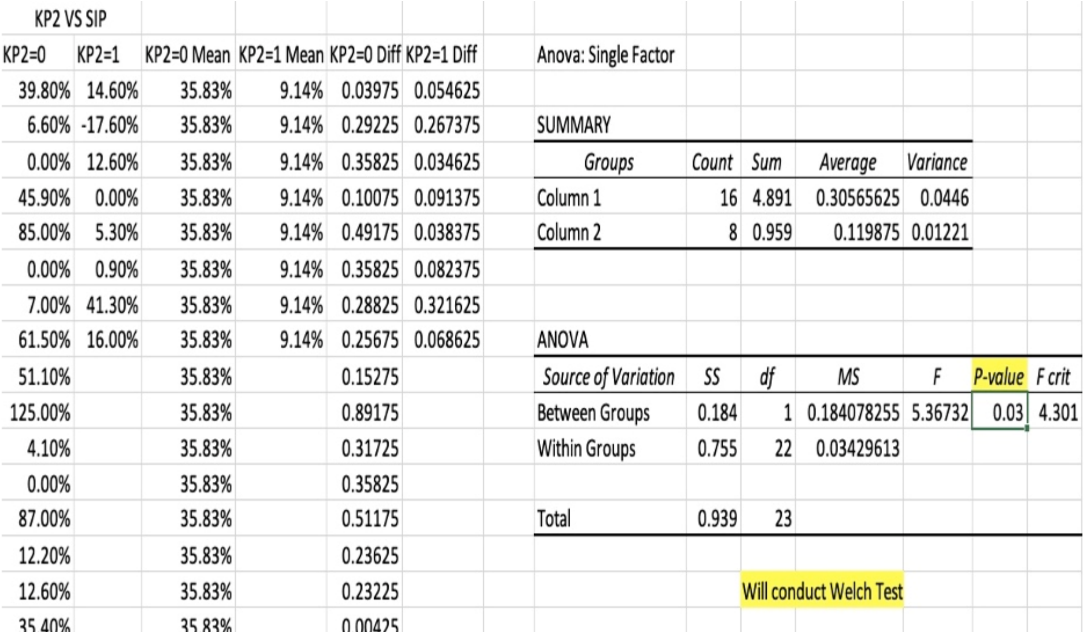
Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	16	11.87	0.742015625	1.73468
Column 2	10	0.4	0.03996	0.0008

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.033	1	3.033120619	2.79686	0.107	4.26
Within Groups	26.03	24	1.084474042			
Total	29.06	25				

Will conduct STD T-Test

Figure 19. KP2 vs. UCC



KP2 VS SIP

KP2=0	KP2=1	KP2=0 Mean	KP2=1 Mean	KP2=0 Diff	KP2=1 Diff
39.80%	14.60%	35.83%	9.14%	0.03975	0.054625
6.60%	-17.60%	35.83%	9.14%	0.29225	0.267375
0.00%	12.60%	35.83%	9.14%	0.35825	0.034625
45.90%	0.00%	35.83%	9.14%	0.10075	0.091375
85.00%	5.30%	35.83%	9.14%	0.49175	0.038375
0.00%	0.90%	35.83%	9.14%	0.35825	0.082375
7.00%	41.30%	35.83%	9.14%	0.28825	0.321625
61.50%	16.00%	35.83%	9.14%	0.25675	0.068625
51.10%		35.83%		0.15275	
125.00%		35.83%		0.89175	
4.10%		35.83%		0.31725	
0.00%		35.83%		0.35825	
87.00%		35.83%		0.51175	
12.20%		35.83%		0.23625	
12.60%		35.83%		0.23225	
35.40%		35.83%		0.00425	

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	16	4.891	0.30565625	0.0446
Column 2	8	0.959	0.119875	0.01221

ANOVA

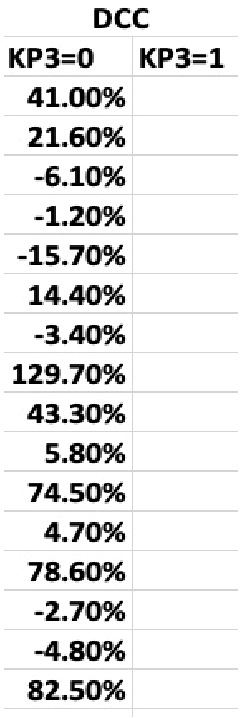
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.184	1	0.184078255	5.36732	0.03	4.301
Within Groups	0.755	22	0.03429613			
Total	0.939	23				

Will conduct Welch Test

Figure 20. KP2 vs. SIP

QCP	
KP3=0	**KP3=1**
-12.10%	
25.00%	
0.00%	
0.90%	
0.00%	
0.00%	
0.00%	
-8.70%	
182.50%	
-9.10%	
28.20%	
-3.40%	
0.00%	
0.00%	
0.00%	
-13.80%	

Figure 21. KP3's QCP "0" and "1"



DCC	
KP3=0	**KP3=1**
41.00%	
21.60%	
-6.10%	
-1.20%	
-15.70%	
14.40%	
-3.40%	
129.70%	
43.30%	
5.80%	
74.50%	
4.70%	
78.60%	
-2.70%	
-4.80%	
82.50%	

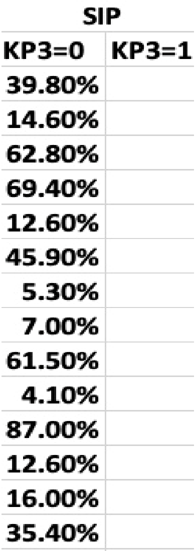
Figure 22. KP3's DCC "0" and "1"

PCC	
KP3=0	KP3=1
-1.80%	
40.90%	
1.60%	
7.30%	
-15.90%	
-5.70%	
9.10%	
-19.10%	
260.80%	
-16.90%	
62.10%	
-1.40%	
-2.30%	
9.50%	
-4.70%	
40.20%	

Figure 23. KP3's PCC "0" and "1"

UCC	
KP3=0	KP3=1
21.80%	
2.80%	
-1.00%	
4.60%	
4.60%	
-17.40%	
1.30%	
9.00%	
-1.80%	
-6.30%	
-0.40%	
29.10%	
4.50%	
17.00%	
7.60%	
-4.80%	
72.60%	

Figure 24. KP3's UCC "0" and "1"



SIP	
KP3=0	KP3=1
39.80%	
14.60%	
62.80%	
69.40%	
12.60%	
45.90%	
5.30%	
7.00%	
61.50%	
4.10%	
87.00%	
12.60%	
16.00%	
35.40%	

Figure 25. KP3’s SIP “0” and “1”

C. VISUAL TEST RESULTS

The purpose of the visual test was to analyze whether certain DOD agencies were more efficient in applying the KPs. It was found that the Air Force was the most efficient, with the Army coming in second. Additionally, it was discovered that KP3 was the most frequently overlooked KP; 0% of programs assessed at KP3 had statistically controlled production processes., I also visually analyzed the recorded dependent variables to determine whether programs that consistently met one or more of the KP criteria experienced a decrease in QCP, UCC, DCC, PCC, or SIP. It was visually determined that programs that implemented more than one KP consistently had a smaller UCC. The Data Demographics are shown in Table 5.

Table 5. Data Demographics

	Number of Programs	Percent of Dataset
Air Force	11	32%
Army	6	18%
Navy/ Marine Corp	16	47%
Joint DOD	1	3%

V. CONCLUSIONS

For more than two decades, the GAO has been a champion of the Knowledge-Based Acquisition Approach. They assert that initiatives that adhere to the KBA will achieve superior results in terms of budget, schedule, and performance. This thesis investigated the GAO's claim regarding MDAPs. This study was partly inspired by Wyman's thesis and research on the effect of KAT on defense acquisition programs completed in 2010, and interestingly, almost a decade later, there were some parallels in the findings (Wyman, 2010). Both research findings corroborated the GAO's assertion in some respects and contradicted it in others (Wyman, 2010). This thesis expands on the Wyman study's finding that the GAO's KAT is a "useful means to program performance" (Wyman, 2010). Following visual examination and inferential statistical analysis, it is determined that the GAO's KBA can aid program managers in meeting their initial cost and schedule projections for providing capabilities to the warfighter.

Following an independent t-test and a welch test, it was determined that the Ho was true in most situations. KP1, KP2, or KP3 had no discernible effect on PCC, UCC, QCP, or DCC. However, it was discovered that KP2 had a clear link with SIP, leading me to reject the null hypothesis for that case. However, it is necessary to emphasize that additional variables such as COVID-19 might have influenced the scheduling variations. Nonetheless, the statistics demonstrated that when a program did not match the KP2 requirements, its SIP was greater than when it did. This indicates that programs that satisfied KP2 had a better scheduling outcome than ones that did not.

Finally, the visual test did support the GAO's assertions regarding UCC. When two or more KPs were met, the UCC was lower. Because the UCC variable was continuously lower when numerous KPs were satisfied, it was the most visually dependable of all the variables as a measure of success. This is unsurprising, given the two KPs that were most frequently satisfied were KP1 and KP2, which are the most significant for defining requirements and design specifications that affect unit cost (GAO, 2004).

A. LIMITATIONS

Due to the study's limitations, more research is necessary. To begin, a constraint on the type of program was applied, significantly limiting the sample size. This analysis assessed only the most recent MDAP initiatives with comparable durations, yielding a total of 34 programs, some which lacked complete data. Future studies can combine MDAPs and MTAs to get a more holistic knowledge of how KBA knowledge points impact program outcomes. Additionally, because the GAO reports span decades, deeper analysis may include information about previous initiatives. A bigger sample of programs may demonstrate that the KBA is only relevant to a subset of program types. Since none of the chosen programs satisfied the criteria, this research was unable to evaluate KP3. All programs were mature enough to accommodate KP3, raising concerns about why it did not occur. A larger sample size may be necessary to illustrate the influence of KP3 on the procurement programs of the Department of Defense.

B. IMPACT TO THE ACQUISITION COMMUNITY

Although this study was unable to statistically confirm that adherence to all three KPs is an effective method to enhance all acquisition results, the data suggests that adhering to the first two KPs of the KBA can help programs achieve more positive outcomes. Understanding the beneficial effect, the KBA has on MDAPs and figuring out how to replicate similar outcomes in other programs can result in the government saving tens of billions of dollars. Additionally, this thesis builds on a model developed in 2010, confirming a successful model that can be used for periodic evaluation to determine whether the GAO's KBA is still accomplishing the desired goal of keeping programs on budget and on schedule, or whether it needs to be modified. This model can be used across DOD departments, ACAT levels, and program types.

C. CONSTRUCTIVE INSIGHT

The study's underlying question has been why program managers do not appear to be willing to follow KBA principles? Perhaps the budget overruns and schedule delays are not due to program managers' unwillingness to implement the KPs, but to a variety of uncontrollable factors that make the GAO's timeline for meeting the KP criteria somewhat unrealistic in the DOD acquisition environment. For instance, the first KP verifies that program managers have achieved a mature TRL prior to Milestone B. However, when dealing with large complex programs, the limitations of immature technology, both hardware and software, may impact the timing of maturing technology, preventing programs from adhering precisely to the GAO's recommended development schedule. Frequently, programs must rely on a slightly lower TRL to mitigate risk and continue the program.

Additionally, many of the GAO's recommended KPs are already incorporated into the DOD's acquisition process and are simply restated, but with inadequate criteria. For instance, one of KP2's tenets states that at least 90% of engineering drawings should be completed prior to conducting the critical design review (GAO, 2004). This raises the question, why only 90%? One may argue that program managers should practice completing all engineering drawings prior to doing the critical design review to maximize the possibility that the system would advance to manufacturing, demonstration, and testing. Additionally, having completed all engineering drawings prior to doing the critical design review enhances the possibility that the program will fulfill all performance objectives within the constraints of the budget and schedule (GAO, 2021a). Another example is found in KP3's tenets, which state that programs must have a manufacturing readiness level of at least 9 or that critical processes must be statistically controlled by Milestone C (GAO, 2004). According to Boudreau, "These manufacturing readiness metrics [already] overlay the milestones and phases of the Defense Acquisition System, providing concrete measures of preparation and activity that culminate in full-rate production" (Boudreau, 2017). Therefore, since this "readiness metric" is already incorporated into the acquisition process, the question becomes why program managers are failing to implement it (Boudreau, 2017)? According to Boudreau, this might be due of the culture inside the DOD's acquisition community, which requires PMs to progress their programs regardless of whether they completely fulfill exit requirements or not (Boudreau, 2017). Boudreau also states that if this is the true, the solution becomes the responsibility of the milestone decision authority. He notes that the milestone decision authority must be uncompromising, not allowing the program's continuation to the next phase unless all criteria are satisfied (Boudreau, 2017).

As Albert Einstein once stated, “In theory, theory and practice are the same, in practice they are not” (Haddad, 2019). In theory, the KPs recommended by the GAO are seemingly simple to implement, but in practice there are some challenges. There is evidence that the GAO recommendations will place acquisition developmental programs on the right track for better outcomes, as many of the KP’s tenets are already part of the acquisition process. However, a deeper look into why programs have resisted adopting the GAO’s KBA might be beneficial to the acquisition community.

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Acquisition Research Program
Department of Defense Management
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net