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A Study Of The Material Inspection Record And Quality Systems: A Case In The United States Department Of The Navy

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A STUDY OF THE MATERIAL INSPECTION RECORD AND QUALITY SYSTEMS: A CASE IN THE UNITED STATES DEPARTMENT OF THE NAVY

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ABSTRACT

Defective products and services are a part of every industry, sector, and organization. Minimization of those defects is essential for business success. The later those defects are found, the more they cost the business and consumer. This study investigated the impact having an accredited Quality Management System (QMS) had on the acceptance of delivered product. The study focused on the products delivered to the Naval Sea Systems Command (NAVSEA) and Naval Supply Systems Command (NAVSUP) organizations. This study investigated the statistical significance between the means of the groups within size and number of accreditation. The dependent variables were Material Inspection Record (MIR), units received, and units rejected, or products delivered to the NAVSEA and NAVSUP organizations.

The study used the PDREP Metric Dashboard data for fiscal year 2012, quarter 1 through fiscal year 2016, quarter 2, resulting in more than 8,000 records analyzed and interpreted using a one-way ANOVA and General Linear Model.

The results of the analysis indicated there were no significant differences between size or accreditation of organizations, when compared to the number of rejected units and Material Inspection Report (MIR) acceptance or rejection. The analysis did suggest there is statistical significance when size and accreditation are compared to MIR acceptance or rejection (F-Value 3.01, P-Value 0.006). Additional analysis was conducted for within group comparisons and small organizations were identified as having a statistically disproportionate percentage of units rejected (76.61 percent), when compared to the percentage of units received (55.24 percent).

Within small organizations, organizations with one accreditation had the highest ratio of units rejected compared to units received (2.00 to 1) as a percentage of units received within small organizations. Further research was recommended to explore other factors that would improve risk assessment and mitigation within the Department of Defense (DoD).

PREFACE

I would like to dedicate this dissertation to my wife, Valerie Brown, through her support, patience and love; I am able to strive for my dreams. I would also like to dedicate it to my children: Lauren, Dylan, Victorya, Mason & Finn. Through education, all things are possible.

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INTRODUCTION

Defective products and services are a part of every industry, sector, and organization. Minimization of those defects is essential for business success. The later those defects are found, the more they cost the business and consumer. This leads to more waste and is indicative of a poor quality management system (QMS). The United States Government spends hundreds of billions of dollars each year procuring equipment and services on behalf of the American people. Included in that number is several hundred billions of dollars spent by the Department of Defense (DoD) to procure and maintain the various weapons systems employed by our military. Government spending is a serious concern in the United States. Now politicians, economists, the media, and citizens trying to understand why their taxes and the deficit are steadily increasing with little to no increase in the amount or quality of the goods being procured. Why are our tax dollars buying less than in previous decades?

These groups are scrutinizing, more than ever, every dollar spent by the government. The more money that is spent, the more everyone wants to know on what it is being spent and from where it will come. However, they are unable to identify exactly what is causing the quality, schedule, and cost issues.

As of September 30, 2015, TreasuryDirect.gov (n.d.) lists the U.S Historical Debt Outstanding at $18,150,604,277,750.63. This growing debt is significantly impacted by the amount of Department of Defense (DoD) spending, currently at a projected $585.3 billion for

FY16 (Office of the Under Secretary of Defense, 2015). In order to reduce the rate of spending and debt, the DoD needs to devise a better method of measuring contractor performance that will enable them to track and/or identify trends and predictors for poor quality, escalating costs, and increases in delivery schedules.

According to the United States Department of Defense Fiscal Year 2016 Budget Request (2015), the actual total budget for FY 2014 was $581.4 billion, FY 2015 enacted total budget of $560.4 billion, and FY 2016 had a requested total budget of $585.3 billion. While much of this money is spent on labor, a large portion of it is allocated for procurement of products and services for DoD agencies. These costs have begun to significantly increase on some of the most visible and costly Acquisition Category (ACAT) I programs. One need look no further than the cost of the DoD F-35 program and the Navy aircraft carrier programs.

The F-35 program, according to the Government Accountability Office (GAO) report for the F-35 Joint Strike Fighter (2015a), began in 2001 and has undergone three restructurings (2003, 2007, and 2012) due to costs exceeding critical thresholds. Since the initial baseline was established in October of 2001 at $233 billion, the program baseline has gone up to $395.7 billion at the March 2012 baseline (GAO, 2015a). This represents a 69.82 percent increase in the original baseline cost. Another big problem that is being ignored is the System Design and Development and 2003 annual plan called for 1,966 aircraft to be delivered by 2019 and the 2012 annual plan calls for only 585 aircraft to be delivered by 2019 (GAO, 2015a). This represents a 70.24 percent decrease in the quantity. Meaning the government is paying more money for fewer aircraft, a lot more money.

The Navy has seen its own share of problems. The new Ford Class Carrier has been on rocky ground since it was introduced in the 2006-2007 timeframe. Originally, the cost for the

CVN 78 (the original carrier) carrier was scheduled to be $10.5 billion per carrier (GAO, 2015b). By the time the GAO report had come out, the costs was at $12.9 billion and the ship was to be delivered incomplete (GAO, 2015b). Meaning the cost could go up even more. The bigger problem was the second ship CVN 79 was to be delivered at a cost of $8.1 billion but in 2013, the Navy requested a cap increase to $11.5 billion (GAO, 2015b). This represents an increase of 41.98 percent over the original cost estimate with the Congressional Budget Office estimating it will cost more than $12.5 billion when delivered, which is more than $1 billion more than Congress has set the cap (GAO, 2015b). This means the increase in cost for the first two Ford Class Carriers would nearly be enough to buy one additional Ford Class Carrier at the $8.1 billion price.

In order to hide or rebaseline costs, the Navy has decided to delay some of the costs by deferring their incorporation until after the carriers are delivered to the fleet. This is done by moving the costs to other accounts, such as maintenance upgrades, and possibly deferring costs to the F-35 program through joint upgrades. As part of the DoD budget, the government spends hundreds of millions on ensuring their contracts contain language requiring contractors to be maintain quality systems equivalent to industry standard quality management systems (QMS) such as AS9100 and ISO9001:2008. Even though they spend billions attempting to ensure they are receiving quality products, the government had more than 17,000 Product Quality Deficiency Reports (PQDRs) issued for defective products for FY 2015. This totaled more than $1.1 billion in defective products in through the first three quarters of 2015 (NAVSEA, 2015). The government needs a better system and method of identifying defective product before it is delivered to the end user (soldiers, sailors, airmen, and marines) and suppliers need to be more proactive in identifying defective product prior to shipping it to the DoD.

Inside the DoD, the Defense Contract Management Agency (DCMA) is responsible for executing contract management responsibilities for more than 20,000 contractors, more than 345,000 contracts, and more than $223 billion in unliquidated government obligations (DCMA, 2015). The government must find a way to reduce, significantly, the amount of overhead and oversight required to manage these contractors and contracts, while continuously improving the quality and delivery schedules to the warfighters. Reducing costs does not mean reduction in quality or loss of schedule. Rather it means managing resources better and placing emphasis on contractors that underperform, miss deadlines, or overshoot the program costs.

Need for the Study

The DoD has long struggled with the balance of cost, schedule, and quality when dealing with contractors. This has become more complex in recent years, when contractors subcontract out to other contractors for work they are under contract to perform. In order to reduce costs and focus their limited resources on problem areas, the DoD needs to be able to identify problem contractors and/or contracts that continually or sporadically underperform and apply the appropriate level of resources to improve the contract/contractor performance. Through sound analysis of trends and performance on contracts, the DoD should be able to focus these limited resources on contracts and contractors that are problem areas and provide minimal oversight on contracts and contractors that are considered high performers.

Currently, there is not a single, definitive method of determining the costs, schedule, and quality overruns on contracts. Nor is there a method of determining how those things impact the warfighters that rely on the supplies and services, that are not being delivered to them when they are needed most. Each organization is responsible for tracking earned value on their contracts and adjusting schedule, cost, and quality based on the needs of the organization.

According to David Christensen (2015), cost and schedule overruns are reported on cost management reports. The contractor and/or government usually prepare the management reports. According to Christensen (2015) are "excessively optimistic throughout the lives of the contracts examined." These cost management reports fail to take into account the quality issues, quantity reductions, reduced capability, or escapes that can significantly influence the cost and schedule for DoD programs.

This sense of "excessively optimistic" was presented previously when the F-35 and Ford Class Carrier reports were presented. The Ford Class Carrier program, according to the GAO (2015b), was rebaselined and used "optimistic assumptions of construction efficiencies and cost savings." The F-35 program, according to the first GAO report in 2001 (GAO, 2015a), began as a $34.4 billion program, that would take 10 years to develop at a cost of $69 million per aircraft.

In the 2014 report, the GAO placed the cost at $55.2 billion, 18 years to develop at a cost of $135 million per aircraft (GAO, 2015b). The GAO states in the conclusion of their report "…DOD plans to steeply increase its procurement funding requests over the next 5 years and projects that it will need between $14 and $15 billion annually for nearly a decade…"(GAO, 2015a). This means the funding needed would be $140 to $150 billion over the next decade, nearly three times the $55.2 billion currently reported.

For quality related issues the DoD relies on many different inputs, at various stages of the program, from different organizations, to address quality. These inputs collectively could provide the DoD with a significant amount of data to analyze and provide informed decisions when determining how to award and administer contracts. These data sources are owned by various organizations, and no one individual organization is tasked with managing or sharing these data sources. For instance, the Defense Contract Management Agency (DCMA) manages Corrective

Action Request (CAR) data, the Navy manages Material Inspection Report (MIR) data, the individual organizations within the DoD manage Product Quality Deficiency Report (PQDR) data, etc. (PDREP, 2016).

This research is needed in order to reduce the number of defective products reaching the end user. The high number of defects reaching the end user increases costs, causes time delays, and can result in serious damage to products or loss of life. Improving the current system is needed to protect all DoD assets.

Statement of the Problem

Currently, the DoD does not have a comprehensive method or model to use in determining the level of risk, performance of contractors, nor the amount of oversight that will be required when administering contracts on behalf of the government. Each individual program office is responsible for determining how they want to procure products based on the Federal Acquisition Regulation (FAR) requirements. More importantly, much of the information that is available is stove piped, not only within a specific branch within the DoD but within specific programs within those branches.

Additionally, contractor past performance is one of the factors to consider when awarding contracts (Manuel, 2015). When a contractor is problematic on multiple programs or on very large programs, that information is not being shared at the appropriate levels to make better contract decisions. According to Kate Manuel (2015), the Contractor Performance Assessment Reporting System (CPARS) contains some information that is transmitted to the Past Performance Information Retrieval System (PPIRS) but that information is limited and can only be viewed by authorized government personnel or the contractor that it pertains. This makes identifying poor performance difficult. Kate Manuel also adds that while this information is to be kept there is no requirement in the FAR for program offices to use this information in source selection.

There is a significant amount of research showing the benefits that private industry organizations can reap from having a registered or accredited quality management system (QMS). One need only use an Internet based search engine and type in “benefits of ISO accreditation”. I used Google.com to try this and received 536,000 results in 0.48 seconds.

Mark Hammar (n.d.) identifies six benefits of implementing an ISO 9001 accredited system within your organization. Most revolve around improving the organization, and only one identifies the customer (customer satisfaction). This requires the organization to be actively engaged with the customer to determine needs.

In their study on the effects of ISO 9000 on profitability, Heras, Casadesus, and Ochoa (n.d.) identified that ISO certification increased average economic profitability for certified versus non-certified organizations. Psomas also identifies other studies that, depending on the motive, showed increase in profitability or show that quality programs are not effective.

Because the federal government cannot endorse one QMS over another, they can only require the contractor comply with higher-level quality standards (ISO9001, AS9100, etc.) per the FAR 52.246-11 Higher-Level Contract Quality Requirement (DEC 2014). Certification cannot be required of a contractor to any particular standard.

There is extensive research on the benefits of organizations implementing a certified QMS and the benefits or drawbacks to doing so. There is very little research on how certifications can translate into cost, schedule, and quality benefits to organizations receiving the products manufactured under an accredited QMS, when the organization is the DoD or another federal agency. There is even less information when those customers operate outside of private industry, such as federal governments, public institutions, and other nonprofit organizations. The federal, nonprofit, and public institutions typically do not produce goods and their services are generally guided by laws or policies that are restrictive and difficult to change. This is especially true when dealing with DoD transactions.

Purpose of the Study

This research investigated the relationship between products produced by organizations that are not accredited to a QMS, products produced by organizations with one accredited QMS, and products produced by organizations with more than one accredited QMS, using the MIR data supplied by the PDREP program. Using statistical analysis to determine the relationship between the QMS variable, lot acceptance/rejection, and organization size, this research will fill gaps between previous research and current information.

The primary focus was to determine if there is a significant relationship between the means of the following variables:

- Size
- MIR
- Accreditations
- Units Rejected

Utilizing the Production Data Reporting and Evaluation Program (PDREP) data sets covering 2012 through 2016, this research used these datasets to determine the relationship between the QMS variable (Accreditation), lot acceptance/rejection variable MIR, Units Rejected and Size. The results of this study can provide DoD officials and PCOs guidance in the contracting process to administer higher-level quality requirements (Federal Acquisition Regulation 52.246-11) in contracts or identifying areas of high/low risk. Additionally, the analysis could be used to determine when government oversight is necessary and when direct shipments would be more beneficial. This could lead to significant cost and schedule savings, as well as substantial improvements in the reduction of MIRs issued.

Research Questions

1. Does the size of an organization affect the quantity of units rejected or MIR acceptance?
2. Does the number of accreditations an organization obtains affect the quantity of units rejected or MIR acceptance?
3. Is there a relationship between accreditations and organization size that affects the MIR acceptance?
4. Is there a relationship between accreditations and organization size that affects the quantity of units rejected?
5. Can a model be developed from the analysis that aid in contract decisions?
6. Can a model be developed from the analysis that will aid in risk assessment and risk management within the DoD?

Hypotheses

Hypotheses 1 – 4 were developed to answer questions Research Questions 1 and 2. Hypotheses 5 and 6 were developed to answer Research Questions 3 and 4. Research Questions 5 and 6 were answered from the analysis of the data and hypotheses 1-6.

Ho_1: There is no statistically significant difference between the mean for the variables Size and MIR.

Ha_1: There is a statistically significant difference between the mean for the variables Size and MIR.

Ho_2: There is no statistically significant difference between the mean for the variables Size and Units Rejected.

Ha_2: There is statistically significant difference between the mean for the variables Size and Units Rejected.

Ho_3: There is no statistically significant difference between the mean for the variables Accreditation and MIR.

Ha_3: There is a statistically significant difference between the mean for the variables Accreditation and MIR.

Ho_4: There is no statistically significant difference between the mean for the variables Accreditation and Units Rejected.

Ha_4: There is a statistically significant difference between the mean for the variables Accreditation and Units Rejected.

$Ho_{5:}$ There is no statistically significant difference between the mean for the variables Size, Accreditation and MIR.

Ha_5: There is a statistically significant difference between the mean for the variables Size, Accreditation and MIR.

$Ho_{6:}$ There is no statistically significant difference between the mean for the variables Size, Accreditation and Units Rejected.

Ha_6: There is a statistically significant difference between the mean for the variables Size, Accreditation and Units Rejected.

Definitions

For the purpose of this study, the following definitions apply.

1. *Acquisition Category (ACAT).* Categories of defense programs established to decentralize the decision-making process, execution of the program, and compliance with statutory requirements (DAU, 2016).
2. *Ships Critical Safety Item (CSI)*. Per Defense Federal Acquisition Regulation Supplement (DFARS), a ship critical safety item is "any ship part, assembly, or support equipment containing a characteristic the failure, malfunction, or absence of which could cause a catastrophic or critical failure resulting loss or serious damage to the ship or an unacceptable risk of personal injury or loss of life" (Office of the Undersecretary of Defense for Acquisition, Technology and Logistics, 2016).
3. *Defense Contract Management Agency (DCMA).* The component of the DoD that helps to ensure supplies and services procured by the DoD, Federal Government, and allied governments meet all contractual and technical requirements (DCMA, 2016).
4. *Defense Logistics Agency (DLA).* The component of the DoD providing worldwide logistics support for military services, civilian agencies, and foreign countries during peacetime and during conflicts (Defense Logistics Agency, 2016).
5. *Federal Acquisition Regulation (FAR) 52.246-11. Higher-Level Contract Quality Requirement.* This regulation prescribes the inclusion of higher-level quality standards in contracts when the items being procured are critical and complex or when the technical requirements require control of design, work operations, in-process control, testing, and inspection. In addition to those, attention to organization, planning, work instructions, documentation control, and advanced metrology are also included (.

6. *Material Inspection Record (MIR)*. An inspection record, used by Navy activities alone or in conjunction with DCMA, for recording non-conformances with contract or specifications (NAVSEA, 2016b).
7. *Naval Sea Systems Command (NAVSEA)*. According to the NAVSEA website, the NAVSEA is the largest of the Navy's five system commands with a budget of nearly $30 billion (25 percent of the Navy budget). NAVSEA engineers, builds, buys, and maintains the Navy fleet and their combat systems.
8. *Naval Supply Systems Command (NAVSUP)*. According to NAVSUP's website (2016), NAVSUP is the logistics arm of the navy. NAVSUP provides the centralized inventory management of the non-nuclear ordinance for the NAVY.
9. *Product Data Reporting & Evaluation Program (PDREP)*. "The single authorized Department of the Navy database used to record, collect, retrieve and analyze contractor performance data" (NAVSEA, 2016b).
10. *Product Data Reporting & Evaluation Program-Automated Information System. (PDREP-AIS*). The authoritative source, for the Department of the Navy, for all Navy Ships Critical Safety Items (CSI) and Counterfeit Material Reporting. Additional there are multiple record types that are supported, stored, and easily retrieved through PDREP-AIS (NAVSEA, 2016b).
11. *Product Quality Deficiency Report (PQDR)*. A DoD process used to identify, report, and resolve conditions impacting the war fighter (NAVSEA, 2016b). Allows originating activities a means for cost reimbursement, product replacement, and/or a method for contractual remedies for quality non-conformances resulting from workmanship,

specification, drawing, standard, process, or other technical deficiencies (NAVSEA, 2016b).

12. *Program Acquisition Unit Cost (PAUC)*. "The total cost of development, procurement, and construction divided by the number of units procured" (Schwartz & O'Connor, 2011).
13. *Procurement Unit Cost (PUC)*. "The total procurement cost divided by the number of units to be procured" (Schwartz & O'Connor, 2011).
14. *Quality Management System (QMS)*. "A formalized system that documents processes, procedures, and responsibilities for achieving quality policies and objectives" (ASQ, n.d.a).
15. *The RAND Corporation (RAND)*. A nonprofit research organization. RAND provides objective analysis and solutions for public and private sectors all over the world (Arena, et al., (2006).
16. *Systems Commands (SYSCOM)*. The major components of the Department of the Navy designed to provide full-lifecycle support to the various naval programs and weapons platforms. There are seven SYSCOMS: Naval Air Systems Command (NAVAIR), Naval Sea Systems Command (NAVSEA), Space and Naval Warfare Systems Command (SPAWAR), Naval Facilities Engineering Command (NAVFAC), Naval Supply Systems Command (NAVSUP), Office of Naval Research (ONR) and Marine Corps Systems Command (MCSC).

Limitations of the Study

The study was limited to the information available for MIRs in the PDREP METRIC DASHBOARD Q1FY15 – Q2FY16 data sets. These data sets are limited to organizations that conduct business with the United States Navy. Findings may not be generalizable to other DoD organizations or the six other types of discrepancy reports the PDREP system contains.

Summary

The United States Department of Defense spends billions each year for products and services that aid our warfighters, civilian workforce, and allies to defend our ideals throughout the world. Any advantage that could be gained, to give the procuring activities better buying power, should be investigated. The research contained in this dissertation investigated one aspect of the PDREP reporting system, the Material Inspection Record, and identified variables that impact the accept/reject of units delivered to the Department of the Navy.

The dissertation is organized into five chapters as follows:

- Chapter 1 – Introduction: background, need for the study, statement of the problem, purpose of the research, research questions, hypotheses, definitions and limitations of the research.
- Chapter 2 – Review of Literature: review of literature relevant to problems in industry and within the DoD relating to cost, schedule, and quality. Industry was included due to the limited availability of articles and research related to quality, cost, and schedule within the DoD.
- Chapter 3 – Methodology: description of the data, comparisons to be made, data analysis, and summary.

- Chapter 4 – Results and Findings – results of analysis of the data, ANOVA, and answering research questions.
- Chapter 5 – Summary, Conclusions, and Recommendations – summary of previous chapters, conclusion, discussion, recommendations for the DoD and potential areas for future research.

CHAPTER 2

REVIEW OF LITERATURE

The purpose of the literature review was to assess the availability of studies and report related to cost, schedule, and quality in government contracts. The first section addressed the current state of literature and studies relating to costs associated with government contracts. The second section addressed the current literature and studies related to schedules associated with government contracts. The third section reviewed current literature and studies related to quality associated with government contracts.

Cost

Regardless of opinions of government spending, cost is a significant factor when trying to determine which contracts are awarded and which contracts the government chooses not to accept. As part of this process, the government has begun a shift away from the lowest bidder to the best value on many of their contracts. There are few studies and articles outlining the cost overruns on government contracts.

According to Bob Lohfeld (2012), the lowest price strategy is not appropriate for complex services or uncertain performance risk. This would also be applicable to complex supplies/goods procured on government contract. Lohfeld goes on to identify a method known as lowest price, technically acceptable (LPTA). Under this method, the government can look at factors in addition to price (technical, management, past performance, capabilities, etc.) to determine the best value to the government. This approach is not without merit; however, much of the information that is needed to make a sound decision on the LPTA offer is not readily available to the government contracting officer responsible for making the decision on the contracts. Another important point made by Lohfeld is the lowest price, after all other factors are figured in, can lead to more risk to the government and poor performance by the contractor selected. This results in higher costs to the government and reduced availability to the warfighters and government agencies procuring the supplies and services.

John Pritchard and John Krieger provide a substantial amount of information as to the problems associated with cost in their 2011 article *Something for Nothing*. In this article, Pritchard and Krieger place a significant amount of importance on cash flow and progress payments towards contractors who deal in government contracts. While this approach seems feasible from a contracts perspective, from a quality management perspective it drives the contractor to submit items on time. However these items are not completed, per the contract, or they have intentionally cut corners to meet the deadline for the progress payment. Pritchard and Krieger go on to reference the 2013 annual reports for the top three defense contractors and the information contained in those reports. The contractors, per Pritchard and Krieger (2011), reference the term cash flow(s) 225 times in three reports. This shows the amount of emphasis placed on revenue and costs, and how little emphasis is placed on quality of products being delivered. While the method they use seems straight forward and simple to understand, Pritchard and Krieger fail to account for contractors, especially the large defense contractors, challenging the withhold of progress payments or cancellation of contracts where they do not meet the schedule or quality requirements.

Pritchard and Krieger (2011) goes on to identify the “superior contractor incentive program” as a means of improving performance. However, what they fail to identify is that there are approximately 30 to 50 contractors, in any given year, on this program out of thousands of government contractors/contractors. If you took this approach with the contractors/contractors that deal with DCMA (approximately 20,000), this would account for approximately 0.25 percent of contractors/contractors. Clearly not a feasible program or method to improve cost, schedule, or quality. The approach would, in theory, help drive down the costs with these 30-50 contractors/contractors. What would be the approach for the other thousands of contractors/contractors that do business with the government on a daily basis?

The Project on Government Oversight (POGO) (n.d.) identified the top 10 contractors, by total FY14 contracts awarded, instances of misconduct (since 1995), and total penalty amounts levied against each (since 1995). Several of the contractors listed under the “superior contractor incentive program” were listed. From this listing, the top 10 contactors received more than $117 billion in contract awards in FY14 (Project on Government Oversight, n.d.). These top 10 have accounted for 312 instances of misconduct and more than $7.28 billion in penalties since 1995. has identified the I believe cost and quality, in government contract administration services, can be managed equally to provide the best possible quality to the warfighters without having to sacrifice schedule or cost to achieve. This project just identifies instances of misconduct and not projects that have cost overruns. For my research, I will be looking at the organizations from the cost, schedule, and quality aspects to see if there is a significant relationship between the variables and these three things.

According to Steven Meir (2010), the Government Accountability Office (GAO) found cost growth on the 95 weapon systems reviewed was $295 billion and the average delay in schedule was 21 months. Meir also indicated this was a 702 percent cost growth increase over the 2000 data the GAO reported. His article does a phenomenal job capturing the cost overruns and scheduling problems but does little to provide a solution that will allow contracting officers and program managers do a better job and be better stewards of taxpayer dollars. Instead, Meir looks at the existing system and exposes some of the shortcomings. This study like others does not offer a comprehensive approach to driving down costs nor does it offer any regulatory changes that would impact the acquisition system and costs associated with government contracts. Meir was the first study/research the study I came across that attempted to put actual cost overruns in perspective as far as dollars and percentages. Much of this cost overrun is charged back to the government and can seriously impact the readiness, operation and maintenance costs (O&M), and can ultimately lead to the cancellation of the program or other programs to sustain the overrun programs. In Figure 1 below, the Government Accountability Office (GAO) indicates the cost growth for major programs with requirements changes is seventy-two percent, while programs without requirements changes only see an increase of eleven percent. This is significant because requirements changes can be a direct result of poor quality, schedule delays, or poor design. Controlling the quality up front, rather than after the design or at the end of the production leads to reduced costs and improved schedule.

In the most recent study from the GAO (2016), there were thirty-seven programs with cost decreases and forty-two programs that saw an increase in cost. Shown in Figure 2 (GAO, 2016), is the distribution of the change in total acquisition cost (TAC) for programs in the 2015 portfolio.

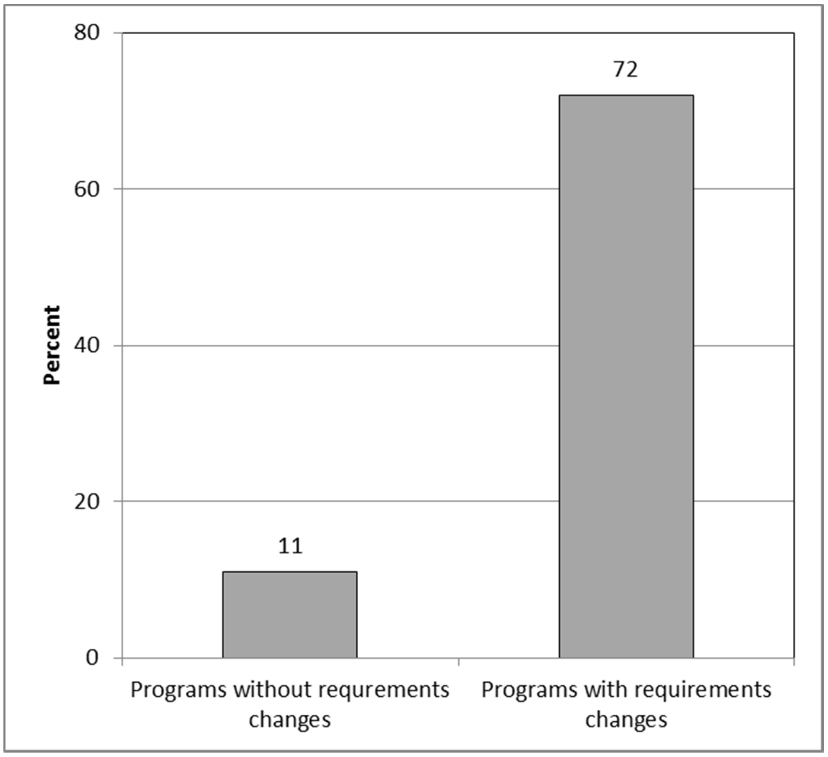

Figure 1. Cost Growth Due to Requirements Changes (GAO-08-674T).

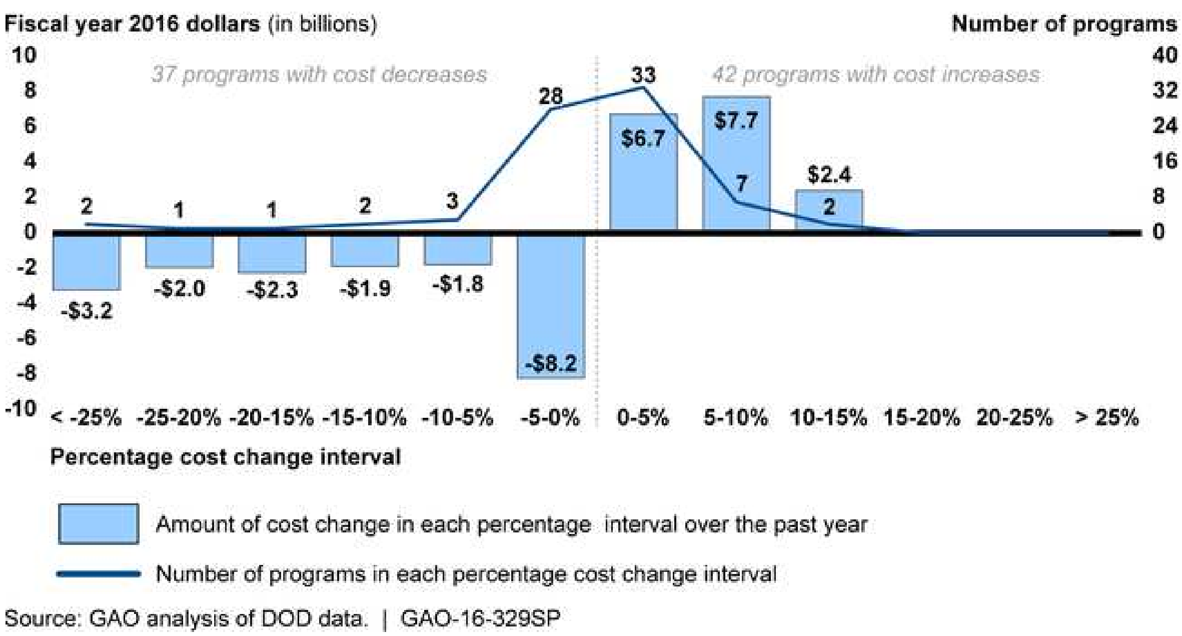

Figure 2. Distribution of the 1-year Change in Total Acquisition Cost within the 2015 Portfolio (GAO-16-329SP).

In their article, Cantwell, P. R., Sarkani, S., & Mazzuchi, T. A. (2013) present information that should be of serious concern to all U.S. citizens. Using the numbers from the 2011 GAO report half of major defense programs are beyond their cost projections. Cantwell et al. (2013) makes a point of indicating the trend of DoD contracts and their overruns is getting worse and not better. Unlike private industry projects, Cantwell et al (2013) makes the allowance that most DoD projects are developmental in nature and many times do not have a basis for comparison or the only comparison is the initial contract awarded, which is usually a developmental contract. One of the major problems pushing contracts down this path is noted in Cantwell's article and explored more in depth by David Sorenson in his 2009 book: *The process and politics of defense acquisition: A reference handbook*.

In the GAO report for the Joint Strike Fighter (JSF) program (2008), the GAO estimated seeing an increase of more than $23 billion due to increased procurement costs. The GAO went on to state the program is facing probable cost overrun, even though the JSF program office was eliminating requirements and removing the alternate engine program. Other activities reported were the reduction of test activities, which increases the risk of problems not being detected until later in the operational testing and production phases. Just as significant in this report is the reporting of the three independent defense offices that concluded the program cost estimates are underrepresented by up to $38 billion. This indicates a growing trend in the DoD of sacrificing quality and requirements to save money when contracts overrun on fixed price contracts. As of this report, two-thirds of the budget for the JSF has been spent, yet only fifty percent of the work has been completed. Another key point made by the GAO report is the JSF, which is replacing the F-16, is expected to be more costly per flight hour and costs are rising with almost 90 percent of the program still ahead.

According to ISO (2012), the Organisation for Economic Co-operation and Development (OECD) and the US Department of Commerce indicate 80 percent of the world trade in commodities is directly related to standards and conformity to those standards. ISO (2012) goes on to state Prof. Junijiro Shintaku indicate standards had a direct impact on the growth of the DVD market from $1 billion to over $19 billion between 1998 and 2004. This information is consistent with other publications in identifying standards as a method for businesses to improve their profits and growth.

The effects of cost on DoD programs are more than just dollars. For every cost saving measure, something in the program must be sacrificed. Typically, the sacrifice is made to the quality or technical requirements (impacting the quality and performance of the final product) of the program with no significant gain in cost savings.

Sandra Erwin (2013) uses her article in the *National Defense* journal to identify the seriousness of the drastic cost overruns many of the Air Force programs are facing and the serious impact those overruns are having on the ability to maintain their level of air superiority. Erwin indicates Air Force Maj. Gen. Wendy Masiello, deputy assistant secretary for contracting, is $12 billion in the red from a budgetary standpoint. This is significant because acquisitions chief Frank Kendall is interested in cutting programs that are unaffordable for the Air Force. Further Erwin goes on to indicate many contractors are against Maj. Gen. Masiello for wanting to know how much money is being made by the contractors, while many of these programs are already well beyond their agreed-upon prices. The contractors on the other hand are interested in not revealing how much profit they are making because the prices were already negotiated at fixed-price rates.

In the ISO publication *What's the bottom line?*, ISO claims benefits of implementing standards can improve annual sales revenues by 0.5 to 4 percent (2012). Another example of profit increase with no mention of quality improvement or schedule impacts that are occurring by organizations that are accredited by ISO and operating in the DoD contracting sector.

In their report to RAND, Arena, Blickstein, Younoussi, and Grammich (2006) provide many reasons for the increase in U.S. Naval ship cost increases over several decades. The shipbuilding industry, in the report, indicated an unstable business base, shrinking vendor base, labor issues, and increased government regulation. Arena, Blickstein, Younoussi, and Grammich (2006) identified, through this report, cost increases from 7 to 11 percent beginning in the 1950s. These cost increases outpaced inflation by almost double, inflation was indicated at 4 to 5 percent for the same period.

Additionally Arena et al. (2006) indicated in Table 1 the increases in cost between ships procured in 1967 and 2005 in FY 2005 dollars. In every scenario, the increase in ships has seen at a minimum a 100 percent increase in price. This would indicate there is an increase of approximately 25 to 100 percent per decade increase in the price of these Navy ships. There is no real evidence to suggest the quality is getting better.

The majority of the research available for cost and pricing for DoD contracts simply identify the amount of cost overrun or overall reasons for cost increases/overruns, from a very high level. Very few researchers attempted to tie the reasons for the cost overruns to quality problems, any correlation between price increases and other factors, or identification of the reasons for the drastic cost increases for individual DoD contracts.

Table 1

Cost Escalation of Naval Ships Arena (Arena et al., 2006)

Ship Class	Cost Escalation of Naval Ships Cost in 1967 (FY 2005 millions $)	Cost in 2005 (FY 2005 millions $)	Cost Increase (%)	Real, Annual Growth Rate (%)
Nuclear attack submarines	$484	$2,427	401	4.3
Guided missile destroyers	$515	$1,148	123	2.1
Amphibious ships	$229	$1,125	391	4.3
Nuclear aircraft carriers	$3,036	$6,065	100	1.8

In his article, Gilmore (2011) identified the Army by itself spent more than $1 billion per year, since 1996, on programs that would eventually be cancelled and never reached completion. If that trend continued through 2016, the Army alone will have spent more than $20 billion on programs that have been cancelled.

From the several articles cited, costs are definitely a concern for the DoD acquisition community and military leadership. Much of the cost overruns are attributed to changing requirements, material delays, labor problems, and small order quantities. Almost none of the cost overruns are directly attributed to the quality of the product being provided. However, changing requirements lead to test failures and unrealistic performance measures, which result in poor quality or repeated test failures. Labor problems lead to higher inspection costs or quality system implementation problems, all of which result in poorer quality good being procured and delivered to the DoD. Finally, the small order quantities limit the availability of testing resources and difficult to implement quality requirements.

Schedule

Unfortunately, schedule is one of the primary drivers for the DoD and contractors have been significantly underperforming. As stated previously, Steven Meir (2010), the Government Accountability Office (GAO) found the average delay in schedule was 21 months.

This data is for Acquisition Category (ACAT) II and III programs. Figure 3, shows 139 of the 170 programs did not have the information available to assess cost performance. This means for 81.76% of ACAT II and III programs, the government cannot determine if the contractors on these contracts are meeting cost requirements of the contract. In addition to the cost problems, 61.76% of these same programs do not have the available information to assess how well they are performing in relation to contract scheduling requirements.

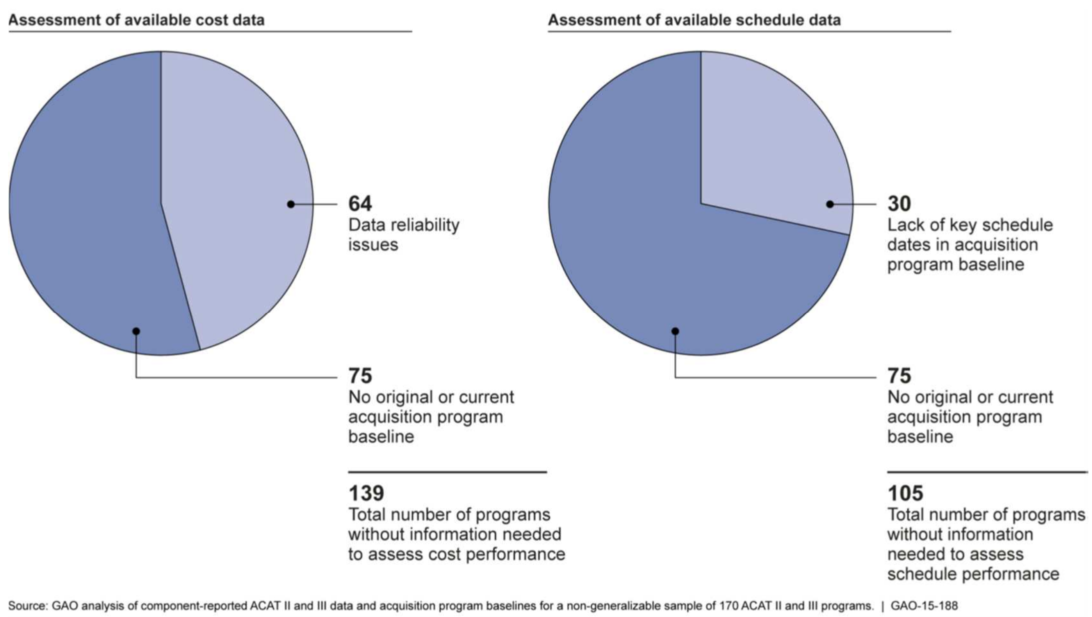

Figure 3. Assessment of Data Available to Measure ACAT II and III Cost and Schedule Performance (sample size of 170 programs) (United States Government Accountability Office 2015).

The problem only worsens for ACAT I programs. According to Clark (2015), of the 29 active ACAT I programs under the Air Force, 112 months of schedule was added in FY14 alone.

Clark goes on to add about half of these programs will miss the next milestone objective by 3 or fewer months and approximately one third will miss it by six months or more. This is in addition to the schedule growth reported between September 2011 and September 2012. Clark (2012) states the 26 active ACAT I programs saw between 190 and 250 months of schedule growth. Also alarming in this number is the fact the government cannot determine if it is 190 or 250 months of growth. This means the growth is somewhere between almost 16 years and almost 21 years for ACAT I programs alone. ACAT I programs averaged seven months of schedule increase over this period.

In 2014, Clark also noted the increase in schedule for ACAT I programs, from September 2012 through September 2013, to be more than 102 months or 8.5 years. Between September 2011 and September 2014, the ACAT I programs in the Air Force saw an increase of between 404 and 464 months of schedule increase or 33 years 8 months to 38 years 8 months. This information does not include data for the other services.

The GAO (2016), states there was an increase of 2.4 months, on average, per program for the 79 major defense acquisition programs. This represents a significant increase when looking at it from a holistic approach. For seventy-nine programs, that is an increase of nearly 190 months or almost 16 years. Does this have to do with contractor/contractor inability to provide products on time or does this have to do with the constantly changing requirements on most government programs?

According to the US Government Publishing Office (2008), the Joint Strike Fighter (JSF) program saw increases in cost approaching $1 trillion and saw schedule slippage between 12 and 27 months (estimated). Much of this had to do with cost increase of more than $23 billion for higher estimated procurement costs. Another example of excessive schedule increase at a significant increase in price. When reviewing the data from the US Government Publishing office and other government sources it is evident, these sources did not make a significant or deliberate attempt to identify issues with quality or products or draw a correlation between these variables.

In much of the information available for government contracting, schedule slippages are treated as a product of doing normal business with contractors. Much of this could be reduced or eliminated through analysis of the problems and identification of the root cause of the problem. The research of the scheduling problems shows between 12 and 464 months of schedule increase on ACAT I programs. This does not take into account the many non-ACAT I programs that are less costly but more prevalent.

The Navy and Air Force are not the only services facing cost, schedule, and quality problems. The Army is facing similar concerns with some of the weapon systems currently under contract or recently awarded. Due to delay in the Army's Future Vertical Lift (FVL), the Army has been put in the position of keeping the current fleet of helicopters operational and viable against current and future threats. Scheduled for production sometime in the 2030s, the FVL will not become a viable option until 2037, when they expect to have a full brigade's worth of this aircraft (Freedberg, 2015b). Even then, the Army will still be fielding thousands of other aircraft, including the CH-47 Chinook helicopter that entered service in Vietnam and is not scheduled to be retired until 2065 (Freedberg, 2015b). This would mean the Chinook helicopter would have been in service for more than a century.

As with the other DoD organizations, legacy programs tend to have fewer schedule delays and more cost problems, due to the lack of availability of replacement parts or contractors willing to take on small orders for highly complex part orders. This leads to downed equipment and/or early retirement of equipment that potentially had decades of useful service life remaining.

It is the newer programs that are facing developmental problems, especially when the talk shifts to requirements. According to Sydney Freedberg (2015a), several of the Army programs were having problems prior to 9/11 and the new programs are seeing success. This is in large part due to the scaled down requirements and the reduced number of major modernization programs.

J. Michael Gilmore, Ph.D. does an exceptional job in his article on defense acquisition delays. In his paper, he cites five categories that cause schedule delays:

1. manufacturing and development (to include quality control, software development, and integration issues,
2. programmatic (scheduling or funding problems),
3. performance in Developmental Testing (DT),
4. performance in Operational Testing (OT), and
5. conducting the test (such as range availability, test instrumentation problems, and text execution problems) (Gilmore, 2011).

In this study (Gilmore, 2011) 67 major programs were reviewed because they experienced significant delays and/or a Nunn McCurdy breach. A Nunn McCurdy breach is a breach that falls into one of the following categories:

- "A significant breach: the Program Acquisition Unit Cost or the Procurement Unit Cost increases by 15% or more over current baseline estimates or 30% or more over the original baseline estimate" (Schwartz & O'Connor, 2011).

- "A critical breach: the Program Acquisition Unit Cost or the Procurement Unit Cost increases by 25% or more over current baseline estimates or 50% or more over the original baseline estimate" (Schwartz & O'Connor, 2011).

Schwartz & O'Connor (2016) identified there have been 37 Nunn-McCurdy breaches since 2007, 24 of them critical and 13 of them significant. This is important because the critical breaches almost double the significant breaches. Another important fact is the review by Gilmore identified 36 of the 67 programs experiencing a breach with six of those programs resulting in cancellation. In Figure 4 Gilmore identifies the breakdown of failures in the five categories. From Figure 4, 56 of the programs had issues in testing and only eight had problems with the actual conducting of the testing causing a delay in the program. The bigger issue here is the 67 programs had a combined 158 instances that caused scheduling delays. According to Gilmore, many of the programs had multiple problems relating to the five categories. Of significance was the eight-test conduct problems versus the 82 performance problems related to the programs (Gilmore, 2011). Gilmore was clear to note that testing results and not the testing were more often the reason for the delays. These delays ranged from no delay to 15 years with 37 of the programs experiencing a delay of more than three years (Gilmore, 2011).

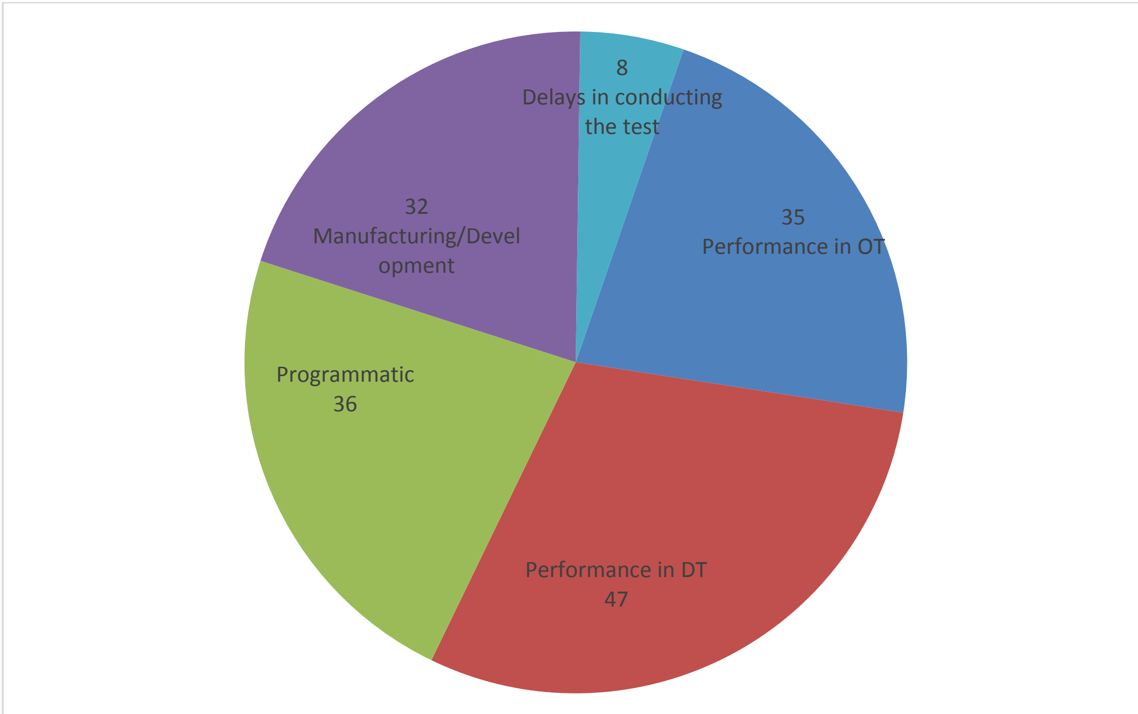

Figure 4. Reasons for Program Delays (Gilmore, 2011).

The downfall of the Nunn-McCurdy act is it does not apply to all elements of a system that is procured. Primarily the operations and support/maintenance costs. These are considered O&M dollars, which accounted for more than $199 billion in DoD spending in FY2015 according to the Office of the Under Secretary of Defense (Comptroller) (2014). In the report titled *Operation and Maintenance Overview: Fiscal Year 2015 Budget Estimates*, the comptroller indicates the growth from the FY2014 budget was nearly $4 billion. Therefore, the failure to account for the information in the paper by Gilmore (2011) is leaving out a significant amount of money that could be directly related to schedule delays or poor quality.

Quality

Quality should be led from the top down. According to Dr. Deming (2000), management committing to the improved quality of a product or service is not enough. Instead, management needs to understand what they are committing to and understand what it is they need to do (Deming, 2000). Unfortunately, in the DoD, most of the top level, decision-making managers have no idea or input into the quality decisions made for the products they are procuring from contractors. Because of this, the DoD relies on DCMA to provide that valuable information and help make those decisions. In FY15, DCMA saved the DOD more than $1.8 billion (Montgomery, 2016). While DCMA is providing cost savings through their contract management services, there is so much more out there that can be done.

According to the Juran Institute (2009), the cost of poor quality can run from < 10 percent of sales (6 sigma) to 30-40 percent of sales (2 sigma). Based on these numbers, a figure between $22 and $89.2 billion is being lost to poor quality for the DoD.

H. James Harrington brought the term cost of poor quality (COPQ) into mainstream in his 1987 book *Poor Quality Costs.* In his article *The Real Cost of Poor Quality* (2002), H. James Harrington identifies a poor-quality cost model. This model divides the poor-quality costs into three categories:

- Controllable poor-quality cost – Includes prevention and appraisal costs. Controlled by management to prevent nonacceptable products or services from reaching the customer (Harrington, 2002).
- Resulting poor-quality cost – Includes all costs resulting from errors incurred by the company (Harrington, 2002).

- Equipment poor-quality cost – Unique and reported separately to management (Harrington, 2002).

Each of these categories drives a different cost, has different factors, and can be lumped together into what Harington describes as "direct poor-quality costs". These are called direct costs because they can be measured directly in the cost structure of the organization (Harrington, 2002).

In their 2006 presentation, *Using the Cost of Poor Quality to Drive Process Improvement*, Dan Olivier and Javad Seyedzadeh define the cost of poor quality as the difference between the actual cost and the cost if the process were effective in manufacturing products. They go on to state the products must meet customer needs and be free of defects. Olivier and Seyedzadeh (2006) provide a quote from Joseph Juran that states "In the US about a third of what we do consists of redoing work previously "done". These are costs not factored into the PQDR data sets; rather they are a large part of the original product cost for the DoD. Further research is necessary to determine how much of the product cost is actually driven by high quantities or scrap, rework, or use as is materials.

Moshe Eben-Chaime (2013) provides sound logic and analysis on the costs of defects, rework, and quality in a manufacturing system. Eben-Chaime states, "Only a fraction of the initially planned production volume can be used as sellable output." These are costs that are associated with the production of the product and not costs post-delivery. Like the information from Oliver and Seyedzadeh, Eben-Chaime's information would greatly benefit research focused on production costs related to initial product costs but not to defective product costs related to post-delivery activities.

Jessica Anderson (2015) presents information in her paper that show costs associated with manufacturer warranty problems. According to Anderson, the median price consumers paid for extended warranties was $1200, however the median savings for repairs was only $840. This means consumers paid $360 more for the extended warranty than was covered for repairs. This affects one in three car buyers and the profit margin for dealership (50% or greater) makes this a lucrative sell for the dealership (Anderson, 2015). Because the DoD does not obtain extended warranties, this is typically not a problem for the proposed research. However, the DoD typically does have a one-year warranty for products after acceptance from the customer, no matter when the product is put into service. This can be problematic when an item is purchased and store in a warehouse for six months or more. There is no way of knowing if the product was bad from the beginning or if the warehouse storage cause the problems.

In his research, Andrew Yim (2014) discusses many topics that are of importance in this paper. One of the more important ideas is latent defects. This ties into the topic of Jessica Anderson's paper on warranties. Because latent defects are not detectable, they would fall outside of the scope of a warranty and would be considered costs absorbed by the manufacturer. The DoD has trouble, many times, proving a defect is latent or could have been detected by normal inspection. This can have catastrophic consequences for the DoD. Because many of the prime contractors are the sole source for products or services, it can be difficult to find another contractor for the product or service.

Yim goes on to point out single source and multiple sourcing for products or services. Industry can struggle with this problem and the DoD is no different. Some contracts are either sole source, something the DoD is attempting to move away from, or there are multiple contractors building to the same design or product specifications. An example of this would be uniforms, headgear, and boots for the different branches of the armed services.

Small batch production is used in many of the big-ticket items for the DoD. The DoD buys aircraft, ships, and tanks in small batches because of the limited need and cost associated with those items. Schmidt, Weiderhold, Damn, et al (2014) present a risk evaluation of the failure to evaluate the probability of making a false measurement decision. Unfortunately, they do not evaluate the risk to the consumer or customer and only evaluate the risk in the process to determine if it will affect the process capability. This research would also be beneficial for initial production cost research but does not provide much for post-delivery research related to organizations who have a certified/accredited QMS.

Andrei Paraschivescu (2014) presents the idea of "zero defects" to show the shift in philosophy from a six sigma approach to one where no defects are acceptable. This concept is derived from Crosby's notion that everything must be done well the first time and every time after. According to Paraschivescu, Juran held defects are mainly caused by poor management; operators are only responsible for a small percentage of defects. Zero defects was attainable. Paraschivescu provides some valuable insight into the zero defects concept but does not expand on his topic; rather he only gives the theory behind the information. Like the other research previously included, Paraschivescu does not tie it to a particular industry, sector, or organization. While many of the concepts used in the research reviewed are applicable to government to commercial entity relationships, there are unique aspects that are not covered.

In the ISO publication *What's the bottom line?*, ISO indicates several companies operating outside the United States are seeing significant cost savings and improved earnings through the implementation of standards. How can this implementation be used to reduce cost overruns on government contracts and at the same time maintain the quality level of the products being produced? If these companies can implement standards and see savings, why do DoD contractors continue to see significant increases in costs and schedule delays in the government sectors and a reduction in performance and degradation in product quality, while commercial arms of the businesses are seeing drastic improvements in efficiency and significant cost savings? Is there some variable that is missing that makes commercial standards non-compatible with government contracting in the United States?

From the data sets used in this research, 556,578 out of 6,505,113 units were rejected for small organizations or 8.56 percent, accounting for $22,239,499. For medium organizations, 36,467 out of 1,488,263 units or 2.45 percent were rejected. The cost of the rejected units was $5,183,947. The costs for large organizations was $17,117,517 for 97,469 units rejected out of 3,470,548 or 2.81 percent. This was a preliminary assessment of the main three organization sizes over the five year period of this study. These numbers represent returns only for the NAVSEA and NAVSUP programs.

Overall, Arena et al. (2006) indicated there were several factors that led to escalating cost increases in Navy ship production but none of the reported causes were linked to poor quality, defects, or delays due to rework or redesign.

The closest the RAND (2006) report came to indicating there may be an issue with quality was the indication by the shipbuilders that there was a lack of skilled workers and the Navy should build to commercial standards rather than military standards. The issue with a lack of skilled workers will lead to quality issues, schedule delays, and increases in the quantity of product requiring rework and/or scrap.

The building of ships to commercial standards versus military standards is another way of saying build a lower quality vessel for the same price. The military has specific requirements based on specialized needs; quality plays an important role in ensuring the warfighters have the best available technology and that the technology functions in the manner designed.

All of the articles, reports, books, and other media reviewed had one common theme. Cost and schedule are the most important aspects of government contracts. Sacrifices to quality were necessary to achieve cost and schedule demands. However, many failed to take into account the relief to cost and schedule, also included relief from performance and quality requirements for these programs. These sources do a definitive job indicating cost and schedule delays, increases, or other issues. Most do not attempt to delve into the quality and product issues that are arising from the cost and schedule cutting measures nor do they attempt to quantify the impact the quality and product issues are having on the increase in schedule delays and constant growth in many of the program budgets.

Summary

Much of the literature available for review focuses on the problems associated with commercial manufacturing and the relationship between contractor and consumer. There is a limited amount of research and published information on the relationship between contractors and the government. In addition to this, government focus on monitoring the contractors and not taking an active role in the manufacturing process has limited the amount of information available for product defects and higher costs manufacturing costs. Because this process is very different from the commercial process and information is limited to what the government is willing to share, it is not surprising the research is limited.

Another area of consideration could be the quantity of MIRs and PQDRs issued and/or closed in the 2012 to 2016Q2 period. In Table 2, the number of PQDRs closed by service is shown for the 2012 – 2016Q2 FY periods. In the table, it is evident the number of PQDR that are being closed out is growing due to the significant increases in closeouts by the Navy and Marines. Overall, the Army and Navy accounted for more than 66 percent of all PQDR closeouts from FY12 – FY15.

Table 2

Closed PQDRs for All Services FY12 – FY15 (NAVSEA, 2016b)

	Record Count by Service			
Service	FY12	FY13	FY14	FY15
AIRFORCE	4,969	3,533	3,296	3,015
ARMY	6,729	11,749	7,843	7,055
DCMA	61	184	192	256
DLA	527	1,310	1,158	973
MARINES	356	3,634	4,237	3,805
NAVY	3,701	8,276	8,672	8,439
Total	16,343	28,686	25,398	23,543

The number of PQDRs open in the system tells a completely different story. In Table 3, you can see the number of PQDR transactions over the same period. The Army and Navy account for more than 70 percent of the PQDR transactions. The most glaring statistic over this period is the number of PQDRs closed out related to the number of transactions. During FY12 – FY15 only 4.6 percent (93,970 of 2,042,103) of the PQDR transactions were closed for all services. Due to the lack of data for PQDRs they were not used in the data for this research, however, if the data becomes available in the future it could help to build a more robust model.

Table 3

PQDR Transactions for All Services FY12 – FY15 (NAVSEA, 2016b)

	Record Count by Service			
Service	FY12	FY13	FY14	FY15
AIRFORCE	68,735	76,611	72,058	59,016
ARMY	164,356	186,394	316,208	206,676
DCMA	7,282	8,052	11,025	8,151
DLA	15,854	20,342	14,287	13,668
MARINES	30,076	81,516	79,554	39,944
NAVY	121,530	171,577	138,012	131,179
Total	407,833	544,492	631,144	458,634

The primary purpose for this research is to determine if number of accreditations and/or organization size affect the acceptance/rejection of product by the Navy, using MIR data. Secondary purpose is to open up research interest in government contracting; increasing the quality of products and services received by the government from commercial contractors, and make better use of limited government resources.

If the data becomes available in the future, use of the data could be used to develop a more comprehensive model. In addition to the MIR data, the PDREP system identifies six more reports that can be used, by various organizations and personnel, to input discrepancies or deficiencies into the system. The additional reports contain more than 2.75 million transactions. If these additional data sets could be used in the development of a model, these additional data points could significantly affect the ability to identify problem contractors or contractors without problems. The potential to redirect limited resources to these problem contractors would offer the DoD the ability manage their processes and personnel more efficiently.

CHAPTER 3

METHODOLOGY

The purpose of this study was to use the existing data sets, available through the Product Data Reporting & Evaluation Program (PDREP) system, to determine if there was a relationship between the size of contractor organizations, number of rejected Material Inspection Records (MIRs), and number of quality management accreditations (primarily ISO 9001 and AS9100). The research was used to identify methods and trends that can be used to assist in analyzing the risk manufacturers represent to the overall acquisition strategy for the DoD and improve the allocation of resources expended in contract administration services for exceptional and poor performing contractors. Presently the data is used to track how many MIRs were issued, whether the MIRs were accepted or rejected, the quantity of product, the cost, and to which contractor they were issued. The research answered the following hypotheses:

Ho_1: There is no statistically significant difference between the mean for the variables Size and MIR.

Ha_1: There is a statistically significant difference between the mean for the variables Size and MIR.

Ho_2: There is no statistically significant difference between the mean for the variables Size and Units Rejected.

Ha_2: There is statistically significant difference between the mean for the variables Size and Units Rejected.

Ho_3: There is no statistically significant difference between the mean for the variables Accreditation and MIR.

Ha_3: There is a statistically significant difference between the mean for the variables Accreditation and MIR.

Ho_4: There is no statistically significant difference between the mean for the variables Accreditation and Units Rejected.

Ha_4: There is a statistically significant difference between the mean for the variables Accreditation and Units Rejected.

Ho_5: There is no statistically significant difference between the mean for the variables Size, Accreditation and MIR.

Ha_5: There is a statistically significant difference between the mean for the variables Size, Accreditation and MIR.

Ho_6: There is no statistically significant difference between the mean for the variables Size, Accreditation and Units Rejected.

Ha_6: There is a statistically significant difference between the mean for the variables Size, Accreditation and Units Rejected.

The assumption was made that the data contained in these data sets is accurate and complete. An additional assumption was made that any organization that has an accreditation followed the accreditation requirements in the manufacturing of the products. Any information not contained in these data sets was not considered outside of the independent variables Size and Accreditation.

Population/Specimen

This study focused on the MIR data retrieved from the Department of the Navy PDREP site through the PDREP Metrics section. The information in the data sets contained data for the period FY2012 – FY 2016 Q2 and includes the company name, dollar value received, dollar value rejected, lot size, serial number, reject indicator, units received, units rejected, inspection date, SYSCOM code, SYSCOM, year, and fiscal year.

The dollar value received column is the dollar value of the items contained in the lot. The total of this column indicates all of the items received by both the NAVSEA and NAVSUP commands, reported on the MIR, for the time period covered. The dollar value rejected column is the value of the items found to be nonconforming and reported on the MIR in the lots for the time period covered. The total of this column indicates all of the items received by both the NAVSEA and NAVSUP commands, reported on the MIR, for the time period covered.

The lot size is the number of items in the lot. The serial number is the identification number for the shipment/lot. The reject indicator column indicates if a lot was rejected or not. Units Received column should align with the Lot Size column. There were lines that indicated discrepancies between the Lot Size and Units Received columns. These items were segregated from the data set when the information could not be verified or corrected, using the other information from the row to validate.

The PDREP-AIS is responsible for maintaining the integrity of the data and treats this as paramount to handling transactions to main data integrity (NAVSEA, 2016). The focus of this research was on the MIR data, which was reported for the SYSCOMS NAVSEA, NAVSUP, and Other Navy. Other Navy consisted of all SYSCOMs outside of NAVSEA and NAVSUP. The data sets consist of more than 8,000 records for the FY12 through FY16 years. The following data sets will be used in this research:

- PDREP METRIC DASHBOARD Q1FY15 – Consisting of FY12 through Q1 FY15
- PDREP METRIC DASHBOARD Q2FY15 – Consisting of FY12 through Q2 FY15
- PDREP METRIC DASHBOARD Q3FY15 – Consisting of FY12 through Q3 FY15
- PDREP METRIC DASHBOARD Q4FY15 – Consisting of FY13 through Q4 FY15
- PDREP METRIC DASHBOARD Q1FY16 – Consisting of Q2 FY13 through Q1 FY16
- PDREP METRIC DASHBOARD Q2FY16 – Consisting of Q3 FY13 through Q2 FY16

The information contained in the data sets led to the determination of the variables in Table 4.The two independent variables are Size and Accreditation. The dependent variables are Units Received, Units Rejected, and Dollar Value Rejected.

Table 4
Variables

Variable	Units	Precision	Range		Type
Size	None	N/A	S, M, L, U	Categorical	IV
Size Quantitative	None	1	U=0, S=1, M=2, L=3	Categorical	IV
Accreditation	None	1	0, 1, 2	Categorical	IV
Lot Size	Units	1	1 - 650,000	Quantitative	IV
Lot Category	None	1	0, 1, 2	Categorical	IV
MIR	None	N/A	Y, N	Categorical	DV
Reject Quantitative	None	1	0=N, 1=Y	Categorical	DV
Units Rejected	Units	1	0 – 101,400	Quantitative	DV
Dollar Value Rejected	$USD	0.01	0 - $2,078,059.00	Quantitative	DV

After the variables were identified and their type determined, the additional information contained in Table 4 was input. The next step was to collect the data, to include information that was not contained in the original data set.

For the independent variable Size, an Internet search was used to identify the size of the companies. The Internet search consisted of using the organizations website, the database search at GSAschedule.com, govtribe.com, manta.com, linkedin.com, buzzfile.com, thomasnet.com, sba.gov, and insidegov.com. Size of companies were divided into four categories:

- S – Companies with less than 100 employees.
- M – Companies with 100 but less than 1000 employees.
- L – Companies with 1000 or more employees.
- U – Companies where the size could not be determined.

The Accreditation independent variable also used an Internet search to identify the number of accreditations for each company. The Independent Association of Accredited Registrars (IAAR), the International Aerospace Quality Group (IAQG), thomasnet.com, linkedin.com, and organization websites were used to search for QMS registrations for the organizations identified in the PDREP data sets. Accreditation for the organizations was divided into three categories:

- 0 – No certifications could be found for this organization (through all sources).
- 1 – One certification could be found for this organization (through all sources).
- 2 – More than one certification could be found for this organization (through all sources).

More in depth analysis was needed due to the large span of units delivered in each lot. To combat a lot of 650,000 unduly influencing the outcome, after the initial analysis, the lot size was separated into groups and another analysis was performed to determine if there is significance when lot sizes are grouped. The lot size was grouped as follows:

- Lot size 1 – 10 units.
- Lot size 11 – 100 units.
- Lot size 101 – 1000 units.
- Lot size greater than 1000 units.

The certifications that were considered for the Accreditation variable were:

- ISO 9001 – The international QMS standard (ASQ, n.d.b).
- AS9100 – QMS requirements for Aviation, Space and Defense Organizations (International Aerospace Quality Group (IAQG), n.d.).
- ISO/IEC 17025 – QMS requirements for testing and calibration laboratories (International Organization for Standardization, n.d.c).
- TS 16949 – QMS requirements for automotive production and relevant service part organizations (International Organization for Standardization, n.d.d).
- AS 9003A – QMS requirements for contractor Inspection and Test Quality System for Aviation, Space and Defense Organizations (SAE International, n.d.a).
- ISO 13485 – QMS requirements for medical devices (International Organization for Standardization, n.d.b).
- TAC 2000 – QMS requirements for civil aircraft parts distributors (Transonic Aviation, n.d.).
- ISO 10012 – Measurement management system requirements (International Organization for Standardization, n.d.a).

- AS 9120 – QMS requirements for stocklist distributors for the aerospace industry (SAE International, n.d.b).
- TL 9000 – The QMS standard developed for supply chain and operational quality requirements for the global information and communication technologies (ICT) industry (QuEST, n.d.).

The independent variable, Units Received, was a direct pull from the PDREP data sets. Units Received consisted of direct shipments from contractors to one of the three Navy SYSCOMs. Where the number of Units Received could not be validated as more than 0, the shipment was marked as a zero quantity. Some rows indicated Units Received as 0 and Lot Size as another quantity. These shipments were updated to show Lot Size and Units Received being equal. Lot Size and Units Received are quantitative and represents values from 0 to 650,000.

Additionally, the independent variable Lot Category was created to group Lot Size into distinctive categories. This allowed further analysis to see if Lot Size had an impact on the MIR or Units Rejected.

MIR, a dependent variable, is categorical and dependent upon Size and Accreditation variables. When a MIR was issued, the MIR could be either Y or N (using the information in the Reject Indicator column). Y indicated the lot was rejected and N indicated the lot was accepted.

The dependent variable, Units Rejected, was a direct pull from the data set. The variable indicated the number of units rejected for each lot received. The value in this column had to be less than or equal to the Units Received column in the data set. If the data is more than the Units Received column, the Units Rejected column was adjusted to be equal to the Units Received value. Units Received is quantitative and represented values from 0 to 101,400 units.

It is important to note data, where the Units Received equaled zero, was omitted. This is due to the inability to determine the quantity of items received.

Statistical Analysis

Data was analyzed using a two-way ANOVA (General Linear Model (GLM)) and a one-way ANOVA. A two-way ANOVA (GLM) was selected to test for significance across the main effects for Size and Accreditation, and the ability to test for significance in the interaction between these two. A one-way ANOVA was used to test for significance between the first four relationships, which were a comparison of independent and dependent variables. The MiniTab 18 program was used for the statistical analysis.

The following process delineates the steps that were taken during the statistical analysis of the data set. The following relationships were examined:

- Size and MIRs rejected
- Size and Units Rejected
- Accreditation and MIRs rejected
- Accreditation and Units Rejected
- Size, Accreditation, and MIRs rejected
- Size, Accreditation, and Units Rejected

Because the first four relationships deal with a single IV and DV, a one-way ANOVA was used to develop a linear model for the individual factors to determine if individually they had an impact on rejected MIRs and Units Rejected.

The two-way ANOVA (GLM) was used to determine the relationship, if any, between the Size, Accreditation, Units Rejected, and MIRs rejected. This method was chosen to be able to use multiple IVs to test for the significance of the covariance between the variables.

After the variables and relationships were established, the preliminary analysis was performed using a one-way ANOVA and two-way ANOVA (GLM), to quantify differences between the variables and research hypotheses. Additional analysis tool used in the analysis were Excel for charts, graphs, and simple statistical analysis.

For both the ANOVA and two-way ANOVA analysis (GLM), a .05 α (alpha), 95 percent confidence level was selected. The α (alpha) value as, represents the theoretical risk of a Type I error. A Type I errors is when a statistical significance test is used to make incorrect rejection of the null hypotheses, also known as a false positive. In the research conducted, a 95 percent confidence level was desired for the testing of the independent/dependent variable relationship. The resulting α gave a 5 percent chance or risk of rejecting Ho when it should have been accepted.

Research Plan

The research followed the process outlined below:

1. Identified and sort the data to be used.
2. Completed statistical analysis, using one-way ANOVA, two-way ANOVA (GLM), and other statistical tools (Excel, charts, graphs, etc.).
3. Interpreted the results from Step 2, as it pertains to the relationship in organization size, number of accreditations, MIRs rejected, and units rejected.

CHAPTER 4

RESULTS AND FINDINGS

The information in this chapter contains the results from the analysis conducted on the Product Data Reporting & Evaluation Program (PDREP) data sets from the Department of the Navy. The purpose of this chapter is to determine if the size of an organization and quantity of accreditations it has impact the acceptance/rejection of MIRs or the quantity of units rejected.

Preliminary Statistical Analysis

Prior to beginning the advanced analysis in MiniTab 18, a preliminary statistical analysis was performed on the data to determine what could be identified as potential areas for consideration. Appendix B shows the overall picture of the units delivered for the dataset. Over the five-year period of data, the Navy received 11,775,366 units. For that same period, 726,493 of units were rejected or 6.17 percent.

Figure 5 indicates, when sorted by Size, only the factors S (small organizations) and U (unknown) have a higher percentage of Units Rejected compared to the percentage of Units Received. Small organizations accounted for only 55.24 percent of all units received but accounted for 76.61 percent of units rejected. This represents a 1.39 to 1 ratio. The percent of rejected units, for the data set, was 6.17 percent (as stated earlier).

For medium and large organizations, the government received 4,958,811 units but only rejected 133,936 units (2.70 percent of units received). Small organizations accounted for

6,505,113 units but accounted for 556,578 rejected units (8.56 percent). When procuring from small organizations the government rejects 416 percent or more than four times more units than medium and large organizations. Additionally, unknown organization size accounted for only 311,442 units received but accounted for 35,979 (11.55 percent) units rejected. Unknown organization size was the only other Size factor that had a higher percentage of Units Rejected (4.95 percent) when compared to the percentage of Units Received (2.64 percent). Unknown organization had a 1.88 to 1 ratio. This was a larger ratio than small organizations but due to the low unit received and rejected, unknown organizations did not account for as significant of an impact, when compared to small organizations.

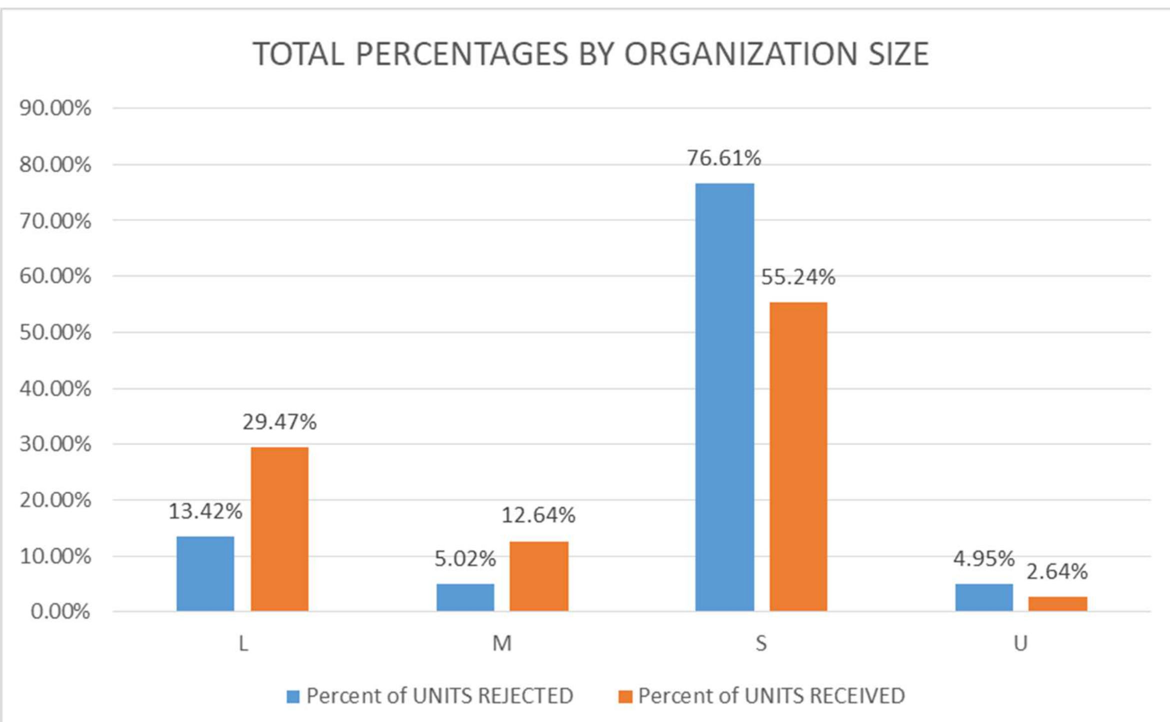

Figure 5. Total Percentages by Organization Size.

Figure 6 shows, when sorted by accreditations, only the Accreditation 1 (one certification) had a higher percentage of Units Rejected (28.60 percent) compared to the percentage of Units Received (14.31 percent), the ratio was 2.00 to 1.

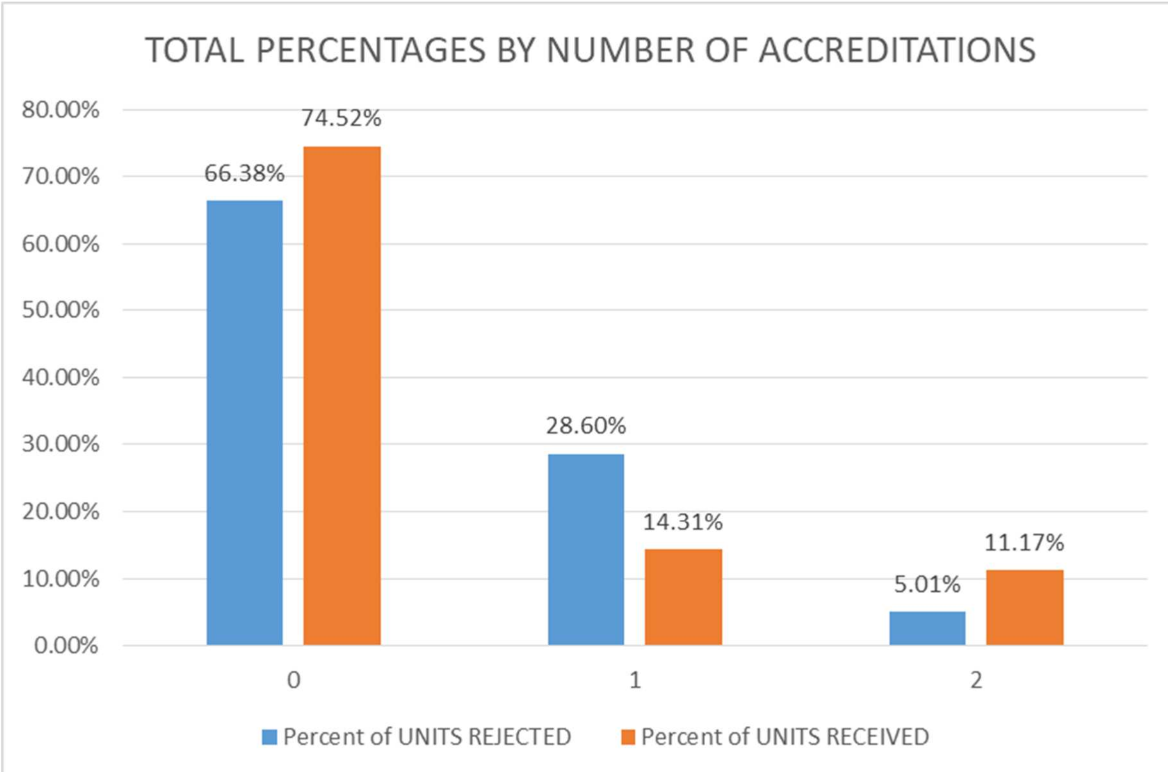

Figure 6. Total Percentages by Number of Accreditations.

Further refinement of the analysis is shown in Table 5. Within the small organization, organizations that held one certification accounted for only 9.70 percent of all Units Received and 24.57 percent of all Units Rejected for this period. A ratio of 2.53 to 1. As a group, small organizations with one certification received 1,025 (12.02 percent) total lots and 228 (14.71 percent) of the rejected lots for this period.

Table 5

Total Percentages by Certifications for Small Organizations

Certifications	Percent Rejected	Percent Received
0	50.00%	42.61%
1	24.47%	9.70%
2	1.24%	2.93%

Initial analysis of the data set to verify normality and distribution of data was conducted and the results are shown in Figure 7. Each year had at least 1,500 data points for use in the study. The data was sufficiently distributed across all five years, providing a sufficient quantity of records for the study.

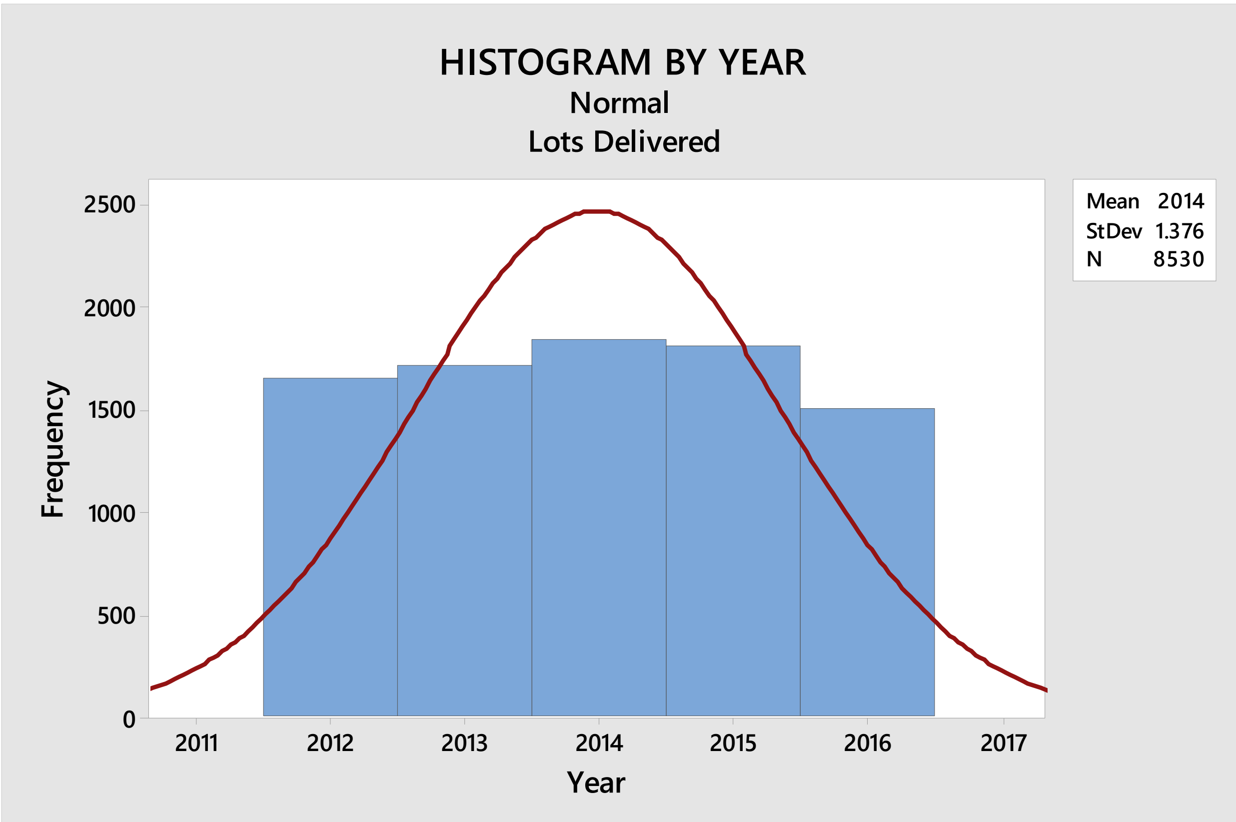

Figure 7. Records Distributed by Year.

After verifying the data was sufficiently distributed across the five-year period, the distribution within the different size categories. Small organizations had by far the most records but there was a sufficient quantity of medium, large and unknown data records to perform the analysis.

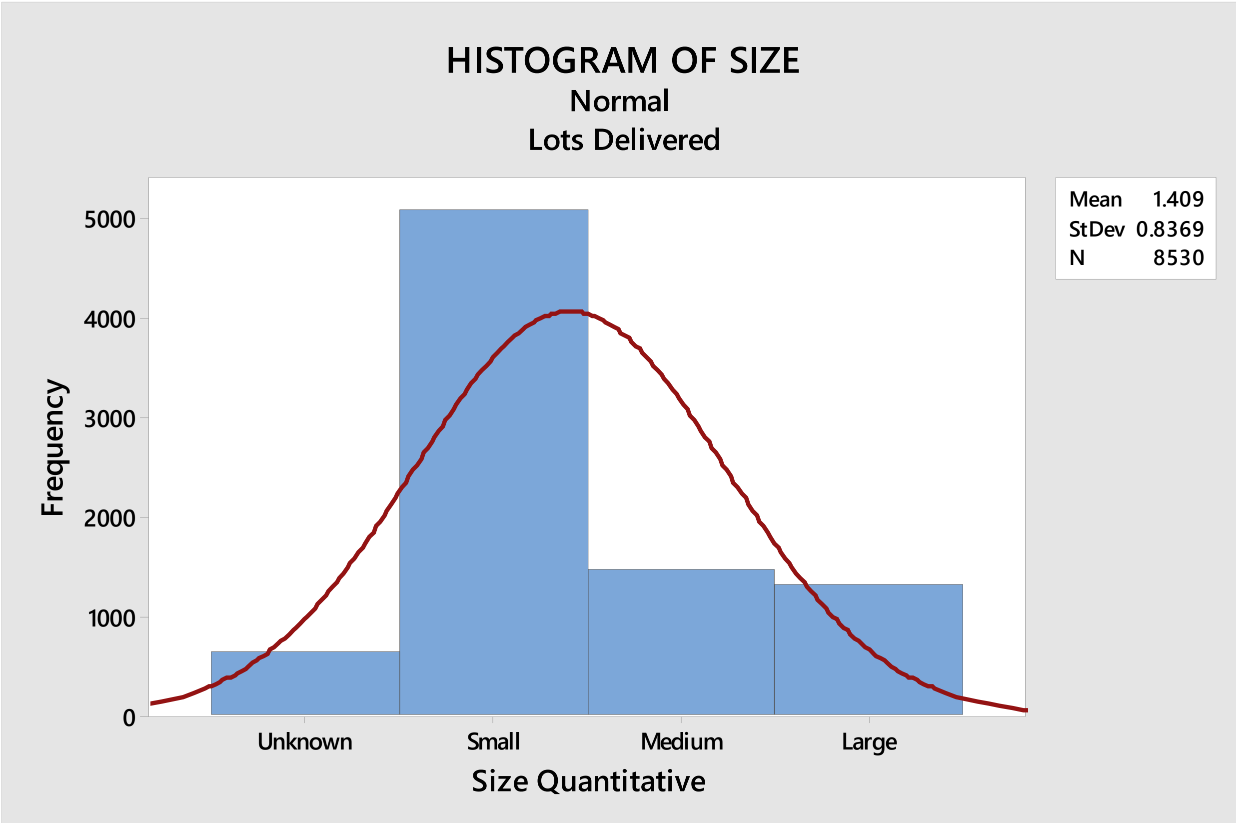

Figure 8. Records Distributed by Organization Size.

Figure 9 shows the records distributed by number of accreditations. While organizations with zero accreditations had the largest number of records, both organizations with one and organizations with two or more accreditations had nearly 2,000 records each. This provided a sufficient quantity of records for use in the study.

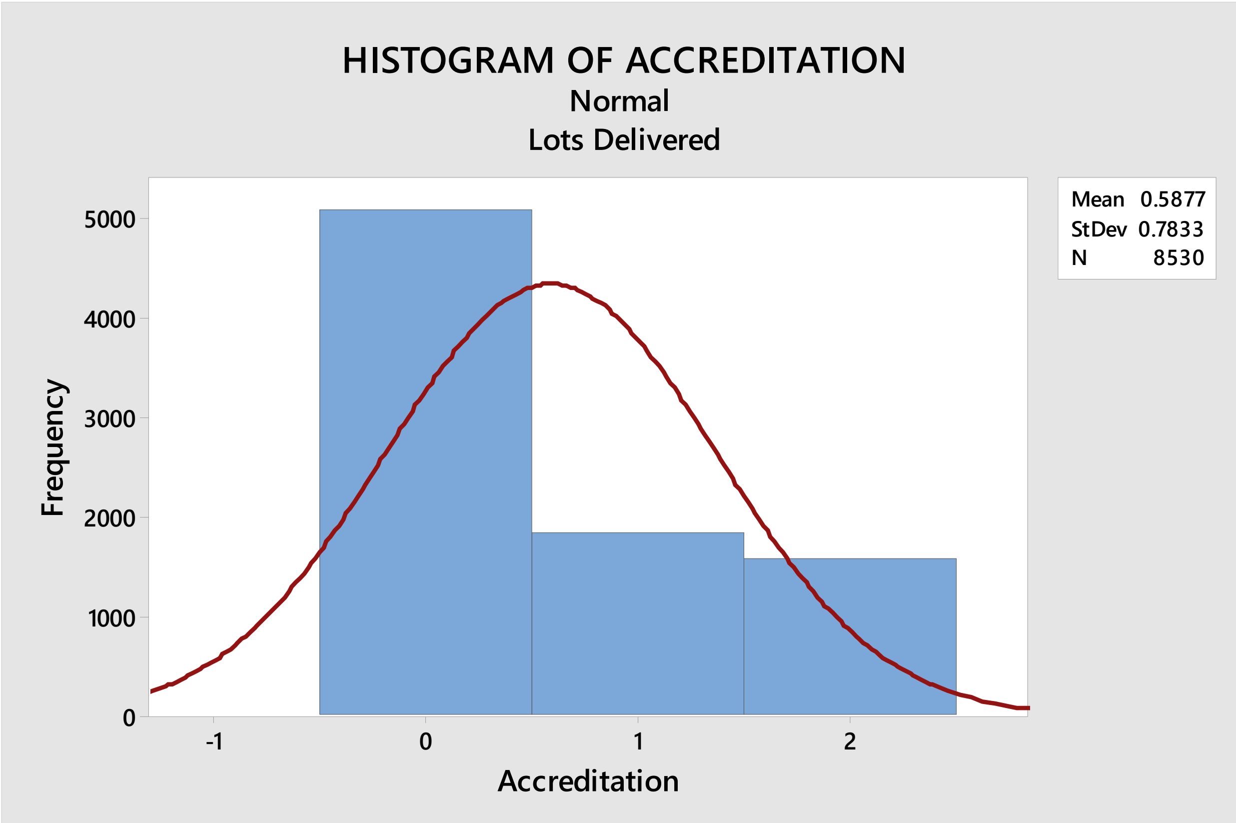

Figure 9. Records Distributed by Number of Accreditations.

Analysis of Variance (one-way ANOVA)

This section covered the analysis of the relationship between size, MIRs rejected and units rejected. Additionally, the analysis covered the relationship between number of accreditations, MIRs rejected and units rejected. Hypotheses 1 through 4 were answered during this research in addition to research questions one and two.

Hypotheses 1 and 2 were based on size of organization, MIR status, and units rejected from 2012 through 2016. Two one-way ANOVAs were conducted to determine if there were variations not only between groups but also to determine if there were variations between subgroups within each group.

The first one-way ANOVA was established to answer the first part of Research Question 1: Does the size of an organization affect MIR acceptance?

Ho_1: There is no statistically significant difference between the mean for the variables Size and MIR.

The primary factor for Hypothesis one was Size. The data sets were loaded into MiniTab 18 and one-way ANOVA was selected to test the hypothesis. Additionally, Fisher's least significant difference method was used to make comparisons between the groups within Size. A significance level of .05 with a 95% confidence interval was used in determining the F-Value and the significance. Table 6 shows the results of the one-way ANOVA analysis, a more detailed analysis can be found in Appendix D.

Table 6
One-Way ANOVA: Size versus MIRs

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Size	3	1.07	0.3557	2.38	0.068
Error	8526	1276.17	0.1497		
Total	8529	1277.24			

The resulting F-Value for Size was 2.38 and the observed P-Value was 0.068, indicating the null hypothesis is not rejected at the .05 significance level and the alternative hypothesis is not tenable. The mean of the MIRs is the same for small, medium, large, and organizations with an unknown size. It can be concluded there is not a statistical significance between the means for Size and MIRs.

Further examination of this relationship, shown in Table 7, indicates there is statistical significance between the difference in the means for small and medium organizations. The detailed analysis for Table 7 can be found in Appendix D. The Fisher Pairwise Comparison shows a T-Value of 2.56 with an adjusted P-Value of 0.011. Indicating the means between these two groups is statistically significant and there is no statistical significance to the difference of the means between the other groups.

Table 7

Fisher Pairwise Comparisons at 95% Confidence - MIRs

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
M - L	-0.0247	0.0146	(-0.0534, 0.0040)	-1.69	0.092
S - L	0.0045	0.0119	(-0.0189, 0.0279)	0.38	0.705
U - L	-0.0137	0.0187	(-0.0504, 0.0229)	-0.74	0.462
S - M	0.0292	0.0114	(0.0068, 0.0516)	2.56	0.011
U - M	0.0109	0.0184	(-0.0251, 0.0470)	0.60	0.551
U - S	0.0183	0.0163	(-0.0502, 0.0137)	-1.12	0.262

Simultaneous confidence level = 79.68%

The Fisher's Test is graphically represented in Figure 10. The Fisher's Test shows the intervals contain zero for all group comparisons except for the small versus medium size comparison.

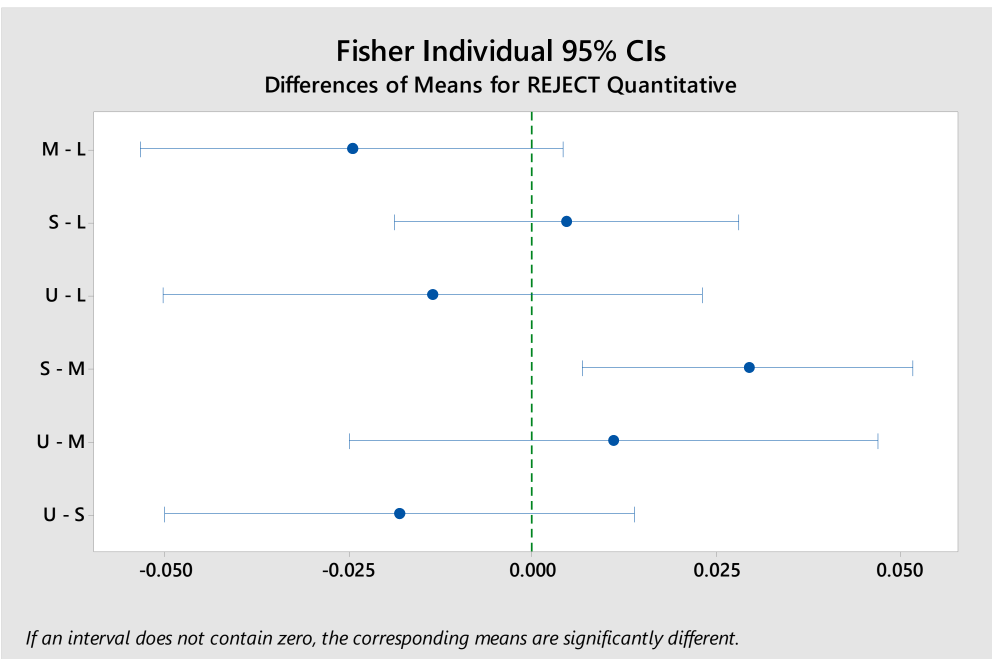

Figure 10. Graph of Fisher Pairwise Comparisons at 95% Confidence - MIR.

Next, a one-way ANOVA was created to answer the second part of Research Question 1: Does the size of an organization affect the quantity of units rejected?

Ho_2: There is no statistically significant difference between the mean for the variables Size and Units Rejected.

The primary factor for Hypothesis two was Size. The data sets were loaded into MiniTab 18 and one-way ANOVA was selected to test the hypothesis. Additionally, Fisher's least significant difference method was used to make comparisons between the groups within Size. A .05 confidence interval was used in determining the F-Value and the significance. Table 8 shows the results of the one-way ANOVA analysis, a more detailed analysis can be found in Appendix D.

Table 8

One-Way ANOVA: Size versus Units Rejected

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Size	3	9016808	3005603	1.30	0.273
Error	8526	19752273091	2316710		
Total	8529	19761289899			

The F-Value for Size was 1.30 the observed P-Value was 0.273, indicating the null hypothesis is not rejected at the .05 significance level and the alternative hypothesis is not tenable. The mean of the Units Rejected is the same for small, medium, large, and organizations with an unknown size. It can be concluded there is no statistical significance between Size and Units Rejected. The detailed analysis for Table 8 can be found in Appendix D.

The Fisher Pairwise Comparison, in Table 9, indicated no statistical significance to pairwise comparisons between groups. Indicating the mean between the groups is not statistically significant.

Table 9

Fisher Pairwise Comparisons at 95% Confidence – Units Rejected

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
M - L	-49.0	57.6	(-161.9, 64.0)	-0.85	0.395
S - L	35.5	47.0	(-56.6, 127.6)	0.76	0.450
U - L	-16.8	73.6	(-161.0, 127.4)	-0.23	0.819
S - M	84.5	45.0	(-3.7, 172.7)	1.88	0.060
U - M	32.1	72.3	(-109.6, 173.9)	0.44	0.657
U - S	-52.3	64.1	(-178.1, 73.4)	-0.82	0.415

Simultaneous confidence level = 79.68%

The Fisher's Test is graphically represented in Figure 11. The Fisher's Test shows the intervals contain zero for all group comparisons, thus no significance to the difference of the means.

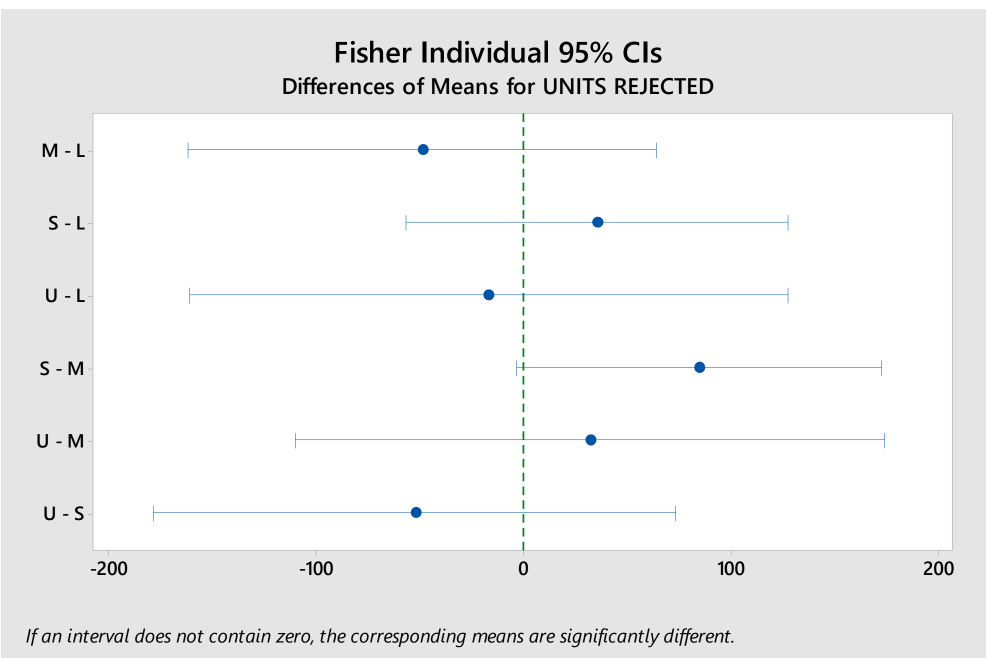

Figure 11. Graph of Fisher Pairwise Comparisons at 95% Confidence – Units Rejected.

Further analysis indicated there was a statistical significance between the means for small and medium size organizations. It can be concluded that Size had no statistical significance on the MIR acceptance or rejection and when comparing between groups only the comparison between the differences of means for small and medium size organizations has a statistical significance.

Hypotheses 3 and 4 were based on number of accreditations an organization has, MIR status, and units rejected from 2012 through 2016. Two one-way ANOVAs were conducted to determine if there were variations not only between groups but also to determine if there were variations between subgroups within each group.

Two one-way ANOVAs were created to answer Research Question 2: Does the number of accreditations an organization obtains affect the quantity of units rejected or MIR acceptance? Hypothesis 3 was developed to address answering the first half of the research question.

Ho_3: There is no statistically significant difference between the mean for the variables Accreditation and MIR.

The primary factor for Hypothesis 3 was Accreditation. The data sets were loaded into MiniTab 18 and one-way ANOVA was selected to test the hypothesis. Additionally, Fisher's least significant difference method was used to make comparisons between the groups within Accreditation. The .05 confidence interval was used in determining the F-Value and the significance. Table 10 shows the results of the one-way ANOVA analysis, a more detailed analysis can be found in Appendix D.

Table 10

One-Way ANOVA: Accreditation versus MIR

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Accreditation	2	0.13	0.06550	0.44	0.646
Error	8527	1277.11	0.14977		
Total	8529	1277.24			

The F-Value for Size was 0.44 the observed P-Value was 0.646, indicating the null hypothesis is not rejected at the .05 significance level and the alternative hypothesis is not tenable. The mean of MIR is the same for all organizations, regardless of number of accreditations. It can be concluded there is no statistical significance between Accreditation and MIRs. The detailed analysis for Table 10 can be found in Appendix D.

The Fisher Pairwise Comparison, in Table 11, indicates no statistical significance to pairwise comparisons between groups. Indicating the mean between the groups is not statistically significant.

Table 11

Fisher Pairwise Comparisons at 95% Confidence – MIR

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
1 - 0	0.0086	0.0105	(-0.0120, 0.0292)	0.82	0.412
2 - 0	-0.0026	0.0111	(-0.0244, 0.0193)	-0.23	0.819
2 - 1	-0.0112	0.0133	(-0.0372, 0.0148)	-0.84	0.399

Simultaneous confidence level = 87.78%

The Fisher’s Test is graphically represented in Figure 12. The Fisher’s Test shows the intervals contain zero for all group comparisons, thus no significance to the difference of the means.

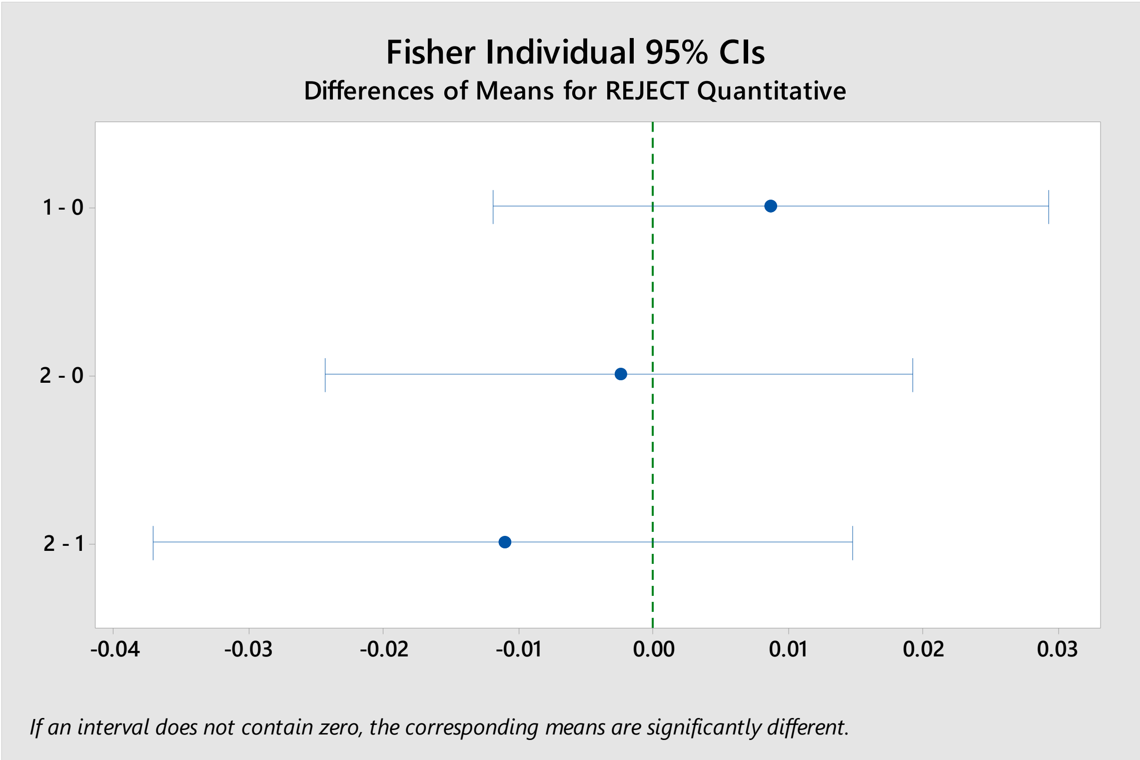

Figure 12. Graph of Fisher Pairwise Comparisons at 95% Confidence – MIR.

Hypothesis 4 was developed to address the second portion of Research Question 2: Does the number of accreditations an organization obtains affect the quantity of units rejected or MIR acceptance?

Ho$_4$: There is no statistically significant difference between the mean for the variables Accreditation and Units Rejected.

The primary factor for Hypothesis 4 was Accreditation. The data sets were loaded into MiniTab 18 and one-way ANOVA was selected to test the hypothesis. Additionally, Fisher's least significant difference method was used to make comparisons between the groups within Accreditation. The .05 significance level with a 95% confidence interval was used in determining the F-Value and the significance. Table 11 shows the results of the one-way ANOVA analysis, a more detailed analysis can be found in Appendix D.

Table 12

One-Way ANOVA: Accreditation versus Units Rejected

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Accreditation	2	7945820	3972910	1.72	0.180
Error	8527	19753344079	2316564		
Total	8529	19761289899			

The F-Value for Size was 1.72 the observed P-Value was 0.180, indicating the null hypothesis is not rejected at the .05 significance level and the alternative hypothesis is not tenable. The mean of the Units Rejected is the same for all organizations, regardless of number of accreditations. It can be concluded there is no statistical significance between Accreditation and Units Rejected. The detailed analysis for Table 12 can be found in Appendix D.

The Fisher Pairwise Comparison, in Table 13, indicates no statistical significance to pairwise comparisons between groups. Indicating the mean between the groups is not statistically significant.

Table 13

Fisher Pairwise Comparisons at 95% Confidence – MIR

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
1 - 0	17.9	41.3	(-63.1, 99.0)	0.43	0.664
2 - 0	-71.5	43.8	(-157.4, 14.3)	-1.63	0.102
2 - 1	-89.5	52.1	(-191.7, 12.7)	-1.72	0.086

Simultaneous confidence level = 87.78%

The Fisher's Test is graphically represented in Figure 13. The Fisher's Test shows the intervals contain zero for all group comparisons, thus no significance to the difference of the means.

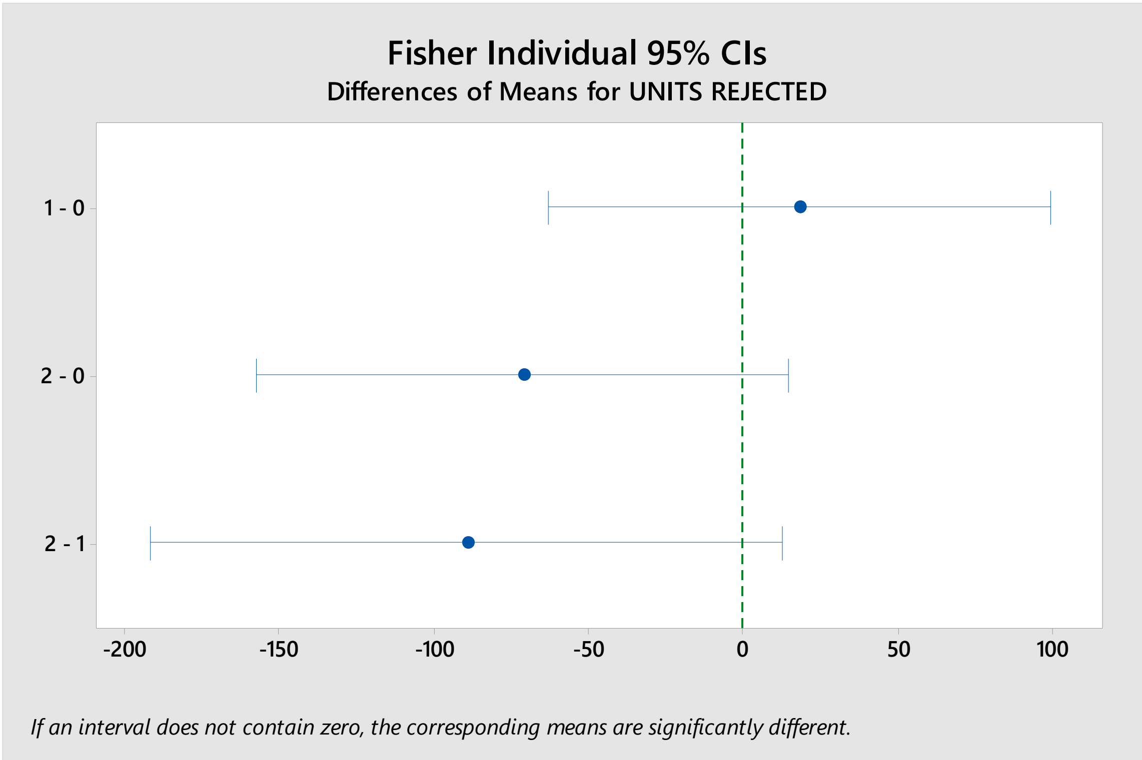

Figure 13. Graph of Fisher Pairwise Comparisons at 95% Confidence – Units Rejected.

Analysis for Accreditation indicated the mean for Accreditation vs. MIR had no statistical significance and the mean for Accreditation vs. Units Rejected did not have a statistical significance. Further analysis indicated there was no statistical significance between the means for within factor grouping. It can be concluded that Accreditation had no statistical significance on the MIR acceptance or rejection nor did it have statistical significance when comparing between groups. It can also be concluded that Accreditation had no statistical significance on the Units Rejected nor did it have statistical significance when comparing between groups.

Two-way ANOVA (General Linear Model (GLM)

This section covered the analysis of the relationship between size, number of accreditations, MIRs rejected and units rejected. Hypotheses 5 and 6 were answered during this research in addition to research questions three and four.

Hypotheses 5 and 6 were based on size of organization, number of accreditations, MIR status, and units rejected from 2012 through 2016. A two-way ANOVA (General Linear Model (GLM) was conducted to determine if there were variations between groups for each hypothesis.

Hypothesis 5 was developed to address Research Question 3: Is there a relationship between accreditations and organization size that affects the MIR acceptance?

$Ho_{5:}$ There is no statistically significant difference between the mean for the variables Size, Accreditation and MIR.

The primary factors for Hypothesis 5 were Size and Accreditation. The data sets were loaded into MiniTab 18 and GLM was selected to test the hypothesis. The .05 significance level with a 95% confidence interval was used in determining the F-Value and the significance. Table 14 shows the results of the GLM, a more detailed analysis can be found in Appendix D.

Table 14

GLM: Size, Accreditation versus MIR

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Size	3	1.18	0.39167	2.62	0.049
Accreditation	2	0.08	0.03830	0.26	0.774
Size*Accreditation	6	2.70	0.45010	3.01	0.006
Error	8518	1273.32	0.14949		
Total	8529	1277.24			

The F-Value for Size was 2.62 the observed significance level was 0.049, indicating the null hypothesis is rejected for at the .05 significance level in favor of the alternative hypothesis. For Accreditation, the F-Value was 0.26 and the P-Value was 0.774, indicating the null hypothesis is not rejected for Accreditation. For these two variables, the results are very similar to the one-way ANOVAs that were presented earlier.

The interaction Size*Accreditation resulted in an F-Value of 3.01 and a P-Value of 0.006, indicating the null hypothesis is rejected for this interaction and the alternative hypothesis is accepted. The result of the GLM indicates there is a statistically significant relationship for MIR for the interaction Size*Accreditation. The resulting model for the GLM was:

MIR = 0.1819 + 0.0041 Size_L - 0.0231 Size_M + 0.0107 Size_S + 0.0083 Size_U - 0.0033 Accreditation_0 + 0.0115 Accreditation_1 - 0.0082 Accreditation_2 + 0.0062 Size*Accreditation_L 0 - 0.0374 Size*Accreditation_L 1 + 0.0312 Size*Accreditation_L 2 + 0.0167 Size*Accreditation_M 0 - 0.0404 Size*Accreditation_M 1 + 0.0237 Size*Accreditation_M 2 - 0.0046 Size*Accreditation_S 0 + 0.0203 Size*Accreditation_S 1 - 0.0157 Size*Accreditation_S 2 - 0.0183 Size*Accreditation_U 0 + 0.0575 Size*Accreditation_U 1 - 0.0392 Size*Accreditation_U 2

The detailed analysis for Table 13 can be found in Appendix D.

Hypothesis 6 was developed to address Research Question 3: Is there a relationship between accreditations and organization size that affects the quantity of units rejected?

$Ho_{6:}$ There is no statistically significant difference between the mean for the variables Size, Accreditation and Units Rejected.

The primary factors for Hypothesis 5 were Size and Accreditation. The data sets were loaded into MiniTab 18 and GLM was selected to test the hypothesis. The .05 significance level with a 95% confidence interval was used in determining the F-Value and the significance. Table 15 shows the results of the GLM, a more detailed analysis can be found in Appendix D.

Table 15

GLM: Size, Accreditation versus Units Rejected

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Size	3	5799293	1933098	0.83	0.475
Accreditation	2	361424	180712	0.08	0.925
Size*Accreditation	6	8379221	1396537	0.60	0.728
Error	8518	19737768461	2317183		
Total	8529	19761289899			

The F-Value for Size was 0.83 the observed P-Value was 0.475, again indicating the null hypothesis is not rejected for Size at the .05 significance level and the alternative hypothesis is not tenable. For Accreditation, the F-Value was 0.08 and the P-Value was 0.925, confirming the acceptance of the null hypothesis for Accreditation. For these two variables, the results are very similar to the one-way ANOVAs that were presented earlier.

The interaction Size*Accreditation resulted in an F-Value of 0.60 and a P-Value of 0.728, indicating the null hypothesis is accepted for this interaction and the alternative hypothesis is rejected. The result of the GLM indicates there is a not a statistically significant relationship for Units Rejected for the interaction Size*Accreditation. The detailed analysis for Table 13 can be found in Appendix D.

Additional Analysis for Lot Size

Additional analysis was conducted to identify if grouping the lots in various sizes had any impact on the results. A summary of the results is listed below. The full results can be viewed in Appendix E.

Table 16 below, shows the results of the One-Way ANOVA for Size vs. MIR for the within group analysis. For lot sizes of 10 or less units, size had a statistical significance (F-Value 3.25, P-Value 0.021). Additionally, for lot sizes of 11 to 100 units, size had a statistical significance (F-Value 8.24, P-Value 0.000). For lot sizes of 11 to 100 units, size had a statistical significance (F-Value 8.24, P-Value 0.000). For lot sizes of greater than 1000, there was no statistical significance.

Table 16

One-Way ANOVA: Size versus MIR (grouping lot size)

Lot Size	F-Value	P-Value
Less than 10	3.25	0.021
11-100	8.24	0.000
101-1000	3.55	0.010
Greater than 1000	1.37	0.251

Table 17 indicates the results of the One-Way ANOVA for Size vs. Units Rejected for the within group analysis. When the lot size was less than 10 (F-Value 1.17, P-Value 0.320) and when lot size was greater than 1000 (F-Value 1.89, P-Value 0.129), there was no statistical significance. When lot size was 11-100 (F-Value 9.42, P-Value 0.000) and when lot size was 101-1000 (F-Value 3.79, P-Value 0.010), there was a statistical significance.

Table 17

One-Way ANOVA: Size versus Units Rejected (grouping lot size)

Lot Size	F-Value	P-Value
Less than 10	1.17	0.320
11-100	9.42	0.000
101-1000	3.79	0.010
Greater than 1000	1.89	0.129

Table 18 indicates the results of the One-Way ANOVA for Accreditation versus MIR for the within group analysis. When the lot size was and when lot size was 11-100 (F-Value 0.46, P-Value 0.631), there was no statistical significance. When lot size was 101-1000 (F-Value 3.28, P-Value 0.038), less than 10 (F-Value 1.17, P-Value 0.320) and when lot size was greater than 1000 (F-Value 3.31, P-Value 0.037), there was a statistical significance.

Table 18

One-Way ANOVA: Accreditation versus MIR (grouping lot size)

Lot Size	F-Value	P-Value
Less than 10	4.04	0.018
11-100	0.46	0.631
101-1000	3.28	0.038
Greater than 1000	3.31	0.037

When a One-Way ANOVA was conducted for Accreditation versus Units Rejected, all of the group sizes indicated there was no statistical significance. This corresponded with the other analyses conducted for Accreditation vs Units Rejected.

Fisher Pairwise Comparisons were conducted at the .05 significance level with a 95% confidence interval, for organization size, when lot size was grouped for less than 10 units, 11-100 units, 101-1000 units, and greater than 1000 units. The results that were statistically significant are shown in Table 19.

Table 19

Fisher Pairwise Comparisons at 95% Confidence – MIR

Lot Size	F-Value	P-Value
Less than 10		
S-L	-2.56	0.010
U-L	-2.86	0.004
11-100		
S-L	3.47	0.001
S-M	4.57	0.000
U-S	-2.00	0.046
101-1000		
S-L	2.77	0.006
U-L	1.96	0.050
S-M	1.97	0.048
Greater than 1000		
S-M	2.80	0.005

Fisher Pairwise Comparisons were conducted at the .05 significance level with a 95% confidence interval, for accreditation, when lot size was grouped for less than 10 units, 11-100 units, 101-1000 units, and greater than 1000 units. The results that were statistically significant are shown in Table 20.

Table 20

Fisher Pairwise Comparisons at 95% Confidence – Units Rejected

Lot Size	F-Value	P-Value
101-1000		
2-0	-2.22	0.027
2-1	-2.40	0.016
Greater than 1000		
2-0	-2.50	0.013
2-1	-2.13	0.033

The additional analysis, when grouping lot sizes, showed that the size of the organization had statistical significance. The statistical significance was most commonly seen when accepting or rejecting a MIR, Figure 14.

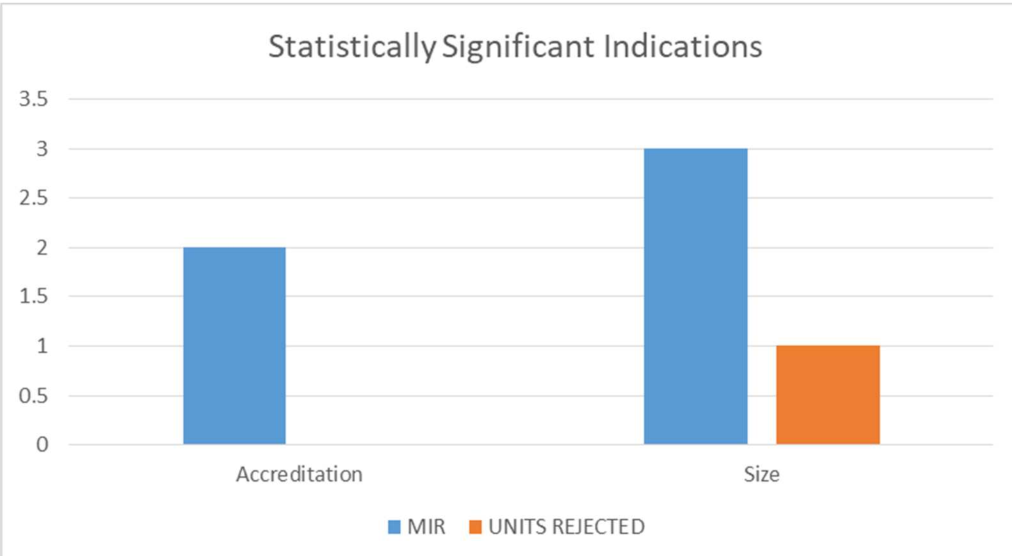

Figure 14. Statistically Significant Indications – Grouping Lot Sizes.

When looking at the within group significance, Figure 15, size of the organization had the most significance when accepting or rejecting a MIR. Small organizations (6 indications) and large organizations (5 indications) had the most indications within groups. However, accreditation had some significance when the lot size is larger than 100 units. Organizations with two or more accreditations had four within group indications.

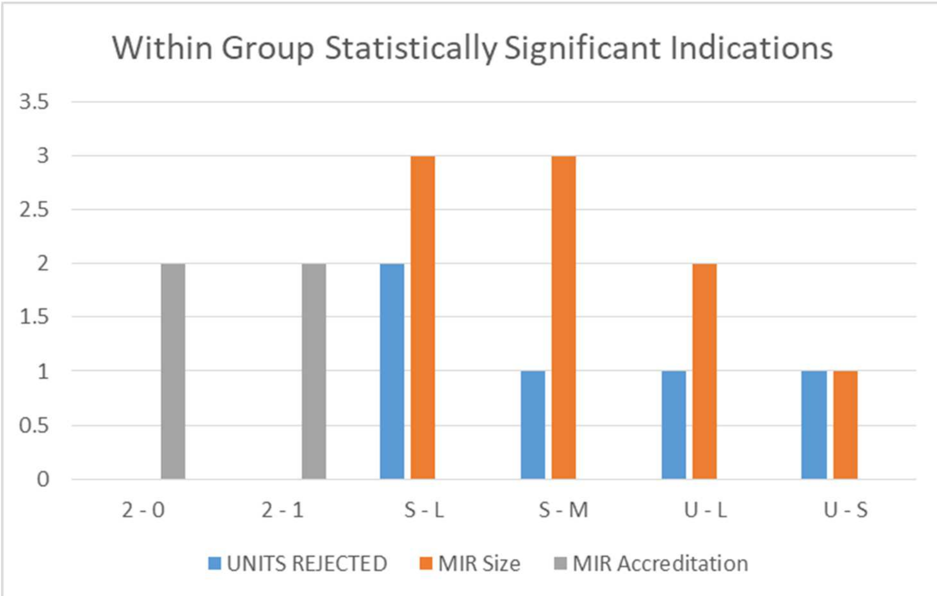

Figure 15. Within Group Statistically Significant Indications – Grouping Lot Sizes.

Summary

The One-Way ANOVA and GLM resulted in two indications of significance for the Size variable and MIR. The additional analysis conducted, when grouping by lot size, showed detail into the within group interactions for the size, accreditation, MIR, and rejected units. Several of these interactions had statistically significant indication. Primarily centering on small organizations with one accreditation. The additional statistical analysis focusing on grouping lot sizes, showed grouping lot sizes increased the number of statistically significant findings. This information can be used to provide greater clarity when trying to decide when and where to apply higher-level quality requirements or identify when to have items inspected at the receiving location versus at the place of manufacture. This information should not be used as a stand-alone factor; rather it should be used as a part of a broader analysis of contractor performance and incorporated into the contract awarding process.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This section provides the summary of the research, conclusions, and recommendations. The summary consists of the problem statement, purpose, research questions, hypotheses, methodology, results and findings. At the conclusion of this section, there are recommendations for future research that has the potential to have a significant impact on the way the DoD awards and administers contracts.

Summary

The DoD continues to struggle with finding the right balance of government oversight and contractors delivering nonconforming product. Over the last several decades, the DoD has tried many different methods of contract administration. The changes in methodology, in addition to the constant cost overruns and schedule delays, have caused the DoD to suffer fleet readiness degradation. Due to the buying activities being far removed from the quality process, many times they are unaware of what quality requirements are needed for the items they are procuring for the DoD. In order to combat this, the DoD needs to develop or consider alternative methods, when trying to determine when to include the DFARS 252.246-11 clause or if they want an item inspected and accepted at the place of manufacture or at the receiving location. To date there has been very little research conducted on the impact of organization size and accreditation status on shipments that are inspected and accepted at destination by the Navy.

Small organizations have some distinct advantages and disadvantages over larger organizations when it comes to implementing a QMS. Many times larger organizations recognize these advantages and outsource work to smaller organizations to take advantage of cost savings. However, the drawback can be schedule delays and quality concerns.

The purpose of this study was to investigate the relationship between products produced by organizations that are not accredited to a QMS, products produced by contractors with one accredited QMS, and products produced by contractors with more than one accredited QMS, using the MIR data supplied by the PDREP program, using PDREP data for the years 2012 through 2015. The study was able to identify factors that affect the acceptance or rejection of MIRs and unit rejection.

Research Questions

1. Does the size of an organization affect the quantity of units rejected or MIR acceptance?
2. Does the number of accreditations an organization obtains affect the quantity of units rejected or MIR acceptance?
3. Is there a relationship between accreditations and organization size that affects the MIR acceptance?
4. Is there a relationship between accreditations and organization size that affects the quantity of units rejected?
5. Can a model be developed from the analysis that aid in contract decisions?
6. Can a model be developed from the analysis that will aid in risk assessment and risk management within the DoD?

Hypotheses 1 – 4 were developed to answer questions Research Questions 1 and 2. Hypotheses 5 and 6 were developed to answer Research Questions 3 and 4. Research Questions 5 and 6 were answered from the analysis of the data and hypotheses 1-6. A summary of the results can be found in Table 21.

Hypotheses

Ho_1: There is no statistically significant difference between the mean for the variables Size and MIR.

Ha_1: There is a statistically significant difference between the mean for the variables Size and MIR.

Ho_2: There is no statistically significant difference between the mean for the variables Size and Units Rejected.

Ha_2: There is a statistically significant difference between the mean for the variables Size and Units Rejected.

Ho_3: There is no statistically significant difference between the mean for the variables Accreditation and MIR.

Ha_3: There is a statistically significant difference between the mean for the variables Accreditation and MIR.

Ho_4: There is no statistically significant difference between the mean for the variables Accreditation and Units Rejected.

Ha_4: There is a statistically significant difference between the mean for the variables Accreditation and Units Rejected.

Ho_5: There is no statistically significant difference between the mean for the variables Size, Accreditation and MIR.

Ha_5: There is a statistically significant difference between the mean for the variables Size, Accreditation and MIR.

Ho_6: There is no statistically significant difference between the mean for the variables Size, Accreditation and Units Rejected.

Ha_6: There is a statistically significant difference between the mean for the variables Size, Accreditation and Units Rejected.

Table 21

Summary of Hypothesis Testing

Research Hypotheses	P-Value	Null hypothesis (Ho)
One: Size vs. MIR	0.068	Do not reject
Two: Size vs. Units Rejected	0.273	Do not reject
Three: Accreditation vs. MIR	0.646	Do not reject
Four: Accreditation vs. Units Rejected	0.180	Do not reject
Five: Size vs. MIR	0.049	Reject
Accreditation vs. MIR	0.774	Do not reject
Size*Accreditation vs. MIR	0.006	Reject
Six: Size vs. Units Rejected	0.475	Do not reject
Accreditation vs. Units Rejected	0.925	Do not reject
Size*Accreditation vs. Units Rejected	0.728	Do not reject

Summary of Findings

The purpose of this research was to try to identify ways the PDREP data can help influence contract decisions. The DoD, if nothing else, collects massive amounts of data, which presently is either inaccessible or not being used by the right personnel to make contracting decisions that affect cost, quality, and schedule. The literature review identified many areas where the DoD has had massive cost and schedule overruns. To combat these overruns, the DoD has sacrificed the quality of the products they have procured, in order to meet schedule demands placed upon them by the end user. Several questions were proposed to help combat this problem:

1. Does the size of an organization affect the quantity of units rejected or MIR acceptance?

Based upon the results of the research, the size of the organization does not have a statistical significance on MIR acceptance (F-Value 2.38, P-Value 0.068). Thus, Ho_1 was not rejected and Ha_1 was rejected. Within the group size, there was statistical significance to the pairwise comparison for small and medium sized organizations (T-Value 2.56, P-Value 0.011). The research showed that there is no statistical significance between the size of the organization and units rejected (F-Value 1.30, P-Value 0.273). This led to Ho_2 not being rejected and of Ha_2 was not tenable. Within the group size, none of the pairwise comparisons indicated there was a statistical significance.

2. Does the number of accreditations an organization obtains affect the quantity of units rejected or MIR acceptance?

The research indicated the number of accreditations did not have a statistical significance on MIR acceptance (F-Value 0.44, P-Value 0.646). Thus, Ho_3 was not rejected and Ha_3 was not tenable. When looking at pairwise comparisons no statistical significance was identified. The number of accreditations did not have a statistical significance on units rejected (F-Value 1.72, P-Value 0.180). This led to Ho_4 not being rejected and Ha_4 was not tenable. There was no statistical significance identified for the pairwise comparisons.

3. Is there a relationship between accreditations and organization size that affects the MIR acceptance?

The research indicated, when using the GLM, size had a statistical significance on MIR acceptance (F-Value 2.62, P-Value 0.049). Additionally, the Size*Accreditation comparison indicated a statistical significance (F-Value 3.01, P-Value 0.006). Indicating, when looking at size and accreditation in conjunction, statistical significance exists. Thus, Ho_5 was not rejected and Ha_5 was not tenable.

4. Is there a relationship between accreditations and organization size that affects the quantity of units rejected?

The research indicated, when using the GLM, size, accreditation, and Size*Accreditation had no statistical significance on units rejected. Thus, Ha_6 was not rejected and Ho_6 was not tenable.

5. Can a model be developed from the analysis that aid in contract decisions?

Based upon the analysis, there is an indication that organization size and accreditation can be used in determining MIR acceptance or rejection. Alone, size and accreditation did not have a statistical significance. When an analysis was done using both factors, statistical significance was identified.

Based on the preliminary analysis, small organizations had the largest percentage of units rejected (76.61 percent) when compared to units received (55.24 percent). Within small organizations, organizations with one accreditation had a disproportionate percentage of the rejected units (2.00 to 1), when compared to other small organizations. This leads to cost increases, schedule delays, and the high percent of rejected units identifies quality issues within small organizations.

The results of this research can be used by contracting officers to identify whether or not to award to a small, medium, or large organization; when the inspect and accept of the MIR is at the receiving location and not at the place of manufacture.

6. Can a model be developed from the analysis that will aid in risk assessment and risk management within the DoD?

The limited amount of variables made the development of a model difficult. However, understanding that there is a much higher chance of receiving non-conforming units from small organizations can be used in conjunction with organization past performance to determine what level of risk, quality problems, and impact to schedule and cost each organization will have. The research alone has identified that small organizations represent a significant risk, when inspection and acceptance is at the receiving facility. Additionally, there is a much higher risk associated with the organization when they have a single QMS certification.

The analysis of the data shows the use of the 52.246-11, Higher-Level Contract Quality Requirement clause would not present a significant return on investment for the government, when looking at medium, large, or unknown sized organizations. Statistically, there is no difference in performance between medium, large, and unknown sized organizations with zero, one, two or more accreditations. Since there is no statistical significance, failing to include the clause or including it would indicate the government did not see an improvement in the acceptance or rejection of units received by the Navy. If inclusion of this clause represents an increased cost, removal would reduce the cost and not present any higher level of risk to the government.

For small organizations, there was statistical significance to the findings. Specifically, small organizations with no accreditation or one accreditation were statistically more likely to deliver nonconforming units or have units rejected. Within small organizations, when lot size was 1000 or less, there were statistically significant indications that would indicate a significant risk to the government. To reduce or mitigate risk, it would be in the best interest of the government to move the inspection and acceptance of units from small organizations, with no accreditation or one accreditation, to the manufacturing facility for any units that are procured.

For medium organizations, there was statistical significance when looking at a comparison between small and medium sized organizations. Specifically, medium sized organizations that had one accreditation had a 9.66 percent rejection rate on units received. This accounted for approximately 75 percent of all rejections by medium sized organizations. To mitigate risk to the government, contracts should move inspection and acceptance to the place of unit manufacture.

Organizations that had an unknown size had statistical significance when the organization did not have an accredited QMS. These organizations had an 11.32 percent rejection rate for units received. Since the data for these organizations was limited or unavailable, more research should be conducted to determine the actual size (small, medium, or large) of the organization to assess the risk to the government.

When there was not a statistical significance to the analysis, it would be more beneficial for the government to remove the 52.246-11 clause from contracts. This could represent a significant reduction in procurement costs, reduction in schedule, and increased quality of units delivered. These organizations represented a significantly lower risk of having rejected units. Additionally, moving the inspection and acceptance to the source would reduce the additional costs and schedule delays that are a direct result of rejected units.

Discussion on Model Development

The model that was developed from the GLM provided analysis of the variables that are currently available. As more variables become available, a more robust model can be developed that will give more precision and accuracy towards identifying risk.

Additionally, the below flow chart, Figure 16, was developed to aid in risk decision making in conjunction with the Lot Risk Table, Table 22, and the Supplier Risk Table, Table 23. The flow chart identifies the process for determining supplier category and how to identify the risk associated with the supplier based on the results of the study or supplier past performance, whichever is the appropriate path.

Table 22, identifies when there are statistically significant indications and the Risk Analysis identifies what risk should be assigned to the particular lot size based on past performance from this research.

Table 22

Lot Risk Table

		Analysis		
Lot Size	Size vs MIR	Size vs Units Rejected	Accreditation vs MIR	Risk Analysis
Less than 10	0.021	0.320	0.018	Moderate
11 - 100	0.000	0.000	0.631	Moderate
101 - 1000	0.010	0.010	0.038	High
greater than 1000	0.251	0.129	0.037	Low

Table 23

Supplier Risk Table

		Analysis		
Organization Size	Accreditation	Unit Rejection Rate	Past Performance	Risk Analysis
Small	0	7.37%	< 95% acceptance	High
Small	1	15.56%	< 95% acceptance	High
Small	2	2.61%	< 99% but ≥ 95% acceptance	Moderate
Medium	0	0.58%	≥ 99% acceptance	Low
Medium	1	9.66%	< 95% acceptance	High
Medium	2	9.28%	< 95% acceptance	High
Large	0	3.14%	< 99% but ≥ 95% acceptance	Moderate
Large	1	4.77%	< 99% but ≥ 95% acceptance	Moderate
Large	2	0.42%	≥ 99% acceptance	Low

The Lot Risk Table and the Supplier Risk Table can be combined to formulate an overall risk analysis that will form the basis for making product inspection and acceptance decisions, when the supplier is new or does not have at least 12 months of performance history to assist in making decisions to mitigate risk to the government. The highest risk rating from the Lot Risk Table and the Supplier Risk Table for the organization size, accreditation, and lots size factors shall be used. For example:

Organization size is small, with two accreditations, and the lot size is more than 1,000 units. The supplier would be risk rated as moderate for organization size and accreditation. The supplier would be risk rated low for lot size more than 1,000. The overall risk rating would be moderate. This would indicate the inspection and acceptance will take place at the supplier until a level of confidence can be established or the risk rating changes for that supplier.

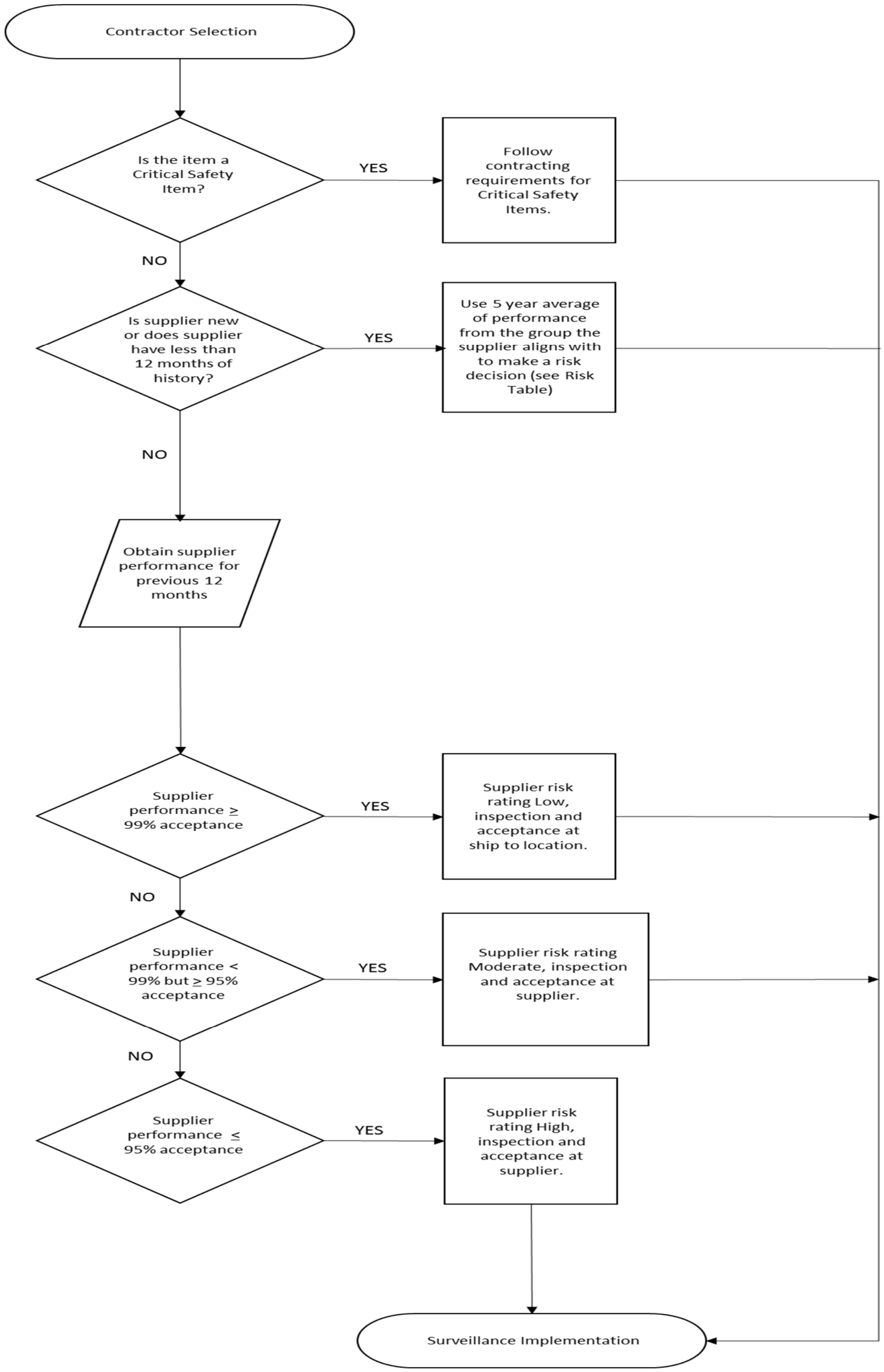

Figure 16. Flowchart for Identifying Supplier Risk and Associated Place of Inspection and Acceptance.

Recommendations for Future Research

Opportunities to conduct future research into contract administration services for the DoD and ultimately other federal and state have been limited. The research presented here has the potential to open up these opportunities and to drive significant changes in the methods employed by federal, state, and non-profit organizations. The more data becomes available, the more research can be conducted to identify opportunities to cut costs, streamline schedule, and improve the quality of products delivered to the DoD.

Currently, DCMA oversees more than $223 billion in contracts for the government. Several billion more in contracts are managed by various DoD agencies. A simple 5 percent reduction in cost could lead to a savings of more than $11 billion that could be used to reduce deficit, support struggling programs, and buy additional products that were cut due to budgetary restraints. For every 5 percent in savings an additional $11 billion in savings could be had.

Further research is needed to identify the most critical factors that affect the quality, cost, and schedule for products procured by the DoD. The Navy PDREP system already houses much of this data. Understanding why product was rejected, complexity of product, field returns, defects, and other characteristics associated with non-conformances could result in a better understanding of what is needed in contracts to provide the lowest price, for the highest quality, with the lowest schedule impact to the end users.

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APPENDIX A: PDREP DATA SAMPLE

COMPANY NAME	DOLLAR VALUE RECEIVED	DOLLAR VALUE REJECTED	Lot Size	REJECT INDICATO	REJECT Quantitative	Units Receive	Units Rejecte	SYSCOM CODE	Year	Size	Size Quantitat	Accreditation
2IS INC	$130,200.00	$130,200.00	3	Y	1	3	3	1	2012	S	1	1
2IS INC	$8,660.00	$ -	19	N	0	19	0	1	2012	S	1	1
2IS INC	$77,049.00	$ -	45	N	0	45	0	5	2012	S	1	1
3M CO	$236.00	$ -	7	N	0	7	0	1	2012	L	3	2
3M CO	$112,032.00	$ -	450	N	0	450	0	5	2012	L	3	2
3M PURIFICATION INC	$103,445.00	$ -	30	N	0	30	0	1	2012	L	3	1
A 1 ALLOYS INC	$208.00	$ -	2	N	0	2	0	1	2012	S	1	0
A AND A CO INC	$183,990.00	$ -	10	N	0	10	0	1	2012	S	1	0
A I M INC	$67,826.00	$ -	1,100	N	0	1,100	0	1	2012	S	1	0
A M CASTLE AND CO	$39,480.00	$ -	3,448	N	0	3,448	0	1	2012	L	3	2
A M CASTLE AND CO	$ -	$ -	24	Y	1	24	24	1	2012	L	3	2
A Z E SUPPLY CO INC	$3,871.00	$ -	42	N	0	42	0	1	2012	S	1	0
A Z E SUPPLY CO INC	$374.00	$374.00	1	Y	1	1	1	1	2012	S	1	0
ABCO WELDING AND INDUSTRIAL SUPPLY	$1,351.00	$ -	250	N	0	250	0	1	2012	S	1	0
ACCURATE TOOL CO INC	$640.00	$ -	14	N	0	14	0	1	2012	S	1	2
ACE GLASS INC	$106.00	$ -	1	N	0	1	0	1	2012	S	1	0
ACG SYSTEMS INC	$445,499.00	$ -	102	N	0	102	0	1	2012	S	1	0
ACME PRODUCTS AND ENGINEERING INC	$15,600.00	$15,600.00	26	Y	1	26	26	5	2012	S	1	1
ACME PRODUCTS AND ENGINEERING INC	$5,400.00	$5,400.00	2	Y	1	2	2	1	2012	S	1	1
ACOPIAN TECHNICAL CO	$3,748.00	$ -	1	N	0	1	0	1	2012	M	2	1
ACQUISITIONS SERVICES AND	$32,270.00	$ -	2	N	0	2	0	1	2012	U	0	0
ACT TEST PANELS LLC	$752.00	$ -	500	N	0	500	0	1	2012	S	1	1
ACTION MAINTENANCE AND PAINTING LLC	$1,768.00	$ -	4	N	0	4	0	1	2012	S	1	0
ACTION PAK INC	$133.00	$ -	4	N	0	4	0	1	2012	S	1	0
ACUCAL INC	$246.00	$ -	1	N	0	1	0	1	2012	S	1	2
ACUITY MACHINE CO INC	$205,760.00	$ -	157	N	0	157	0	1	2012	S	1	0
ACUSHNET RUBBER CO INC	$131.00	$ -	51	N	0	51	0	1	2012	U	0	0
ADIRONDACK ELECTRONICS INC	$35,839.00	$35,839.00	70	Y	1	70	70	1	2012	S	1	1
ADIRONDACK ELECTRONICS INC	$646.00	$ -	33	N	0	33	0	1	2012	S	1	1
ADIRONDACK ELECTRONICS INC	$628,404.00	$ -	6,066	N	0	6,066	0	5	2012	S	1	1
ADIRONDACK ELECTRONICS INC	$8,303.00	$8,303.00	20	Y	1	20	20	1	2012	S	1	1
ADIRONDACK ELECTRONICS INC	$237,096.00	$ -	3,652	N	0	3,652	0	1	2012	S	1	1

ADMIRAL VALVE LLC	$16,914.00	$16,914.00	20	Y	1	20	20	1	2012	S	1	0
ADMIRAL VALVE LLC	$39,225.00	$ -	151	N	0	151	0	1	2012	S	1	0
ADMIRAL VALVE LLC	$862.00	$ -	8	N	0	8	0	5	2012	S	1	0
ADVANCE MFG CO INC	$33,276.00	$ -	40	N	0	40	0	1	2012	M	2	2
ADVANCED CIRCUITS INC	$26,880.00	$ -	16	N	0	16	0	1	2012	M	2	2
ADVANCED MACHINE AND TOOL CO	$16,390.00	$16,390.00	2	Y	1	2	2	1	2012	S	1	1
ADVANCED PRECISION MFG	$625.00	$ -	10	N	0	10	0	1	2012	S	1	0
ADVANTA INDUSTRIES INC	$274,980.00	$ -	473	N	0	473	0	1	2012	S	1	1
ADVANCED ENGINEERING INC	$4,920.00	$ -	1	N	0	1	0	1	2012	U	0	0
ADVEX CORP	$59,973.00	$ -	1	N	0	1	0	1	2012	M	2	0
AERO HOSE CORP	$ -	$ -	8	Y	1	8	8	1	2012	S	1	2
AERO HOSE CORP	$39,187.00	$ -	17	N	0	17	0	1	2012	S	1	2
AERO HOSE CORP	$59,300.00	$ -	46	N	0	46	0	5	2012	S	1	2
AERO MISSILE COMPONENTS INC	$106.00	$ -	6	N	0	6	0	1	2012	S	1	2
AEROFAB CO INC	$153.00	$153.00	38	Y	1	38	38	1	2012	S	1	2
AEROFAB CO INC	$13.00	$13.00	4	Y	1	4	4	1	2012	S	1	2
AEROFLEX PLAINVIEW INC	$23,995.00	$ -	1	N	0	1	0	1	2012	L	3	2
AEROFLEX WICHITA INC	$144,560.00	$ -	32	N	0	32	0	1	2012	L	3	0
AFP INDUSTRIES INC	$924.00	$ -	22	N	0	22	0	1	2012	S	1	0
AGM CONTAINER CONTROLS INC	$447.00	$ -	15	N	0	15	0	1	2012	M	2	2
AIMTEK INC	$1,267.00	$1,267.00	2	Y	1	2	2	1	2012	S	1	2
AIMTEK INC	$19,544.00	$ -	4,820	N	0	4,820	0	1	2012	S	1	2
AIMTEK INC	$ -	$ -	16	Y	1	16	16	1	2012	S	1	2
AIR OIL PRODUCTS CORP	$4,431.00	$ -	8	N	0	8	0	1	2012	U	0	0
AIRCRAFT HARDWARE WEST	$469.00	$ -	25	N	0	25	0	1	2012	S	1	2
AIRGAS USA LLC	$290.00	$ -	5	N	0	5	0	1	2012	L	3	0
ALANOD WESTLAKE METAL IND INC	$26.00	$ -	3	N	0	3	0	1	2012	S	1	0
ALASKAN COPPER COMPANIES INC	$16,378.00	$16,378.00	111	Y	1	111	111	1	2012	M	2	0
ALASKAN COPPER COMPANIES INC	$ -	$ -	2,376	N	0	2,376	0	1	2012	M	2	0
ALASKAN COPPER COMPANIES INC	$2,328.00	$ -	144	N	0	144	0	1	2012	M	2	0
ALBAR MACHINE CORP	$2,970.00	$2,970.00	45	Y	1	45	45	1	2012	S	1	0
ALBAR MACHINE CORP	$92,908.00	$ -	162	N	0	162	0	1	2012	S	1	0
ALDEC INC	$7,410.00	$ -	2	N	0	2	0	1	2012	M	2	0
ALINABAL HOLDINGS CORP	$60.00	$ -	6	N	0	6	0	1	2012	M	2	2
ALL CITIES STEEL CORP	$25,660.00	$ -	223	N	0	223	0	1	2012	S	1	0
ALL ELECTRONICS CORP	$40.00	$ -	10	N	0	10	0	1	2012	S	1	0
ALL METAL SALES INC	$1,046.00	$ -	3	N	0	3	0	1	2012	S	1	0
ALL QUALITY SPARES INC	$267.00	$ -	4	N	0	4	0	1	2012	S	1	0
ALL SAFE INC	$4,800.00	$ -	10	N	0	10	0	1	2012	S	1	0
ALL TECH ELECTRONICS INC	$12,595.00	$ -	77	N	0	77	0	1	2012	S	1	2
ALL WEST FASTENERS INC	$4,075.00	$ -	55	N	0	55	0	1	2012	S	1	0
ALLAGASH VALVE AND CONTROLS INC	$1,950.00	$ -	2	N	0	2	0	1	2012	S	1	0
ALLAN AIRCRAFT SUPPLY CO LLC	$ -	$ -	2	Y	1	2	2	1	2012	S	1	2
ALLAN AIRCRAFT SUPPLY CO LLC	$16,063.00	$ -	119	N	0	119	0	1	2012	S	1	2
ALLARD NAZARIAN GROUP INC	$1.00	$1.00	1	Y	1	1	1	1	2012	M	2	2
ALLARD NAZARIAN GROUP INC	$123,087.00	$ -	19	N	0	19	0	1	2012	M	2	2
ALLIANT METALS INC	$280.00	$ -	2	N	0	2	0	1	2012	S	1	0

ALLIED DEFENSE INDUSTRIES INC	$9,130.00	$ -	1	N	0	1	0	1	2012	S	1	0
ALLIED ELECTRONICS INC	$191.00	$191.00	1	Y	1	1	1	1	2012	M	2	2
ALLIED ELECTRONICS INC	$156,045.00	$ -	50	N	0	50	0	1	2012	M	2	2
ALLIED PACIFIC BUILDERS INC	$18.00	$ -	13	N	0	13	0	1	2012	S	1	0
ALMA FASTENING SYSTEMS INC	$3.00	$ -	20	N	0	20	0	1	2012	S	1	0
ALPHA ASSOCIATES INC	$453.00	$ -	17	N	0	17	0	1	2012	S	1	0
ALPHA FASTENERS CORP	$1,750.00	$ -	1,400	N	0	1,400	0	1	2012	S	1	1
ALPHA SCIENTIFIC ELECTRONICS INC	$24,600.00	$ -	1	N	0	1	0	1	2012	S	1	0
ALPHA WIRE CORP	$112.00	$ -	6	N	0	6	0	1	2012	M	2	2
ALTEMP ALLOYS INC	$260.00	$ -	1	N	0	1	0	1	2012	S	1	2
ALUMIN ART PLATING CO INC	$345.00	$ -	1	N	0	1	0	1	2012	S	1	0
AM MAC INC	$54.00	$ -	5	N	0	5	0	1	2012	S	1	0
AMEE BAY SAN DIEGO BRANCH OFFICE	$269,353.00	$ -	56	N	0	56	0	7	2012	L	3	1
AMERICAN ALLOY LLC	$15,529.00	$ -	1	N	0	1	0	1	2012	S	1	0
AMERICAN BRAIDING AND MFG	$28,434.00	$ -	115	N	0	115	0	5	2012	L	3	0
AMERICAN BRAIDING AND MFG	$108,498.00	$ -	442	N	0	442	0	1	2012	L	3	0
AMERICAN FABRICATION INC	$11,000.00	$ -	40	N	0	40	0	5	2012	S	1	1
AMERICAN HOSE AND FITTINGS INC	$ -	$ -	4	Y	1	4	4	1	2012	S	1	0
AMERICAN HOSE AND FITTINGS INC	$615.00	$ -	33	N	0	33	0	1	2012	S	1	0
AMERICAN MFG SOLUTIONS	$3,136.00	$ -	14	N	0	14	0	1	2012	S	1	0
AMERICAN SAFETY TECHNOLOGIES INC	$2,385.00	$ -	11	N	0	11	0	1	2012	S	1	0
AMERICAN SOCIETY FOR TESTING AND	$42.00	$ -	5	N	0	5	0	1	2012	L	3	0
AMERICAN STEEL AND WIRE DIV OF	$1,628.00	$ -	200	N	0	200	0	1	2012	U	0	0
AMERITECH DIE AND MOLD SOUTH INC	$29,988.00	$ -	6	N	0	6	0	1	2012	S	1	2
AMETEK PROGRAMMABLE POWER INC	$17,187.00	$ -	7	N	0	7	0	1	2012	L	3	1
AMETEK SCP INC	$139,330.00	$ -	225	N	0	225	0	1	2012	L	3	1
AMETEK SCP INC	$926,038.00	$ -	392	N	0	392	0	1	2012	L	3	1
AMETEK SCP INC	$95,490.00	$95,490.00	11	Y	1	11	11	1	2012	L	3	1
AMITRON INC	$9,545.00	$ -	120	N	0	120	0	1	2012	M	2	1
AMPHENOL CORP	$809.00	$ -	70	N	0	70	0	1	2012	L	3	1
AMPLIFIER RESEARCH CORP	$23,630.00	$ -	1	N	0	1	0	1	2012	L	3	1
AMRON INTL INC	$68,101.00	$ -	11	N	0	11	0	1	2012	S	1	1
ANACHEMIA CHEMICALS LLC	$232,789.00	$ -	9,525	N	0	9,525	0	5	2012	L	3	0
ANALYTICAL INDUSTRIES INC	$5,228.00	$5,228.00	36	Y	1	36	36	1	2012	S	1	1
ANALYTICAL INDUSTRIES INC	$119,105.00	$ -	820	N	0	820	0	1	2012	S	1	1
ANALYTICAL INDUSTRIES INC	$48,804.00	$ -	849	N	0	849	0	1	2012	S	1	1
ANDERSEN PAINT AND INTERIORS INC	$ -	$ -	43	Y	1	43	43	1	2012	S	1	0
ANDERSEN PAINT AND INTERIORS INC	$25,609.00	$ -	22	N	0	22	0	1	2012	S	1	0
ANDERSON GREENWOOD LP	$721.00	$ -	29	N	0	29	0	1	2012	L	3	0
ANGELES PRECISION ENGINEERING LLC	$3,253.00	$3,253.00	160	Y	1	160	160	1	2012	S	1	2
ANGELES PRECISION ENGINEERING LLC	$21,143.00	$21,143.00	1,040	N	0	1,040	0	1	2012	S	1	2
ANGELES PRECISION ENGINEERING LLC	$20,003.00	$ -	1,435	N	0	1,435	0	1	2012	S	1	2
ANRITSU CO	$756.00	$ -	2	N	0	2	0	1	2012	L	3	1

APPENDIX B: TOTAL UNITS RECEIVED AND REJECTED

	S		M		L		U			
Row Labels	Sum of Units Received	Sum of Units Rejected	Sum of Units Received	Sum of Units Rejected	Sum of Units Received	Sum of Units Rejected	Sum of Units Received	Sum of Units Rejected	Total Sum of Units Received	Total Sum of Units Rejected
0	5,017,476	369,773	1,171,116	6,829	2,286,943	71,721	299,735	33,938	8,775,270	482,261
N	4,647,703	0	1,164,287	0	2,215,222	0	265,797	0	8,293,009	0
Y	369,773	369,773	6,829	6,829	71,721	71,721	33,938	33,938	482,261	482,261
1	1,142,396	177,796	53,623	5,179	477,455	22,791	11,671	2,035	1,685,145	207,801
N	964,600	0	48,444	0	454,664	0	9,636	0	1,477,344	0
Y	177,796	177,796	5,179	5,179	22,791	22,791	2,035	2,035	207,801	207,801
2	345,241	9,009	263,524	24,459	706,150	2,957	36	6	1,314,951	36,431
N	336,232	0	239,065	0	703,193	0	30	0	1,278,520	0
Y	9,009	9,009	24,459	24,459	2,957	2,957	6	6	36,431	36,431
Grand Total	6,505,113	556,578	1,488,263	36,467	3,470,548	97,469	311,442	35,979	11,775,366	726,493

APPENDIX C: TOTAL DOLLAR VALUE RECEIVED AND REJECTED

	S		M		L		U			
Row Labels	Sum of DOLLAR VALUE RECEIVED	Sum of DOLLAR VALUE REJECTED	Sum of DOLLAR VALUE RECEIVED	Sum of DOLLAR VALUE REJECTED	Sum of DOLLAR VALUE RECEIVED	Sum of DOLLAR VALUE REJECTED	Sum of DOLLAR VALUE RECEIVED	Sum of DOLLAR VALUE REJECTED	Total Sum of DOLLAR VALUE RECEIVED	Total Sum of DOLLAR VALUE REJECTED
0	$245,904,012	$12,376,743	$49,937,688	$2,309,561	$151,216,962	$8,491,775	$16,841,461	$1,175,876	$463,900,123	$24,353,955
N	$233,527,269	$ -	$47,628,127	$ -	$142,725,187	$ -	$15,665,585	$ -	$439,546,168	$ -
Y	$12,376,743	$12,376,743	$2,309,561	$2,309,561	$8,491,775	$8,491,775	$1,175,876	$1,175,876	$24,353,955	$24,353,955
1	$119,266,861	$8,405,663	$53,662,735	$1,044,360	$49,940,545	$1,597,468	$246,033	$8,885	$223,116,174	$11,056,376
N	$110,861,198	$ -	$52,618,375	$ -	$48,343,077	$ -	$237,148	$ -	$212,059,798	$ -
Y	$8,405,663	$8,405,663	$1,044,360	$1,044,360	$1,597,468	$1,597,468	$8,885	$8,885	$11,056,376	$11,056,376
2	$31,477,708	$1,457,093	$44,297,192	$1,830,026	$156,418,167	$7,028,274	$53,074	$7,736	$232,246,141	$10,323,129
N	$30,020,615	$ -	$42,467,166	$ -	$149,389,893	$ -	$45,338	$ -	$221,923,012	$ -
Y	$1,457,093	$1,457,093	$1,830,026	$1,830,026	$7,028,274	$7,028,274	$7,736	$7,736	$10,323,129	$10,323,129
Grand Total	$396,648,581	$22,239,499	$147,897,615	$5,183,947	$357,575,674	$17,117,517	$17,140,568	$1,192,497	$919,262,438	$45,733,460

APPENDIX D: STATISTICAL TESTING

One-way ANOVA: REJECT Quantitative versus Size

Method

Significance level	$\alpha = 0.05$

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Size	4	L, M, S, U

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.386885	0.08%	0.05%	0.00%

Means

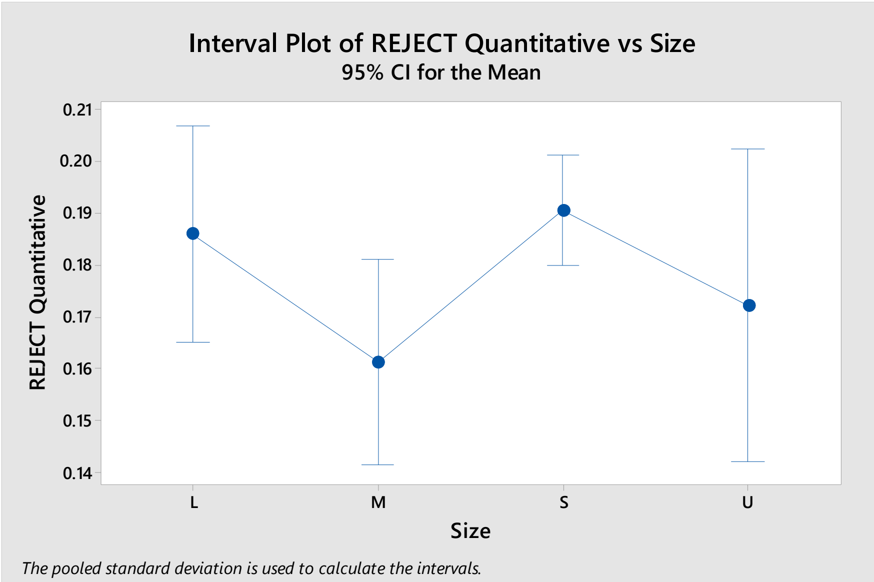
Size	N	Mean	StDev	95% CI
L	1323	0.1859	0.3892	(0.1651, 0.2068)
M	1476	0.16125	0.36788	(0.14151, 0.18099)
S	5098	0.19047	0.39271	(0.17985, 0.20109)
U	633	0.1722	0.3778	(0.1421, 0.2023)

Pooled StDev = 0.386885

Fisher Pairwise Comparisons
Grouping Information Using the Fisher LSD Method and 95% Confidence

Size	N	Mean	Grouping	
S	5098	0.19047	A	
L	1323	0.1859	A	B
U	633	0.1722	A	B
M	1476	0.16125		B

Means that do not share a letter are significantly different.


Interval Plot of REJECT Quantitative vs Size
95% CI for the Mean
REJECT Quantitative
0.21
0.20
0.19
0.18
0.17
0.16
0.15
0.14
L
M
S
U
Size
The pooled standard deviation is used to calculate the intervals.

One-way ANOVA: Units Rejected versus Size

Method

Significance level $\alpha = 0.05$

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Size	4	L, M, S, U

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1522.07	0.05%	0.01%	0.00%

Means

Size	N	Mean	StDev	95% CI
L	1323	73.7	1029.8	(-8.4, 155.7)
M	1476	24.71	352.49	(-52.95, 102.37)
S	5098	109.2	1875.0	(67.4, 151.0)
U	633	56.8	627.2	(-61.7, 175.4)

Pooled StDev = 1522.07

Fisher Pairwise Comparisons
Grouping Information Using the Fisher LSD Method and 95% Confidence

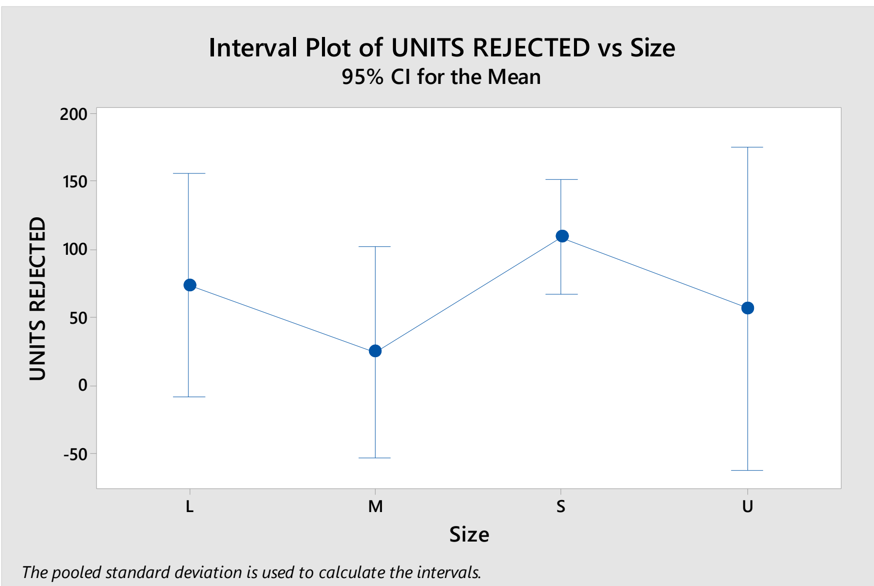
Size	N	Mean	Grouping
S	5098	109.2	A
L	1323	73.7	A
U	633	56.8	A
M	1476	24.71	A

Means that do not share a letter are significantly different.

Fisher Individual Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
M - L	-49.0	57.6	(-161.9, 64.0)	-0.85	0.395
S - L	35.5	47.0	(-56.6, 127.6)	0.76	0.450
U - L	-16.8	73.6	(-161.0, 127.4)	-0.23	0.819
S - M	84.5	45.0	(-3.7, 172.7)	1.88	0.060
U - M	32.1	72.3	(-109.6, 173.9)	0.44	0.657
U - S	-52.3	64.1	(-178.1, 73.4)	-0.82	0.415

Simultaneous confidence level = 79.68%



One-way ANOVA: REJECT Quantitative versus Accreditation

Method

Significance level α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Accreditation	3	0, 1, 2

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.387004	0.01%	0.00%	0.00%

Means

Accreditation	N	Mean	StDev	95% CI
0	5100	0.18196	0.38585	(0.17134, 0.19258)
1	1847	0.19058	0.39286	(0.17293, 0.20823)
2	1583	0.17941	0.38381	(0.16034, 0.19847)

Pooled StDev = 0.387004

Fisher Pairwise Comparisons
Grouping Information Using the Fisher LSD Method and 95% Confidence

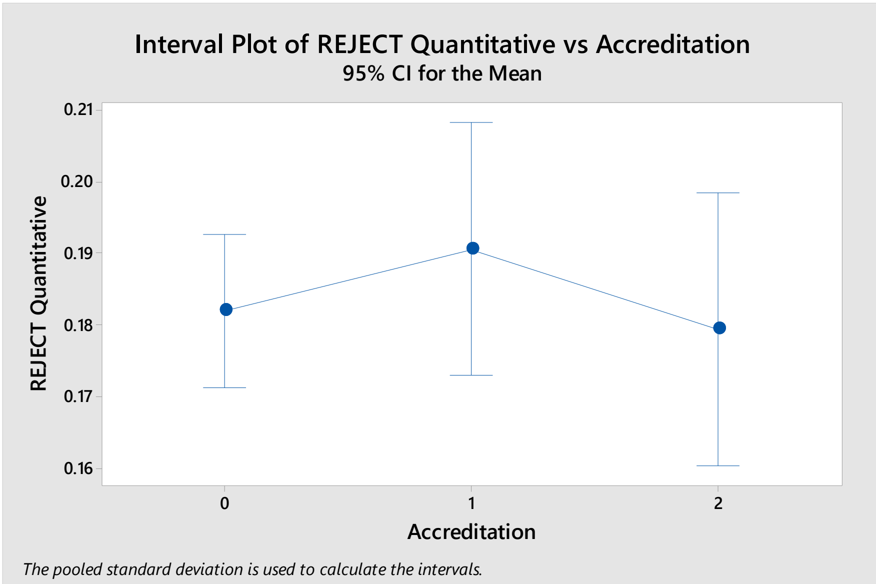
Accreditation	N	Mean	Grouping
1	1847	0.19058	A
0	5100	0.18196	A
2	1583	0.17941	A

Means that do not share a letter are significantly different.

Fisher Individual Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
1 - 0	0.0086	0.0105	(-0.0120, 0.0292)	0.82	0.412
2 - 0	-0.0026	0.0111	(-0.0244, 0.0193)	-0.23	0.819
2 - 1	-0.0112	0.0133	(-0.0372, 0.0148)	-0.84	0.399

Simultaneous confidence level = 87.78%


Interval Plot of REJECT Quantitative vs Accreditation
95% CI for the Mean
REJECT Quantitative
0.21
0.20
0.19
0.18
0.17
0.16
0
1
2
Accreditation
The pooled standard deviation is used to calculate the intervals.

One-way ANOVA: Units Rejected versus Accreditation

Method

Significance level α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Accreditation	3	0, 1, 2

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1522.03	0.04%	0.02%	0.00%

Means

Accreditation	N	Mean	StDev	95% CI
0	5100	94.6	1694.0	(52.8, 136.3)
1	1847	112.5	1635.4	(43.1, 181.9)
2	1583	23.01	340.44	(-51.97, 98.00)

Pooled StDev = 1522.03

Fisher Pairwise Comparisons
Grouping Information Using the Fisher LSD Method and 95% Confidence

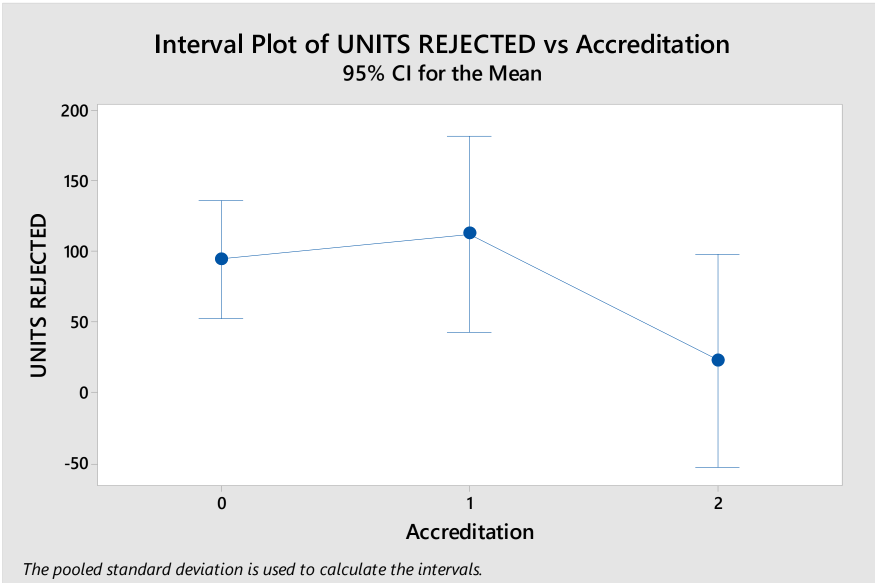
Accreditation	N	Mean	Grouping
1	1847	112.5	A
0	5100	94.6	A
2	1583	23.01	A

Means that do not share a letter are significantly different.

Fisher Individual Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
1 - 0	17.9	41.3	(-63.1, 99.0)	0.43	0.664
2 - 0	-71.5	43.8	(-157.4, 14.3)	-1.63	0.102
2 - 1	-89.5	52.1	(-191.7, 12.7)	-1.72	0.086

Simultaneous confidence level = 87.78%


Interval Plot of UNITS REJECTED vs Accreditation
95% CI for the Mean
200
150
100
50
0
-50
UNITS REJECTED
0
1
2
Accreditation
The pooled standard deviation is used to calculate the intervals.

General Linear Model: REJECT Quantitative versus Size, Accreditation

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Size	Fixed	4	L, M, S, U
Accreditation	Fixed	3	0, 1, 2

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.386633	0.31%	0.18%	0.02%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.1819	0.0143	12.71	0.000	
Size					
L	0.0041	0.0163	0.25	0.799	3.36
M	-0.0231	0.0160	-1.44	0.149	3.48
S	0.0107	0.0151	0.71	0.478	5.16
Accreditation					
0	-0.0033	0.0149	-0.22	0.825	7.77
1	0.0115	0.0184	0.62	0.533	7.76
Size*Accreditation					
L 0	0.0062	0.0180	0.35	0.730	3.31
L 1	-0.0374	0.0215	-1.74	0.082	2.40
M 0	0.0167	0.0178	0.94	0.349	3.49
M 1	-0.0404	0.0213	-1.90	0.057	2.84
S 0	-0.0046	0.0159	-0.29	0.773	7.06
S 1	0.0203	0.0196	1.03	0.302	4.57

Regression Equation

MIR = 0.1819 + 0.0041 Size_L - 0.0231 Size_M + 0.0107 Size_S + 0.0083 Size_U
- 0.0033 Accreditation_0 + 0.0115 Accreditation_1
- 0.0082 Accreditation_2 + 0.0062 Size*Accreditation_L 0
- 0.0374 Size*Accreditation_L 1 + 0.0312 Size*Accreditation_L 2
+ 0.0167 Size*Accreditation_M 0 - 0.0404 Size*Accreditation_M 1
+ 0.0237 Size*Accreditation_M 2 - 0.0046 Size*Accreditation_S 0
+ 0.0203 Size*Accreditation_S 1 - 0.0157 Size*Accreditation_S 2
- 0.0183 Size*Accreditation_U 0 + 0.0575 Size*Accreditation_U 1
- 0.0392 Size*Accreditation_U 2

General Linear Model: Units Rejected versus Size, Accreditation

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Size	Fixed	4	L, M, S, U
Accreditation	Fixed	3	0, 1, 2

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1522.23	0.12%	0.00%	0.00%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	57.8	56.4	1.02	0.305	
Size					
L	5.7	64.0	0.09	0.929	3.36
M	-33.2	63.1	-0.53	0.599	3.48
S	41.0	59.3	0.69	0.490	5.16
Accreditation					
0	17.8	58.7	0.30	0.762	7.77
1	22.3	72.5	0.31	0.758	7.76
Size*Accreditation					
L 0	42.0	70.9	0.59	0.554	3.31
L 1	-26.9	84.7	-0.32	0.751	2.40
M 0	-30.4	70.1	-0.43	0.665	3.49
M 1	-34.2	83.7	-0.41	0.683	2.84
S 0	-6.2	62.4	-0.10	0.921	7.06
S 1	52.4	77.3	0.68	0.498	4.57

Regression Equation

Units Rejected = 57.8 + 5.7 Size_L - 33.2 Size_M + 41.0 Size_S - 13 Size_U
+ 17.8 Accreditation_0 + 22.3 Accreditation_1 - 40 Accreditation_2
+ 42.0 Size*Accreditation_L 0 - 26.9 Size*Accreditation_L 1
- 15 Size*Accreditation_L 2 - 30.4 Size*Accreditation_M 0
- 34.2 Size*Accreditation_M 1 + 65 Size*Accreditation_M 2
- 6.2 Size*Accreditation_S 0 + 52.4 Size*Accreditation_S 1
- 46 Size*Accreditation_S 2 - 5 Size*Accreditation_U 0
+ 9 Size*Accreditation_U 1 - 3 Size*Accreditation_U 2

APPENDIX E: STATISTICAL TESTING FOR LOT SIZE VARIATIONS

One-way ANOVA: REJECT Quantitative versus Size lot size 10 or less

Method

Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Size	4	L, M, S, U

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.410372	0.27%	0.19%	0.05%

Means

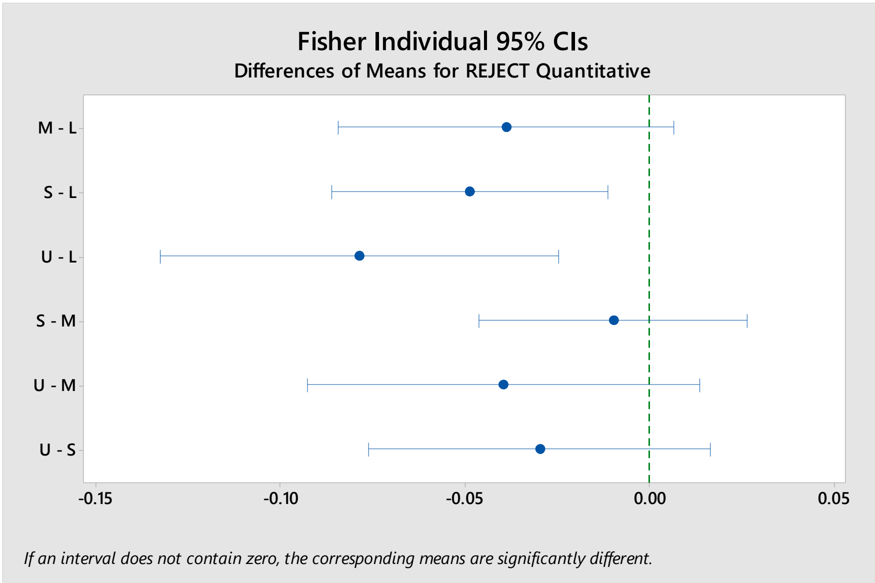
Size	N	Mean	StDev	95% CI
L	604	0.2566	0.4371	(0.2239, 0.2894)
M	648	0.2176	0.4129	(0.1860, 0.2492)
S	1983	0.20777	0.40581	(0.18970, 0.22583)
U	354	0.1780	0.3830	(0.1352, 0.2207)

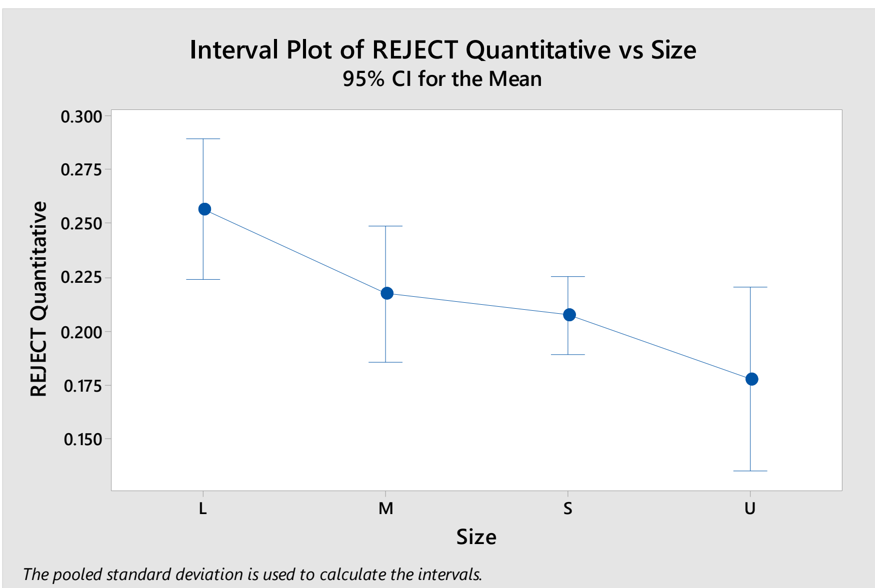
Pooled StDev = 0.410372

Fisher Pairwise Comparisons
Grouping Information Using the Fisher LSD Method and 95% Confidence

Size	N	Mean	Grouping	
L	604	0.2566	A	
M	648	0.2176	A	B
S	1983	0.20777		B
U	354	0.1780		B

Means that do not share a letter are significantly different.


Fisher Individual 95% CIs
Differences of Means for REJECT Quantitative
M - L
S - L
U - L
S - M
U - M
U - S
-0.15
-0.10
-0.05
0.00
0.05
If an interval does not contain zero, the corresponding means are significantly different.


Interval Plot of REJECT Quantitative vs Size
95% CI for the Mean
REJECT Quantitative
0.300
0.275
0.250
0.225
0.200
0.175
0.150
L
M
S
U
Size
The pooled standard deviation is used to calculate the intervals.

One-way ANOVA: REJECT Quantitative versus Accreditation lot size 10 or less

Method

Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Accreditation	3	0, 1, 2

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.310114	0.82%	0.57%	0.16%

Means

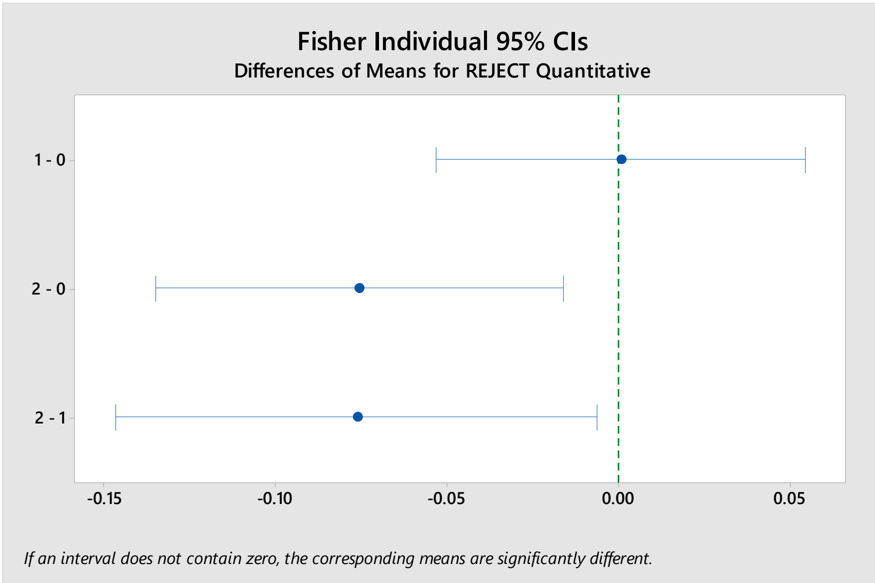
Accreditation	N	Mean	StDev	95% CI
0	497	0.1207	0.3261	(0.0934, 0.1480)
1	173	0.1214	0.3275	(0.0751, 0.1677)
2	133	0.0451	0.2083	(-0.0077, 0.0979)

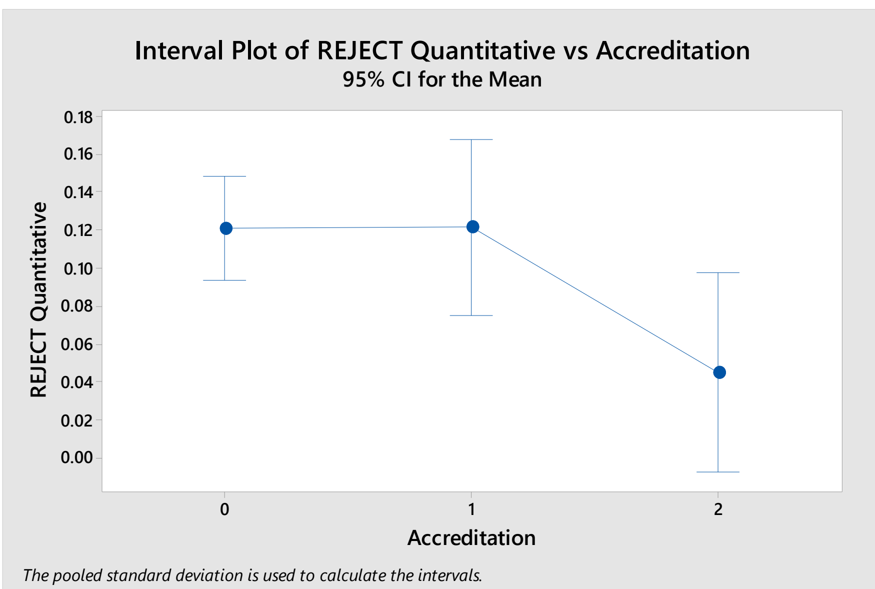
Pooled StDev = 0.310114

Fisher Pairwise Comparisons
Grouping Information Using the Fisher LSD Method and 95% Confidence

Accreditation	N	Mean	Grouping	
1	173	0.1214	A	
0	497	0.1207	A	
2	133	0.0451		B

Means that do not share a letter are significantly different.


Fisher Individual 95% CIs
Differences of Means for REJECT Quantitative
1 - 0
2 - 0
2 - 1
-0.15
-0.10
-0.05
0.00
0.05
If an interval does not contain zero, the corresponding means are significantly different.


Interval Plot of REJECT Quantitative vs Accreditation
95% CI for the Mean
REJECT Quantitative
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
1
2
Accreditation
The pooled standard deviation is used to calculate the intervals.

One-way ANOVA: REJECT Quantitative versus Size lot size more than 10 less than 100

Method

Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Size	4	L, M, S, U

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.378721	0.98%	0.86%	0.69%

Means

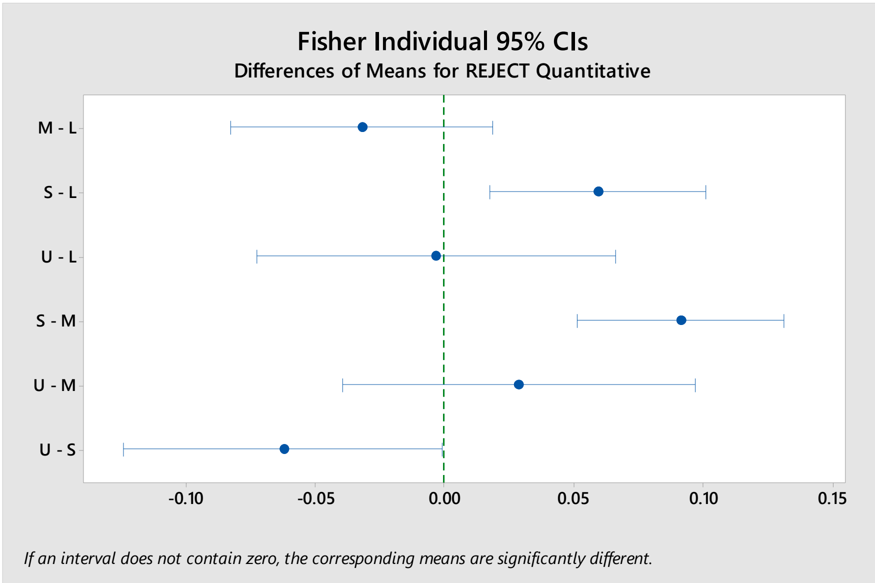
Size	N	Mean	StDev	95% CI
L	403	0.1464	0.3539	(0.1094, 0.1834)
M	455	0.1143	0.3185	(0.0795, 0.1491)
S	1490	0.2054	0.4041	(0.1861, 0.2246)
U	161	0.1429	0.3510	(0.0843, 0.2014)

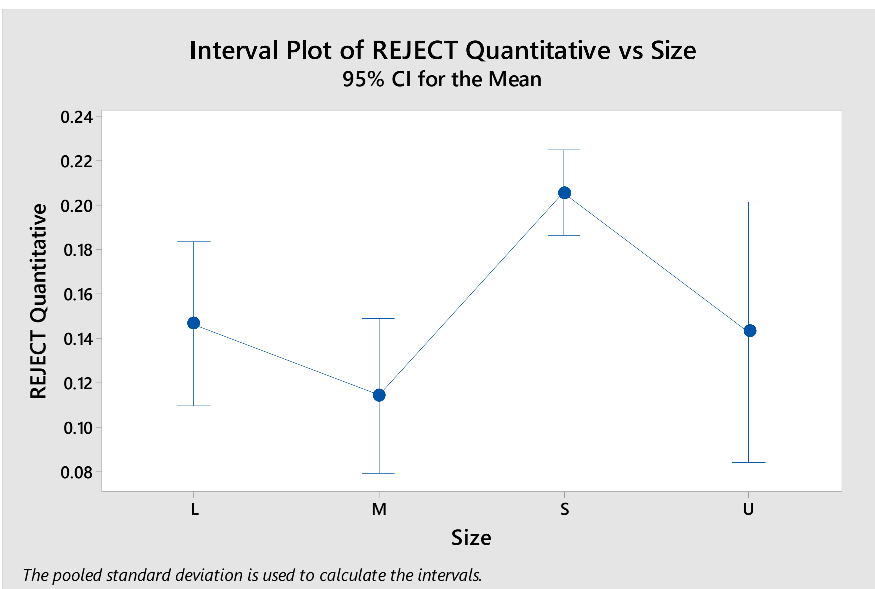
Pooled StDev = 0.378721

Fisher Pairwise Comparisons
Grouping Information Using the Fisher LSD Method and 95% Confidence

Size	N	Mean	Grouping	
S	1490	0.2054	A	
L	403	0.1464		B
U	161	0.1429		B
M	455	0.1143		B

Means that do not share a letter are significantly different.


Fisher Individual 95% CIs
Differences of Means for REJECT Quantitative
M - L
S - L
U - L
S - M
U - M
U - S
-0.10
-0.05
0.00
0.05
0.10
0.15
If an interval does not contain zero, the corresponding means are significantly different.


Interval Plot of REJECT Quantitative vs Size
95% CI for the Mean
REJECT Quantitative
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
L
M
S
U
Size
The pooled standard deviation is used to calculate the intervals.

One-way ANOVA: Units Rejected versus Size lots size more than 10 less than 100

Method

Significance level α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Size	4	L, M, S, U

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
17.2541	1.12%	1.00%	0.86%

Means

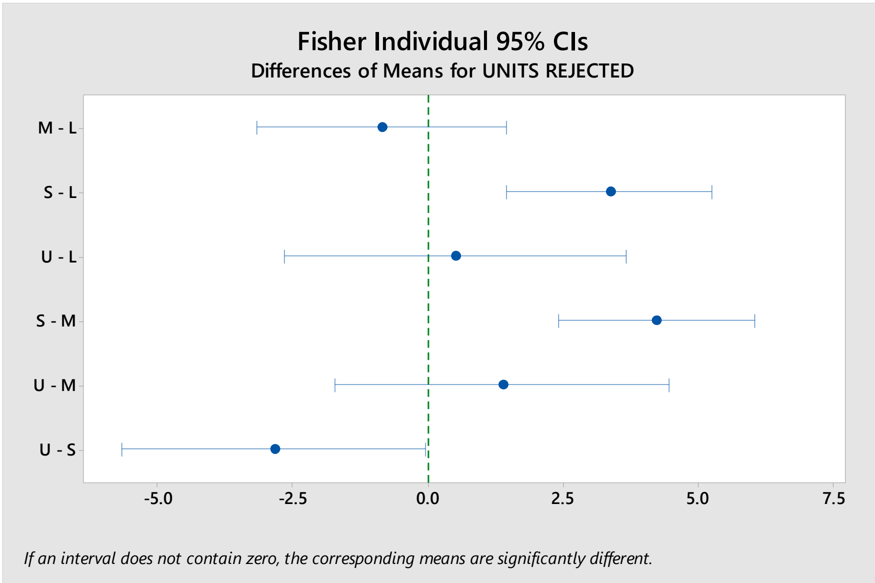
Size	N	Mean	StDev	95% CI
L	403	4.605	13.212	(2.920, 6.291)
M	455	3.741	13.136	(2.155, 5.327)
S	1490	7.964	19.385	(7.087, 8.840)
U	161	5.11	15.35	(2.44, 7.77)

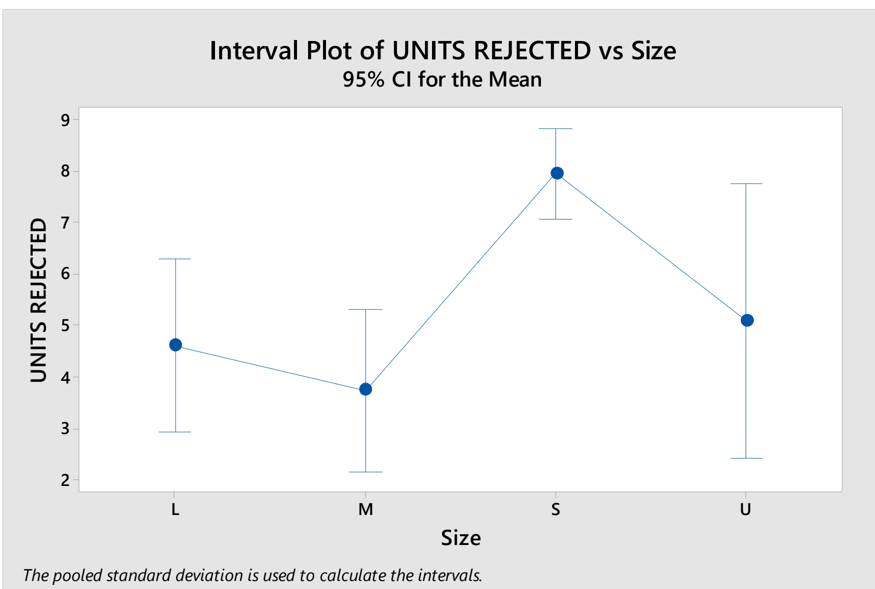
Pooled StDev = 17.2541

Fisher Pairwise Comparisons
Grouping Information Using the Fisher LSD Method and 95% Confidence

Size	N	Mean	Grouping	
S	1490	7.964	A	
U	161	5.11		B
L	403	4.605		B
M	455	3.741		B

Means that do not share a letter are significantly different.


Fisher Individual 95% CIs
Differences of Means for UNITS REJECTED
M - L
S - L
U - L
S - M
U - M
U - S
-5.0
-2.5
0.0
2.5
5.0
7.5
If an interval does not contain zero, the corresponding means are significantly different.


Interval Plot of UNITS REJECTED vs Size
95% CI for the Mean
UNITS REJECTED
9
8
7
6
5
4
3
2
L
M
S
U
Size
The pooled standard deviation is used to calculate the intervals.

One-way ANOVA: REJECT Quantitative versus Size lot size more than 100 through 1000

Method

Significance level α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Size	4	L, M, S, U

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.361650	0.66%	0.47%	0.18%

Means

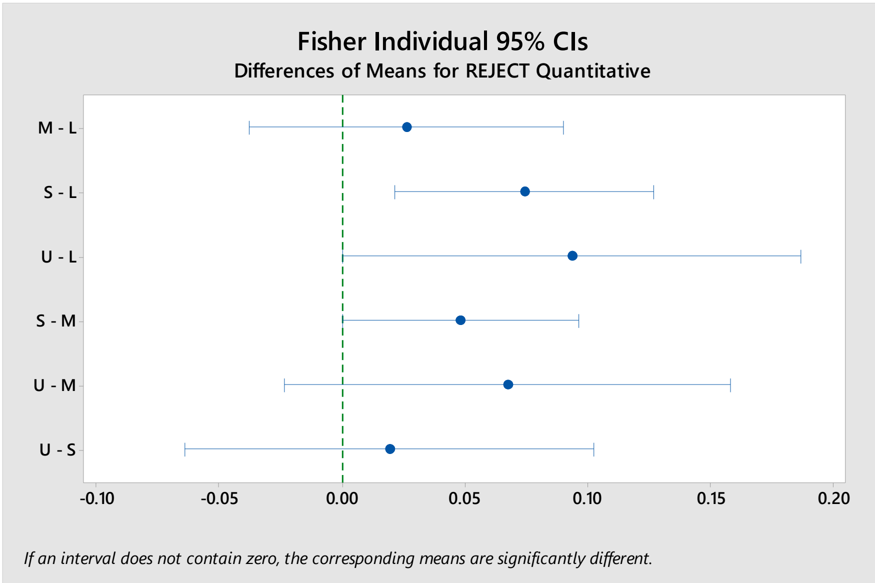
Size	N	Mean	StDev	95% CI
L	222	0.0991	0.2995	(0.0515, 0.1467)
M	280	0.1250	0.3313	(0.0826, 0.1674)
S	1034	0.1731	0.3785	(0.1511, 0.1952)
U	78	0.1923	0.3967	(0.1120, 0.2726)

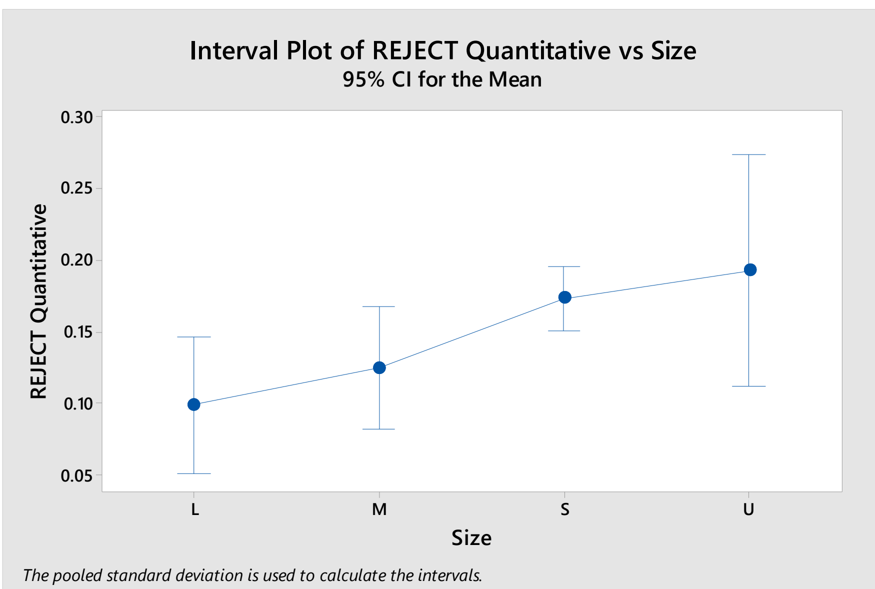
Pooled StDev = 0.361650

Fisher Pairwise Comparisons
Grouping Information Using the Fisher LSD Method and 95% Confidence

Size	N	Mean	Grouping		
U	78	0.1923	A	B	C
S	1034	0.1731	A		
M	280	0.1250			C
L	222	0.0991		B	C

Means that do not share a letter are significantly different.


Fisher Individual 95% CIs
Differences of Means for REJECT Quantitative
M - L
S - L
U - L
S - M
U - M
U - S
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
If an interval does not contain zero, the corresponding means are significantly different.


Interval Plot of REJECT Quantitative vs Size
95% CI for the Mean
REJECT Quantitative
0.30
0.25
0.20
0.15
0.10
0.05
L
M
S
U
Size
The pooled standard deviation is used to calculate the intervals.

One-way ANOVA: Units Rejected versus Size lot size more than 100 through 1000

Method

Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Size	4	L, M, S, U

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
160.726	0.70%	0.52%	0.27%

Means

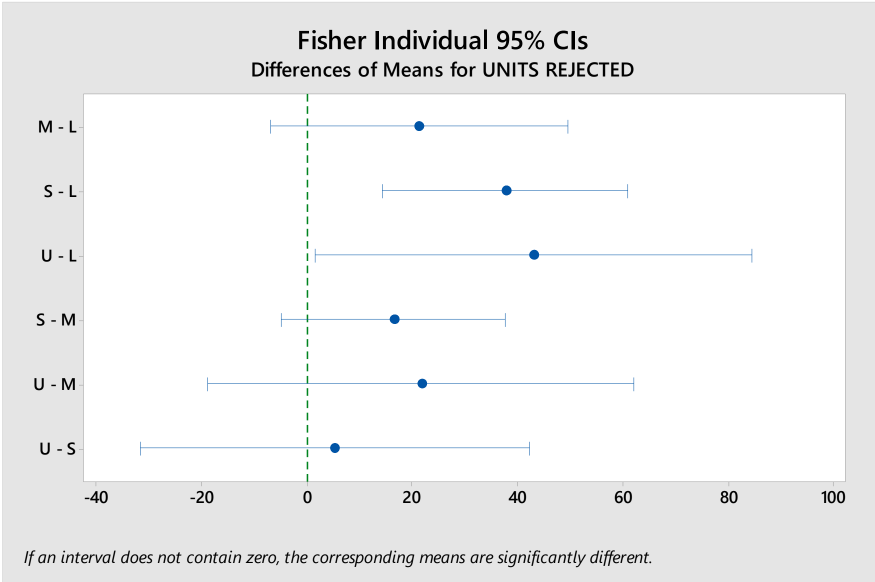
Size	N	Mean	StDev	95% CI
L	222	23.82	103.35	(2.66, 44.98)
M	280	45.08	149.94	(26.24, 63.92)
S	1034	61.44	173.02	(51.63, 71.24)
U	78	66.7	162.5	(31.0, 102.4)

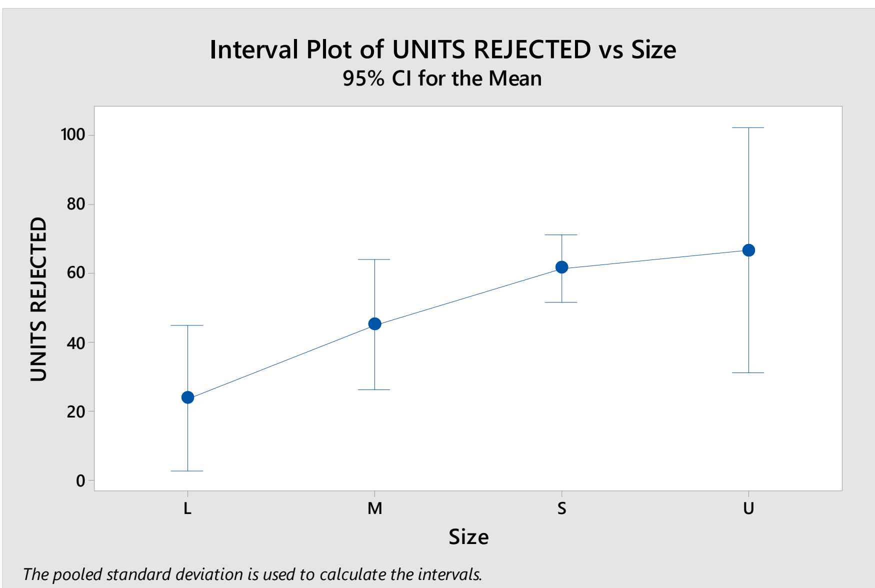
Pooled StDev = 160.726

Fisher Pairwise Comparisons
Grouping Information Using the Fisher LSD Method and 95% Confidence

Size	N	Mean	Grouping	
U	78	66.7	A	
S	1034	61.44	A	
M	280	45.08	A	B
L	222	23.82		B

Means that do not share a letter are significantly different.


Fisher Individual 95% CIs
Differences of Means for UNITS REJECTED
M - L
S - L
U - L
S - M
U - M
U - S
-40
-20
0
20
40
60
80
100
If an interval does not contain zero, the corresponding means are significantly different.


Interval Plot of UNITS REJECTED vs Size
95% CI for the Mean
UNITS REJECTED
100
80
60
40
20
0
L
M
S
U
Size
The pooled standard deviation is used to calculate the intervals.

One-way ANOVA: REJECT Quantitative versus Accreditation lot size more than 100 through 1000

Method

Significance level $\alpha = 0.05$

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Accreditation	3	0, 1, 2

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.361996	0.41%	0.28%	0.05%

Means

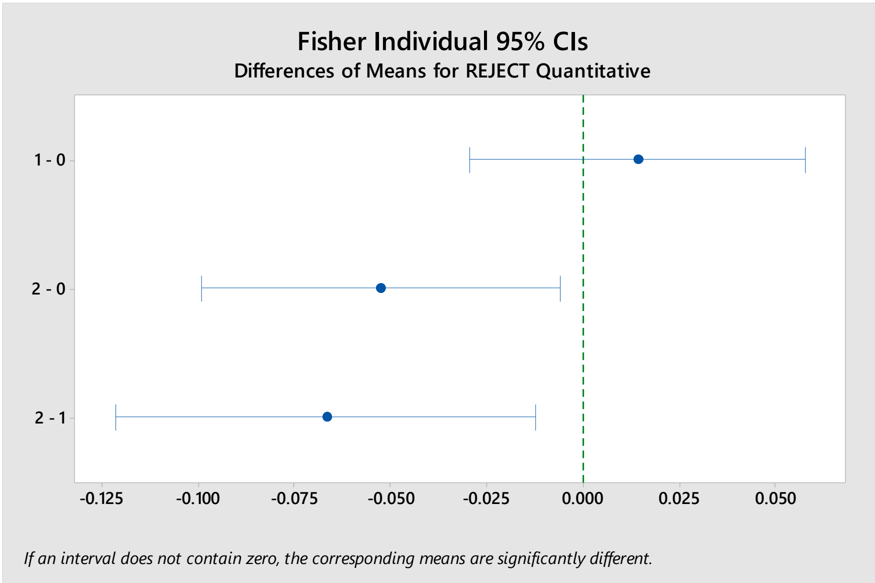
Accreditation	N	Mean	StDev	95% CI
0	930	0.1624	0.3690	(0.1391, 0.1856)
1	374	0.1765	0.3817	(0.1398, 0.2132)
2	310	0.1097	0.3130	(0.0694, 0.1500)

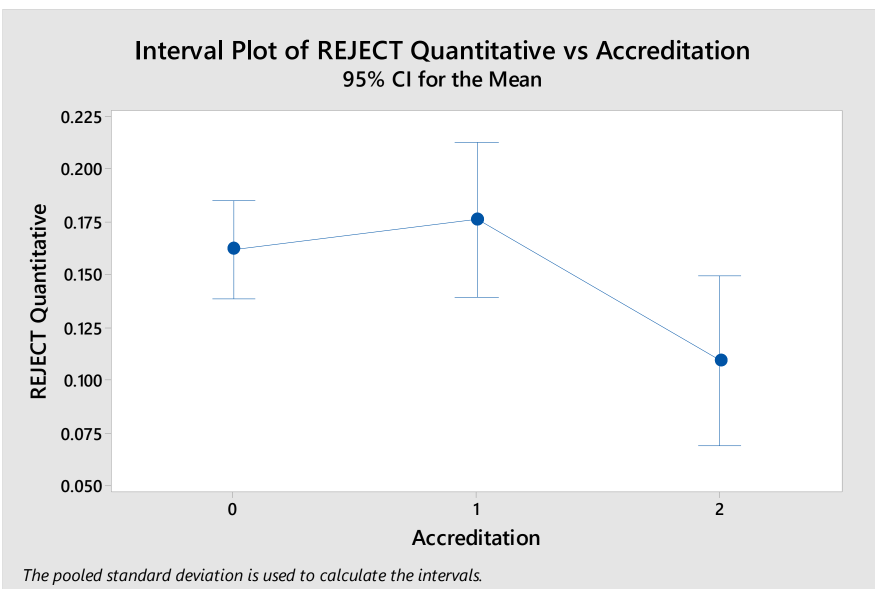
Pooled StDev = 0.361996

Fisher Pairwise Comparisons
Grouping Information Using the Fisher LSD Method and 95% Confidence

Accreditation	N	Mean	Grouping	
1	374	0.1765	A	
0	930	0.1624	A	
2	310	0.1097		B

Means that do not share a letter are significantly different.


Fisher Individual 95% CIs
Differences of Means for REJECT Quantitative
1 - 0
2 - 0
2 - 1
-0.125
-0.100
-0.075
-0.050
-0.025
0.000
0.025
0.050
If an interval does not contain zero, the corresponding means are significantly different.


Interval Plot of REJECT Quantitative vs Accreditation
95% CI for the Mean
REJECT Quantitative
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0
1
2
Accreditation
The pooled standard deviation is used to calculate the intervals.

One-way ANOVA: REJECT Quantitative versus Accreditation lot size more than 1000

Method

Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Accreditation	3	0, 1, 2

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.310114	0.82%	0.57%	0.16%

Means

Accreditation	N	Mean	StDev	95% CI
0	497	0.1207	0.3261	(0.0934, 0.1480)
1	173	0.1214	0.3275	(0.0751, 0.1677)
2	133	0.0451	0.2083	(-0.0077, 0.0979)

Pooled StDev = 0.310114

Fisher Pairwise Comparisons
Grouping Information Using the Fisher LSD Method and 95% Confidence

Accreditation	N	Mean	Grouping	
1	173	0.1214	A	
0	497	0.1207	A	
2	133	0.0451		B

Means that do not share a letter are significantly different.