# MAXIMIZING FINANCIAL BENEFIT OF LEAN SIX SIGMA PROJECTS THROUGH OPTIMIZED SELECTION CRITERIA

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by

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Army Strong!

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<u>Maximizing Financial Benefit of Lean Six Sigma Projects through Optimized Selection Criteria</u>

Advisor: Professor Eli Olinick, Ph.D.

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As evolving threats across the globe keep pace with increasing budget constraints, the US Army's major subordinate commands and their sub-organizations are constantly challenged to do more with less. Resources such as human capital, information technology, facilities, and budgeted funding are stretched as thin as ever, while requirements to serve the Warfighter remain paramount. Each dollar of financial benefit gained through cost reduction efforts at the US Army can affect the Warfighter directly. Budgeted money saved or avoided is reprogrammed both locally and atop the hierarchy at the Department of Treasury to serve the Warfighter better.

Ordinal Logistic Regression was performed to analyze the selection criteria and financial benefit results from Lean Six Sigma projects executed within the US Army's Tank-Automotive and Armaments Lifecycle Management Command (TACOM LCMC). TACOM LCMC Headquarters, its depots, arsenals, Program Executive Offices, and logistics center reported over $366,000,000 in total Continuous Performance

Improvement (CPI) financial benefit in fiscal year 16. Seventeen selection criteria from an array of scholarly articles, textbooks, and proprietary industry sources were analyzed retroactively against TACOM's FY16 results.

The study produced a number of organization-specific results, as well as a modular process that can be used in any industry to analyze project selection criteria and their effect on an ordinal output. In the case of all FY16 TACOM LCMC projects, it was found that projects initially selected with the factors of a predicted high financial benefit or strong internal documentation of poor performance led to the highest probability of yielding $1M or more in financial benefit. Projects selected with factors of a three month timeline or internal-only focus led to lower financial benefit results.

This analysis was also performed on non-gated LSS projects executed within the TACOM LCMC's depots and arsenals. This analysis case resulted in the significant factors of having the right non-human capital resources in place or the prediction of a high benefit corresponding to a positive odds ratio, and again the restriction of a three month timeline which corresponded to a negative odds ratio with respect to achieving the highest financial benefit.

Additionally, the Army-specific output measure of readiness was analyzed across all projects. This study found that factors such as a predicted high financial benefit, strong leadership buy in, external gap-focused, and the consideration of readiness yielded a greater probability of achieving the highest levels of readiness when a given project was complete. Factors such as stretch goals and internal gap-focused decreased the likelihood of positively affecting readiness.

The specific results and underlying process presented in this Praxis will enable US Army CPI leaders to make better informed decisions which will result in achieving maximum financial benefit for the betterment of the Warfighter, the Army, Department of Defense, and United States.

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# CHAPTER 1

# INTRODUCTION

On March 13, 2017, United States President Donald Trump signed an executive order tasking federal agencies with reducing waste through reevaluation and reorganization. According to the President at the time of signing the order, every executive branch agency will be called upon to “identify where money can be saved and services improved” (Katz, 2017, para. 2).

The U.S. Army uses a combination of Continuous Performance Improvement (CPI) tools to reduce costs and remove waste from its processes and products. The tools used are Lean Six Sigma (LSS) and Value Engineering (VE; U.S. Army Office of Business Transformation [OBT], 2007). In this section, the background and practical application of both tools and their governing programs will be discussed. Following this section, practitioners’ training and methods for selecting qualified projects are presented.

Lean Six Sigma is defined as a management discipline combining the ideals of working better (Six Sigma) and working faster (Lean; OBT, 2007). Six Sigma and its tools focus on centering a process’ output on a target while reducing variation. Lean tools aim to remove waste, such as transportation, inventory, motion, waiting, over-processing, overproduction, and defects. By combining disciplines into one approach, many Fortune 500 companies and public organizations have experienced increased customer satisfaction and lower costs through defect and process lead-time reduction.


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Value Engineering is a method used to reduce product cost through functional analysis. Whereas LSS focuses on improving the process, VE focuses on improving the product. Lawrence Miles (2015), the originator of the term “Value Analysis,” defines VE as a method to assess the function of a product, facility, or process to determine ways to provide the needed functions in a cost effective manner. Public Law 104-106 (National Defense Authorization Act for Fiscal Year 1996) defined VE as the analysis of the functions of a program, project, system, product, or item of equipment, building, facility, service, or supply of an executive agency performed by qualified agency or contractor personnel, directed at improving performance, reliability, quality, safety, and life cycle costs.

### 1.1. Overview of Army CPI

VE and LSS contribute to the U.S. Army’s mission by lowering costs of processes and products, allowing higher leadership to re-allocate or budget monetary and time savings to serve the Warfighter better. The focus of this research is on the LSS program, and how projects are selected by the organization.

“The goal of the Lean Six Sigma deployment, which includes civilians and contractors as well as active duty, Army Reserve and National Guard personnel, is to “make the business side of the Army as efficient as the war-fighting side is effective” (Rezek as cited in Schmidt, n.d., para. 5). The U.S. Army is now examining its processes as business transactions, even down to an individual solider. Every time a soldier is paid, supplied, moved from point A to point B, a process has been executed and a transaction has occurred.

In 2006 the Department of Army developed a Lean Six Sigma program that is supported throughout all of its major commands. The Army OBT is the headquarters for training, certification, and metrics of the program and its practitioners. Common training, project tracking, and continuous process improvement are pillars of the program that has seen more than 7,000 individuals' complete forms of the training.

The Army CPI organizational hierarchy has well-defined roles. The Army's CPI program relies heavily on senior leaders to assume responsibility for setting the pace and direction of the programs and projects. Senior leaders are accountable for the results of CPI programs, and are often evaluated on their results. For example, in fiscal year (FY) 2016, the TACOM Deputy Commanding General reported over $366 million in financial benefits resulting from CPI efforts. Senior leaders also allocate or delegate the responsibility for resources to attend training and work projects that would not normally be included in regular job duties.

Strategic Leadership ultimately sets the stage for Deployment Directors to arrange resources to meet the overall need of the organization. Deployment Directors are typically experienced CPI professionals who oversee a deployment plan for their organization. Their responsibilities include managing resources, meeting deadlines, and maintaining the overall CPI project portfolio. The Deployment Director ensures that project teams are properly staffed with mentors and resource managers, who validate a projects financial benefit claims.

The organizational hierarchy is divided into levels that are designated with colored belts. For example, Master Black Belts (MBB) report to Deployment Directors and can be found at various levels of an organization. They are responsible for leading complex projects and identifying future projects. A major aspect of the MBB role is mentoring Black and Green Belt candidates through certification. A typical workload for an MBB can include mentoring as many as five individuals with lower-level belts, while leading two to three projects at a time.

Black and Green Belt associates comprise the ground troop aspect of the Army's LSS program. These associates are deployed to solve complex issues using standardized methods and tools. Black and Green Belt associates report to their own leadership, as well as MBBs and other subject matter experts to accomplish tasks, leading to the development and implementation of an improved product or process.

### 1.2. Lean Six Sigma Training

CPI programs rely heavily on human capital. The importance of LSS methodology and tools training was abundant in the literature review completed for this research. The U.S. Army LSS training program has resulted in over 600 Green Belt associates, 500 Black Belt associates, and nearly 140 MBBs at the time of this research. While substantially greater numbers of individuals attempt to complete training at each belt level, less actually complete the program's certification requirements, and fewer remain in a LSS-relevant role. For example, 92 MBBs were active practitioners at the time of this research. LSS training is consistent for all Army civilians and military members; with consistent course materials, methodologies, and tools used in the instructional process, regardless of application or location.

Green Belt training is a two-week course that provides applicants with an understanding of LSS principles and tools, as well as project management fundamentals. Successful graduates can become active contributors to Black Belt projects and lead small-scope LSS projects. Topics of the training include: establishing effective improvement teams; understanding the voice of the customer; and implementing the Define, Measure, and Analyze, Improve, and Control (DMAIC) methodology. The training incorporates a three-week break between the two weeks to allow candidates to work on their assigned LSS projects.

Black Belt training is a four-week course that builds on the Green Belt course and familiarizes students with the principles, practices, and tools of LSS to maximize cost reductions and improve customer satisfaction. Covered topics include an overview of LSS, as well as all aspects of traditional DMAIC methodology and tools. Associates who successfully complete the course are expected to be able to identify non-value-added activities and lead teams tackling larger scoped and more complex projects. The Black Belt curriculum accommodates students with no prior LSS experience as the Green Belt training is not a prerequisite for course attendance. A three-week break is incorporated between each of the four weeks of training to allow candidates to work on their assigned LSS projects.

Master Black Belt training is a three-week course that builds on the Black Belt course. MBB training and certification provides the foundation for Army organizations to have in-house experts to disseminate LSS policy, execute enterprise-level projects and provide support to training. Successful MBB graduates also provide coaching and mentoring to Strategic Leaders, Deployment Directors, Process Owners, Project


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Sponsors, Black Belts and Green Belts. Topics covered in the MBB curriculum include teaching and coaching LSS; reinforcing behavioral concepts; and LSS curriculum —teach backs, in which students instruct their peers. All MBB candidates (MBBc) must first be certified as an Army Black Belt to attempt the course and certification. In addition to LSS skills and knowledge, MBBs must demonstrate leadership ability, organizational and management abilities, good instructional techniques, group facilitation skills and organizational change skills before being admitted into the training (Army Lean Six Sigma Deployment Guidebook, 38). There is generally a three-week break between each week of training so that candidates can work on their second LSS DMAIC project.

A testament to the training, in FY 16, there were 29 Green Belt, 29 Black Belt, and 4 Master Black Belt training courses scheduled and executed. The typical class size is around 30 students for the Green and Black Belt programs, and 10 to 15 students for the Master Black Belt program. Two full time instructors split the workload of training the belt candidates while a Deployment Director who is a senior MBB is typically on hand to support as needed.

The Army Master Black Belt exam is comprehensive and includes material from all belt-levels; the 6.5-hour test encompasses non-parametric statistics, Lean methodologies, coaching, teaching, and extensive use of the Minitab statistical software. Students may use only their statistics books and course notes while attempting the proctored exam. Historically, there is a 66% pass rate for Master Black Belts sitting for the exam, and even lower rates become full-fledged Master Black Belts. Because of their expertise and leadership qualities, Army MBBs are often poached by outside


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organizations offering lucrative career opportunities, leaving gaps in the Army's CPI project deployment.

Additionally, certified MBBs often use the training and certification processes, as well as the organizational publicity, to advance to higher level positions, often leading them outside of the CPI realm. At the time of this research, over one-third of the Army certified MBB population were no longer involved in CPI inside the Federal Government.

**1.3. LSS Project Selection**

One critical aspect of the MBB role is to facilitate the selection of LSS projects for execution. While ultimately at the discretion of leadership, MBBs are called on to give input towards the selection of projects for both new and experienced Belts to lead. The Army CPI program recognizes two sub-groups of LSS projects, "gated" and "non-gated."

Gated projects follow the Define Measure Analyze Improve Control (DMAIC) construct, where the term "gated" comes from the mandatory tollgate meeting between each phase. A tollgate is intended for the process owner, champion, and other key stakeholders to review the progress of the project team, and give a go or no-go decision on continuing the effort. This practice allows close examination of resources and facilitates discussion on the perceived outcomes of the effort as it progresses through the DMAIC phases. Typical gated projects require anywhere from 6-12 months of full time effort for a belt, or belt candidate, and are assigned MBB mentors to ensure the proper use of the DMAIC methodology and its tools.  In addition to the tollgate meetings, gated projects are carefully monitored from their selection through completion and reporting of operational and financial benefit by Deployment Directors by monthly or weekly sync meetings.

Gated projects are required for all Army LSS Belts seeking certification.  Every training module within the Army's LSS program of instruction can be linked back to various stages of the DMAIC philosophy, providing LSS students a roadmap for linking the proper tools together and increasing the probability of successful completion of a project.  Because of the rigorous and resource-intensive nature of gated LSS projects, the Army has adopted a common project selection process.  The formal Project Identification and Selection Workshop (PISW) is executed by senior leaders, MBBs, and process owners to match process improvement opportunities to Belt candidates.  The selection criteria for gated LSS projects are defined through the PISW process as relating to the organization's strategic, financial, customer and process-focused "value levers," (Army Lean Six Sigma Deployment Guidebook, 46).

After a Belt achieves certification status, he or she is immediately eligible to complete "non-gated" style process improvement projects to be counted towards an organization's CPI goal.  Certified Belts have demonstrated the skills and abilities to complete a gated project, pass a rigorous project review process, and are now entrusted with executing additional projects, some in a full-time capacity.  Because there is no formal certification sought by completing a non-gated project, the methodologies and tools used can vary from project to project.  Often, non-gated projects are smaller in scope, requiring less resources than a gated project. A non-gated project may be ideated, selected, initiated, and then completed with minimal oversight from leadership. The focus of non-gated efforts center on the output results of the project itself.

The selection criteria for non-gated LSS projects in the Army are not defined nor optimized for the greatest financial benefit. In fact, in the Army's LSS Deployment Guidebook, non-gated projects are only briefly mentioned and given standard template treatments, but no selection methodology nor selection criteria are outlined.

A visualization of the current CPI project selection process is displayed in Figure 1.1. Based on a number of internal stakeholder interviews, it was determined that the LSS gated project selection process within TACOM LCMC followed a relatively common process within each sub-organization. Project ideas are generated, captured, and commissioned after selection. After projects are completed, the total benefits are validated and reported. However, it was also clear during initial discussions that the process to decide which CPI projects to pursue did not always follow the PISW process exactly for gated projects, and non-gated projects were in most cases selected by ad-hoc criteria at best. The table depicted in the middle of the visualization depicts the sub-organizations CPI project selection committee.

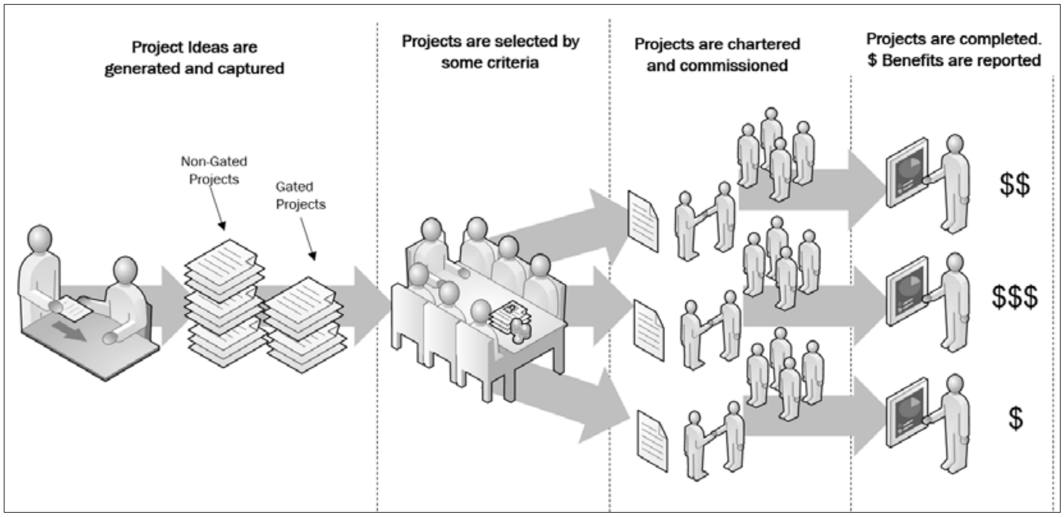


Figure 1.1. LSS Project Selection Visualization

## 1.4 TACOM LCMC Organization Overview

In this section an overview of each organization within the TACOM LCMC CPI reporting group that comprises the scope of this research will be defined. In total the results of nine organizations will be studied and analyzed. The organizations included in this research are commanded by a single governing body for all CPI related manners; the TACOM LCMC CPI steering committee on which the author of this research sits. It has been previously concluded that each individual organization has been given latitude to execute their own programs so long as they meet financial benefit targets which are assigned annually in October. While the scope of this particular research is limited to these nine organizations within the TACOM LCMC, it is important to consider the possibility of replication. The proposed Praxis methodology, process, and results, may be of interest to the remaining AMC sub-organizations (the Aviation Missile Lifecycle Management Command and its stakeholder organizations, for example) and beyond.

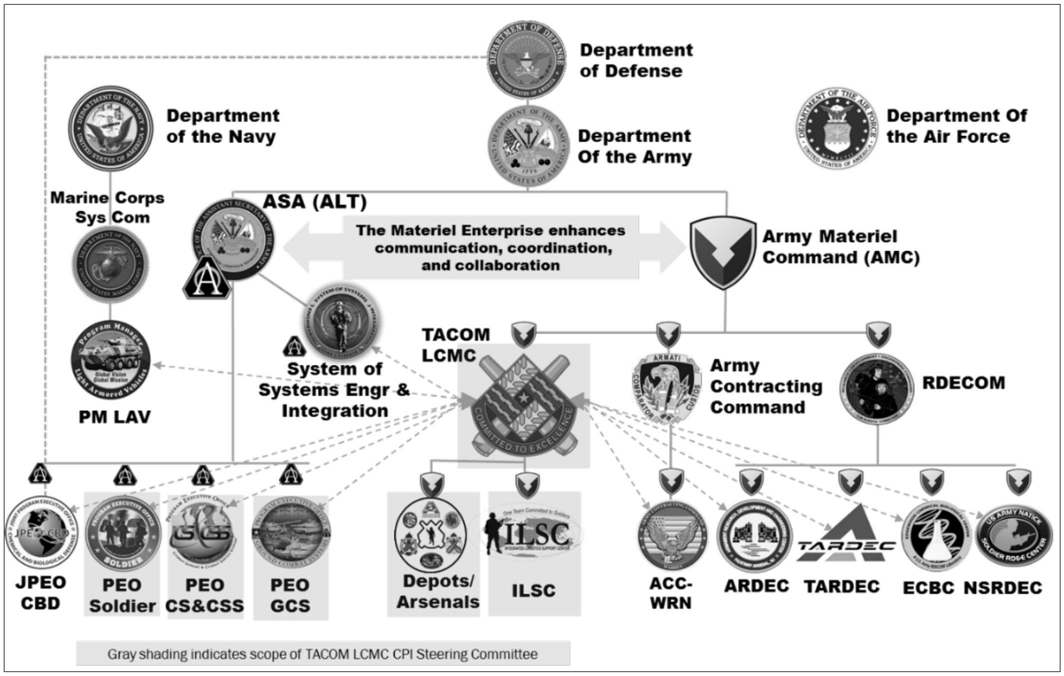


Figure 1.2. TACOM LCMC CPI Steering Committee Scope

Tank-Automotive and Armaments Life Cycle Management Command (TACOM LCMC)

The U.S. Army TACOM Life Cycle Management Command is headquartered in Warren, Michigan. TACOM LCMC partners with the Army's Program Executive Offices and is one of the Army's largest weapon systems research, development, and sustainment organizations. TACOM LCMC is called upon to develop, acquire, equip, and sustain the U.S. Army’s ground and support systems. Additionally TACOM LCMC integrates the acquisition, logistics, and technology for the ground domain across the joint services (TACOM, 2016).

Integrated Logistics Support Center (ILSC)

The Integrated Logistics Support Center (ILSC) is also located in Warren, Michigan. The ILSC is responsible for sustaining warfighting readiness and managing a large part of the Army's investment in weapon systems. Nearly 3,000 weapon systems that form the core of the Army's war fighting capability are managed by the ILSC. Additionally, the ILSC is responsible for the entire life cycle support of aircraft armament, small arms, field artillery, mortars, tools and training systems, tactical vehicles, light and heavy combat vehicles, watercraft, soldier/biological/chemical systems and deployment/support equipment (ILSC, 2016).

Anniston Army Depot (ANAD)

Anniston Alabama's Anniston Army Depot is the designated Center of Industrial and Technical Excellence for the Army's tracked and wheeled ground combat vehicles (excluding the Bradley fighting vehicle). ANAD is also responsible for the Army's towed and self-propelled artillery, assault bridging systems, individual and crew served small caliber weapons and locomotives, rail equipment and non-tactical generators. ANAD is also responsible for performing depot-level maintenance on vehicle systems such as the M1 Abrams tank, M88 Recovery Vehicle, Stryker, M113 M9 Ace Combat Earthmover and the Assault Breacher Vehicle. ANAD completes overhauls on major components of each vehicle and returns them to service (ANAD, 2016).

Rock Island Arsenal (RIA)

Located in Rock Island, IL, the Rock Island Arsenal is chartered to provide manufacturing, logistics, and base support services for the Armed Forces. RIA is an active U.S. Army factory, which manufactures ordnance and other equipment. Some of the Arsenal's most successful manufactured products include the M198 and M119 Towed Howitzers, and the M1A1 gun mount. Rock Island Arsenal is home to more than 70 Department of Defense, federal and commercial tenant organizations, including the headquarters of three major worldwide Army organizations, four regional Army offices, and also hosts the Rock Island site of the Defense Finance and Accounting Service (Security, 2016).

Red River Army Depot (RRAD)

Established in Texarkana, TX, the Red River Army Depot sustains the Warfighter’s combat power by providing ground combat and tactical systems sustainment maintenance operations. RRAD provides maintenance and repair on the Army’s tactical wheeled vehicles which includes the High Mobility Multipurpose Wheeled Vehicle (HMMWV) and Mine Resistant Ambush Protected Vehicle (MRAP). In its mission statement, RRAD claims to seek building and rebuilding the highest quality vehicles at the lowest cost in the least amount of time (RRAD, 2016).

Sierra Army Depot (SIAD)

Located in Herlong, CA, the Sierra Army Depot is chartered for new Army system assembly, reset, repair, rebuild, and various fielding support. Additionally, SIAD completes New Equipment Training (NET). SIAD offers the unique capability to receive, identify, classify, record store, and manage items while retaining the ability to ship assets world-wide. Ground vehicle reclamation activities seek to provide a readiness and operational value to the Army and the nation through management and assets redistribution to meet future and urgent needs (SIAD, 2016).

Watervliet Arsenal (WVA)

Situated on the west bank of the Hudson River in New York, Watervliet Arsenal seeks to provide the U.S. Army with manufacturing, engineering, procurement, and quality assurance for cannons, mortars and associated materiel throughout the acquisition life cycle.  The site of the arsenal has been declared a National Historic Landmark.  WVA manufactures products that support and sustain warfighters with respect to artillery, cannons, mortars and integration with tank and automotive platforms (WVA, 2016).

Program Executive Office for Combat Support and Combat Service Support (PEO CS&CSS)

The Program Executive Office for Combat Support and Combat Service Support is part of the acquisition detachment of the U.S. Army that leads an innovative, disciplined lifecycle management team.  PEO CS&CSS is located on the same campus (Detroit Arsenal) as the TACOM headquarters and ILSC in Warren, MI.

The team seeks to enable Warfighters by unburdening Soldiers in the field and constantly providing and improving the integrated, combat-enabling systems they need to dominate the full spectrum of Joint and Unified Land Operations.  The vision of the PEO

CS&CSS organization is to deliver effective, affordable combat-enabling capabilities before the point of need (CS&CSS, 2016).

Program Executive Office Ground Combat Systems (PEO GCS)

Also located on Detroit Arsenal is the Program Executive Office for Ground Combat Systems (PEO GCS). PEO GCS is responsible for providing sustainable ground combat equipment to Warfighters. By focusing on developing advanced technologies, PEO GCS is leading the design and development of the Army's Future Fighting Vehicle and Armored Multi-Purpose Vehicle, the Army's highest priority combat vehicle. Foreign Military Sales are also vital to PEO GCS' portfolio which benefits U.S. national security and foreign policy objectives (GCS, 2016).

Program Executive Office Soldier (PEO Soldier)

Located on Ft. Belvoir, PEO Soldier seeks to provide soldiers with the finest equipment and protection available as quickly as possible. The organization invests in soldiers to give them the decisive edge while also being good stewards of taxpayer funding. The Program Management Office's organizational structure offers the essential platform needed to design, develop, procure and field the hundreds of pieces of equipment used to enhance Soldiers' performance and safety. PEO Solider oversee a total of nine Product Management Offices and Directorates that are responsible for managing the life cycles of virtually everything Soldiers wear or carry into combat (Soldier, 2016).

### 1.5. FY16 CPI Policy Additions

For Fiscal Year 2016, AMC signed and disseminated two relevant CPI policies and an overarching CPI plan that facilitated the completion of this research. The existence and adoption of these policy documents allows, for the first time, a high quality set of Army CPI data to analyze and draw conclusions from. Due to the length of time required to write and implement these policies and plan, and the sub-organization's acceptance, it is unlikely that AMC's sub-organizations will receive significant updates to these documents in the near future.

The first policy signed into effect for FY16 ensures that financial benefits claimed by each CPI project were reviewed and approved by an objective third-party Resource Manager (RM). The RM is defined in the policy as a budget expert, typically from the organization's Resource Management organization, sometimes referred to as the G8. Based on the new policy, an RM is now mandated to examine all financial benefit claims for accuracy, as well as appropriately designate the budget affected by selecting a number of tags in the CPI system of record (the PowerSteering Application which will be discussed later). The financial tags included in the RM's review include the Management Decision Package (MDEP), Appropriation code (APPN), Army Program Element (APE) and Resource Organization Code (ROC). These tags trace financial benefits back to their original funding source. Also mandated by this policy is the inclusion of an RM approval form to be uploaded with each completed project. This form includes the RM's signature indicating that the financial benefits yielded from the project were accurately calculated and ready to be re-programmed or spent on other unfunded requests. For the first time in the Army CPI program history there is now a policy ensuring that the financial benefit data recorded is accurate in the eyes of the budget owner, RM and other budget administrators.

The second AMC policy signed and adopted in FY16 concerns the reporting of CPI projects and their results. This policy mandates that each CPI project is captured in the authoritative reporting source known as PowerSteering. The policy also designates the standard operating procedure used to upload and submit completed project documentation, including approved financial benefit packages reviewed and signed by the RM into the PowerSteering application. Additionally, the policy gives guidance to all users on how to properly use the PowerSteering application from the initiation of a CPI project through closure and final reporting. This policy ensures that starting in FY16 every CPI project was captured in a single data source, allowing us to pull data with both high confidence and relative ease.

A FY16 CPI plan integrating the LSS and VE programs was also disseminated to CPI Deployment Directors and practitioners from AMC. This plan outlined the combination of the LSS and VE reporting structure, set financial benefit goals for both LSS and VE programs at the organization level, and mandated that each organization draft and approve a strategic plan for reaching those targets. The strategic plans, which are reviewed and kept on file at AMC, include sections on program leadership and risks, development of human capital, and program self-sufficiency. Because both LSS and VE programs are now being reported under a single management structure, AMC is able to view the results of both programs at various organizational levels as well as individual projects.

### 1.6. FY16 Completed CPI Projects

Fiscal Year 16 resulted in $366M in financial benefit for the CPI program within the TACOM LCMC. This figure includes both the Value Engineering and Lean Six Sigma results, both of which can be further divided into categories of gated and non-gated projects (gated VE projects use the "DMEDI" approach). Some projects completed within the CPI construct are focused only on an operational benefit. Projects in this category do not result in a financial benefit whatsoever. These projects, which are important to the Army for purposes of improving safety, stewardship or other workplace initiatives, are shown in the following graphical summary, descriptive statistics and boxplot charts along with the projects resulting in financial benefits. We will be using the entire data set for our analysis.

In Figure 1.2 a total snapshot of the FY16 CPI program in terms of financial benefit is displayed (units are $1 USD). The reader will note the skew to the histogram, and minimum value of $0. Again, this is due to the presence of projects yielding operational benefits exclusively. Based on the P-value of the Anderson-Darling Normality test the distribution of financial benefit is nonparametric.

The Descriptive statistics shown in Table 1.1 further refines the data set into categories of VE and LSS, and their gated and non-gated project results respectively. This data is once more shown in a different format in Figure 1.3, a Box Plot, to illustrate the central tendency and spread of each program and its gated and non-gated project results.

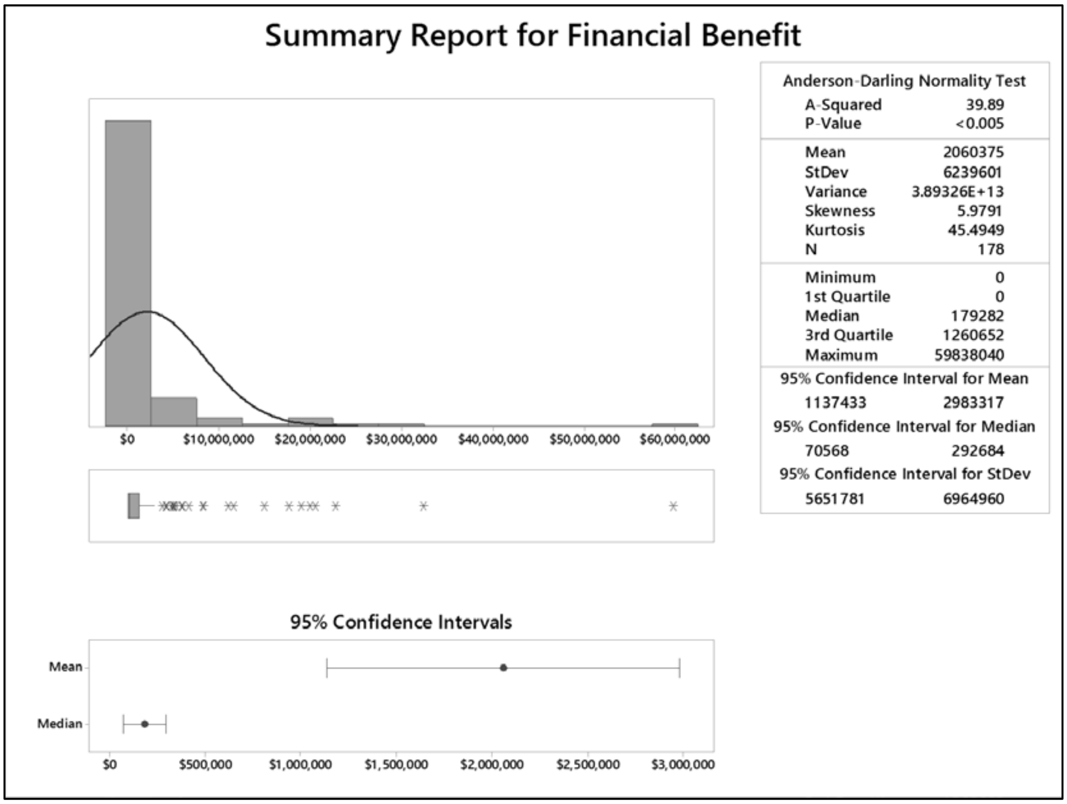


Figure 1.3. Summary Report for FY16 CPI Financial Benefit

Table 1.1. Descriptive Statistics for FY16 CPI Programs

**Descriptive Statistics: Financial Benefit (units in $)**

| Variable | TYPE | N | N* | Mean | SE Mean | StDev | Minimum |
|---|---|---|---|---|---|---|---|
| Financial Benefit | LSS-GATED PROJECT | 19 | 0 | $3,963,797 | $3,136,049 | $13,669,719 | $0 |
| | LSS-NON GATED PROJECT | 133 | 0 | $1,374,775 | $334,165 | $3,853,773 | $0 |
| | Value Engineering-GATED | 16 | 0 | $4,471,422 | $2,097,181 | $8,388,723 | $204,812 |
| | Value Engineering-NON GA | 10 | 0 | $3,704,676 | $1700,335 | $5,376,933 | $179,052 |

| Variable | TYPE | Q1 | Median | Q3 | Maximum |
|---|---|---|---|---|---|
| Financial Benefit | LSS-GATED PROJECT | $0 | $25,911 | $1,265,678 | $59,838,040 |
| | LSS-NON GATED PROJECT | $0 | $73,503 | $651,435 | $22,800,000 |
| | Value Engineering-GATED | $417,435 | $1,246,176 | $3,630,714 | $32,424,620 |
| | Value Engineering-NON GA | $381,836 | $1,157,202 | $5,139,081 | $17,662,525 |


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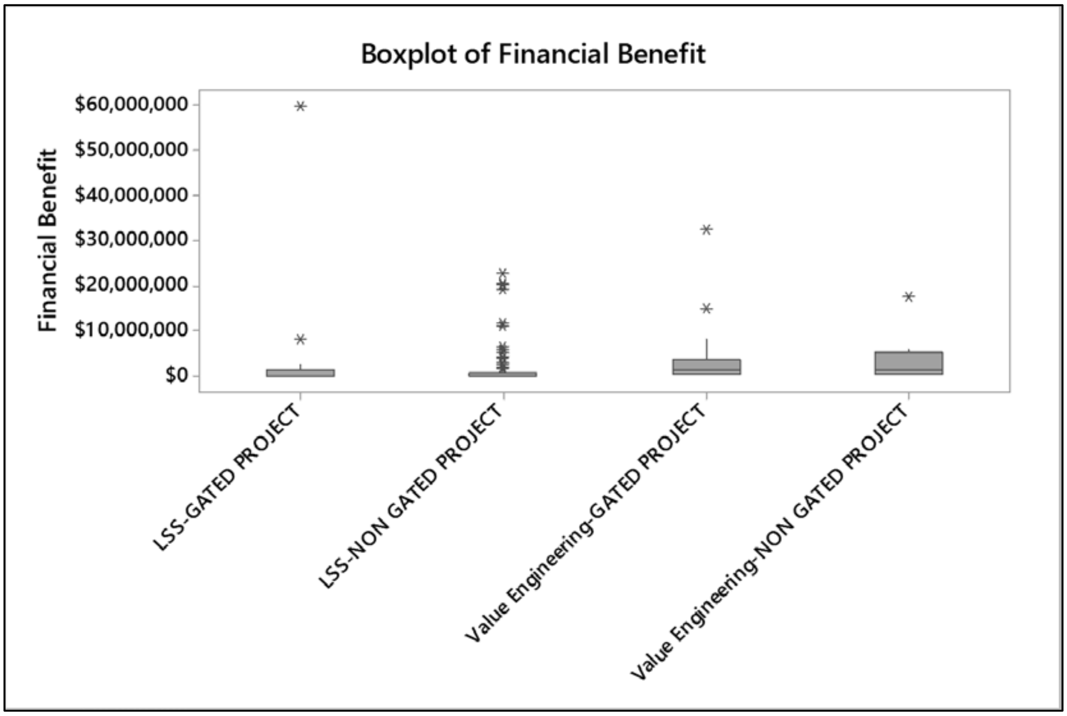



Figure 1.4. Boxplot of FY16 CPI Financial Benefit by CPI Project Type

Additionally, by use of Pareto analysis it is detected that LSS non-gated projects accounted for 49.9% of all financial benefit from TACOM LCMC in FY16. This result is shown in Figure 1.5.

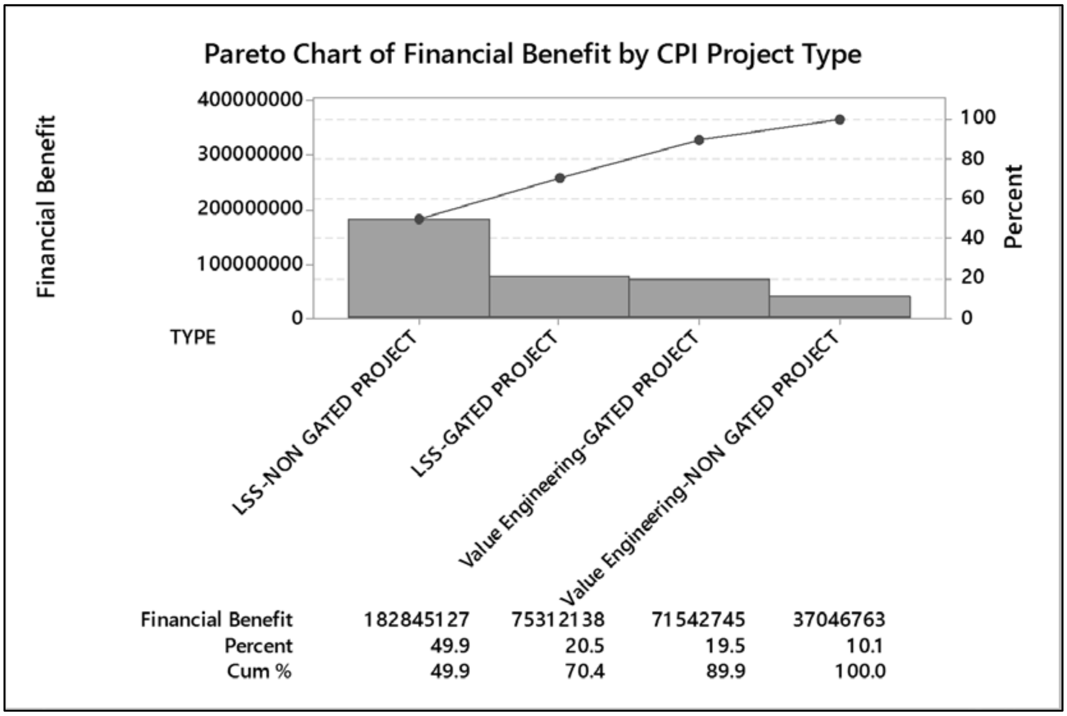



Figure 1.5. Pareto Chart of Financial Benefit by CPI Project Type

Additionally, by using the Pareto analysis shown in Figure 1.6 it is detected that LSS non-gated projects constituted 74.7% of all CPI projects completed in TACOM LCMC in FY16.

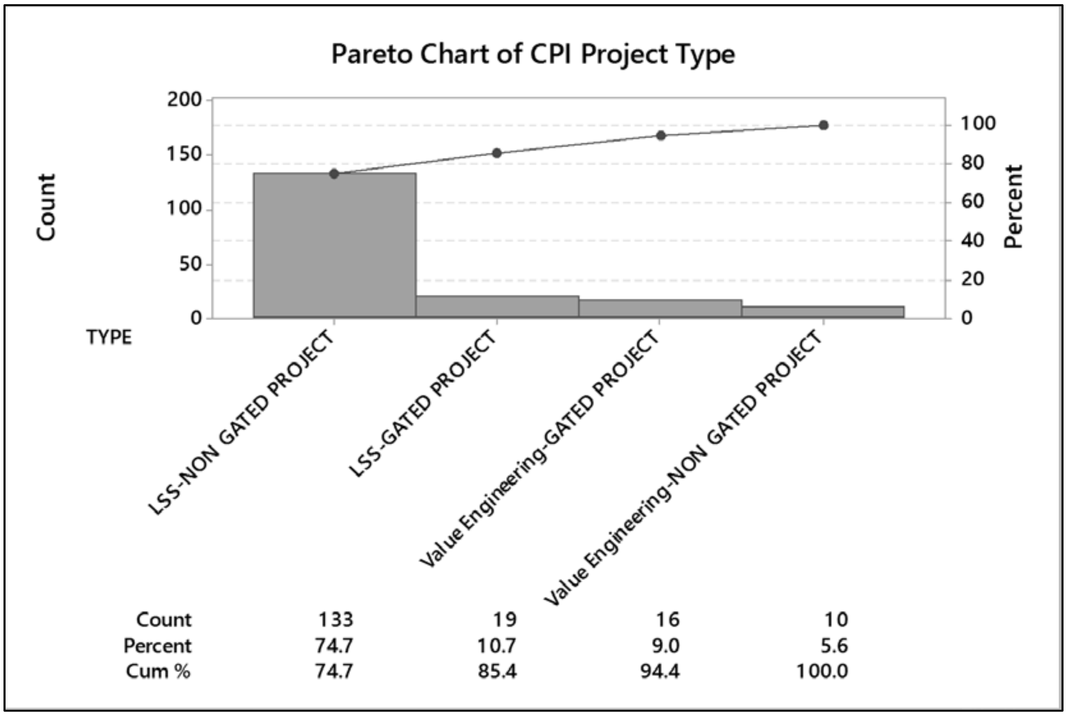



Figure 1.6. Pareto Chart of Completed CPI Project Type

By analyzing only the results of the LSS non-gated projects, a significant variation in terms of financial benefit is determined. As shown below in Figure 1.7, standard deviation is calculated to be $3.8M. From examining our Anderson Darling Normality test, again it is concluded that the data set is not normally distributed. As the data is nonparametric, the median is examined as a measure of centrally tendency and calculated to be $73,503.

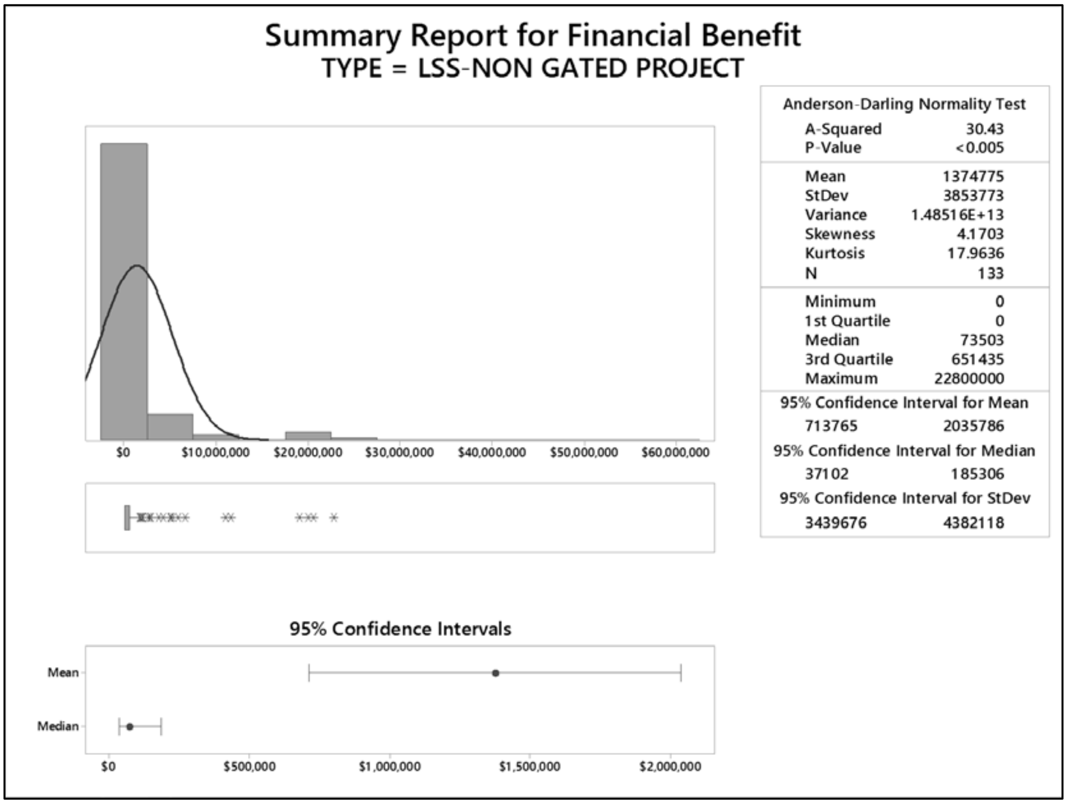



Figure 1.7.  Summary Report for FY16 LSS Non-Gated Project Financial Benefit

An average cost of $46,000 in labor hours to complete a LSS non-gated project has been calculated.  This calculated value will be used only as a reference point further on into the analysis.  A limited discussion on the return on investment (ROI) of completing LSS non-gated projects will be presented at the conclusion of the report, in an effort to offer the reader or implementing organization a control plan for the proposed selection criteria.

## 1.7. Praxis Research Statement

This Praxis seeks to answer the following problem statement: is there a relationship between LSS project selection criteria and financial benefit? We can represent this practical problem as a general statistical problem with a null and alternate hypotheses:

*$H_o$: There is no relationship between selection criteria and LSS project's financial benefits for FY16 at US ARMY TACOM LCMC*

*$H_a$: There is a relationship between selection criteria and LSS project's financial benefits for FY16 at US ARMY TACOM LCMC*

Furthermore, if this research is able to reject the null hypothesis and in fact conclude that a relationship between selection criteria and the financial benefit of LSS project exists, a mathematical model and optimal set of criteria will be provided as appropriate. The output of this research will affect change at the TACOM LCMC level and above, resulting in the ability to select projects based on maximizing financial benefit.

The remainder of this proposal includes a literature review of CPI selection criteria as well as a proposed methodology for capturing and analyzing data required to answer our research statement. CPI selection criteria from textbooks, scholarly articles, and four organizations were catalogued, analyzed, and decomposed to formulate a survey in order to retrospectively analyze the financial benefit of FY16 TACOM LCMC LSS non-gated projects. The analysis section of this proposal will include detail on how the data will be analyzed, as well as provide a historical reference for the development of this

Praxis research, allowing replication and further research.

# CHAPTER 2

# REVIEW OF LITERATURE

## 2.1. Outline

Due to the large volume of literature available, this research relies on a sample of both scholarly articles and textbooks to establish a baseline for LSS project selection criteria. Additionally, four organizations' proprietary LSS project selection criteria have been obtained and will also be used in the analysis. All four organizations studied displayed a significant LSS program at the time of this research, and as such their respective selection criteria are expected to have been evolved over their program's existence. Due the proprietary nature of the organizations discussed, the individual organizations will be described at a high level, but no formal identifiers will be used. It should be noted that throughout the literature review phase of this Praxis, no scholarly articles, textbooks, or organizational selection methods were found to contain selection criteria specifically for LSS non-gated projects.

The process of decomposing lists of criteria or even paragraphs of insight from the sources was a painstaking effort, sometimes calling for a one-to-many transfer of information, and requiring high energy discussion between the author, stakeholders, and subject matter experts. Each selection criteria discovered from the selected literature sources was cataloged, analyzed, decomposed and translated into generic criteria statements and then affinitized into common groups. The process was repeated each time a new source was added to the analysis, and then the entire sample was affinitized again by four groups of impartial LSS students as part of a class exercise.

To give an example of the how the decomposition process worked, the verbatim project selection criteria from George Eckes' book *The Six Sigma Revolution*, "It is strongly recommended that the first set of criteria will be the strategic business objectives of the organization," was translated to the more generic criterion "Effort was strongly linked to one or more of the organization's strategic goals at the time of selection," to be used in retrospective analysis. This statement was originally affinitized as an "Organization-Focused" criterion, and upon second pass it was re-classified as an "Improvement Focus-Internal," criterion as the list of potential criteria grew.

This decomposition and affinitization process yielded a manageable list of possible criteria that had redundancies removed, while retaining the original source traceable to each criterion statement. Over 140 individual criteria from the literature review, and a single additional implied criterion (pertaining to changes of scope), were mapped to 17 questions that will be used to formulate a survey to be used in the data-collection phase of this Praxis, which is outlined in the Methodology section of this research. Through this iterative process, the literature review allowed the convergence on a set of seven distinct selection criteria groups. The criteria groups converged on are: Improvement Focus, Goals, Scope, Resources, Current-State Performance, Organizational Buy-in, and Perceived Ease of Execution.

The following sections will discuss the affinitized groups of criteria, first for the scholarly articles and text books, and then the organizations studied. Lastly, novel or relevant concepts found throughout the literature review will be discussed at the conclusion of this chapter.

### 2.2. Textbook Review Methodology

The textbooks reviewed were pulled from the author's home LSS library, the Army's Tank-Automotive Research Development and Engineering Center (TARDEC) and TACOM's CPI offices. All of the textbooks referenced in this research are available through online retailers such as Amazon.com or AbeBooks.com. This is noted such that the reader will be aware that the textbooks used in this research would likely be found in any CPI practitioner's office or even included in Belt training material (George's Lean Six Sigma Pocket Toolbook, for example, is included in both the Army's Green and Black Belt training courses), increasing the possibility of the replication of this research. In total eight textbooks were analyzed to produce nearly 70 unique selection criteria.

Figure 2.1 describes the tendencies of selection criteria as stated by the studied LSS textbooks. It is evident that there was a strong focus on what was declared to be criteria judging an effort's focus on improvement, either internal or external. An effort's goals, scope, resources, and current-state performance were also heavily referenced. All of these topics will be further discussed later in this chapter. The textbooks studied tended to have very little emphasis on selecting potential efforts based on the organization's buy-in nor the perceived ease of execution.

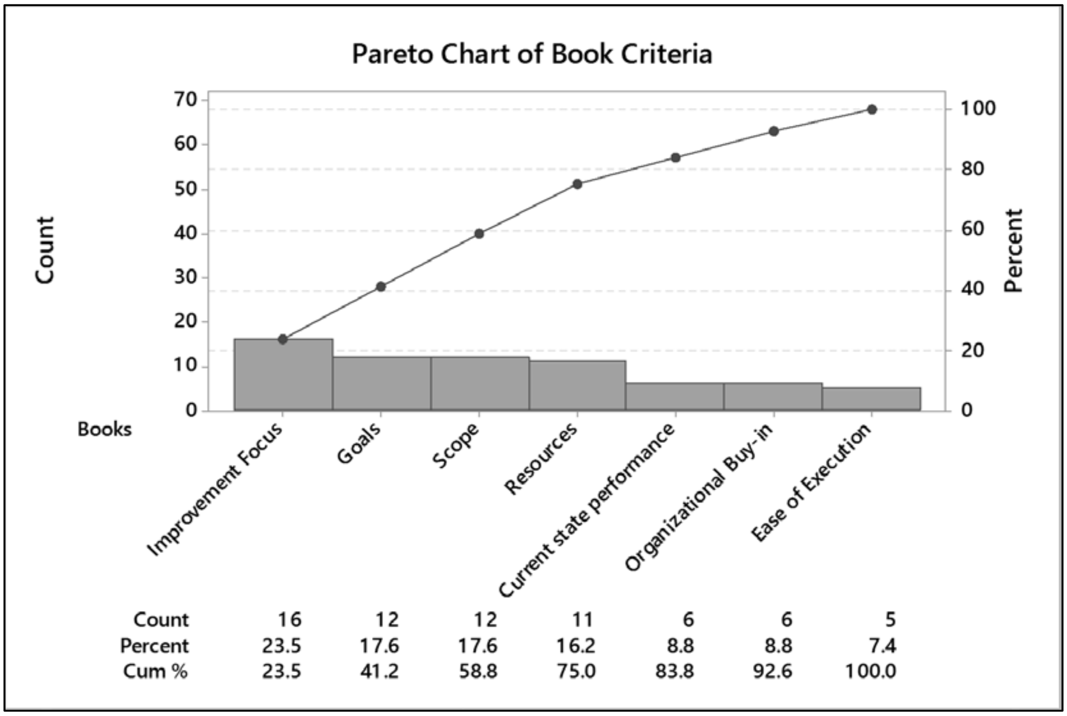



Figure 2.1. Pareto Chart of Selection Criteria from Textbook Review

## 2.3. Article Review Methodology

The scholarly articles analyzed as part of this research required subscriptions to a number of online research sites and article repositories. One strength of the articles analyzed were the global origins of the articles and application of the research itself. For example, LSS selection methods and criteria from numerous European countries were documented, whereas the textbook research focused primarily on US organizations and applications. Due to the heavy focus of culture on the successful implementation of LSS in organizations, having an awareness of the impact of project selection in different geographical locations is also of interest as the US Army currently operates in over 100 countries.

Nine scholarly articles were reviewed for this research. These articles produced over 40 example selection criteria. The same decomposition process used for the textbook review was employed for our scholarly articles. Figure 2.2 describes the tendencies of selection criteria as collected from the studied LSS scholarly articles.

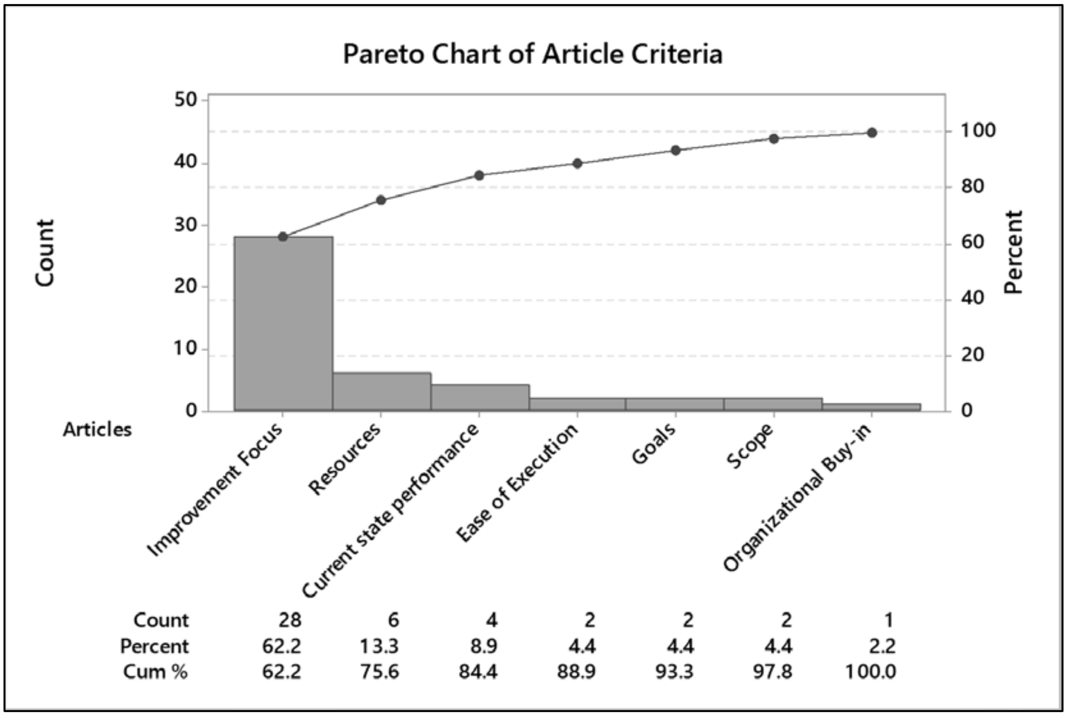



Figure 2.2. Pareto Chart of Selection Criteria from Article Review

Similar to the textbooks studied, the articles studied focused primarily on the focus of the improvement, as well as resources perceived to be required. The articles placed a higher emphasis on the process' current state performance, as well as the perceived ease of execution. One possible explanation is that many of the articles referenced seek to serve as a baseline for LSS program ideation or adoption- the "quick wins" generated by completing the so-called easy projects, or low-hanging-fruit, can give a new organization much needed momentum and publicity.  Additionally, the emphasis on this criterion may be due to the lack of awareness of many academic CPI researchers that the existence of data may be rare even for dramatically underperforming processes in real life.

## 2.4. Organizational Review Methodology

In total four organization's CPI selection processes were analyzed to produce over 30 unique selection criteria.  As stated earlier, the selection criteria of these organizations are deemed proprietary, and as such the names or the organizations will not be released in this report.  Three out of the four studied organizations are for-profit.  Descriptions of the organizations included in this study are displayed in Figure 2.1.

Table 2.1.  Organizations Reviewed

| **Organization** | **Industry** | **Approximate # Employees** | **FY16 Revenue** |
|---|---|---|---|
| Organization 1 | Government Defense R&D (Public) | 12,000 | n/a |
| Organization 2 | Government Defense R&D (Private) | 85,000 | $18B |
| Organization 3 | Automotive Manufacturer | 80,000 | $83B |
| Organization 4 | Consumer Technology | 135,000 | $10B |

Figure 2.3. Outlines the tendencies of selection criteria as stated by the organizations included in this study.

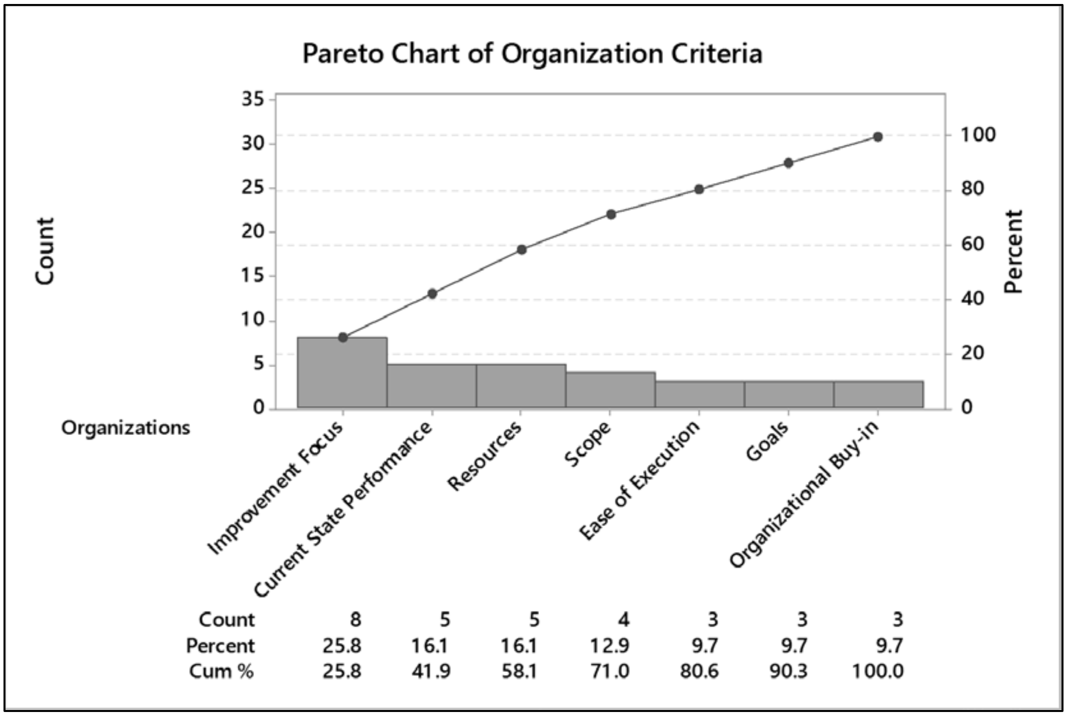
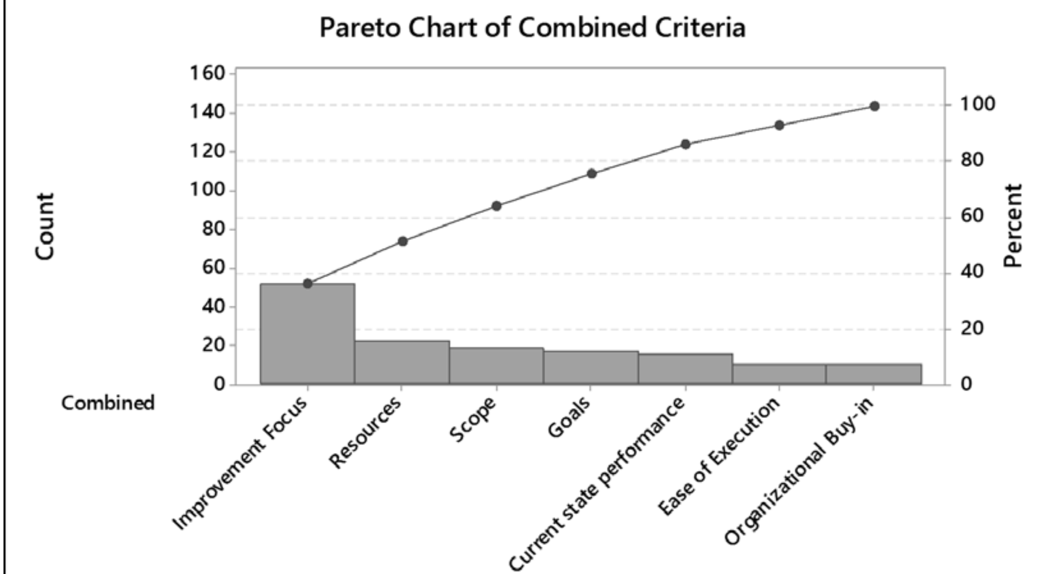



Figure 2.3. Pareto Chart of Selection Criteria from Organization Review

Again the focus of the criteria from organization's studied relies in the improvement's focus, current state performance, and resources. What is very interesting is that the topic of organizational buy-in ranked the lowest in this aspect of the literature review. Due to the nature of three out of the four organizations, this may be due to the bottom-line driven nature of the culture of the organization itself.

## 2.5. Selection Criteria Themes

The themes identified from the literature review will be outlined in this section. The combined list of criteria from the three groups reviewed (textbook, article, organization) was examined and is presented in Figure 2.4.




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Count | 52 | 22 | 18 | 17 | 15 | 10 | 10 |
| Percent | 36.1 | 15.3 | 12.5 | 11.8 | 10.4 | 6.9 | 6.9 |
| Cum % | 36.1 | 51.4 | 63.9 | 75.7 | 86.1 | 93.1 | 100.0 |

Figure 2.4. Pareto Chart of Combined Selection Criteria

For all literature surveyed, improvement focus ranked highest in terms of total count following the decomposition and affinitization. Resources, scope, and goals followed behind in the middle section. The least referenced topics included current state performance, ease of execution, and organizational buy-in when all literature review data was compiled. This information is presented in Table 2.2. All seven themes will be outlined and qualified with excerpts from the literature review in the following sub-sections.

Table 2.2. Comparative Ranking of Selection Criteria

| | COMAPARATIVE RANKING | | | |
|---|---|---|---|---|
| **Criteria Category** | **Overall** | **Textbook** | **Article** | **Organization** |
| Improvement focus | 1 | 1 | 1 | 1 |
| Resources | 2 | 4 | 2 | 2 (tied) |
| Scope | 3 | 2 (tied) | 4 (tied) | 3 |
| Goals | 4 | 2 (tied) | 4 (tied) | 4 (tied) |
| Current state performance | 5 | 5 | 3 | 2 (tied) |
| Ease of execution | 6 | 7 | 4 (tied) | 4 (tied) |
| Organizational buy-in | 7 | 6 | 7 | 4 (tied) |

### 2.5.1. Focus of Improvement Effort

The most frequently referenced concept throughout the literature review conducted centers on the idea of the selection of projects based on their perceived benefit to either the organization's internal or external customers. For example, Mikel Harry in *Six Sigma the Breakthrough Management Strategy* states that "Every Six Sigma project is designed to ultimately benefit the customer and improve the company's profitability," (Harry, 242). It is evident from this statement that two sub-criteria are present addressing both internal and external customer needs.

Throughout this research, whenever a selection criterion referenced the betterment of the organization's day-to-day operations, employee satisfaction, or longevity (to include profitability), it was categorized as an internally-benefiting improvement focus. An example of this type of criterion is from Thomas Pyzdek's *The Six Sigma Handbook*. Pyzdek states that projects should be selected that have the potential to substantially and statistically significantly increase overall employee satisfaction (Pyzdek, 191). This theme prevailed in nearly all textbooks, scholarly articles, and in some organizations studied.

Additionally, a topic found in every piece of literature reviewed was the concept of selecting projects that had an impact on the external customer. This theme permeated the literature review in varying levels of complexity. In the article “An integrated analytic approach for Six Sigma project selection,” Büyüközkan and Öztürkcan develop a mathematical model for project selection based on the criteria of customer satisfaction (Büyüközkan and Öztürkcan, 5838). Pyzdek also states that projects should be selected that “substantially and statistically significantly increase overall customer satisfaction or loyalty,” (Pyzdek, 191). One outside organization studied, a Government Contractor, simply uses the criteria asking if an “effort appears to benefit the organization’s customers.”

Also included in this category were any criteria that referenced linkage to an organization’s strategic objectives, with the mindset being that any effort that links back to the organization’s strategic objectives serves ultimately to better the organization or its customers. One of the outside organizations (for-profit) studied relied so heavily on this aspect of selection criteria that it comprised 75% of the organization’s selection criteria.

Based on the review of literature, an inquiry on the improvement focus of each effort can be reduced to two primary statements to be used in a retrospective analysis:

A.) At the time of selection, the improvement effort chosen was intended to positively impact external customers or stakeholders, to include closing a known customer need or gap.

B.) At the time of selection, the improvement effort chosen was intended to positively impact internal customers or stakeholders, to include meeting the organization's strategic objectives.

### 2.5.2. Resources required for effort

The second most frequently referenced project selection criteria theme was focused on having the right resources in place, and ready to be allocated at the time of project selection.  Everything from the cost to execute a potential project to having the proper skill sets on the team is referenced.  As the table of selection criteria evolved, the topic of resources as a selection criteria would further be decomposed into human and non-human resources.

Again, this literature reviewed yielded variation in both the complexity and emphasis of the use of resources as a selection criteria.  George Eckes states that a project worth considering for selection has the full commitment and use of resources from a human capital perspective (Eckes, 26).  Peter Pande, on the other hand, is more concerned with the financial aspect of resources; "costs (of a potential project) can be absorbed within the current budget," is listed a selection criteria (Pande, 149).

One organization studied, a large-scale automotive manufacturer, listed its top selection criterion as having the process improvement team with the right knowledge, skills, and abilities identified and assigned at the time of selection.  Another organization studied called upon its selection committee to calculate both the total cost of the project and the cost of the man hours before listing each project for selection discussions, representing both aspects of resources identified in this research.

Based on the review of literature, an inquiry on the resources required for each effort can be reduced to two primary statements to be used in a retrospective analysis:

A.) At the time of selection, the improvement effort chosen had the human capital consisting of the right knowledge, skills, and abilities available and assigned to work on the project team.

B.) At the time of selection, the improvement effort chosen had adequate budgetary, information technology, and other non-human capital resources available and ready to be assigned.

### 2.5.3. Scope of improvement effort

The next most referenced criteria theme was the perceived scope of effort of the project at the time of selection. This theme encompasses two primary sub-themes: the formally defined and communicated boundaries of the project's efforts, as well as the perceived ability for the project to be executed and completed by a project team in a set amount of time.

In review of textbooks and articles there were many instances of scope being referenced in terms of the project's starting and ending points. Furthermore, how those bookends were defined and communicated from top leadership was a recurring selection theme. Pyzdek states that project selection relies on the "scope of new or improved process, product or service to be created is clearly and completely defined," (Pyzdek, 191).

A project charter was also commonly referenced as a way of defining and communicating the scope of a potential project. Pyzdek states that in order for a project to be selected, a charter must be present and accurately filled out. Further, that charter document must present a clear link from the project's activities to its expected deliverables (Pyzdek, 191). A project charter is a common tool in CPI project selection and deployment. In the Army's CPI program, a partially completed charter may or may not be present at the time of project selection.

Another aspect of scope that was frequently referenced in the literature review was the estimate or perceived magnitude of effort to accomplish a prospective project. This frequently included time, the crossing of organizational boundaries, and the existence or presence of a known solution (making the effort more focused on implementation). Pande and other sources converge on a short timeframe for anticipated project completion, "a short-term window (less than 3 months) looks feasible," (Pande, 149). Pande also posits that projects that are qualified for selection won't duplicate or clash with other on-going efforts, nor require significant outside support.

All organizations studied demonstrated a great amount of emphasis on the project's anticipated or projected schedule duration. One organization included specific selection criteria related to scope that included the project's timeline, the availability of data linked to the problem statement, and the existence of a formal definition for the defect in question. Another organization stated that only projects that met the criteria of being narrow enough in scope with the intention that one team can work on it should be selected. All of these topics point to an emphasis of not only formulating and communicating a project's scope, but also keeping it laser focused on accomplishing the project's goal.

Further, it was apparent both in the literature review and practical experience that changes in a project's scope while underway can have a dramatic effect on project completion as well as financial and operational benefits realized. This is not something that can be directly measured at the time of project selection – scope changes typically occur at tollgate meetings through stakeholder suggestion or management directive. It is less common for non-gated projects to experience scope change as they are largely managed by the project team itself. Scope changes can be viewed as a lagging measure or metrics and can still offer information about the FY16 non-gated projects in the data set.

Based on the review of literature, an inquiry on the scope of each effort can be reduced to two primary statements to be used in a retrospective analysis, including an additional potential question regarding possible changes in the project's scope while underway:

A.) At the time of selection, the improvement effort chosen had a well-defined and communicated scope.

B.) At the time of selection, the improvement effort chosen had a scope that would allow a full-time improvement team, of average skills, experience, and abilities, to complete its objectives in less than 3 months.

C.) During the execution of this project, the scope was significantly changed by either the project team or the organization's leadership.

### 2.5.4. Goals of improvement effort

A common theme from the literature review was the concept of goal definition and goal-communication. This topic is closely related to the previous section on scope. In many cases, the scope of an effort can be directly proportional to the effort's goals. The concept of "stretch" goals was also introduced by nearly half of the literature reviewed, as well as selecting projects that were perceived to have a high return on investment.

Nearly all of our literature sources, including the organizations studied, suggest selecting projects that have goals defined in advance of their launch. Eckes recounts a successful implementation of LSS at an organization where leadership would challenge process owners to predict project gains 90 days from kickoff of potential projects (Eckes, 26). These financial values would then be used to further filter and refine the projects before selection.

Easton and Rosenzweig in *The role of experience in six sigma project success: An empirical analysis of improvement projects* describe taking the idea of a project goal further by stating that a project worth selecting will have a 'stretch' goal (Easton, 9). Stretch goals are meant to encourage the overmatch of the solution to the stated goal.

One organization studied used stretch goals set at 150% of the minimum acceptable outcome to challenge teams to produce more improvement while guarding against failure.

Pande also comments that in-flight projects should be able to be tracked against their goals. One of the selection criteria present in his literature is not only the ability for tracking project as they progress towards their goal, but also having a team member identified to perform the tracking and documentation of the results (Pande, 149).

Due to the bottom-line-driven nature of many organizations implementing Lean Six Sigma, the concept of judging a project against its perceived return on investment was common in this research. Evans and Lindsay state that prospective projects should be analyzed for their “financial return, as measured by costs associated with quality and process performance, and impacts on revenues and market share,” (Evans, 68). Other sources, such as Pyzdek, report actual dollar amounts to draw conclusions from, suggesting that projects projected to save over $500,000 should be considered “excellent ROI” projects and selected for execution (Pyzdek, 191).

Michael George warns that projects identified and selected at lower levels in the organization may miss this concept entirely. “The traditional approach has often allowed Black Belts to pick projects, with input from Champions and process owners. This seldom led to projects that were related to corporate strategy or prioritized around ROIC,” (George, 234). This concept again ties into leadership involvement, which will be discussed in a later section in this chapter.

Based on the review of literature, an inquiry on the stated goals, communication of goals, and predicted benefit for each effort can be reduced to two primary statements to be used in a retrospective analysis:

A.) At the time of selection, the improvement effort chosen had a well-defined and communicated goal or goals.

B.) At the time of selection, the improvement effort chosen had a well-defined and communicated "stretch" goal or goals.

C.) At the time of selection, the improvement effort chosen had a goal or goals that were predicted by the organization's leadership or the project team itself to yield a high financial benefit.

### 2.5.5. Current state performance

The process's current state performance was also identified as a common selection theme. Mentioned in nearly all of the literature reviewed, it was determined that poor current state performance is a likely catalyst for selecting and executing a project which aims to improve its performance. Poor current state performance was further broken into the categories of nonconformance with respect to internal and external needs.

This criteria may seem similar to the earlier topic of improvement focus, but it is differentiated by the idea of examining the current state of an existing process itself. An organization may in fact be aware of a process that is performing poorly before a customer files a complaint or otherwise raises notice. An organization's CPI department is likely to examine processes by way of metrics or other feedback mechanisms and can determine if it is performing well with respect to either, or both, internal and external requirements. Often this separation of process performance and customer need is referred to as the Voice of the Process and the Voice of the Customer.

Many literature sources reviewed in this research made generalizations on this topic. For example, Eckes states that projects should be selected based on "current process performance," (Ecke, 26), and George proposes the idea of starting the project selection process by examining current state process maps and analysis (George, 234). Mader, in the ASQ article *How to Identify and Select Lean Six Sigma Projects*, uses the term "risk" to indicate the worthiness of selecting a process improvement project based on its current state performance (Mader, 58).

Other authors, Antony Jiju, for example, list specific current-state metrics to examine. In order to determine if a project is a worthy candidate for selection he proposes that cycle time or throughput yield be examined (Jiju, 7). Those processes with a long cycle time (externally focused) or low throughput yield (internally focused) should be prioritized and selected for improvement.

Michael George alone addresses this important point in project selection particularly when referring to projects in the US Government. He states that projects should also be selected if they relate to improving gaps or deficiencies in environmental, health, or safety regulations (George, 26). As mentioned previously, projects that are completed in the realm of TACOM CPI that do not yield much, or any, financial benefit are typically selected based on metrics relating to safety, or environmental, stewardship.

All four organizations studied referenced the idea of starting with poorly performing processes when selecting CPI projects. This may be due to the bottom-line or profit-driven nature of three out of the four of these organizations, but also perhaps due to the need to show progress and build momentum and reputation to grow an organization's internal CPI team in terms of headcount and mission scope. One organization had the selection criterion of "a recurring problem" listed, while another uses the blanket criteria of the effort addressing "key areas of process improvement." All four organizations were careful to mention that the current-state processes performance had to be well-documented. Simply put, there needed to be data to back up the claims of the process owner or customer. This element was not seen in the other literature sources.

Based on the review of the literature, an inquiry on the effort's current state performance can be reduced to two primary statements to be used in a retrospective analysis:

A.) At the time of selection, the improvement effort chosen had a well-documented or understood account or record of poor performance with respect to meeting external customer or stakeholder needs.

B.) At the time of selection, the improvement effort chosen had a well-documented or understood account or record of poor performance with respect to meeting internal customer or stakeholder needs (including regulatory or safety requirements).

### 2.5.6. Perceived ease of execution

Similar to the concept of scope, another common selection theme was the perceived ease of execution and completion of a potential project. The literature review suggests that if an organization views that a potential effort appears to have a high degree of ease to complete, it may be a worthy project to select instead of more complex opportunities.

Easton and Rosenzweig propose that if a prospective project presents what appears to be a solvable problem, it should be executed (Easton, 10). Eckes goes a step further and discusses the topics relating to the feasibility of a potential project to complete, including the perceived degree of difficulty (Eckes, 26). Pande introduces the idea of a known solution which the selection committee has a high degree of confidence in, as well as commenting on the solution itself being sustainable. Pande also warns that if a project will require significant information technology or is likely to face significant technical obstacles, it may be wise to forgo it on selection day (Pande, 149).

Evans and Lindsay, in *An Introduction to Six Sigma & Process Improvement*, bluntly state that projects with a high probability of success should be selected (Evans, 68). This topic was heavily referenced in the organizations studied, along with the idea of a known solution being identified and ready for implementation.

All but one of the organizations studied had an element of ease of execution in their selection plans. The one organization that did not use a form of ease of execution or probability of success as a selection criteria was, perhaps coincidentally, the highest revenue generating out of the group- the automotive manufacturer.

Based on the review of the literature, an inquiry on the effort’s ease of execution and completion can be reduced to two primary statements to be used in a retrospective analysis:

A.) At the time of selection, the improvement effort chosen had a clearly defined or understood solution that only needed to be put into action or implemented (little data collection, analysis or improvement idea generation would be required).

B.) At the time of selection, the improvement effort chosen was perceived to have a high probability of success from the organization's leadership or project team.

C.) At the time of selection, the improvement effort chosen was perceived to be unlikely to require significant IT or other significant technical solutions or investments to implement and complete.

**2.5.7. Organizational buy-in**

The final selection theme identified through the literature review is the organization's buy-in to the project or effort. Organizational buy-in can refer to an organization's overall interest in the project or effort, including leadership involvement or even a visible sense of ownership. Furthermore, the identification and assignment of Champions and Master Black Belt mentors to a given project at the time of selection was highly referenced in the literature studied.

Taho Yang and Chiung-Hsi Hsieh qualified "Leadership" as one of their top criteria when analyzing Six Sigma project selection with a Delphi decision-making method (Yang, 1). Mikel Harry proposes that "The projects selected to improve business productivity must be agreed upon by both business and operational leadership, and someone must be assigned to "own" or be accountable for the project, as well as someone to execute it," (Harry, 239). Pyzdek also states that projects being selected must have director-level sponsors identified, duties specified, and sufficient time committed and scheduled (Pyzdek 191).

All four organizations studied made clear connections to organizational buy-in. Identified and engaged leadership-level Champions and Master Black Belts are all referenced as basic requirements to select a process improvement project. The automotive organization took this selection theme further, mandating a third-party process improvement project sponsor, different from the MBB, be to be assigned and an active participant in the effort.

Based on the review of the literature, an inquiry on the effort's organizational buy-in and assignment of senior-leader level involvement can be reduced to two primary statements to be used in a retrospective analysis:

A.) At the time of selection, the improvement effort chosen had significant positive buy-in or ownership from one or more levels of the organization's leadership.

B.) At the time of selection, the improvement effort chosen had a senior leader-level Champion and/or Master Black Belt mentor identified and assigned to it.

## 2.6. Additional Relevant Topics found in Literature Review

While the primary focus of the literature review in this Praxis was to generate a list of potential LSS non-gated project selection criteria, there were some interesting findings realized along the way. This review indicated that there is a need to better understand and quantify selection criteria for non-gated LSS projects, as well as optimize them for the highest financial benefit. The following subsections will outline these discoveries and their relevance to this research. To illustrate the global presence of these research discussions, the country of origin for each article is provided.

### 2.6.1. An integrated analytic approach for Six Sigma project selection

Büyüközkan and Öztürkcan propose the use of Decision Making Trial and Evaluation Laboratory (DEMATEL) in their 2010 research titled “An integrated analytic approach for Six Sigma project selection.” This article comes from Turkey. The authors propose the use of DEMATEL to detect complex relationships and build relation structure among criteria for selecting Six Sigma projects (Büyüközkan, 1).

There are two known limitations of this research with respect to this Praxis. The first limitation is based on the definition, or lack thereof, of a Six Sigma effort. It is unclear if the projects studied are gated or non-gated in nature. The assumption of this Praxis is that in the US Army CPI deployment model, there is a clear difference between gated and non-gated projects.

Secondly, the research is based off of a list of 14 criteria containing a number of which that decidedly do not apply for analysis of a non-profit organization’s CPI results. The criteria studied in this article are focused on revenue generation, customer loyalty, and increased market share which are not applicable in the scope of this research

(Büyüközkan, 4). Additionally, the authors of this research are concerned with studying aspects of Six Sigma program deployment that the US Army has previously optimized or is simply out of scope, such as employee competency development and the cost of HR. The remaining criteria identified by Gülçin Büyüközkan and Demet Öztürkcan were used in forming the survey discussed later in this research.

### 2.6.2. A systematic methodology for the creation of Six Sigma projects: A case study of semiconductor foundry

Chao-Ton Su and Chia-Jen Chou developed a combined approach of creating and selecting Six Sigma projects using an analytic hierarchy process (AHP) and failure mode effects analysis (FMEA). FMEA is presented as a method to evaluate the risk of candidate projects and prioritize them via AHP for selection and execution. The standard calculation for Risk Priority (RPN) is presented as means to filter and prioritize possible project ideas. The AHP model is used to decide which projects to attack using a numerical ranking of relative impact for the severity, occurrence, and detection criteria output from the FMEA model (Su, 3). Rating projects against criteria on a Likert-type scale is an important take-away from this article. There are six selection criteria presented, two of which are related to business cash flow and revenue enhancement. In this article the distinction between gated and non-gated projects is missed.

### 2.6.3. Critical success factors of Six Sigma implementations in Italian companies

In the 2002 research Alessandro Brun proposes to answer the question: is there an

"Italian way" to Six Sigma?  The author utilizes an approach created by Anthony and Banuelas in their research *Key Ingredients for the effective implementation of Six Sigma program* to compare critical success factors in LSS implementation at the organizational level.  Topics such as management involvement and commitment, cultural change, linking Six Sigma to business strategy or customer, and project prioritization and selection are surveyed and reported out over a number of American and Italian companies (Brun, 4-5).  While particular selection criteria, and again the distinction of gated versus non-gated, are absent, the research provides more momentum for pursuing this Praxis.

Both American and Italian organizations ranked the topic of project prioritization and selection towards the bottom of their respective lists on maturity.  It is the intent of this Praxis to further investigate the importance of selection criteria with respect to project financial benefit.

**2.6.4. How to Identify and Select Lean Six Sigma Projects**

Douglas P. Mader outlines a step by step method to select Lean Six Sigma projects in a July 2007 article published by the American Society for Quality (ASQ, 58). Mader discusses the preliminary steps such as understanding the organization's strategic plan, alignment with the strategy, understanding the policy deployment system, and understanding the organization's core business processes.  After those prerequisites have been achieved, according to Mader, Champions and Master Black Belts can begin to follow a structured method for identifying, prioritizing, and selecting LSS projects.

The criteria Mader proposes centers on risk, return, and goal analysis. After outlining myriad potential risks, Mader proposes that many said risks can be alleviated by having a "well-run" project identification process where priorities of the organization as well as potential LSS projects are communicated to key stakeholders. We are not offered any explicit selection criteria. One positive from the Mader research is his awareness that not all LSS projects are made equal – he notes that Lean Six Sigma, Six Sigma, Design for Six Sigma, and "their various permutations," exist as strategic thrusts, hinting towards, yet not defining, a discussion on gated versus non-gated efforts.

#### 2.6.5. Six-Sigma project selection using national quality award criteria and Delphi fuzzy multiple criteria decision-making method

This research emanating from Taiwain composed by Taho Yang and Chiung-Hsi Hsieh uses a Delphi fuzzy multiple criteria decision-making methodology to analyze the effectiveness of Taiwanese national quality award selection criteria. The research also proposes a unique hierarchical criteria evaluation process. The four step process includes determining project selection criteria, use of fuzzy group decision-making method to determine the strategic criteria weights, use of fuzzy linguistic variables to evaluate sub-criteria weights with respect to each project candidates, and finally ranking each project by fuzzy "defuzzification."

The Taiwan national quality award criteria are provided in this article which include themes such as leadership, customer/market development, and business result (Yang, 2). While the proposed methodology appears powerful, it again lacks the delineation between gated and non-gated projects.  Further, it assumes knowledge of an initial set of selection criteria to rate on a subjective basis prior to selection.  This Praxis will take into account the Taiwan national award criteria, but the scope of this research is fundamentally different.

### 2.6.6. Six Sigma Programs: An implementation model

Chakravorty provides a detailed approach to implementing an organized approach to Six Sigma in this research.  This research concludes that a primary reason for the failure of a Six Sigma program, to include the execution of projects, development of Belts, and realization of financial benefit, stems from poor implementation. Project identification and selection is briefly mentioned in this research as part of the fourth step in an organization's implementation of Six Sigma (Chakravorty, 2).  However, Chakravorty only goes as far as to mention that the prioritization of projects is determined by "many criteria," such as cost to benefit ratio or use of the Pareto priority index.  This research does not deliver a list of applicable criteria, nor a differentiation in the type of LSS project being selected with respect to this Praxis.

### 2.6.7. The role of experience in Six Sigma project success: An empirical analysis of improvement projects

Easton and Rosenzweig compiled data over a six year time span with the intent of understanding the relationship between improvement project team member experience and the team's performance.  Their research concluded that the strongest predictor of improvement-project success was the team leader's improvement-project experience, followed by the organization's combined experience (Easton, 8). Additionally, the research rejected the notion that individual team members (other than the team leader) had an effect on the project's outcome. The authors suggest that a well-developed and deployed approach or structure to solving problems through Six Sigma is paramount, while intra-team familiarity and experience has a reduced effect on performance.

This research does not mention the specifics of any selection method or criteria deployed by the organizations studied, nor does it mention the difference between gated and non-gated project types. However, it does conclude that team leaders may have an effect on project selection by trending towards properly-scoped projects that seek to target solvable problems, even if those problems involve "stretch goals."

**2.6.8. Critical success factors for the successful implementation of six sigma projects in organizations**

Ricardo Banuelas Coronado and Antony Jiju describe Critical to Success Factors (CSF) for implementing Six Sigma projects in this article published in the Total Quality Management (TQM) Magazine. This research was conducted in the United Kingdom and outlines the common pitfalls of failed Six Sigma projects, and programs, based a number of factors including the program's linkage to the customer, linkage to the overarching business strategy, the organization's understanding of Six Sigma tools and techniques, project management skills, and the prioritization and selection of induvial projects. The authors stress that projects should be selected such that they are closely tied to the business goals or business objectives of the organization (Jiju, 9). Further, the authors discuss the concept that while each organization is likely to select different measurements to judge a project's worthiness of selection and completion, they proclaim that every project should be selected so that it will help the company improve its competitive advantage, business profitability, process cycle-time, or throughput yield. The authors do not discuss non-gated projects, nor offer insight to project selection criteria for non-profit organizations.

# CHAPTER 3

# METHODOLOGIES OF PRAXIS

## 3.1. Outline

This Praxis is the result of a culmination of a number of analysis methodologies learned while in the SMU DEEM program linked together to identify and solve a real-world problem. This Praxis delivers insight into the selection of LSS projects and sought to quantify the relationship between selection criteria and financial benefit. Selection criteria from an array of scholarly articles, textbooks, and proprietary industry sources were analyzed in the previous chapter, and will be used to analyze FY16 TACOM LCMC results. The mathematical model and underlying process presented in this Praxis will enable U.S. Army CPI leaders to make better-informed decisions while selecting CPI projects which will result in achieving maximum financial benefit for the betterment of the Warfighter, the Army, Department of Defense, and United States.

In this section, each step in the Praxis process from the ideation of the Praxis topic to its defense will be outlined. This chapter itself will serve as a historical reference of how the Praxis was completed, as well as give insight to why and how the individual tools were used in conjunction with each other. It is also the intent of this Praxis for the described process and methodology to be replicated and used by other government and non-government organizations to increase the ability of maximizing financial return of both LSS gated and non-gated projects.

### 3.2. Praxis Process Flow

Figure 3.1 outlines the overarching process used to ideate, formulate, execute, analyze, and present the findings of this Praxis.  The approach used in this Praxis will be shown to generally follow the DMAIC methodology.  This process began in the Spring of 2016, and extended until the time of dissertation defense.  A gray-shaded process step is shown each time a tool or methodology learned in the DEEM program at SMU was used.

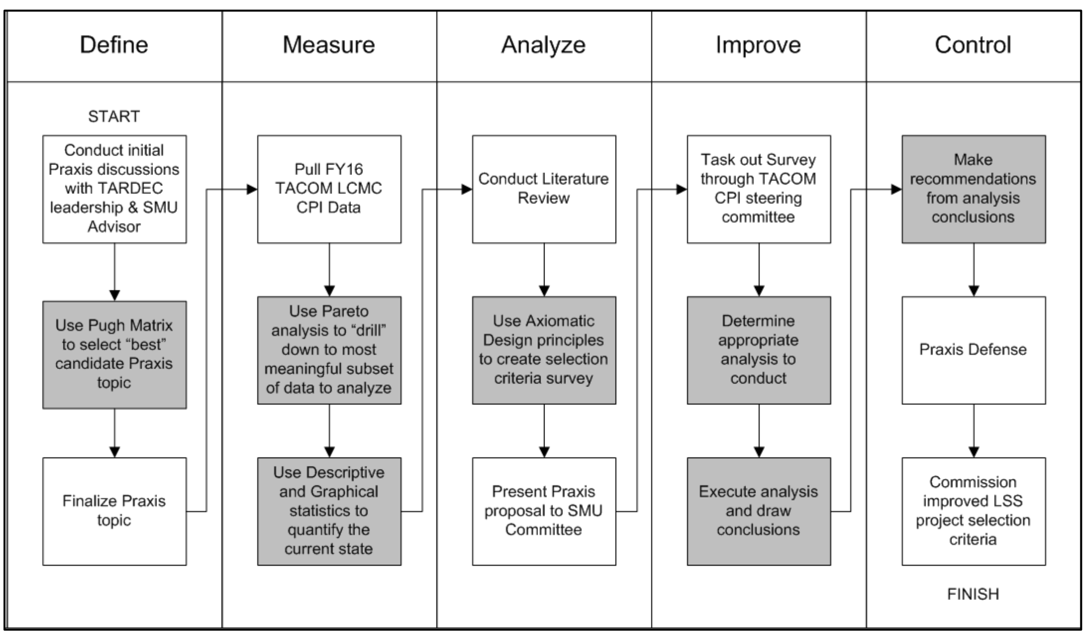



Figure 3.1.  Praxis Methodologies

#### 3.2.1. The DMAIC Methodology

The Define Measure Analyze Improve and Control (DMAIC) methodology has been referenced earlier in this research many times. Recall that DMAIC style projects are also referred to as “gated” as they require a tollgate in between each phase. The tollgate meeting is a go or no-go decision point, where the project either continues on to the next phase or is cancelled without proceeding any further.

The Define phase often starts with a vague problem or opportunity statement and initiates the project team who attempts to clarify the actual problem or research question being asked. A common objective of the Define phase is to capture the Voice of the Customer; this information is used to quantify our process’s performance in the Measure phase. As projects tollgate out of the Define phase, they typically contain a well-defined and scoped problem and goal statement, a list of team members, and a tentative timeline for completing the next phases. This research conceptually reached the end of the Define phase after the first three semester hours of Praxis study when a generalized topic had been decomposed into a discrete research statement and scope.

The Measure phase relies heavily on collecting data from the current state of the process in question. There are many tools used in the Measure phase to ensure the right data is being collected, such as data collection plans and the use of measurement systems analysis. Following the initial data collection, descriptive and graphical statistics are often used to make judgements on the current state performance of the process in question. Many times advanced statistical analysis, such as Control Charts or Process Capability, will be used at this point to quantify the ability of the current state process to meet the Voice of the Customer.

The Analyze phase builds on the data collected in the Measure phase and seeks to understand the root causes that are preventing the process from meeting the customer's needs. Tools such as the Ishikawa diagram, Failure Modes and Effects Analysis (FMEA), and other more advanced statistical methods are frequently used. In this research, after the initial data was collected, the analysis portion started with the literature review. The Analyze phase will continue on until all survey data has been collected and analyzed.

The Improve phase again takes what was learned in the previous phases and builds on it. So far the research question has been defined, data has been collected and baseline analysis has been executed. Improvements on the current state can now be executed. An example relating to this research is the creation of a mathematical model to better select LSS non-gated projects. During the improve phase, a pilot of potential solutions or improvements is conducted to ensure they will meet the customer's needs.

The Control phase is the last phase in the DMAIC methodology. Piloted solutions that have exhibited positive improvement are commissioned and transitioned back to the process owner. The goal for Control phase is for the process improvement team to be able to walk away from the process they improved and have the solution endure. The newly improved process is handed back over to its owner, and the process improvement team disbands. Two tools commonly used to facilitate this changeover are the transition plan and control plan.

It is clear that the DMAIC methodology was used to structure the approach for this research. Many DMAIC tools were used to keep the research on track and always focused on the goal of answering the research question. The tollgate between Analyze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and Improve can be represented by the Praxis Proposal meeting, held on 25 APR 2017.

### 3.2.2. Initial Praxis topic discussions

Following the Preliminary Counseling Exams held in February of 2016, the author presented the following initial, high-level, Praxis interest areas:

1. Reliability, Availability, Maintainability, and Synchronization of US ARMY TARDEC laboratories
2. Return on Investment of Process Improvement programs for the Department of Army
3. Optimization of Human Capital investments for US ARMY TARDEC
4. Design of Experiment Use and Advantages at US Army Laboratories

While the Praxis timeline and availability of resources precipitated focusing on a single topic, it is encouraged that future studies cover the remaining topics. As the reader will note, the scope of each of the possible Praxis varies, and can be attempted by other Department of Army employees. A Pugh Matrix, described next, was used to decide which topic to pursue.

### 3.2.3. Pugh Matrix

Interestingly, the author noted that the selection criteria for this Praxis itself was not readily available, nor commonly accepted amongst internal leaders and stakeholders. An ad-hoc set of selection criteria mimicking the organization’s technical project selection process was instead used. The author, the organizations leaders, and the SMU Praxis advisor came to agreement on a single topic through use of a Pugh Matrix. The Pugh Matrix is a weight-based objective selection tool. The author filled in the relationship scores, and leadership gave input on the criteria weights. In this case, all four criteria were equally weighted.

| | Criteria and Weighting | | | | | | |
|---|---|---|---|---|---|---|---|
| | 25% | 25% | 25% | 25% | | | |
| General Topic Presented | Leadership Support/Visibility | Potential ROI ($) | Burden on the Workforce | Impact on the Warfighter | Total Score | Weighted Score | Rank |
| Reliability, Availability, Maintainability, and Synchronization of US ARMY TARDEC laboratories | 7 | 7 | 5 | 7 | 26 | 6.5 | 2 |
| Return on Investment of Process Improvement programs for the Department of Army | 9 | 9 | 7 | 7 | 32 | 8 | 1 |
| Optimization of Human Capital investments for US ARMY TARDEC | 9 | 5 | 1 | 3 | 18 | 4.5 | 3 |
| Design of Experiment Use and Advantages at US Army Laboratories | 5 | 9 | 1 | 3 | 18 | 4.5 | 3 |

Figure 3.2. Praxis Selection Matrix

The criteria were set as Leadership Support/Visibility, Potential Return on Investment (ROI), Burden on the Workforce, and Impact on the Warfighter. A Likert scale was used to quantify the strength of relationship between the Praxis ideas and the criteria. A score of 1 indicated a strongly negative relationship, and a score of 9 indicated a strongly positive relationship. After calculating a weighted score using a sum-product formula, the highest scoring Praxis idea was selected.

As indicated in Figure 3.2 the Pugh Matrix directed us towards pursuing a Praxis topic related to the Department of Army's CPI program. More specifically, how to increase the return on investment of the programs.

### 3.2.4. Finalization of Praxis Topic

After the high-level Praxis topic was selected, seven months of weekly one-hour meetings were conducted until the Praxis was scoped appropriately. In these meetings, the author and advisor met with the intent to continually down-scope the Praxis theme into a single, tangible problem statement. Along the way, the process led to many discoveries both internal and external to the author's organization that would ultimately lead to the finalization of the Praxis topic as you are seeing it now.

Figure 3.3 is an inverted pyramid that illustrates the process used to decompose the original Praxis theme into an existing problem faced by the TACOM LCMC organization.

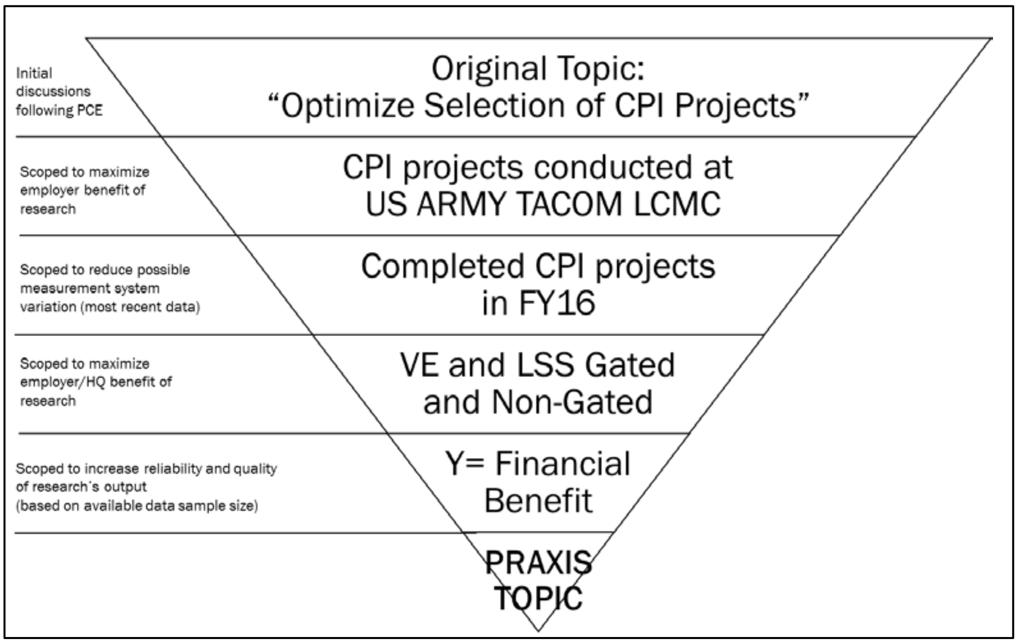



Figure 3.3.  Praxis Scoping Diagram

### 3.2.5. FY16 Data Pull

The initial data pull was completed by executing a report which was generated by the Army's authoritative source for CPI project data.  PowerSteering (PS), a web-based project portfolio management solution, is the system that the Army uses to track solutions and financial benefits for all Lean Six Sigma projects.

PS provides senior leaders, CPI/LSS deployment directors, process owners and project managers a real time visibility, strategy alignment and CPI/LSS belt practitioner effectiveness to drive strategy and accelerate results across the Army. PS is used to manage financial benefits and support Army leaders and practitioners in tracking all CPI projects. The ability to track and provide metrics on each project allows Army leaders to align local and enterprise-level projects and initiatives within their strategic goals and objectives.

By providing "line-of-sight" visibility into the portfolios, Commanders, Senior Leaders, Deployment Directors, Process Owners and Project Managers have the information they need to make more effective project investment decisions, reduce costs and prioritize projects. Risks are identified and issues can be managed in real-time. The Army also uses PowerSteering as its only source to track operational and financial benefits derived from continuous process improvement and Lean Six Sigma projects.

### 3.2.6. Pareto Analysis

Pareto analysis was used during the formative stages of this Praxis. Pareto analysis, sometimes referred to as the Pareto principle, aims to separate the vital few from the trivial many. Pareto analysis is frequently used by CPI teams to examine large quantities of summary data with the hope of reducing the scope of their effort on the most influential process steps, getting the most impact for their effort. This type of analysis allows for both continuous and discrete data to be analyzed. Many times this type of analysis is referred to the “80-20 rule,” as it is posited that 80% of a given process’s output can be traced back to, or described by 20% of the process’s inputs.

The 80-20 rule can be seen in a wide array of applications, such as employee award bonuses (80% of the bonus money is allocated to 20% of the organization), athletic events (80% of the football team's points are scored by roughly 20% of players on the roster) and even on Wall Street, where one of our Praxis stakeholders who was a former stock broker had used the Pareto principle to decide which customers to focus 80% of his time on; the 20% of his customers who had the most money invested in his firm.

### 3.2.7. Descriptive and Graphical Statistics

Descriptive and graphical statistics were also used frequently throughout this Praxis. Minitab 17 was used to analyze data sets and create various plots throughout this Praxis. The reader will note the use of descriptive statistics, graphical statistics, and Pareto plots in Chapters 1 and 2. These basic statistical tools were used to obtain measures of central tendency and spread, as well as examining data sets for normality. In Chapter 4, Minitab 17 will also be used to analyze data and perform hypothesis tests. A further description of the hypothesis tests used will be covered later in this chapter.

### 3.2.8. Literature Review

The literature review process is described in Chapter 2. A number of sources were studied and their individual selection criteria were captured. The criteria underwent a number of decomposition and affinitization steps before being mapped to a set of 17 unique questions. Figure 3.4 outlines how these steps are linked to collecting the survey's response as well as analyzing the resulting data set.

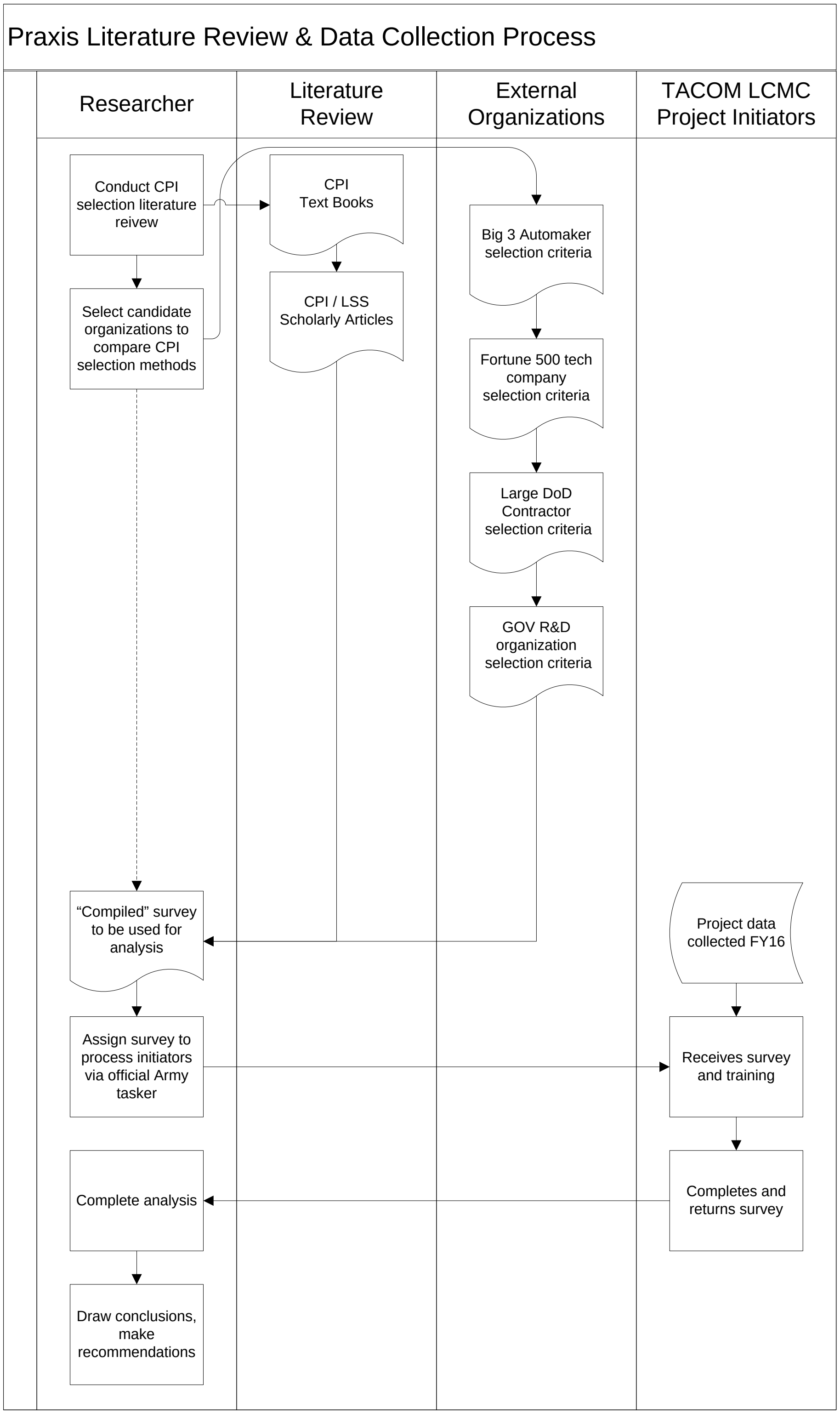



Figure 3.4. Praxis Literature Review and Data Collection Process Diagram

### 3.2.9. Survey Creation

The process for matching each reduced criterion to its original source was completed by using a matrix similar to what would be used in an Axiomatic Design study. The survey questions serve the purpose of the functional requirements and are driven by the original sources, which serve as the design parameters. The purpose of this exercise was to ensure that the resulting survey would not over-burden the survey responders with redundant or unnecessary questions. No weighting has been given to any single question nor question theme or group.

The survey respondents were defined as the set of the individuals or groups who initially selected a LSS project in FY16 in one of the TACOM LCMC organizations. Each project was assigned a copy of survey questions along with a Likert scale to complete. The survey was issued as a mandatory tasker, assigned and collected by the TACOM LCMC CPI Steering Committee in the month of May 2017. A mockup of the survey and the response scale is presented later in this chapter.

### 3.2.10. Survey Question Mapping

Figure 3.5 illustrates how source criteria were mapped to 17 survey questions. An "x" indicates a direct coverage of a specific criterion from a literature review source to one of the survey questions created. Note, the entire table is available in the Appendix. For example, one source criterion from Douglas Mader ("Effort had set goals") is captured by the question Q8 "At the time of selection, the improvement effort chosen had a well-defined and communicated goal or goals.”

| | | | | | | | | Survey Question | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Source Criteria | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7* | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 |
| A01 | | X | | | | | | | | | | | | | | | |
| A02 | | X | | | | | | | | | | | | | | | |
| A03 | | X | | | | | | | | | | | | | | | |
| A04 | | | | | | | | | | | X | | | | | | |
| A05 | | | | | | | | | | | X | | | | | | |
| A06 | | X | | | | | | | | | | | | | | | |
| A07 | | | | | | | | X | | | | | | | | | |
| A08 | | X | | | | | | | | | | | | | | | |
| A09 | | | | | X | | | | | | | | | | | | |
| A10 | | | | | | | | | | | | | X | | | | |
| A11 | | | | | | | | | X | | | | | | | | |
| A12 | | | | | | | | | | | X | | | | | | |
| A13 | X | | | | | | | | | | | | | | | | |
| A14 | | X | | | | | | | | | | | | | | | |
| A15 | | X | | | | | | | | | | | | | | | |
| A16 | | | | | | | | | | | X | | | | | | |
| A17 | | X | | | | | | | | | | | | | | | |
| A18 | X | | | | | | | | | | | | | | | | |
| A19 | | X | | | | | | | | | | | | | | | |
| A20 | | X | | | | | | | | | | | | | | | |

Figure 3.5.  Survey Question to Criteria Mapping Initial Diagram

Figure 3.6 displays the use of the spreadsheet software to rearrange the ordering of the source criteria to form a diagonal line, indicating that there is no coupling amongst the source and the survey, and no redundancies within the survey itself.  Again only a brief sample of the 140 criteria are displayed.

| | | | | | | | Survey Question | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Source Criteria | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7* | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 |
| A13 | X | | | | | | | | | | | | | | | | |
| O24 | | X | | | | | | | | | | | | | | | |
| A36 | | | X | | | | | | | | | | | | | | |
| A25 | | | | X | | | | | | | | | | | | | |
| B61 | | | | | X | | | | | | | | | | | | |
| B41 | | | | | | X | | | | | | | | | | | |
| A07 | | | | | | | | X | | | | | | | | | |
| B12 | | | | | | | | | X | | | | | | | | |
| B06 | | | | | | | | | | X | | | | | | | |
| O18 | | | | | | | | | | | X | | | | | | |
| O17 | | | | | | | | | | | | X | | | | | |
| O29 | | | | | | | | | | | | | X | | | | |
| O09 | | | | | | | | | | | | | | X | | | |
| B40 | | | | | | | | | | | | | | | X | | |
| A38 | | | | | | | | | | | | | | | | X | |
| O21 | | | | | | | | | | | | | | | | | X |

Figure 3.6.  Survey Question to Criteria Mapping Diagonal Diagram

The reader will note that Question 7 does not contain a match among the surveyed criteria.  This question was defined by the author as “During the execution of this project, the scope was significantly changed by either the project team or the organization’s leadership”. While this criterion was not prevalent in the literature review, it was deemed to be an important data point through discussions with CPI stakeholders when retroactively analyzing a project portfolio.  It has been placed in the seventh question slot due to its proximity in nature to Q5 and Q6.  The data collected via this question was not used in this Praxis.

### 3.2.11. Survey Question mockup with Likert Scale

The following questions were derived from the literature review and was randomized for each project studied.  Additionally, two Army-specific questions regarding force readiness were included. These additional questions were posed with the intent to determine if a given project was selected based on the perception or goal of improving readiness as well as reporting if the project had a significant impact on readiness when complete. Following each survey question in parenthesis is the coded variable that was used in the analysis phase of this research.

1. *At the time of selection, the improvement effort chosen was intended to positively impact external customers or stakeholders, to include closing a known customer need or gap. (ExtGap)*
2. *At the time of selection, the improvement effort chosen was intended to positively impact internal customers or stakeholders, to include meeting the organization's strategic objectives. (IntGap)*
3. *At the time of selection, the improvement effort chosen had the human capital consisting of the right knowledge, skills, and abilities available and assigned to work on the project team. (HCRes)*
4. *At the time of selection, the improvement effort chosen had adequate budgetary, information technology, and other non-human capital resources available and ready to be assigned. (NonHC)*
5. *At the time of selection, the improvement effort chosen had a well-defined and communicated scope. (ClearScope)*

6. *At the time of selection, the improvement effort chosen had a scope that would allow a full-time improvement team, of average skills, experience, and abilities, to complete its objectives in less than 3 months. (3Months)*
7. *During the execution of this project, the scope was significantly changed by either the project team or the organization's leadership. (ScopeChanged)*
8. *At the time of selection, the improvement effort chosen had a well-defined and communicated goal or goals. (Goals)*
9. *At the time of selection, the improvement effort chosen had a well-defined and communicated "stretch" goal or goals. (StretchGoals)*
10. *At the time of selection, the improvement effort chosen had a goal or goals that were predicted by the organization's leadership or the project team itself to yield a high financial benefit. (HighBenefit)*
11. *At the time of selection, the improvement effort chosen had a well-documented or understood account or record of poor performance with respect to meeting external customer or stakeholder needs. (ExtDoc)*
12. *At the time of selection, the improvement effort chosen had a well-documented or understood account or record of poor performance with respect to meeting internal customer or stakeholder needs (including regulatory or safety requirements). (IntDoc)*
13. *At the time of selection, the improvement effort chosen had a clearly defined or understood solution that only needed to be put into action or implemented (little*

*data collection, analysis or improvement idea generation would be required). (SolKnown)*

14. *At the time of selection, the improvement effort chosen was perceived to have a high probability of success from the organization's leadership or project team. (HighSuccess)*
15. *At the time of selection, the improvement effort chosen was perceived to be unlikely to require significant IT or other significant technical solutions or investments to implement and complete. (LowTech)*
16. *At the time of selection, the improvement effort chosen had significant positive buy-in or ownership from one or more levels of the organization's leadership. (BuyIn)*
17. *At the time of selection, the improvement effort chosen had a senior leader-level Champion and/or Master Black Belt mentor identified and assigned to it. (MBB)*
18. *At the time of selection was the improvement effort's impact on readiness was considered. (Readiness1)*
19. *The results of this improvement effort impacted readiness (a lagging measure). (Readiness 2)*

The following Likert scale was required for answering each question:

*1 Strongly Disagree*

*3 Slightly Disagree*

*5 Neither agree nor disagree*

*7 Slightly Agree*

*9 Strongly Agree*

### 3.2.12. Praxis Proposal

The Praxis Proposal meeting was conducted on 25 April 2017. In this session, the committee members provided feedback and determined that the Praxis topic should proceed onto the next phases including data collection, analysis, and conclusions. The committee agreed to include both non-gated and gated LSS projects in the analysis. Specific analysis methods were discussed but not selected at this time.

### 3.2.13. Survey Dissemination

Following an initial brief and training session with all survey responders, the survey was executed in May 2017. The data collection survey was disseminated digitally via the TACOM internal portal, ensuring each completed survey is tracked to both the project being analyzed as well as the person completing the survey. Responses were to be required within 30 days of the tasker being issued, although 60 days were allowed for those who were out of the office or unable to complete the survey in time. Non-compliances were to be resolved by the TACOM LCMC CPI Steering Committee at the next available monthly meeting, however, at the end of the 60 day period, a judgement was made by the Steering and Praxis Committees that a minimum sample size had been reached, ending the data collection period. The resulting data was immediately available in summary tabular form as well as in an unstacked format and ready for analysis in Minitab and SPSS.

### 3.2.14 Benchmarking *Ordinal Logistic Regression: An Application to Pregnancy Outcomes*

While researching potential analysis approaches in the Minitab 17 software package, a then unknown approach to the author was uncovered. Nested in the regression analysis menu, Ordinal Logistic Regression was identified as a potential analysis approach for this Praxis. Cursory research was conducted to gain a baseline understanding of the approach (details presented in the following subsection), followed by the analysis of number of relevant case studies in an effort to find a promising benchmark for this Praxis.

The 2010 study conducted by K.A. Adeleke and A.A. Adepoju, "Ordinal Logistic Regression: An Application to Pregnancy Outcomes," used the methodology to model the categorical response of pregnancy outcome to a number of patient-specific predictor variables at a Nigerian State hospital. This case study used 100 patient records, collected retrospectively, to analyze the probability of an ordinal categorization of pregnancy outcomes. The predictor variables studied included environmental factors such as a previous cesareans, hospital service availability, behavioral factors such as antenatal care and diseases, and demographic factors such as maternal age, marital status, and weight. The ordinal outcomes studied with these predictors, arranged in increasing category, were abortion, still birth, and livebirth.

The authors concluded a number of findings, including the result that women carrying a baby which had a weight less than 2.5 kg were 18.4 times more likely to have had a livebirth than are women with history of babies greater than or equal to 2.5 kg in the studied geographic region. This information, though somewhat limited by its sample size, could potentially be used to inform patients and doctors in efforts to improve the likelihood of the higher ordinal category output (livebirth). The study resulted in a number of practical conclusions, recommendations, and methodology which may reach a wide audience as the Journal of Mathematics and Statistics published their findings in 2010.

Adeleke and Adepoju's research serves a solid baseline for this research for many reasons. First, Adeleke and Adepoju's study was conducted with a similar number of data points, collected retrospectively. It should be noted that Ordinal Logistic Regression (OLR) is highly dependent on sample size- their article containing 100 samples was found sufficient in drawing practical conclusions, and to be published in a scientific journal. This Praxis resulted in the collection of 119 data points from the previous fiscal year.

The data in this study was regressed over an ordinal outcome, which had a logical order. Instead of pregnancy outcomes, this Praxis will use financial benefit outcomes, in ordinal categories: no financial benefit, low financial benefit, medium financial benefit, and high financial benefit (defined in the following chapter). The predictor variables studied by Adeleke and Adepoju exhibited variation in subject matter. For example, variables relating to environmental factors contrast heavily when compared to an individual's previous pregnancy history. Adeleke and Adepoju's predictor variables clearly relied on differing data types (binary to continuous). In this Praxis a common

Likert scale for each predictor variable was captured in a single survey.

As outlined in the following subsections, Adeleke and Adepoju's OLR study was used in conjunction with other analysis types. Following the use of the General Linear Model and Logit Link function, the group used Multiple Regression and Best Subsets Regression to further refine their conclusions. The following three subsections outline the analysis types executed in support of this Praxis, two of which were utilized by Adeleke and Adepoju.

#### 3.2.14.1 Ordinal Logistic Regression

Ordinal Logistic Regression is a procedure for regressing a number of predictor variables over a range of ordinal output categories. The intent of this analysis is to examine the relationship between the predictors and their likelihood to result in, or predict, a given categorical response existing naturally in an ordinal fashion. The ordinal response in this analysis is seen as a natural ordering of at least three output categories, such as low, medium, high. If the categories had no natural ordering, nominal regression logistic regression would be preferred.

Ordinal variables may be also exist as the independent variables in an equation. In the case of this research we have an ordinal scale being used to collect the level of agreement with a number of predictive survey questions, as well as the output variable of financial benefit. According to Winship and Mare's 1984 entry in the *American Sociological Review*, ordinal independent variables may be treated as continuous variables for analysis (Winship and Mare, 517).

In both Minitab 17 and SPSS, the Generalized Linear Model (GLM) is used in conjunction with n-1 logit functions to execute the analysis. The GLM assumes there is a latent continuous outcome variable that has been discretized into j-ordered groups- a perfect match for this study (as will be shown in the following chapter, actual numerical financial benefits from each sample will be categorized into the classifications of no financial benefit, low financial benefit, medium, and high financial benefit) This analysis assumes the effect of the predictor is common across all response categories.

The basic form of the GLM is given as:

$$link(\gamma_j) = \frac{\theta_j - [\beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k]}{\exp(\tau_1 z_1 + \tau_2 z_2 + \cdots + \tau_m z_m]}$$

where $\gamma_j$ is the cumulative probability for the *j*th category, $\theta_j$ is the threshold for the *j*th category, $\beta_1 \ldots \beta_{1k}$ are the regression coefficients, $x_1 \ldots x_k$ are the predictor variables, and *k* is the number of predictors. The numerator on the right side determines the location of the model. The denominator of the equation specifies the scale. The $\tau_1 \ldots \tau_m$ are coefficients for the scale component and $z_1 \ldots z_m$ are *m* predictor variables for the scale component (chosen from the same set of variables as the *x*'s).

The link function is the function of the probabilities that results in a linear model in the parameters. It defines what goes on the left side of the equation shown above. This function acts as the link between the random component on the left side of the equation and the systematic component on the right. The standard GLM contains 5 Link models to choose from based on the distribution of the underlying predictor data. As will be shown in the following chapter, the data in this Praxis has categories that are fairly evenly distributed, and the overall changes in cumulative probabilities are gradual which suggests using the Cumulative Logit function.

It is recommended to the reader that they carefully select the proper Link function based on a table such as Figure 3.7, adopted from SPSS 13.0 Advanced Statistical Procedures Companion, by Marija J. Norušis (page 84).

| **Function** | **Form** | **Typical application** |
|---|---|---|
| Logit | $\ln\left(\frac{\gamma}{1-\gamma}\right)$ | Evenly distributed categories |
| Complementary log-log | $\ln(-\ln(1-\gamma))$ | Higher categories more probable |
| Negative log-log | $-\ln(-\ln(\gamma))$ | Lower categories more probable |
| Probit | $\Phi^{-1}(\gamma)$ | Analyses with explicit normally distributed latent variable |
| Cauchit (inverse Cauchy) | $\tan(\pi(\gamma-0.5))$ | Outcome with many extreme values |

Figure 3.7 : Link Function Descriptions

The primary assumption of Ordinal Logistic Regression is that the effect of the independent variables are proportional across the different thresholds or splits between each pair of categories of your ordinal outcome variable. The assumption essentially requires the explanatory variables have the same effect on the odds regardless of the threshold. This test is performed automatically within both SPSS and Minitab 17 statistical software packages, and is represented with a p-value.

### 3.2.14.2 Principal Component Analysis

Principal Component Analysis (PCA) is a procedure for identifying a smaller number of uncorrelated variables ("principal components") from a large set of data. The goal of this type of analysis is to explain the maximum amount of variance with the fewest number of principal components. It is unclear if Adeleke and Adepoju used this type of analysis in their case study.

This type of analysis can be executed following the collection of the data to not only reduce the number of variables studied, but also avoid multicollinearity among the input variables. The value of the PCA is determining if a smaller number of uncorrelated variables that are easier to interpret and analyze can be modeled (Principal Component Analysis Overview).

An example of where multicollinearity may exist in this research, or its replication, would be a project that was selected to positively impact both internal and external customers. Additionally this analysis may suggest that the selection criteria improvement focus and current state performance are highly correlated. A project selected because it performed very poorly in the current state may also have a high degree of perceived impact on the external customer. Further, that project's selection criteria may also be correlated with having a clearly defined scope and goals, as leadership may be under heavy fire to solve the problem as soon as possible.

#### 3.2.14.3 Best Subsets Multiple Regression

Best Subsets Multiple Regression could also be used to answer our primary hypothesis statement if we do not detect multicollinearity among our predictor terms.

Adeleke and Adepoju used this analysis to conclude their study on pregnancy outcomes at a State hospital in Nigeria.

Best subsets regression is an automated analysis that results in the best-fitting regression model based on the data analyzed. R-squared, adjusted R-squared, predicted R-squared, Mallows' Cp, and s are calculated by the best subsets procedure and are used by criteria for model comparisons. A subset of predictor variables is the result of the analysis (Basics of best subsets regression).

In a best subsets analysis, the highest $R^2$ model contains the largest number of predictor terms. For example, a model with five predictor terms will always have a larger $R^2$ than a four term model. $R^2$ is used for comparing models of the same size while adjusted $R^2$ and Mallows' Cp is instead used to compare models with different numbers of predictor terms. Models with lower adjusted $R^2$ may include insignificant terms.

An alpha value of .05, or 95% confidence level will be used. As such, P values below .05 will cause us to reject the Null Hypothesis and support the Alternative Hypothesis.

This analysis will seek to understand which, if any, selection criteria predict the highest financial benefit for LSS projects. This will be completed by examining both the P values from the regression analysis, and the magnitude of each variable in the regression equation. The regression equation will also be analyzed for its fit to the current data set, where $R^2$ adjusted and the normality of residuals will be documented. Any $R^2$ value above .7 will be reported as an indication of moderate correlation. $R^2$ values above .9 will be reported as an indication of strong correlation.

### 3.2.15. Praxis Defense

The Praxis Defense will be completed following the data collection, analysis, and conclusions or recommendation phases of this research have been completed. The Praxis Defense will be held onsite at SMU in University Park, TX.

### 3.2.16. Commissioning of Praxis Findings

Following the Praxis Defense, the findings of this research will be communicated throughout the TACOM LCMC. The results may effect change on local processes and policies with respect to the selection of LSS non-gated projects. Additionally, the findings from this research will be presented to the AMC CPI team in Huntsville, AL.

Further, the outline of this research project will be available to all Department of Defense employees and contractors through the Defense Technical Information Center (DTIC), allowing others to replicate and build on these findings. For example, an organization in the Department of Navy may use this research process to better refine and optimize their own criteria for selecting LSS non-gated projects, while an organization in the Air Force may use this as a template to study their selection criteria for other CPI program and project types such as gated VE, non-gated VE, or gated LSS projects.

### 3.3. Measurement System Analysis

This research relies on two sets of data to be collected. The first set of data comes from an online database known as PowerSteering. Because of the newly implemented polices and standard operating procedures released by AMC for use in FY16, the initial data set has been deemed to have little measurement system concern. In the past, before the implementation of the new mandates, the same conclusion would likely not have been drawn.

When examining the measurement system of the second data collection (the survey), there is more concern to be mitigated. Because the data being extracted from the project initiator may be over a year old, it is important to consider that a number of measurement error types may be present. In order to best mitigate these measurement errors, a number of discussions where held where the considerations or effects each type of measurement error they may have on the output of this research were discussed and outlined. Table 3.1 depicts possible discrimination, bias, stability, repeatability, and reproducibility measurement errors and their consideration based on stakeholder feedback.

Table 3.1. Measurement System Errors

| Type of Measurement Error | Description | Considerations to this Research |
|---|---|---|
| Discrimination (resolution) | The ability of the measurement system to divide measurements into “data categories” | A 1-3-5-7-9 Likert Scale survey was used. (Completely Disagree, Somewhat Disagree, Neither, Somewhat Agree, Completely Agree) – We will work with SMU Stat Service to solidify scale. |
| Bias | The difference between an observed average measurement result and a reference value | There will inherently be bias in this study based on the time of projection selection to the time of the survey . This is a primary reason why we are looking solely at |

| | | |
|---|---|---|
| | | FY16 projects – projects are top of mind and recently celebrated. |
| Stability | The change in bias over time | There may be stability error in this study based on the time of projection selection to the time of survey . However, since we are only asking the survey to be filled out once per project, it is not a concern. |
| Repeatability | The extent variability is consistent | Project initiators will be trained to use historical documents and email traffic to reference during completion of survey. Only in rare cases will we except a survey to be filled out ‘from memory’ |
| Reproducibility | Different appraisers produce consistent results | We will only collect data from one person per project. We will train the survey taker to include others who were involved in the project selection in filling out the survey. |
| Variation | The difference between parts | This is output we are researching – we expect to have part to part (or project to project) variation. |

# CHAPTER 4

# ANALYSIS RESULTS

## 4.1. Outline

This chapter describes the process of processing and analyzing the data collected both from the FY16 LSS project results, obtained from PowerSteering, the Army's system of record for CPI project results (see Figure 1.3 and Table 1.1), as well as the project selection survey executed in 2017. Data was collected over a period of two months via an online survey disseminated through the TACOM LCMC CPI Steering Committee, a governance and reporting board for all CPI financial and operational benefiting projects.

During the early stages of the analysis phase of this Praxis, it was determined that creating a predictive equation of sixteen or more predictors that aimed to pinpoint a specific numeric financial benefit output was practically infeasible. If it turned out that a strong relationship and predictive equation could be calculated, it would still be unlikely for practical use in TACOM LCMC or other organizations. Instead, the focus shifted on the ability to predict, based on those same predictors, a category or level of financial benefit. Similar to the Nigerian hospital research referenced in Chapter 3, this type of analysis could lead to important findings and recommendations for the future performance of the CPI program; and result in the selection of LSS projects that were most likely to yield high financial benefits (or the highest category of readiness, for example).

Over a number of feedback sessions the steering committee provided input on the survey itself, adding in two additional questions regarding LSS project impact to "readiness;" which was defined both as an Army-specific predictor (was readiness considered) and outcome (was readiness positively impacted). Readiness is a general term used to quantify the ability of the Army's forces to continue to execute and win in theatre. In addition to financial benefit, each project's effect on Readiness will be regressed over to provide additional insight into how projects may be selected that do not aim to maximize financial benefit.

Prior to collecting data from each FY16 project initiator, a thirty minute hands-on training event was held to ensure the proper documentation and submission of each survey. As outlined previously, each FY16 LSS project that was completed was assigned a copy of the survey with the intent of having each project's selection criteria returned to the author. As will be discussed in the following section, while not all FY16 project data was captured, a significant amount of project selection criteria data was successfully documented and submitted, allowing the analysis phase to be executed and the overall progression of this research.

## 4.2. Survey Results

The data collection survey resulted in 119 LSS project data points to be matched with their corresponding financial benefit output. The survey initially aimed to collect all 152 completed LSS project selection criteria data, including 33 gated projects and 119 non-gated projects. Due to the retirement of a FY16 LSS Deployment Director, not all non-gated projects were accounted for (there was no known documentation left behind). It should be noted that the significance and practicality of any analysis conducted with data collected from individual historical records needs to be carefully vetted and ensured to be free from bias and other measurement errors, as outlined in Chapter 3. The data collected, stratified by project type and organization type, is shown in summary form in Table 4.1. Included in this table is the number of projects data was collected for each analysis case, the total financial benefit accounted for, and the percentage of each analysis case's contribution to the total financial benefit represented in the sample.

Table 4.1 : Survey Response Summary

| **Analysis case** | **N** | **Financial benefit accounted for** | **% of total $ collected** |
|---|---|---|---|
| All FY16 | 119 | $196,669,892 | 100% |
| All Gated | 19 | $75,186,088 | 38.23% |
| All Non-Gated | 100 | $121,669,892 | 61.77% |
| Non-Gated Arsenal & Depot | 64 | $20,856,476 | 10.60% |
| Non-Gated PEO | 33 | $89,319,449 | 45.42% |
| Gated Arsenal & Depot | 3 | $10,515,027 | 5.35% |
| Gated PEO | 10 | $64,524,208 | 32.82% |
| Gated HQ & ILSC | 6 | $146,853 | 0.07% |
| Non-Gated HQ & ILSC | 3 | $11,307,879 | 5.75% |

Figure 4.1 depicts the stratification of responses again by project type and

organization type.  The 33 absent non-gated projects were initially selected by two former PEO deployment directors who are no longer with the DoD (their departments had no record of their decision making process).

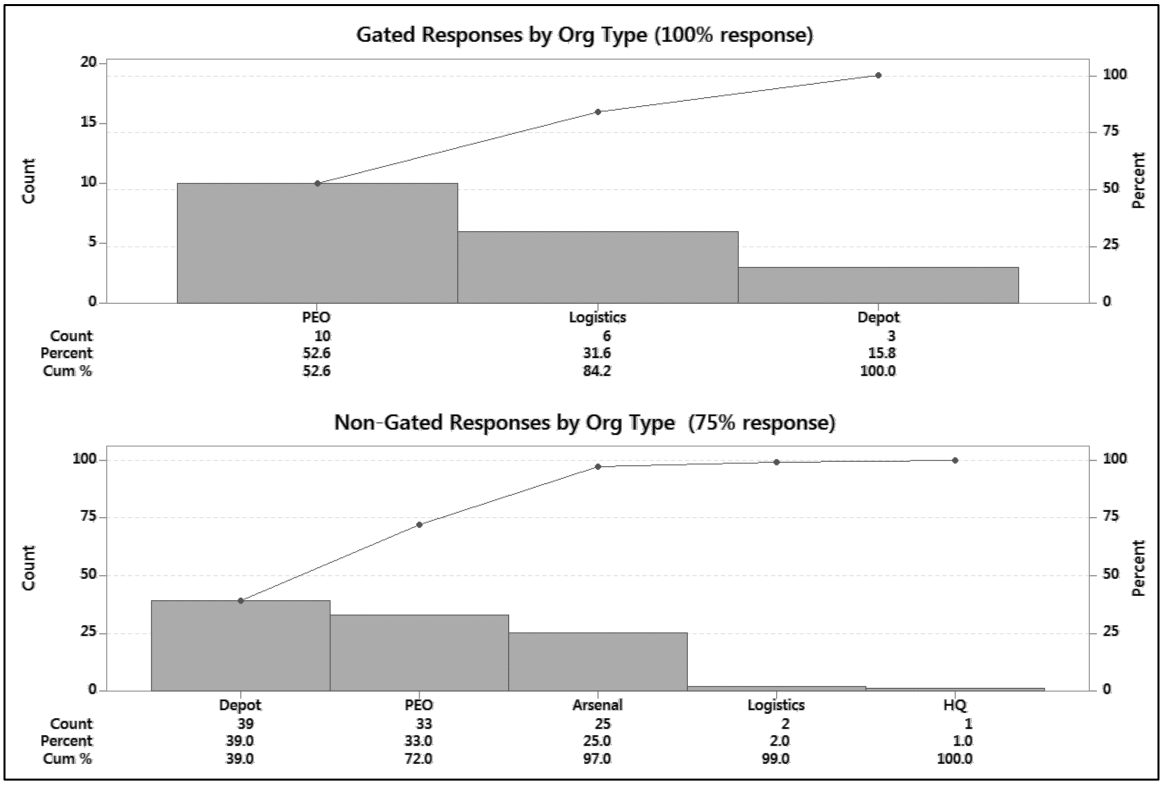



Figure 4.1 : Survey Response Summary

## 4.3. Assignment of Ordinal Categories: Financial Benefit

As illustrated in Figure 1.3, the range of continuous financial benefit of the surveyed projects was vast.  In order to execute an Ordinal Regression study, ordinal categories needed to be defined.  These categories were determined, pre-analysis, as depicted in Table 4.2.  It should be noted that while the ordinal categories follow a logical increasing pattern, the spacing of each category is not consistent - Ordinal Logistic Regression offers the analysis of this scenario. Further, we note that the distribution of each ordinal category is relatively constant- this allows the use of the Cumulative Logit Link function which assumes a relatively even probability of a project picked at random to fall in any of the four ordinal categories.

Table 4.2 : Ordinal Categories for Financial Benefit

| Ordinal Category Name | Lower limit | Upper limit | % of sample |
|---|---|---|---|
| No financial benefit | none | $0.00 | 35% |
| Low financial benefit | $0.01 | $99,999.99 | 24% |
| Medium financial benefit | $100,000.00 | $999,999.99 | 22% |
| High financial benefit | $1M | None | 19% |

### 4.4. Ordinal Logistic Regression Summary Results

Using both Minitab 17 and SPSS, the GLM and Cumulative Logit function was executed on the following four analysis cases: all FY16 projects, all non-gated projects, non-gated projects from Arsenals and Depots, and non-gated projects from PEOs. The remaining analysis cases did not present a sufficient sample size to execute Ordinal Logistic Regression.

Table 4.3 outlines each analysis case including its sample size, p-value, Pearson coefficient, and lists significant predictor factors at the 95% confidence level. While we stated the overarching hypothesis statements for this research in the opening chapters, it is now appropriate to state the specific null and alternate hypothesis statements for this particular tests. The generalized null hypothesis for this analysis can be described as follows:

*$H_0$: There is no relationship between a unit increase in a given predictor variable and the probability of the corresponding output variable achieving its highest ordinal category.*

*$H_a$: There is a relationship between a unit increase in a given predictor variable and the probability of the corresponding output variable achieving its highest ordinal category.*

Further, a Person chi-square test is executed to judge whether a particular model fit is adequate. While we are looking for p values less than .05 (at 95% confidence), we are looking for chi-square values whose values exceed .05 in order to proceed in examining specific significant factors. Recall that each predictor variable emanated from the literature review, and was surveyed for each represented project. The ordinal category of each project was assigned after pulling the financial benefit of each from PowerSteering. As seen in the P-value column, two of the analysis were statistically significant: the All FY16 study and the non-gated Arsenal and Depot study. A detailed analysis of the first analysis case, “All FY16,” is presented in the following section.

Table 4.3 : Ordinal Logistic Regression Results

| **Analysis case** | **N** | **P** | **Pearson χ2** | **Significant factors (p<.05)** |
|---|---|---|---|---|
| All FY16 | 119 | .002 | 341.385 | ▪ IntGap<br>▪ 3Months<br>▪ HighBenefit<br>▪ IntDoc |
| All Gated | 19 | Insufficient sample size | | |
| All Non-Gated | 100 | .072 | 292.872 | ▪ 3Months<br>▪ IntDoc |
| Non-Gated Arsenal & Depot | 64 | .018 | 172.440 | ▪ NonHC<br>▪ 3Months<br>▪ HighBenefit |
| Non-Gated PEO | 33 | .067 | 91.398 | ▪ ExtGap<br>▪ Goals<br>▪ LowTech |
| Gated Arsenal & Depot | 3 | Insufficient sample size | | |
| Gated PEO | 10 | Insufficient sample size | | |
| Gated Other | 6 | Insufficient sample size | | |
| Non-Gated Other | 3 | Insufficient sample size | | |

We can conclude from these results a number of observations. First, the ability to perform this analysis required a sample size only found in four of our available test cases. Second, out of the four analysis cases computed, only two were statistically significant (able to reject the null hypothesis based on p-value) and had good model fits (chi-square). Of the two significant cases studies, we see that the list of significant factors for each exhibit variation. Due to its inclusion of all data points, and the known practice of changing governance and standard operating procedures being conducted at the highest level of the LCMC, we will choose the first analysis case, All FY16 LSS projects, for a deeper dive, presented in the following section.

### 4.4.1 Ordinal Logistic Regression: All FY16 Results

The output of the financial benefit Ordinal Logistic Regression study completed with all 119 projects collected is shown below in Table 4.4.

Table 4.4 : Ordinal Logistic Regression Results: All 119 projects, Financial Benefit

```
Link Function: Logit


Response Information

Variable           Value   Count
FB Classification  High       23
                   Medium     26
                   Low        29
                   None       41
                   Total     119


Logistic Regression Table

                                                    Odds     95% CI
Predictor            Coef    SE Coef      Z       P  Ratio  Lower  Upper
Const(1)        -0.599641    1.87123  -0.32  0.749
Const(2)         0.743937    1.87519   0.40  0.692
Const(3)          1.98410    1.88116   1.05  0.292
```

```
ExtGap         -0.172026  0.0924623  -1.86  0.063   0.84   0.70   1.01
IntGap         -0.398327   0.190264  -2.09  0.036   0.67   0.46   0.97
HCRes          0.0485625   0.171812   0.28  0.777   1.05   0.75   1.47
NonHC          -0.141568   0.149401  -0.95  0.343   0.87   0.65   1.16
ClearScope     0.0102973   0.180474   0.06  0.954   1.01   0.71   1.44
3Months        -0.246664  0.0854070  -2.89  0.004   0.78   0.66   0.92
Goals           0.250717   0.150771   1.66  0.096   1.28   0.96   1.73
StretchGoals    0.101789  0.0864321   1.18  0.239   1.11   0.93   1.31
HighBenefit     0.163300  0.0773465   2.11  0.035   1.18   1.01   1.37
ExtDoc        -0.0752099  0.0807129  -0.93  0.351   0.93   0.79   1.09
IntDoc          0.182492  0.0775603   2.35  0.019   1.20   1.03   1.40
SolKnown       0.0992532  0.0677665   1.46  0.143   1.10   0.97   1.26
HighSuccess   -0.0547564  0.0949974  -0.58  0.564   0.95   0.79   1.14
LowTech        0.0293702  0.0905589   0.32  0.746   1.03   0.86   1.23
BuyIn           0.148212  0.0874747   1.69  0.090   1.16   0.98   1.38
MBB           -0.0935181  0.0737102  -1.27  0.205   0.91   0.79   1.05
Readiness1     0.0349643  0.0708981   0.49  0.622   1.04   0.90   1.19


Log-Likelihood = -142.987
Test that all slopes are zero: G = 37.987, DF = 17, P-Value = 0.002


Goodness-of-Fit Tests

Method    Chi-Square   DF      P
Pearson      341.385  325  0.255
Deviance     278.703  325  0.970


Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs       Number  Percent  Summary Measures
Concordant    3711     71.1  Somers' D               0.43
Discordant    1487     28.5  Goodman-Kruskal Gamma  0.43
Ties            19      0.4  Kendall's Tau-a         0.32
Total         5217    100.0
```

We first interpret the Goodness-of-Fit tests. We see that both the Pearson and Deviance tests were successfully performed. The values of both the chi-square and P indicate that both tests were passed and the model itself can be trusted.

Then we look at the overall model's significance by examining the p value. The value of this p-value is reported as 0.002, less than the alpha value selected at .05. Therefore, we can conclude that the Ordinal Regression analysis is statistically significant.

Next we examine each predictor variables' p value. Any variable p-value less than alpha is interpreted as statistically significant. For this test, the following predictor variables were found to be statistically significant: Internal Gap, 3 Months, High Benefit, and Internal Documentation.

At this point, we have not made any claim to which, if any, of the significant predictors have a positive or negative impact on the output. We can now determine the effect of each predictor variable, which is to answer the question what is the effect of an increase in a unit to the output's probability of achieving its highest ordinal category. This analysis is completed by examining the odds ratio of each predictor variable, paying particular attention to statistically significant variables. For example, the odds ratio of the statistically significant predictor variable "High Benefit" has a point estimate of 1.18, and a 95% confidence interval of 1.01 to 1.37. Notice that the odds ratio does not contain the value 1.0, whereas each non-significant predictor does. The interpretation of this result is as follows: any single unit increase in the predictor rating of High Benefit will increase the probability the rated project achieving the highest level of financial benefit ($1M or more) between 1% and 37%.

Conversely, if we examine a predictor variable which has been determined to be statistically significant, and has a odds ratio interval less than 1.0, we find that single unit increases decrease the probability of the highest financial benefit output. For example, the predictor variable "Internal Gap," which has an odds ratio interval from 0.67 to 0.97. For every one unit increase in Internal Gap rating, we expect the probability of achieving the highest level of financial benefit to decrease between 3% and 33%.

Similarly, we can examine the variable of 3 Months. It is determined that the predictor is statistically significant due to its p-value of .004. We can then look at the odds ratio which is stated as a point estimate of .78 – an increase in the prediction of a project taking three months or less results in a 22% decrease in odds of having the highest ordinal category output. The 95% confidence interval for this odds ratio is bound by .66 and .92. We can confirm this negative effect by examining the coefficient which is reported as -.246.

Due to the large number of predictor variable studied in this Praxis, it is useful to plot each's odds ratio for comparison. In Figure 4.2 we have plotted all predictor variables, including those not statistically significant, in a spider chart. This chart includes a "-" indicating a lower confidence interval, a "+" indicating an upper confidence interval, and a black diamond indicating the point estimate for each predictor's odds ratio. The continuous dashed line represents the value 1.0. Any confidence interval that contains 1.0, or crosses the dashed line, is insignificant, and any confidence interval wholly on one side of 1.0 indicates a positive or negative relationship between predictor and output ordinal category.

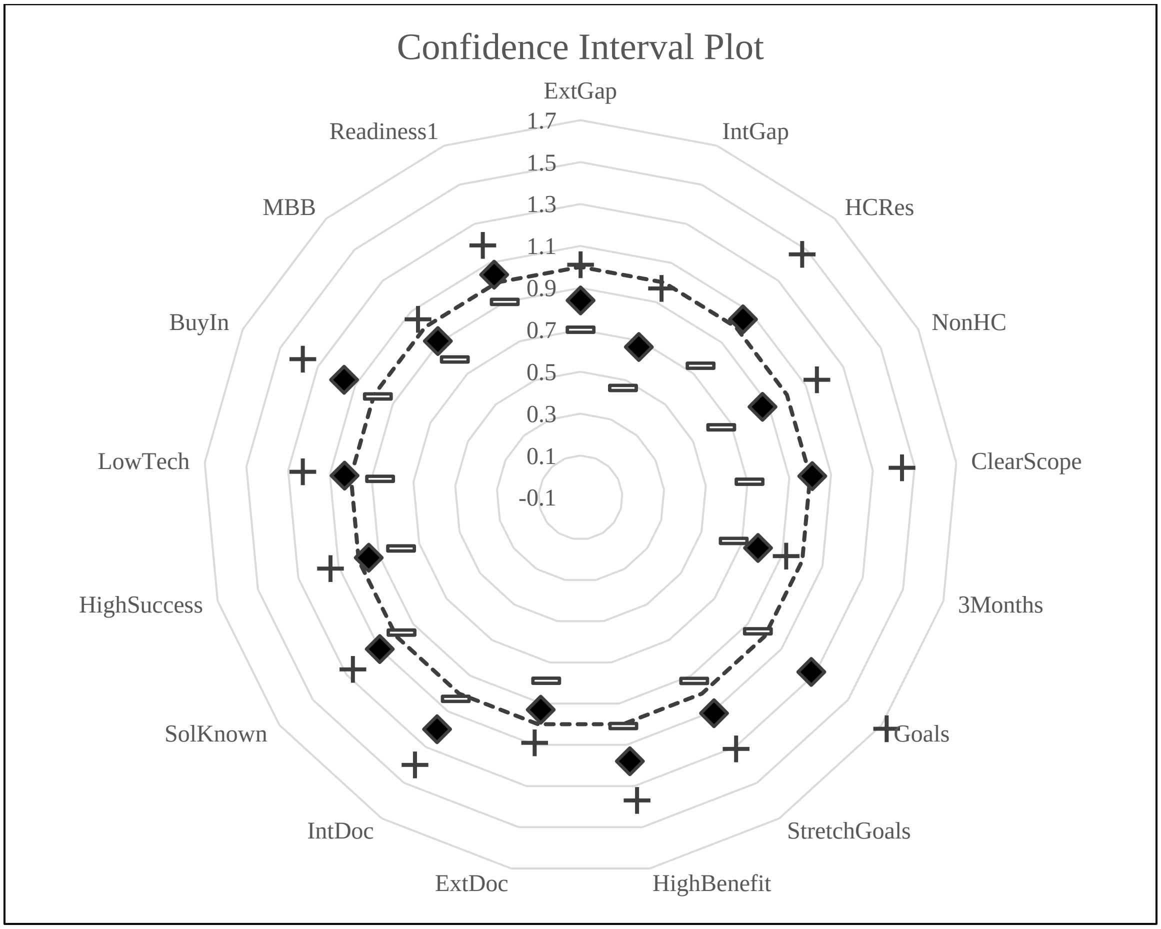



Figure 4.2 : Confidence Interval Plot for Odds Ratio

### 4.4.2 Ordinal Logistic Regression- Readiness

Based on the previous analysis and discussion on Ordinal Logistic Regression, it was proposed that the study also determine if one or more predictor variables had a significance on the output of Readiness. One of AMC's strategic goals, as stated in the AMC Strategic Plan 2013-2020, is to restore strategic depth by rebuilding unit capability and readiness during the Army Force Generation process (ARFORGEN), (page 34).

Readiness was an output measure studied as part of the survey conducted during this Praxis. Each project was rated on the Likert scale (1,3,5,7,9) on whether it affected readiness when complete. This output or Y variable is not to be confused with the predictor or X variable, "Readiness1," which contains information on whether a given project had readiness considerations at the time of selection. Regardless, our null and alternate hypothesis for the regression study remain structurally the same in this event:

*$H_0$: There is no relationship between a unit increase in a given predictor variable and the probability of the corresponding output variable achieving its highest ordinal category.*

*$H_a$: There is a relationship between a unit increase in a given predictor variable and the probability of the corresponding output variable achieving its highest ordinal category.*

However, our ordinal categories have increased from four to five, and the distribution has also skewed towards the higher categories, which will necessitate the use of a more appropriate Link function.

Table 4.5 : Ordinal Categories for Readiness

| **Ordinal Category Name** | **Likert value** | **% of sample** |
|---|---|---|
| Strongly Disagree | 1 | 9% |
| Slightly Disagree | 3 | 7% |
| Neither agree nor disagree | 5 | 18% |

| | | |
|---|---|---|
| Slightly Agree | 7 | 24% |
| Strongly Agree | 9 | 42% |

Due to the higher probability of achieving a 7 or 9 rating based on the 119 projects selected (66%), the Complementary log-log link function has been used to execute the analysis. Minitab 17 executes this as the Complementary Log-Log function. As shown below, Table 4.6 depicts the Minitab 17 output of the analysis on Readiness, using the Complementary Log-Log Link function.

Table 4.6 : Ordinal Logistic Regression Results: All 119 projects, Readiness

```
Link Function: Complementary Log-Log


Response Information

Variable    Value  Count
Readiness2  9         50
            7         28
            5         22
            3          8
            1         11
            Total    119


Logistic Regression Table

Predictor           Coef    SE Coef      Z      P
Const(1)        -5.07871    1.26245  -4.02  0.000
Const(2)        -4.08074    1.23232  -3.31  0.001
Const(3)        -3.22031    1.20163  -2.68  0.007
Const(4)        -2.77510    1.19079  -2.33  0.020
ExtGap          0.145166  0.0589146   2.46  0.014
IntGap         -0.263133   0.117516  -2.24  0.025
HCRes           0.107807   0.109888   0.98  0.327
NonHC           0.129262  0.0968469   1.33  0.182
ClearScope     -0.181599   0.108593  -1.67  0.094
3Months        0.0687131  0.0502157   1.37  0.171
Goals           0.169426  0.0911628   1.86  0.063
StretchGoals   -0.140991  0.0633697  -2.22  0.026
HighBenefit     0.127318  0.0458853   2.77  0.006
ExtDoc         0.0519674  0.0507675   1.02  0.306
IntDoc         0.0565568  0.0453962   1.25  0.213
SolKnown      -0.0310075  0.0417454  -0.74  0.458
HighSuccess    0.0745587  0.0593649   1.26  0.209
```

```
LowTech        -0.0414694  0.0557536  -0.74  0.457
BuyIn            0.162986  0.0563185   2.89  0.004
MBB             0.0244542  0.0463266   0.53  0.598
Readiness1       0.201249  0.0475285   4.23  0.000


Log-Likelihood = -134.114
Test that all slopes are zero: G = 69.367, DF = 17, P-Value = 0.000


Goodness-of-Fit Tests

Method    Chi-Square   DF      P
Pearson      390.152  439  0.955
Deviance     268.228  439  1.000


Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs       Number  Percent  Summary Measures
Concordant    4058     79.5  Somers' D               0.59
Discordant    1034     20.3  Goodman-Kruskal Gamma  0.59
Ties            12      0.2  Kendall's Tau-a        0.43
Total         5104    100.0
```

We first interpret the Goodness-of-Fit tests. We see again that both the Pearson and Deviance tests were successfully performed. The values of both the chi-square and P indicate that both tests were passed and the model itself can be trusted.

Then we look at the overall model's significance by examining the p value. The value of this p-value is reported as 0.000, less than the alpha value selected at .05. Therefore, we can conclude that the Ordinal Regression analysis is statistically significant.

Next we examine each predictor variables' p value. We observe that External Gap, Internal Gap, Stretch Goals, High Benefit, Buy In, and Readiness-considered are all significant factors relating to Readiness-achieved.

We can now examine the magnitude of each significant factors by examining the coefficients of each and interpret the practical affect of each. The highest positive coefficients of significant factors are Readiness-considered (.201), Buy In (.163), and External Gap (.145). High Benefit has a coefficient of 0.127. Each of these factors represent a positive impact on achieving a higher level of readiness as their unit is increased. We see that as projects with high levels of readiness-consideration are selected, the more likely they are to actually impact readiness when the project is complete.

The remaining significant factors, Internal Gap and Stretch Goals have negative coefficients of -0.263 and -0.141 respectively. These factors decrease the probability of achieving higher readiness levels when increased for each project. For example, setting Stretch Goals for a project is likely to decrease the impact of the project on Readiness.

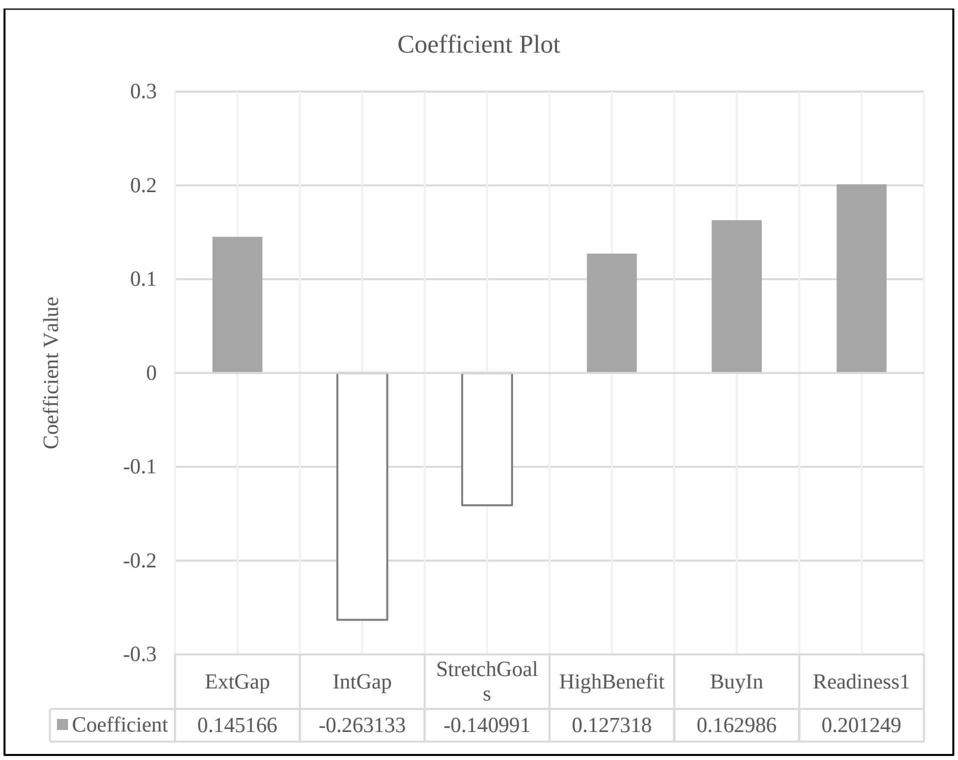



Figure 4.3 : Coefficient Plot for Significant Predictors, Readiness

## 4.5. Multiple Regression Summary Results

As discussed in earlier stages of this Praxis, the initial analysis approach selected was a combination of Principal Component Analysis and Multiple Regression. As the author and team became more aware of practical limitations of this analysis, eventually favoring Ordinal Logistic Regression, it remained an option based on the collected data for Financial Benefit. Multiple Regression was performed on four analysis cases, ranging from the full sample of 119 projects to as few as 19 projects consisting of only the gated LSS projects. Table 4.7 depicts the results of each Multiple Regression study, including r-squared and r-squared adjusted values in addition to significant factors at the 95% confidence level.

Table 4.7: Multiple Regression Summary Results

| **Analysis case** | **n** | **Financial benefit accounted for** | **% of total $ collected** | **Significant factors (p<.05)** | **$r^2$** | **$r^2$ adj.** |
|---|---|---|---|---|---|---|
| All FY16 | 119 | $196,669,892 | 100% | IntGap<br>Goals | 17.93% | 4.12% |
| All Gated | 19 | $75,186,088 | 38.23% | n/a | 24.29% | 0.00% |
| All Non-Gated | 100 | $121,669,892 | 61.77% | IntGap<br>Goals<br>LowTech<br>Readiness1 | 35.71 | 21.42% |
| Non-Gated Arsenal & Depot | 64 | $20,856,476 | 10.60% | HCRes<br>NonHC<br>ScopeChanged<br>IntDoc | 46.85% | 27.21% |
| Non-Gated PEO | 33 | $89,319,449 | 45.42% | | 57.98% | 10.37% |
| Gated Arsenal & Depot | 3 | $10,515,027 | 5.35% | Insufficient sample size | | |

| | | | | |
|---|---|---|---|---|
| Gated PEO | 10 | $64,524,208 | 32.82% | Insufficient sample size |
| Gated Other | 6 | $146,853 | 0.07% | Insufficient sample size |
| Non-Gated Other | 3 | $11,307,879 | 5.75% | Insufficient sample size |

The reader will note that no single analysis case resulted in a strong relationship between predictor X variables and the Y output variable of financial benefit. Some factors were found to be significant, although the strength of those conclusions are statistically weak. One of the major drawbacks of this analysis is that is very unlikely and impractical to use the resulting mathematical model to select a project for execution. It would be very difficult to find the proper mix of 16 predictor variables in the natural project selection process in order to maximize a response of predicted financial benefit. Additionally, the practice of predicting a precise numerical financial benefit output was virtually unheard of during the data collection and interviews conducted as part of this research. Instead, categories such as our ordinal groupings, were favored in discussion and perceived to be a more logical approach by most surveyed.

In the Appendix we present the reader with the results of the Multiple Regression results for the largest sample size case (all 119 projects), as well as an unsuccessful attempt to simplify the model using the both the stepwise and best subsets regression features in Minitab 17. Neither approaches yielded an improved r-squared adjusted value. Additionally, the Principal Component Analysis was completed yet resulted in very limited practical application for selecting projects.

# CHAPTER 5

# DISCUSSION & SUMMARY

This praxis' findings and processes is useful in many ways, including individual and organizational awareness gained by posing of the most basic question, "How do we select LSS projects?" Answering this question retrospectively has granted us the ability to complete the analysis outlined in this praxis and better select future projects, ultimately impacting the Warfighter and taxpayer while increasing local command return on investment. While a predictive model was desired, no statistically significant model could be established based on this data set. However, a number of optimal project selection conditions were discovered. The most immediate use may be implementing updated LSS project selection criteria and practices locally based on the findings. These results may provide input to policy and procedures for selecting LSS projects at the TACOM LCMC level, to include PEOs, Depots, and Arsenals.

The initial plan for this analysis was to run a series of Multiple Regression analyses to create a predictive model for selecting projects in the future with the highest predicted financial benefits. Through this process we learned that Ordinal Logistic Regression was the preferred methodology to retrospectively analyze our FY16 projects based on predictive qualities, then relate them to the probability of achieving the highest output, whether it be financial benefit or another variable such as Readiness.

The specific process generated by this Praxis can be used by any organization which has a goal of driving towards the highest level of financial benefit.  It is the recommendation of this Praxis to use the Ordinal Logistic Regression model to inform and make recommendation to the project selection criteria used.  The process, in conjunction with organizational leaders, can be summarized as follows:

I. Determine predictor variables of interest
   - 16 predictor variables determined in this study
   - Add organization-specific variables ("Readiness")

II. Determine Ordinal groups for output study
   - Deployment Director and COO discussion

III. Collect data from project initiators
   - Establish "point of selection" record keeping

IV. Conduct Ordinal Logistic Regression
   - High level (all data points) analysis
   - Lower levels (gated, non-gated, non-gated PEO, e.g.) as sample size allows

V. Use significant results to inform and refine project selection criteria and process (take action!)
   - Between & Within groups
   - (Model must be statistically significant)

VI. Repeat and refine process over time

This Praxis also provides a high-level process road map to follow for any organization attempting to optimize the results of their CPI or LSS programs based on the selection of projects. The high-level process itself is agnostic to the output and input measures of interest, as well as the analysis type conducted. It may be such that other organizations can readily use the Ordinal Logistic Regression outlined in this Praxis. This high-level process is depicted in Figure 3.8.

We can break the process proposed by this praxis into two distinct timeframes: the initial study, and the follow-on recurring study or studies. In this process, the CPI team receives strategic guidance from the organization's leadership on which output measures are of most importance for optimizing. In our examples, we used both financial benefit and readiness. Next, the CPI team develops, or leverages a survey to determine how projects are currently being selected. Following the return of the survey data, analysis is conducted and the leadership is informed of recommendations. Following the initial study, it is our recommendation that the process be executed at a regular time interval that makes most sense for the individual organization. At this point, the process should mature to where the CPI team can install measurement tools such that LSS project selectors and executors can document their selection criteria in real-time, eliminating the need for retrospective analysis and surveys, as well as improving the measurement system itself. This data would then be constantly updated into the model and leadership would be informed and able to readily report CPI summary and project-specific input, and output, measures.

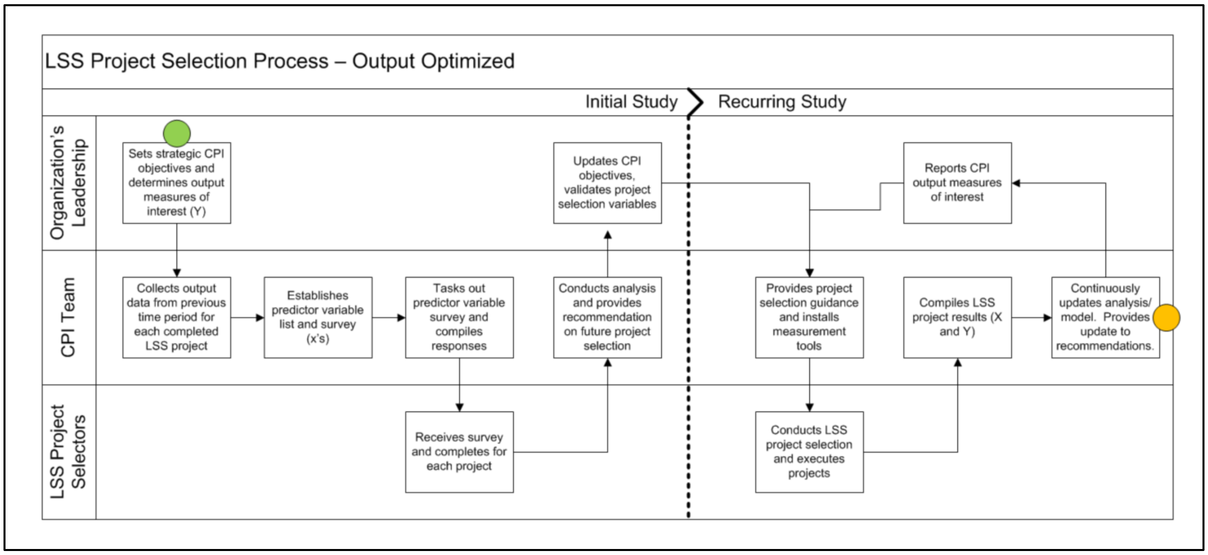



Figure 5.1.  LSS Project Selection Process – Output Optimized

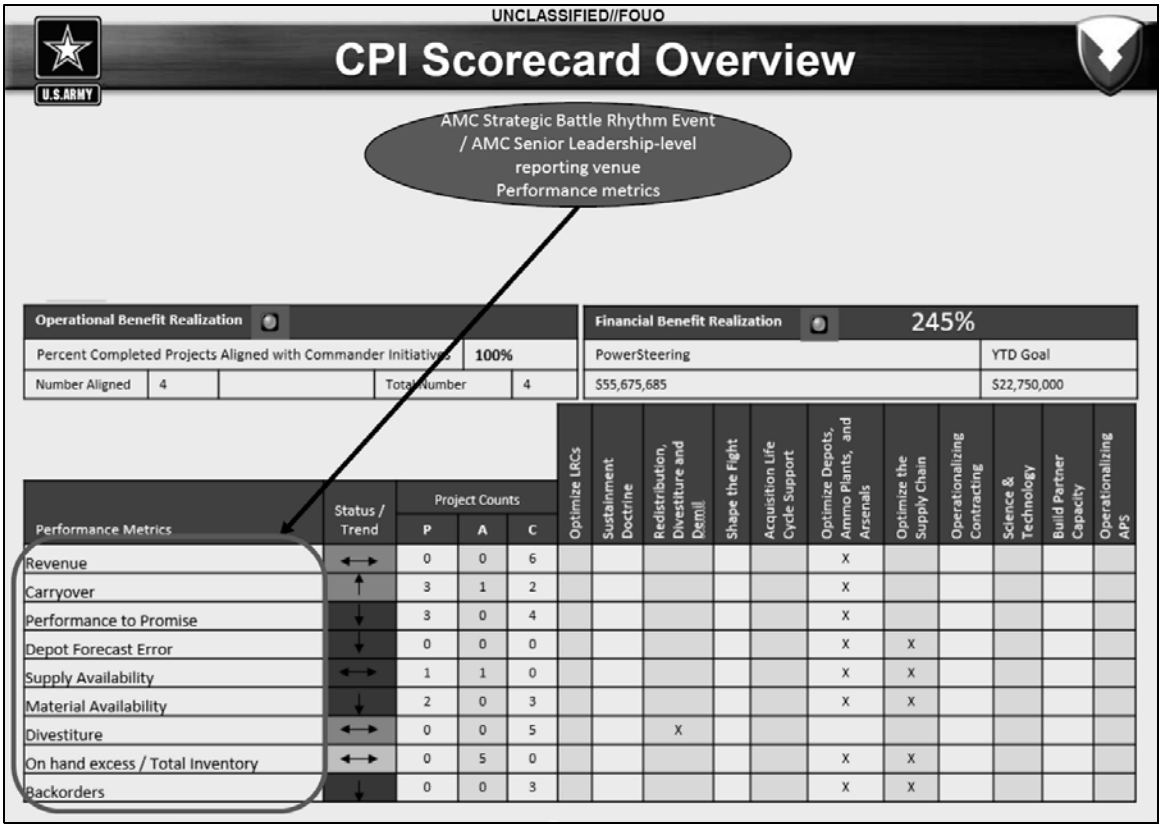
Based on the results shown in this praxis, TACOM LCMC should attempt to select projects that have the highest rating in selection criteria concerning internal documentation and the prediction of high benefit when trying to maximize the output of financial benefit.  The organization should avoid projects that have the highest rating in selection criteria concerning internal gap-focus and three month timeline.  The statistical significance of these four predictor variables not only narrows the scope of our future selection processes, potentially removing the noise of considering other factors, but paves the way for the implementation of stronger measurement systems at the point of project selection. TACOM LCMC may also consider also other output measures of interest such as ‘readiness’ which was also analyzed by using this model and process.

There are a number of AMC organizations that may immediately benefit by implementing the prescribed process for refining LSS project selection criteria.  The following AMC organizations have been found to exhibit similar CPI programs and reporting structures up to HQAMC:

- Aviation Missile Life Cycle Management Command (AMCOM)
- Army Sustainment Command (ASC)
- Communications-Electronics Command Life Cycle Management Command (CECOM)
- Joint Munitions & Lethality Life Cycle Management Command (JM&L)
- Military Surface Deployment and Distribution Command (SDDC)

While each of the above AMC organizations have clear differences in terms of funding types, deliverables, and customers, the use of the prescribed process may not only be used to draw inference to the similarities in how each selects LSS projects, but also may hold the key for unlocking future improvement opportunities across the higher command.

Shortly before the defense of this Praxis, AMC disseminated a new CPI scorecard for immediate use by all major subordinate commands. This scorecard is to be used throughout FY18, and provides leadership oversight of project portfolio performance with respect to financial benefit goals, as well as mapping to other senior-leader output measures such as supply availability, revenue, and materiel availability. A snapshot of the FY18 scorecard is shown in Figure 3.8.




| Performance Metrics | Status / Trend | Project Counts P | A | C | Optimize LRCs | Sustainment Doctrine | Redistribution, Divestiture and Demil | Shape the Fight | Acquisition Life Cycle Support | Optimize Depots, Ammo Plants, and Arsenals | Optimize the Supply Chain | Operationalizing Contracting | Science & Technology | Build Partner Capacity | Operationalizing APS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Revenue | ↔ | 0 | 0 | 6 | | | | | | X | | | | | |
| Carryover | ↑ | 3 | 1 | 2 | | | | | | X | | | | | |
| Performance to Promise | ↓ | 3 | 0 | 4 | | | | | | X | | | | | |
| Depot Forecast Error | ↓ | 0 | 0 | 0 | | | | | | X | X | | | | |
| Supply Availability | ↔ | 1 | 1 | 0 | | | | | | X | X | | | | |
| Material Availability | ↓ | 2 | 0 | 3 | | | | | | X | X | | | | |
| Divestiture | ↔ | 0 | 0 | 5 | | | X | | | | | | | | |
| On hand excess / Total Inventory | ↔ | 0 | 5 | 0 | | | | | | X | X | | | | |
| Backorders | ↓ | 0 | 0 | 3 | | | | | | X | X | | | | |

Figure 5.2.  FY18 CPI Scorecard Overview

The findings of this praxis may also be used to compare with commercial or industrial organizations as well.  The process is applicable and scalable for any type, size, or geographically located organization, even though the results are expected to be different for each organization.  For example, the four outside organizations studied in the literature review, an automotive manufacturer, consumer technology center, and both public and private defense research and development organizations could all use this model to gain statistical insight into which, if any, of their project selection criteria are helping them to achieve their desired output goals.

Further, the findings of this praxis may be solidified by comparing and contrasting the results of analyzing TACOM LCMC FY17 LSS projects, which will be available in Spring 2018. The model and process proposed in this praxis is hypothesized to gain power statistically and strength in practical application as the sample size of projects increases. Users of the model and process may find convergence on a number of significant factors leading to higher ordinal output categories, or conversely, variation in the model's result over time (fiscal year to fiscal year, for example).

It may be prudent to factor in the organization's cost of project execution when selecting said projects. If an organization is continually selecting and executing projects which have benefits that fall below the price of execution itself, the organization may consider re-examining their selection process, a natural starting point for adopting and executing the process outlined in this praxis.

The use of Process Capability to judge, retroactively, the performance of the model for project selection is also proposed as an output of this praxis. Process Capability is a statistical tool used in process improvement methodologies such as Lean Six Sigma. It is a quantifiable comparison of allowed variation, which comes from the Voice of the Customer, to the variation exhibited by the process or product itself. A typical Process Capability study, which produces a unit-less measure "Cp," consists of interviewing or collecting the Voice of the Customer (expressed in Upper and Lower Specification Limits) and analyzing the processes or product's current state variation.

Cp values can range from negative infinity to positive infinity. Cp values at or above 1.33 to indicate a 'capable' process or product. Cp values below 1.33 are said to be 'not capable.' Often Cp studies are conducted before and after an improvement effort to quantify the level of improvement.

Figure 3.9 outlines the basic calculations of Cp, and Cpk. The reader will note that Cp is used when process data is normally distributed and centered between spec limits, and Cpk accounts for scenarios where the data is not centered on the target value. Nonparametric data can also be analyzed for Cp or Cpk with relative ease through automated statistical software packages.

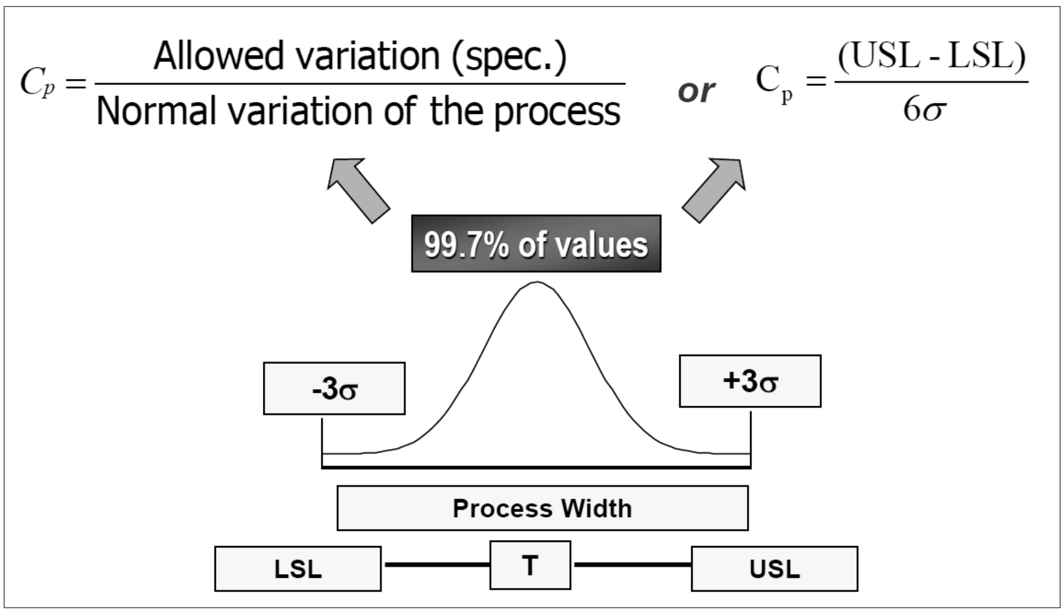



Figure 5.3. Process Capability Calculation

In this application, the Lower Specification Limit may be set to a value greater than the average project investment cost in a given organization. In more mature organizations, this value may be set higher, 1.5 times the average investment cost, for example. The CPL value calculated will give the organization both a leading and a lagging metric to judge its project performance and validate its selection model.

A final observation and recommendation centers on the collection, affinitization, and cataloging of organization-specific predictor and output measures. An online repository could be established such that organizations could define and share their project selection criteria and output measures of success. For example, an Army command may share its organization-specific predictor of “readiness,” while an Automotive organization may share criteria related to supply chain delay, for example. Additionally, organizations may share output measures of interest such as financial benefit, process lead time reduction, risk reduction, readiness improvement, and other quality improvement measures. This catalog would, over time, build the body of knowledge on different selection criteria for LSS projects to be leveraged by all CPI and LSS practitioners in an effort to advance the community.

# APPENDIX: Additional Analysis Results

## 4.5.1. Multiple Regression – All FY16 Projects

Table 4.8: Multiple Regression Results – All FY16

```
Analysis of Variance

Source           DF       Adj SS       Adj MS  F-Value  P-Value
Regression       17  8.46001E+14  4.97648E+13     1.30    0.209
  ExtGap          1  4.41618E+11  4.41618E+11     0.01    0.915
  IntGap          1  2.44034E+14  2.44034E+14     6.37    0.013
  HCRes           1  9.56322E+12  9.56322E+12     0.25    0.619
  NonHC           1  2.66459E+12  2.66459E+12     0.07    0.793
  ClearScope      1  1.10824E+14  1.10824E+14     2.89    0.092
  3Months         1  3.05103E+13  3.05103E+13     0.80    0.374
  Goals           1  1.61836E+14  1.61836E+14     4.22    0.042
  StretchGoals    1  1.11449E+13  1.11449E+13     0.29    0.591
  HighBenefit     1  5.10451E+13  5.10451E+13     1.33    0.251
  ExtDoc          1  1.12197E+12  1.12197E+12     0.03    0.864
  IntDoc          1  3.44825E+13  3.44825E+13     0.90    0.345
  SolKnown        1  8.76304E+12  8.76304E+12     0.23    0.634
  HighSuccess     1  1.40034E+12  1.40034E+12     0.04    0.849
  LowTech         1  4.93752E+13  4.93752E+13     1.29    0.259
  BuyIn           1  1.18716E+13  1.18716E+13     0.31    0.579
  MBB             1  9.28273E+12  9.28273E+12     0.24    0.624
  Readiness1      1  1.41988E+13  1.41988E+13     0.37    0.544
Error           101  3.87143E+15  3.83310E+13
  Lack-of-Fit    97  1.30793E+15  1.34838E+13     0.02    1.000
  Pure Error      4  2.56350E+15  6.40874E+14
Total           118  4.71743E+15


Model Summary

      S    R-sq  R-sq(adj)  R-sq(pred)
6191203  17.93%      4.12%       0.00%



Regression Equation

Financial Benefit = 15984239 - 32135 ExtGap - 1275790 IntGap + 276195 HCRes
- 128395 NonHC
                    - 995649 ClearScope - 240963 3Months + 965782 Goals
- 149479 StretchGoals
                    + 275198 HighBenefit - 45254 ExtDoc + 231182 IntDoc
+ 104409 SolKnown
                    - 58566 HighSuccess - 338447 LowTech - 155538 BuyIn
- 117082 MBB
                    - 140871 Readiness1
```

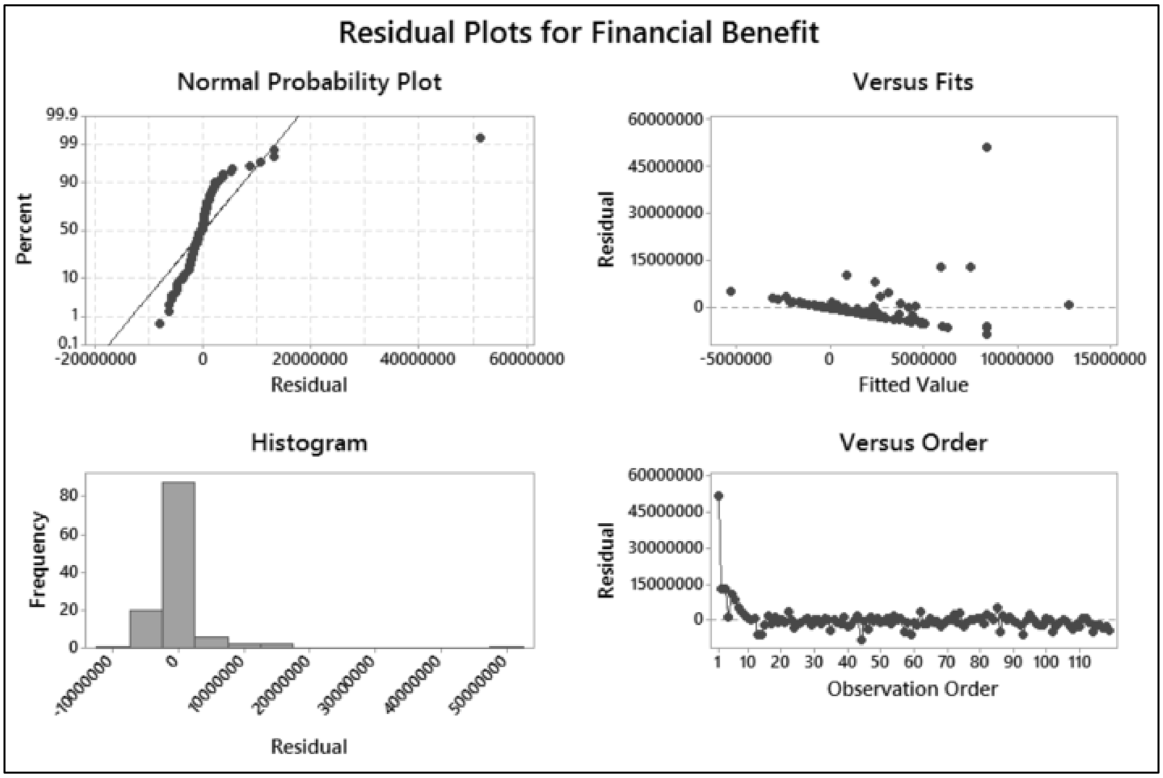



Figure 4.3: Residual Plots

## 4.5.2. Stepwise Multiple Regression Results

Table 4.9: Stepwise Multiple Regression Results

```
Stepwise Selection of Terms

α to enter = 0.15, α to remove = 0.15


Analysis of Variance

Source          DF       Adj SS       Adj MS  F-Value  P-Value
Regression       3  5.15439E+14  1.71813E+14     4.70    0.004
  IntGap         1  2.94610E+14  2.94610E+14     8.06    0.005
  3Months        1  8.82943E+13  8.82943E+13     2.42    0.123
  HighBenefit    1  9.64759E+13  9.64759E+13     2.64    0.107
```

| | | | | | |
|---|---|---|---|---|---|
| Error | 115 | 4.20199E+15 | 3.65391E+13 | | |
| Lack-of-Fit | 111 | 1.63850E+15 | 1.47612E+13 | 0.02 | 1.000 |
| Pure Error | 4 | 2.56350E+15 | 6.40874E+14 | | |
| Total | 118 | 4.71743E+15 | | | |

Model Summary

| S | R-sq | R-sq(adj) | R-sq(pred) |
|---|---|---|---|
| 6044755 | 10.93% | 8.60% | 1.21% |

Regression Equation

Financial Benefit = 10506901 - 1139036 IntGap - 314919 3Months + 352851 HighBenefit

### 4.5.3 Best Subsets

Table 4.10: Best Subsets Multiple Regression Results

Response is Financial Benefit

| Vars | R-Sq | R-Sq (adj) | R-Sq (pred) | Mallows Cp | S | ExtGap | IntGap | HCRes | NonHC | ClearScopes | 3Months | Goals | StretchGoals | HighBenefit | ExtDoc | IntDoc | SolKnown | HighSuccess | LowTech | BuyIn | MBB | Readiness1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.8 | 6.0 | 0.0 | -0.4 | 6128689 | | X | | | | | | | | | | | | | | | |
| 1 | 3.3 | 2.5 | 0.0 | 4.0 | 6243301 | | | | | | | | | | | | | | X | | | |
| 2 | 9.1 | 7.5 | 0.0 | -1.1 | 6081548 | | X | | | | | | | X | | | | | | | | |
| 2 | 8.9 | 7.3 | 0.5 | -0.9 | 6087344 | | X | | | | X | | | | | | | | | | | |
| 3 | 10.9 | 8.6 | 1.2 | -1.4 | 6044755 | | X | | | | X | | | X | | | | | | | | |
| 3 | 10.7 | 8.4 | 0.2 | -1.1 | 6053076 | | X | | | | | | | X | | | | | X | | | |
| 4 | 12.5 | 9.4 | 0.0 | -1.3 | 6018926 | | X | | | X | | X | | | | | | | X | | | |
| 4 | 12.4 | 9.3 | 0.0 | -1.2 | 6020420 | | X | | | X | X | X | | | | | | | | | | |
| 5 | 14.3 | 10.6 | 0.0 | -1.6 | 5980000 | | X | | | X | | X | | X | | | | | X | | | |
| 5 | 14.1 | 10.3 | 0.0 | -1.3 | 5987069 | | X | | | X | X | X | | X | | | | | | | | |
| 6 | 15.3 | 10.7 | 0.0 | -0.7 | 5973927 | | X | | | X | X | X | | X | | | | | X | | | |
| 6 | 15.1 | 10.6 | 0.0 | -0.6 | 5978331 | | X | | | X | | X | | X | | | | | X | | | X |
| 7 | 16.0 | 10.7 | 0.0 | 0.4 | 5975229 | | X | | | X | X | X | | X | | | | | X | | | X |
| 7 | 15.9 | 10.6 | 0.0 | 0.5 | 5979293 | | X | | | X | X | X | X | X | | | | | X | | | |
| 8 | 16.5 | 10.4 | 0.0 | 1.8 | 5985824 | | X | | | X | X | X | | X | | X | | | X | | | X |
| 8 | 16.3 | 10.3 | 0.0 | 2.0 | 5989855 | | X | | | X | X | X | X | X | | | | | X | | | X |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 16.9 | 10.1 | 0.0 | 3.2 | 5996400 | | X | | | X | X | X | | X | | X | | | X | | X | X |
| 9 | 16.9 | 10.0 | 0.0 | 3.3 | 5996843 | | X | | | X | X | X | X | X | | X | | | X | | X | |
| 10 | 17.3 | 9.6 | 0.0 | 4.8 | 6010514 | | X | | | X | X | X | X | X | | X | | | X | | X | X |
| 10 | 17.3 | 9.6 | 0.0 | 4.8 | 6011698 | | X | | | X | X | X | X | X | | X | | | X | X | X | |
| 11 | 17.6 | 9.1 | 0.0 | 6.5 | 6028500 | | X | | | X | X | X | X | X | | X | | | X | X | X | X |
| 11 | 17.4 | 8.9 | 0.0 | 6.6 | 6033797 | | X | | | X | X | X | X | X | | X | X | | X | | X | X |
| 12 | 17.7 | 8.4 | 0.0 | 8.3 | 6052952 | | X | X | | X | X | X | X | X | | X | | | X | X | X | X |
| 12 | 17.7 | 8.3 | 0.0 | 8.3 | 6053366 | | X | | | X | X | X | X | X | | X | X | | X | X | X | X |
| 13 | 17.8 | 7.6 | 0.0 | 10.2 | 6077082 | | X | X | | X | X | X | X | X | | X | X | | X | X | X | X |
| 13 | 17.7 | 7.5 | 0.0 | 10.3 | 6080080 | | X | X | X | X | X | X | X | X | | X | | | X | X | X | X |
| 14 | 17.8 | 6.8 | 0.0 | 12.1 | 6104489 | | X | X | X | X | X | X | X | X | | X | X | | X | X | X | X |
| 14 | 17.8 | 6.8 | 0.0 | 12.1 | 6104836 | X | X | X | | X | X | X | X | X | | X | X | | X | X | X | X |
| 15 | 17.9 | 5.9 | 0.0 | 14.0 | 6132157 | | X | X | X | X | X | X | X | X | X | X | X | | X | X | X | X |
| 15 | 17.9 | 5.9 | 0.0 | 14.1 | 6132894 | X | X | X | X | X | X | X | X | X | | X | X | | X | X | X | X |
| 16 | 17.9 | 5.0 | 0.0 | 16.0 | 6161130 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 16 | 17.9 | 5.0 | 0.0 | 16.0 | 6161672 | X | X | X | X | X | X | X | X | X | | X | X | X | X | X | X | X |
| 17 | 17.9 | 4.1 | 0.0 | 18.0 | 6191203 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

### 4.5.3. Principal Component Analysis Results

Table 4.11: Principal Component Loadings

Eigenanalysis of the Correlation Matrix

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Eigenvalue | 3.7997 | 2.3225 | 1.6242 | 1.2911 | 1.1263 | 1.0527 | 0.8540 | 0.7850 | 0.6936 | 0.6079 |
| Proportion | 0.224 | 0.137 | 0.096 | 0.076 | 0.066 | 0.062 | 0.050 | 0.046 | 0.041 | 0.036 |
| Cumulative | 0.224 | 0.360 | 0.456 | 0.532 | 0.598 | 0.660 | 0.710 | 0.756 | 0.797 | 0.833 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Eigenvalue | 0.5452 | 0.4980 | 0.4458 | 0.4194 | 0.3557 | 0.3286 | 0.2501 |
| Proportion | 0.032 | 0.029 | 0.026 | 0.025 | 0.021 | 0.019 | 0.015 |
| Cumulative | 0.865 | 0.894 | 0.920 | 0.945 | 0.966 | 0.985 | 1.000 |

| Variable | PC1 | PC2 | PC3 | PC4 |
|---|---|---|---|---|
| ExtGap | -0.131 | -0.524 | 0.088 | 0.163 |
| IntGap | 0.290 | -0.012 | 0.192 | -0.196 |
| HCRes | 0.292 | -0.152 | 0.365 | -0.101 |
| NonHC | 0.260 | -0.080 | 0.432 | -0.002 |
| ClearScope | 0.297 | -0.218 | 0.204 | -0.125 |
| 3Months | 0.274 | -0.040 | -0.424 | 0.224 |
| Goals | 0.358 | -0.138 | -0.017 | -0.149 |
| StretchGoals | -0.118 | -0.462 | 0.077 | 0.268 |
| HighBenefit | -0.011 | -0.162 | -0.168 | -0.567 |
| ExtDoc | -0.004 | -0.443 | -0.274 | 0.211 |
| IntDoc | 0.246 | 0.013 | -0.213 | 0.096 |
| SolKnown | -0.201 | -0.221 | -0.302 | -0.316 |
| HighSuccess | 0.318 | 0.037 | -0.278 | -0.188 |
| LowTech | 0.264 | -0.003 | -0.263 | -0.019 |
| BuyIn | 0.304 | 0.066 | -0.147 | 0.088 |
| MBB | 0.221 | 0.190 | 0.006 | 0.496 |
| Readiness1 | 0.166 | -0.318 | -0.014 | 0.030 |

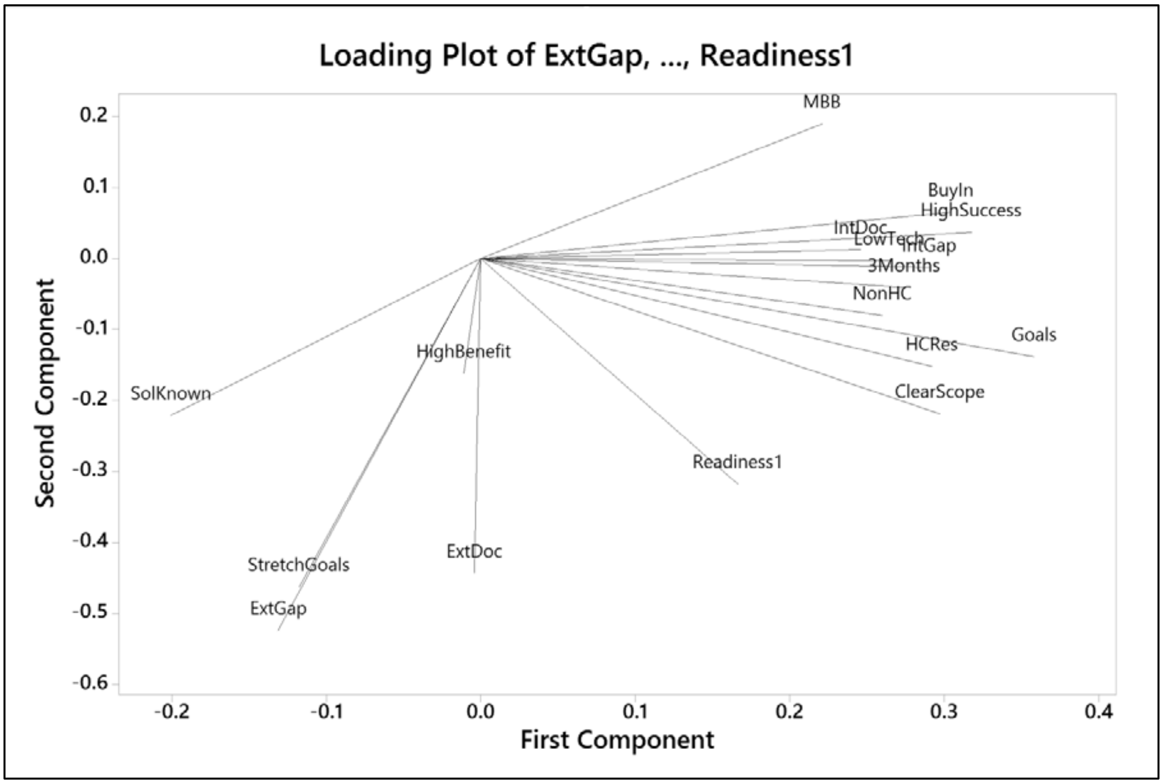



Figure 4.4: Loading Plot

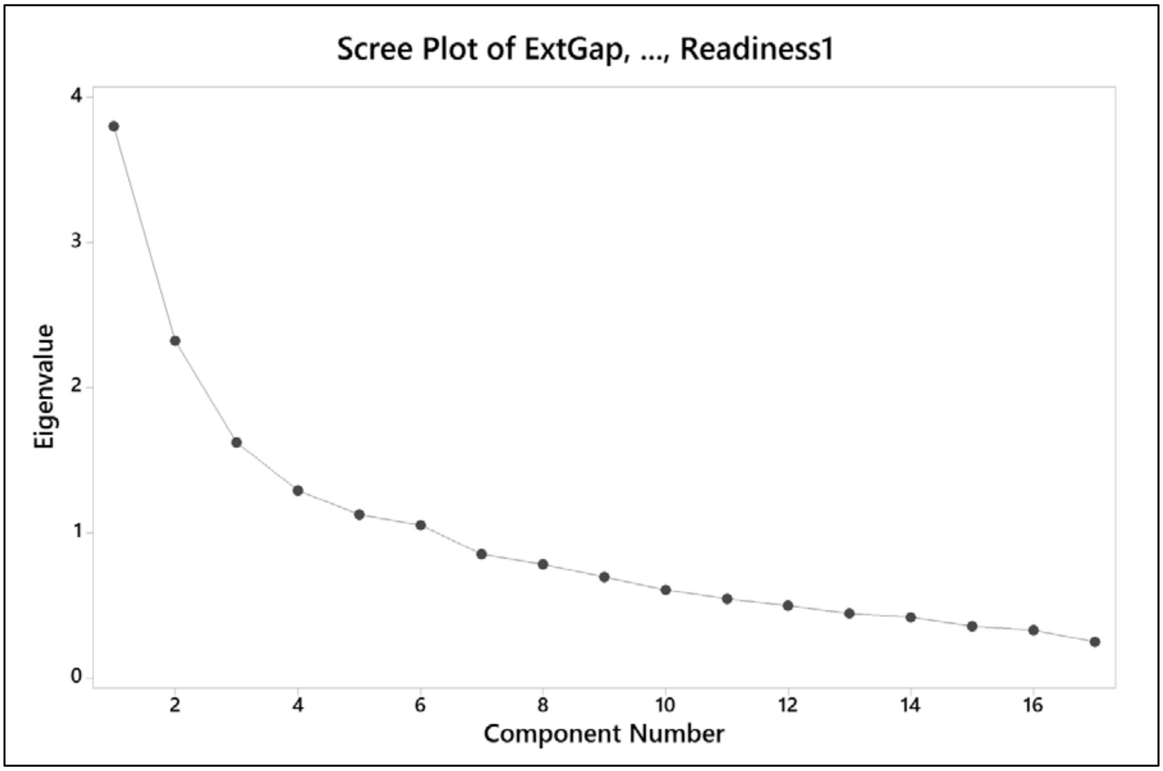



Figure 4.5: Scree Plot

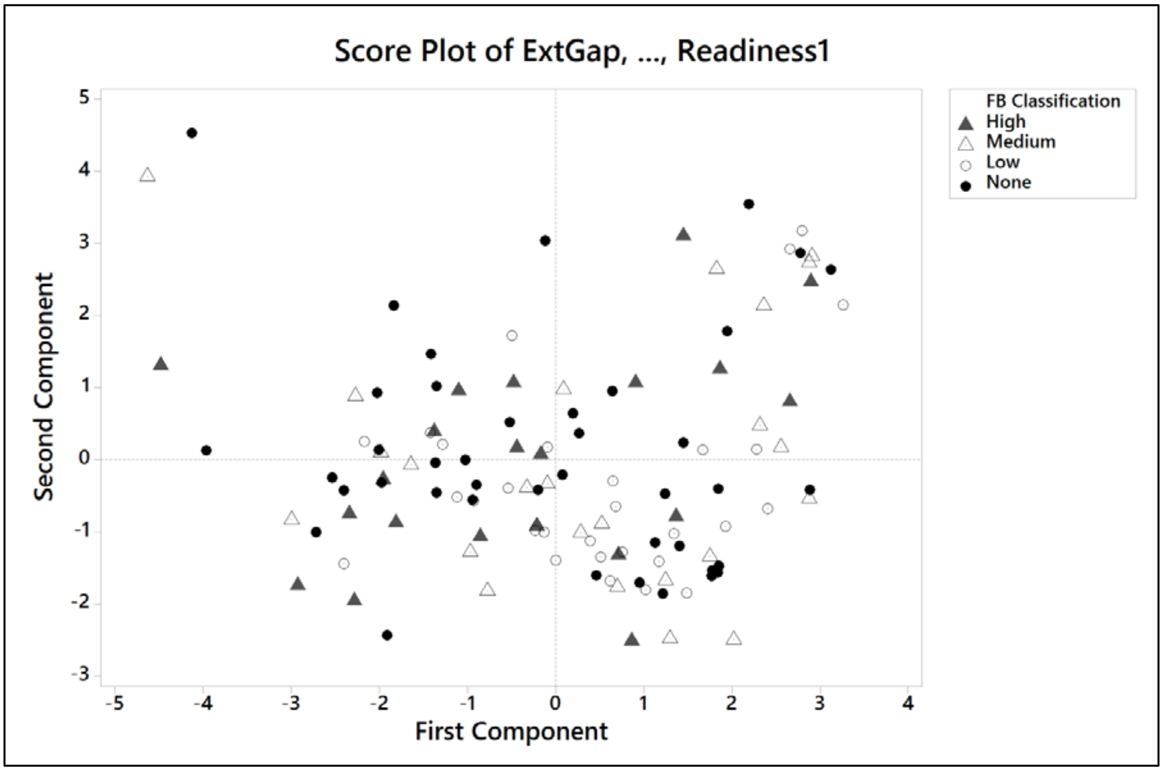



Figure 4.6: Score Plot

## 4.5.4. Gated vs. Non-Gated Chi Square Results

Chi-Square Test for Association: Type, Ordinal Response

Rows: Type   Columns: Ordinal Response

| | High | Low | Medium | None | All |
|---|---|---|---|---|---|
| GATED PROJECT | 5 | 5 | 2 | 7 | 19 |
| | 3.672 | 4.630 | 4.151 | 6.546 | |
| NON GATED PROJECT | 18 | 24 | 24 | 34 | 100 |
| | 19.328 | 24.370 | 21.849 | 34.454 | |
| All | 23 | 29 | 26 | 41 | 119 |

Cell Contents: Count
Expected count

Pearson Chi-Square = 1.970, DF = 3, P-Value = 0.579
Likelihood Ratio Chi-Square = 2.182, DF = 3, P-Value = 0.536

**Fail to reject null hypothesis: conclude there is no statistically significant difference in output between gated and non-gated projects.**

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