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# Improving Infrastructure Budget Allocation with Lean Six Sigma

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**Abstract:** The U.S. Army's Chemical Biological Center (CBC) is a research and development center for chemical defense that operates out of Aberdeen Proving Ground (APG), MD. Aberdeen Proving Ground is an aging installation that requires significant infrastructure maintenance and improvement. Currently, the CBC's infrastructure sustainment process is running above budget and behind schedule. As a result of process inefficiencies, $105M of priority infrastructure projects were unfunded in FY2021. This paper uses Lean Six Sigma, a process improvement methodology, to analyze process inefficiencies within the CBC's service order process. The paper makes a series of recommendations to reduce costs and errors in the service order process, allowing the CBC to execute more of its currently unfunded projects.

*Keywords:* Lean Six Sigma, DMAIC Process, Budget Analysis

## 1. Introduction

Lean manufacturing was first invented by Toyota manufacturing after World II (Jiju Antony, 2017). Mikel Harry and Bill Smith developed the Six Sigma aspect in the 1980s while working at Motorola. The concept of Lean Six Sigma "has become an important business strategy for many organizations including manufacturers, distributors, transportation companies, financial services organizations, health care providers, and governmental agencies" (Montgomery & Woodall, 2008). Using Lean Six Sigma (LSS) allows for companies and individuals all across the globe to use its concepts to develop effective strategies and ideas by taking a "statistically based approach for reducing variability, removing defects, and eliminating waste from products, processes and transactions" (Montgomery, 2008)

A methodology used for a LSS project is the DMAIC (*Define, Measure, Analyze, Improve,* and *Control)* process, which provides users with a method to approach problem-solving. The DMAIC process uses "…a powerful statistical technique for fact-finding and empirical verification of ideas, which acts as a problem structuring device… the DMAIC process allows LSS teams to offer solutions to a poorly structured collection of techniques that are without strategic guidance" (Lokkerbol, 2012). This paper will use the DMAIC process to improve the budget allocation process of the CBC at APG. Currently, the CBC's infrastructure sustainment execution process is running above budget and behind schedule. As a result, in FY21, approximately $105M of priority projects remain unfunded. This paper will examine APG's CBC budget problem within each phase of the DMAIC process in order improve the process, allowing for the completion of more priority projects. Further, the project looks to create a process of accountability and traceability of service orders (SOs).

## 2. Literature Review

In the Define phase of the DMAIC process, the project team creates an outline of the project to include a project charter, clarifies the needs of the customer, creates a problem statement, identifies the priority of problems identified, confirms resources available, conducts the process mapping, develops a goal statement, and informs others of project progress (Tanjuakio, 2017). The Define phase is very important to every LSS project because it is the initial guidance given to the project team and helps narrow the project scope to ensure the problem is being solved at the correct level. In the Define phase, it is extremely important to understand where the problem is. In simple terms, the Define Phase is centered around creating a problem statement and defining the scope of the project (Three Tools of the Six Sigma Define Phase of DMAIC, 2022)

Once complete with the Define Phase, projects will move into the Measure Phase. The Measure Phase "is used to thoroughly understand the current state of the process and collect reliable data on process speed, quality, and costs that you will use to expose the underlying causes of the problem" (Lyu, 2009). While the Define Phase focused primarily on a qualitative assessment of the problem (i.e., voice of the customer/business), the Measure Phase provides statistical proof that a problem exists. Further, this phase is important because it is the phase where analysts first have the opportunity to work with data and develop quantitative baselines for the processes being evaluated. The data in the Measure Phase helps narrow the project scope to ensure the problem is being solved at the right level. Once a problem is statistically confirmed, the LSS group then moves into analyzing the data, to identify the root cause of the process.

The Analyze Phase helps the project team to determine where inefficiencies are occurring and possibly how to improve them. Understanding the problem for the Analyze Phase guides the LSS team in making determinations on what the root cause(s) are. To find root causes, the Analyze Phase uses data visualization tools such as Minitab to help project teams run different statistical analyses on processes and product quality including statistical quality control charts (Jacobson, 2017). Another data visualization tool the team can use is the Pareto chart, which shows the data as a bar graph represented by percentages, as seen in Figure 1. This particular pareto chart was used in the Analyze Phase and will be discussed on the next page. Other methods such as Analysis of Variance (ANOVA), Tukey, and Design of Experiments can help show companies where their products or processes are out of control or inefficient. By seeing where root causes exist, the Analyze Phase makes way for the LSS team to create alternative methods to then improve efficiency and get rid of the waste that was coming from the root cause(s).

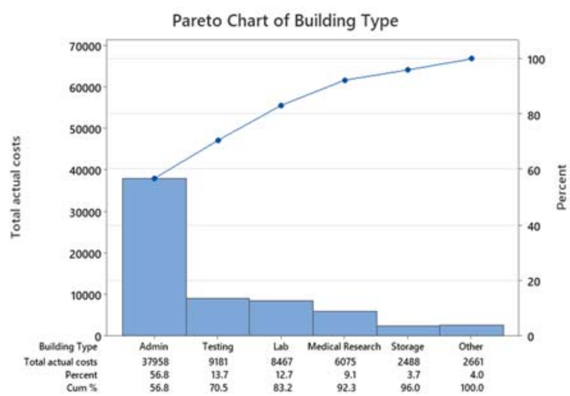


Figure 1. Pareto Chart Displaying Significant Admin Costs

The focus of the Improve Phase is to make changes to the root causes identified in the Analyze Phase. This phase "implements solutions or changes to the business process to address these root causes identified during analysis" by designing experiments to test possible solutions and analyzing their results (Hwang, 2006). The Improve Phase utilizes experiments to determine what appropriate measures can be used to create more value and less waste within the process. These experiments then create possible solutions that are placed into a value and feasibility matrix in order to determine what potential solutions will be implemented in a pilot plan. In the Improve Phase, it is important to incorporate strategies and methodologies consistent with DMAIC processes, such as an updated project charter, an overarching value stream map/detailed process map, a data collection plan, estimated financial and operational benefits, baseline statistics and process performance, and a measurement systems analysis. By having these strategies and methodologies present and coherent, the Control Phase can then create a system check that is utilized to sustain the improvements made to the process.

The Control Phase is where the greenbelt transitions ownership of the process back to the client. This requires some final work on the process improvement team prior to the handover to ensure a successful transfer. A successful Control Phase transfer requires the creation of a training plan to give to the process owner so that they are familiar with how to sustain the process changes and reeducate the individuals in the process to be familiar with the changes. The project improvement team will also launch the implementation of a data collection process, if it did not exist before for use in future CPI projects, to allow for future projects to occur and create future improvements. With this newly improved process, a new set of standard operating procedures (SOP) will be developed so that current and future process handlers can know how the process works, and how to fix it if there are future issues (George, 2004). To maintain process stability, a set of control plans, detailing how the process can remain at its improved state, is handed is given to the process owner and periodically checked upon by members of the LSS team. Finally, the greenbelt will perform an audit of the results and confirm the measurements and financial/business impacts of the project meet the specifications agreed upon.

Looking ahead, the group will be applying the DMAIC process to our project in a different capacity than what is common in other LSS projects. While most LSS projects are more tailored towards manufacturing and production type projects that look to improve the physical process steps that occur when making an item, our work with APG is focused toward creating improved quality, costs, and efficiencies within a service type industry that lacks a formalized process. This allows us to take a novel approach in deciding what tools within the DMAIC framework we will utilize. Furthermore, this type of process also creates challenges in figuring out ways to manipulate LSS tools so that they fit the scope of our project.

## 3. Methodology

The CBC's initial problem statement was the following: "[Our] infrastructure sustainment execution process is running above budget and behind schedule, causing a misallocation of funds, repeated lines of effort, and delayed service order completion. As a result, in FY21, approximately $105M of priority projects remain unfunded." During the Define Phase, the team set up working meetings with the client to understand their fiscal vulnerabilities and generate the appropriate scope for the project. For the purposes of our project, both sides agreed the proper scope would come from looking at one of the directorates that are subordinate to the CBC, the Engineering Directorate. The scope was further limited to only infrastructure projects at APG.

Given the proper scope, the team set out to define cost, quality, and time goals for the project. The initial goals agreed upon with the client were to reduce the cost-of-service orders by 10%, reduce additional and duplicate service orders by 15%, and reduce the average days to complete a service orders by 10%. It is important to note that saving the client money refers to the reallocation of funds in order to fund more priority projects for APG in the future. In other words, a direct consequence of the team achieving our goals would not be a reduction in money spent, but a result in more projects funded and completed.

Once the project was clearly defined with reasonable goals and scope in/out, the LSS team then started to measure the data to validate and understand what the customer's issues have been thus far. First, the team sought to understand the data descriptively. A calculated summary statistics and used histograms to visualize the data, as seen in Figure 2.

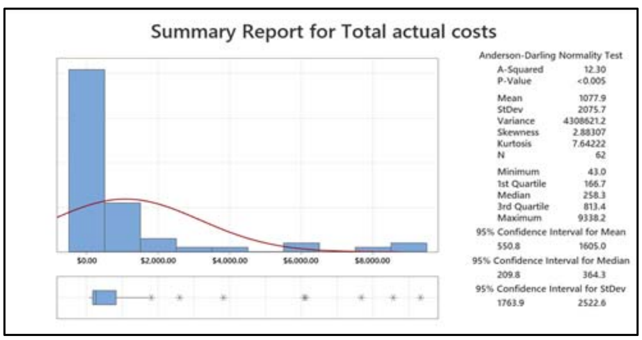


Figure 2. Histogram of Total Actual Costs, CBC ENG Directorate.

The Measure Phase helped us to find the true averages, totals, and variance that the client has seen with respect to their service order cost and time. The data for total days looked like that of the total costs shown in Figure 2. Importantly, the team noticed the data is positively skewed instead of a normal distribution. The team's hypothesis was that the data was going to be normally distributed based off the standard null and alternative hypotheses. As a result, the group updated the cost and time goals to reflect the median number of days, instead of the average. Further, a determination was made that there are eight outlier expenses overall which greatly affect the distribution of data and the average cost the client is seeing. Another key point to note from our pareto chart analysis was that admin buildings saw the highest total costs and time spent, as depicted in Figure 1. Once the team noticed the high sums for these two building types, the data was then broken down into averages of days and expenses to see if there was a statistical difference between the building types with respect to cost and time.

For the Analyze Phase, the LSS team looked further into these identified potential root causes found in the Measure Phase. It is important to note that service orders are broken down into two classes: 1) normal wear and tear and 2) mission-related service orders. This distinction is important because U.S. Army Garrison handles funding service orders that fall into the normal wear and tear category, while the CBC is responsible for paying for mission-related service orders. Through some cost analysis, the team also identified a possible root cause through a discrepancy in the data where the ENG directorate was paying 10% more for service orders than other directorates, as seen in Figure 3.

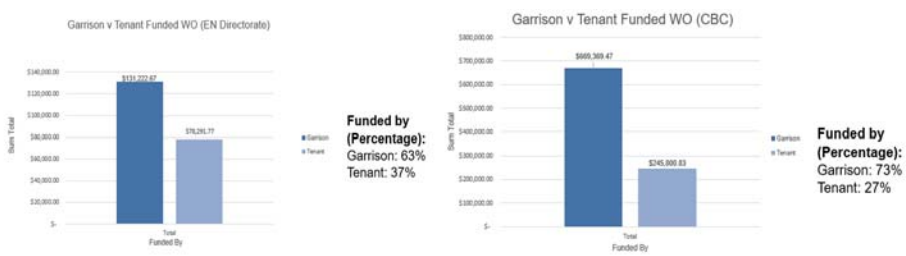


Figure 3. Difference in Funding between Sister Directorates and the ENG Directorate

The LSS team counted the number of times each WBS number was used, and the total cost associated with each to better understand the financial issues the ENG directorate was seeing. One WBS stood out because it was used 44/62 times and accounted for $43,000. In congruence with this, the data was broken down to figure out how often service orders were being funded by the tenant instead of Garrison. At the higher end, the data found that 76% of service orders were being funded by the ENG Directorate when they should have been funed by garrison, creating a depletion of funds that could be used for other priority projects.

Based on this finding, an adjustment was made to the second goal. Instead of reducing the number of additional and duplicate service orders, which was difficult to derive from the data, the team decided instead to focus its efforts on reducing the number of WBS funding errors from 76% to 50%. This reduction in funding errors would result in cost avoidance for the CBC, shifting costs back to U.S. Army Garrison. After talking to the client we were ale to identify that these funding errors come from improper formatting of the service order, which led to the incorrect charging of WBS numbers. The money saved could then be allocated to other priority projects within the CBC.

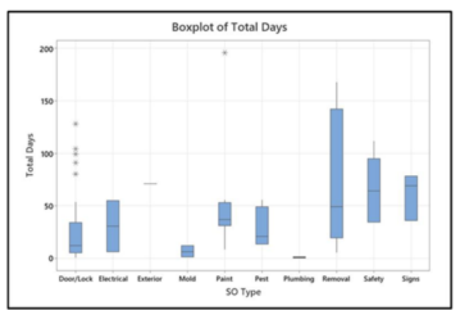


Figure 4. Service Order Type Box Plot

Next, a question was raised to determine if there were specific types of service orders that were contributing to the CBC's problems. From the boxplot in Figure 4, service order types that raise questions are Removal, Safety, Signs, and Doors and Locks. Other categories also have room for improvement such as mold or pest since DPW should oversee overall building maintenance, not the tenant. Service orders categorized as 'Doors and Locks' displayed a high concentration, but it also contained five outliers above the median which shows that there is likely improvement that can be made in the length of time when handling doors and locks service orders. Once there was a more thorough understanding of the data, the team created a cause-and-effect fishbone diagram to visualize what is causing issues for APG seen in Figure 5.

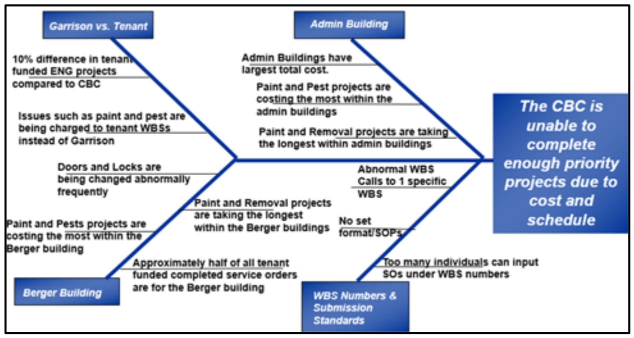


Figure 5. Cause and Effect Diagram ENG Directorate

The Improve Phase addresses the main pain points expressed by the APG CBC. The Five main points are 1) too many individuals can input SOs under WBS numbers, 2) confusing remarks that describe where/what the SO is located, 3) approximately half of all tenant's funded completed service orders are for one specific admin building (E3549), 4) admin buildings are the largest total cost across the ENG Directorate, and 5) doors and locks are being changed abnormally frequently.

In accordance with the analysis, the team decided to develop two courses of action focused on solving the first two issues described above. Similar to the way the SO system is run now any employee can spot and report the need for a SO. However, currently, employees can input data directly into the system of record, Army Maintenance Activity (ArMA). For example, DPW had received five service orders for the same issue, making it hard to determine if the issue has been corrected or not. Instead, our proposed system recommends that employees submit, via a Microsoft Forms online survey, service orders to a limited number of employees who have access to ArMA. The limited number of employees will act as a quality control check, making sure service orders only get submitted to ArMA once.

Further, the data shows that service orders that are input into ArMA are often vague and difficult to understand. As a result, DPW could waste time looking for the location of the service order. More importantly, it is the team's belief these vague descriptions may lead to funding errors. Therefore, our solution also recommend a SOP for data input into ArMA. Service orders must include the APG North Address, the building number and room number, the cardinal direction of the issue area, and a one-sentence description of the problem. Also required would be an image of the issue. Including the photo allows complete transparency and makes it easier for the ones completing the service order to diagnose the problem and equip themselves with the necessary materials needed to complete the SO.

Implementing a standard operating procedure (SOP) and limiting the number of individuals is the best solution that the LSS team determined. As a part of the pilot plan, the team created training slides for the client to use as they implemented the new SOP. Those slides consisted of training for the identified Quality Control (QC) individuals and for all other employees. Doing this will consolidate all of the necessary information in a concise, correct, and standardized format, requiring a filter through the limited individual for revisions and(or) more information before being inputted into ArMA. Finally, the group recommends that the client has a bi-monthly G4/G8 sync, where service orders are scrubbed line by line to determine if there have been funding errors. The goal of these bi-monthly meetings will be to track the allocation of funds amongst WBS numbers to ensure the correct entity is being charged for the service order. The G4 and G8 have the ultimate decision authority and therefore would be able to have any final changes to funding decisions. Although the team does not have the data to back up its claims, the hypothesis is that the changes will address the quality goal of reducing the number of funding mistakes from 76% to 50% within the ENG directorate, indirectly allowing more funds and work hours to go towards priority projects for the CBC.

In closing out this project through the Control Phase, the LSS team will then implement the final SOP, that contains the changes identified from the improve phase and the control plan that will be utilized by the ENG directorate to monitor the process and to maintain the gains created throughout the DMAIC process. The control plan will require the ENG Directorate to maintain the necessary information in a understandable way and uphold a filter through the limited individuals more information before being inputted into ArMA. These two documents will allow the client to sustain the quality of the SOs submitted by the ENG directorate and actively monitor service orders input in ArMA to flag potential mistakes such as funding errors (i.e. tenant is paying when garrison should be).

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## 4. Conclusion

At the writing of this paper, the client is in the process of instituting the recommended pilot plan and the LSS team is awaiting data that will confirm or deny the value of the recommended changes. However, the team believes with proper implementation of the newly created SOPs for SO submission and the bi-monthly G4/G8 sync, the adjusted goal statement is attainable. The LSS project goals are to reduce median SO cost by 10%, reduce the number of funding errors from 76% to 50%, and reduce the median number of days it takes for SO to be completed by 10%. Achieving these three goals should allow for funding of higher priority projects. While the process laid out by the ENG Directorate from APG may not be a process traditionally addressed by a LSS team, providing transparency and insight into the shortcomings and points of friction has substantial benefits and provides momentum in pursuing complete process efficiency.

This project was scoped for one of six directorates within DEVCOM's CBC. Future work should include scaling the recommendations for the other five directorates to maximize cost savings across the entire organization. Futher, this project only considered improvements to the SO process, but other solutions may exist. For example, the CBC could look at building utilization rates and consolidate its footprint, thereby reducing cost on buildings that are rarely used. Given the right data on utilization rates and mission requirements, this type of project could also be executed with a LSS methodology.

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