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Effectively Using Lean Six Sigma and the DMAIC Methodology for Process/System Improvement for Tobyhanna's Small Component Paint Branch

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Abstract: TYAD repairs and maintains a plethora of systems essential for our military effectiveness and daily operations. Employees at TYAD have noticed a tall number of overrun hours for projects in their small component paint branch. This high number of overrun hours has led to TYAD steadily losing revenue and profitability on their projects. This capstone group utilized Lean Six Sigma's (LSS) DMAIC (Define, Measure, Analyze, Improve, and Control) process to decrease the number of overrun hours experienced and to increase throughput through the system. The efforts of this group led to discoveries of issues with the implementation of quality control tools. Our discoveries led to a revamped quality control protocol that will decrease the number of overrun hours experienced by TYAD and ultimately save them an estimated $478,000.00 over the course of the next three years.

Keywords: Lean Six Sigma, DMAIC

1. Introduction

Tobyhanna Army Depot's purpose is to provide the equipment necessary for the United States Army to be prepared for any task at hand. In the small component paint branch, they apply camouflage and color to individual components to assist and protect military personnel and assets. Due to the nature of the profession, the Army needs their equipment repaired and returned by TYAD in an efficient manner. We have found that the Small Component Paint Branch at TYAD, an essential part of their processes, is overrunning hours due to inefficiencies in their system processes. Using Lean Six Sigma and DMAIC principles has allowed us to view the TYAD system processes in a critical light that leads to improvements. The DMAIC process is comprised of five individual phases that lead to improvements in the efficiency of the system. The first phase of this process is the Define Phase, where the problem or inefficiency is identified, and the scope of the project is established. The second phase in this process is the Measure Phase, where important metrics are captured, and the magnitude of the problem is identified. The third phase is Analyze, where the metrics taken are analyzed, and the root cause of the inefficiency or problem is identified. The fourth phase of the process is Improve, where potential solutions are created, and the best solutions are implemented. The fifth and final phase of the project is Control, where a plan to sustain and manage the solution is developed and distributed to the system process owners.

2. Lean Six Sigma

Lean Six Sigma methodology in the manufacturing world applies the concepts of Lean Manufacturing and Six Sigma to create an ideology fit for the 21st century. The Japanese process of Lean Manufacturing involves reducing human effort, stocks, production space, and delivery time while still being efficient and delivering quality products (Drohomeretski, 2014). Six Sigma differs from Lean because Six Sigma focuses more on the reduction of process variation. Six Sigma, a process initially created by the company Motorola, seeks to eliminate defects and identify errors so they can be fixed (Drohomeretski, 2014). Six Sigma relies heavily on achieving stability by using data-driven analytics to make assessments on the defect level (Laureani, & Antony, 2019). The process is focused on precision and accuracy with the goal of getting a product manufactured perfectly on the first try (Laureani, & Antony, 2019).

Both Lean Manufacturing and Six Sigma contribute great changes to work environments. However, the business environment is dynamic, and every company is seeking to gain an edge. The clash of both these independent models together is the response to this changing environment (Manville et al., 2012). The Lean Six Sigma methodology focuses on reducing waste, non-value-added work, cycle time, and instability in a process (Drohomeretski, 2014). The goal of a process is to be as efficient as possible while still producing the highest quality products. The methodology takes the good aspects of Lean Manufacturing and Six Sigma to create a contemporary ideology. The benefits of using Lean Six Sigma outweigh the other processes' strengths individually. Lean Six Sigma can increase morale, functional teamwork, consistency, and effective decision-making qualitatively (Manville et al., 2012). Quantitatively, the reliance on data and facts has improved production efficiency across companies in the world (Manville et al., 2012). Companies such as Samsung and Xerox have seen increasing profits and quality improvements with its implementation (Hilton & Sohal, 2012). Furthermore, when Amazon incorporated Lean Six Sigma into their daily routines, their profit skyrocketed (Alshmrani, 2020). The new concept of Lean Six Sigma is revolutionizing the manufacturing industry and driving competitiveness in the business industry.

3. DMAIC Methodology

The Define Phase is the most important part of the DMAIC process. Real-world problems require real-world solutions, so if one is unable to define the problem properly, then everything that comes after will be useless. The purpose of the Define Phase is to have the team and sponsor reach an agreement on the scope, finances, and performance goals (George, 2005). This phase consists of gathering data to identify how big the problem is (Sreedharan & Sunder, 2018). It is important to not have a scope that is too broad or vague, and identifying the proper scope may take time and effort (George, 2005). One of the most useful tools in the Define Phase is the creation of a SIPOC Map. SIPOC stands for suppliers, inputs, process, outputs, and customers. The SIPOC Map is a useful tool that helps define boundaries for scope identification (Sreedharan & Sunder, 2018).

The Measure Phase uncovers the problems in the process. The purpose of the Measure Phase is to understand the daily operations of the process and collect data on the processing speed, quality, and costs that will identify the causes in the future (George, 2005). The Measure Phase is all based on the collection of data. The data must focus specifically on the process and be reliable (Sreedharan & Sunder, 2018). After the data collection, the process capability must be calculated to reflect the current efficiency of the process (Sreedharan & Sunder, 2018).

The Measure Phase is the first step that requires an exploration into data and explores what is happening in the process. The Measure Phase is "more than just a number," and represents the process as a whole (Pearson, 2002). This phase requires a certain set of deliverables in order to move on to the next step (George, 2005). The most frequently used Measure Phase techniques are process mapping, control charts, descriptive statistics, graphical summaries, and process capabilities (Hollingshed, 2022). These tools and more emphasize the data behind a process.

The Analyze Phase utilizes the previous data to make assumptions on what causes the problems of the process. The Analyze Phase should end with the root causes of the problem and the important controllable factors of the process identified (Mandal, 2012). The purpose of the Analyze Phase is to identify and establish causes affecting the input and output variables of the process (George, 2005).

The Improve Phase is where the solutions to the problems are generated. In this phase, one should "attack" the root cause and project the problem head-on (Sreedharan & Sunder, 2018). The first steps in the Improve Phase are to develop and evaluate potential solutions. This is where Lean Six Sigma thinking is exhibited. The use of a Solution Matrix and Pugh Matrix help evaluate solutions and when one solution is chosen, an LSS method (Design of Experiments, Pull systems, Defect Prevention, etc.) is piloted. Once the optimal solution is implemented, the solution should be compared to the original data to see if project goals were met (George, 2005). Finally, key documents such as the project charter and project plan should be updated.

The Control Phase is about the continuous monitoring of the implemented changes made to the process (Sreedharan & Sunder, 2018). The purpose of this phase is to complete all project work and hand the owner the improved procedures to monitor and maintain the benefits of the change process (George, 2005). The major steps in this phase are to develop supporting methods and documentation, launch the implementation, lock in the performance gains, monitor the implementation of the improved process, develop process control plans, audit the results, finalize the project, and validate performance and financial results (George, 2005). Control charts are helpful for analyzing the process over time to watch out for anything that could be out of control.

4. Results

In the Define Phase, information provided by Tobyhanna Army Depot (TYAD) contributed to defining the problem statement and goal statements as well as to outlining the process. It was discovered that TYAD's Component Paint Branch was operating behind schedule, overrunning 242 hours per month with trends remaining consistent. The small paint work center was identified as being a main contributor to the overrun hours in the branch thus providing the scope of focus for the team's work. The goals of this project were to reduce monthly overrun hours by 25% from 242 hours to 182 hours and to increase process throughput by 20% within the Component Paint Branch, specifically the small paint work center, by 01 May 2023.

Figure 1 below provides a clear illustration of the small paint process as a high-level process map where the characteristics of the small paint process are shown. The small paint process consists of five major steps: Receive Asset, Prime Asset, Paint Asset, Stencil Asset, and Ship Asset. TYAD classifies its various branches of work around the depot as prime shops. These prime shops begin the small paint process when they deliver individual components to the Small Paint Work Center. The components are received and enter the first step of the process. From there, individual components move to the paint booths where they are primed and then immediately dried. The components are then moved back to the booth to be painted and dried again. The fourth step of the process is for the component to receive stenciling work if necessary. With basic quality inspections happening throughout the entirety of the process, all that is left is for each individual component to be checked off before it is shipped to its next location.

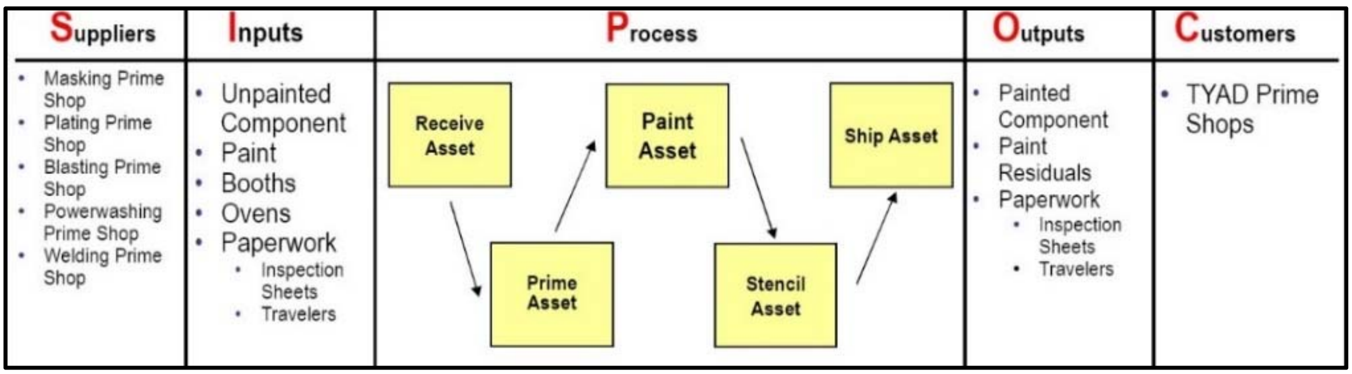

Figure 1. SIPOC Map

The Measure Phase Tollgate provided crucial information about the current situation of the process. In general, the Measure Phase tools and data allowed us to identify issues needing further analysis in the next phase of the DMAIC process, the Analyze Phase. For the process shown in Figure 2, the five main phases are broken down into Receive, Prime, Paint, Stencil, and Ship. In each of these main phases, the responsibilities of the painter leader, painter and inspector were documented. By completing an in-depth process map, a value stream map was easily created to mock the process. The purpose of a value stream map is to capture all key flows in a system and its metrics, which is beneficial since it identifies and quantifies waste. (George, 2005).

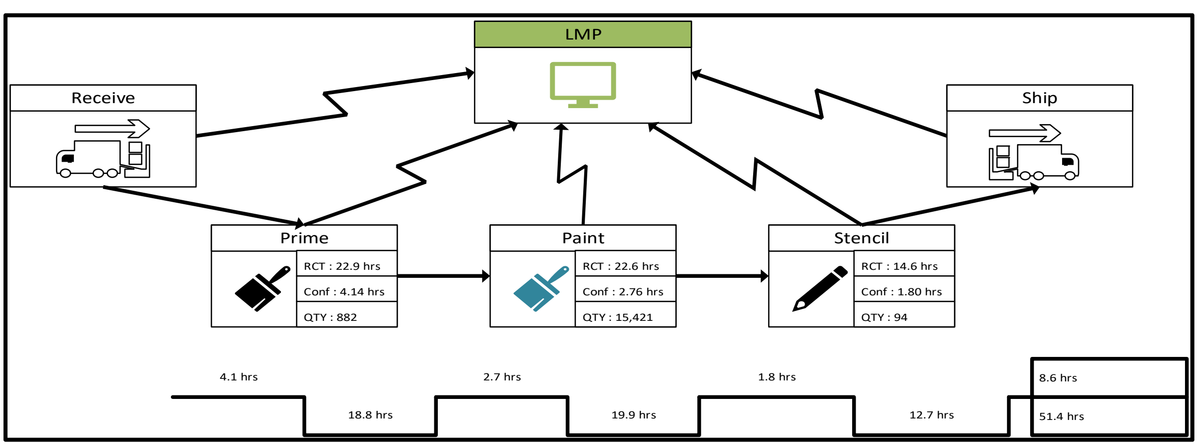

Figure 2. Value Stream Map

To prepare for the Analyze Phase, the data needed to be evaluated, and understood in order to set a baseline. According to the data, on average, TYAD is overrun by 1.2322 hours with a standard deviation of 2.48 hours. This result informs us that when there is an overrun, they are only overrun by a slight amount. To create a better understanding of overrun hours, Pareto Charts were developed. The Pareto Charts in Figure 3 reflect how batch size, process type, and component type influence overrun hours. The batch size chart in the first Pareto Chart reveals that most of the issues came from single batch components, which made up 55% of all overrun hour issues. Next, based off the process type Pareto Chart, most issues came from the paint process, as 90% of all overrun problems dealt with paint. Lastly, Radio Components, 146/147, TRC-190 made up the most overrun problems based off the Asset Group Pareto Chart. Radio had the most with 23% of all observations having dealt with radio.

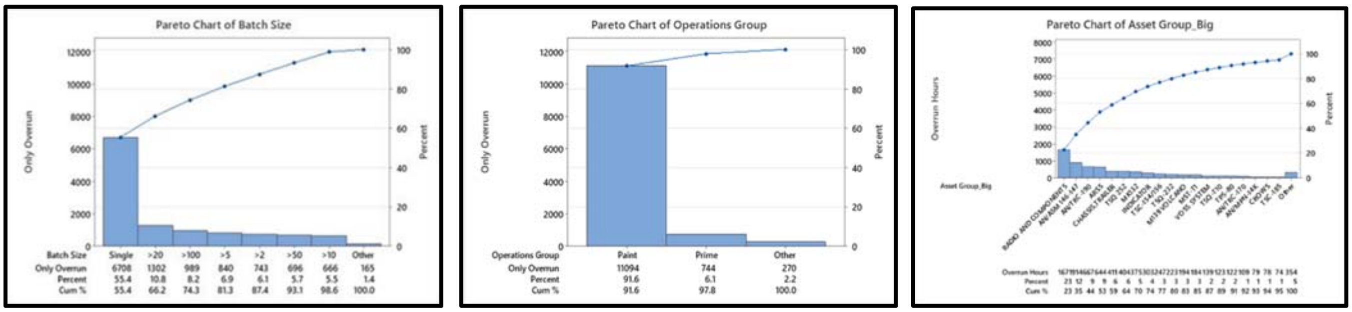

Figure 3. Collection of Pareto

Lastly, TYAD's current process was validated to see if it was capable of reducing overrun hours and increasing throughput. Based off the process capability and throughput capability, the process was deemed not capable. Since the process is not operating within the implied standards set by TYAD, the DMAIC process can be further applied to reach those standards. All of the statistical analyses done effectively visualize the results given to us by TYAD. These baseline statistics are necessary to gain a better understanding of the current throughput at TYAD as well as to gain information that could potentially be useful for us in the Analyze Phase.

Understanding the root cause for the problems at TYAD continued our thought into fixing those problems and invoked areas of change we wanted to focus on most. First and foremost, to get to where we wanted, we needed to identify and understand the problem's origin. During the Analyze Phase, we met with subject matter experts (SMEs) to discuss various issues and thoughts of concern that we knew were contributors to overrun hours within the component paint branch itself. SMEs include but are not limited to painters, gatekeepers, and chief operators. We had several in-person and telephone meetings to go over step by step the components and subcomponents thereof, that contribute to or influence overrun hours. There were multiple components we decided to focus on more than others given we already had statistical data that could support what we wanted to fix as well as time working on the project being a limiting factor. As we narrowly tailored our cause and effects, we aimed to deep dive statistically and determine if our causes are significant contributors to overrun hours. We tested Batch Size, Operational Months, and Asset Groups to determine whether those components were substantial contributors to overrun hours. Batch Size and Operational Months were evaluated using a Moods Median test (p=0.0001) because it is nonparametric and didn't make assumptions about the underlying distribution of the provided data. For asset groups, the Levene's Test (p=0.0001) was used to find significant levels because it assumed the variances of the different asset groups were equal. We concluded three major points from these tests. First, we validated that most overrun hours come from single batch components. Furthermore, we confirmed the assets that contribute most to overruns are AN/TRC 190, ARSS, AN/ASM 146-146, and radio components. Lastly, it was determined that months of the year do not contribute and are not correlated with overrun hours. The test results are shown below.

We then went into formulating and constructing a FMEA (Failure Mode Effect Analysis) chart that was completed in conjunction with the TYAD team. We took a deep dive into the five-step process from our Value Stream Map and examined potential failure modes, their effects, and the causes of those modes, as well as controls in place that try and limit mishaps or unwanted overrun hours. We then, along with the TYAD, conducted multi-voting to vote on the severity, occurrence, and detection of such issues and concerns and then narrowed down again the big problems and areas we could fix. Upon completing the FMEA, we prioritized our root causes and effects and let the TYAD team know specific areas where we intend to improve and find solutions in the phases to follow. This immediately provided a link for the group to transition into the Improve Phase with concrete ideas of what problems we can improve.

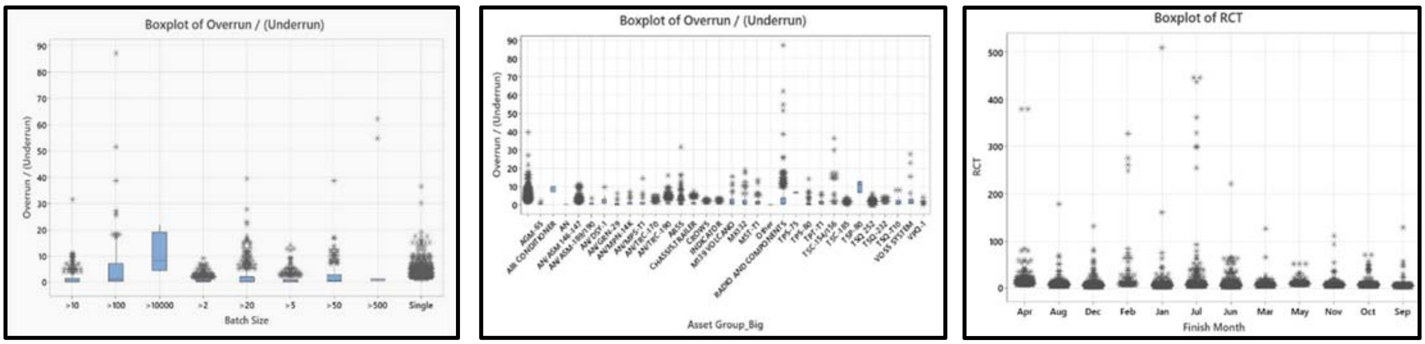

Figure 4. Month Diagrams

The Improve Phase of the project began with generating ideas with the subject matter experts at TYAD. The solution generation technique utilized during this project was brainstorming. The brainstorming session yielded four potential solutions that would solve the root causes identified in previous phases. Statistical analysis and coordination with the team led us to focus on the implementation of 2502's and an improved gatekeeper document. A 2502 is a form used by TYAD to change the number of hours allotted to paint a component and the gatekeeper document is a checklist for components coming into the small paint branch shop. Figure 5 shows how the number of overrun hours that the small component paint branch decreases drastically after implementing 2502's. This was also shown by our implementation of the Mood's Median test. The team referred to our FMEA to mitigate or prevent any possible failures to the proposed solutions. A pilot plan was developed and briefed to TYAD management. The pilot plan consisted of TYAD using an updated gatekeeper reference sheet and paint shop members continuing submissions of 2502's when they run into consistent inaccurate work estimates.

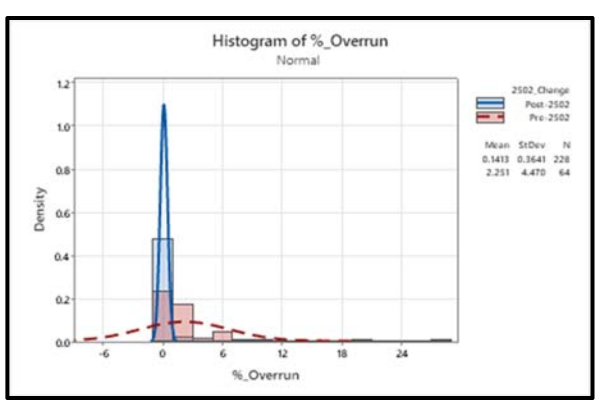

Figure 5. Overruns after 2502 Implementation

5. Conclusion

The Lean Six Sigma and DMAIC processes and methodology allow for process owners or businesses to effectively identify problems in their process or systems that lead to inefficiencies. Subsequently, a more efficient way to identify problems or waste in a process or system makes the formulation of a solution easier. As process owners or businesses introduce increasingly effective solutions, they will conclude that the Lean Six Sigma processes work not just once but can be utilized iteratively to continually improve their process or system. As long as these processes or systems can still be improved in the slightest, there will always be a place for the Lean Six Sigma and DMAIC processes and methodology to make those improvements.

Although our group has not yet reached the Control Phase in the DMAIC process, we have an idea of how we want to continue the positive momentum that has been achieved through this process. We will leave the TYAD team a way in which to measure and readjust the positive changes made from the Improve Phase. The implementation of these changes will lead to future projects which will rework the 2502 system and the traveler process. The end result will be TYAD taking control of this process and implementing changes as they see fit. We will accomplish this by utilizing control charts, developing a finalized process map, creating an SOP for the process, and educating all related team members on how to utilize the new process.

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