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Applying Lean Six Sigma to Reduce Repair Cycle Time (RCT)

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Abstract: This report details ongoing efforts in a yearlong capstone project to improve the repair and overhaul process for the Command Post Platform (CPP) system at Tobyhanna Army Depot (TYAD). Current repair times consistently exceed the U.S. Army Communications-Electronics Command (CECOM) standard of 120 days, and recently have been averaging upwards of 200 days. Applying Define, Measure, Analyze, Improve, and Control (DMAIC) for process improvement, the project team evaluated three critical Operations in the repair development process, OP 180: Rack Mechanical; OP 190: Reassembly; and OP 220: Final Test and Inspection. The team developed a prioritized list of solutions for the client as well as several easily implementable "quick wins." With these recent improvements, one CPP saw a reduction in repair time of 36%. Upon completion of this project, the client expects annual savings of $956,000 and an average reduction in repair times of 39 days.

Keywords: Lean Six Sigma, Process Improvement, Repair Cycle Time, Tobyhanna Army Depot, Command Post Platform

1. Introduction

Lean Six Sigma (LSS) is a focused, but flexible methodology that seeks to improve efficiency and reliability in a process. Numerous organizations in manufacturing, healthcare, and even technology adopted LSS after Toyota, Motorola and General Electric fully developed and proved LSS's ability to improve processes requiring high output, precision, etc. (Trzeciak, 2018). The methodology derives from a combination of both Lean and Six Sigma methodologies. The former focuses on eliminating waste and creating customer value with tools that reduce process work and constraints, focusing only on what the customer wants. The latter focuses on "data driven management" to eliminate defects in processes, contributing to LSS's emphasis on reliability and precision in processes (Wang, 2010). The process-improvement approach to LSS for this project follows five general and sequential phases: Define, Measure, Analyze, Improve, and Control.

The client, Tobyhanna Army Depot (TYAD), is a leader in C5ISR (Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance and Reconnaissance systems) and has deep connections to the LSS methodology through their Process Improvement Division. The Process Improvement Division conducts projects across TYAD programs that result in monetary and time savings. Through a partnership with the United States Military Academy, TYAD conducts joint capstone projects with seniors in the Department of Systems Engineering, allowing these seniors to obtain their Army LSS Green Belt certification at the conclusion of a successful project once approved by the Army Material Command (AMC). For this project the Process Improvement Division at TYAD asked the capstone team to reduce the repair cycle time (RCT) for their Command Post Platform (CPP) repair line. From the date of Inception to when the CPPs are returned to the customer, repair times have been consistently exceeding the standard time of 120 days. Implementation of this project's recommended solutions thus far have reduced repair times by 39 days, with expected annual savings of close to $1M.

2. DMAIC Process

The capstone team conducted this project following the five-phase DMAIC process: Define, Improve, Analyze, Improve and Control. Required 'tollgate' deliverables are mandated for each phase; project teams do not move to the next phase until all key tasks and requirements have been completed. This paper starts with an overview of the DMAIC process and then documents the team's work in each phase.

2.1 Define Phase

Within the Define Phase, the primary objective is to identify the problem and begin outlining the scope of the project. The project team and their sponsors develop a project charter consisting of an initial problem statement, a project goal statement, potential business impact, and who the core project team members will be. This document provides high-level, preliminary analysis and provides greater understanding of what the company is trying to provide for its customers as well as what the project team is trying to provide for the company (Fu Kwan, 2010).

2.2 Measure Phase

Once the problem is defined and the work is agreed upon, the LSS team begins the Measure Phase with initial data collection to determine the "as-is" state of the process and start initial quantification of the problem. The process of data collection may already exist within the company's infrastructure or the team may have to create a data collection system to gauge the current state of the process. The selected collection method is significant as it typically remains the same throughout the duration of the project. Additionally, the data collected during this phase will be used as a baseline for process comparison during the Improve Phase to quantify the success of the project team's changes. This phase concludes with a process capability analysis where the data of the current process' behavior is analyzed to determine if, in its current state, the process can achieve the goal developed in the project charter, which ultimately results in the process sigma level (Jayaram, 2016).

2.3 Analyze Phase

Once data is collected, it must then be analyzed to make informed decisions regarding solution design, recommendations for the client, and process improvements. The Analyze Phase applies statistical tools and techniques such as root cause analysis, fishbone diagrams, the 5-whys, and Failure Mode and Effects Analysis (FMEA) to ensure the *true* cause of the problem is identified. Occasionally organizations overlook this phase because of a desire to jump right to a solution and prevent the problem from occurring, however identifying the real cause of the problem is vital to significant, lasting improvements. Other useful tools within this phase are histograms, pareto charts, and value stream mapping, a way to visualize the value-adding (and non-value adding) steps to determine where and what waste can be eliminated from the process (Drohomeretski, 2014).

2.4 Improve Phase

With the data analyzed and the actual problem clearly pin-pointed, the team is ready to begin the Improve Phase. This phase is focused on implementing recommended solutions to the problem statement. The phase begins with brainstorming potential solutions and then evaluating the potential solutions using decision criteria. This criterion can be in the form of swing weight matrices or FMEA depending on the project parameters. Once evaluated, solutions are prioritized, and a pilot plan is developed for implementation. The pilot plan allows the team to evaluate the success of their prioritized solution at a low cost and low impact to the company. The results of the pilot are compared to the original measurements taken in the Measure Phase to determine if the improvements significantly changed the results of the process. If the pilot succeeds, the team moves forward with full implementation, applying their improvements across the process. Finally, a detailed risk analysis with mitigation recommendations is completed in order to highlight potential problems and possible mitigation strategies.

2.5 Control Phase

The fifth and final phase of the DMAIC process is the Control Phase. This phase occurs following the implementation of the solution and continues to monitor project progress. One useful tool in this phase is a control chart to identify whether the solution is improving or if there is a degradation in performance. The Control Phase is ongoing, and the performance results help indicate if any further adjustments are needed. The impetus usually then lies with stakeholders as to whether they should further allocate resources to the project.

3. Application of DMAIC Process

3.1 Define the CPP Process

Throughout this project the capstone team focused on frequent, deliberate contact with critical stakeholders at TYAD. Through phone calls and face to face meetings, the team developed a thoughtfully developed project charter and communications plan. Through initial information gathering sessions, all pertinent project information was consolidated into a Supplier-Inputs-Process-Outputs-Customers (SIPOC) map and a Voice of the Customer/Business (VOC/VOB) chart. The team learned that the US Army Communications Electronics Command (CECOM) has a repair timeline requirement for Command Post Platforms (CPPs) of 120 days, but after conducting preliminary data analysis, the team learned that on average, CPP repairs were being completed in 210 days. Through a follow-on pareto analysis, most of the overages were occurring in three critical operations: OP 180: Rack Mechanical, OP 190: Reassembly, and OP 220: Final Test and Inspection. As a result, the team scoped the project to focus solely on these three operations.

3.2 Measure the Process Capability

The Measure Phase for this project focused on accurately depicting the step by step process for operations 180, 190, and 220 and using Minitab software to perform quantitative analysis. Through an on-site visit and deliberate conversation with the technicians of Tobyhanna, inconsistencies in the order that the tasks were being performed were discovered. Proper adjustments were made to the process map to reflect the reality on the shop floor. In addition to correcting the process map, individual task times were created. Operations 180, 190, and 220 each have a standard time for the overall operation. However, prior to this project, TYAD had no data on individual task times within each of these operations. The capstone team, in conjunction with Tobyhanna technicians, created an estimated time for each task using a weighted three-point estimation technique of the best case, most likely case, and the worst case for how long each step would take. After reviewing these estimates, the totals of these estimated times within each operation were below the standard times assigned to operations 180, 190, and 220.

The capstone team then employed Minitab for quantitative analysis of the repair cycle time of the CPP. TYAD collects time-data on all process lines using the Logistics Modernization Program (LMP) database for production and quality management efforts. The LMP data consisted of 13 CPPs and 4 were found to be outliers. The outliers were removed before Minitab analysis was conducted. The team generated graphical representations of the mean repair cycle time, the process capability, and process control charts. The mean repair cycle time of a CPP was 210 days and standard deviation of 63 days. The process capability chart generated a process capability index (Cpk) of -0.51. The -0.51 meant the process was not capable of meeting the 120-day repair time set by the customer. The process control charts showed the process being in control; the team attributed that fact to the small data set provided. The quantitative analysis reaffirmed that the problem was in Operations 180, 190, and 220.

The Measure Phase concluded with the creation of data collection sheets for individual task times in Operations 180, 190, and 220. The data collection sheets were designed to gather more granular data and establish a proper transition into the Analyze Phase.

3.3 Analyze the Issue

The capstone team began the Analyze Phase with a quick win opportunity that, as George et al. (2005) state, offered immediate improvement to the process in RCT while having little to no disruption to the process itself. By moving steps 1.6.1-1.6.4 in OP 190 to OP 180, the team reflected how technicians install the AN/VCR-103/4, 92F and FHMUX bases after several cable arrays in OP 180. This eliminated any risk of lost time due to incorrect data collection for a differing order of tasks, ensuring future solutions address the process as is. Next, a more granular time logging system was needed to identify issues located at the task level. The challenge with the LMP system is that it only collects data at the operation level, ignoring variation and delays found within and in between individual tasks. The team addressed this by supplementing LMP with customized log sheets for technicians to record task start dates, end dates, and times along with comments for any issues and defects. This enabled the team to specifically analyze how long individual tasks were taking and how much delay may or may not happen between them.

The team validated its improved data collection system by using Minitab to compare the normality of RCT versus billed hours of each CPP. RCT sums all time from the start to the end of a task or operation, while billed/confirmed hours only include the time technicians are actively working on a task until completion. Because of this, RCT of any CPP can vary from many factors (i.e. delays, complications, waiting on external shops, etc.). Thus, billed hours are far more favorable for analysis as any variation reflects directly on something impacting the work and the working technicians. Billed hours of past and current CPPs consistently proved normal in all three OPs where RCT times only did in OP 190 when analyzed with an Anderson-Darling normality test (Figure 1). The team concluded that the data sheet times were normally distributed and could draw statistically sound conclusions for further analysis. The team can make statistically sound conclusions from this data as opposed to RCT from the LMP system, which accounts for too many variables.

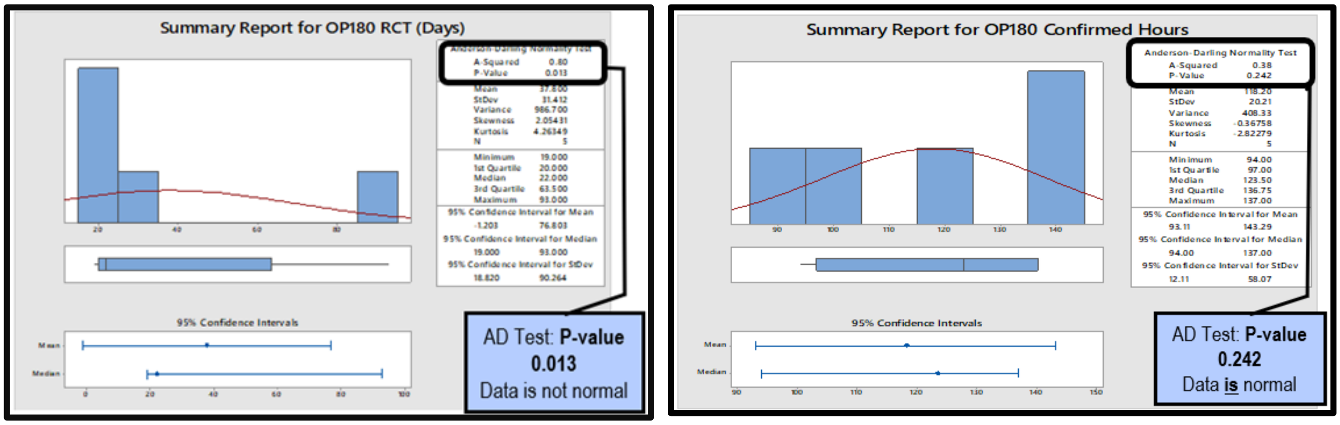

Figure 1. Minitab analysis of RCT (left) and billed hours (right) of current CPPs in process since 2018. Only RCT for OP 190 was normally distributed, for billed hours

The team consolidated this now proven data into a pareto chart listing the specific tasks across OPs 180, 190 and 220 that caused the most overage time. Specifically, Deep Clean Shelter, Install Antennae Bases and Validate Proper Paperwork were the leading tasks over the expected time. These tasks were our recommendation to the technician teams that should be first to get new SOPs in the interest of cutting down on RCT. The capstone team then conducted Value-Add analysis with the head technicians. Together, the joint group identified significant non-value added (NVA) time in OP 220 in the form of pre-inspection “rework” ranging from three to five hours before each inspection step. OP 220 averaged about 33 total hours of pre-inspection rework. The capstone team considered these 33 hours of NVA time and several other key findings in a brainstorming session with lead technicians and stakeholders to identify the biggest root causes of excess RCT time in the CPP line. Using an Ishikawa diagram and 5 Why’s chart to map the generated thoughts, the group concluded that the biggest issues to the three OPs were conflicting SOP documents used by technicians, a lack of pre-checks in OPs 180 and 190 and poor version identification of CPPs causing delays and rework. With these three root causes in mind, the team had everything they needed to go into the Improve Phase and implement solutions onto the CPP line.

3.4 Improve the Process

Improvement for a process using the LSS principles requires finding solutions to the identified relationships found during the Analyze Phase, using the data collected in the Measure Phase. For this project, the capstone team used the standard Failure Mode Effect Analysis (FMEA) to evaluate each proposed solutions’ risk priority. Each root cause was given a Risk Priority Number (RPN) based on the severity, likelihood, and potential of detection each root cause had on the total RCT time. The effects were then paired with a potential solution and the RPN was recalculated to reflect the impact of the potential solution.

The potential solutions were then prioritized in the order of greatest improvement. The prioritized list for this project was: create standardized SOPs, implement version management, remove all pre-inspection rework tasks in OP 220, and introduce a visual progress management tool. The next step was to create the “to be” process map which shows what the process could look like given full implementation of the prioritized solutions (Figure 2). A full implementation of SOPs will ensure tasks in OPs 180 and 190 are being done correctly the first time, removing all NVA rework in 220, which would result in a total reduction of 33 hours as seen in the graphic below.

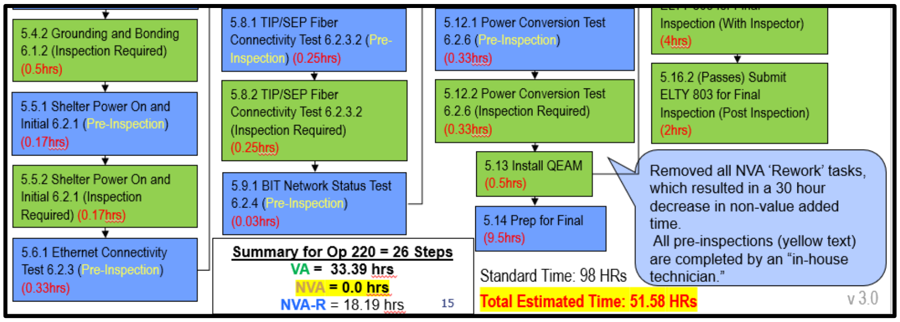

Figure 2. Portion of the "To Be" Process Map for OP 220

The root cause of most of the wasted time in rework and excessive troubleshooting came from the lack of simple and effective SOPs. When completing a task in one of the three operations, technicians currently need to reference multiple documents that are often conflicting, out of date, and difficult to interpret. Rework can be reduced dramatically if there were specific, accurate, and simple instructions that allow a technician of any skill level to correctly complete the task on the first attempt. This solution became the number one priority because it had the best potential to eliminate the NVA time in each operation. SOPs will also allow the team to remove the NVA tasks in OP 220, the final inspection operation, as a result of tasks being completed properly in OP 180 and 190, which solves two of the four prioritized solutions.

The next priority for improvement is mitigating rework early in the process by properly identifying the shelter version upon its induction. A significant amount of costly time and rework could be attributed to misidentification of shelters early in the process. Each shelter variation includes its own unique equipment and steps, and so the team proposed creating a 3'x'2 board that hangs on the shelter through the process and identifies several critical shelter characteristics including the specific version. The board also includes a timeline of milestone dates at which the shelter should complete each operation. This board will provide visibility to technicians of progress that was not experienced previously. Presenting both version management and visual progress tracking on one tool allowed the team to complete the final two prioritized solutions, which was considered a quick win for our project.

The pilot plan for this project, designed to validate the creation of SOPs using best practices from experienced technicians, should result in the reduction of all NVA time as depicted in the "to be" process map. The project's pilot measured the total time charged to one shelter in which all work was conducted by the most experienced technician to prove that if tasks are completed properly, the tasks times themselves will decrease and, more importantly, the NVA rework steps will be removed. The results of the pilot showed that the tasks completed by the most experienced technician were successful at lowering the amount of time to complete the tasks, as well as removing most NVA rework from OP 220. If these results can be achieved by the most experienced technician, then it is reasonable to believe that the same technician who completed the pilot can also create SOPs allowing all technicians to perform at this level. The team then drafted two example SOPs based on the best practices of the technician that performed the pilot for two tasks within OP 180. This pilot was considered a success as the results showed a reduction of 56 total billable hours in OPs 180, 190, and 220 and an overall reduction of 75 billable hours, which ultimately equated to a reduction of 39 days of RCT. Figure 3 shows the results from the pilot plan which includes the project's three OPs (red) as well as results from areas external to the project (yellow).

Following the pilot, the team created a schedule for completing the remaining SOPs for all tasks in OPs 180, 190, and 220. The tasks that are currently averaging longer than the SME estimated time from the Measure Phase need an SOP the most and are at the top of the schedule. This schedule is how the team moved forward with full implementation of creating all SOPs using the two SOPs as templates and concluding the Improve Phase.

Op.	Standard Hrs.	Hrs. Used	% Used
180	90	80	88.89%
190	53	44	83.02%
220	98	61	62.24%
Total (180, 190, 220)	241	185	76.76%
Total (Full Process)	484	409	85%

Figure 3. Pilot results

3.5 Control

The control phase's intended outcome is to set the company or process up for success in the future. Although the project has not completed this phase yet, a pilot plan was implemented and proven a success. Establishing new SOPs for each technician to use in the future is the solution that the capstone team will provide TYAD. A new SOP was created for two different tasks within the process and proved successful in reducing the RCT time. The SOP template was given to the TYAD to move forward in creating SOP's for all tasks while maintaining uniformity. Upon the completion of this project, TYAD must continue to make improvements and use the SOP template and visual management control boards provided. If the project makes the process better and more efficient, then TYAD, or follow on capstone teams, can the focus on other tasks that are still creating delays in the process.

4. Conclusion and Future Work

The prioritized list of solutions and pilot plan that were developed in the Improve Phase have now been implemented at TYAD and the team is already starting to observe positive results. One CPP saw a reduction in repair cycle time by 39 days. The team believes that with granular task-level SOPs, to include pictures and detailed instructions, new technicians will be able to complete their required tasks faster, and ultimately cause less rework in the Final Test and Inspection operation, OP 220. A visual management control board will also assist with version identification and prevent rework errors. Before this project began, there was no data or institutional standard for how long each task within each operation should take. Using a three-point estimation tool and interviewing subject matter expert technicians, the project team and the TYAD leadership now have clarity for how long each individual step or task in the operation should take. They can now also clearly identify any causes of delay. The project team then developed a data collection tool for TYAD to assist in data collection process in the future and recommend the utilization of this tool beyond the completion of this project. Although the process did improve, the CPP repair line has many other operations outside the scope of the three operations that this project evaluated. The team recommends the CPP repair line be considered for multi-generational project planning (MGPP), and that the Process Improvement Division apply the lessons learned here to other projects with other systems and programs at the depot.

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