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Lean Six Sigma: Direct Labor Hour Reduction in the System Preparation Branch, Tobyhanna

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Abstract: This case study aims to investigate the application of Lean Six Sigma (LSS) methodology in reducing Direct Labor Hours (DLH) for the Systems Preparation Branch at Tobyhanna Army Depot. This paper outlines the five-phase methodology of LSS, DMAIC (Define, Measure, Analyze, Improve, Control) as well as other LSS tools. The contribution of this research is valuable because it offers insight to how LSS tools and methodology can be used to improve efficiency in the workplace. The team's work and proposed solutions to reduce direct labor hours in Tobyhanna's Wash Prime Work Center will decrease the annual cost of direct labor hours by 20%.

Keywords: STT, DMAIC, WSHPRIM1, TYAD

1. Introduction

Tobyhanna Army Depot (TYAD) provides logistical support for the Army across a range of systems. This includes the manufacturing and refurbishment of equipment necessary to supporting Army operations (Tobyhanna, 2022). Within the depot, there are several opportunities to apply LSS tools to improve processes with regards to time, quality, and cost. From Oct 2019 through June 2021, the Systems Preparation Branch at Tobyhanna consistently worked too long on assets. For each asset, Tobyhanna has a predetermined set number of direct labor hours they think it will take to refurbish or construct each asset. Clients, which consist of different Army Units, pay Tobyhanna based on this set number to fix their assets. Every worker is paid by the hour, so if they take too long to complete an asset, Tobyhanna had to pay for the labor out of their own budget, not from the clients that ordered the assets. An opportunity to decrease the number of DLH was found within the Wash Prime Work Center (WSHPRIM1), one of the work centers within the Systems Preparation Branch. WSHPRIM1 contributed to the majority of DLH in the Systems Preparation Branch with 229 hours. If the process time to refurbish assets within WSHPRIM1 could be made more efficient, less DLH would occur. An asset that takes a long time to refurbish within WSHPRIM1 is a satellite transportable terminal (STT). Decreasing the DLH spent refurbishing this asset would decrease the number of DLH within WSHPRIM1 and save Tobyhanna money. The goal of the project was to use LSS methodologies to decrease the average amount of DLH in refurbishing STTs from 20 hours to 14 hours.

2. Literature Review

LSS is a deliberate project structure that follows a specific sequence of steps: Define, Measure, Analyze, Improve, and Control (DMAIC) (Maleyeff, Arnheiter, & Venkateswaran, 2012). LSS is a system that improves operations in a business while keeping in mind economic and external factors (Maleyeff, Arnheiter, & Venkateswaran, 2012). DMAIC follows specific steps to ensure all changes are accounted for and able to be distributed to other departments. One of the largest impacts implementing LSS tools and methodology in a business is the change in the organization's structure, culture, change adaptability, innovation, and reputation (Alblooshi & Shamsuzzaman, 2020). LSS's emphasis on cross-functional design, customer input, manufacturability design, and quality function deployment focused on meeting customers' expectations helps organizations achieve a competitive position in the marketplace (Alcaide-Muñoz & Gutierrez-Gutierrez, 2017). LSS is a powerful tool that many large organizations use to improve processes through statistical analysis in order to increase their revenue, decrease their costs, and improve customer satisfaction.

2.1 Define

The Define Phase is the introductory phase where a team will specify attributes of a project like goals, scope, and boundaries (Kumar, 2008). This step is important for LSS projects because it allows the team to understand the reasoning and purpose behind their work, as well as the necessary requirements for the project. For example, the Toyota Motor Company would utilize the Define Phase to plan how many parts are going to be necessary for a certain number of units that they are producing at a given time (Toyota Production System). Essentially, Toyota is understanding the scope of their problem in this step, which is of the utmost importance of the Define phase. The three major activities in the Define Phase are: develop a project charter, translate customer needs into requirements, and produce a process map. These three activities will create a visual depiction of the process and the problem at hand (Selvi, Majumdar, 2014). All three of these activities are critical to a successful Define Phase because the project team will have a clear understanding of the process before they determine which parts of the process they should measure in the Measurement phase. The project charter includes the business case, problem and goal statements, project scope, milestones, and roles for each team member (Selvi, Majumdar, 2014). Translating customer needs into requirements allows the project team to satisfy the customer when submitting a proposed solution to the stakeholders. Finally, developing a detailed process map enables both the stakeholders and project team to visualize each step of the process that the team is attempting to optimize.

2.2 Measure

The Measurement Phase is a key phase in the LSS process as this is when baseline data is collected to better understand the current process (Brook, 2020). This data becomes important because it will be used as a source in the Analyze phase to determine the root causes of the problem. Within the Measurement Phase there are a variety of benchmarks that should be reached, which when aggregated, give full clarity on the current performance of the process (Sao & Sridhar, 2015). The general flow of these benchmarks is: determine what data is important to be measured, determine how to collect data, collect the necessary data, summarize the data, determine if the data is capable of meeting customer requirements, look for quick win opportunities, then calculate the financial benefits of the project (George et al., 2004). To reach these benchmarks, there are many tools used during this phase to ensure a wholistic measurement of the system and its processes. Measurement tools are useful, but their significance to the Measurement Phase is dependent on how important the information they collect, organize, or measure, is to the goals of the project team (Villanova University, 2020). The success of the measurement phase is determined at its tollgate review, where the project team presents the information gathered during this phase (Six Sigma Tollgates Provide a Reliable, Logical Way to Approach Process Improvement, 2020). The information should accomplish a few tasks. First, it should be objective data that shows the inputs and outputs, costs, and variations caused by the problem. When this is determined, the team can reestablish goals previously determined in the Define Phase. This is because the data will help the team understand the feasibility of their goals. Lastly, the information should be substantial for the Analyze Phase to determine where the exact issue is coming from, as backtracking to the measure phase would cause the need to take more measurements, increase costs, and increase project time.

2.3 Analyze

The purpose of the Analyze Phase is to, “pinpoint and verify causes affecting the key input and output variables tied to project goals,” to “find the critical X’s,” that impact the project’s goals (George & Rowlands & Price & Mackey, 2004). In conducting the process analysis, the project team will complete steps to ensure the collected data is used effectively to determine the process steps that are not up to standard. The first step in the Analyze Phase is to conduct value analysis (George & Rowlands & Price & Mackey, 2004). During this step, the team will identify value-add, non-value-add, and business non-value-add steps. Value-Added steps are defined as any activity in the process that is essential to deliver the service or product to the customer. Business Non-Value-Added, also known as non-value-added required steps, are defined as activities that are required by the business to execute the process but add no real value to the customer. This includes work that reduces financial risk or is required by law or regulation. Finally, Non-Value-Added activities are those that add no value from the customer’s perspective and are not required by law or regulation. These activities are waste to the process. After determining which process steps are required, the team will analyze the process flow by looking for bottleneck points and constraints in a process. The team will then analyze the data collected during the Measure Phase and generate theories to explain causes of process step failure. Theories of process step failure can be generated using brainstorming tools such as the C&E Matrix, Fishbone Diagram, and the 5 Whys (George & Rowlands & Price & Mackey, 2004). These tools will help the team narrow the search for potential root-causes and significant cause-and-effect relationships. Finally, the team will use more advanced statistical tools to further analyze the data and verify statistically significant relationships. Upon doing this, the team will have a list of which root causes will be targeted for action during the Improve Phase.

2.4 Improve

In the Improve Phase, the project team focuses on creating solutions to the client's problems using the findings discovered in the Analysis Phase. By using the information that we collected during the Analyze Phase, better-informed decisions can be made of which solutions could be considered. Furthermore, information during the Analyze Phase will help determine if these solutions are feasible. In the Improve Phase, a specific process is used to decide on a solution to implement. The first step is to generate possible solutions. In this step, the team applies the analysis that they gather from the data collected during the Measure Phase to assist in idea generation (Brook, 2020). Once the ideas have been generated, the team must convert those ideas into feasible alternatives (Brook, 2020). This requires a screening of ideas. Ideas are screened by comparing each idea to certain criteria. These criteria ensure the idea is in harmony with the stakeholders' requirements. After the ideas have been converted into a group of feasible alternatives, the project team now must decide of which solution is the best. The following tools assist the team in deciding on an alternative: Assessment Criteria, Paired Comparisons, Prioritization Matrix, and Solution Screening (Brook, 2020). The final step of the Improve phase is to conduct a risk analysis. The purpose for a risk assessment is to identify the potential risks that implementing the solution may entail. A few methods of conducting risk analysis are by using sensitivity analysis to see how the model would survive the most drastic situations, a FMEA (Failure Modes and Effects Analysis), and cost analysis.

2.5 Control

The final phase in the DMAIC process is the Control Phase. The purpose of the Control Phase is to, "complete project work and hand off the improved process owner, with procedures for maintaining the gains," (George & Rowlands & Price & Mackey, 2004). Throughout the Control Phase, the project team will work through a series of steps to confirm the process' successful improvement. The first step is to develop supporting methods and documentation to sustain the full-scale implementation of the solution (George & Rowlands & Price & Mackey, 2004). The next step is to launch the implementation and lock in the performance gains. To do this, the team will use mistake proofing to prevent the customer from returning to the old method. The team will monitor the solution implementation and develop Process Control Plans and hand off control of the process to the owner. The team will then audit the results of the implementation to confirm measures of improvement. After full implementation and confirmation of the solution's success, the team has completed all the steps in the DMAIC process.

3. Methods and Results

The goal of the Define phase was ensure a collective understanding of the process and the problem at hand between the stakeholders and the project team. The scope of developing this understanding began at a very high level and gradually shrank, becoming more specific to directly target the problem. For the project team, this involved understanding first how Tobyhanna operates, then the Systems Preparation Branch, and lastly, the Wash Prime Work Center. Two key deliverables of the Define Phase were the SIPOC map and project goals. The SIPOC map is shown in Figure 1.

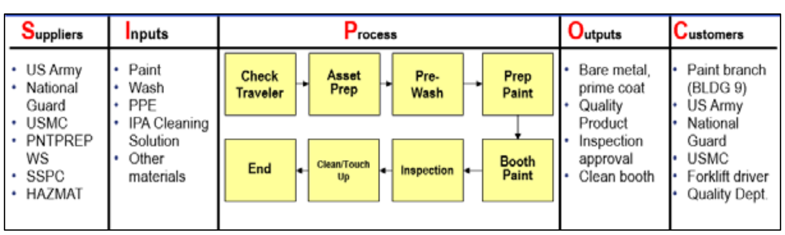

Figure 1. SIPOC Diagram

The SIPOC map provided an outline of what goes into a process, the process itself, and the outputs of the process. Figure 1 depicts the SIPOC map of WSHPRIM1. The key supplier was the United States Army. Inputs are necessary materials WSHPRIM1 adds into the process. Outputs are what leaves the WSHPRIM1. Customers are who the outputs go to.

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The goal statements were also created in the Define Phase. The three goals of this project were: reduce WSHPRM1 monthly DLH from an average of 108 hours to 87 hours by April 2022; reduce annual cost for DLH in the WSHPRIM1 work center by 20% by April 2022; and increase the sigma quality level to three by April 2022. This was determined by consulting stakeholders at Tobyhanna, as well as the project team's mentor. By outlining goals during the Define phase, the group was well positioned to start working towards those goals in the following phases.

The goal of the Measure Phase was to collect the necessary data that could show which process steps used the most DLH. Success in the Measure Phase required a clear understanding of what in the process was important to measure in order to give objective evidence of a defect in the process. To do this, operational definitions were developed to define key terms in the process. These key terms were used to clean data that was collected in WSHPRIM1 from 2019 until August of 2021. Cleaning the data involved removing partially filled data, sorting the data by assets, and sorting the data by process steps. The Process steps of the WSHPRIM1 are Asset Prep, Prewash, Paint Prep, Paint, Touch Up, and Clean Up. The most important step of cleaning the data was calculating the time it took to complete each asset, as well as the time it took to complete each process step. The total DLH of all assets that were processed through the WSHPRIM1 work center were compared in Figure 2. STTs were chosen to be analyzed because they accounted for the 41 percent of all DLH that the shop experienced. This was the most DLH of any asset. More measurements specific to the STT assets was then collected. To further measure STTs, the process capability was determined; a graphical depiction is shown in Figure 3.

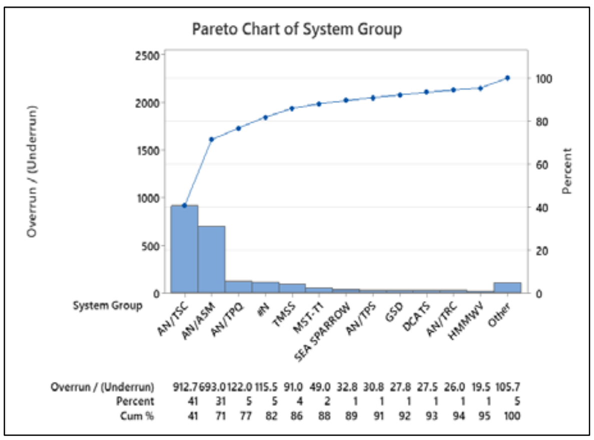

Figure 2. Total Hours of All Assets

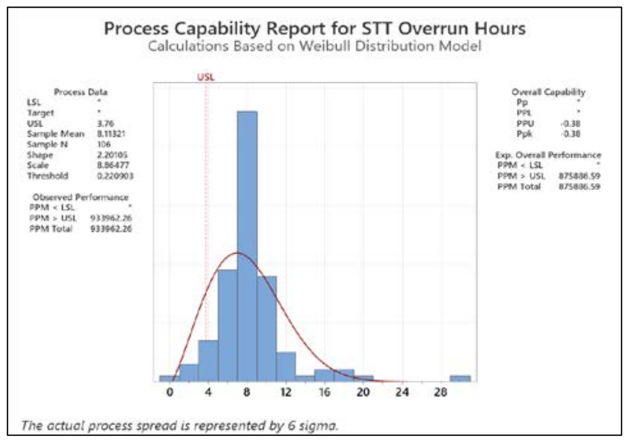

Figure 3. Process Capability of STTs

From 2019 to 2021, the average time per asset was 4.7 hours. The goal of the project was to reduce the number of DLH by 20%. This meant the target number of DLH was 3.76 hours, which is represented by the upper specification line (USL) in Figure 3. As the goal was to have no more than 3.76 hours, the project will be successful if all data is left of the USL. It is evident from Figure 3 that the current process is not meeting stakeholder demands.

With STTs as the chosen asset to improve DLH, the project team looked to further explore the process of refurbishing STTs. The DLH of each process step was examined. A pareto chart of the process steps was developed. The total time to complete each step was gathered from the data; 99.3% of all hours derived from two of the six process steps: paint and paint preparation. The team found that overrun hours was an important metric to analyze because the more overrun hours there were, the more room for an opportunity to decrease DLH.

With a better understanding of the process, a data collection plan was developed. The previous data was from 2019 to the beginning of 2021. The current process could have changed between the end of the old data collection and the start of the project. This meant it was important to collect data on current efficiency of WSHPRIM1. The data collection plan laid out what was going to be measured, how it was going to be measured, and why that data was necessary to collect. The plan was executed by developing a data collection sheet that the painters working on the assets could fill out as they worked on an STT. Because the problem involved DLH, the data collection sheet focused on all information relevant to parts of the process that added time to the process. The data collected on this sheet would provide the necessary information in the Analyze Phase to determine the root cause of DLH.

In analyzing the WSHPRIM1 Work Center, the team worked to determine potential root causes of DLH. First, the team worked to identify potential root causes. This was done by conducting quantitative data analysis, completing a Cause and Effect (C&E) Matrix, conducting qualitative analysis by brainstorming, doing a fishbone diagram, asking "5 Whys," and value stream map analysis. After completing this step, the team came out with a list of potential root causes, shown in Figure 4, and additional quick wins. Quick wins included: follow paint prep process SOP (complete); increase training of painters (incomplete); standardize break time (incomplete); and having two painters work on an asset at the same time (incomplete).

Potential Root Causes
Painter variation of experience, level, shift number…
Paint gun inefficiency
Masking process and paint mixing is inconsistent
External humidity is a non-controllable factor that influences asset drying time

Figure 4. Potential Root Causes

Next, the team reduced the list of potential root causes by completing root cause analysis, pareto analysis, and statistical analysis. After reducing the list, confirmation of the relationship between the potential root causes and output metrics was done. This step accomplished this by conducting statistical analysis using the Kruskal-Wallis Test to evaluate the relationship between different variables. The team used the Kruskal-Wallis to determine if there was a significant difference between the wage grade (WG) of painter, either seven or nine, when it came to the amount of time it took to add value to the asset. A significant difference was noted between the two WGs when it came to touch up time, total time, and the total time when a WG9 painter prepped the asset. All statistical analysis results and conclusions are shown in Table 1. After conducting statistical analysis, the team had a basis of understanding for potential root causes and a means of evaluating potential solutions to reduce DLH.

Table 1. Description of Hypothesis Tests

Hypothesis Test	**Factor (x) Tested**	**P-Value**	**Observations / Conclusion**
Kruskal-Wallis	Touch Up Time vs. WG	0.035	When a WG9 Paints an asset, the Touch Up step takes less time
Kruskal-Wallis	Paint Time vs. WG	0.355	Impact of WG9 painter is not significant in paint time
Kruskal-Wallis	Total Time vs WG	0.028	Total time of process is affected if a WG 9 painter is involved
Kruskal-Wallis	Total Time vs Paint Prep	0.028	The total time of process is reduced when a WG 9 is involved in prep

Next, the team began exploring ways to improve the process to reduce STT monthly DLH and reduce annual DLH cost for the WSHPRIM1 work center during the Improve phase. The team used brainstorming and group thinking strategies to create solutions and alternatives that could improve the areas that were designated as significant in the statistical analysis. The solutions that the team produced were to create an SOP for painters by WG9 painters, offset the shifts that WG9 painters are on, increase training to equalize painter skills, and create a schedule that allows WG9 painters to do asset prep. To screen the effectiveness of the potential solutions, the team used the evaluation criteria depicted in Figure 6. The criteria that the team used to assess the solutions were: how well it reduces paint time; how well it reduces touch up time; does it reduce overall defects; and is it easy to implement. The team then assigned weights to each criteria signifying their overall importance to our stakeholders. The team gave each alternative a score for each criterion, with one being it has low significance in meeting the criteria designated and nine being it has high significance in meeting the criteria designated. The team then multiplied these scores with each criterion's corresponding weight and summed the products to get a total score for each alternative.

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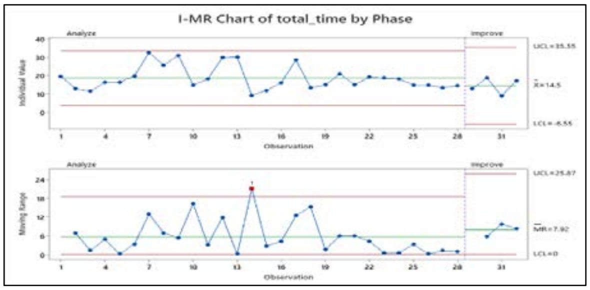

Figure 5. Control Charts

Swing Weights were determined by what percentage of significance they were to improving the process.	**Reduce Paint Time:**	**Reduce time for touch up:**	**Reduce Overall Defects:**	**Ease of Implementation Effort**	**Total Score**
Weight	(30%)	(40%)	(10%)	(20%)	
Create SOP for painters by WG 9 painter	High 9	Low 1	High 9	Medium 3	4.6 (9(.30)+1(.4)+9(.1)+3(.2))= 4.6
Offset the shifts that WG 9 painters are on.	Medium 3	Low 1	Medium 3	High 9	3.4
Increase training to equalize painter skills	High 9	High 9	High 9	Low 1	7.4
Create schedule that allows WG 9 painters to do asset prep	Low 1	High 9	High 9	High 9	6.6
Create regular maintenance schedule for paint booth.	Medium 3	Low 1	Medium 3	High 9	3.4

Figure 6. Alternative Assessment

Once the alternatives were ranked, the team created a pilot plan for the WSHPRIM1 center to implement for two weeks. At the end of the two weeks, the team received the results from the pilot plan and analyzed the data using control charts as shown in Figure 5. The team assessed the pilot plan's success by comparing the results to the data collected during the Analyze phase; this showed a five hour decrease in total DLH.

4. Conclusion and Future Work

In identifying the origin of DLH at Tobyhanna's WSHPRIM1 Work Center, the paint and paint prep process steps accounted for 99.3% of DLH. The team found when a WG9 preps the asset, less total time is required. Additional statistically significant findings were when a WG9 paints an asset, the touch up step takes less time and when a WG9 is involved, the total time of paint prep is reduced. The implementation of solutions in the Improve phase will be applied to the organization and will be sustained through the Control phase. To ensure that the benefits are sustainable, prolonged methods such as creating standard operating procedures (SOPs) will be utilized. In SOPs, the main factor for success is making sure everyone in the workplace has the same understanding. Thus, if an issue arises, the correct protocols can be used to efficiently neutralize the threat. In addition, to support Tobyhanna's goal in reducing total DLH, a process control plan will be integrated in the Control phase. This will aid Tobyhanna to detect any changes in the system before the effect becomes detrimental to the organization. By implementing the solutions determined by the project team, Tobyhanna's WSHPRIM1 work center will reduce the annual costs related to DLH by 20%. The operational benefits of this project will be seen immediately upon implementation of the team's proposed solutions.

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