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Utilizing LSS for Industrial Process Improvement at Aberdeen Proving Ground

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Abstract: The Aberdeen Proving Ground uses an abundance of highly calibrated tools to manufacture, test, and support technology in the Advanced Manufacturing facility (ADM). Workers at ADM have experienced a rise in improperly tracked tools throughout their shops that have resulted in unwanted time and money spent finding the tools or replacing them. This capstone team utilized LSS's DMAIC methodology to improve the tracking of ADM's calibrated tools. The group's effort resulted in a pilot plan for workers at ADM to implement that will save time and money by reducing the time required to find tools and reducing the frequency of tools being lost.

Keywords: LSS, DMAIC, Aberdeen Proving Ground

1. Introduction

Aberdeen Proving Ground (APG) is a military proving ground located in Aberdeen, Maryland which tests and supports technology for protection, intelligence, shooting, movement, and communication (Aberdeen Proving Ground In-depth Overview, n.d.). APG consists of more than 21,000 employees who use various sets of tools to work toward their mission. Within APG is the Chemical and Biological Center and within this sub-organization is the Advanced Manufacturing (ADM) facility. This paper scope includes the ADM facility, focusing on one of these specific set of tools used in high volume at ADM known as calibration tools. There are ~35 or more diverse kinds of calibration tools within this facility and between the various kinds of tools there are more than 370 of them in the system. The goal of this project was to implement Lean Six Sigma (LSS) methods to improve the overall tracking of these calibration tools as they can be expensive and improperly tracking them is costing ADM time and money.

In recent years, companies and industries have implemented methodology and principles to reduce variation and limitations in production known as LSS. LSS has become increasingly popular around the world, especially in corporate America. LSS is a broad topic, but it constitutes implementing continuous improvement for an optimal solution (The Origins of Lean Six Sigma, 2017). LSS revolves around the idea of lean thinking – a way to maximize customer value while minimizing waste (What is Lean?, 2009). Businesses utilize this type of thinking to effectively improve aspects of production that will reduce waste. According to Montgomery and Woodall, what makes LSS stand out among other ways to optimize production is its "disciplined, project-oriented, statistically based approach for reducing variability, removing effects, and eliminating waste from products, processes, and transactions" (Montgomery & Woodall, 2008). However, what mostly makes LSS stand out for optimization is its use of DMAIC methodology. DMAIC is an acronym short for Define, Measure, Analyze, Improve, and Control.

This paper outlines each phase of the DMAIC process and how the team used this methodology to eliminate waste in the tool tracking process at ADM. The literature review discusses each phase of the DMAIC process in depth, including the intended end results of each phase. The methods and results section discusses how the DMAIC process was applied to improve and eliminate waste in the tool tracking process at ADM. Lastly, the paper concludes with expectations and ideas for maintaining improvement in the future. Since this paper covers an ongoing project, the plans for the Control phase are detailed under future work because it has yet to be completed.

2. Literature Review

The DMAIC Process begins with the Define phase. This phase sets up the rest of the project for either success or failure. The goal of this phase is to clearly identify measurable goals and an end state to the project (Montgomery & Woodall, 2008). A poorly executed define phase will include vague requirements for the project and a very wide scope that does not direct the project in any specific direction. Therefore, a project charter is crucial. A project charter is a way of ensuring that all the boxes are checked and that the project starts off with a clear and concise direction. (Snee & Hoerl, 2003) A project charter in the define phase may include a problem/goal statement, project scope, a map of the current process, impact on the business and voice of the customer and the business. If a business comes to the project with a narrow scope and strong understanding of what they want done, this phase may be shorter in duration compared to the other phases. Not all customers are the same, often businesses will have an overly broad scope and have little understanding of what they want to carry out. This is when the LSS team must spend more time with the business and customer gaining a better understanding of what is hindering production and what specific component of that process needs to be improved.

When transitioning into the Measure phase, confirming that the elements of the project charter are valid in the eyes of the customer is important. The project charter helps confirm that the project will have a significant impact on the business of the customer. Also, it solidifies the roadmap that will guide the project through the rest of the DMAIC process. The Measure phase figures out the current process performance and analyzes the root causes of the defects and costs. The measure phase can also find customer needs and analyze the process design options to meet those needs (Hu, Barth, Sears, & Pieprzak, 2004). Activities found within the Measure phase include identifying key inputs, processes, output metrics, developing operational definitions, developing a data collection plan, collecting baseline data, validating measurement system, and determining process performance/capability. Four intrinsic data quality dimensions receive the most attention in data quality research: accuracy, timeliness, consistency, and completeness (Jones-Farmer, Ezell, & Hazen, 2014). Each of these four dimensions support the collection of useful, sufficient data. To ensure that these four dimensions of data collection are captured, operational definitions create with consistency, stratification factors increase timeliness and accuracy, and identifying biases and sampling will ensure completeness of the data (Sokolowski, 1987). An organization should develop its performance measurement system that includes a way of tracking data for the assessment of total organization performance. This will support improvements and ensure that the organization responds to internal or external changes in the process (Hung, 2006). The result will help identify problems and potential problem areas and assist in ranking the problems by priority.

The Analyze phase consists of teams extracting the information they gathered in the measure phase and beginning their analysis. However, unlike the phases before it, in the Analyze phase, teams begin to identify potential root causes of problems in their process. Teams use Minitab – a software program that allows the manipulation of data for tests (Brook, 2020). A key and critical aspect of the Analyze phase is narrowing the root causes of a process by identifying causes that are most likely to contribute to a problem. A mapping technique used during the analyze phase that narrows down potential root causes in a process is a Fishbone Diagram. These cause-and-effect diagrams "can help in brainstorming to identify potential causes of a problem and in sorting ideas into useful categories" (Kane & Kane, 2014). A Fishbone Diagram takes into consideration several factors that may lead to a root cause to include causes potential root causes from man, machine, methods, measurements, mother nature, and material. Once teams identify potential root causes, they conduct data analysis to statistically prove the significance of their root causes. Utilizing data to determine the shortcomings of a process allows teams to confirm what they determined in the root cause analysis using numbers to support their results. If the data provided follows a normal trend and passes tests of normality, the data undergoes standard data analysis tests to include ANOVA and linear regression. However, more often than not, data collected in the measure phase does not pass tests of normality. Therefore, groups perform non-parametric data analysis where there are no underlying assumptions present. Non-parametric tests, such as a Mood's Median test, have more statistical power because groups violate basic assumptions such as a normal distribution which makes the data more realistic (Lindstrom, 2010).

The purpose of the improve phase is to use the gained understanding from the previous phases to create solutions and implement them to mitigate the effects of the root cause of the problem within the process (George & Lawrence, 2002). During this phase the process team will "develop, select, and implement the best solutions, with controlled risks" and then measure the effects of the solutions with the Key Process Inputs (KPIs) that were developed during the measure phase (Brook, 2020). The key steps of the process consist of generating potential solutions, selecting and prioritizing the solutions, revising the existing value stream map to reflect the new process after the solution is implemented, performing a risk assessment, and piloting the solution (George, Rowlands, Price, & Maxey, 2005). Once a solution is piloted, the team will confirm if the project goal was actually attained before developing and executing a finalized implementation plan. The team will have reached the end of the phase once it has created an improved process that is "stable, predictable and meets customer requirements" (George, Rowlands, Price, & Maxey, 2005). With the new process implemented, the process team can move on to the final phase of the DMAIC process.

The last phase of the DMAIC process is Control. This phase is one of the more important phases because if the project team does not do the control phase correctly, consequently the whole entire project is worthless. The control phase is where the project teams ensure that the system they put in place will last before the team moves on to their next project. The team can break this phase down into four parts as well: implement, standardize the solution, quantify the improvement, and close the project (Brook, 2020). These steps will help the client company to take over the system, monitor it, and be able to adjust as needed. Often time, projects fail after groups leave because the plan the group left behind is either too complicated or lackluster all together, so it is important to find a balance between these things.

3. Methods & Results

To begin this project, the team had to first develop a baseline understanding of the current process and define several fundamental objectives. This is important for several reasons to include narrowing the scope of both research and problem-solving efforts and determining the present inefficiencies so that accurate and relevant measurement can be leveraged during implementation and control phases. However, without access to raw data, complete identification could not be made until the measure phase. Regardless, the team did define a goal of lowering the inefficiency to less than 1% of all calibration tools being improperly tracked. There was more than one thing that could have solved when looking at the calibration tools to include the scheduling of their calibrations and sending them in and out when they needed to be calibrated. The nature of this calibration represents the scope. Below in Figure 1 is the SIPOC Map created in the Define phase as well. This is a brief overview of the process in the Define phase. Through a few meetings with the ADM team as well as one visit to ADM, representation of the entire process was able to be mapped as it currently is.

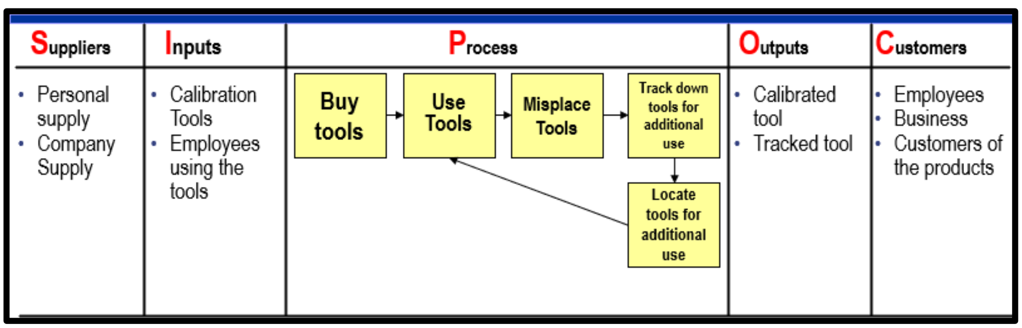

Figure 1. SIPOC Map

The last major component of the Define phase was capturing the Voice of the Customer and Voice of the Business. The SIPOC map was an essential component to this because it allowed the team to see the complete picture of the process from the moment a calibration tool was bought by a worker at ADM to how the calibration tool is received, inputted into the system, tracked when workers use it and return it, and how that cycle is repeated.

In the Measure phase, the team began by observing and understanding the current process. After ADM's transition between buildings, their process for tracking and storing equipment dissipated and there was no resemblance of a proper systemTo understand the current process the team built a data collection plan to gather information about the number of defects, time to find tools, and associated costs. The team created operational definitions to clearly define what constituted a defect, what a calibrated item was, and the importance of cycle time. Since the team could not be at APG facilities collecting the data, these definitions assisted the employees who were tasked to complete the data collection plan. The team received a master list of 374 tools that the inspection room was tracking. Through statistical analysis, the team determined that a sample of 60 items was sufficient to analyze the data. To be more time efficient, the team created three data collection plans for three employees to complete, each plan was randomized with 20 randomized sub-lists of tools off the master list. Data on tool location, calibration status, and time to find tools were collected.

Table 1. Data Collection Plan

Inventory #	Item #	On Master List	Supposed Location	Actual Location	Logged Calibration	Time (Min:Sec)
5	145	Y	Shop Floor	Cart	10/30/2023	5:32
6	94	Y	Shop Floor	Table	11/20/2021	0:43
7	155	Y	Shop Floor	Cart		2:17
8	235	Y	**Not Found**	N/A	11/27/2021	8:00+

Table 1 shows that inventory #'s 5 & 6 were found with proper calibration dates but inventory #5 took a lot longer to find. Inventory #7 was found but it did not have a calibration date label and therefore was considered a defect. Inventory #8 was not found at all and considered a defective lost item. Operational definitions help define anything in the process that might be arbitrary. Anything that could be misinterpreted or might have a different meaning to others should have an operational definition. It defines language used to the specific qualities of the process. During the collection of data there was potential for bias because there were multiple data collectors. There was an attempt to reduce the variation, but the team incurred bias during the data collection process. Having multiple data collectors leaves room for variability because the data can be obtained in diverse ways. To reduce variation, the team stressed the importance that the data collectors understand the operational definitions and how to systematically record the data. From this data the team was able to calculate the number of each type of defect, and the time it took to locate each tool. After meeting with ADM's advisors, the team calculated from the data that a net of $250,000 in the first five years could be saved based on properly tracking items. This cost avoidance is a culmination of missing items cost and the hourly labor costs for time spent looking for misplaced tools.

In the Analyze phase, the team began identifying and validating root causes through data analysis. They used data gathered in the measure phase to perform hypotheses tests to garner conclusions about potential root causes. To identify potential root causes, the team created a cause-and-effect diagram (Fishbone Diagram) to reveal what potential root cause sticks out the most. They then sorted the cause-and-effect diagram into six main categories that could impact proper tool tracking: man, machine. methods, measurements, mother nature, and material. They concluded that the three main causes of improperly tracked items were not storing tools properly, lack of a tool tracking standard, and lack of an updated tool tracking master list. Using these three potential root causes, they used data found from the Measure phase to statistically determine their significance. The team used a total of four hypothesis tests: chi-squared test for association (twice), Mood's Median, and a FMEA chart. Figure 2 shows a summary of each hypothesis test.

Table 2. Hypothesis Test Conclusions

	Factor Tested	p-value	Observations/Conclusions
1.Chi-Squared Test for Association	Not Storing Tools Properly (Location)	0.000	Finding tools is dependent on it being in the proper location.
2.Mood's Median Test	Not Storing Tools Properly (Time)	0.520	The median time to find tools is the same regardless of them being in the proper location.
3.Chi-Squared Test for Association	Lack of a Tracking Standard	0.012	Finding tools within the 2.4 min is dependent on proper tracking of knowing the tools' location.
4.FMEA	All The Above	N/A	Not storing tools properly yielded the highest Risk Priority Number (RPN) followed by lack of standard tracking and complete updated master list, respectively.

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The team drew several observations and conclusions from each hypothesis test. They concluded storing tools properly has a major impact on the time it takes to find the tool's location. Also, they concluded finding a tool in the predetermined 2.4-minute window is dependent on knowing where the tool's location is. Although this may appear as common sense, it was necessary to statistically prove whether the identified root causes impacted the complete tracking of tools. The team used these statistically proven root causes to begin brainstorming ideas to improve the process in the Improve Phase.

During the Improve phase, the team used the root causes to begin developing a pilot solution to be tested by ADM. The team began by brainstorming courses of action to change the location in which the tools were stored and the standard by which they were tracked. Once the courses of actions were created, the team then scored them against the evaluation criteria that were developed to analyze how effective the solutions could be. The team then weighed each evaluation criteria to reflect what was most important to the ADM team. The team then totaled the score for each solution to see what the best fit could be for ADM.

		Evaluation Criteria					
		Control/Track Ability (Average = 4)	Access to Tools – Doesn't Slow Work (Average = 4)	Ability to Calibrate (Average = 2.5)	Culture Alignment (Average = 3)	Implementation Cost/Effort (Average = 1.5)	OVERALL AVERAGE SCORE
Storage COAs	Centralized Location	9	1	9	1	3	70
	Hub and Spoke	3	3	3	3	3	45
	100% Decentralized	1	9	1	9	9	83
	Purchase New Items	1	1	9	3	3	44
	Hybrid Centralized/Decentralized	9	3	3	3	9	78
	3-Level Hybrid	3	9	3	9	3	87
	IDEAL	9	9	9	9	9	135

Weight Criteria: High = 9; Medium = 3; Low = 1

Figure 2. Evaluation of Solutions

After scoring the solutions, the team found that 100% decentralized storage and a 3-level hybrid storage system where the top two solutions for how ADM should store their tools. Additionally, the team found that barcoding and a "location of owner" system were the top two solutions for tracking ADM's tools. The team then developed a FMEA chart to determine the best solution for storing and tracking to send ADM a pilot plan to be tested. Using the pilot solution, ADM will collect the same data as collected in the Measure phase to compare the pilot solution to ADM's current operating procedures.

4. Conclusion

The team's project focused on using DMAIC methodology to improve tool storage at Aberdeen Proving Ground. They worked with Aberdeen Proving Ground employees, whose day-to-day work involves the use of special calibrated tools for manufacturing. The team was utilized due to a poor system for properly tracking tools and managing the schedule for shipping a tool out for calibration. Aberdeen was at risk of using their quality management certification and it was imperative that they started taking steps toward improvement. If Aberdeen loses their certification, then the Army will lose millions of dollars due to facilities and equipment and have the combat readiness of the future force dwindle. A LSS sponsored project goes through each phase of DMAIC to ensure the most optimization as possible. The team defined the project end state and goals for the project in the Define phase. In the Measure phase, the team started to collect data to see the current state of the tool tracking process. The Analyze phase consisted of identifying root causes and conducting hypothesis tests to prove whether the root causes were statistically significant to the process. In the improve phase, the team developed courses of action for each identified root cause. The team used evaluation criteria to select a pilot process solution plan.

For future work, the team will continue to conduct and implement the control phase. The team determined the highest priority is creating and implementing a audit schedule moving forward. The audit schedule is the checks and balances of the system. It is a method to ensure that Lean Management tools input during the process are producing positive results and are working properly. An example of this could be having a quarterly full layout of all inventories to ensure tools are stored properly and accounted

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