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Tobyhanna Army Depot HAZMAT Reduction

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Abstract: Lean Six Sigma (LSS) is a widely used methodology for improving organizational processes by eliminating inefficiencies and reducing variability. This capstone paper examines the DMAIC (Define, Measure, Analyze, Improve, Control) framework and its application to hazardous material (HAZMAT) waste management at Tobyhanna Army Depot. By leveraging process analysis, data-driven decision-making, and waste reduction strategies, this project aims to decrease wasted HAZMAT, resulting in significant cost savings for the depot. The team designed the proposed improvements to be sustainable and scalable, aiming to deliver lasting impact through enhanced operational efficiency and alignment with Lean Six Sigma best practices.

Keywords: Lean Six Sigma, DMAIC, Tobyhanna Army Depot, HAZMAT

1. Introduction

Lean Six Sigma is "a combination of well-known waste elimination and process improvement techniques Lean Manufacturing and Sigma" (Zhang, Irfan, Obadi, Zhu, & Hassan, 2012). The lean process focuses on waste reduction, and the Six Sigma portion emphasizes variation reduction. Successfully implementing Lean Six Sigma into the workplace increases workplace efficiencies and leads to overall company improvement. The Lean Six Sigma process also includes the DMAIC process, a data driven framework that provides structure and step-by-step guidance to the leaning process (Bicheno & Holweg, 2023).

The team applied the DMAIC framework for this capstone project to improve hazardous material (HAZMAT) deficiencies at the Tobyhanna Army Depot (TYAD). TYAD is located in Tobyhanna, Pennsylvania, and serves C5ISR (Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance, and Reconnaissance) goals with logistical support (C5ISR Mission, n.d.). Tobyhanna's capabilities include "full-spectrum support for sustainment, overhaul and repair, fabrication and manufacturing, engineering design and development, systems integration, technology insertion, modification, and global field support to our warfighters" (C5ISR Mission, n.d.). As a key logistics node within the military's sustainment ecosystem, TYAD continues to improve its processes to better fulfill C5ISR goals for the military. TYAD tasked the team with reducing excess wasted HAZMAT to support process improvement. Although the goal was specific, the mediums and methods to accomplish those goals remained relatively vague. To better understand routine operations, the team visited the depot on multiple occasions to discuss the procurement, storage, usage, and disposal of HAZMAT. The team applied the DMAIC process to the information gathered. For each of the DMAIC phases, the team created drafts, received feedback, made improvements, and received approval on each phase from the project sponsor.

2. Literature Review

DMAIC was established by engineer Bill Smith in the 1980s, expanding on ideas in the "Plan Do Study Act" cycle (Monday, 2022). It is a five-step process that drives Lean Six Sigma (George, Rowlands, Price, & Maxey, 2005). Lean Six Sigma originates from the combination of two systems of thinking: lean thinking and Six Sigma. Lean thinking focuses on doing more with less – less space, less time, and fewer materials. Six Sigma focuses on the statistical standard deviations found in engineering processes, representing the process output that meets the customer specifications. Six Sigma process engineering aims to achieve a six-sigma level of process refinement, resulting in a process output of 99.99966%, or approximately 3.4 defects per million opportunities to meet customer specifications (Bicheno & Holweg, 2023). Each phase of the DMAIC process targets a distinct aspect of the Lean Six Sigma process, creating an effective and efficient process within an organization. The two primary options for implementing DMAIC are the project-team approach and the kaizen approach (George, Rowlands, Price, & Maxey, 2005). The project team approach involves all team members working in all phases of DMAIC, spanning 1-4 months (George, Rowlands, Price, & Maxey, 2005). The kaizen approach is a rapid, one-week or less progression through DMAIC, and partial preparatory work on Define and Measure is typically already completed (George, Rowlands, Price, & Maxey, 2005). It is possible to skip phases of DMAIC if there is an obvious solution; however, generally, it would be beneficial for the team implementing DMAIC to adhere to all the phases (George, Rowlands, Price, & Maxey, 2005).

2.1. Define Phase

The first step of DMAIC is the Define phase, which involves distinctly defining the objective and goals of the project, the scope, and the overall time frame of the project (Monday, 2022). Before beginning, a draft project charter from the sponsor and proper resource allocation—such as team time and an initial budget—are necessary (George, Rowlands, Price, & Maxey, 2005). Key steps include reviewing the project charter, validating the problem statement and goals, confirming financial benefits, creating and validating the process map and scope, developing a communication plan, and completing the Define Gate review. A proper project charter should outline the problem statement, stakeholders, business impact, goals, project scope, high-level plan, and team members. Additionally, a Supplier, Input, Process, Output, Customer (SIPOC) diagram should be developed to map and clearly understand the process visually (George, Rowlands, Price, & Maxey, 2005).

2.2. Measure Phase

The second step of DMAIC is the Measure phase. In this phase, the team develops clear and meaningful measurement systems and applies them to the client's process performance to establish a baseline (Brook, 2022). The key steps of the Measure phase involve determining outputs and inputs to the process, articulating the process through value stream mapping, validating the measurement system to see if it is repeatable/reproducible, creating and executing a data collection plan, assessing the capability and performance of the process, and finally conducting the Measure gate review (George, Rowlands, Price, & Maxey, 2005). Given data and risk analysis, a project team can conduct quick-hit improvements to achieve partial goal achievement. Additionally, when collecting data, it's necessary to determine how it will be used and displayed. For example, the team can use the data to assess normality, conduct root cause and correlation analyses, and identify the most significant contributors to the problem. The data could be presented visually using Pareto charts, histograms, control charts, and scatter diagrams (George, Rowlands, Price, & Maxey, 2005).

2.3. Analyze Phase

The third step of DMAIC is the Analyze phase. This phase focuses on identifying what is causing variation and defects for the problem at hand and providing statistical evidence that the causes are legitimate (Bicheno & Holweg, 2023). The key steps in this phase are determining critical inputs, performing data analysis, performing process analysis, determining root causes, prioritizing root causes, and finally completing the Analyze gate review (George, Rowlands, Price, & Maxey, 2005). Some analysis phase tools are the cause-and-effect diagram, the five whys exercise, graphical analysis tools, Pareto charts, failure mode and effects analysis, and statistical process control (DMAIC Analyze Phase: Tools for Data Analysis, n.d.). When evaluating data collection, it is essential to be self-critical, ensuring that the collected data enhances the understanding of the problem's causes. Team members should avoid collecting data if it does not add value to the stated project goal (George, Rowlands, Price, & Maxey, 2005). Teams should also avoid pitfalls such as poor data analysis and incorrectly identifying critical root causes (DMAIC Analyze Phase: Tools for Data Analysis, n.d.). Understanding how to interpret data is essential in this phase. Additionally, it is important to remember the morale of the LSS team implementing the DMAIC processes. An

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unhappy team is often an inefficient and unmotivated one. Discovering some of the root causes of issues is a reason for celebrating team success to keep morale high (George, Rowlands, Price, & Maxey, 2005).

2.4. Improve Phase

The fourth step of DMAIC is the Improve phase. This phase involves fixing the problems identified in the Analyze Phase by "developing, selecting, and implementing the best solutions" (Brook, 2022). The key steps in this phase are generating potential solutions, selecting and prioritizing solutions, applying LSS best practices, performing risk assessments, piloting the solutions, and completing the Improve phase review (George, Rowlands, Price, & Maxey, 2005). Practical tools such as the Solution Priority Matrix and the Pugh Matrix can be employed to evaluate and select the most effective solutions based on defined criteria. The Solution Priority Matrix helps rank potential solutions by weighing impact against the effort required to implement them. At the same time, the Pugh Matrix allows for a structured comparison of multiple options against a baseline using specific evaluation criteria. (George, Rowlands, Price, & Maxey, 2005). Additional tools for generating potential solutions include the SCAMPER technique, chain letters, and billboards. These methods support creative thinking and collaborative brainstorming during the solution development phase. Some common pitfalls to avoid in this phase are choosing a sub-optimal solution and underestimating the impact of changes (The Improve Phase of DMAIC Process: Making Change that Lasts, n.d.). Additionally, when implementing changes in the Improve phase, it is essential to consider regulatory necessities with organizations like the Occupational Safety and Health Commission (OSHA) when implementing them on a full-scale level (George, Rowlands, Price, & Maxey, 2005).

2.5. Control Phase

The fifth step of the DMAIC process is the Control phase. This phase consists of "putting controls into place to sustain the improvements over time and provide statistical evidence of sustainment" (Bicheno & Holweg, 2023). Additionally, this phase marks the handoff of the project to the process owner along with the implemented improvements (George, Rowlands, Price, & Maxey, 2005). The key steps in this phase are implementing ongoing solutions, standardizing solutions, quantifying the improvements, and closing the project (Brook, 2022). Valuable tools that can be implemented in this phase include Statistical Process Control (SPC) charts, which help monitor process stability and ensure sustained performance over time (Bicheno & Holweg, 2023) and testimonials/documentation showing buy-in from those in the organization who are employing the newfound changes of the DMAIC process (George, Rowlands, Price, & Maxey, 2005). It is necessary to create a realistic transition process involving meetings and follow-ups (George, Rowlands, Price, & Maxey, 2005). Ultimately, it is crucial to acknowledge that implementing change is inherently imperfect. Therefore, a dedicated response team must be assigned to address any problems or issues that arise (George, Rowlands, Price, & Maxey, 2005).

3. Methodology/Results

3.1. Define

The Define Phase of this LSS project identified a critical issue in the Hazmat Disposal Process at TYAD: an 11.24% inefficiency rate that led to a financial loss of $344,164.54 between July 2023 and June 2024. According to the literature, the Define Phase focuses on "identifying the issue, stating the problem clearly, and setting the foundation for the rest of the process" (DMAIC Step One, n.d.). TYAD's question for the team that drove our initial steps of the Define Phase was: "Given the financial and environmental costs of the current HDP, how can we reduce inefficiencies to minimize losses and improve sustainability by increasing accountability in HAZMAT ordering and receiving?" Given this prompt, the team began by grounding this project in findings from the literature review, which emphasized that streamlining inventory and waste management processes leads to measurable improvements. Applying these principles at TYAD, the team set a specific objective: reduce HDP waste from 11.24% to 5.62%. This reduction would significantly impact cost savings and environmental responsibility across all cost centers. The team defined the project scope to maintain a focused and actionable approach. Scope-In is the term used to define and refer to all aspects of this project within our scope, encompassing all processes, from HAZMAT purchase through disposal, including inventory management, storage, and expiration tracking. Scope-out refers to the term used to define and refer to all aspects of this project that fall outside our scope, excluding unrelated activities such as general waste reduction and equipment orders. The team gathered and analyzed the Voice of the Customer (VOC) and Voice of the Business (VOB) to align with stakeholder expectations. In this project, our customers were the Cost Centers, and the business was TYAD. Customers requested improved HAZMAT availability, accurate reorder points, streamlined communication, and timely deliveries. In response, the team prioritized enhancements to communication and accountability measures. The team also conducted a Gemba Walk, which is "going to see the actual processes, asking probing questions, learning from those who do

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the work" (Bicheno & Holweg, 2023) at TYAD. The Gemba Walk helped us observe the HDP in real-time and create a detailed Process Map. These observations revealed several key inefficiencies, including overordering, excessive storage, and broken communication loops. These findings directly informed the strategies developed for the Measure and Analyze phases.

3.2. Measure

During the Measure Phase of this LSS project, the team collected and analyzed data to understand the current state of the HDP at TYAD. The TYAD team assigned to our project reviewed the process map developed during the Define Phase. The TYAD team provided valuable insights and suggestions for refinement. This collaborative approach ensured that the process map accurately represented the workflow and potential problem areas, setting a strong foundation for data collection and analysis. The team gathered data from multiple cost centers and the Hazmat Ordering Cell. The MiniTab software transformed the data into the baseline statistics that drove the rest of the DMAIC process. The team utilized a Pareto Chart, revealing that Sealant (26.8%), Paint (11.0%), and Adhesive (9.1%) were the top contributors to wasted HAZMAT, collectively accounting for 46.9% of total waste costs. Figure 1 demonstrates that between October 2022 and October 2024, TYAD purchased $6.8 million worth of HAZMAT materials. In the same period, $5 million worth of HAZMAT was withdrawn from storage by cost centers for use, and $1.1 million in HAZMAT expired. This insight guided the team's focus on these materials for targeted improvements. Additionally, a Material Purchased vs. Material Wasted chart highlighted discrepancies in inventory movement, revealing opportunities for improving inventory management and reducing waste, as seen in Figure 1. The team developed a comprehensive Data Collection Plan to ensure accurate and consistent data gathering throughout the project. Key performance measures included the HAZMAT Dollar Wasted Amount, Physical Amount of HAZMAT Wasted, Material Wasted Ratio, and Transferred Date vs. Expiration Date of HAZMAT. Data was collected using existing reports from LMP, HMIDS, and Tobyhanna systems and stratified by different types of HAZMAT to provide detailed insights into waste patterns. This systematic approach enabled the team to quantify waste and identify key areas for improvement, paving the way for a focused analysis in the subsequent Analyze Phase.

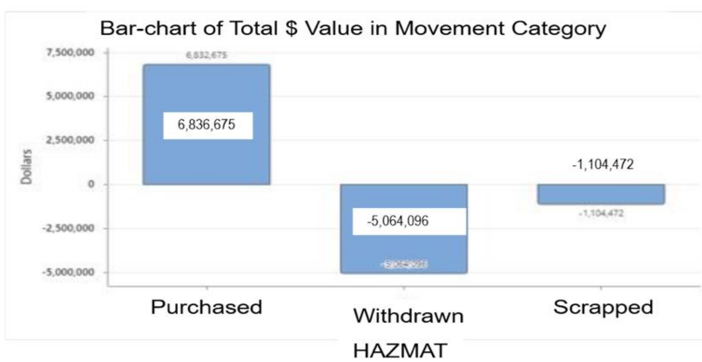

Figure 1. Purchased, Withdrawn, Scrapped HAZMAT

3.3. Analyze

In the Analyze phase, the team aimed to solidify the root causes of the significant inefficiencies impacting the Hazmat Disposal Process (HDP) at Tobyhanna Army Depot. Our methodology combined quantitative data analysis with stakeholder feedback to refine the project scope and ensure alignment with operational needs. The team analyzed data revealing that shops and cost centers waste hazmat drawn from the warehouse. The team conducted a Swim Lane Process Map to visualize responsibilities across cost centers and identify inefficiencies. At the same time, a Customer-Value-Added/Non-Value-Added/Required Non-Value-Added (CVA/NVA/ NVA-R) analysis helped validate the previous waste findings. Material waste data showed that adhesives and sealants contributed most to overall losses, narrowing our focus. We applied Cause & Effect (Ishikawa) diagrams, 5 Whys analysis, and statistical tools such as Failure Modes and Effects Analysis (FMEA). Our findings revealed that poor historical ordering practices, inconsistent enforcement of regulations, and poor First-In-First-Out FIFO adherence led to excessive expiration and disposal of hazardous materials. Additionally, the team determined that forecasting gaps and variations in HAZMAT demand contributed to some inefficiencies in HAZMAT usage. These insights laid a data-driven foundation for the Improve phase, where the team will design targeted interventions to optimize ordering, enhance compliance, and reduce material waste.

3.4. Improve

After identifying the key areas of concern during the Analyze phase, the Improve phase began with a joint brainstorming session with Tobyhanna subject matter experts to devise potential solutions to the identified issues. The project team presented these solutions to TYAD stakeholders, which were ranked on a scale from low to high importance. The key theme identified in the ensuing discussions was a lack of communication between concerned parties, as members of different teams across the depot often had no concept of how their counterparts measured, ordered, or utilized HAZMAT. The ideal solution fosters conversation around HAZMAT ordering, allowing teams to identify, discuss, and address issues on a case-by-case basis. The best-identified solution to accomplish this proposes the creation of a Power BI dashboard, seen in Figure 2, that identifies key indicators of HAZMAT usage. These indicators include past and present snapshots of material expired or nearing expiration, total stock, the cost associated with that material, lead times, and procurement methods. The dashboard mockup includes utilization rate, a measure of HAZMAT used by a shop divided by the amount drawn, order efficiency, and the amount of HAZMAT used out of a given order. This dashboard allows filtering by shop, material, and date range while highlighting key areas of concern, such as the top wasted HAZMAT. In practice, this dashboard serves as a point of reference for members of the ordering team, the engineering team, the Defense Logistics Agency (DLA), and the cost center leadership. Incorrect reorder points or irresponsible material management become quickly apparent and easily digestible, creating a point of conversation at monthly HAZMAT review meetings at TYAD. The end goal is that the dashboard will be consistently checked and reviewed for potential inconsistencies that will further employees' understanding of issues and their response to them.

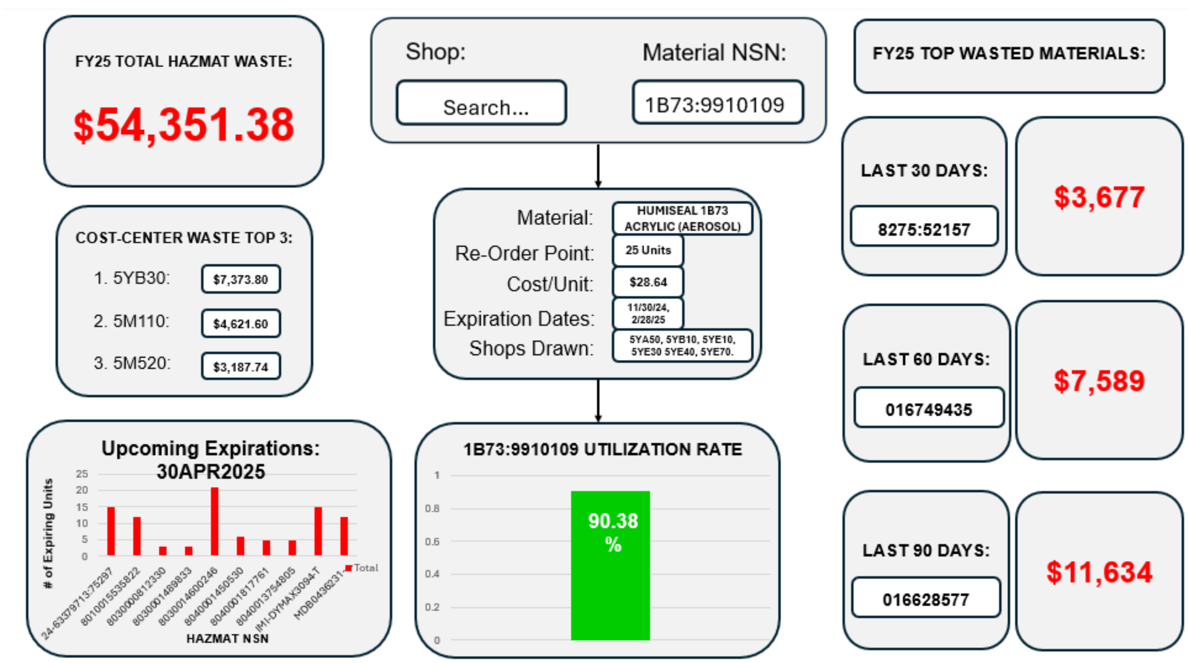

Figure 2: Power BI Dashboard Sample

4. Conclusion

4.1. Summary

This Lean Six Sigma capstone project applied the DMAIC methodology to reduce wasted HAZMAT at Tobyhanna Army Depot TYAD. In the Define Phase, the team identified a significant inefficiency rate of 11.24% in the Hazmat Disposal Process, costing over $344,000 annually. Through stakeholder engagement, on-site assessments, and process mapping, the team established a clear problem statement and project scope. The Measure Phase involved extensive data collection and statistical analysis, revealing that a small subset of materials—particularly sealants, paints, and adhesives—accounted for nearly half of the total waste. In the Analyze Phase, the team identified root causes such as inconsistent ordering practices, poor communication, and limited visibility into inventory usage. The Improve Phase proposed a Power BI dashboard as a centralized, data-driven solution to enhance transparency, accountability, and coordination among key stakeholders. Looking

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ahead, the Control Phase will play a crucial role in institutionalizing these improvements. The team will implement standard operating procedures for TYAD personnel. These actions will ensure the sustainability of the project's gains and support TYAD's ongoing efforts to enhance operational efficiency.

4.2. Future Work

Future work at Tobyhanna primarily consists of the control phase. Executing a quality control phase allows for HAZMAT efficiencies to continue well after the LSS team transitions the project to the new owners. With the future implementation of a control phase, the Tobyhanna team will be able to recognize the projected financial benefits for years to come. Additionally, implementing the control phase will ensure that possible problems in the future regarding HAZMAT will have courses of action to mitigate these problems, including what to do and who to contact if the PowerBI system experiences issues. To ensure the control phase is long-lasting, the LSS team will provide the Tobyhanna Depot with an updated charter, the project storyboard, the control plan, and other work completed during the phase. The LSS team's completion of these deliverables will require final approval from the master black belt assisting us with the project, the project sponsor, and the resource manager. To transition the process to the new process owner, the team must educate the instrumental players at the Tobyhanna depot about how the process works. This in-depth training will involve the process improvement specialists, the chief project lead for material distribution, the equipment and supply branch chief, the general supply specialist, and the material handler for the Defense Logistics Agency. In addition, it will be necessary to educate the Tobyhanna pharmacy, shop workers, and engineers to bridge the communication gap so that the process runs smoothly without significant intervention to mitigate issues. All members at the Tobyhanna Army Depot who use the PowerBI system must be active in monitoring potential problems and taking the necessary actions based on the control plan to maintain success in the long term. Finally, pending our team's success, it is crucial to recognize the members of the LSS team and the supporting cast at Tobyhanna for their contributions to the project with acknowledgments/awards for their dedicated efforts to improving the Tobyhanna Army Depot and their stewardship of the LSS process.

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