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Tobyhanna Army Depot Lean Six Sigma Project

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Abstract: Lean Six Sigma (LSS) is a reputable and respected methodology used to manage processes and encourage constant improvement. Lean Six Sigma combines the elements of Lean, which aims to identify and reduce process waste, and Six Sigma, which aims to reduce process variation, to create the conditions for continuous process improvement. The primary methodology used in LSS is the define, measure, analyze, improve, and control (DMAIC) methodology. The DMAIC methodology helps to solve problems by working through a logical process that ensures an understanding of the issue. This paper summarizes our year-long project using LSS at Tobyhanna Army Depot in the 5M210 Cost Center, a workshop in the component preparation branch that prepares items for painting. Our team worked through the DMAIC process to reduce waste and process variation.

Keywords: Lean Six Sigma, Process Improvement, Tobyhanna Army Depot

1. Define

The define phase involves building a high-level outline of the project, defining the problem, setting the boundaries, and analyzing the customer's needs through tools such as a SIPOC (Supplier, Input, Process, Output, Customer) diagram and customer translation matrix. An integral part of this phase is the development of the project charter, which is a combined document with the problem statement, goal statement, core team, and the scope of the project (Go Lean Six Sigma, 2021). Proper identification of the problem statement and goal statement are critical during the define phase, as a misinterpretation of stakeholder specifications or the goal of the process improvement may lead to a solution which does not solve the problem. Therefore, it is paramount to utilize tools such as a SIPOC diagram, voice of the customer/business, and the business impact to develop a correct goal and problem statement.

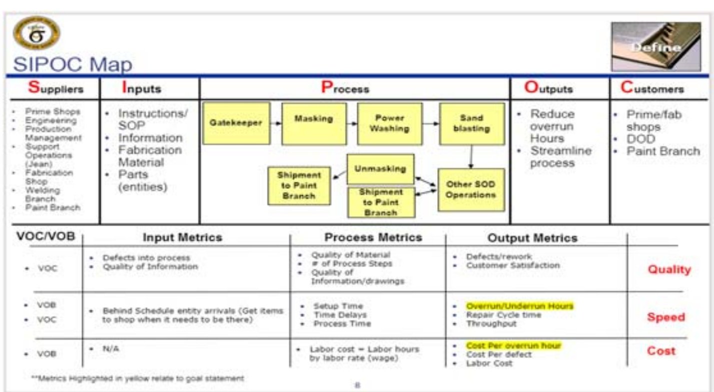

Figure 1. SIPOC Diagram

Our project team began the define phase by receiving the problem statement and goal statement from the Tobyhanna team. While the lean six sigma team usually develops these statements for their clients, Tobyhanna has a robust team of process improvement specialists who were able to state exactly what they wanted from our team's improvements. The problem statement is as follows:

> *The TYAD Component Preparation Branch is currently overrunning 128 hours per month, and the trend has remained consistent since Dec 21. Initial data collected from JAN 22- AUG 22 shows work centers MASK02, SDBLAST02, SDBLST03 and UNMASK01 as the main contributors to the current overrun hours.*

Deconstructed, the problem statement states that the component preparation branch at Tobyhanna currently experiences an average of approximately 128 overrun hours (spending more time on a component than the allotted standard time) per month, which shows that their process for component preparation is operating at a less than optimal level. According to Tobyhanna, the work centers, or stages in the component preparation process, that are the main contributors to overrun hours are tape masking (MASK02), small item sandblasting (SDBLAST02), large item sandblasting (SDBLST03), and tape unmasking (UNMASK01). The provided problem statement provided a good starting point for the project team as it significantly reduced the risk of misidentifying the needs of the Tobyhanna team. Tobyhanna also provided a goal statement which gave our team a target to work towards. The Tobyhanna team identified a 50% reduction in overrun hours as the goal. This means reducing the overrun hours from 128 hours per month to 64 hours by the April 30th of 2023. This goal would free up 768 hours a year for other work and would produce a faster and more effective process for component preparation. It would also save the depot $221,779 over the span of three years when accounting for saved labor hours.

2. Measure

This phase encompasses gathering data on the process to accurately gauge how effective the current process is. The first, and most critical step is to map the process (Brook, 2017). In doing this, we tailor our data analysis to the work centers that are in our scope to include Mask, Sandblasting, Unmask and SOD Shipment. The mapping of the process also provides an opportunity to designate which elements of the process add value and which do not. Our team employed a swim lane diagram to match each work center with a given swim lane containing all activities within that work center. Additionally, we highlighted each activity by color denoting the type of value they add to the process. Green denotes the activity adds value to the process, red indicates the activity is nonvalue added, and Orange indicates nonvalue add required (mainly inspections). The only value added to the process in each work center is the actions required to complete the task. For example, within the masking work center, placing tape on the Product Orders (masking the item) is the only task that adds value within this swim lane and is therefore highlighted in green.

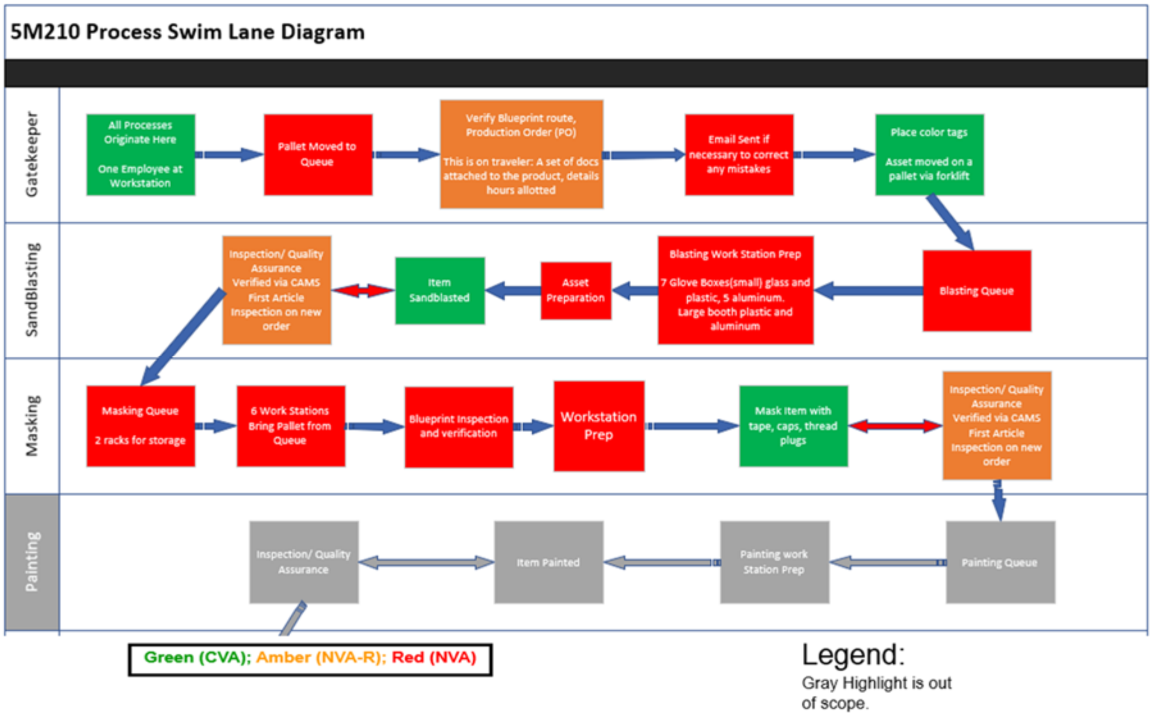

Figure 2. Swim Lane Diagram for Mapping Process Steps

In addition to process mapping, pareto charts are another useful tool in analyzing defects by work center. By utilizing this tool, one can identify problem areas within the process. Work centers that contribute most to the total overrun hours are Mask and Unmask. At 54.8%, they contribute to over half of all overrun hours. The pareto chart, seen in Figure 2, is a visual representation of the overrun hours by work center. In short, the measure phase helps to identify certain trends and patterns we see within the data taken from the process. This data is further broken down in the analyze phase to identify definitive problem areas. This information will help our team concentrate on these areas and find potential solutions.

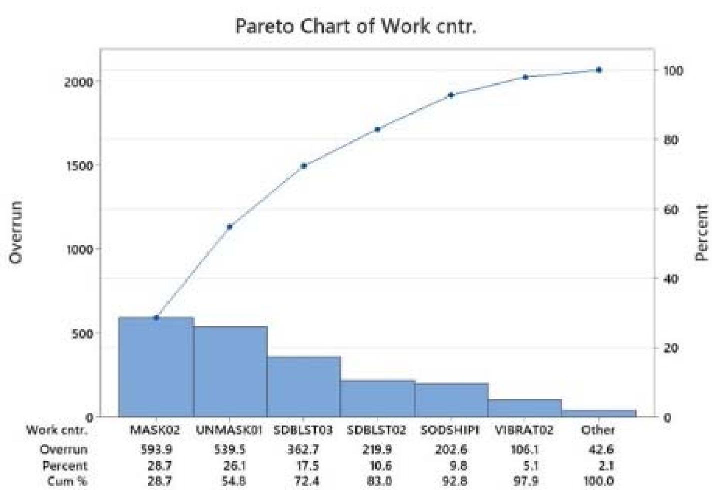

Figure 3. Pareto Chart Analyzing Overrun Hours by Work Center.

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3. Analyze

The analyze phase acts as a point of reflection on the process; a point where the data gathered in the measure phase takes on meaning for the project. The analyze phase, at its crux, is identifying issues and their root causes. The skill of identifying root causes is not specific to any one type of process. Instead, it is a "generic skill that can be applied to nearly any type of problem" (Okes, 2009). It is also important to note that failure is always present in a process. It is impossible to eliminate all sources of failure. Instead, it is the team's responsibility to reduce the likelihood and severity of these failures as much as possible (Stamatis, 2015). The analyze phase is expected to use brainstorming, Failure Modes Effect Analysis (FMEA), cause-and-effect diagrams, and other tools to generate theories. The team can then narrow down the theories by using "brainstorming, selection, and prioritization techniques" (George, et al. 2005, p. 12).

The ideas specifically espoused in FMEA are essential for many stages of the DMAIC process, but especially for the Analyze phase. FMEA identifies potential modes of failure, estimates the risk, and identifies the actions that the project team can take to reduce the risk of failure. The project team can use these ideas anytime they implement a new improvement. This can be a quick win as described in the measure phase, or a full implementation as described in the improve phase. Regardless of the tool, a quantification of the severity, occurrence, and likelihood of detection of the failures of a process, typically represented as the Risk Priority Number (RPN), allows for an objective and quantifiable understanding of the process. The project team can then use these methods to prioritize the process steps that are most likely to fail and to subsequently fix these steps. The FMEA shown in Figure **3** identifies the areas of most concern. Some of the process steps that contribute the most to overrun hours as identified by the FMEA are traveler issues, workstation ergonomics, and a disconnect between workshops.

Step #	Process Map - Activity	Key Process Input	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended
	UNMASK01	Unmasking Queue	Extended time in queue	RCT Overrun	7	Limited capacity and amount of workers	6	Labels	2	84	Queue relies on other parts of the process more than its own. Coordinate with paint branch to increase open stations when high numbers of orders are coming from paint
	SODSHIP1	SOD Shipment Queue	Extended time in Queue, waiting for forklift	RCT Overrun	8	Limited capacity and amount of workers	9	Labeled queue and computer aided system	5	360	Queue relies on other parts of the process more than its own. Coordinate with following branch and forklift operator
	SDBLST02/SDBLST03	Blasting Queue	Extended Time in Queue	RCT Overrun	7	Limited capacity and amount of workers	6	Labels	2	84	Queue relies on performance of blasting operation. Inefficiencies in process will create a longer queue. Adjust worker hours and open stations depending on work flow
		Blasting Workstation Prep	Blueprint Issues	Overrun Hours	5	Size of material or inefficient layout	9	None/eye test	6	270	SOP for setting up work station (Product dependent)
		Blasting Asset Prep	Asset Defects	Overrun Hours	8	Rusty material	6	None/eye test	6	288	Product quality inspection by gatekeeper
	MASK02	Masking Queue	Extended Time in Queue	RCT Overrun	7	Limited capacity and amount of workers	4	Labels	2	56	Queue relies on other parts of the process more than its own. Coordinate throughput with blasting
		Masking Workstation Prep	Getting supplies	Overrun Hours	6	Supplies in closet away from desk	6	None/Eye Test	6	216	Have supplies readily available at work
		Transfer Product to Workstation	Extended time due to product size	RCT Overrun	5	Inability to move heavy products/ availability of pallet jack	5	Eye Test	4	100	Decrease occurrences by increasing pallet jack availability
		Blueprint Inspection and Verification	Failure to have attached blueprint	Overrun Hours	9	Missing information/ incorrect information	8	Color coded packet label	6	432	Have checks to make sure blueprints placed on product. Gatekeeper check before sending into work stations

Figure 4. Process FMEA

In our specific iteration of the analyze phase, our team incorporated many of the elements expressed above. We created a cause-and-effect diagram and subsequent matrix, pareto charts, and data visualizations while using stakeholder input to conduct a root cause analysis. The cause-and-effect diagram proved to be the baseline of all work completed in the analyze phase. With the input of the stakeholders at Tobyhanna Army Depot, we identified three main causes of the overrun hours in the process – issues with traveler information, worker training/experience, and artisan workspace and ergonomics.

Outputs	PO Quality	Cycle Time	Workstation Time	Cost of PO		
Importance of each output to the customer	3	9	9	3		
Inputs (X Variables)					Weighted Value by Input	% of Net Effect by Input
Movement to Queue	1	9	1	3	102	16.0%
Pallet Verification	9	3	1	1	66	10.4%
Workstation Preparation	3	9	9	3	180	28.3%
Workstation Work	9	9	9	9	216	34.0%
Quality Control Inspection	9	3	1	3	72	11.3%
Weighted effect on each output	93	297	189	57		

KEY:
1 = Least Correlated
3 = Moderately Correlated
9 = Highly Correlated

= Focus Areas

Figure 5. Cause-and-effect Matrix for Correlation Between Inputs and Outputs of the Process.

To supplement the cause-and-effect diagram, our team also created a cause-and-effect matrix as shown in Figure 5**.** This matrix helped the team to identify the importance of each input and how it relates the values of the output to the customer. This matrix, when combined with the cause-and-effect diagram, solidified the root causes. These products identified the workstation work itself and workstation preparation as the focus points for future improvements. These findings complement the conclusions in the FMEA and the cause-and-effect diagram. Workstation work includes the same ergonomics and worker training identified in the C&E diagram while both workstation preparation and workstation work includes the traveler and its effects as well as the engineer-artisan disconnect identified in the FMEA. This overlap in identification supports the findings in all the tools and highlights the areas needing special attention moving into the Improve phase.

The stakeholders then provided input to quantify the importance of each root cause. The team asked questions of how important each root cause is to leadership, what the cost of the root cause is, and how much of an effect each root cause has on time. Each question was ranked on a scale of one to five, with one being the least impactful and five being the most impactful. The higher the score the more prioritized the root cause. The result of this process found that issues with the traveler were the most prioritized followed by the artisan workspace, with worker training/experience coming third. Our group decided to decompose worker training/experience into a shorter time horizon to allow for the time constraints of the project. In the end we grouped worker experience with the engineer-artisan disconnect to address both issues within a shorter time frame.

4. Improve

The improve phase in a LSS project is the culmination of the first three phases tying in the goals of the owner with the analysis conducted. This involves developing alternatives that will best solve the problem identified in the define phase. One aspect to revisit is the project scope as to not design alternatives that breach the established boundaries. It is easy to formulate ideas that are outside the scope of the project and follow down a path that overshadows the initial project goals, which makes it imperative to consistently refer to the project charter to ensure the initial conditions are being satisfied.

Throughout the project and during our visits to Tobyhanna Army Depot, potential improvement ideas occurred naturally as we identified areas of contention. We conducted one final brainstorming session, throwing sticky notes onto a whiteboard in a freeform style event. Following the brainstorming session, we grouped the alternatives by which critical X they were most associated with affecting and then identified the time horizon in terms of a short term (1-2 weeks), medium term (1-2 months) and long term (6+ months) that each alternative best corresponded with based on the amount of time it would take to implement and the number of resources required. From there, we ranked the alternatives within their respective critical X groups by the most likely to achieve the goals and commenced the evaluation.

The tools we used for evaluating the alternatives were an Evaluation Criteria Weighted Matrix from *What is Six Sigma* and a Failure Modes Effects Analysis (FMEA) for the failure points of each solution. In the Evaluation Criteria Matrix, the criteria we identified with the help of our stakeholders from most important to marginally important were "reduce overrun hours, adhered to rules and regulations, worker satisfaction, cheap implementation, sustainability, time to implement." Each one of these criteria was given a score of 1-10 based on how important it was to the stakeholder and then each alternative with given another score of either a 1, 3, or 9 based on how much it met the requirements of each criterion. We chose 1, 3, or 9 because it would give a greater distinction between the weighted scores and made us seriously consider how each alternative

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met the criteria. The team then multiplied the alternative score number by the corresponding value of the criteria it met and then summed with the rest for the solution to identify a value score for each. We finally ranked these value scores from highest to lowest, revealing which alternatives would provide the most benefit to the 5M210 center.

We then created another FMEA, separate from our previous one that only considered the alternatives and their potential failure modes, but the same in functionality. In this new FMEA, we only considered the top two alternatives from the Evaluation Matrix from each critical X category. This allowed us to narrow the selection to solutions that would best achieve the goals. The FMEA allowed us to evaluate the different possibilities of how each alternative could fail to achieve the goals. We then generated the RPN by multiplying the severity, occurrence, and likelihood of detection for each alternative and moved on to decision making.

To determine which alternatives to recommend, we then created the table in Figure 4 displaying the solutions and their associated values, risk, and implementation horizon. This allowed us to conduct a cost-benefit analysis to weigh the value of the solution with how risky it would be that the solution failed. Our RPNs came out relatively low and therefore did not weigh into the decision as much as the value of each solution did.

Solutions	Weighted Value	RPN	Implementation Time Horizon
Protect Traveler	432	12	Short Term
Artisan-Engineer Sync	372	40	Short Term
Quick Dirt Wipe Off Before Paint	308	12	Short Term
Improved Station Ergonomics	372	30	Medium Term
Formalized on Board Training	324	48	Medium Term
Training on Most Common Offenders	316	100	Medium Term
QR Codes/RFID/Tech Insert	548	48	Long Term

Figure 6. Benefit vs Risk Table

From Figure 6 we recommended "Protect Traveler, Artisan-Engineer Sync, Improved Station Ergonomics, and QR Codes/RFID/Tech Insert." Our "Protect Traveler" solution involves placing the production order travelers within a waterproof folder or container that will be passed around with the production order. This is in conjunction to an SOP emphasizing the importance of keeping the traveler in-tact. In terms of cost, this is minimal as lamination sheets sell for cents and could be reused once a production order has finished its path within the work center. Our "Artisan-Engineer Sync" involves establishing a weekly or bi-weekly meeting between the artisans who perform the work and the engineers who assign the work so they can share issues with specifications and refine the instructions within the traveler. This option has effectively zero associated cost because it does not cost any resources except an average of a few minutes from the employees each day. Our "Improve Station Ergonomics" solution involves introducing rolling stools, pallet jacks and moving the materials to each workstation so the artisans can work straight off the pallet in a more comfortable manner than they already do. The average price for a rolling mechanics stool is $20-$40 and the average price of a pallet jack table is $1000-$3000. Realistically, only 2-3 of these tables would fit in the shop and only about 6-10 rolling stools would need to be purchased thus costing the 5M210 cost center around $9500 to fully implement these changes. The final solution we recommended is the "QR Codes/RFID/Tech Insert" which involves providing iPads at each workstation so the artisans can download digital blueprints that they can see real time updates on, in color, and scale it to a size they can read. This solution also involves placing an RFID tracker on each PO so that they can be tracked throughout the shop and found easily while recording more accurate touch time and cycle time. While the QR code would cost next to nothing since it would just be a piece of paper, a new base model iPad costs an average of $250, and the shop would need around 15 of these to properly outfit each artisan with one. On top of the cost to buy the iPads they would also have to install internet and hire a software developer to write a program for the digital travelers. This could cost anywhere from $30-$70 per hour and could take hundreds of hours to develop. Considering these factors the iPad/Tech insert alternative would cost Tobyhanna upwards of $20,000 to implement. The solutions identified above were the best mix of value, risk, and implementation horizon that achieved the project goals.

5. Control

The control phase of the DMAIC process ensures that improvements made during the previous planning and design phases continue throughout the life cycle of the process. This phase includes a review of the project from the beginning of the process versus after the project team makes the improvements. At the end of the control phase, the project team should be able to hand off an improved process to the process owner with procedures for maintaining the gains (George & Rowlands, 2017). The main objective of the control phase is to measure the improved process and validate if the changes helped with the issue. Deliverables during the control phase include a documented plan to transition the improved process back to the process owner, before and after data on process metrics, operational training, a system for monitoring the implemented solution and completed project documentation. A vital part of the control phase is the control plan, which is a method for documenting and implementing the functional elements of quality control.

After suggesting our solutions, the project team created a survey that asked the workers of the 5M210 cost center how satisfied and how helpful the changes were in lowering overrun hours. The feedback the team received emphasized the need to use the stools in conjunction with the raised pallet jack tables to decrease touch time and thus overrun hours. We also received preliminary data from our pilot plan that showed a six hour decrease in overrun hours per month. While this is below the goals outlined in our project charter, the team only implemented a pilot plan and are awaiting the opportunity to move to a full-scale implementation. The project team anticipates writing revised SOPs after Tobyhanna is ready to implement the full solutions. To transition the process to Tobyhanna, the project team created a Responsibility Assignment Matrix (RACI) as well as process control tools to ensure a successful continuation of the project after the LSS team leaves. Both Tobyhanna and the project team anticipate significant improvements to the process as the solutions are added to the process.

6. Conclusion

The components of Lean Six Sigma used by the project team provide just one example of the efficacy of the LSS methodology in process improvement. Future work would do well to use the same steps expressed in the DMAIC strategy to improve other processes. Although the Tobyhanna 5M210 work center already runs at a high level of efficiency, LSS methodologies brought the best out of the work center and further improved an already impressive process. This shows the fundamental lesson of LSS – process improvement is continuous and should never stop, no matter how good a process may be.

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