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# Improve End Item Delivery Impacting Frozen Performance to Promise Metric

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**Abstract:** Tobyhanna Army Depot (TYAD) underperformed in the Frozen Process to Performance (FP2P) metric. The LSS team focused on issues with parts (procurement process), command scheduling (MD04/Command Schedule), and bill of materials (BOM) to improve this metric. The Lean Six Sigma (LSS) methodology guided the team's approach, combining Lean's waste reduction and Six Sigma's process variation reduction. The DMAIC process (Define, Measure, Analyze, Improve, Control) served as the teams problem-solving framework. TYAD's goal was to increase FP2P from 78% to 80% by April 2023. Using a SIPOC, process map, Fishbone, and FMEA, the LSS team gained an understanding of the root causes of the issue. After statistical analysis, the team scoped down to parts issues. A pilot solution led to a standardized process that a Logistic Management Specialist (LMS) could use to proactively identify parts issues. The pilot solution demonstrated coincided with over 80% FP2P for three months in a row.

*Keywords:* Lean Six Sigma (LSS), DMAIC Process, Frozen P2P (FP2P)

## 1. Introduction

Lean Six Sigma (LSS) is a systematic approach striving to reduce waste and decrease variation in processes. LSS is driven by stakeholders vested in the system or organization. Lean involves identifying and reducing bottlenecks to increase the speed and efficiency of the process, whereas Six Sigma strives to decrease the variability of a process by delivering products and services the same way every time (Brook, 2023). One of the structured problem-solving methodologies used by Green Belts and Black Belts is the DMAIC process (George, Rowlands, Price, & Maxey, 2005). The DMAIC process is broken down into five phases: Define, Measure, Analyze, Improve, and Control. These phases help one understand the problem and implement practices that companies can use to ensure the solutions stay effective (George, Rowlands, Price, & Maxey, 2005). The team utilized the DMAIC process with TYAD. This process typically takes between 1- 4 months and ensures every team member helps work on all five phases (George, Rowlands, Price, & Maxey, 2005). The authors will provide an overview of how LSS is used at TYAD to achieve the teams' goal of elevating the FP2P at TYAD from 78% to 80% by April 2023.

## 2. Literature Review

The purpose of the define phase is to come to an agreement with the project sponsor on the financial and performance targets, goals, and scope of the project (George, Rowlands, Price, & Maxey, 2005). The define phase consists of refining the initial project charter, SIPOC diagram, process map, understanding the voice of the customer/ business, conducting a duplication review, and establishing a communication plan with the team. Process mapping is a graphical representation of the entire process flowing from one step or activity to another (Mohamed & Usmen, 2015). Due to the customer-driven nature of LSS methodology, translating the voice of the customer (VOC) into a cost, quality, or time metric is essential in the define phase. The VOC is important for understanding the customer's needs, wants, and desires. The voice of the business (VOB) is important for understanding where the business is feeling "pain," and the goals the business seeks to implement in the project (Sheikh, 2019). A common way to gain the VOB is to interview and meet with the employees, the team, and leadership within the company. These key deliverables must be completed to receive formal permission to move on to the measure phase.

The purpose of the measure phase is to understand the current state of the process and collect reliable data on process speed, quality, and costs that may be used to detect the problems underlying causes (George, Rowlands, Price, & Maxey, 2005). Data collection is one of the main components within the measure phase. Measurement system analysis (MSA) is the best practice in determining the accuracy, precision, and stability of a data collection system. One tool to help facilitate this analysis is a Gauge R&R, which looks at reproducibility between operators, and repeatability of measurements by the same operator. Once the data collection processes have been validated, the next step involved a baseline analysis of data to depict the "pain" in the process, or those areas that are most costly to time, quality, and money. This step relies heavily on statistical analysis to depict the "pain" in the process and central tendencies within the data.

The analyze phase is an important phase where the "project heads and organizational directors need to select the critical issues for further improvements" (Singh, Rathi, Antony, & Garza-Reyes, 2023, p. Abstract). The Analyze phase uses a Fishbone Diagram and Failure Modes Effects Analysis to analyze the data collected in the measure phase. A Fishbone Diagram uses the 5Ms and 1P: Material, Method, Machine, Measures, Mother Nature, and People to compile a list of potential causes to the identified root problem (Pande, Neuman, & Cavanagh, 2000). After a Fishbone Diagram is created, the next step is to create a statistical experimentation or scoring method, known as a FMEA, where the riskier causes are singled out (de Mast & Lokkerbol, 2012). The "purpose of FMEA is to prioritize the failure modes of the product or system in order to assign the limited resources to the most serious risk items" (Liu, Liu, & Liu, 2013, p. 829). This method uses brainstorming to identify all possible potential failure modes of the product/system (Liu, Liu, & Liu, 2013). Then, critical analysis is conducted on the failure modes for the three risk factors of occurrence (O), severity (S) and detection (D) (Liu, Liu, & Liu, 2013).

During the improve phase, various tools and methodologies are utilized to identify possible solution concepts, prioritize which solutions would bring the greatest benefit to the client, and implement the overall best solution. It is important to encourage creativity while brainstorming improvements, with tools like an affinity diagram, where each possible solution is typically written on a sticky note and posted on a board. The sticky notes are then moved and grouped with solutions that contain a common theme or characteristic (George, Rowlands, Price, & Maxey, 2005) Affinity diagrams, according to Uluskan, are a popular qualitative tool as teams look to refine to ideas generated during their brainstorming sessions (Uluskan, 2016). A useful technique used to establish who is responsible, accountable, consulted, and informed regarding completing an activity or task is a RACI Chart (Smith & Erwin, 2005). Another technique that can be used is Poka-Yoke, which can be defined as "a device which could prevent the occurrence of abnormality during the execution of the process and also a device which could protect the health and safety of the workers" (Vinod, Devadasan, Sunil, & Thilak, 2014, p. 318). Largely equated with inspections, Poka-Yoke can look unique across different industries but the concept of catching deficiencies and eliminating them prior to them reaching the customer remains the same. It is critically important to remember that all the solutions need to be focused on addressing the root cause of the problem as was discovered and confirmed in the define, measure, and analyze phase. Failure to pursue a solution that works to solve the identified problem goes against Lean principles.

After proper risk analysis, the solution is prepared to be implemented on a pilot scale. This pilot solution will allow the team to collect some initial data to assess performance prior to the change being rolled out full scale. This pilot plan is critical as its performance ultimately determines whether the problem identified, measured, and analyzed can be solved with the conceived plan (Hetrick, McDonald, Park, Zimmerman, & Razon, 2021). The data window for the pilot program will match that collected during the measure phrase to ensure an accurate image of the effects is captured. This prevents any improvements from being portrayed as more or less effective than they are. Significant positive effects on the process demonstrated in the pilot solution prepares the solution for a full-scale implementation. Once the solution is implemented, the project is prepared to move into the control phase to ensure the solution is adopted by the project sponsor and monitored to ensure the system remains in control and does not rebound to old practices.

The control Phase of the DMAIC process is crucial for showcasing Lean Six Sigma improvements, both quantitatively and qualitatively. This phase answers critical questions about meeting customer requirements and the effectiveness of the improvements on quality, defect rates, cost, speed, efficiency, and other key process metrics (Deinlein, 2015). It ensures the transfer of findings and improvements to the project sponsor for sustained success (George, Rowlands, Price, & Maxey, 2005). The establishment of Standard Operating Procedures (SOPs), a Training Plan, Error-Proofing, Failure Modes and Effects Analysis (FMEA), Statistical Process Control (SPC), PUGH analysis, and a data collection plan solidify this phase and allow for the prediction of future process failures, ensuring ongoing improvement and system governance (Al-Aomar, Williams, & Ulgen, 2015). Specific SOPs ensure consistent performance and quality through uniform work procedures (Nakagawa, 2004). Training plans with process maps and instructions ensure adherence to SOPs, enhancing process efficiency and quality (PV & Hessing, 2014). Furthermore, Control Charts and Statistical Process Controls play a pivotal role in monitoring process performance, identifying special cause variation, and enabling timely corrective actions (George, Rowlands, Price, & Maxey, 2005). Effective communication strategies ensure timely dissemination of project-related data and information (Ahmed et al., 2020). In essence, the Control Phase serves as the crucial bridge consolidating prior DMAIC stages, confirming both customer satisfaction and process metrics, and laying the groundwork for sustained excellence (Nakagawa, 2004). The emphasis in the control phase should be focused on transitioning responsibility of the solution to the project owner for a full-scale implementation.

## 3. Methodology

The initial problem statement was "from October 2022 to April 2023, the Tobyhanna Army Depot frozen P2P (FP2P) averaged 78%, indicating missing end item delivery within the month of execution" (McKeefery, Brundage, & Enos, 2024). The original goal of this project was to improve FP2P from 78% to 85% missing end item deliveries by April 2023. Using a SIPOC map, the LSS team developed a high-level understanding of how FP2P was collected. The team quickly identified that the problem had many nuances of complexity and would require an iterative approach to demonstrate improvement. This made the DMAIC philosophy perfectly applicable as it provided a framework for a full analysis of the problem at hand and a data-driven approach to possible solutions.

First, the team had to fully comprehend what exactly went into the FP2P metric. Three conditions that needed to be confirmed for a project to be included in the overall FP2P metric was that 1) a WBS needed to be in place, 2) the item had to be inducted, and 3) the promise for that project had to be in that month. Within the execution month, the project is either completed as promised (met) or it is not (not met). If the item is subject to not meeting its promised agreement, the Logistics Management Specialist (LMS) must complete a schedule change in the Logistic Management Program (LMP) that classifies the defect under one of the eight possible "reason codes." When these command schedule changes happen within the month of execution, the FP2P is negatively impacted. If a command schedule change is submitted and approved prior to the month of execution, it is still considered a P2P slip, however it does not negatively impact the FP2P metric. With a better understanding of the scope of this problem and the many operational definitions outlined, the LSS team worked to define time, quality, and cost goals for the project. The team worked to understand the number of on-time parts per production order, amount of backorder parts per production order, and when items planned delivery time was not met as these were determined to be critical to quality (CTQ) metrics. The team sought data to better understand which of the 8 reason codes were connected to each slip that did not meet the planned delivery time.

After multiple conversations and a site visit down to the depot, the LSS team developed the process map displayed in Figure 1, which visually depicted all the steps involved with schedule changes and the collection of the FP2P metric. The process is started the month prior to execution when the directorate management analyst sends the projected program schedule for the upcoming month to the LMS team. The process ends on the last calendar day of the execution month. This is when FP2P can be calculated based on how many projects were completed as promised.

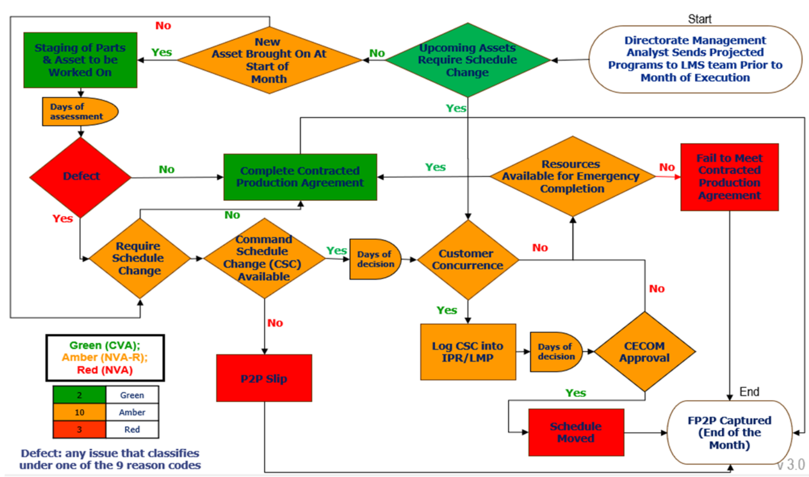


Figure 1: FP2P Process Map

While on the site visit, the LSS team interacted with the TYAD team, various LMS's, and floor workers to understand the VOC and VOB. The customers of TYAD wanted accurate predictions of project completion dates. The team explained this issue stemmed from poor scheduling, inaccurate promises during contracting, and poor accountability to contract promises. For VOB, the team gathered that TYAD wanted to improve the number of assets completed on time. This situation arises when employees are not proactive in ordering parts, or the quality of the parts are not sufficient once received. Additionally, TYAD wanted to reduce unmet potential regarding profit because TYAD experienced variation in predicted cash flow. Lastly, TYAD wanted to reduce the overhead from unmet contracts. The main issue preventing TYAD from meeting this goal stemmed from purchasing parts that could not be used, or the warranty expiring before the part was used.

With a clearly defined problem, the LSS team moved to the measure phase. Following the introduction of an updated project charter, the team analyzed the business impact of the project. The team determined that the FP2P slips were resulting in $1.2 million of missed potential revenue generation. This analysis demonstrated that when projects were held back and not delivered, the time that was reallocated to finish those projects was waste. A slipped project represented resources that could have been allocated to starting new projects, but instead were focused on finishing existing projects thus demonstrating an inefficient use of resources.

In the data collection plan, the team identified that they wanted to collect data on the total program count for each month, a breakdown of the P2P slip categorizations for each month, the reason codes and narratives submitted for each slip, and the overall FP2P metric reported at the end of each month. The team analyzed the reason codes for the slipped projects utilizing Pareto charts, displayed in Figure 2, to identify the key defects that were leading to unmet contracts. Following the Pareto principle, the team analyzed the reason codes that were causing eighty percent of the problem. These reason codes included: 1) Customer Managed Parts Outside OIB Control 2) Requirements Changes 3) Lack of Assets 4) No Reason Code; Tobyhanna Issue. That final defect accounts for those that cannot be accounted for with a reason code in LMP. The Pareto chart to the right in Figure 2 provided a more in-depth breakdown of those eleven defects. Nine were attributed to production issues within the depot and two were attributed to process issues within the depot. The key takeaway from these charts was that parts issues were resulting in the greatest number of P2P slips. This served as valuable information as the team moved into the Analyze phase and was the start of team being scoped into parts issues as the root cause of the identified problem.

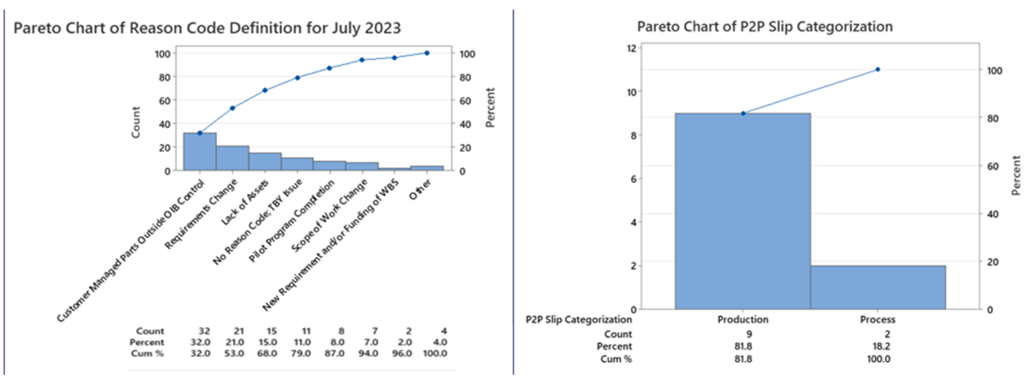


Figure 2: Pareto chart of the reason codes for P2P slips in July 2023 (left). Detailed breakdown of the P2P slips with no reason code due to issues internal to Tobyhanna (right).

During the analyze phase, the team created a Fishbone and FMEA diagram with the TYAD team. The purpose of the Fishbone Diagram was to help brainstorm possible root causes of a problem. In this case, the team used a multi-vote technique to generate possible results for the root causes of P2P slips. Using a multi-vote technique, the team had the LMSs rank their top three root causes with a red, yellow, and green sticker representing a weighted vote depending on the color, as indicated. The red sticker indicated the most critical while yellow was second most and green third. From there, the team was able to count the points of each root cause and identify the top three causes generated from the Fishbone Diagram. This included lack of pre-production planning, unplanned material requirements, and bad data/no BOM reviews. Supported by the data from the measure phase and the root causes identified by the Tobyhanna team, the project was scoped down to look solely at parts issues. With a more refined scope, the goal statement for the project was modified and the LMS team was now working towards improving the FP2P metric from a monthly average of 78% to 80%. After identifying the top three root causes from the Fishbone diagram, the team built a FMEA diagram as depicted in Figure 3. The purpose of the FMEA diagram was to take actions to eliminate or reduce failures, starting with the highest-priority ones. Here, the team used the top three root causes identified in the Fishbone diagram to act as the potential failure modes and then used seven process steps identified in the process map as the baseline for the diagram. The team used a question-analysis technique to walk through the diagram and assess the severity (S), occurrence (O), and detectability (D) score for each failure mode. The team took the product of those scores to calculate the RPN ($S \times O \times D = RPN$). The failure modes with the highest RPN identified those that needed to be mitigated most.

Table 1: FMEA chart providing deeper analysis and prioritization of the most prominent root causes as identified in the Fishbone diagram.

| Process Step / Input | Potential Failure Mode | Potential Failure Effects | SEVERITY | Potential Causes | OCCURRENCE | Current Controls | DETECTION / Effect | RPN |
|---|---|---|---|---|---|---|---|---|
| What is the process step and Input under investigation? | In what ways does the Key Input go wrong? | What is the impact on the Key Output Variables (Customer Requirements)? | | What causes the Key Input to go wrong? | | What are the existing controls and procedures (inspection and test) that prevent either the cause or the Failure Mode? | | |
| **Projected programs sent to LMS team prior to month of execution** | **Unplanned material** | **Bad Data, overrun programs** | **7** | **Lack of pre-production planning** | **9** | **Tobyhanna Regulation 750-38 Tobyhanna Army Depot Project Management Handbook** | **9** | **567** |
| **New asset brought in start of month** | **Lack of Pre-Production Planning. Change in customer requirements** | **Slipped P2P. Bad data** | **8** | **Lack of communication** | **8** | **Unwritten business practice** | **5** | **320** |
| **Staging of parts and assets to be worked on** | **Competing requirements (putting one requirement before another)** | **Bottleneck constraint. Bad Data** | **9** | **Lack of communication on priority projects. Capacity constraints of shops.** | **6** | **Capacity Planning "provide guidance" / Electronic production control board (ePCB)** | **5** | **270** |

The team then conducted analysis on how many projects were “met” versus “not met” for each individual LMS. Each LMS was given a random name to ensure individual people were not blamed while still allowing the team to identify potential outliers and additional stratification factors to analyze. The team also analyzed the reason codes for P2P slips for each LMS which displayed general trends in issues experienced through different areas of the depot.

The team worked to generate potential solutions that addressed the issues identified during the Analyze phase exercises. The solutions needed to be centered around increasing the detectability of parts issues across the different projects as well as increasing a shared understanding of the actions required for different parts issues. The FMEA identified that the highest priority of effort should be placed in the failure modes of pre-production planning and communication. For those two failure modes, the detectability and severity scores of those failure modes was quite high. When speaking with the LMS team, it became clear that the term of “parts issues” was far too broad. The team then categorize the different types of parts issues that could occur into 11 buckets. The team then utilized a RACI chart and, for each parts issue, identified who in the depot was responsible for detecting that parts issue, who was accountable for the detection of the issue, who needs to be consulted when the issue is found, and who needs to be informed of the parts issue and the actions taken to remediate it. With each parts issue, the team also identified possible tools utilized to detect it. This RACI chart was designed to provide shared understanding across multiple echelons at the depot so parts issues could be better communicated and addressed.

The tool of greatest value was the supply sensitivity analysis (SSA) dashboard developed with the Material Planning Division (MPD). This tool allowed the LMS team to quickly see a breakdown of their parts status for upcoming projects. Specifically, this tool allowed LMSs to clearly see what parts were at less than 60 days of supply and what parts had a terminal AAC code (Y or V). Rather than sifting through multiple programs and spreadsheets, the SSA Power BI dashboard centralized them into a single location and increased efficiency. This tool increased the detectability of parts issues in the failure mode of pre-production planning. Once detected, the LMS could refer to the RACI chart for proactive planning solutions.

For the pilot solution, the team trained up three LMSs on the use of the tools discussed above. The LMSs selected were those of projects that were upcoming on the March 2024 command schedule and had experienced issues in the past. The systems were SMART-T, STT, Sea Sparrow, and Installation & EQ (Kitting). The team led a virtual training at the beginning of February on the use of the RACI chart, the SSA, and the Microsoft Form used to collect data regarding command schedule changes submitted using the various tools. At the end of the month, the team met with the LMSs to collect feedback on the tools that could be incorporated as the team looked to roll the solutions out on a larger level. During this time, the team also completed the left side of the FMEA, reassessing the severity, occurrence, and detection levels of the failure modes identified through the Fishbone exercise, but this time with the tools from the pilot solution in mind. For the issue of parts issues stemming from unplanned material, the SSA and RACI chart reduced the risk priority number from 567 to 189, thanks largely due to the increased detection these tools provide. For the issue of lack of pre-production planning, the risk priority number was reduced from 320 to 240, largely caused by a decrease in severity of the issue due to the tools implemented.

The pilot solution proved useful to not only improve the tools the team created, but also provided valuable repetitions at how to effectively train individuals on the tools so they could be utilized to the greatest potential. Since the FP2P metric is taken at a monthly interval and the initial training with the pilot solution LMS team took longer than expected, the team replicated the pilot solution for the month of March, looking at the command schedule for April. Utilizing the SSA and RACI chart, the LMS team of the above projects identified 5 parts issues for the projects on the April command schedule. Because these parts issues were detected prior to the month of execution, the CSCs for these projects were prevented from negatively impacting the FP2P for the month of April. With 445 projects on the April command schedule, the five CSCs represent 1% of projects that will not be measured as negatively impacting FP2P. This small impact demonstrated promising success within the pilot solution that led the team to look towards implementing the solution at a larger scale in the Control phase. On the larger scale, the increased emphasis to parts issues and FP2P resulted in the depot performing at a 89% FP2P for the month of February.

The control plan starts with ensuring the long-term viability of the pilot solution, the LSS team will define SOPs regarding preproduction planning and LMS's use of the SSA. These SOPs will be incorporated into LMS and Controller training at the depot to establish a base level of competence with the SSA implemented to detect parts issues. The SOPs will also create a shared schedule among LMSs across the depot to align pre-production meetings with command schedule change windows to ensure that FP2P is being prioritized by LMSs when reviewing the progress of their programs. All depot LMSs will be trained on the finalized SOPs. The control plan starts in the RACI chart developed in the previous phase. All members of a program team have been assigned individuals who will report specific parts issues, streamlining and mandating communication. This will serve as a monitoring program for individuals at different levels of the program. Controlling the schedule, responses to parts issues, and training on new interfaces will ensure the project sponsor can monitor process metrics and sustain excellence.

## 4. Conclusion & Future Work

In conclusion, the LSS team used the DMAIC process to identify and breakdown FP2P. The DMAIC process proved to be extremely effective in addressing the voice of the customers, the voice of the business, and the stakeholders needs. Tools such as the SIPOC, Fishbone diagram, FMEA, and Process Map led to a deeper understanding of the FP2P metric. Further understanding the metric allowed the team to scope the problem into strictly parts issues. After creating a pilot solution and implementing it with a select number of LMS personnel, the team was able to effectively reduce the risk of missed end item deliveries. The pilot solution led to a FP2P rate over the goal of 80% for three straight months. Future work will include establishing SOPs, training plans, and implementation of the RACI chart depot wide will further enhance the effect of the pilot solution on TYAD. Streamlining and mandating communication between the different entities interconnected at the depot will also measure the process is monitored and excellence is sustained.

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