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Applying Lean Six Sigma to Improve Serialized Inventory Defense Logistics

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Abstract: Serialized materiel sustainment operations in defense logistics environments present unique challenges due to strict accountability requirements, variable demand patterns, and complex storage configurations. These conditions increase handling complexity and make warehouse performance more sensitive to inefficient layout, poor inventory placement, and excess movement. This study applied the Lean Six Sigma (LSS) Define-Measure-Analyze-Improve-Control (DMAIC) framework to evaluate a serialized materiel staging process within a defense warehouse and develop practical improvement strategies. Through time studies, process mapping, and root cause analysis, excess movement and inconsistent inventory placement were identified as the primary contributors to delay. The team then screened improvement concepts using a weighted decision matrix, resulting in strategies centered on designated storage locations, standardized organization, and demand-informed pre-staging. The project shows how structured process improvement methods can be adapted to high-accountability logistics environments to improve flow, reduce delays, and support more consistent warehouse performance.

Keywords: Lean Six Sigma (LSS), DMAIC, Defense Logistics, Serialized Inventory Management

1. Introduction

This project was conducted in partnership with government defense contractors responsible for managing serialized equipment in a secure warehouse. Unlike commercial distribution warehouses designed for high-volume and repetitive picking, defense sustainment warehouses operate in a low-volume, high-mix environment where each item must be individually tracked and accounted for. These serialized accountability requirements limit storage flexibility, increase handling complexity, and make warehouse performance more sensitive to inefficient movement and poor inventory placement. As a result, unnecessary travel, disorganized storage, and variable staging practices can increase cycle time and reduce operational responsiveness.

To address these challenges, the team applied the LSS DMAIC framework. Lean focuses on improving flow and reducing waste, while Six Sigma focuses on understanding variation and identifying root causes of poor performance. Together, these methods provide a structured approach to evaluating complex operational systems and developing measurable improvements (George et. al, 2005). In this project, the team used time studies, process mapping, and root cause analysis to evaluate the serialized staging workflow and develop improvement strategies to reduce movement, improve inventory placement, and increase consistency in warehouse throughput.

2. Literature Review

LSS is a process improvement approach that focuses on reducing waste, variation, and unnecessary work within a system. One of the most common frameworks used within LSS is DMAIC, which stands for Define, Measure, Analyze, Improve, and Control. The structure of DMAIC helps teams work through problems step by step and rely on data rather than assumptions when making decisions (Brook, 2024). In defense logistics environments, these structured improvement methods have been used to increase throughput, shorten lead times, and make processes more consistent across organizations (Hardy, 2018). Some case studies show that even small operational changes can produce large results. For example, process improvements at Red River Army Depot increased vehicle recapitalization output from three vehicles per week to thirty-two per day after bottlenecks in the workflow were addressed (Apte & Kang, 2007). While every environment is different, examples like this show that structured improvement methods can still have a large impact on complex military logistics systems.

Research on warehouse operations also points to several common causes of inefficiency. Many studies show that workers often spend significant time searching for items, traveling between storage locations, or dealing with poorly organized inventory. These types of issues increase cycle time and reduce overall warehouse performance (Adeodu et al., 2023). Lean-based warehouse studies have shown that improvements usually come from increasing item visibility, reducing unnecessary travel, and organizing materials to make them easier to find and retrieve. In one case study, improving work sequencing and reducing search behavior reduced non-value-added work by over seventy percent (Adeodu et al., 2023). Other studies have found that improving inventory traceability and visibility can dramatically reduce cycle time in warehouse operations (Rungruengkultorn & Boonsiri, 2022). Overall, the literature suggests that warehouse delays are often less about individual worker performance and more about how materials and information flow through the system.

Serialized inventory environments pose additional challenges beyond standard warehouse operations because each item must be tracked and documented. This requirement adds extra handling steps and makes it harder to organize inventory flexibly. Several studies note that delays frequently occur when workers must search through bulk storage areas to locate specific serial numbers, especially when system-selected inventory is buried or difficult to access (Rungruengkultorn & Boonsiri, 2022). Research on serialized inventory systems also suggests that improving item visibility, organizing storage areas more clearly, and creating designated staging locations can reduce search time and improve process consistency (Adeodu et al., 2023). These issues closely resemble the challenges observed in the warehouse staging process, where workers must locate specific ballistic plates from large mixed-inventory cages before staging can begin. Because this workflow involves multiple teams and several sequential steps, the literature supports using the DMAIC framework as a structured way to analyze delays and develop improvements in serialized logistics systems.

3. Define Phase

The Define phase establishes the problem context, project scope, and performance objectives that guide the remainder of the DMAIC process. In LSS, this phase ensures that improvement work begins with a clear understanding of the problem, stakeholders, and measurable outcomes before data collection begins (George et al., 2005; Maleyeff, 2012). For this project, the Define phase began before the formal capstone kickoff when one team member completed a three-week internship at a defense logistics warehouse responsible for serialized materiel sustainment. This early exposure allowed the team to observe warehouse operations, understand how serialized items moved through the facility, and build working relationships with personnel responsible for the workflow. These observations revealed significant variability in how workers identified, located, and staged serialized requirements before entering the warehouse pull process. When the academic year began, these insights informed the team's initial scoping discussions.

During the early weeks of the project, the team applied foundational LSS tools to develop a shared understanding of the serialized workflow. The team used stakeholder interviews, Gemba walks, spaghetti diagrams, process maps, and value stream mapping to trace how requisitions moved from requirement identification through final staging prior to warehouse pulling, as displayed in Figure 1. These tools are commonly used in the Define phase to clarify process boundaries and identify stakeholders before deeper analysis begins (Gutiérrez et al., 2016). Early discussions revealed that the originally proposed project scope lacked sufficient boundaries to support a full DMAIC analysis. Through continued engagement with warehouse leadership and operational personnel, the team refined the scope to focus specifically on serialized ballistic plate staging, which represented a high-variability portion of the workflow with measurable operational impact.

Initial problem scoping showed that the staging process required significant effort from both administrative personnel and warehouse operators. Program Support Specialists (PSS) spent approximately three hours each morning identifying serialized requirements and coordinating staging activities, while warehouse personnel spent nineteen labor hours per week locating and moving plates from bulk storage to staging areas. These activities frequently produced staging lead times of two to three days before requisitions or orders could be released for pulling, reducing warehouse flexibility during high-demand periods. Based on these observations, the project goal was defined as reducing serialized staging lead time by at least 25 percent, with an aspirational target of 50 percent reduction, while also reducing the administrative effort required for requirement identification.

Clear scope boundaries were established to maintain analytical focus within a complex operational environment. The project scope begins when serialized requirements are identified within a requisition and ends when the required items are staged and ready for warehouse pulling. Downstream activities such as pre-shipping, shipping, and inspection workflows were excluded because they occur after staging or operating on independent schedules. The team developed a high-level Supplier-Input-Process-Output-Customer (SIPOC) diagram to clarify suppliers, inputs, process steps, outputs, and customers within the workflow. Voice of the Customer discussions with warehouse personnel emphasized the need for faster and more predictable staging timelines, while Voice of the Business discussions with leadership highlighted the importance of maintaining throughput and serialized accountability. The Define phase concluded with the development of a project charter and the recognition that existing warehouse systems lacked reliable timestamp data for serialized item movement. As a result, the team developed manual time-study methods to support measurement and analysis.

One key takeaway from the Define phase was the importance of investing time early to clearly understand the operational environment before locking in the project scope. Initial assumptions about the problem did not fully capture where delays were occurring, and early observations showed that the original project definition would not support a meaningful DMAIC analysis. Conducting stakeholder interviews, Gemba walks, and process mapping helped the team identify where variation and inefficiencies were concentrated, allowing the project to be rescoped to a more impactful portion of the workflow. Another important lesson was that tools such as SIPOC diagrams and value stream maps should be treated as working documents rather than one-time deliverables. The team repeatedly returned to these tools throughout the project to refine its understanding of the process and validate assumptions with stakeholders. Finally, early discussions about potential data collection revealed limitations in the warehouse's information systems, which did not capture the level of process detail needed for analysis. Recognizing this during the Define phase allowed the team to begin developing manual time-study approaches before the Measure phase began. For future LSS teams, the Define phase should focus not only on writing a project charter but also on validating scope, confirming data availability, and building a shared understanding of the process with stakeholders before proceeding to deeper analysis.

4. Measure Phase

The purpose of the Measure phase in the DMAIC process is to develop a clear and reliable understanding of the current state of the process. This phase focuses on collecting data describing how the system currently performs, so problems can be analyzed with evidence rather than assumptions. According to George et al. (2005), the Measure phase is used to collect reliable data on process speed, quality, and cost to identify the underlying causes of inefficiencies. The goal is to establish a factual performance baseline to support the Analyze phase. Typical deliverables include baseline metrics, process capability measurements, and updates to the project charter as understanding of the system improves.

After the Define phase established an initial understanding of the serialized staging workflow, available data sources within the warehouse system were evaluated. However, discussions with stakeholders and process mapping revealed a major limitation. The existing inventory system did not consistently record timestamps across the full serialized workflow. While some transactions were captured, the system could not reliably track item movement between process steps. This made it difficult to quantify staging lead time, measure variation across requisitions, or evaluate how specific activities contributed to delays. To address this gap, manual time studies were developed to capture end-to-end process data.

Five time studies were created to capture the major steps of the workflow: PSS Requisition, Serialized Item Processing, Movement, Picklist, and Pre-Shipping. Each study recorded start and end times for specific activities, allowing total processing time and variation between steps to be measured (See Figure 2). The format of each study was standardized so that datasets could be combined during analysis. Instructions were developed to ensure consistency in data collection, with the goal of making the studies usable even for personnel unfamiliar with the project. Data was collected across multiple requisitions to capture variability in workload, item type, and processing conditions.

Data collection was also impacted by external constraints. A temporary government shutdown delayed communication and slowed the return of completed time studies. Additionally, all data required review before release to ensure no sensitive information was included, which extended the timeline for the Measure phase. To improve dataset reliability, time study collection continued beyond the formal tollgate to increase sample size and better represent actual process performance.

One key takeaway from the Measure phase was the importance of designing the measurement system before large-scale data collection begins. Small details, such as identifying the data collector, can significantly impact the ability to validate results later. Another takeaway was that in secure or regulated environments, manual data collection may be necessary when existing systems do not capture the required level of detail. These lessons directly informed the dataset used in the Analyze phase and improved the team's ability to evaluate process performance.

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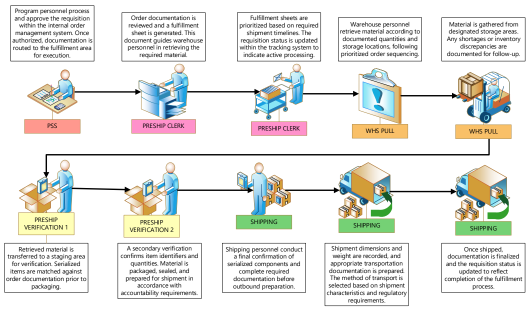

Figure 1: Value Stream Map

Serialized Item Ballistic Team Time Study

Time Frame: Start ____________ End ____________

Example: Time Frame: Start 10/13/2025 End 10/17/2025

Date	Start Picklist Time (24-hour clock)	Completed Picklist Time (24-hour clock)	# of Serialized Items in Picklist	# of Different Requisitions	# of different NSNs	# of Different SEG Codes	Pull Complete Time (24-hour clock)	Plates organized and staged in D-Bay (Ready for pre-staging) Time	Comments: Any worthwhile notes.
Example: 10/13/2025	0830	0930	25	6	8	3	1100	1330	*Picklist delayed because backordered _NSN and needed substitute*

Additional Comments:

Figure 2: Example Time Study

5. Analyze Phase

The Analyze phase focuses on identifying the root causes of inefficiencies using the data collected during the Measure phase. After establishing baseline performance, the goal is to determine which factors contribute most to delay and variation. Common outputs include identifying value-added and non-value-added work, linking process inputs to outputs, and isolating root causes of poor performance (George et al., 2005). In this project, time-study and demand data were used to determine where delays accumulated in the serialized staging workflow.

The first step in the analysis was to organize and clean the datasets collected during the Measure phase. Time study observations were consolidated into structured datasets to support analysis using LSS tools. Pareto analysis, cause-and-effect diagrams, stratification, and statistical evaluation in Minitab and R were used to identify patterns in the data. Pareto analysis was particularly useful because it allowed the team to focus on the small number of process steps that contributed to the majority of the total cycle time. Multiple units of analysis were evaluated, including requisition-, item-, shipment-, and NSN-level metrics. Based on data consistency and process flow, the analysis focused primarily on requisition-level and item-level measurements. This allowed the team to track how time accumulated across the full workflow rather than focusing on isolated tasks.

Figure 3 shows that Movement, PSS processing, and Organization were the largest contributors to total cycle time, accounting for approximately 88% of overall processing time. Movement involved travel between storage and staging locations, while Organization involved sorting and arranging serialized items upon retrieval. These results indicated that delays were driven primarily by physical movement and material handling rather than administrative or verification steps. After reviewing the results with stakeholders and referencing the project charter, the PSS processing step was determined to be outside the project's scope due to the limited ability to implement operational changes. As a result, the analysis focused on Movement and Organization, which were primarily performed by warehouse personnel and offered greater opportunity for improvement.

Further analysis confirmed that travel between storage locations and staging areas was the single largest contributor to delay; the team used an Ishikawa Fishbone Diagram to visualize root causes, such as layout inefficiencies, poor storage organization, and excessive movement, as the primary drivers of variation in cycle time (See Figure 4). Demand data was also analyzed over an 11-month period to identify patterns in requisition size and item characteristics. By comparing time per requisition and time per item, the team gained a better understanding of how workload variability affected total processing time.

During this phase, stakeholders also reported a significant operational error in which a bulk requisition was shipped without the required serialized items. Although the issue was relevant to overall warehouse performance, it occurred outside the defined project boundary. Based on the project charter, the event was excluded from analysis to prevent scope creep and maintain focus on the staging process.

One key takeaway from the Analyze phase was the importance of defining a clear key process output variable (KPOV). Early analysis of isolated task durations did not capture how delays accumulated across the system. By shifting to requisition-level analysis and examining variation across workload characteristics, a clearer picture of total process performance emerged. This approach allowed the team to identify movement and organization as the primary drivers of delay and provided a focused direction for improvement in the next phase.

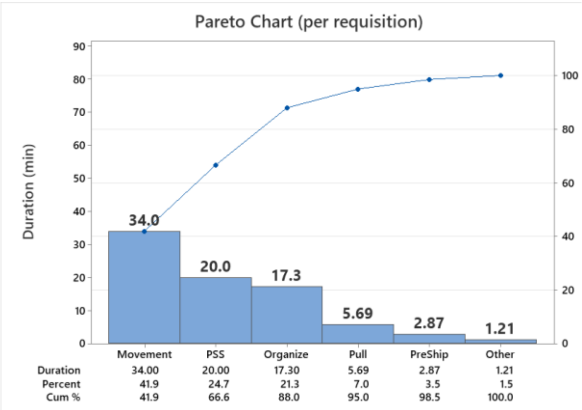

Figure 3: Pareto Chart Depicting Processing Time per Requisition

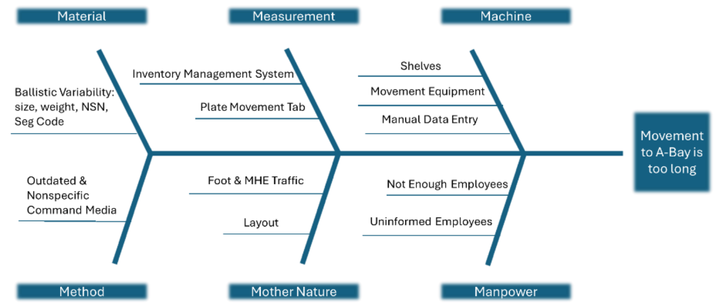

Figure 4: Ishikawa Fishbone Diagram Identifying Cause and Effects

6. Improve Phase

The Improve phase marks the transition from analysis to action in the DMAIC framework. The main steps in the Improve phase are to generate potential solutions, evaluate and select the best options, assess risks, and pilot implementation. Once ideas are generated, teams establish criteria to compare the solutions. When establishing criteria and evaluating solutions, it is important to involve stakeholders in the decision-making process to ensure the team does not miss any key perspectives. The solutions then go through a screening process to ensure they meet project requirements. Finally, pilot solutions are developed and tested to validate their effectiveness before full-scale implementation. These steps in the Improve phase are essential for narrowing down all solutions and selecting the optimal solution (Brook, 2024).

During the Improve phase, efforts focused on addressing the root causes identified in the Analyze phase by developing and evaluating potential solutions to reduce inefficiencies in the current warehouse process. Several concepts were generated that directly targeted the prioritized root causes. These solutions were then evaluated using a weighted decision matrix incorporating criteria for process duration, scalability, and implementation complexity. These criteria were defined, standardized, and weighted to ensure comparability across the solutions despite differences in units and impact. This structured approach allowed for objective ranking of alternatives and ensured that selected solutions targeted key inefficiencies, including excessive search time and unnecessary movement, while remaining feasible for stakeholder implementation.

Throughout this process, the team continuously referenced the project charter to ensure all improvement efforts remained within the project's scope. After ranking the solutions using the weighted decision matrix, meetings were conducted with key stakeholders to review the results and confirm alignment on the best improvement strategies. Through this communication and collaboration with stakeholders, several potential solutions were eliminated that did not directly support the project's goal statement or would have been difficult to implement given ongoing process changes and security protocols. A final set of solutions was selected that were both impactful and realistic for stakeholders to implement, including designated storage locations, standardized organization, and demand-informed pre-staging. Finally, pilot plans were developed to test these improvements within the warehouse, allowing for validation of the proposed solutions before full implementation.

The team also identified quick wins that could be implemented with minimal resources while still delivering immediate process improvements. The first quick win involved improving visual indicators for serialized storage locations by replacing the small labels with larger, brightly printed labels to increase visibility and reduce search time for serialized items. The second quick win addressed the warehouse's command media clarity by implementing a Gemba walk with operational personnel. This will allow each team to observe others' processes and gain a clearer understanding of roles and workflows across the operation.

The key takeaway from the Improve phase was the importance of early and continuous stakeholder engagement. Evaluation criteria were presented to ensure that the weighted decision matrix reflected what the stakeholders truly valued. While briefing the highest-ranked solutions, the team was able to gauge feasibility and alignment before investing time in implementation planning. This approach saved time and prevented the team from pursuing solutions that stakeholders would have found unrealistic to execute. Additionally, clearly defined pilot implementation plans are essential to ensure the pilot runs smoothly and produces meaningful data to evaluate the effectiveness of the improvements.

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7. Control Phase

The Control phase focuses on sustaining improvements and ensuring that implemented changes continue to produce the desired results over time. This phase includes ongoing measurement, standardization of successful solutions, and verification that project goals have been achieved (Brook, 2024).

At the time of writing, the team is preparing to transition into this phase by measuring performance after implementation of the proposed improvements. Key performance indicators (KPIs) include staging lead time and daily processing time, which will be tracked using the time-study methods developed during the Measure phase. These metrics directly align with the project goal of reducing staging lead time by at least 25%. Comparing pre- and post-implementation performance will allow the team and stakeholders to assess whether the improvements are producing meaningful reductions in cycle time.

If the improvements demonstrate consistent performance gains, the next step will be to standardize the process. This will include implementing visual controls, updating procedures, and providing operator training to ensure the improved workflow is followed consistently. Tools such as control plans and basic statistical process control (SPC) methods can be used to monitor performance and detect any regression over time.

One important consideration in this phase is ensuring stakeholder ownership of the improvements. Sustaining change in a warehouse environment depends on both management support and operator adoption. Clear communication, training, and visible process standards will be necessary to maintain the improvements after the project concludes.

Overall, the Control phase ensures that the improvements developed in this project are not temporary but become part of a stable, repeatable process. By linking performance metrics directly to the original project goals and establishing standard procedures, the warehouse can continue to benefit from reduced staging time and improved operational consistency.

8. Conclusion

This study demonstrated that LSS methods can be effectively applied in serialized defense logistics environments, where strict accountability requirements often limit flexibility. Through structured DMAIC analysis, movement and organization were identified as the primary drivers of delay, accounting for most of the staging time. The proposed improvements directly target these inefficiencies through improved storage organization, reduced travel distances, and pre-staging techniques informed by demand data. While full implementation results are still being evaluated, the project establishes a clear path toward achieving the target reduction in staging lead time and improving overall warehousing responsiveness. More broadly, this work highlights that even in constrained military logistics systems, process-level improvements can significantly enhance performance without requiring major technological changes or advances.

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