Optimizing Warehouse Operations Using the DMAIC Framework: A Case Study on the Implementation of 5S and FIFO in Industrial Logistics

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Abstract
The current competitive and sustainable logistics environment demands skilled warehouse management in the quest for operational flexibility, cost-effectiveness and environmental sustainability. This present study is a systematic improvement project aiming to optimize warehouse efficiency within an industrial setting through the DMAIC (Define, Measure, Analyse, Improve, Control) approach. The project included the application of lean thinking, specifically the 5S work organization system and FIFO (First-In, First-Out) inventory rotation strategy to minimize waste and improve operational effectiveness. The key issues found included suboptimal layout configuration, delayed fulfilment time, inventory discrepancies and the lack of standardized practice. Root cause analysis by means of tools like the 5 Whys and the Fishbone Diagram identified process-level gaps hindering performance. Improvement interventions entailed redesigning the layout of the warehouse conducting employee training, introducing standardized labelling and the implementation of Standard Operating Procedures (SOPs) all guided by precisely defined performance indicator. Outcomes from such interventions revealed noteworthy enhancements toward better utilization of space, stock accuracy and the elimination of non-value-added activities, each representing potential environmental benefits through improved efficiency of resources. The study concludes that integrating lean tools within the DMAIC framework offers a practical and effective pathway for warehouse transformation with broader implications for scalability and continuous improvement in industrial logistics.

Keywords: DMAIC; FIFO; 5S; Inventory Control; Warehouse Improvement.

1.0 Introduction
During the fast-evolving competitive logistics of today, efficient warehouse operations are critical for ensuring timely deliveries, accurate inventory control and overall supply chain responsiveness. Nonetheless, inefficiencies are widespread in numerous industrial warehouses owing to antiquated warehouse architecture, inadequate inventory management and the absence of codified systems. The facility under investigation in this study encounters multiple obstacles, including inconsistencies, order processing deficiencies, inefficient storage utilization and persistent safety threats (Tran et al., 2025). These operational bottlenecks have escalated cost, diminished service quality and compromised scalability.

Numerous studies have validated the effectiveness of Lean tools particularly 5S methodology and First-In, First-Out (FIFO) inventory system in addressing these inefficiencies. Rizkya et al. (2021) demonstrated that 5S significantly improves workplace organization, space utilization and inventory accuracy whereas Alamsah et al. (2025) confirmed that FIFO reduces product expiry and enhances traceability. Despite the success of such machines in other industries, there is no systematic utilization of this equipment in this warehouse (Rizkya et al., 2021).

To address this gap, this study adopts the define, measure, analyse, improve, and control (DMAIC) framework, a structured Six Sigma problem-solving methodology widely applied in logistics to reduce process variability and drive sustainable operational improvements (Saputra & Handayati, 2025). Adeodu et al. (2023) demonstrated the effective application of DMAIC for storage system optimization, reducing process variation and improving the major performance indicators such as picking rate and inventory turnover.

Furthermore, case studies by A. Mostafa and Essam (2024) highlight that integrating Lean tools within the DMAIC framework not only optimizes warehouse processes but also fosters a culture of continuous improvement. While much of the existing body of word centres on large-scale warehouses or very automated warehouses, very few are found to tackle mid-sized semi-manual warehouses. This study aims to fill that gap by applying DMAIC, 5S and FIFO in a medium-scale industrial warehouse to improve inventory accuracy, space utilization and operational responsiveness.

2.0 Methodology

The DMAIC framework was used as a structured, data-driven methodology to optimize warehouse operations through Lean tools such as 5S and FIFO system by Monday (2022). In the Define phase, a cross-functional team identified key challenges including inefficient layout, disorganized inventory and delayed order processing. Four primary goals were established: enhanced productivity, improve inventory turnover, maximizing use of space and slimfying processes in order to continually imrpove. In the Measure phase, process mapping, time-motion studies and visual walkthroughs were carried out to provide baseline information regarding on key performance indicators (KPIs) such as picking time, inventory accuracy and space utilization. This is consistent with existing studies positing that the selection methods account for over 50% of overall labour cost in warehouses as noted by Khan et al. (2023).

In the Analyse phase, Root Cause Analysis tools including 5 Whys and Fishbone Diagram identified inefficiencies stemming from the absence of SOPs, poor visual management and bad inventory rotation practices. These findings resulted in the improvement of staff training, redesign of layout, SKU labelling and color-coded zones in the Improve stage that resulted in measurable efficiency and traceability gains by Monday (2022). Finally, in the Control phase institutionalized enhancements through SOPs, KPI dashboards, auditing and visualizations to attain sustainability, evoking the best practices enshrined by Adeodu et al. (2023). This integration of Lean and DMAIC successfully transformed warehouse performance in a replicable and scalable manner by Mubarik et al. (2021).

3.0 Results and Discussion

This chapter presents the outcomes of the implementation of the DMAIC methodology with lean tools which are 5S and FIFO in the warehouse highlighting how each phase addressed key operational inefficiencies such as inventory discrepancies, delayed order processing and underutilized storage space supported by quantitative and qualitative data.

3.1 Define Phase

The Define phase laid the foundation for the warehouse improvement initiative by aligning stakeholders through a structured team meeting and clearly outlining the project scope based on the DMAIC framework, which has been widely adopted to effectively enhance warehouse performance (Monday, 2022). Responsibility, schedules, outputs and communication procedures were outlined to guarantee responsibility and effective coordination. A cross-functional representatives from warehouse, logistics and transportation departments was formed to provide diverse operating insights and drive collaborative solutions (Adeodu et al., 2023).

A validated problem statement was then developed to address persistent inefficiencies including disorganized inventory, suboptimal warehouse layout and frequent order fulfilment delays. In response, four strategic goals were formulated: to boost productivity through layout optimization, improve inventory flow via FIFO, enhance space utilization using 5S principles and to institutionalize standardized procedures for sustained continuous improvement. Recent studies affirm that Lean practices like 5S and visual management are highly effective in eliminating non-value-added tasks and improving process visibility (Rizkya et al., 2021), reinforcing the relevance of these goals in guiding subsequent project phases.

3.2 Measure Phase

In the Measure phase, a comprehensive diagnostic assessment was carried out to evaluate the current state of warehouse performance by focusing on the three core functional areas of warehouse operations: movement, storage and information transfer. Emphasis was placed on the order picking process, as it is widely recognized as the most labour-intensive activity accounting for approximately 50% to 55% of total operational labour costs (Khan et al., 2023). The observations from the visual studies and time-motion studies identified wasteful movement patterns, generated by poorly planned placement of stores and unclear stock positions as the source of substantial loss of picking efficiency. Key performance indicators (KPIs) like item search time, picking accuracy and storage utilization rates were studied to quantify such inefficiencies.

Based on these findings, measurable targets were set to (i) minimize item retrieval time by reconfiguring the warehouse layout, (ii) implement the FIFO system to reduce ageing inventory and improve stock rotation, (iii) enhance space utilization through decluttering and structured 5S activities, and (iv) cultivate a continuous improvement culture by providing targeted training on 5S and FIFO to all warehouse personnel. These measurement benchmarks established a clear baseline for evaluating the effectiveness of interventions in subsequent phases, aligning with recent literature that underscores the critical role of data-driven diagnosis in Lean-based warehouse transformation (Adeodu et al., 2023).

3.3 Analyse Phase

The Analyse phase was dedicated to the unravelling of the root causes of the inefficiencies witnessed within in the layout of the warehouse as well as the day-to-day functions. The step is very important as the introduction of corrective measures without solving the root problem often results in the reoccurrence of the issue. The team used the fishbone Diagram and the 5 Whys Analysis two most common Root Cause Analysis (RCA) tools to ensure an orderly and evidence-based review.

The 5 Whys technique was applied to examine the causes and effect chain driving warehouse inefficiency from the general question of why operations were being hampered. As the inquiry progressed, it was discovered that poor layout and disorganization stemmed from a lack of standardized processes, absence of visual management and limited awareness of lean practices such as 5S and FIFO (Harendsa and Pulansari, 2025). Ultimately, the fifth why revealed that the root issue was a lack of managerial prioritization and resistance to adopting systematic inventory and layout strategies. The detailed breakdown of this root cause analysis is illustrated in Table 1 which clearly maps the logical progression from surface-level symptoms to underlying systemic causes and proposed corrective actions.

Table 1: 5 Whys Analysis

Why	Questions	Answers	Correction Action
Why 1 (Occurrence)	Why are there inefficiencies and operational challenges in the warehouse facility?	The existing layout constraints affect stock, flow and productivity	Redesign layout using 5S and FIFO principles.
Why 2 (Occurrence)	Why do the existing layout constraints impact productivity, inventory management, and workflow efficient?	Previous layout lacked proper organization → mix-ups, delays, poor space use, safety risks.	Train staff on organization, 5S, and FIFO.
Why 3 (Occurrence)	Why did the previous layout lack Proper organization and result in inventory mix- ups, delays, inefficiency, and safety hazards?	Poor standardized procedures and visual management tools.	Create standardized procedures for utilizing space, order and stock.
Why 4 (Occurrence)	Why was there a lack of standardized processes and visual management practices in the current layout?	Management didn't prioritize systematic methods (like 5S).	Conduct regular audits & inspections to enforce 5S and FIFO.
Why 5 (Occurrence)	Why did the warehouse Management not prioritizing cleanliness, organization and systematic approaches like the 5S methodology?	Lack of awareness of benefits → resistance to change.	Promote employee engagement and a culture of improvement.

Based on the validation process as illustrated in Table 2, potential root causes were systematically evaluated across five categories: Man, Measurement, Material, Environment and Method (Kholil, 2024). The evaluation revealed that issues related to employee training, technological obsolescence, material quality and environmental disorganization were not the primary contributors to the observed inefficiencies. These factors were eliminated through extensive validation such as confirming the presence of adequate training, available equipment and functioning systems thus categorizing them as false causes. In contrast, within the Method category, poor planning and inadequate stock rotation procedures were validated as the actual cause. Specially, the lack of structed inventory movement and the absence of formalized processes contributed to frequent delays, stock aging and disorganized storage.

Table 2: Validation of Root Cause

Category	Potential Root Cause	Validation/ Investigation	Findings	Conclusion: True/False
Man	Insufficient training	Lack of onboarding and ongoing education.	This is not the root cause	False
Measurement	Outdated technology	Insufficient budget allocation for necessary tools.	This is not the root cause	False
Material	Lack of inventory control methods	Using substandard materials that cause rejections and production delays.	This is not the root cause	False
Environment	Disorganized workspace	Lack of regular maintenance and organization.	This is not the root cause	False
Method	Inefficient planning or scheduling	Absence of proper stock rotation practices.	Optimizing warehouse layout with 5S and FIFO enhance efficiency and lowering inventory losses.	True

Hence, certain improvements were focused on reconfiguring the warehouse layout, implementing the FIFO system and applying 5S principles. These enhancements directly address the verified root cause improving inventory control, cutting waste and increasing overall operational effectiveness.

3.4 Improve Phase

The Improve phase focused on performing specific interventions drawn from the root causes discovered during the analysis stage. As indicated in figure 1, the improvement process began with structured training sessions for warehouse personnel, emphasizing the practical application of 5S principles and the FIFO inventory rotation systems. Proper usage of inventory monitoring system and record-keeping tools was also covered in training to promote traceability and accountability.

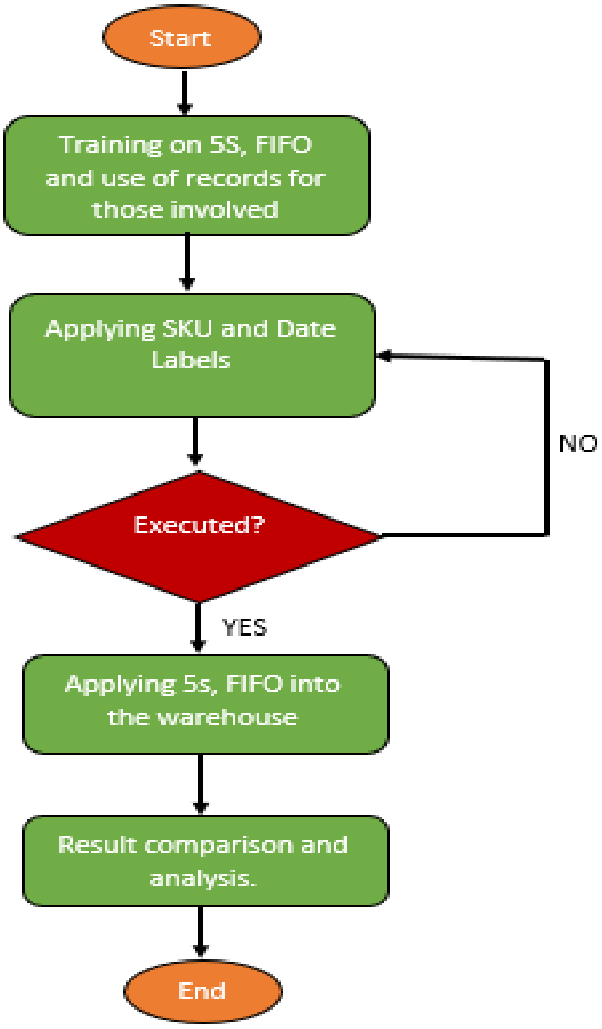

Figure 1: Flow Chart for implementation of model proposed.

Following the training, all inventory items were systematically labelled with SKU (Stock Keeping Unit) codes and expiration dates to facilitated product traceability and effective stock rotation. A decision checkpoint was established to verify full implementation of labelling and staff training before progressing to operational changes. Upon confirmation 5S and FIFO strategies were incorporated into daily warehouse practices, emphasizing well-ordered storage areas, visual signage and orderly stock movement. Afterward, an appraisal of performance was made by comparing pre- and post-intervention data to monitor the decline/increase in stock accuracy, utilization of storage space and overall process performance.

To support these interventions, visual management tools were introduced throughout the warehouse. Figure 2 shows the implementation of FIFO and date labelling, where each inventory tray is tagged with date-coded labels to ensure proper stock rotation. Figure 3 further displays the FIFO colour coding scheme, which gives visual indications for detecting inventory age and movement priority.

Figure 2: FIFO and Date Labelling

Figure 3: FIFO Colour Coding

Additionally, product separators, as seen in Figure 4 were employed to distinguish between different product types and prevent cross-mixing. The combined application of 5S and FIFO principles is shown in Figure 5 illustrating a well-organized shelf layout with clearly labelled and colour-coded inventory. These visual tools significantly enhanced staff visibility, reduced retrieval time and promoted compliance to standard procedures, thereby supporting the overall improvement initiative.

Figure 4: Product Separator

Figure 5: 5S and FIFO Implement

Comparative analysis of the pre- and post-implementation phases of the 5S and FIFO initiatives revealed notable operational improvements. Initially, the warehouse was experiencing of following issues amid disorganized, poor utilization of space and poor control inventories. The issues led to the lengthy duration taken to retrieve items, excessive stock holdings and the risk of product spoilage. After the implementation of 5S and FIFO practices, the warehouse showed remarkable transformation with inventory organization with items now systematically sorted, labelled and stored for easier access and more efficient stock handling. Space utilization was optimized through decluttering and strategic layout adjustments while the FIFO system ensured that older stock was prioritized, minimizing waste and improving stock freshness. Additionally, inventory control strengthened through enhanced visibility, accurate record-keeping and standardized stock rotation practices. These changes in work also fostered a safer work environment, with clearer pathways, cleaner spaces and reduced hazards, efficient and sustainable warehouse system.

3.5 Control Phase

In the Control phase, organized measures were made to implement long-term sustainability of improvements introduced during the warehouse optimization initiative. This began with the formulation of Standard Operating Procedures (SOPs) covering essential warehouse activities such as product labelling, receiving operations, inventory placement and safety compliance thereby providing a standardized framework to ensure consistent execution across all shifts (Clemente-Pecho et al., 2023; Khan et al., 2023). To institutionalize these practices, structured training programs were conducted at regular intervals to equip warehouse staff with the knowledge and skills required to maintain FIFO and 5S standards, aligning with best practices in continuous improvement (Adeodu et al., 2023).

Complementing the SOPs, routine internal audits and inventory verification checks were introduced to monitor compliance. Real-time KPIs were tracked to evaluate performance metrics such as picking accuracy, FIFO adherence and shelf integrity (Mostafa & Essam, 2024). The use of a dedicated Inventory Management System (IMS) enabled accurate monitoring of stock levels, automated alerts for stock expiry and enforcement of FIFO rotation protocols (Alamsyah et al., 2024; Tran et al., 2025). Additionally, visual management tools such as colour-coded floor markings, bin labelling and directional signage were deployed to reinforce spatial organization and enhance worker orientation essential elements in sustaining 5S initiatives (Flores et al., 2022). Furthermore, periodic layout evaluations and Kaizen-driven workshops were held to drive incremental enhancements, ensuring that operational gains remained embedded and adaptable to evolving warehouse requirements.

4.0 Conclusion

This study confirmed that structured application of the DMAIC methodology supported by Lean practices such as 5S and FIFO can significantly enhance the efficiency, accuracy and responsiveness of warehouse operations. By addressing critical inefficiencies including suboptimal layout design, non-standardized procedures and inadequate inventory rotation the project achieving measurable improvements in space utilization, picking time and inventory traceability. These findings are like the body of current scholarship favouring the implementation of lean tools under systematic problem-solving practices as a way towards realizing deep changes within logistics settings. To maintain such improvements, the organization is advisable to institutionalize best practices by means of recurrent employee training, strict compliance with Standard Operating Procedures (SOPs) as well as ongoing tracking of key performance indicator (KPIs) like FIFO compliance and picking accuracy.

Further, the implementation of digital-based inventory management tools and phased automation will significantly enhance the scalability of the system, rendering the same more adaptive. The establishment of the culture for continuous improvement within the organization will also require cross-functional working as well as strong leadership backing. Nonetheless, the current research is also susceptible to certain extents of limitations. The study is based on data from one semi-automated mid-sized warehouse, so the generalizability of the outcome to larger or even highly automated warehouses will be restricted. Despite such limitations, the insights obtained are helpful for warehouse operations optimization and can be used as a reference point for future research in similar circumstances.

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Conflicts of Interest
This manuscript is an original work and is not currently submitted to any other journal. All contributing authors have reviewed and approved the final version and declare no conflict of interest in the manuscript

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