

Production Model for Reducing the Return Rate in A Textile Manufacturing Company by Applying Lean Manufacturing and TQM Tools

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Abstract

This study addresses the problem of a high return rate in a company that manufactures industrial workwear. Over the past four years, the organization recorded an average return rate of 12.6%, exceeding the industry standard by 7.14%. The root causes identified were a lack of standardization in finishing processes, the absence of quality controls at critical points, disorganization in the storage area, and deficiencies in production planning. This research proposes a comprehensive improvement model based on Lean Manufacturing and quality management tools, such as Total Quality Management, process standardization, and 5S. The results obtained through the implementation of the tools proposed in this study show a projected reduction in the return rate of 5.16%, a decrease in the defective rate from 15% to 5.6%, and an improvement in the On-Time Delivery (OTD) indicator from 72.5% to 77%. In economic terms, the model generates an estimated savings of between \$41,734 and \$47,696 annually, thus contributing to the sustainability and competitiveness of the company in the Peruvian textile sector. This research provides a practical and scalable contribution for textile SMEs, demonstrating how the integration of Lean and TQM tools can standardize manual finishing operations, reduce variability, and strengthen quality assurance. The proposed model is structured in a way that allows replication in similar manufacturing environments facing high rework levels and unstable delivery performance, positioning it as a valuable reference for operational improvement across the Latin American textile industry.

Keywords

Textile industry; Lean Manufacturing; returns; quality control.

1. Introduction

The Peruvian textile sector represents 2% of national GDP and faces challenges related to low productivity, lack of standardization, and outdated machinery. The studied company, with 35 years of experience in industrial workwear, reports a persistent increase in defective products and delayed deliveries. Its return rate of 12.6% exceeds the industry average by 7.14%. This research addresses the need for an engineering-based intervention to reduce losses, improve OTD, and strengthen product quality through Lean and TQM principles.

1.1 Objectives

- Reduce the total return rate by 6.8%.
- Decrease defective product rate from 15% to below 4.8%.
- Improve OTD from 72.5% to at least 77%.

- Implement standardized work and quality control in finishing processes.
- Validate improvements through numerical and simulation-based results.

2. Literature Review

Research on operational optimization within the textile and apparel industry in Peru and Latin America has grown substantially in recent years. Several authors highlight persistent problems related to variability in finishing operations, absence of standardized processes, and weak quality-control systems. Alanya et al. (2023), in a study focused on garment-process stability, identified that SMEs commonly operate with operator-dependent methods, resulting in inconsistent finishing outcomes and elevated rework rates. Similarly, Balvin Azaña, Peceros Pinto, and Robles Fabián (2022) demonstrated that quality failures in textile SMEs are primarily linked to lack of documented work sequences and inadequate inspection routines. López et al. (2023) additionally report that a large share of Peruvian textile MYPEs lack formalized production guidelines and access to training, which hinders the adoption of standardized finishing practices. Ledesma-Munive et al. (2024) further document that textile clusters exhibit recurring gaps in cross-functional coordination and process audits, undermining sustained quality improvements. Kaka et al. (2024) provide evidence on the high economic impact of common finishing defects (e.g., loose threads, oil stains, skipped stitches), reinforcing the need for robust inspection systems. Tejada et al. (2024) emphasize that machinery limitations and maintenance shortfalls are key drivers of rework and quality variability in Peruvian factories. Finally, Giurfa Barrientos et al. (2023) show that Lean Logistics and simple warehouse interventions can significantly reduce logistic errors and improve On-Time Delivery in SMEs.

Studies by Calderón Ávila & Dávalos Llacua (2021) and Canales-Jeri et al. (2022) emphasize the strong relationship between workplace disorder, prolonged search times, and quality variation. Their findings show that the implementation of 5S and structured visual control significantly improves material flow, reduces contamination in finishing areas, and optimizes lead times. This is consistent with TQM-based textile research conducted by De-La-Flor, Vigil & Ruiz-Ruiz (2020), who reported that the establishment of defect-recording systems and standardized inspection checklists reduces defective rates by enabling earlier detection of non-conformities.

International studies reinforce this trend. Asif et al. (2021) demonstrated that Lean-TQM integration improves first-pass yield and process stability in garment manufacturing by combining standardized work and continuous inspection protocols. Santos et al. (2020) similarly found that structured quality documentation and operator-training programs significantly reduce seam irregularities, attachment defects, and reprocessing in finishing operations.

Peruvian authors such as Collao-Díaz et al. (2022) and Giurfa Barrientos & Gaspar Culcas (2022) note that textile SMEs commonly lack methodological frameworks that unify workplace organization, standardized procedures, and inspection routines. This gap results in elevated return rates and poor On-Time Delivery (OTD) performance. Fibre2Fashion (2023) adds that global textile competitiveness increasingly depends on reducing variability in finishing areas, where manual tasks generate most quality deviations.

Furthermore, Silva et al. (2022) highlight that order-fulfillment failures in Peruvian textile SMEs are strongly associated with internal communication gaps, insufficient operator training, and weak coordination between production and logistics departments. These structural deficiencies generate recurring delivery delays and prevent the establishment of stable OTD performance, reinforcing the need for standardized workflows and clearly defined responsibilities within finishing and dispatch processes. Likewise, Flores et al. (2022) report that inadequate supervision of subcontracted suppliers is a major contributor to missed deadlines and product inconsistencies, often resulting in financial penalties and customer dissatisfaction. Their findings emphasize the importance of formal quality-control mechanisms, supplier monitoring systems, and continuous feedback loops—elements fully aligned with the Lean-TQM principles applied in this study.

3. Methods

The methodological framework adopted in this study followed a structured, engineering-driven sequence aligned with IEOM applied research standards. The approach was divided into four coordinated phases. The first phase consisted of a comprehensive diagnostic assessment involving process flow inspection, baseline metric extraction, and analysis

of defect-generation patterns in finishing operations. This diagnosis incorporated time studies, defect-type classification, and workflow observation to identify sources of instability and operational variability.

The second phase focused on determining critical causes through analytical tools such as Pareto analysis, Ishikawa cause–effect mapping, and procedural verification in the finishing and storage areas. These tools enabled the identification of systemic deficiencies related to non-standardized work, inspection gaps, and disorganized material handling.

The third phase involved the design and deployment of the Lean–TQM improvement model. Core components included 5S workplace organization, standardized work protocols, visual quality controls, and structured inspection checkpoints. Engineering design principles guided the integration of these tools to ensure consistency, repeatability, and operational alignment.

Finally, the fourth phase focused on validation through pre–post comparison using operational indicators, simulation outputs, and consistency checks. Numerical evidence from defective-rate reduction, OTD improvement, and process efficiency validated the reliability and effectiveness of the implemented interventions as shown in Figure 1

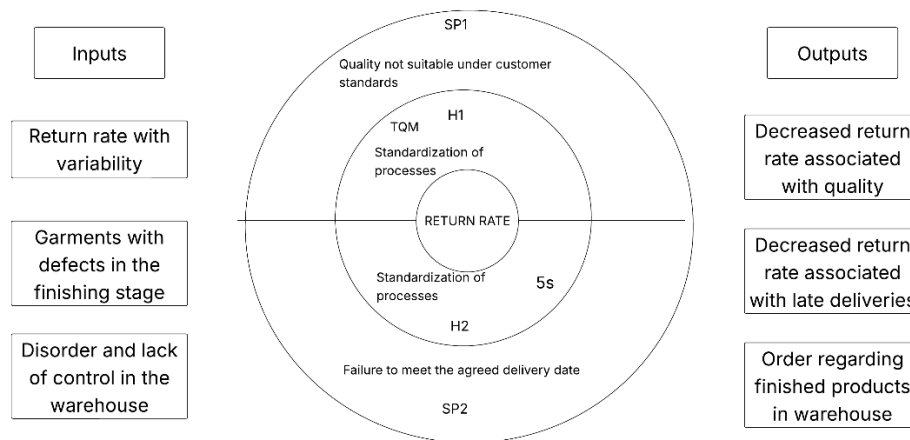


Figure 1. Conceptual Model

4. Data Collection

The data collection process was organized into two complementary phases. The first phase involved extracting operational records from the company's ERP, production logs, defect registries, and delivery timelines covering 2021–2024. These data provided the baseline for understanding the magnitude and distribution of defective-rate fluctuations, OTD deviations, and reprocessing cycles. Additionally, non-value-added activities were monitored in finishing, storage, and dispatch areas, including tool-search time variability, queue formations, and work-in-process accumulation. To determine the sample size, the formula for finite populations was used, considering a population size of $N = 50$ orders, a confidence level of 95% ($Z = 1.96$), an expected proportion $p = 0.5$ and its complement $q = 0.5$, as well as a margin of error of $d = 0.05$. With these values, a sample size of $n = 44.34$ was obtained.

The second phase focused on in-situ observation and measurement. Time studies were conducted across critical finishing operations such as buttoning, buttonholing, reinforcing, and thread-cleaning. Storage-area assessments captured drawer-level inconsistencies, material misplacement frequency, and operator search times. These observations were integrated with defect-type categorization to construct a comprehensive diagnostic dataset. The collected information established the factual baseline required to evaluate the impact of Lean–TQM interventions.

5. Results and Discussion

5.1 Numerical Results

According to Table 1, the numerical analysis characterized the initial operational performance and the impact of the Lean–TQM model. Historical data (2021–2024) showed a return rate of 12.6%, above the 7.14% sector benchmark. Defective rate reached 15%, and OTD averaged 72.5%.

Table 1. Historical Data

Year	Total produced (thermal jacket)	Total deliveries (thermal jacket)	Return overall (annual)	Return Rate (%)
2024	50 000	50 000	7 500	12,27 %
2023	55 000	55 000	8 100	12,91 %
2022	45 000	45 000	7 200	13,00 %
2021	60 000	60 000	8 225	12,03 %

Cost-impact demonstrated annual losses of \$65,572 due to quality failures, late delivery penalties, logistics, reprocessing, and opportunity costs. operations: buttons (66.99%), buttonholes (67.51%), reinforcing (75%), and thread-cleaning variability.

5.2 Graphical Results

Graphical tools complemented the numerical assessment. The Pareto chart of return causes shows quality-related failures as the dominant category, while Pareto of root causes highlights standardization gaps, inspection failures, and storage-area disorder.

The Problem Tree illustrates how defects and delays propagate into financial losses and customer dissatisfaction. The Figure 2 will be presented below.

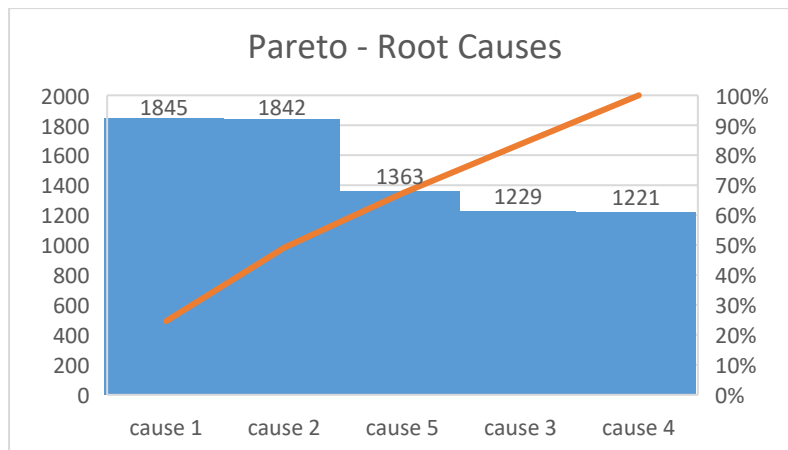


Figure 2. Pareto for Root Causes

5.3 Proposed Improvements

5.3.1 5S Methodology

The 5S methodology was deployed in the finishing and storage areas to restore order and visibility. During the initial audit, the zones exhibited dispersed materials, unlabeled drawers, and long tool-search times. After implementing Seiri and Seiton, obsolete items were removed, tools were classified and assigned fixed locations, and visual labels were introduced in cabinets and racks. Seiso reinforced cleaning routines at the end of each shift, reducing the presence of textile residues and defects caused by contamination.

According to Figure 3, the subsequent evaluations showed progressive advances: Seiri reached a compliance level of 60%, while Seiton and Seiso achieved 48%, indicating that the organization and cleanliness routines were starting to stabilize. Seiketsu scored 28% and Shitsuke 9%, revealing the need to consolidate standards and discipline through continuous audits and supervisory follow-up.

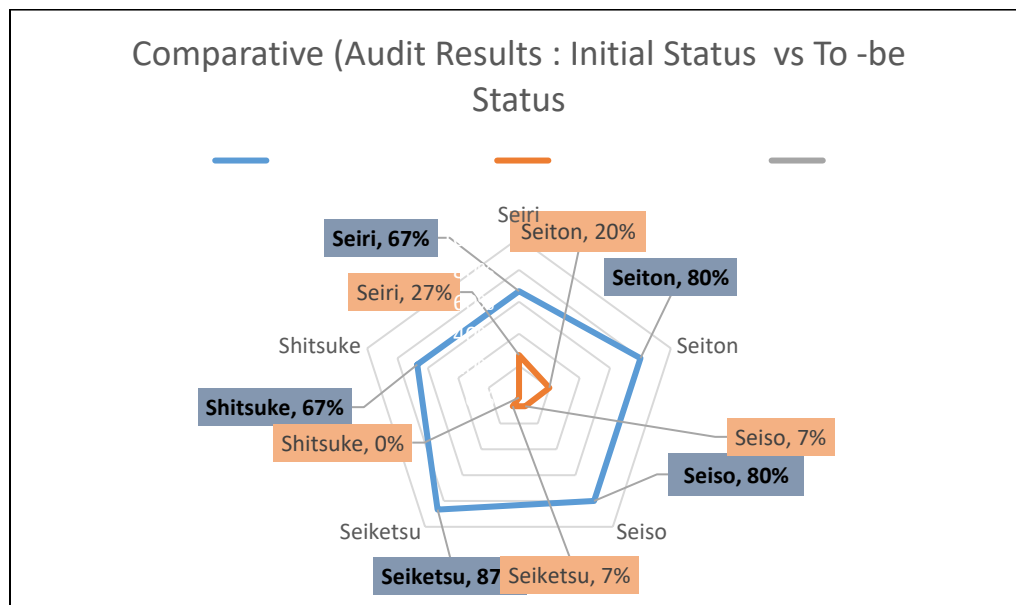


Figure 3. Radar Picture (As-Is vs To-Be)

5.3.2 Standardized Work

According to Figure 4, Standardized work was developed for the most critical finishing operations: buttoning, buttonholing, reinforcing and thread-cleaning. For each operation, the standard sequence, normal time, and key quality checkpoints were defined. Work instructions were documented in simple, illustrated formats and posted at each workstation. This reduced operator-to-operator variability and facilitated training of new personnel.

The introduction of standardized work contributed to a reduction of errors associated with omitted steps, incorrect stitch types, and inadequate tension settings. Efficacy in buttons and buttonholes increased from 66.99% and 67.51% respectively to levels consistent with the target defective rate of 5.6%. The stabilization of sequences also facilitated more reliable capacity planning in the finishing area.

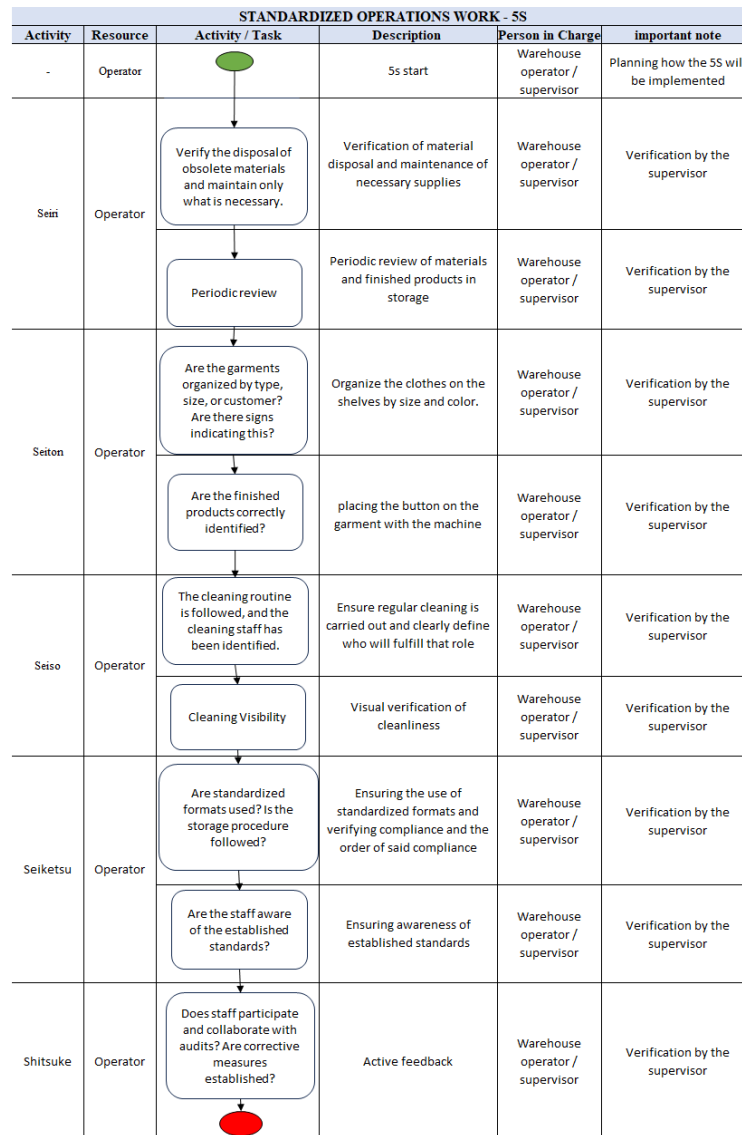


Figure 4. Standardized Work Manual for 5S Methodology

5.3.3 Total Quality Management

TQM principles were integrated through formalization of inspection points, defect recording, and use of control checklists. Inspection criteria were defined for in-process and final garments, and responsibility was assigned to specific roles in the finishing and dispatch stages. The introduction of standardized quality forms enabled systematic recording of non-conformities and facilitated root-cause analysis.

The combination of TQM tools with 5S and standardized work led to a reduction in rework and an increase in first-pass yield. Quality-related returns decreased as defects were detected earlier in the process, and operators received immediate feedback on recurring issues. This closed-loop mechanism reinforced continuous improvement and aligned day-to-day operations with long-term quality objectives. Table 2 shows the proposed improvements in first instance.

Table 2. Proposed Improvements

Indicators	Frequency	As - Is	To - Be (proposed)	Source / Justification
Return Rate	Monthly	12,7%	6,8%	Barriento et al (2023)
Defective Rate	Monthly	8,15%	4,8%	Kaká et al (2024)
On time Delivery	Monthly	72,50%	77,00%	López et al (2023)

5.4 Validation

The validation stage was conducted through a structured comparison of the As-Is and To-Be conditions using operational indicators, statistical evidence, and simulation-based analysis. The defective rate was reduced from 15% to 5.6%, reprocessing time decreased by 52%, and OTD improved from 72.5% to 77%. According to Table 3- Table 4 and Figure 5– Figure 8, Arena simulations showed reduced variability and the improved model, shorter queues and narrower confidence intervals under the improved scenario, confirming process stabilization.

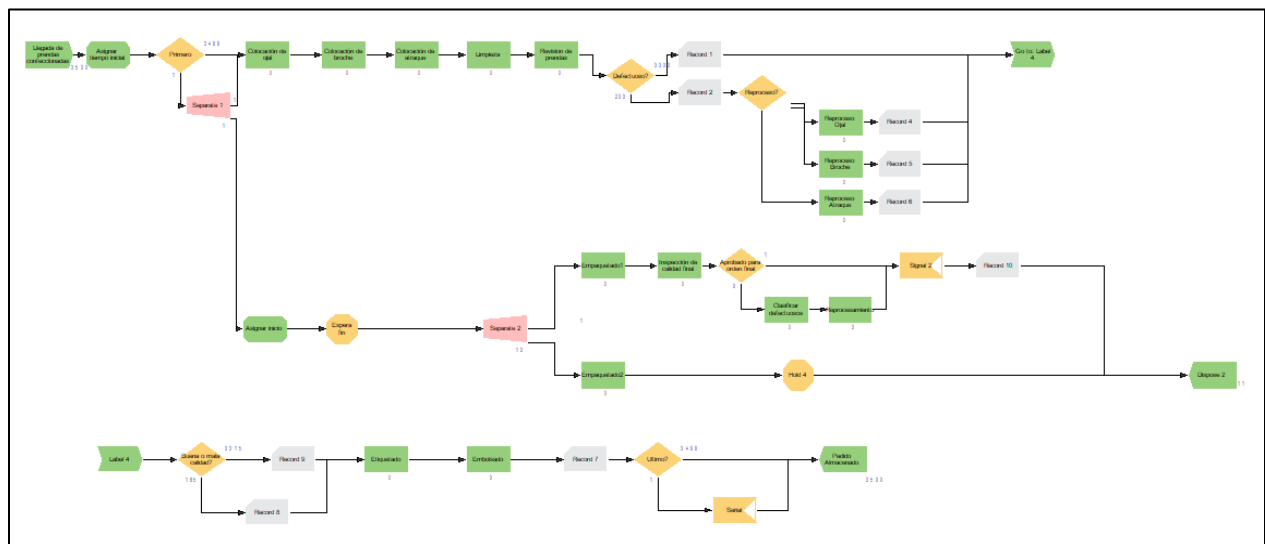


Figure 5. Arena Model To Be (Improved Model)

The following table presents the current scenario indicators with confidence interval.

Table 3. Indicator Table of the Current As-Is Scenario with Confidence Interval

Activity	Average	Standard desviation	0.95 c.i. half-width	Minimum value	Maximum value	Number of obs.	Units
Put on a berth	9.84	0.0188	0.0134	9.79	9.86	10	seconds
put brooch	19.6	0.0188	0.0134	19.6	19.7	10	seconds
To put a buttonhole	21.3	0.0277	0.0198	21.2	21.3	10	seconds
Review process	90.7	0.0612	0.0438	90.6	90.8	10	seconds
Lead Time	26.5	1.79	0.158	21.4	32.8	500	days
Defective Rate	0.122	0.00542	0.00388	0.116	0.131	10	%
OTD	0.729	0.0761	0.0545	0.578	0.844	10	%

The table of indicators for the future scenario with confidence interval will be presented below in Table 4.

Table 4. Indicator Table for the To-Be Scenario with Confidence Interval

Activity	Average	Standard desviation	0.95 c.i. half-width	Minimum value	Maximum value	Number of obs.	Units
Put on a berth	7.82	0.0119	0.00849	7.8	7.84	10	seconds
put brooch	15.7	0.0122	0.0087	15.7	15.7	10	seconds
To put a buttonhole	17	0.0153	0.0109	17	17	10	seconds
Review process	73	0.0594	0.0425	72.9	73.1	10	seconds
Lead Time	25	1.72	0.151	20.3	30.4	500	days
Defective Rate	5.57%	0.00481	0.00344	0.0454	0.0626	10	%
OTD	75.30%	0.0814	0.0583	0.6	0.844	10	%
Obtaining pieces for making	6.04	0.0899	0.0498	5.83	6.21	15	days

The following figure will show the Defective rate (As-Is vs To-Be)

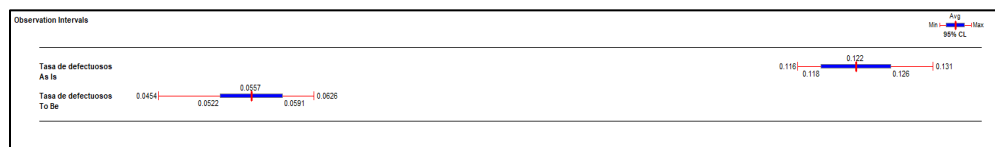


Figure 6. Defective rate (As-Is vs To-Be)

The following will present the Figure 7 of On-Time Delivery (As-Is vs To-be)

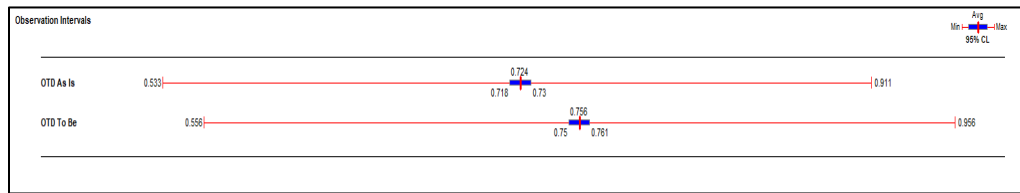


Figure 7. On time Delivery (As-Is vs To-be)

Overall, the validation confirmed that the integrated Lean-TQM model stabilized operations, reduced variability in finishing processes, improved quality outcomes, and enhanced delivery performance, demonstrating the effectiveness of the proposed framework for textile SMEs. The figure will be presented below in Figure 8.

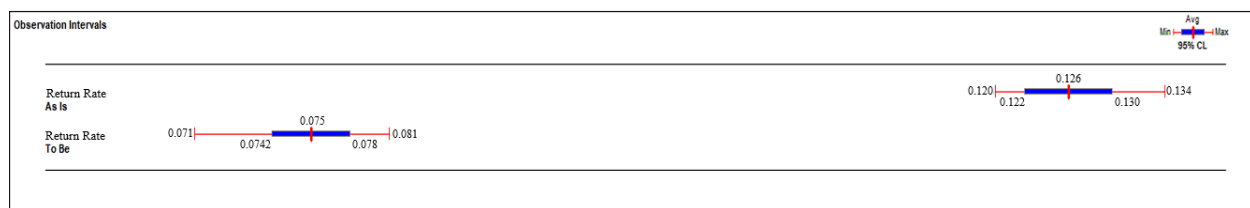


Figure 8. Return Rate (As-Is vs To-be)

6. Conclusion

The results obtained in this study demonstrate that the integrated Lean-TQM model applied to the textile finishing process successfully addressed the main sources of operational instability identified in the diagnostic phase. The combination of data analysis, graphical tools, and structured process evaluation confirmed that the most critical deficiencies were concentrated in non-standardized finishing activities, inadequate inspection practices, and disorganized material handling in storage areas.

The implementation of 5S improved workplace organization and visibility, reducing tool-search times and eliminating unnecessary materials that contributed to rework and delays. Standardized work provided clear operational sequences and consistent quality checkpoints for buttoning, buttonholing, reinforcing, and thread-cleaning operations, significantly reducing operator variability.

Second, the development of standardized work for critical finishing operations (buttoning, buttonholing, reinforcing, and thread-cleaning) significantly reduced operator variability. The establishment of defined sequences, illustrated work instructions, and explicit quality checkpoints strengthened process repeatability and directly contributed to reducing the defective rate from 15% to 5.6%, fulfilling the second objective of minimizing finishing defects.

Third, the incorporation of TQM tools, such as structured inspection points, defect-recording formats, and formalized quality criteria, improved early detection of non-conformities and created continuous feedback loops. This enhanced the reliability of in-process and final inspections, supporting the reduction of quality-related returns and ensuring consistency with industry performance benchmarks.

Validation through numerical indicators and simulation confirmed the effectiveness of the proposed Arena model. Defective rate decreased from 15% to 5.6%, reprocessing time was reduced by 52%, and OTD improved from 72.5% to 77%. Simulation results demonstrated lower variability, shorter queues, and narrower confidence intervals under the improved scenario, confirming that the new operational design stabilized the finishing process.

Finally, the integrated Lean-TQM approach achieved the core objective of reducing the overall return rate by 5.16%, aligning the company more closely with sector standards. The consistency between observed improvements, numerical indicators, and simulation results demonstrates that the model is both technically feasible and operationally

impactful. The proposed framework offers a scalable and sustainable foundation for continuous improvement initiatives in textile SMEs, reinforcing their competitiveness in the Peruvian industrial textile sector.

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Biographies

Ignacio Delgado-Guardia is an Industrial Engineer from Universidad de Lima, specializing in operational excellence, quality management, and continuous-improvement systems. His professional experience spans operations, logistics, occupational safety, and human-capital management in the metal-mechanical and telecommunications industries, where he held progressive roles ranging from HR coordination to operational analysis. He has led the implementation of performance-evaluation systems, occupational safety protocols, internal audits, and national-level operational controls for major service brands such as DIRECTV, WIN Internet, and WOW. His work includes developing standardized processes, improving recruitment efficiency, optimizing warehouse accuracy through internal audits, and strengthening KPIs for workforce performance and field operations. His current research focuses on Lean Manufacturing, TQM, and process standardization within the Peruvian textile sector, contributing engineering-based solutions to reduce operational variability and improve delivery performance in SMEs.

Fabricio Omar Pezo-Chahua is a Peruvian Industrial Engineer from the Universidad de Lima, with academic interests focused on production systems, quality engineering, and continuous improvement methodologies. His research work emphasizes Lean Manufacturing, Total Quality Management, and process standardization within labor-intensive industries such as apparel manufacturing. He has contributed to applied research projects centered on

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Jorge Antonio Corzo-Chavez is currently a professor in industrial engineering career at Universidad de Lima, chief executive officer at Conquista Lab, and associate consultant at Manpower Group for multinational companies. He holds a Master in Business Administration from Universidad ESAN (Perú), a Master in Marketing Science from ESIC Business & Marketing School (Spain) and is Industrial Engineer from the Universidad de Lima (Perú). He has experience in advising industrial and service companies to improve productivity and development of business models. He has worked in areas of entrepreneurship and innovation, marketing and commercial for the construction, metalworking, mining, services, and education sectors. His main research interests are lean manufacturing, master production schedules, logistics, machine learning, and innovation for small and medium-sized enterprises.

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