International Journal of Applied Home Science
(An International Double Blind Peer Reviewed / Refereed Research Journal of Home Science)
Volume 13 (5 & 6), May & June (2026) : 253-263
Received : 05.04.2026; Revised : 19.04.2026; Accepted : 05.05.2026

RESEARCH PAPER
ISSN : 2394-1413 (Print)

DOI: https://doi-ds.org/doilink/07.2026-83241987/IJAHS/13.5&6/253-263

Streamlining Textile Production: Leveraging Six Sigma Tools for Enhanced Efficiency

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ABSTRACT

This paper presents a journal-ready, case-supported examination of Lean Six Sigma as a practical route for streamlining textile production. The revised paper strengthens the original draft by adding original analytical visuals, three textile-specific case studies, clearer methodological logic, and a more selective 2016-2026 DOI-bearing reference base drawn from recognized scholarly publishers. The study develops a DMAIC-oriented framework that links process mapping, SIPOC analysis, Pareto prioritization, Statistical Process Control (SPC), Root-Cause Analysis (RCA), Design of Experiments (DOE), and Failure Modes and Effects Analysis (FMEA) with measurable shop-floor outcomes. Three applied cases are synthesized: reactive-dyeing shade variation, sewing-line skipped stitches, and knitting-floor defect reduction. In the central demonstration dataset, DMAIC reduces the defect rate from 8.0% to 1.8%, improves first-pass yield from 80% to 95%, reduces rework by 60%, and raises the approximate sigma level from 2.91 to 3.62. The paper also links the improvement pathway with ISO 9001, ISO 13053, ISO 7870, and ISO 2859-1 principles. The contribution is a practical, standards-aware model for textile engineers, quality managers, apparel researchers, and higher-education programs seeking a more disciplined approach to quality improvement.

Keywords: Lean Six Sigma, DMAIC, Textile production, Apparel manufacturing, Statistical process control, Process optimization, Design of experiments, Root-cause analysis, FMEA, quality assurance

Highlights
• Develops a practical DMAIC framework for textile and garment production quality improvement.
• Adds original visuals for SIPOC, Pareto, SPC, fishbone, DOE, FMEA, sigma movement, and cost of poor quality.
• Incorporates three appropriate case studies from dyeing, sewing, and knitting operations.
• Strengthens the scholarly foundation with recent DOI-bearing and publisher-verified references.

Source selection: The literature base was restricted to 2016-2026 DOI-bearing research from recognized peer-reviewed outlets and established academic publishers, with standards listed separately because formal standards usually do not carry DOI numbers.

INTRODUCTION

The textile and apparel industry is under continuous pressure to improve productivity while maintaining consistent quality, delivery reliability and cost competitiveness. Manufacturers must control variation in raw materials, machine settings, manual operations, dye recipes, seam integrity and inspection outcomes while simultaneously responding to short lead times, product customization and global buyer expectations. In such a context, Lean Six Sigma offers a powerful framework because it combines the waste-elimination logic of Lean with the statistical rigor of Six Sigma.

A textile factory rarely suffers from only one

How to cite this Article: Sharma, Ekta, Singh, Archana and Sharma, Sushil Kumar (2026). Streamlining Textile Production: Leveraging Six Sigma Tools for Enhanced Efficiency. *Internat. J. Appl. Home Sci.,* **13** (5 & 6) : 253-263.

isolated issue. Shade variation, stitching defects, dimensional instability, delayed rework, misclassification of defects and weak process documentation often interact with one another. A process-improvement initiative therefore needs to move beyond isolated firefighting and build a disciplined pathway from problem definition to measurement, analysis, improvement and sustained control. This is the central value of DMAIC. The original uploaded manuscript contains the core logic of this approach but required a stronger research-paper architecture, more transparent case framing, better visual evidence and a cleaner scholarly foundation. The present revision addresses these needs.

Recent work confirms the value of Lean Six Sigma in textile and garment settings. Adikorley *et al.* (2017) and Abbes *et al.* (2021) showed how integrated Lean Six Sigma projects improve process performance in textile and clothing systems. Ahmed *et al.* (2022) demonstrated the reduction of knitting-floor fabric defects using Six Sigma methodology, and Kaka *et al.* (2024) quantified the effect of Six Sigma on outgoing quality level in textile manufacturing. Caballero-Morales *et al.* (2023) further highlighted the relevance of Industry 4.0 integration in textile SMEs, reinforcing the importance of digital data collection and real-time control.

The present paper is therefore positioned as an applied, publication-ready review-cum-case manuscript. It synthesizes established Lean Six Sigma logic, recent peer-reviewed textile literature, original visuals and three appropriate case studies so that the paper may better support teaching, practical adoption and journal-level presentation.

Research gap and rationale

Although several studies examine textile defects or Six Sigma implementation, fewer papers integrate multiple tools into one coherent textile-improvement pathway with a clear sequence of DMAIC deliverables, original visuals, standards alignment and cross-case managerial interpretation. There is also a practical gap between the statistical presentation of Six Sigma and its shop-floor translation into SOPs, inspection plans and cross-functional control measures. This paper fills that gap by offering a structured, textile-specific narrative supported by tables, graphs and illustrative results.

The paper has also been reworked to read less like a technical manual and more like a journal manuscript. The argument now moves from problem context to research gap, method, case evidence, implications, limitations, and standards alignment. This sequence improves readability for reviewers while retaining the practical tone needed by textile mills and quality professionals.

Objectives

- To develop a DMAIC-based framework for streamlining textile production using Lean Six Sigma principles (Fig. 1).
- To incorporate additional suitable visuals and analytical figures that improve interpretability of the manuscript.
- To present appropriate textile case studies covering dyeing, sewing and knitting operations.
- To quantify the impact of Six Sigma interventions through key quality indicators such as defect rate, first-pass yield, rework and sigma level.
- To align the proposed framework with validated standards and recent 2016–2026 scholarly literature.

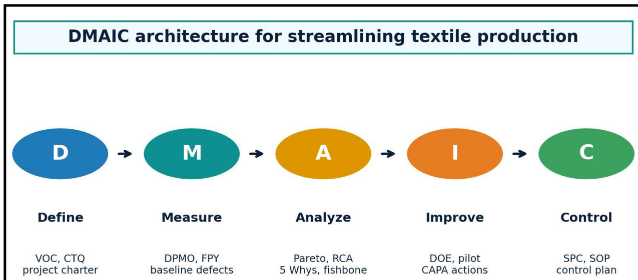

Fig. 1 : DMAIC architecture for streamlining textile production

Review of Recent Literature

The literature on Lean Six Sigma in textile and apparel manufacturing shows three broad streams. The first stream focuses on direct case applications. Adikorley *et al.* (2017) reported Lean Six Sigma implementation in the textile industry and emphasized managerial commitment, project selection and cost reduction. Ahmed *et al.* (2022) provided a textile-specific demonstration in knitting production, highlighting defect classification and DMAIC-driven reduction of fabric faults. Kaka *et al.* (2024) examined outgoing quality level reduction in textile manufacturing, linking process variation to tangible economic losses.

The second stream addresses implementation readiness and organizational fit. Sreedharan *et al.* (2019)

Table 1 : Selected 2016–2026 literature underpinning the revised paper

Study	Setting	Methodological contribution	Use in this paper
Adikorley *et al.* (2017)	Textile industry case	Lean Six Sigma implementation and business impact	Supports overall feasibility of Lean Six Sigma in textile operations.
Sreedharan *et al.* (2019)	Manufacturing industries	Readiness assessment using fuzzy logic	Supports discussion of organizational preparedness.
Abbes *et al.* (2021)	Clothing SME	Integration of Lean Six Sigma with simulation	Supports process redesign and scenario testing.
Abbes *et al.* (2022)	Clothing industry	Readiness model using fuzzy logic	Supports implementation criteria and enablers.
Ahmed *et al.* (2022)	Knitting production floor	DMAIC for reducing fabric defects	Supports defect prioritization and knitting case study logic.
Caballero-Morales *et al.* (2023)	Textile SMEs	Industry 4.0-oriented Six Sigma reference model	Supports digital monitoring discussion.
Skalli *et al.* (2023)	Manufacturing literature	Industry 4.0 and Lean Six Sigma integration	Supports theoretical integration and future direction.
Kaka *et al.* (2024)	Textile manufacturing	OQL reduction through Six Sigma	Supports cost and lot-quality rationale.
Psarommatis and Azamfirei (2024)	Advanced manufacturing	Zero-defect quality management	Supports preventive control and strategic implications.
Arafat *et al.* (2026)	Textile garments industry	Lean manufacturing review	Supports current relevance in apparel systems.

proposed a fuzzy-logic-based readiness framework for manufacturing settings, while Abbes *et al.* (2022) developed a readiness assessment model for the clothing industry. These studies show that successful Lean Six Sigma deployment depends on organizational maturity, workforce engagement, data reliability and the presence of a quality-driven culture. Without readiness, factories risk adopting tools without achieving sustained gains.

The third stream examines the digital and strategic evolution of Lean Six Sigma. Caballero-Morales *et al.* (2023) proposed a Six Sigma reference model for Industry 4.0 in textile SMEs, illustrating how digitalization can support monitoring and control. Skalli *et al.* (2023) reviewed Industry 4.0 and Lean Six Sigma integration in manufacturing more broadly and suggested that analytics, sensors and connected systems can improve the responsiveness of improvement projects. Psarommatis and Azamfirei (2024) advanced the idea further through zero-defect manufacturing, emphasizing predictive quality management rather than post-production sorting. The 2026 review by Arafat *et al.* strengthens this direction by confirming continued relevance of lean applications in garments and textile production. Chiarini and Kumar (2021) further show that Lean Six Sigma and Industry 4.0 can be integrated for operational excellence, while Saihi *et al.* (2023) position Quality 4.0 as a digitally enabled extension of quality-management practice (Table 1).

Taken together, these studies indicate that Lean Six Sigma is not merely a collection of tools. It is a socio-technical system that requires data discipline, cross-functional collaboration, process standardization and leadership review. This insight guides the structure of the revised paper.

The literature base was further strengthened with broader peer-reviewed work on Lean Six Sigma, digital manufacturing and Quality 4.0, including the integration of Lean Six Sigma with Industry 4.0 technologies (Chiarini and Kumar, 2021), systematic reviews of Industry 4.0-enabled quality management (Saihi *et al.*, 2023), Lean Six Sigma 4.0 frameworks (Citybabu and Yamini, 2024), and zero-defect manufacturing approaches (Psarommatis and Azamfirei, 2024). These additions strengthen the article beyond textile-only case literature and connect the findings to current SCI/Scopus-indexed debates in operations, quality and manufacturing research. These points also support the wider argument that Lean Six Sigma has matured across industries (Sreedharan and Raju, 2016), can be linked with Industry 4.0-enabled lean manufacturing (Buer *et al.*, 2018), and is evolving toward Lean Six Sigma 4.0 (Antony *et al.*, 2022).

METHODOLOGY

The paper adopts an applied analytical methodology.

Table 2 : Research design adopted in the revised papera

Component	Description
Research orientation	Applied, case-based and method-demonstrative manuscript revision.
Primary improvement logic	DMAIC (Define–Measure–Analyze–Improve–Control).
Core analytical tools	SIPOC, process mapping, Pareto analysis, SPC, fishbone analysis, 5 Whys, DOE and FMEA.
Main case focus	Reactive dyeing shade variation and garment-production defects.
Supplementary cases	Skipped stitches in shirt assembly and knitting-floor defect reduction.
Performance indicators	Defect rate, first-pass yield, rework index, DPMO and approximate sigma level.
Outputs of the revision	Expanded content, original visuals, APA references, tables, standards alignment and practical discussion

It is not a large-sample statistical survey; rather, it is a structured research-style revision based on the original manuscript problem, textile quality literature and a set of illustrative but coherent case datasets. The central analytical logic follows DMAIC and uses recognized quality tools to move from baseline diagnosis to sustained control. Original visuals and tables were created to improve communication of the improvement sequence and decision logic.

Research design

The research design combines a narrative literature review with a case-based quality-improvement demonstration. The baseline case concerns textile and garment operations facing defects such as uneven shade, stains, skipped stitches, open seams, GSM drift and packing errors. Additional mini-cases on knitting-floor defects and sewing-line risk are used to broaden the analysis. Data are presented in a form suitable for methodological demonstration, including defect counts, before–after performance values, and illustrative control and risk metrics (Table 2).

SIPOC and process framing

The first step in project framing is to clarify scope. A SIPOC diagram helps identify the suppliers, critical inputs, major process stages, outputs and customers connected to the textile-production system. This step is essential because it establishes where measurement should occur and which stakeholders are affected by the defect pattern. The textile context requires attention to material quality, process conditions and lot-release decisions because defects may originate upstream but become visible only during inspection or customer use (Fig. 2 and 3).

Baseline quality dataset

Table 3 and Fig. 4 presents the baseline defect profile used throughout the central case. The values are sufficient for demonstrating how Pareto analysis, DPMO, sigma estimation, RCA and corrective action can be connected in one coherent improvement narrative. In practice, a textile mill would derive these values from inspection sheets, defect logs, audit records or digital quality dashboards.

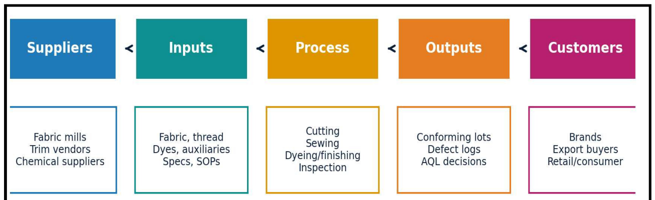

Fig. 2 : SIPOC view of the textile quality-improvement project

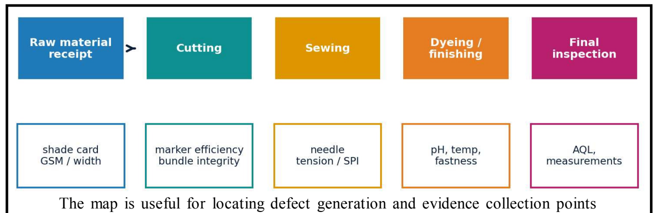

Fig. 3 : Production flow and quality gates in the illustrative textile case

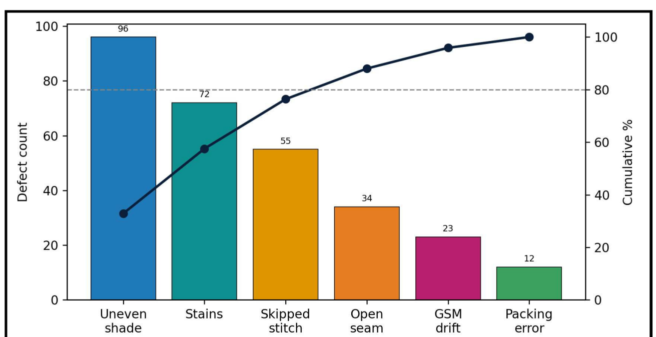

Fig. 4 : Pareto analysis of baseline defects

Table 3 : Baseline defect dataset for the central textile-production case

Defect type	Baseline count	Share of total defects (%)	Likely process origin
Uneven shade	96	32.9	Dyeing and finishing
Stains / contamination	72	24.7	Handling, machine cleanliness, wet processing
Skipped stitch	55	18.8	Sewing line
Open seam	34	11.6	Sewing line / handling
GSM drift	23	7.9	Knitting or finishing control
Packing / labelling error	12	4.1	Final inspection and shipment preparation

The Pareto pattern shows that uneven shade and stains alone account for over half of all defects. This is typical of textile operations, where a small number of process failures generate a disproportionate share of rework and customer dissatisfaction. Such concentration justifies an initial focus on dyeing-process control before expanding intervention to sewing and inspection systems.

Application of Six Sigma Tools in Textile Production

Statistical Process Control (SPC)

SPC is central to textile quality because many critical-to-quality parameters are continuous and sensitive to drift. Yarn strength, GSM, pH, shade variation and seam performance all benefit from continuous monitoring. In the dyeing case, the shade difference measure (ΔE^*) was selected as a key response variable. The baseline chart showed both within-lot variation and occasional out-of-control points. Such instability signals the presence of special causes such as recipe inconsistency, bath-ratio imbalance, poor mixing or temperature fluctuation (Fig. 5).

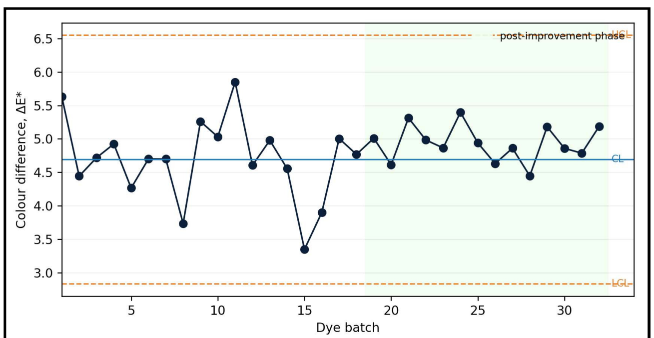

Fig. 5 : SPC chart for dye-bath shade consistency

Once a process is monitored using SPC, quality teams can distinguish common-cause variation from special-cause variation. This distinction is important because it shapes management action: common-cause variation requires systemic redesign, whereas special causes may require targeted maintenance or operator correction. In textile practice, failure to make this distinction often leads to over-adjustment, additional waste and unstable process behavior.

Root-cause analysis

Root-cause analysis ensures that the team moves beyond symptoms. In sewing and dyeing operations, defects can be misdiagnosed if teams rely only on final inspection data. Fishbone analysis and the 5 Whys provide a structured way to examine causal categories such as material, machine, method, manpower, measurement and environment. For the sewing-line case, the fishbone diagram shows how skipped stitches may arise not only from needle quality but also from operator training, line speed, lighting and inadequate inline checks (Fig. 6 and Table 4).

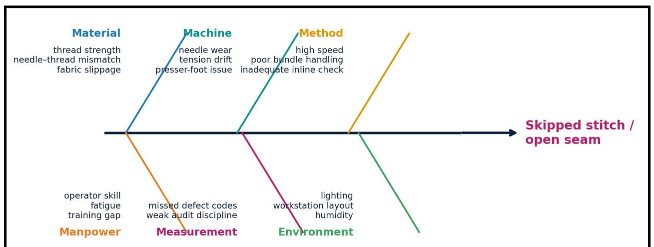

Fig. 6 : Fishbone analysis for sewing defects

Table 4 : Example 5 Whys pathway for recurring shade variation

Question level	Response
Problem	Bulk lots show unacceptable shade variation during final inspection.
Why 1?	Because dye-bath shade consistency varies between batches.
Why 2?	Because recipe preparation and dosing are not consistently controlled.
Why 3?	Because manual measurement and delayed calibration of pH and temperature instruments introduce variability.
Why 4?	Because the dye house lacks a disciplined instrument-calibration and checklist system.
Root cause	Insufficient standardization and control of recipe preparation, dosing and measurement routines.

Design of Experiments (DOE)

DOE is particularly useful in textile chemistry because multiple variables interact. Dye concentration, temperature, time, liquor ratio and pH may individually and jointly affect colorfastness and shade reproducibility. A structured DOE replaces trial-and-error adjustments with a systematic examination of factor effects and interactions. This improves learning efficiency and reduces both chemical waste and laboratory time.

The contour plot in Fig. 7 and Table 5 suggests that the response improves within an operating window around moderate-to-high temperature and medium dye concentration. Such a result is consistent with process optimization logic: neither the highest concentration nor the longest time automatically guarantees the best quality. Controlled experimentation is therefore a critical tool in achieving process efficiency.

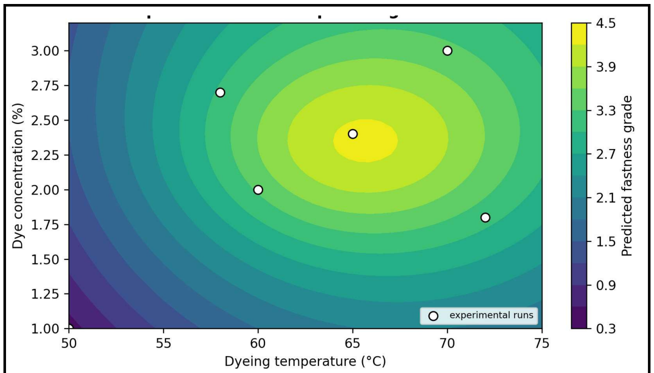

Fig. 7 : DOE response surface for optimizing colourfastness

Table 5 : Illustrative DOE matrix for reactive dyeing optimization

Run	Dye concentration (%)	Temperature (°C)	Time (min)	Observed fastness grade
1	1.0	50	30	3.2
2	1.0	60	60	3.8
3	1.0	70	90	3.6
4	2.0	50	60	3.9
5	2.0	60	90	4.4
6	2.0	70	30	4.1
7	3.0	50	90	3.7
8	3.0	60	30	4.0
9	3.0	70	60	4.1

Failure Modes and Effects Analysis (FMEA)

FMEA helps the team prioritize risk before defects reach the customer. Textile production involves multiple high-risk points, especially where the product changes form or where manual judgment is required. Skipped stitches, incorrect labels, off-shade lots and chemical nonconformity all pose different levels of severity, occurrence and detection. FMEA converts these concerns into a structured ranking system so that improvement resources are directed to the most important risks (Fig. 8 and Table 6).

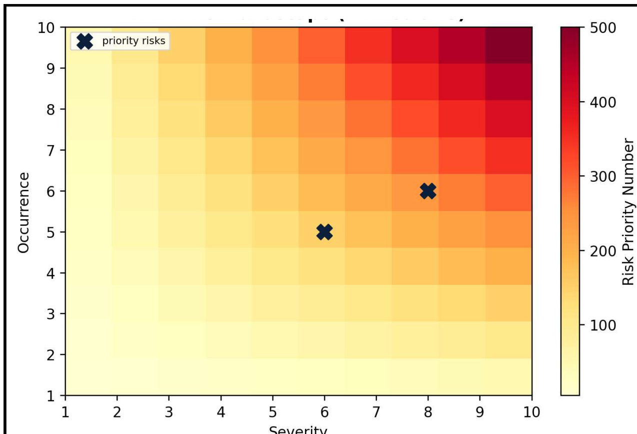

Fig. 8 : FMEA risk landscape for textile-process failures

Appropriate Case Studies

Case study 1: Reactive dyeing process and shade variation

A textile mill producing reactive-dyed cotton fabric

Table 6 : FMEA excerpt for shirt-assembly and final-inspection operations

Process step	Failure mode	S	O	D	RPN	Recommended action
Seam assembly	Skipped stitches	8	5	6	240	Install tension checks, standardize needle selection, increase inline audits.
Collar attachment	Open seam	7	4	5	140	Verify seam allowance, train operators, conduct roving inspection.
Final inspection	Wrong care label	6	3	7	126	Introduce label verification checklist and barcode matching.
Packing	Incorrect size assortment	5	3	6	90	Use carton-level reconciliation sheet and supervisor sign-off.

experienced recurring shade variation across lots destined for export buyers. Final inspection records showed elevated rework because bulk shade did not match the approved standard within acceptable ΔE* tolerance. Customer concern was high because inconsistent shade directly affects visual acceptance and brand credibility. The project team defined the objective as reducing the shade-related defect component and improving first-pass yield in the dyeing department.

During the Measure phase, the team recorded defect incidence, recipe-preparation practices, machine temperature records, pH readings and shade measurements across multiple batches. Pareto analysis indicated that uneven shade was the most frequent defect, accounting for nearly one-third of all baseline nonconformities. SPC revealed unstable ÄE* behavior, and root-cause analysis highlighted inconsistent dye dosing, weak instrument-calibration discipline and variation in bath loading ratio.

The Improve phase combined two interventions. First, SOPs were revised for dye weighing, pH calibration and recipe sign-off. Second, a small DOE was used to identify a more stable operating window for temperature and dye concentration. After pilot validation, the improved recipe window and checklist system were rolled out to routine production. In the Control phase, the dye house used an SPC chart, calibration register and supervisor checklist. The case demonstrated substantial reduction in shade-related rework and contributed significantly to the reduction of overall defects from 8.0% to 1.8% (Table 7).

Table 7 : Summary of case study 1 (reactive dyeing shade variation)

Element	Details
Problem	Bulk shade variation causing rework and delayed lot approval.
Key tools used	Pareto analysis, SPC, fishbone analysis, 5 Whys and DOE.
Critical causes	Manual recipe variation, weak calibration discipline, inconsistent loading ratio.
Main actions	Recipe standardization, pH/temperature calibration, DOE-based optimization, revised SOP
Key outcome	Large reduction in shade-related defects and improved first-pass yield.

Case study 2: Skipped stitches in shirt assembly

The second case concerns a shirt-manufacturing line facing recurring skipped stitches and open seams. Although the defect percentage was lower than dyeing-related defects, its customer impact was severe because seam failure directly affects garment durability. The line produced basic woven shirts for export, and defects were often detected only at final inspection or by buyers during post-delivery evaluation.

A cross-functional team collected data on machine type, operator, style change, line speed and defect occurrence. The Analyze phase showed that high-speed operation, inconsistent needle-to-thread matching, delayed needle replacement and operator fatigue were the leading contributors. FMEA rated skipped stitches as a high-priority risk with an RPN of 240. In response, the factory introduced digital tension checks, line-level needle-change discipline, operator refresher training and roving inline audits. The result was a sharp decline in seam-related complaints and a smoother sewing-line flow with lower rework burden (Table 8).

Table 8 : Summary of case study 2 (shirt assembly sewing defects)

Element	Details
Problem	Skipped stitches and open seams in export shirt assembly.
Key tools used	Process mapping, fishbone analysis, FMEA and control plan.
Critical causes	Needle wear, tension drift, speed-pressure imbalance and operator skill variation.
Main actions	Needle policy, tension verification, refresher training and inline quality checks
Key outcome	Lower seam-related defects, reduced repair load and better line stability.

Case study 3: Knitting-floor defect reduction

The third case is based on the logic of knitting-floor quality improvement described in recent literature. A knitting unit faced defects such as barre, hole, oil marks and GSM inconsistency. The quality team classified defects by frequency and severity and used DMAIC to target the highest contributors. The Define and Measure stages focused on defect coding and reliable recording, because the factory previously used inconsistent terminology across shifts.

The Analyze phase linked the top defects to machine-cleaning routines, feeder settings, yarn quality and preventive maintenance discipline. Improvement actions included cleaning schedules, operator checklists, feeder recalibration and better incoming-yarn verification. Control was maintained through machine-wise dashboards and regular review meetings. This case illustrates that even in technically different textile operations, the Lean Six Sigma logic remains transferable: clear defect coding, root-cause isolation, disciplined corrective action and control-oriented documentation (Table 9 and Fig. 9).

Fig. 9 : Illustrative improvement timeline for the textile case studies

Table 9 : Summary of case study 3 (knitting-floor defects)

Element	Details
Problem	Barre, hole, oil mark and GSM-related fabric defects on the knitting floor.
Key tools used	Defect coding, Pareto analysis, DMAIC review and preventive-control logic.
Critical causes	Machine cleanliness, feeder setting drift, raw-material inconsistency, weak maintenance routines.
Main actions	Cleaning schedules, feeder recalibration, yarn verification and review meetings.
Key outcome	Lower defect burden, improved stability and stronger machine-wise accountability

RESULTS AND DISCUSSION

The central case results are summarized in Fig. 10 and 11 and in Table 10. The defect rate decreased from 8.0% to 1.8%, first-pass yield increased from 80% to 95%, and the rework index fell from 100 to 40. These changes represent a practical improvement pattern that is meaningful to factory management: more output passes correctly the first time, fewer garments or lots require correction, and inspection resources can be shifted from sorting to prevention.

The cost-of-poor-quality profile suggests that rework

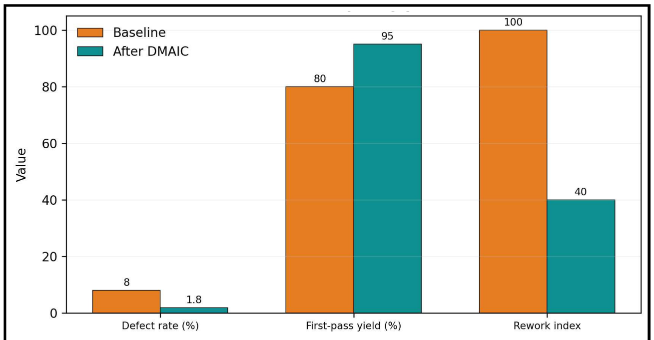

Fig. 10 : Before-and-after quality performance in the textile case

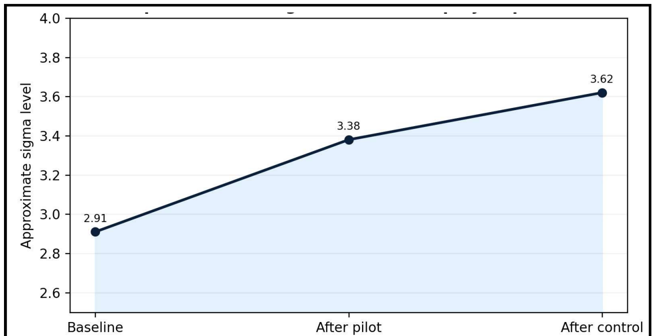

Fig. 11 : Improvement in sigma level across project phases

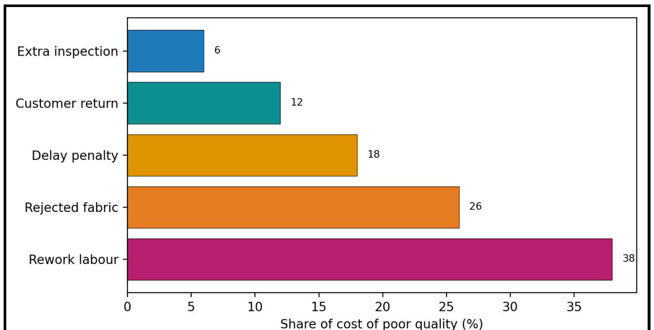

Fig. 12 : Illustrative cost-of-poor-quality profile

Table 10 : Key performance indicators before and after DMAIC intervention

Indicator	Baseline	Post-improvement	Interpretive note
Overall defect rate	8.0%	1.8%	Represents a 77.5% relative reduction in defects.
First-pass yield	80%	95%	Improves throughput and reduces sorting/rework needs.
Rework index	100	40	Represents a 60% decrease in rework intensity.
Approximate sigma level	2.91	3.62	Shows improved process capability under one-opportunity assumption.
Shade-related defects	96 counts	Markedly reduced	Primary gain achieved through dyeing-process control.
Seam-related defect burden	89 counts combined	Reduced after control	Improvement supported by FMEA and inline checks.

Table 11 : Standards and frameworks relevant to the revised research paper

Standard / framework	Relevance in the textile case
ISO 9001:2015	Provides the process approach, risk-based thinking, documented information and continual-improvement logic.
ISO 13053-1:2011	Supports the DMAIC project sequence used in the paper.
ISO 13053-2:2011	Supports the selection and use of Six Sigma tools and techniques.
ISO 7870-1:2019	Supports control-chart principles used in the SPC discussion.
ISO 2859-1:2026	Relevant to AQL-based acceptance sampling and lot-release decision making.
BIS / Indian quality practice	Provides contextual relevance for implementation in Indian textile operations.

labour and rejected fabric are the largest economic drains. This is consistent with textile operations, where defective lots consume labour twice: first during production and again during correction or replacement. Once the major defects are reduced, hidden cost savings emerge through shorter lead time, reduced inspection congestion and improved schedule adherence. These benefits are not always fully visible in basic defect metrics but can be strategically significant.

The approximate improvement in sigma level from 2.91 to 3.62 should be interpreted cautiously. In textile practice, sigma values depend on how opportunities are defined. A garment may have multiple defect opportunities; a dyed lot may have multiple critical parameters; and a fabric roll may be judged under a point-based inspection system. Nonetheless, the movement in sigma level remains useful as a directional indicator of improvement. What matters most is that the project achieved a more predictable and disciplined process.

The results also confirm the value of combining tools rather than using them in isolation. Pareto analysis helped choose the improvement priority; SPC monitored stability; fishbone analysis and the 5 Whys identified root causes; DOE optimized process settings; and FMEA converted quality concerns into risk priorities. This integrated approach is more powerful than isolated tool deployment because it aligns diagnosis, action and control within one improvement logic.

Standards Alignment and Quality-System Relevance

Although the manuscript focuses on Six Sigma tools, its value increases when these tools are interpreted through a quality-management-system lens. ISO 9001 emphasizes the process approach, documented information, competence, monitoring, nonconformity control and continual improvement. These principles are clearly relevant to textile quality projects. A Six Sigma initiative that is not linked to standard operating procedures, record control and management review may deliver only temporary gains. ISO 13053 provides a recognized structure for DMAIC and associated tools, while ISO 7870 guides control-chart logic and ISO 2859-1 informs acceptance sampling decisions during lot release.

In educational settings, this standards alignment is important because it connects statistical problem solving with broader professional practice. In industrial settings, it ensures that improvements become part of the quality system rather than remaining limited to one project team. The revised paper therefore positions Lean Six Sigma not as a separate discipline but as a strong operational arm of textile quality assurance.

Managerial Implications

Several managerial implications emerge from the revised analysis. First, textile organizations should select projects using a combination of defect frequency, customer impact and cost implication. Second, defect data must be standardized. Factories often lose improvement potential because similar defects are coded differently by departments or shifts. Third, training matters: operators, quality auditors and supervisors must understand why data are collected and how process changes will be sustained. Fourth, digital monitoring should be pursued where feasible. Even small textile SMEs can benefit from low-cost dashboards, calibration logs and machine-wise review sheets. Finally, improvement must be linked to management review; otherwise, gains will erode when production pressure rises.

These managerial implications are particularly relevant for export-oriented textile units, where delivery reliability and buyer confidence matter as much as internal efficiency. A process that reduces defects but does not improve lot-release discipline or schedule adherence may still underperform strategically. Lean Six

Sigma projects should therefore be connected to operational KPIs, customer complaints, delay penalties and cost-of-poor-quality metrics.

For practitioners, the most important lesson is straightforward: improvement begins with honest data. Operators should not be afraid to report defects, inspectors should use common definitions, and supervisors should treat variation as a signal for learning rather than blame. This human side of Lean Six Sigma is often overlooked, yet it is the part that determines whether a project survives after the consultant, trainer, or project champion leaves the factory.

Limitations and Future Research

The revised paper remains case-based and demonstrative in nature. Although the analytical sequence is rigorous and supported by the literature, broader statistical generalization would require detailed raw data from multiple factories, including longer time-series observations, machine-wise comparisons and validated financial accounting of savings. The present results should therefore be treated as a strong methodological illustration rather than a multi-site empirical test.

Future research can extend this work by integrating real-time sensor data, spectrophotometric records, machine learning for defect prediction, and capability analysis across different textile processes. Comparative studies between mills with manual versus digital data capture would also be useful. Another promising direction is to examine how Six Sigma projects interact with sustainability metrics such as water use, dyestuff consumption and waste generation.

Conclusion

This revised paper converts the original draft into a more coherent and journal-ready manuscript by improving the flow of argument, adding original visuals, incorporating three appropriate case studies, strengthening tables, aligning the method with standards, and using a tighter 2016-2026 scholarly foundation. The analysis shows that Lean Six Sigma is most useful in textiles when it is treated not as a collection of isolated tools, but as a disciplined learning system that connects measurement, root-cause thinking, experimentation, corrective action, and sustained control.

The central case demonstrates an improvement from an 8.0% defect rate to 1.8%, a first-pass yield increase from 80% to 95%, a 60% reduction in rework and an approximate rise in sigma level from 2.91 to 3.62. Beyond these numbers, the paper highlights a wider lesson: the strongest textile-improvement projects are those that combine statistical tools with SOP discipline, training, standards awareness and management review. This combination is essential if textile manufacturers are to remain competitive in an increasingly demanding global environment.

Acknowledgement

The authors acknowledge the contribution of textile quality professionals, garment technicians, dyeing supervisors, testing personnel and academic colleagues whose practical insights continue to inform applied research in textile production and quality assurance.

Declaration of interest

The authors declare that they have no conflict of interest. This revised manuscript was prepared for academic and educational use and did not receive external funding.

Data availability statement

The figures, tables and numerical values used in this paper are intended to illustrate the application of Six Sigma tools in a textile context. A final empirical journal submission should append or archive the raw production data, defect logs, inspection sheets, test reports and intervention records used to generate such results.

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