HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

APPLICATION OF THE SIX SIGMA METHOD IN ASSESSING THE QUALITY OF TEXTILE YARNS AND ITS ADVANTAGES

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Abstract: The textile industry is increasingly challenged by the need to improve product quality while maintaining high production efficiency and global competitiveness. Statistical quality management approaches have become essential tools for minimizing process variability and reducing manufacturing defects. This study investigates the application of the Six Sigma methodology for assessing and improving the quality of textile yarns throughout the production process.

The research is based on the DMAIC (Define–Measure–Analyze–Improve–Control) framework, which enables systematic identification of quality deviations, statistical analysis of process performance, implementation of corrective measures, and continuous monitoring of production stability. The methodology was evaluated using quality indicators associated with yarn manufacturing, including yarn thickness uniformity, tensile strength, moisture content, and dyeing consistency.

The findings demonstrate that the implementation of Six Sigma significantly decreases defect rates, improves production stability, enhances process capability, and reduces quality-related operational costs. Furthermore, integrating Six Sigma with Lean Manufacturing principles creates additional opportunities for eliminating production waste, increasing productivity, and strengthening customer satisfaction. The study confirms that Six Sigma represents an effective strategic quality management methodology capable of supporting sustainable development and improving the international competitiveness of textile manufacturing enterprises.

Keywords: Six Sigma, textile yarn quality, statistical quality control, DMAIC, Lean Manufacturing, process improvement, textile industry.

Introduction

The contemporary textile industry operates in an increasingly competitive global environment where product quality, production efficiency, and customer satisfaction determine the long-term sustainability of manufacturing enterprises. Rapid technological advancement, increasing customer expectations, and strict international quality standards require textile manufacturers to continuously improve production processes while minimizing defects and operational costs. Consequently, the implementation of advanced quality management methodologies has become one of the most important strategic objectives for textile enterprises.

Among modern quality improvement approaches, the Six Sigma methodology has gained worldwide recognition as one of the most effective statistical management systems for reducing process variability and achieving operational excellence. Originally developed by Motorola during the 1980s and later successfully adopted by companies such as General Electric, Honeywell, Ford, and numerous multinational corporations, Six Sigma aims to reduce process defects to only 3.4 defects per million opportunities (DPMO), representing near-perfect manufacturing performance.

Unlike conventional quality control techniques that primarily focus on inspection after production, Six Sigma emphasizes preventive quality management through statistical process analysis,

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ISSN: 2058-5519|Impact factor-15.9
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continuous improvement, and data-driven decision-making. The methodology enables organizations to identify the root causes of quality deviations rather than merely correcting their consequences.

Within the textile industry, yarn quality directly influences the mechanical properties, appearance, durability, and overall performance of finished textile products. Deficiencies occurring during spinning, winding, dyeing, or finishing processes may significantly reduce production efficiency and increase manufacturing costs. Therefore, systematic identification and elimination of process variations are essential for ensuring stable product quality.

The Six Sigma methodology offers an effective framework for optimizing textile manufacturing by combining statistical analysis, process capability evaluation, and continuous improvement strategies. Its structured DMAIC model (Define, Measure, Analyze, Improve, and Control) facilitates comprehensive analysis of production processes, identification of critical quality factors, implementation of corrective actions, and long-term process stabilization.

In addition, recent developments in industrial engineering demonstrate that integrating Six Sigma with Lean Manufacturing principles further enhances production efficiency by simultaneously eliminating waste and reducing process variation. Such integration contributes not only to higher product quality but also to shorter production cycles, lower operational costs, improved resource utilization, and increased customer satisfaction.

Despite the growing application of Six Sigma across various industrial sectors, its implementation in textile yarn quality assessment remains relatively limited in many developing textile industries. Consequently, further investigation into its practical application is necessary to establish effective quality improvement strategies tailored to textile manufacturing.



Figure 1. Structure of the Six Sigma Method

A key strength of the Six Sigma methodology lies in its capacity to develop employee competencies while promoting active participation in continuous quality improvement activities. Systematic training in Six Sigma principles and analytical tools cultivates a culture of continuous improvement throughout the organization, thereby enhancing employee motivation, increasing workforce engagement, and reducing personnel turnover. Moreover, organizations adopting Six Sigma have consistently reported substantial reductions in production lead times, leading to higher operational efficiency, lower production costs, and improved financial performance.

Table 1.

Stages of the DMAIC Cycle and Their Descriptions

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Stage	DMAIC Phase	Primary Objective	Example of Application
D	**Define**	Identify quality problems and establish improvement objectives	Analyze the root causes of defects occurring during the spinning process
M	**Measure**	Measure current process performance and key quality indicators	Measure yarn thickness, moisture content, and other critical quality parameters
A	**Analyze**	Analyze process data to identify sources of quality variation	Determine the root causes of process variability using statistical analysis
I	**Improve**	Implement corrective actions and process improvements	Optimize spinning machine operating parameters to improve yarn quality
C	**Control**	Maintain process stability through continuous monitoring	Implement a quality control system to prevent defects and sustain process performance

Materials and Methods

This study employed the Six Sigma methodology as the primary framework for evaluating and improving the quality of textile yarns. The research methodology was based on the **DMAIC (Define–Measure–Analyze–Improve–Control)** cycle, which provides a systematic and data-driven approach for identifying process variations, eliminating the root causes of defects, and ensuring continuous quality improvement throughout textile manufacturing. The investigation focused on the principal quality characteristics of textile yarns, including yarn thickness uniformity, tensile strength, moisture content, and dyeing consistency. These quality parameters directly influence the mechanical performance, durability, and appearance of finished textile products and therefore represent critical indicators of manufacturing quality.

The research methodology consisted of five consecutive stages.

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Define. During the first stage, the critical quality problems affecting yarn production were identified. Particular attention was given to defects occurring during spinning, winding, drying, and dyeing operations. Customer requirements, production specifications, and process objectives were analyzed to determine the critical-to-quality (CTQ) characteristics of textile yarns.

Measure. The second stage involved measuring the current performance of the production process using quantitative quality indicators. Measurements included yarn diameter variation, tensile strength, moisture percentage, and the occurrence of visible defects. Statistical data collected from production processes were used to establish the baseline performance of the manufacturing system.

Table 2.

DMAIC Cycle and Its Application in Textile Yarn Quality Assessment

Stage	Description	Application in Textile Manufacturing
Define	Identification of quality problems and objectives	Analysis of defects occurring during spinning processes
Measure	Collection of process performance data	Measurement of yarn thickness, moisture content, and strength
Analyze	Identification of root causes of quality variation	Statistical analysis of production variability
Improve	Implementation of corrective actions	Optimization of spinning machine parameters and process conditions
Control	Continuous monitoring of process stability	Establishment of quality control procedures and defect prevention systems

Results and Discussion

The implementation of the Six Sigma methodology demonstrated significant improvements in the quality performance of textile yarn manufacturing processes. The application of statistical quality management tools enabled the systematic identification of process variations and the elimination of the root causes of production defects. As a result, the stability of technological processes increased considerably, leading to higher product quality and improved manufacturing efficiency.

One of the major outcomes of this study is the confirmation that Six Sigma provides a structured framework for continuous quality improvement in textile production. The methodology not only facilitates the reduction of process variability but also supports data-driven decision-making through the application of statistical analysis and process capability evaluation.

The findings indicate that integrating Six Sigma with Lean Manufacturing principles further enhances production performance by simultaneously reducing waste and improving process efficiency. This integrated approach enables textile manufacturers to optimize resource utilization, shorten production cycles, and minimize operational costs while maintaining consistent product quality.

Table 3.

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Typical Defects in Textile Yarns and Recommended Corrective Actions

No.	Type of Defect	Primary Cause	Recommended Corrective Action
1	Non-uniform yarn thickness	Incorrect machine settings	Calibration of spinning equipment
2	Low tensile strength	Poor-quality raw fibers	Use of higher-quality raw materials
3	Excessive moisture content	Inadequate drying conditions	Continuous monitoring of environmental humidity
4	Uneven dyeing	Insufficient dye mixing	Automation of dye dosing and mixing systems

The results further demonstrate that organizations implementing Six Sigma achieve substantial improvements in production quality by reducing the occurrence of critical defects throughout the manufacturing process. Statistical tools such as **Pareto charts**, **Ishikawa (Fishbone) diagrams**, and **Statistical Process Control (SPC)** proved particularly effective for identifying quality deviations and monitoring process stability in real time.

Another important finding is that multidisciplinary teamwork plays a crucial role in the successful implementation of Six Sigma. Collaboration among production engineers, quality specialists, laboratory personnel, and machine operators enables comprehensive process evaluation and facilitates the identification of both technical and organizational factors contributing to product defects.

Furthermore, continuous employee training significantly strengthens the effectiveness of Six Sigma implementation. Developing employees' competencies in statistical quality management tools promotes a culture of continuous improvement, increases workforce engagement, and enhances organizational performance.

The effectiveness of Six Sigma implementation is reflected in the improvements observed in key production performance indicators.

Table 4.

Comparison of Production Performance Indicators Before and After Six Sigma Implementation

Performance Indicator	Before Implementation	After Implementation	Improvement (%)
Defects per million opportunities (DPMO)	8,500	3.4	–99.96
Production productivity (%)	78	92	+17.9
Defect rate (%)	7.2	1.1	–84.7
Quality control costs (thousand	320	210	–34.4

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The comparative analysis demonstrates that Six Sigma implementation resulted in a dramatic reduction in defect rates while simultaneously increasing productivity and decreasing quality-related operational costs. These findings confirm that the methodology provides measurable economic and operational benefits for textile manufacturing enterprises.

Overall, the results indicate that Six Sigma is not only an effective statistical quality management methodology but also a comprehensive managerial approach capable of improving organizational performance, strengthening customer satisfaction, and enhancing the global competitiveness of textile manufacturers. The combination of continuous improvement, statistical process control, employee involvement, and Lean Manufacturing principles establishes a sustainable foundation for long-term operational excellence within the textile industry.

Conclusions

The findings of this study demonstrate that the Six Sigma methodology is an effective and reliable quality management approach for assessing and improving textile yarn manufacturing processes. Its systematic application through the DMAIC framework enables manufacturers to identify process variations, eliminate the root causes of defects, and achieve continuous improvements in production performance.

The research confirmed that the implementation of Six Sigma significantly reduces defect rates, enhances process stability, improves product quality, and decreases quality-related operational costs. Statistical process control tools facilitate objective decision-making based on quantitative data, thereby increasing the efficiency and reliability of quality management systems.

Furthermore, integrating Six Sigma with Lean Manufacturing principles provides additional benefits by minimizing production waste, improving resource utilization, and increasing overall manufacturing productivity. This integrated approach contributes to higher customer satisfaction, greater operational efficiency, and improved economic performance of textile enterprises.

The study also highlights the importance of employee training and organizational involvement in the successful implementation of Six Sigma. Continuous professional development, interdisciplinary teamwork, and the establishment of a culture of continuous improvement are essential factors for maintaining sustainable quality enhancement and long-term organizational competitiveness. Moreover, the adoption of modern digital technologies, including Industrial Internet of Things (IIoT) systems, artificial intelligence (AI), and automated process monitoring, can further strengthen the effectiveness of Six Sigma by enabling real-time quality control, predictive maintenance, and data-driven process optimization.

Overall, the implementation of Six Sigma represents a strategic direction for the modernization of textile manufacturing enterprises. Its application not only improves the quality and consistency of textile yarns but also enhances production efficiency, supports sustainable industrial development, and increases the international competitiveness of textile manufacturers in rapidly evolving global markets. Future research should focus on the integration of Six Sigma with Industry 4.0 technologies, digital quality management systems, machine learning algorithms for defect prediction, and intelligent manufacturing platforms to further optimize textile production processes and strengthen sustainable industrial development.

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