

APPLICATION OF TPM AND REFA METHODS FOR IMPROVING  
OPERATIONAL EFFICIENCY IN UZBEKISTAN'S TEXTILE INDUSTRY

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**Annotatsiya:** Mazkur maqolada O‘zbekiston to‘qimachilik korxonalarida operatsion samaradorlikni oshirishda Total Productive Maintenance (TPM) va REFA metodologiyalarini qo‘llash imkoniyatlari tahlil qilingan. Tadqiqot ushbu metodlarning uskunalarning ishonchligini oshirish, mehnat unumdorligini yaxshilash va ishlab chiqarish jarayonlarini optimallashtirishdagi ahamiyatini baholaydi. Natijalar TPM va REFA metodlarini kompleks joriy etish korxonalarining raqobatbardoshligini oshirishga xizmat qilishini ko‘rsatadi.

**Kalit so‘zlar:** TPM, REFA, to‘qimachilik sanoati, operatsion samaradorlik, mehnat unumdorligi, mehnatni me‘yorlash, O‘zbekiston.

**Аннотация.** В статье рассматриваются возможности применения методологий Total Productive Maintenance (TPM) и REFA для повышения операционной эффективности текстильных предприятий Узбекистана. Исследование оценивает их влияние на повышение надежности оборудования, производительности труда и оптимизацию производственных процессов. Результаты показывают, что комплексное внедрение TPM и REFA способствует росту эффективности и конкурентоспособности предприятий.

**Ключевые слова:** TPM, REFA, текстильная промышленность, операционная эффективность, производительность труда, нормирование труда, Узбекистан.

**Abstract.** This article examines the application of Total Productive Maintenance (TPM) and the REFA methodology to improve the operational efficiency of textile enterprises in Uzbekistan. The study evaluates their impact on equipment reliability, labor productivity, and process optimization. The findings indicate that the integrated implementation of TPM and REFA can enhance production efficiency and strengthen the competitiveness of textile enterprises.

**Keywords:** TPM, REFA, textile industry, operational efficiency, productivity, work measurement, Uzbekistan.

**Introduction.** The textile industry is one of the strategic sectors of Uzbekistan's economy, representing a significant share of industrial production, exports, and employment. In recent years, considerable investments have been made in modern

spinning, weaving, dyeing, and garment manufacturing facilities. However, many enterprises continue to experience production losses caused by equipment downtime, inefficient labor organization, non-standardized work procedures, and insufficient maintenance planning.

In highly industrialized countries, particularly Germany and Japan, these challenges are successfully addressed through systematic implementation of Lean Manufacturing methodologies. Among the most effective approaches are Total Productive Maintenance (TPM), which focuses on maximizing equipment effectiveness through preventive maintenance and employee involvement, and the REFA methodology, a German system for work measurement, labor standardization, and process optimization.

Unlike many lean tools that primarily target waste elimination, TPM and REFA simultaneously improve the technical and organizational dimensions of production. Their integration enables enterprises to reduce machine failures, optimize labor utilization, increase productivity, improve product quality, and establish a culture of continuous improvement. Although Uzbek textile enterprises have actively invested in modern equipment, the implementation of systematic maintenance management and scientific work measurement remains limited. Therefore, studying the applicability of TPM and REFA under the conditions of Uzbekistan holds both scientific and practical importance<sup>1</sup>.

The objective of this study is to analyze the principles of TPM and REFA methodologies, evaluate their applicability in Uzbekistan's textile enterprises, and propose an integrated implementation model aimed at improving operational efficiency and product quality.

### **Research Framework.**

The textile industry is characterized by complex production processes that require the continuous interaction of machinery, human resources, and production management systems. Operational problems such as equipment failures, production interruptions, labor inefficiencies, and inconsistent quality often occur simultaneously and cannot be effectively solved through isolated improvement initiatives. Therefore, an integrated management approach is required to address both technical and organizational aspects of production.

In this study, Total Productive Maintenance (TPM) is considered as the primary methodology for improving equipment reliability, reducing unplanned downtime, and increasing overall equipment effectiveness. At the same time, the REFA methodology provides systematic tools for work measurement, labor standardization, process

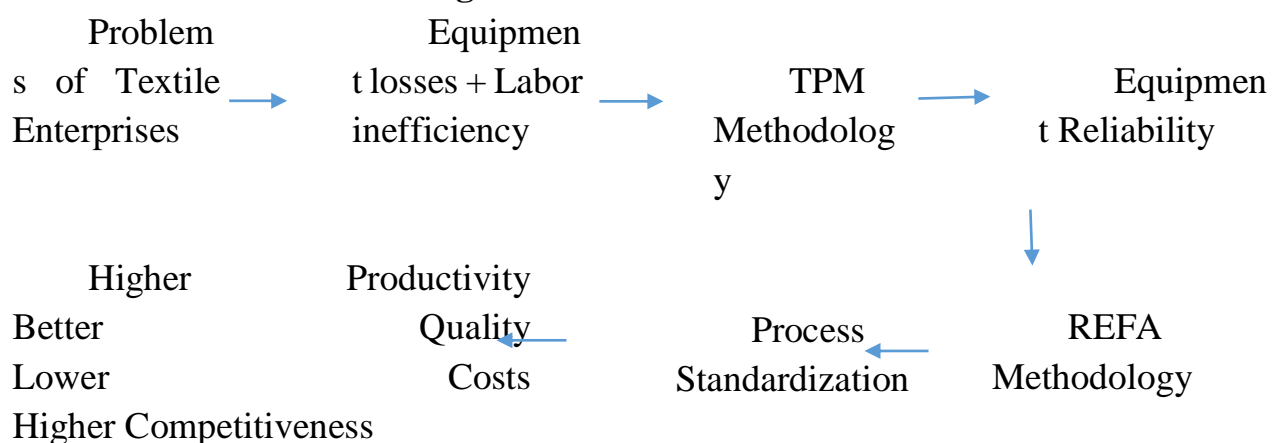
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<sup>1</sup> Wickramasinghe, G. L. D., & Perera, A. (2016). Effect of total productive maintenance practices on manufacturing performance: Investigation of textile and apparel manufacturing firms. *Journal of Manufacturing Technology Management*, 27(5), 713–729.

analysis, and optimization of human resources. The combination of these two approaches creates a comprehensive framework for improving both production technology and labor organization.

To systematically investigate the potential of TPM and REFA methodologies for improving the operational performance of Uzbekistan's textile enterprises, a conceptual research framework was developed (Figure 1). The framework reflects the logical sequence of the study and illustrates the relationship between the key production challenges, the selected management methodologies, and the expected operational outcomes. It serves as the theoretical basis for analyzing how technical maintenance and scientific work organization can jointly contribute to enhancing production efficiency.

**Figure 1. Research Framework<sup>2</sup>**



The proposed research framework presented in Figure 1 summarizes these relationships and demonstrates the conceptual logic of the study. The research framework illustrates the conceptual relationship between the operational challenges faced by textile enterprises and the proposed management solutions. Production inefficiencies, such as equipment failures and labor losses, represent the initial problems affecting firm performance. These issues are addressed through the implementation of Total Productive Maintenance (TPM), which focuses on improving equipment reliability and reducing unplanned downtime. Afterwards, the REFA methodology contributes to the scientific organization of labor by analyzing work processes, establishing labor standards, and optimizing production operations. The integration of these two approaches ultimately leads to higher productivity, improved product quality, lower operational costs, and increased competitiveness of textile enterprises. The framework demonstrates that sustainable operational excellence requires simultaneous improvement of both technical systems and labor organization<sup>3</sup>.

**TPM Methodology for Textile Enterprises.** Total Productive Maintenance

<sup>2</sup> Applications of Lean Manufacturing in the Textile Garments Industry. (2026). International Journal of Advanced Manufacturing Technology. Springer Nature.

<sup>3</sup> Hochschule Albstadt-Sigmaringen. (2025). Tex-Lab: Research and Textile Laboratories.

(TPM) is one of the fundamental methodologies of Lean Manufacturing aimed at maximizing equipment effectiveness through preventive maintenance, employee involvement, and continuous improvement. Unlike traditional maintenance systems that primarily respond to equipment failures after they occur, TPM emphasizes preventing failures before they happen. This proactive approach enables enterprises to minimize production interruptions, reduce maintenance costs, improve product quality, and extend equipment service life.

The TPM philosophy was originally developed in Japan and has since become an essential element of operational excellence in many European manufacturing companies, particularly in Germany. German industrial enterprises apply TPM as an integrated management system that combines engineering practices, standardized maintenance procedures, operator responsibility, and data-driven decision-making. The methodology has demonstrated significant improvements in Overall Equipment Effectiveness (OEE), machine reliability, and production stability across various manufacturing sectors<sup>4</sup>.

For textile enterprises, TPM is particularly important because production processes are highly dependent on the continuous operation of technologically interconnected equipment. A failure in one production stage, such as spinning or weaving, often disrupts the entire production flow, causing delays, increased costs, and quality problems. Consequently, preventive maintenance becomes a strategic component of production management rather than merely a technical support function.

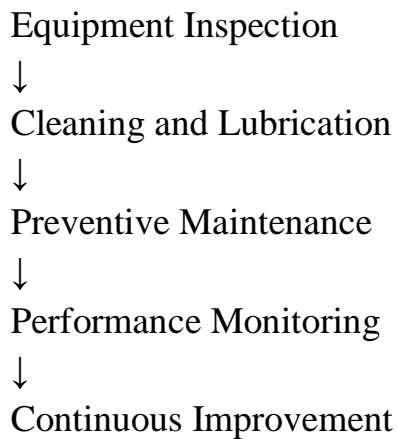
The implementation of TPM requires cooperation between machine operators, maintenance personnel, production managers, and quality specialists. Operators are encouraged to participate actively in routine inspections, cleaning, lubrication, and early detection of abnormalities. Maintenance engineers focus on preventive and predictive maintenance activities, while management establishes performance indicators and provides continuous training. Such collaboration creates a culture where equipment reliability becomes the responsibility of every employee rather than only a technical support function.

So, how companies should use TPM on their manufacture. We can see the figure 2, where illustrated the continuous operational cycle of Total Productive Maintenance within textile enterprises.

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<sup>4</sup> Nakajima, S. (1988). Introduction to Total Productive Maintenance (TPM). Productivity Press.

**Figure 2. TPM Methodology for Textile Enterprises<sup>5</sup>**



The process begins with regular equipment inspection, during which operators identify visible abnormalities before they develop into serious failures. Routine cleaning and lubrication reduce mechanical wear and improve machine stability. Preventive maintenance activities are then scheduled according to operating hours and technical recommendations rather than after breakdowns occur. Equipment performance is continuously monitored using operational indicators such as downtime, defect rates, and production efficiency. The final stage focuses on continuous improvement, where maintenance results are analyzed to identify opportunities for further optimization. The cyclic nature of the model reflects the fundamental TPM principle that maintenance is an ongoing process rather than an isolated activity.

Textile production involves several technologically linked stages, including fiber preparation, spinning, weaving, dyeing, finishing, and garment manufacturing. Because each production stage depends on the stable operation of specialized machinery, equipment failures can quickly propagate throughout the production chain. During spinning operations, unstable spindle rotation may reduce yarn quality and increase breakage rates. In weaving departments, loom stoppages disrupt production schedules and lower equipment utilization. Dyeing machines require precise temperature and pressure control, while sewing equipment demands consistent mechanical accuracy to maintain product quality.

TPM addresses these challenges through systematic maintenance planning, standardized inspection procedures, operator training, and performance monitoring. Daily autonomous maintenance performed by machine operators allows minor abnormalities to be detected before they develop into major failures. Planned maintenance conducted by technical specialists further reduces unexpected downtime and improves equipment reliability.

The methodology also contributes to higher production quality. Machines

<sup>5</sup> Gesamtmasche & Hochschule Albstadt-Sigmaringen. (2024). Training Concept for Sustainability in the Textile Industry.

operating under stable technical conditions produce more consistent yarn thickness, fabric density, color uniformity, and sewing accuracy. Consequently, enterprises experience lower rejection rates, improved customer satisfaction, and decreased production costs.

**Figure 3. TPM Application Across Textile Production Stages<sup>6</sup>**



This demonstrates how TPM supports each stage of textile production. Preventive maintenance begins with spinning equipment, where stable machine operation ensures consistent yarn quality. During weaving, properly maintained looms reduce stoppages and increase production speed. Dyeing equipment benefits from accurate process control, minimizing color variations and chemical waste. In garment production, regular maintenance improves sewing precision and reduces machine failures. Finally, stable equipment performance contributes directly to improved product quality during final inspection. The figure emphasizes that TPM is not limited to maintenance activities but supports the entire production value chain.

The implementation of TPM generates measurable improvements in several operational performance indicators. First, preventive maintenance significantly reduces equipment downtime by eliminating the primary causes of unexpected failures. Second, stable equipment operation increases production capacity because machines remain available for longer production periods. Third, consistent machine performance reduces process variability and improves product quality.

In addition, TPM enhances workplace safety by ensuring that equipment operates under suitable technical conditions. Employees become more involved through participation in autonomous maintenance activities, contributing to higher accountability and stronger teamwork. Although the implementation of TPM requires investments in employee training, maintenance scheduling, and performance tracking, international experience shows that these costs are typically offset by long-term improvements in productivity, quality, and equipment utilization<sup>7</sup>.

### **REFA Methodology for Textile Enterprises**

The REFA methodology is one of the most established German approaches to work organization, labor measurement, and production process optimization. Developed by the German Association for Work Design, Business Organization and Corporate Development (REFA), the methodology provides standardized techniques

<sup>6</sup> Gesamtmasche. (2019). Digital Textile Learning Factory at Albstadt-Sigmaringen University.

<sup>7</sup> Womack, J. P., & Jones, D. T. (2003). *Lean Thinking*. Free Press.

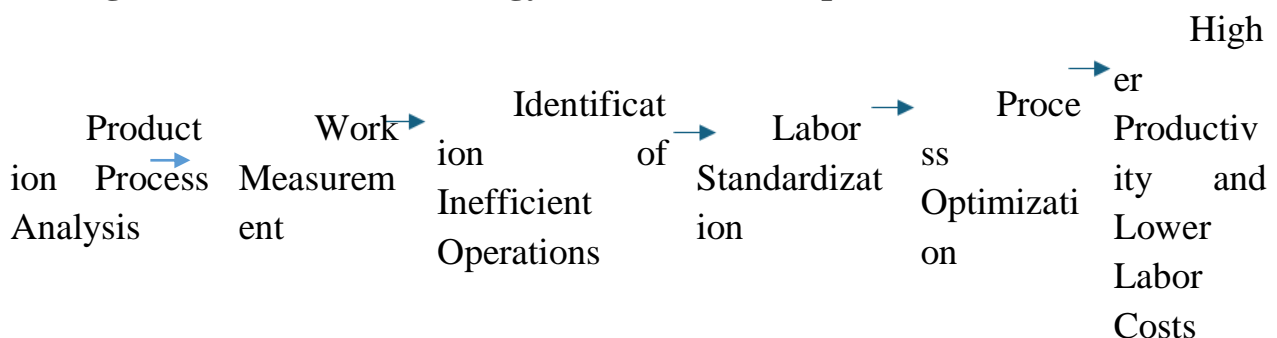
for analyzing production operations, determining labor standards, improving workplace organization, and raising overall production efficiency. Unlike maintenance-oriented management systems, REFA primarily focuses on optimizing human work and production processes by eliminating unnecessary activities, balancing workloads, and establishing scientifically justified work standards.

In textile manufacturing, production consists of numerous sequential operations performed by both machines and operators. Any imbalance between these operations creates waiting time, bottlenecks, excess labor costs, and reduced productivity. The REFA methodology systematically evaluates each production activity by measuring operation time, identifying non-value-added work, and improving process flow. As a result, enterprises achieve better utilization of both labor and equipment while maintaining consistent production quality.

The application of REFA is particularly relevant for Uzbekistan's textile industry, where many enterprises continue to rely on traditional labor organization methods. In spinning departments, REFA can optimize operator workload by determining the appropriate number of machines assigned to one employee and minimizing idle time during machine supervision. In weaving production, time studies help identify delays caused by material transportation, machine setup, or operator movements. Dyeing departments benefit from standardized operating procedures that reduce process variation and improve resource utilization. In garment manufacturing, REFA contributes to balancing sewing lines, reducing unnecessary movements, and establishing realistic production norms based on actual working conditions<sup>8</sup>.

The implementation of REFA generally follows several consecutive stages. The first stage involves observation and detailed analysis of production operations. The second stage consists of measuring operation times using standardized time-study techniques. The collected information is then analyzed to identify inefficient work elements and unnecessary activities. Based on these results, improved work methods and labor standards are developed. Finally, the optimized processes are continuously monitored and adjusted to maintain stable production performance.

**Figure 4. REFA Methodology for Textile Enterprises<sup>9</sup>**



<sup>8</sup> Gesamtmasche. (2019). Digital Textile Learning Factory at Albstadt-Sigmaringen University.

<sup>9</sup> Hochschule Albstadt-Sigmaringen. (2025). Research Focus: Sustainable Development, Smart Materials and Production Technologies (NESP).

We can see on the figure the logical sequence of the REFA methodology applied to textile enterprises. The process begins with a detailed analysis of production operations and continues with systematic work measurement to determine the actual duration of each task. Based on the collected data, inefficient activities, unnecessary movements, waiting time, and process interruptions are identified. The obtained results serve as the basis for establishing scientifically justified labor standards and improving work organization. The optimized production processes contribute to higher labor productivity, better utilization of production resources, improved production planning, and lower operating costs. The figure demonstrates that REFA creates a systematic framework for continuous improvement of labor organization throughout the entire textile production process.

### **Integrated TPM–REFA Model for Uzbekistan**

While TPM primarily focuses on improving equipment reliability and minimizing production downtime, REFA concentrates on optimizing labor organization and production processes. Since equipment efficiency and labor productivity are closely interconnected, the simultaneous implementation of both methodologies creates a comprehensive production management system capable of addressing both technical and organizational challenges.

For textile enterprises in Uzbekistan, where production efficiency is often limited by aging machinery, inconsistent maintenance practices, insufficient labor standardization, and production imbalances, integrating TPM and REFA offers significant opportunities for sustainable operational improvement. TPM ensures stable machine performance through preventive maintenance, operator involvement, and continuous equipment monitoring. REFA complements these improvements by optimizing work methods, balancing workloads, eliminating unnecessary operations, and establishing standardized production procedures.

The proposed integrated model follows a gradual implementation strategy suitable for enterprises with different levels of technological development. The process begins with management commitment and employee training to establish awareness of modern production management principles. TPM activities are then introduced to improve equipment availability and reduce unplanned breakdowns. After production stability has been achieved, REFA methods are applied to analyze labor processes, optimize workflows, and establish performance standards. Finally, continuous monitoring and improvement mechanisms ensure long-term sustainability of operational excellence.

The combined application of TPM and REFA creates multiple organizational benefits. Stable equipment operation reduces production interruptions, while optimized labor organization shortens production cycles and improves resource utilization.

Together, these improvements increase production capacity, enhance product quality, lower operational costs, and strengthen the international competitiveness of Uzbekistan's textile enterprises<sup>10</sup>.

**Figure 6. Comparative Contribution of TPM and REFA to Textile Enterprise Performance**

Performance Indicator	TPM	REFA	Integrated TPM-REFA
Equipment reliability	★★★★★	★★☆☆☆	★★★★★
Labor productivity	★★☆☆☆	★★★★★	★★★★★
Process standardization	★★★☆☆	★★★★★	★★★★★
Downtime reduction	★★★★★	★★☆☆☆	★★★★★
Production quality	★★★★☆	★★★★☆	★★★★★
Cost reduction	★★★★☆	★★★★☆	★★★★★
Overall competitiveness	★★★★☆	★★★★☆	★★★★★

Figure 6 compares the individual contributions of TPM and REFA to the operational performance of textile enterprises. TPM shows the strongest impact on equipment-related indicators, including equipment reliability and downtime reduction, due to its focus on preventive maintenance and continuous monitoring of production machinery. REFA, in contrast, yields greater improvements in labor productivity, process standardization, and work organization through scientific analysis of production activities and the establishment of standardized work methods.

The comparison indicates that neither methodology alone can fully address the complex operational challenges faced by textile enterprises. While TPM enhances the technical efficiency of production systems, REFA optimizes the human and organizational aspects of manufacturing. Their integration produces the highest level of performance across all evaluated indicators, resulting in improved product quality, reduced operating costs, and stronger international competitiveness. Therefore, the combined TPM-REFA approach represents the most comprehensive strategy for modernizing Uzbekistan's textile industry<sup>11</sup>.

**Conclusion**

This study demonstrates that the combined application of Total Productive Maintenance (TPM) and the REFA methodology offers a comprehensive approach to

<sup>10</sup> Imai, M. (2012). *Gemba Kaizen: A Commonsense Approach to Continuous Improvement Strategy*. McGraw-Hill.

<sup>11</sup> Liker, J. K. (2004). *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*. McGraw-Hill.

improving the operational performance of textile enterprises. Although these methodologies focus on different aspects of production management, they complement each other and contribute to the development of an efficient and sustainable manufacturing system. TPM enhances production stability by improving equipment reliability, reducing unexpected machine failures, and promoting preventive and autonomous maintenance. Regular monitoring of equipment conditions and active employee involvement support continuous production without unnecessary interruptions and contribute to consistent product quality<sup>12</sup>.

REFA complements TPM by improving the organization of labor and production processes. Through work measurement, standardized operating procedures, and process analysis, REFA enables enterprises to optimize workflow, eliminate non-value-added activities, and improve the utilization of human resources. As a result, production processes become more organized, transparent, and easier to manage.

The integration of TPM and REFA creates a balanced production management model that simultaneously improves equipment performance and labor efficiency. Such an approach supports continuous improvement, strengthens cooperation between management and employees, and promotes a culture of operational excellence throughout the enterprise<sup>13</sup>.

For Uzbekistan's textile industry, where enterprises are actively modernizing production and increasing their competitiveness in international markets, the implementation of TPM and REFA represents a practical and sustainable management solution. Successful implementation requires management commitment, employee training, standardized procedures, and continuous monitoring of production performance.

In conclusion, the integrated use of TPM and REFA provides a solid foundation for increasing production efficiency, improving product quality, optimizing resource utilization, and supporting the long-term sustainable development of textile enterprises in Uzbekistan<sup>14</sup>.

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