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(Research Article)

Enhancing Lean Performance through TPM–VSM Integration: A Case Study in Spare Parts Production

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Abstract

In today's highly competitive manufacturing landscape, achieving Lean Manufacturing Excellence is critical for maximizing efficiency, minimizing costs, and enhancing customer satisfaction. This study examines the strategic integration of Total Productive Maintenance (TPM) and Value Stream Mapping (VSM) to optimize spare parts production. TPM enhances equipment reliability through proactive maintenance, while VSM streamlines material and information flows to eliminate waste and improve process efficiency. Conducted in the machining process of an Egyptian spare parts manufacturing company, this research develops a robust framework leveraging advanced analytical and improvement methodologies. A data-driven case study quantifies the impact of TPM-VSM synergy, demonstrating significant performance gains. Over three months, implementation increased Total Effective Equipment Performance (TEEP) from 58% to 68%, improved Overall Equipment Effectiveness (OEE) from 65% to 76%, and elevated value-added process efficiency from 37% to 54%. These results validate the effectiveness of integrating Lean methodologies with proactive maintenance strategies to drive productivity, minimize waste, and sustain operational excellence. This study provides a practical framework for industry professionals seeking to foster continuous improvement, data-driven decision-making, and Lean-driven optimization in spare parts manufacturing.

Keywords: Productive maintenance, TPM, OEE, Value Stream Mapping, VSM, Lean Six Sigma, Continuous Improvement.

1. Introduction

Manufacturing excellence aims to maximize productivity, quality, and cost-effectiveness while minimizing waste and ensuring consistent, high-quality output. Lean manufacturing, a widely adopted strategy, focuses on waste elimination, value creation, and continuous improvement to enhance efficiency [26,27]. Total Productive Maintenance (TPM) and Value Stream Mapping (VSM) are key Lean tools that drive productivity gains by optimizing equipment performance and streamlining process flow [9,28,29]. TPM is a proactive maintenance approach that involves all employees in sustaining operational efficiency. It integrates with Total Quality Management (TQM) to achieve zero breakdowns, zero defects, and zero accidents [1,29]. TPM eliminates common inefficiencies, such as downtime, equipment failures, excessive inventory, and process delays [30]. A foundational element of TPM is the 5S methodology, which ensures a clean, organized, and efficient workspace [4,6]. The Japan Institute of Plant Maintenance (JIPM) introduced an eight-pillar TPM framework (Figure 1) to enhance process efficiency and effectiveness [33,55]. These pillars empower operators with greater equipment ownership, reducing unplanned downtime and defects while optimizing production processes [12,64,70]. TPM also addresses the Six Big Losses in manufacturing, categorizing inefficiencies into three primary areas: Availability Losses (equipment failures and setup delays), Performance Losses (idling, minor stoppages, and reduced speed), and Quality Losses (process defects and scrap) [4,30,41]. VSM is a Lean decision-making tool for visualizing, analyzing, and optimizing material and information flow. By distinguishing value-added (VA) from non-value-added (NVA) activities, VSM helps manufacturers eliminate waste, shorten lead times, and improve efficiency [11,16]. The VSM process involves four key steps: Current State Mapping, which identifies inefficiencies and delays; Bottleneck Identification, which highlights waste sources such as excessive inventory and unnecessary movements; Future State Mapping, which designs an optimized workflow; and Lean Implementation, applying tools like Kanban, 5S, and Single-Minute Exchange of Dies (SMED) to improve process flow [15,30,58]. A future state VSM (Figure 2) helps eliminate bottlenecks and enhance overall system performance. This study evaluates the strategic impact of integrating TPM and VSM in enhancing manufacturing productivity and reliability. This research is organized as follows: Section 2 presents the literature review, Section 3 discusses the research gap analysis, Section 4 explains the methodology, Section 5 explains the case study in detail,

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Section 6 discusses the results, and Section 7 presents the conclusions and future research directions.

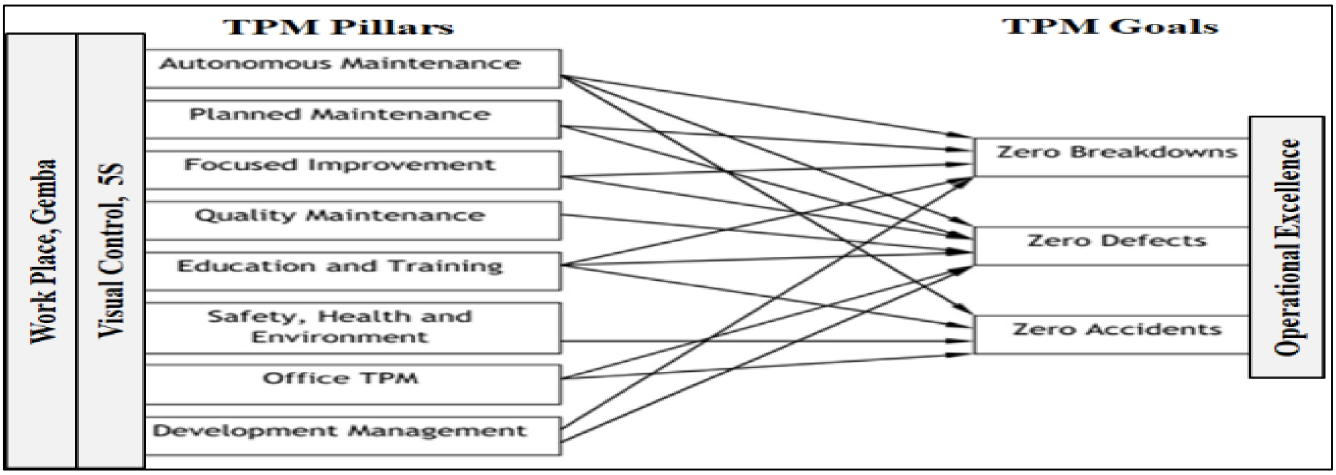

Figure 1. TPM pillars and goals

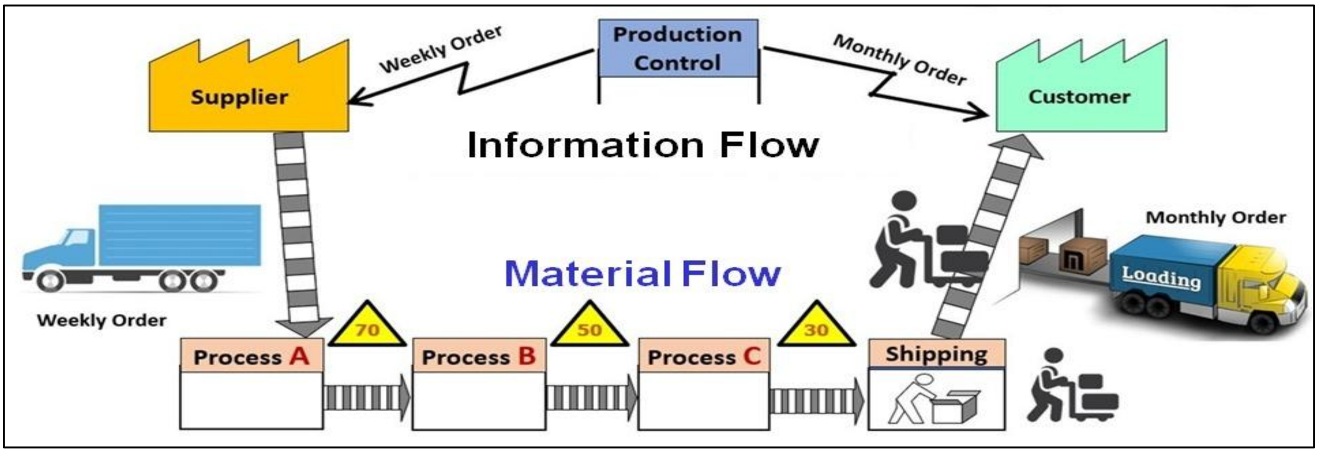

Figure 2. The main element of the VSM diagram

2. Literature Review

Continuous improvement in production processes is essential for achieving high efficiency, superior quality, and cost reduction. Lean manufacturing has emerged as a transformative methodology that optimizes industrial operations by eliminating waste and enhancing value creation. A comprehensive literature review was conducted to establish relevant theoretical foundations for this research [20,32,61].

2.1 Critical review of total productive maintenance: Total Productive Maintenance (TPM) is a holistic approach aimed at achieving operational excellence by minimizing breakdowns, defects, and delays. It focuses on proactive and preventive maintenance strategies to enhance equipment reliability and production efficiency [23,24,68,71]. TPM effectively eliminates maintenance-related losses such as unplanned downtime, recurring failures, waiting times, and rework. Industries worldwide have successfully implemented TPM, improving product quality, reducing waste, lowering manufacturing costs, increasing equipment availability, and enhancing overall equipment effectiveness [23,24,68,71].

2.2 Critical review of value stream mapping: Value Stream Mapping (VSM) is a critical lean tool used to identify, visualize, and eliminate inefficiencies in production processes. By optimizing material and information flow, VSM enhances production speed, reduces costs, and improves overall process performance [8,15,37,42,66]. It has been widely adopted across various industries, including manufacturing [54], textiles [35], automotive [37], food processing [66], telecommunications [57], oil and gas [34,63], healthcare [60], and pharmaceuticals [19]. Integrating TPM and VSM creates a powerful synergy by combining equipment reliability with process optimization. TPM reduces machine downtime [4,28,31], while VSM pinpoints operational inefficiencies, leading to streamlined production and enhanced value delivery [36,52,53,58].

2.3 Review of the integration of TPM and VSM: Table 1 presents a comprehensive survey of TPM and VSM studies (2021–2024), categorized by contribution, application, objectives, and key Lean Six Sigma tools. The findings indicate that integrating TPM and VSM significantly improves machine efficiency, boosts production performance, and enhances overall process productivity. Further analysis of TPM-VSM integration focused on critical success factors (CSFs) that influence effective implementation in manufacturing environments. CSFs represent key challenges organizations must address to achieve TPM-VSM objectives successfully. Table 2 highlights the most critical CSFs identified in existing research [3,7,10,17,25,30,33,39,42,51,59,65,69,70].

The literature review confirms that TPM-VSM integration strengthens lean manufacturing by improving equipment reliability and optimizing operational workflows. This synergy enhances manufacturing productivity in several ways: TPM minimizes downtime, ensuring a smooth and predictable production flow as mapped by VSM. Additionally, VSM identifies inefficiencies, while TPM addresses equipment-related waste, such as overproduction caused by frequent breakdowns. TPM data also informs VSM analysis, helping to pinpoint root causes of delays and optimize workflows [44,45,46,47]. Moreover, both methodologies emphasize workforce engagement, fostering a culture of ownership, accountability, and continuous improvement [48,49,50,53,58].

Table 1. TPM & VSM studies (from 2021 to 2024), for example

#	Reference	Contribution	Application	Main objectives	Main tools
1	Jurewicz1, 2024, [38]	Proposed TPM framework	A case study in machinery fleet	Improving OEE	TPM, 5S, OEE
2	Trubetskaya, 2024, [62]	Developed DMAIC for maintenance	A case study in the dairy industry	Reducing maintenance downtime	DMAIC, VOC, Process mapping, SIPOC, TPM, 5S.
3	Macalinao, 2024, [43]	Described TPM framework	A case study in pharmaceutical manufacturing	Reducing maintenance downtime	TPM, 5S, t-test
4	Gomaa, 2023, [28]	Reported DMAIC for maintenance	A case study in a petrochemical company	Improving OEE and reliability	DMAIC, VOC, process mapping, SIPOC, VSM, KPIs, RACI, FMEA, TPM, 5S.
5	Al Farihi, 2023, [4]	Developed lean maintenance framework	A case study in wiring harness production	Reducing unplanned downtime and MTTR	TPM, RCM, VSM, RCA, 5S.
6	Shannon, 2023, [53]	Proposed LSS for maintenance	A case study in a pharmaceutical ingredient plant	Improving OEE and reliability	TPM, RCM, FMEA, OEE, VSM, RCA, 5S, pareto chart, KPIs.
7	West, 2023, [67]	Developed LSS for the maintenance process	A case study in oil service company	Increasing machine availability	DMAIC, TPM, SIPOC, statistical tests.
8	Ardi, et al., 2023, [13]	Developed a TPM framework	A case study in cut-size line machines	Improving OEE	TPM, RCA, OEE
9	Antosz, 2022, [10]	Reported LSS for maintenance	A case study in floor coverings company.	Improving machine reliability	DMAIC, CTQ, TPM, 5S, SIPOC, charts, statistical tests.
10	Korchagin, 2022, [40]	Developed a framework for lean maintenance	A case study in the aviation industry	Improving maintenance process efficiency	JIT, TPM, Poka-Yoke, process mapping.
11	Drewniak, 2022, [21]	Proposed TPM framework	A case study in crude oil processing	Improving OEE and reliability	TPM, 5S, OEE
12	Singh, 2022, [56]	Developed TPM framework	A case study in a metal industry	Improving OEE	TPM, 5S, OEE
13	Al Hazza, et al., 2021, [5]	Reported TPM framework	A case study in a machining process	Improving OEE	TPM, OEE
14	Suryaprakash, et al., 2021, [58]	Developed TPM framework	A case study in a machining center	Improving OEE	TPM, 5S, VSM, SMED, OEE
15	Imanov, 2021, [36]	Proposed a framework for lean maintenance	A case study in aircraft maintenance	Reducing aircraft downtime	VOC, VSM, TPM, 5S, Kaizen, Poka-Yoke, PDCA.

Table 2. Critical success factors (CSFs) for TPM-VSM implementation

Behavioral factors	1) Management support, commitment, and involvement,
	2) Effective coordination between maintenance and production departments
	3) Effective long-term planning and clear vision
	4) Drive out fear and create a proactive culture

Technical factors	5) Continuous education and training system
	6) Training in diagnosing failures and problems for critical equipment
	7) Technical knowledge and educated workforce
	8) Awareness and understanding of TPM tools and principles
	9) Effective process quality management system (QMS)
	10) Effective maintenance auditing system
Human & cultural factors	11) Employee engagement, empowerment, commitment and satisfaction
	12) Employee motivation and loyalty to achieve specific goals
	13) Willingness of human resources to adopt TPM
	14) Work culture and environmental factors
	15) Effective coordination, teamwork, and empowerment
Methodologies	16) Effective methodologies like kaizen, 5S, lean, six sigma, and TQM
	17) Effective maintenance planning and control
	18) Effective maintenance information and documentation system
	19) Effective computerized maintenance management systems (CMMS)
	20) Effective quality management system
	21) Effective production planning and control
	22) Effective integration between production and maintenance systems
	23) Clear project communication plan and control
	24) Effective external and internal benchmarking of best practices
	25) Effective performance evaluation, KPIs, and monitoring
	26) Effective organizational structure and responsibility matrix
	27) Effective standardization and standard operating procedures (SOPs)
	28) Effective system for assessing and improving machine availability and reliability
	29) Effective technology and information system
	30) Effective spare parts inventory management
Financial factors	31) Funds for additional resources at the beginning of TPM implementation
	32) Funds to support improvement initiatives
	33) Financial rewards and incentives programs

3. Research Gap Analysis

Despite extensive research on Total Productive Maintenance (TPM) and Value Stream Mapping (VSM), their combined impact within Lean Manufacturing Excellence remains underexplored. Most studies examine TPM and VSM separately, lacking empirical validation of their synergy in improving Overall Equipment Effectiveness (OEE), waste reduction, and lean transformation. Their integrated role in optimizing spare parts production is particularly limited, leaving a gap in both research and industry practice. Moreover, sector-specific applications, especially in highly automated industries, process manufacturing, and smart factories, are insufficiently studied. The integration of TPM and VSM within Industry 4.0 frameworks, including digital manufacturing, predictive maintenance, and real-time decision-making, has received little attention. Additionally, challenges related to workforce resistance, cultural adaptation, and leadership commitment remain underexamined. While Critical Success Factors (CSFs) for TPM and VSM are well-documented individually, no structured framework evaluates their combined implementation. Another key gap is the long-term sustainability of TPM-VSM integration, as most research focuses on short-term improvements rather than continuous enhancement. Existing studies rely heavily on qualitative insights, with limited adoption of data-driven models, simulation techniques, or predictive analytics. The potential of AI, machine learning, and advanced analytics to optimize TPM-VSM applications remains largely untapped.

Future research should develop a structured implementation framework that integrates digital technologies, predictive analytics, and real-time monitoring to address these gaps. Empirical validation through industry-specific case studies, simulation models, and AI-driven tools is crucial to ensure the practicality, scalability, and long-term success of TPM-VSM synergy in Lean Manufacturing Excellence.

4. Research Methodology

This study integrates Total Productive Maintenance (TPM) and Value Stream Mapping (VSM) to enhance manufacturing efficiency, productivity, and quality. TPM improves equipment reliability and minimizes downtime, while VSM optimizes workflows and eliminates waste, driving cost reduction and process improvement. The methodology follows a structured approach, beginning with baseline assessments of equipment performance and process efficiency, accompanied by employee training in TPM, 5S, and VSM. Cross-functional teams oversee implementation, ensuring seamless collaboration.

Pilot projects validate the integration before full-scale deployment. Progress is monitored using key performance indicators (KPIs) such as Overall Equipment Effectiveness (OEE) and lead time reduction to sustain improvements. A TPM office is established to streamline operations and promote continuous improvement. The TPM framework follows a five-phase, 14-stage approach, with Autonomous

Maintenance (AM) empowering operators to handle minor maintenance tasks, enhancing equipment reliability and fostering ownership.

The implementation is reinforced by Lean tools, including a 5S checklist for workplace organization, a Lean 8 Wastes checklist to identify inefficiencies and a TPM audit checklist for ongoing evaluation. By integrating TPM and VSM, organizations achieve sustained operational excellence, reduce inefficiencies, and optimize manufacturing performance, creating a highly efficient, cost-effective, and quality-driven production system.

This study presents a structured approach for implementing Total Productive Maintenance (TPM) to enhance manufacturing productivity and efficiency. The primary objective is to establish a TPM roadmap for critical production equipment, ensuring systematic performance improvements and waste reduction. The first step in TPM implementation is the creation of a TPM office, which plays a crucial role in enhancing productivity, optimizing administrative and technical functions, and identifying and eliminating losses. This includes process analysis and office automation to improve efficiency. Office TPM fosters collaboration, aligning all personnel toward performance improvement while increasing motivation among employees and management. The proposed organizational structure of the TPM office is illustrated in Figure (3). The TPM methodology follows a structured five-phase approach, outlined in Figure (4), with implementation progressing through 14 defined stages, as shown in Figure (5). A key element is Autonomous Maintenance (AM), where operators take responsibility for basic machine adjustments and minor maintenance tasks, leveraging their firsthand equipment knowledge. The proposed AM strategy is depicted in Figure (6). To support TPM implementation, structured Lean tools are integrated. 5S visual management serves as the foundation, uncovering inefficiencies and driving continuous improvement. The TPM auditing checklist, detailed in Table (4), ensures ongoing evaluation and refinement. Additionally, Table (3) outlines the key activities required to establish a comprehensive and sustainable TPM program, ensuring long-term operational excellence.

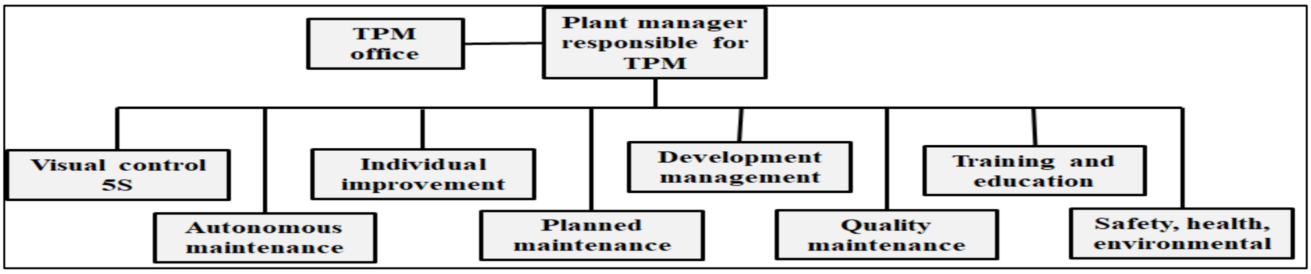

Figure 3. Proposed organizational structure for TPM office

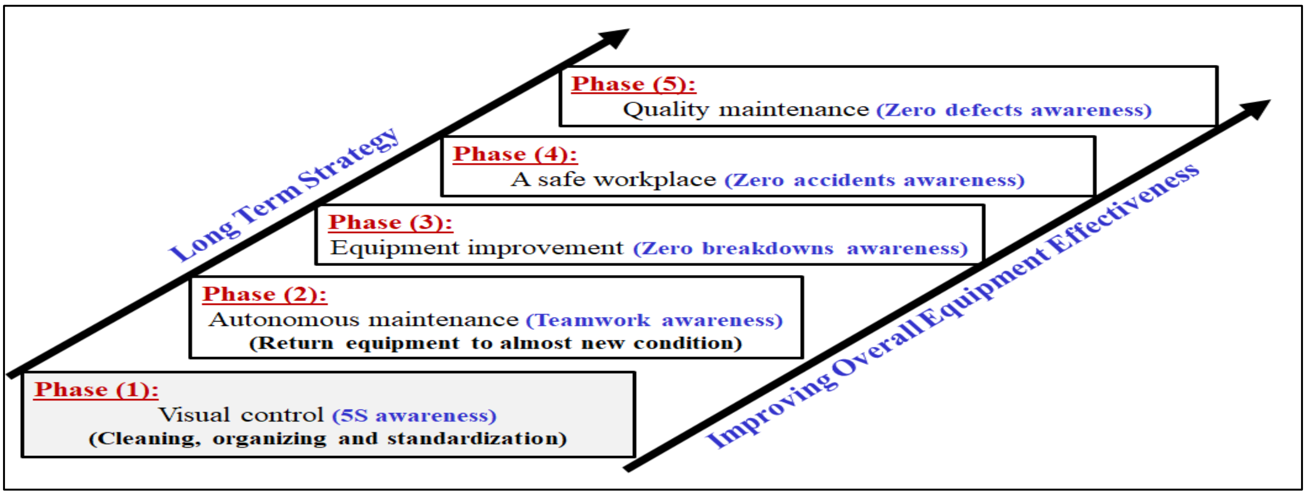

Figure 4. The proposed TPM phases and strategy

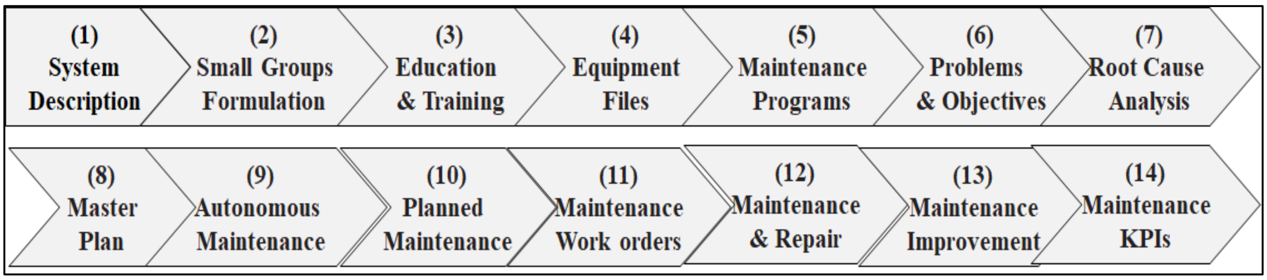

Figure 5. Proposed 14 stages of TPM implementation

Autonomous Maintenance (AM) Strategy

- **Startup Phase:**
  - Educating and training of operators
  - Conducting initial machine cleaning and inspection
- **Development Phase:**
  - Removing causes of contamination
  - Developing standards for lubrication and inspection
  - Conducting general inspection and monitoring
- **Maturity Phase:**
  - Standardizing visual maintenance
  - Striving for continuous improvement

Figure 6. Proposed autonomous maintenance (AM) strategy

Table 3. Proposed activities for building the TPM program

#	TPM pillars	Description	Main activities for building TPM
1	Office TPM	Throughout a company, the concepts of administrative functions are spread	1) Creating the organizational structure of the TPM office 2) Improving synergy between different business functions 3) Designing standard TPM data records 4) Collecting daily TPM data for each machine
2	Visual control 5S	Establish an efficient and productive workspace	5) Applying 5S housekeeping procedures
3	Autonomous maintenance	Machine operators are in charge of doing routine maintenance.	6) Developing an autonomous maintenance program 7) Enhancing operator skills 8) Conducting autonomous maintenance activities
4	Focused improvement	Improvement efforts are carried out with the help of cross-functional teams.	9) Upgrading of the TPM program 10) Identifying and eliminating of losses 11) Determining the root cause analysis of losses 12) Achieving improved system efficiency
5	Planned maintenance	Maintenance program based on machine failure rate encountered	13) Constructing a master plan for TPM implementation 14) Planning the maintenance program efficiently 15) Improving MTBF and MTTR
6	Development management	Design of new machine based on prior TPM activities	16) Developing the TPM program 17) Improving system performance 18) Achieving maintenance improvement initiatives
7	Quality maintenance	Quality is integrated into the machine to eliminate faults.	19) Establishing a quality maintenance system 20) Designing TPM KPIs dashboard 21) Tracking equipment problems and root causes 22) Setting maintenance quality assurance and control 23) Setting 5S auditing checklist 24) Setting lean 8 wastes auditing checklist 25) Setting the TPM auditing checklist
8	Training and education	Addressing the skills and knowledge gap through all workers' training	26) Update the training program and advocate the importance of TPM 27) Evaluating and updating skills periodically
9	Health, safety, environment (HSE)	Ensuring a safe working environment free of accidents and injuries	28) Establishing the management system of HSE 29) Ensuring HSE working environment 30) Providing standard operating procedures

Table 4. Proposed TPM auditing checklist

Factor	Item	Check
Cleaning	• Availability of cleaning schedule • Availability of a cleaning checklist sheet • Availability of cleaning tools • Availability of visual controls for cleaning activities • Availability of cleaning standards • Availability of autonomous maintenance (cleaning) training	

Inspection	• Availability of inspection schedule • Availability of the inspection checklist sheet • Availability of inspection tools • Availability of visual controls for inspection activities • Availability of inspection standards • Availability of autonomous maintenance (inspection) training	
Lubrication	• Availability of lubrication schedule • Availability of the lubrication checklist sheet • Availability of lubrication tools • Availability of visual controls for lubrication activities • Availability of inspection standards • Availability of autonomous maintenance (inspection) training	
Tightening	• Availability of the tightening schedule • Availability of the tightening checklist sheet • Availability of tightening tools • Availability of visual controls for tightening activities • Availability of tightening standard • Availability of autonomous maintenance (inspection) training	

5. Case Study

This study investigates the synergistic integration of Total Productive Maintenance (TPM) and Value Stream Mapping (VSM) to drive operational excellence in the machining process of a leading spare parts manufacturing company in Egypt. Site visits, direct machine observations, and data analysis identified key inefficiencies, including unplanned maintenance, frequent tool breakage, extended cycle times, and setup inefficiencies. Additionally, maintenance and cleaning during production hours reduced equipment availability, while high defect rates and poor working conditions further impacted Overall Equipment Effectiveness (OEE) and overall plant efficiency. To address these challenges, TPM was implemented as a structured framework to eliminate production losses and improve equipment reliability and performance. The process began with a master plan, defining the program scope, selecting critical equipment, and establishing performance objectives. During autonomous maintenance, TPM teams were trained in 5S and TPM principles, with operators taking responsibility for routine maintenance tasks such as cleaning, inspections, and minor repairs under maintenance personnel supervision. Planned maintenance introduced a predictive maintenance schedule, integrated into production planning to prevent breakdowns and scheduling conflicts. As implementation progressed, efforts focused on refining equipment performance assessments, conducting periodic analyses (e.g., thermal imaging, oil analysis), and optimizing spare parts inventory to minimize downtime. Finally, continuous improvement ensured that TPM practices became embedded in standard operations, streamlining processes, enhancing equipment management, and reducing maintenance efforts for sustainable operational excellence.

Through historical data analysis and operational assessments, a comprehensive list of problems, goals, objectives, and key performance indicators was identified, as summarized in Table (5). TPM employs OEE as a core metric to evaluate production system performance, with Table (6) detailing its role in assessing TPM implementation success. Additionally, brainstorming sessions were conducted to analyze the current system’s strengths and weaknesses, as outlined in Table (7). A root cause analysis, visually represented in Figure (7), was performed to diagnose inefficiencies and develop targeted strategies for sustainable performance improvements.

Table 5. Main problems and target objectives (before improvement)

Perspective	Main problems	Target objectives
Facility	• Low facility productivity	• Improving facility productivity
Maintenance	• High machine downtime	• Reducing machine downtime
	• High failure rate	• Reducing failure rate
Operation	• Low time utilization	• Improving time utilization
	• Low performance rate	• Improving performance rate
Quality	• High defect ratio	• Reducing defect ratio

Table 6. Current process performance (before improvement)

Perspective	KPIs	Current	Target	Variance%
Facility	1) TEEP	%58.4	%78.4	%20.0
	2) OEE	%64.5	%81.6	%17.1
Maintenance	3) Availability	%70.4	%85.0	%14.6
	4) Reliability	%82.8	%99.0	%16.2
Operation	5) Utilization	%90.6	%96.0	%5.4

	6) Performance	%95.3	%98.0	%2.7
Quality	7) Quality % (after rework)	%96.1	%98.0	%1.9

Table 7. Current situation analysis through brainstorming

#	Factors	Strength points	Weakness points
1	Manpower	• Sufficient staff • High employee retention	• Lack of training & education • Lack of motivation • Lack of kaizen culture
2	Method	• Good information system • Good IT infrastructure	• Lack of process planning • Lack of standardization • Lack of objectives & KPIs
3	Machine	• New equipment	• Equipment breakdown • Low performance rate • Limited equipment
4	Materials	• High material availability • Good supplier relationship	• Low material quality • Lack of material control • Poor storage conditions
5	Measurement	• Good inspection plan	• Inefficient inspection tools • Lack of statistical tools • Lack of tools calibration
6	Management system	• Top management support • Good leadership • Focus on customer	• Lack of KPIs dashboard • Lack of knowledge about LSS • Lack of benchmarks
7	Environmental	• Good layout & space	• Unsafe working conditions • Lack of safety PPE • Lack of safety audit

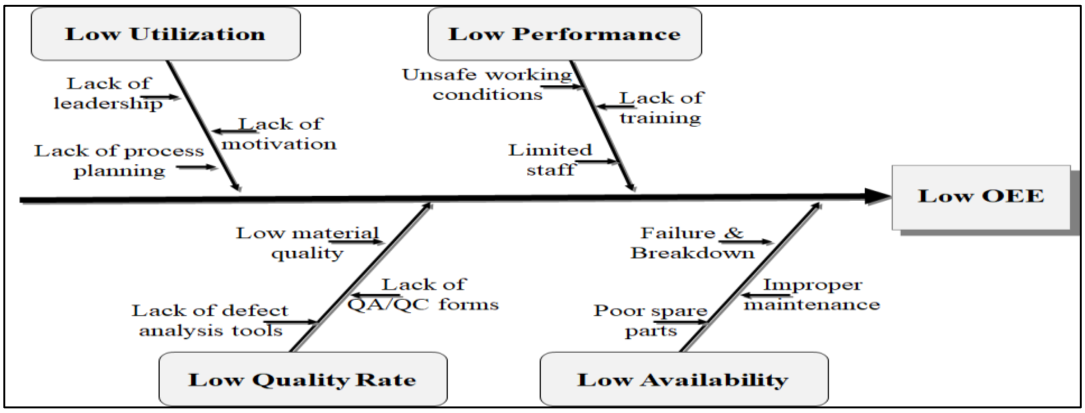

Figure 7. C&E diagram for low overall equipment effectiveness

6. Results and Discussion

This section presents a comparative analysis of key performance metrics, highlighting the impact of the TPM-VSM approach over a three-month implementation period. A Value Stream Map (VSM) was created to document the flow of materials, information, and lead time. As shown in Figure (8), the initial value-added process efficiency was 37.2%. A detailed process analysis identified non-value-added activities and sources of waste, as illustrated in Figure (9). A brainstorming session was conducted to determine the root causes of these inefficiencies, leading to a cause-and-effect diagram for waste reduction, shown in Figure (10). The primary objective of TPM is to minimize non-value-added activities and enhance overall equipment effectiveness (OEE). After implementing the proposed TPM methodology, an updated Value Stream Map (VSM) was developed, as shown in Figure (11), reflecting an improvement in value-added process efficiency to 54.1%. Further analysis identified remaining inefficiencies and process waste, as depicted in Figure (12).

As summarized in Figure (13), the results confirm that the proposed methodology significantly improved process efficiency and performance. Key performance indicators showed notable enhancements: Total Effective Equipment Performance (TEEP) increased from 58.4% to 67.6%, Overall Equipment Effectiveness (OEE) improved from 64.5% to 75.7%, and value-added process efficiency rose from 37.2% to 54.1%. These metrics are widely recognized as essential quantitative tools for evaluating productivity in manufacturing operations. In particular, OEE serves as a core measure in the formulation and execution of a TPM improvement strategy.

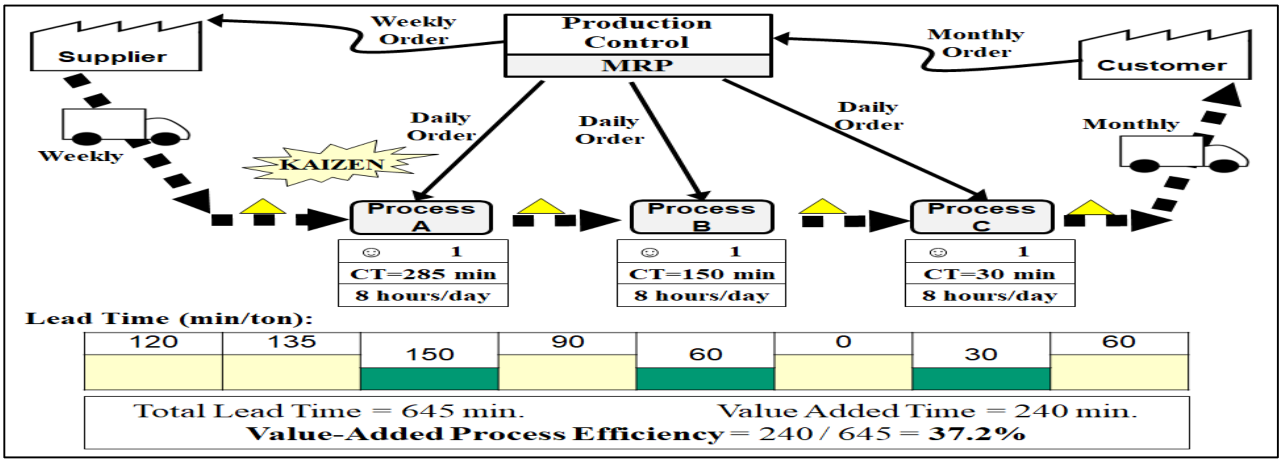

Figure 8. Value stream mapping (before improvement)

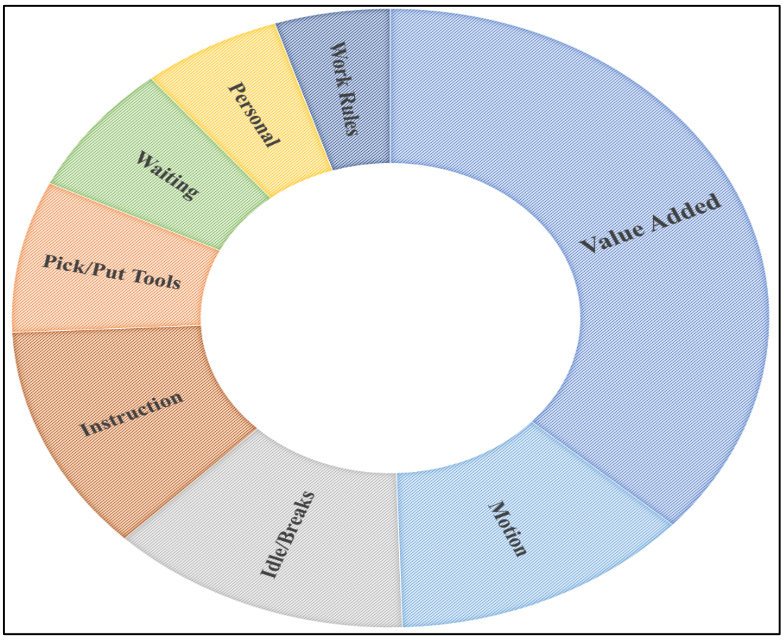

Figure 9. Value-added time elements for one shift (before improvement)

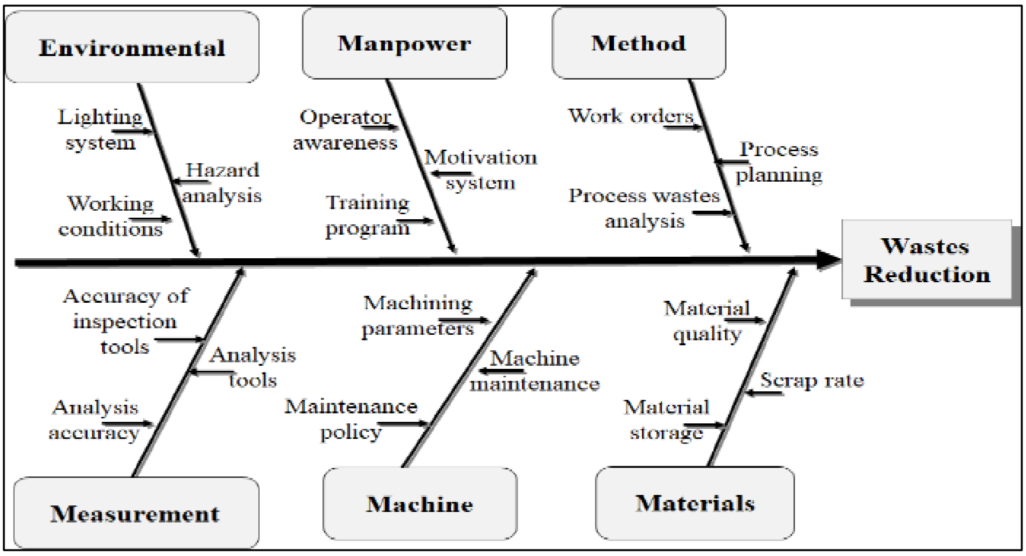

Figure 10. C&E diagram for non-value-added reduction

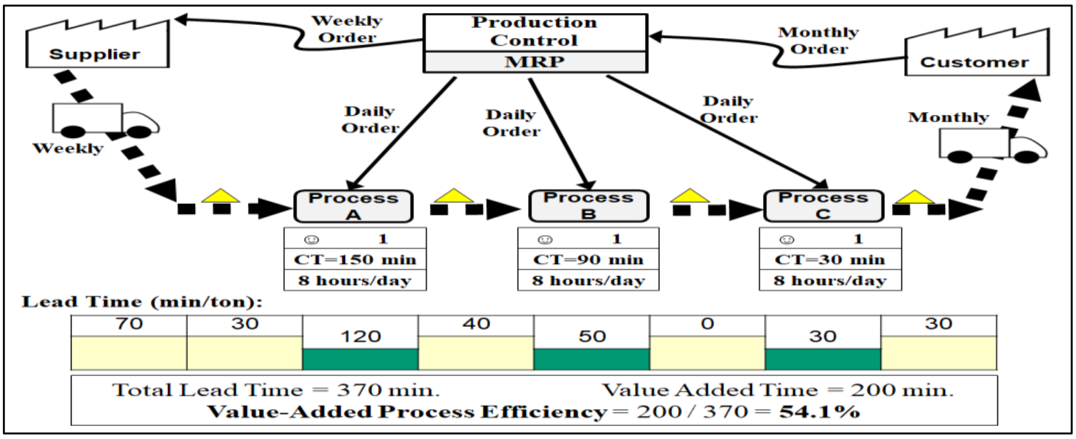

Figure 11. Value stream mapping (after improvement)

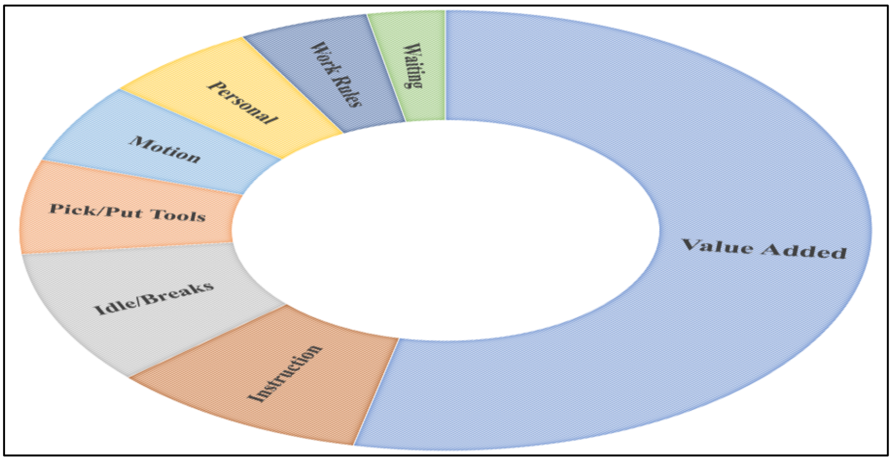

Figure 12. Value-added analysis for one shift (after improvement)

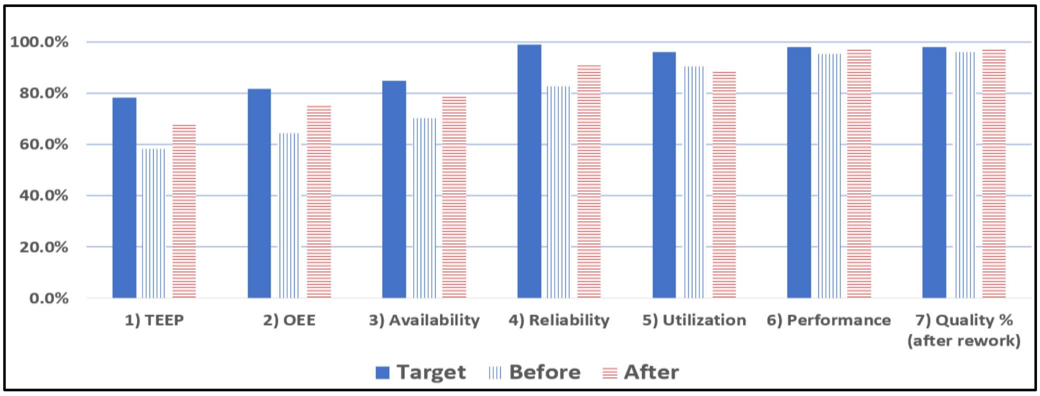

Figure 13. KPIs analysis (before and after improvement)

7. Conclusion and Further Work

This study explores the integration of Total Productive Maintenance (TPM) and Value Stream Mapping (VSM) to enhance efficiency, reduce waste, and improve equipment reliability. TPM maximizes equipment effectiveness through collaboration between maintenance and production teams, while VSM streamlines material and information flow by identifying inefficiencies. Their integration forms a structured TPM-VSM methodology for achieving manufacturing excellence. This research, conducted in the machining process of an Egyptian spare parts manufacturing company, developed a robust TPM framework utilizing advanced analysis and improvement methodologies. Over three months, results showed significant improvements: Total Effective Equipment Performance (TEEP) increased from 58% to 68%, Overall Equipment Effectiveness (OEE) improved from 65% to 76%, and value-added process efficiency rose from 37% to 54%. These findings contribute to operations management by optimizing maintenance strategies and enhancing machine utilization. This study also provides insights for academics and industry professionals on applying Lean Six Sigma (LSS) tools. Future research should focus on real-world case studies across manufacturing.

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