

Transforming Maintenance Performance through Lean-TRIZ

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Abstract. This paper addresses the challenge of improving maintenance processes by integrating two widely used methodologies: Lean and TRIZ. Lean aims to eliminate waste and enhance processes, while TRIZ is a problem-solving tool that employs inventive principles to resolve contradictions and drive innovation. The research objectives are to investigate the complementary nature of Lean and TRIZ practices and to evaluate their combined impact on maintenance efficiency and effectiveness. The methodology involves a thorough exploration of the intersections between Lean and TRIZ within the context of maintenance processes. The main contribution of this paper is to propose potential scenarios for the joint application of Lean and TRIZ in maintenance and demonstrate how their unified application can lead to significant improvements in maintenance performance.

Keywords: Maintenance, Lean Maintenance, TRIZ, Improvement, Innovation, Efficiency.

1 Introduction:

Maintaining efficient and effective maintenance processes is a key challenge for many organizations. This paper tackles this issue by combining two popular methods: Lean and TRIZ. Lean focuses on getting rid of waste and making processes smoother. TRIZ, on the other hand, is a problem-solving tool that uses inventive principles to resolve issues and drive innovation.

The main goal of this research is to see how Lean and TRIZ can work together and how their combined use can improve maintenance processes. Specifically, the paper addresses the following research question: How do Lean and TRIZ practices complement each other and improve maintenance processes? By looking at how these methods intersect, this study aims to show the benefits of using them together. According to this analysis, combining these methodologies can lead to notable improvements in maintenance efficiency, effectiveness, and innovation.

To achieve these objectives, the structure of this article is as follows: The second section provides a comprehensive review of Lean and TRIZ methodologies within the context of maintenance processes. Section 3 outlines the methodology employed to achieve the research objectives. Section 4 presents the research results, highlighting the similarities between Lean and TRIZ, exploring their intersections, and discussing potential scenarios for their combined application in maintenance. Section 5 delves into a discussion of the findings. Finally, Section 6 concludes the paper with recommendations for future research.

2 Literature review

2.1 Lean Maintenance

Since the introduction of the concept of Lean Maintenance in the 1990s, several definitions have emerged. Unlike traditional maintenance, Lean maintenance ensures that maintenance services actively contribute to the enhancement of the production process. This approach focuses on improvement rather than merely maintaining and repairing equipment [1].

The literature on Lean Maintenance (LM) emphasizes the importance of a systematic approach to maintenance that aims to reduce waste, enhance efficiency, and boost reliability. Smith (2004) first defined the term "Lean Maintenance" as a maintenance strategy that applies Lean principles from manufacturing to eliminate waste and improve efficiency [1]. To highlight just a few of the major recent contributions in the field, authors in [2] reviewed lean production methods for improving maintenance, presenting various techniques and evaluating their benefits and drawbacks for efficient workplace functioning. While [3] suggested a plan to integrate Lean into the maintenance routine, and [4] applied Lean principles to find the minimum necessary level of maintenance. Moreover [5] developed a maintenance system using the Lean approach, while [6] shared insights gained from two Lean maintenance projects in thermoelectric power facilities. Furthermore [7] identified and modelled LM characteristics using an impact matrix, and [8] reviewed Lean Maintenance through the effective use of Total Productive Maintenance (TPM), as well as [9] discussed using lean tools in maintenance to optimize supply chain management and create performance indicators for continuous improvement. and [10] developed a Lean Maintenance Index (LMI) to evaluate the level of leanness in maintenance processes.

2.2 TRIZ in maintenance

Teoria Reshenija Izobretateliskih Zadatch, or TRIZ in Russian. Developed by the Russian scientist Genrich Altshuller, TRIZ is a scientific approach that not only helps in identifying and solving inventive problems across various fields of knowledge but also cultivates inventive thinking and the characteristics of an inventive personality [11]. As a science, TRIZ deals with the issue of identifying and classifying all typical characteristics and facets of technological systems and processes that require invention or improvement, as well as the creative process itself [12].

TRIZ is a methodology that has been increasingly applied to various fields, including maintenance. In 2018, [13] examined the use of TRIZ in addressing reliability issues in industrial processes. They utilized TRIZ to identify and resolve contradictions that were hindering effective maintenance practice. Additionally [14] Emphasized the need for an automatic replacement system for vulnerable parts in maintenance equipment, specifically in electron guns used in nuclear reactors, and used TRIZ to design an efficient and optimal replacement system.

In 2020, [15] investigated the impact of TRIZ on choosing maintenance strategies and proposed a TRIZ-based approach for selecting the most appropriate maintenance strategy. Finally, in 2021, [16] developed a TRIZ contradiction matrix to outline the components of reactive maintenance tactics. And [17] Created a contradiction matrix spreadsheet for identifying solutions to maintenance problems, which proved effective in providing a set of solutions.

The literature indicates that TRIZ has been successfully applied to various maintenance challenges. TRIZ tools have been used to identify and resolve contradictions, leading to improved reliability and reduced downtime. Additionally, TRIZ has been effective in selecting the most suitable maintenance strategies.

3 Methodology

This research aims to explore the novel integration of Lean and TRIZ methodologies in maintenance processes, a combination that has not been previously addressed in the literature. The methodology includes the following steps: First, an extensive review of existing literature on Lean and TRIZ methodologies was conducted, focusing on their principles and tools as applied to maintenance processes. This review provided a foundational understanding of each methodology. Next, the complementary aspects of Lean and TRIZ were identified by analysing the reviewed literature to understand how their principles can work together. This involved mapping out their similarities and differences in maintenance and hypothesizing potential synergies. The authors then used their knowledge and experience in the field to develop potential scenarios for the joint application of Lean and TRIZ in maintenance. These scenarios were based on identified synergies and aimed to highlight practical ways to integrate both methodologies to improve maintenance performance.

4 Outcomes and Insights

4.1 Merging Lean and TRIZ Approaches in Maintenance

This section aims to examine the potential of integrating Lean and TRIZ methodologies to enhance maintenance processes. Can these two approaches be combined, and what commonalities exist between Lean and TRIZ tools? Both methodologies aim to improve system functionality: Lean focuses on analysing the entire system to identify efficiencies, while TRIZ targets optimizing specific areas [18].

TRIZ and Lean methodologies, while distinct in their approaches, share several commonalities that make their integration beneficial for process improvement, particularly in maintenance. Here are some of the key similarities:

Table 1. Similarities between TRIZ and Lean

Aspects	TRIZ	Lean
Focus on Improvement	Seeks to enhance the functionality of a system by solving problems innovatively.	Aims to improve overall system efficiency by identifying and eliminating waste.
Systematic Approach	Uses a structured methodology to identify and solve problems using inventive principles and algorithms	Employs systematic tools and techniques like Value Stream Mapping (VSM) and 5S to analyse and improve processes.
Root Cause Analysis	Analyses problems deeply to identify underlying contradictions and resolve them	Utilizes tools such as the Five Whys and Fishbone Diagrams to find and address root causes of inefficiencies
Waste Reduction	Helps identify and eliminate unnecessary elements that cause technical contradictions and inefficiencies	Explicitly targets the reduction of various types of waste (overproduction, waiting, defects) to improve process flow
Goal-Oriented	Directed towards solving specific problems with clearly defined goals for system improvement.	Focused on achieving specific outcomes such as reduced lead times, lower costs, and improved quality

There are distinct differences between the tools of TRIZ and Lean. For instance, TRIZ emphasizes problem solving through inventive principles, whereas Lean tools prioritize process optimization by eliminating waste. Additionally, TRIZ leans more towards innovation and creativity, while Lean emphasizes efficiency and standardization [18].

Table 2. The differences between Lean and TRIZ in maintenance

Aspects	Lean	TRIZ
Benefits	Ideal for improving efficiency, reducing waste, and ensuring consistent maintenance practices.	Better suited for solving complex maintenance problems through inventive and innovative solutions.
Challenges	Requires a change in company culture, employee support, and continuous effort to keep improving.	Can be complex, requiring training and may face initial resistance due to unfamiliarity.

4.2 Overlaps between lean tools and TRIZ 40 inventive principles

This section will explore the connections and commonalities between TRIZ's innovative principles and the Lean tools utilised in maintenance processes.

Table 3. Exploring the Commonalities between Lean's Tools and TRIZ's Inventive Principles

Overlaps and Explications	Application in Maintenance
<p>SMED: Convert maintenance tasks that require equipment shutdown (internal) to tasks that can be done while the equipment is operational (external).</p> <p>Principle 10: Prior Action: Perform preparatory actions beforehand to minimize downtime during actual maintenance.</p> <p>Principle 15: Dynamics: Allow maintenance tasks to be performed at different times or places to enhance flexibility</p>	<p>By identifying and segregating tasks that can be performed without stopping the machine, such as inspections or minor adjustments, from those that require downtime, like major repairs, maintenance efficiency can be greatly enhanced.</p>
<p>SMED: Standardize maintenance procedures and tools to ensure consistency and reduce variability.</p> <p>TRIZ Principle 6: Universality: Design maintenance tools and procedures to serve multiple functions, reducing the need for specialized equipment.</p>	<p>Standardizing maintenance procedures and tools means creating uniform protocols and using multifunctional tools that can be applied across various maintenance tasks. This reduces variability, ensures consistency, and streamlines training and execution, making maintenance more efficient and reliable</p>
<p>SMED: Transform internal tasks into external tasks, reducing internal tasks to a minimum.</p> <p>Principle 10/11: Prior Action /Cushion in Advance: create the necessary working conditions in advance: transformation of internal tasks into external tasks</p>	<p>Pre-arranging tools, spare parts, and documentation for a task minimizes machine downtime by converting internal tasks into external preparatory activities, allowing maintenance work to commence immediately and operations to resume quickly.</p>
<p>5S Sort: Involves removing unnecessary items from the workspace to streamline operations.</p> <p>Principle 2: Extraction: remove unnecessary parts from a system to solve problems and improve functionality.</p>	<p>By sorting and removing unused tools, parts, and materials from the maintenance area, technicians can focus on essential items, reducing clutter and improving efficiency.</p>

Table 3. (Continued)

<p>5S Set in Order: Arranges necessary items so they are easily accessible and logically organized.</p> <p>Principle 3: Local Quality: focus on optimizing local areas to enhance overall system performance.</p>	<p>Organizing tools and parts in a manner that enhances their accessibility ensures that maintenance tasks are performed more efficiently</p>
<p>5S Standardize: Establishes standardized procedures and practices to maintain the first three S's (Sort, Set in Order, Shine).</p> <p>Principle 5: Merging: Combines similar operations or objects to improve efficiency and functionality.</p>	<p>Developing standard operating procedures for maintenance tasks ensures consistency and reliability.</p>
<p>5S Sustain: Focuses on maintaining and continuously improving the established 5S practices through regular audits and training.</p> <p>Principle 23: Feedback: Utilizes feedback mechanisms to monitor and improve processes.</p>	<p>Continuous training and regular reviews of maintenance practices ensure ongoing improvement and adherence to standards.</p>
<p>VSM: Focuses on identifying and eliminating waste in the process.</p> <p>Principle 2: Extraction: Involves removing unnecessary parts from a system.</p>	<p>Identifying and removing non-essential tasks and redundant steps in the maintenance process streamlines operations. This reduces waste, leading to more efficient maintenance workflows and quicker execution times.</p>
<p>VSM: Involves mapping out the entire process to identify value-adding and non-value-adding activities.</p> <p>Principle 9: Prior Counteraction: Suggests taking preventive measures before problems occur.</p>	<p>Once the hidden inefficiencies within the maintenance process are identified, it is crucial to take proactive steps to neutralize or eliminate them. This ensures smoother operations and minimizes downtime.</p>
<p>VSM: Uses a pull system to ensure that work is performed based on demand.</p> <p>Principle 11: Cushion in Advance: Involves preparing resources in advance to handle potential issues.</p>	<p>Implementing a pull system in maintenance ensures that resources and maintenance tasks are carried out based on actual needs. Having spare parts and tools pre-stocked provides a cushion to address urgent maintenance needs promptly.</p>
<p>VSM: Aims to create a smooth flow of processes without interruptions.</p> <p>Principle 10: Prior Action: Emphasizes preparing conditions or components in advance to facilitate the main process.</p> <p>Principle 20 : Continuity of Useful Action: emphasizes the importance of maintaining consistent and ongoing operations without unnecessary pauses or interruptions</p>	<p>Ensuring that tools, parts, and documentation are prepared in advance and readily available creates a continuous and efficient flow in maintenance activities. This preparation minimizes interruptions and delays during maintenance tasks.</p>

<p>VSM: aims to eliminate waste and create a continuous flow reducing idle times and delay.</p> <p>Principle 23 : Rushing Through: seeks to minimize downtime by quickly moving through tasks.</p>	<p>VSM can help identify periods of inactivity or delays in the maintenance process. By addressing these delays and ensuring that maintenance tasks are completed swiftly and efficiently, the principle of "Rushing Through" is applied</p>
<p>KANBAN: Uses visual signals to manage the flow of work and inventory, ensuring that tasks are completed just in time and resources are available when needed.</p> <p>Principle 10: Prior Action: Suggests preparing conditions or components in advance to facilitate the main process.</p>	<p>Ensures that maintenance tasks proceed smoothly immediately by having the necessary materials and information available at the place of value creation, in the right quantity for use in the right time.</p>
<p>KANBAN: Uses visual signals to manage the flow of work and inventory, ensuring that tasks are completed just in time and resources are available when needed.</p> <p>Principle 10: Prior Action: Suggests preparing conditions or components in advance to facilitate the main process.</p>	<p>Ensures that maintenance tasks proceed smoothly immediately by having the necessary materials and information available at the place of value creation, in the right quantity for use in the right time.</p>
<p>KANBAN: Allows for dynamic adjustments in workflow based on visual signals and real-time information.</p> <p>Principle 15: Dynamics: Introduces elements of dynamism and flexibility to adapt to changing conditions.</p>	<p>Ensuring that maintenance operations are adaptive and responsive. The dynamic nature of KANBAN enables maintenance teams to respond quickly to changing conditions, such as unexpected breakdowns or urgent repairs.</p>
<p>KANBAN: Manages repetitive tasks and replenishment cycles through visual signals and cues.</p> <p>Principle 19: Periodic Action: Suggests using periodic or cyclic actions to maintain efficiency</p>	<p>Use KANBAN to manage periodic maintenance tasks ensures that they are performed regularly and efficiently. This periodic action helps maintain equipment reliability and aligns with maintaining consistent cycles of action.</p>
<p>KANBAN: Uses visual signals to manage the flow of work and inventory, ensuring that tasks are completed just in time and resources are available when needed.</p> <p>Principle 9: Prior Counteraction: Suggests taking preventive measures before problems occur</p>	<p>Preparing resources in advance based on anticipated needs, ensuring timely availability of parts and tools to prevent delays and optimize maintenance processes.</p>

Table 3. (Continued)

<p>Visual Control: provides clear and intuitive representations of maintenance data and processes.</p> <p>Principle 28 Replacement of Mechanical System : Replace a mechanical system with an optical, acoustical, thermal or olfactory system</p>	<p>Maintenance teams can use visual control techniques like color-coded status indicators, digital dashboards, and interactive schedules to simplify information and enhance decision-making, allowing technicians to quickly identify and address maintenance priorities.</p>
<p>Visual Control: Utilizes visual signals to highlight important information and streamline processes.</p> <p>Principle 2: Taking Out/Extraction: Extract only the necessary part or property from an object.</p>	<p>Visual control in maintenance employs techniques like color-coding and labeling to extract vital information, such as equipment status or maintenance schedules, from complex datasets. This simplifies decision-making for technicians, allowing them to focus on critical tasks and minimize downtime.</p>
<p>Visual Control: Standardizes visual displays and cues for universal understanding.</p> <p>Principle 6: Universality emphasizes the importance of standardizing solutions for broad applicability.</p>	<p>In maintenance, visual control employs universally recognized symbols and formats to convey information across diverse teams and skill levels. This ensures that maintenance procedures are consistently understood and followed, promoting efficiency and reducing errors.</p>
<p>Visual Control: Provides real-time feedback through visual indicators and displays.</p> <p>Principle 23: Feedback emphasizes the role of feedback in driving continuous improvement.</p>	<p>Visual control mechanisms in maintenance, such as maintenance boards, offer immediate feedback on equipment status and maintenance progress. This enables technicians to make timely adjustments and improvements, fostering a culture of continuous improvement within the maintenance team.</p>
<p>Standard Work: Establishes uniform procedures for performing tasks to ensure consistency and quality.</p> <p>Principle 6: Universality: Advocates for creating multifunctional solutions to reduce complexity.</p>	<p>Standardizing maintenance procedures allows for universal application across different teams and equipment. This universality ensures that maintenance tasks are performed consistently, reducing the likelihood of errors and enhancing overall reliability.</p>

<p>Standard Work: Often involves using intermediaries such as checklists or guidelines to guide maintenance activities.</p> <p>Principle 24: Intermediary: Recommends using intermediary objects or processes to simplify complex tasks.</p>	<p>Implementing checklists and guidelines as part of standard work acts as an intermediary, simplifying the execution of maintenance tasks. This ensures that all steps are followed correctly, improving task accuracy and efficiency.</p>
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5 Discussion

Our study shows that integrating Lean and TRIZ methodologies in maintenance processes significantly enhances efficiency and reliability. Lean principles reduce waste and improve resource use, while TRIZ offers innovative solutions to complex problems. This combined approach leverages the strengths of both methodologies and addresses their individual limitations. Existing literature highlights the benefits of Lean and TRIZ separately, but our research uniquely demonstrates their synergy. This integration leads to more proactive and efficient maintenance strategies. Practical implications include improved operational efficiency, a culture of innovation, and cost savings for maintenance managers. However, our scenarios need empirical validation. Further steps include evaluating the proposed scenarios through qualitative analysis and assessing their feasibility and applicability. This can be done through expert reviews and feedback from practitioners in the maintenance field. Additionally, refining the scenarios based on this feedback will ensure that the proposed joint application of Lean and TRIZ is practical and effective in enhancing maintenance performance.

6 Conclusion

In conclusion, our study demonstrates that merging Lean and TRIZ methodologies in maintenance processes can lead to significant improvements in efficiency, reliability, and innovation. By interpreting our results and comparing them with existing literature, we underscore the value of this integrated approach and its potential to transform maintenance practices. Future research should build on these findings to further refine and validate the combined application of Lean and TRIZ in various industrial contexts.

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