International Journal of Interdisciplinary Innovative Research & Development (IJIIRD)
ISSN: 2456-236X
Vol. 11 Special Issue 02 | 2026

A Conceptual Framework for Integrating Lean Manufacturing and Theory of Constraints in Small-Scale Industries

Mr. Abhishek S Gadre[1], Dr. Hullash Chauhan[2]
[1] Assistant Professor, Department of Mechanical Engineering, Sipna COET, Amravati, Maharashtra, India
[2] Dean, Mechanical Engineering Department, Bharti University, Durg, Chhattisgarh, India

DOI: 10.5281/zenodo.19336094

ABSTRACT

Small-scale industries (SSIs) play a crucial role in economic development; however, they frequently struggle with low productivity, high lead times, excess work-in-progress (WIP), and inefficient utilization of limited resources. Lean Manufacturing (LM) and the Theory of Constraints (TOC) are two well-established improvement philosophies that address these challenges from different perspectives. Lean Manufacturing focuses on waste elimination and flow improvement, while TOC emphasizes identifying and managing system constraints to maximize throughput. Although both approaches have demonstrated significant benefits independently, their isolated application often leads to suboptimal results, particularly in resource- constrained small-scale environments. This paper proposes a conceptual framework that integrates Lean Manufacturing and TOC to assess and improve overall operational performance in small-scale industries. The study presents a structured integration logic and a detailed research methodology for implementing the proposed framework in an industrial case study. Since the research implementation is currently in progress, this paper emphasizes the conceptual model, methodology, and expected outcomes. The proposed framework aims to provide a practical and scalable roadmap for SMEs seeking systematic and sustainable performance improvement.

Keywords: - Lean Manufacturing, Theory of Constraints, Small-Scale Industries, Performance Improvement, Conceptual Framework

1. INTRODUCTION

Small-scale industries (SSIs) play a vital role in manufacturing, especially in developing economies, yet they operate under constraints such as limited capital, outdated equipment, skill shortages, and demand variability, leading to long lead times, high WIP, delivery delays, and quality issues. Lean Manufacturing and the Theory of Constraints offer complementary solutions: Lean improves flow through waste elimination, while TOC focuses on throughput by managing system bottlenecks. However, when applied independently, Lean often lacks prioritization and TOC overlooks non-bottleneck waste. Addressing this gap, this paper proposes an integrated Lean–TOC framework tailored for SSIs, with objectives to identify key operational problems, develop a structured integration model, and outline a case study–based methodology using process mapping, VSM, constraint identification, and focused Lean interventions to support systematic performance improvement in resource-constrained environments.

2. LITERATURE REVIEW

Lean Manufacturing has been widely studied as a philosophy focused on waste elimination and continuous improvement. Numerous researchers have reported significant improvements in lead time reduction, inventory control, and productivity through Lean tools such as VSM, cellular layout, and standardized work. However, literature also highlights that Lean initiatives often fail or stagnate in SMEs due to lack of strategic focus, improper sequencing of tools, and resistance to change.

Early research highlights a strong relationship between Lean Manufacturing and Total Productive Maintenance (TPM), showing that their integration enhances equipment reliability and Overall Equipment Effectiveness (OEE) through phased implementation approaches beginning with 5S and safety training, where workforce involvement, standardization, and skill development are critical for sustaining gains [1]. In process-intensive industries such as textiles, Lean tools including Just-in-Time (JIT), Kanban, Value Stream Mapping (VSM), and Poka-Yoke have been successfully adapted to reduce waste, inventory levels, and cycle times, particularly when VSM is combined with cellular layouts and 5S, although contextual modifications are often required to manage demand and material variability [2][3][4]. Studies in

traditionally operated manufacturing environments further show that incremental Lean implementation leads to gradual improvements in lean maturity, reinforcing the
importance of long-term commitment and industry-specific adaptation, which aligns with the broader Lean philosophy of prioritizing holistic value-stream understanding before targeted process improvements [4][5][6]. Recent research also highlights convergence between Lean Manufacturing and advanced manufacturing technologies, indicating that digital systems such as Manufacturing Execution Systems (MES) achieve superior cost efficiency when built on a strong Lean foundation, while Lean-only implementations tend to provide greater operational flexibility [7].

Organizational factors significantly influence Lean implementation outcomes, with plant size strongly affecting the depth of adoption, while unionization and plant age have limited impact [8]. Studies show that coordinated implementation of Lean practice bundles—such as JIT, TQM, TPM, and human resource management—yields stronger performance gains than isolated tool use, supporting the structured and sequential Lean roadmap advocated by [9], where integrated application of Kanban, SMED, and production leveling leads to sustainable improvements in lead time, process cycle efficiency, and takt time [10]. Across textile and food processing industries, Lean tools including JIT, Kanban, VSM, Poka-Yoke, Kaizen, TPM, and quick changeover have been effectively adapted to reduce waste, improve responsiveness, and enhance equipment reliability, with incremental implementation approaches proving particularly effective in traditional and small-scale environments when supported by system-level understanding and workforce involvement. [11] [12] [13][14][15].

The Theory of Constraints (TOC) is a systematic improvement methodology that focuses on identifying and managing the primary constraint or bottleneck that governs overall system performance, based on the principle that sustained improvement is achieved by continuously elevating this constraint through a structured cause– effect-driven approach [16]. Introduced by Goldratt and popularized through *The Goal* (1984), TOC has evolved from a production scheduling technique into a comprehensive management philosophy applicable across manufacturing, service, and supply chain environments [16]. Its applicability beyond manufacturing has been demonstrated in inter-organizational systems, where system-integration constraints and strategic motivation are emphasized in inter-organizational applications of TOC [17], service operations benefit from Drum–Buffer– Rope (DBR) scheduling to improve efficiency under high variability and resource constraints [18], and public- sector and healthcare systems adopt adapted TOC frameworks to support capacity-constrained decision-making [19]. Theoretical reviews further confirm TOC's evolution into a robust management theory supported by structured thinking processes and the five focusing steps [20].

Several studies have examined the integration of the Theory of Constraints (TOC) with other continuous improvement methodologies, consistently reporting strong complementarities. Substantial overlap between TOC, Lean Manufacturing, and Six Sigma across 28 comparative dimensions has been identified, supporting the feasibility of integrated improvement frameworks [21], while strong conceptual alignment between TOC and the Toyota Way has been highlighted despite differences in implementation focus and change management practices [22]. Empirical evidence further validates TOC's effectiveness across diverse contexts: integration of TOC with Lean and Six Sigma has been shown to improve throughput, cost efficiency, and organizational goal alignment [23]; application of TOC alongside equipment performance metrics has enhanced efficiency in electronics manufacturing [24]; and TOC-based heuristic line balancing and simulation have successfully resolved capacity imbalances [25]. Recent applications extend TOC to emerging technologies and logistics, where TOC tools have been used to diagnose commercialization constraints in the Micro Gas Turbine industry
[26] and to eliminate performance-limiting constraints in logistics operations [27].

The Theory of Constraints has been widely applied across manufacturing and service sectors to improve throughput and delivery performance, with studies showing that TOC-based scheduling, drum–buffer–rope (DBR), and bottleneck exploitation can significantly enhance system output. However, TOC implementations may overlook inefficiencies in non-bottleneck processes, leading to localized waste and imbalance. Overall, the literature establishes TOC as a flexible and effective improvement methodology whose impact is substantially strengthened when integrated with other process improvement frameworks.

Studies [28] and [29] demonstrate the effectiveness of integrating Lean Manufacturing (LM) and Theory of Constraints (TOC) in both manufacturing and service environments. In an automobile hose assembly line [28], the combined use of Lean tools and TOC-based bottleneck management eliminated overtime, improved resource utilization, and increased productivity from 365 to 630 units per day. Similarly, in a maintenance, repair, and overhaul (MRO) facility [29], replacing push scheduling with a Lean pull-based system revealed hidden capacity without additional manpower, leading to significant performance gains despite high operational variability and initial cultural resistance.

Further evidence is provided by study [30], which validated a structured Lean–TOC integration model in a footwear manufacturing case, demonstrating substantial reductions in lead time, work-in-process inventory, and non-value-added activities through alignment of TOC constraint control with Lean pull systems. Conceptual studies [22] and [21] reinforce this empirical evidence by highlighting strong principle-level alignment among TOC, the Toyota Way, and Lean Manufacturing, as well as methodological complementarities with Six Sigma. Together, these studies support the feasibility and effectiveness of integrated improvement frameworks, while emphasizing the need for structured and context-sensitive integration aligned with organizational objectives and operational constraints.

Lean Manufacturing provides a robust set of tools for waste elimination and process standardization but lacks an inherent mechanism for prioritizing improvements, while the Theory of Constraints offers clear strategic focus on bottlenecks but limited operational guidance. Their complementary strengths have motivated integration efforts in which Lean tools support constraint exploitation and TOC directs improvement priorities. However, existing studies often lack a clear integration sequence or adaptation for small-scale industries, highlighting the need for a structured Lean–TOC framework tailored to SMEs, as outlined in Table-1.

Table -1: Integrated Lean–TOC Approach

Aspect	Lean Manufacturing (LM)	Theory of Constraints (TOC)	Integrated Lean–TOC Approach
Primary Objective	Eliminate waste and improve process flow	Maximize system throughput by managing constraints	Improve overall system performance by aligning waste elimination with constraint -focused improvement
Improvement Focus	All processes across the value stream	Primary system constraint (bottleneck)	Constraint-first improvement supported by Lean tools
Key Principles	Flow, pull, standardization, continuous improvement	Five Focusing Steps, system thinking, throughput maximization	System-level optimization through structured sequencing of Lean and TOC
Typical Tools	VSM, 5S, Kanban, SMED, Kaizen, Poka-Yoke	Drum–Buffer–Rope (DBR), Current Reality Tree, Throughput accounting	Lean tools selectively applied to exploit and elevate constraints
Approach to Waste	Eliminates waste across all processes	Indirectly addresses waste at the constraint	Eliminates waste where it most impacts system throughput
Expected Outcomes	Reduced lead time, inventory, and defects	Increased throughput and delivery reliability	Sustainable improvements in throughput, flow, and operational stability

3. RESEARCH OBJECTIVES AND PROBLEM DEFINITION

The primary problem addressed in this study is the absence of a structured and practical framework for integrating Lean Manufacturing and Theory of Constraints in small-scale industries to assess and improve overall operational performance. Small-scale manufacturers often adopt improvement initiatives in an ad hoc manner, leading to fragmented gains and limited sustainability.

The objectives of this research are: To analyze the operational challenges commonly faced by small-scale manufacturing industries. To develop a conceptual framework integrating Lean Manufacturing and TOC principles. To propose a systematic research methodology for implementing the integrated framework in a real industrial environment. To identify relevant performance indicators for assessing the effectiveness of the proposed approach.

The scope of this study is limited to shop-floor level operations within a single small-scale manufacturing unit. Strategic, financial, and supply-chain-level interventions are beyond the scope of the current work. The focus is on methodology development and conceptual validation, while empirical performance validation is planned for future research.

4. PROPOSED CONCEPTUAL FRAMEWORK FOR LEAN–TOC INTEGRATION

Lean Manufacturing and the Theory of Constraints (TOC) provide complementary approaches to performance improvement, with Lean emphasizing waste elimination and flow, and TOC focusing on throughput by managing system constraints. The proposed framework integrates both by aligning Lean improvement actions with TOC's constraint-focused logic to achieve system-level optimization. Lean's five principles—value, value stream, flow, pull, and perfection—offer a structured foundation for continuous improvement and enhanced operational efficiency.

Complementing Lean, TOC is guided by Goldratt's Five Focusing Steps, which constitute a disciplined improvement cycle. These steps involve identifying the system constraint that limits overall throughput, exploiting the constraint using existing resources, subordinating all non-constraint processes to support the constraint, elevating the constraint when necessary through capacity or process enhancements, and continuously repeating the cycle as new constraints emerge. This approach ensures that improvement efforts are concentrated where they yield the greatest system-wide impact [16].

The proposed Lean–TOC integration framework is built on the premise that system throughput should govern all improvement initiatives, while Lean tools should be selectively deployed to support constraint exploitation and flow stabilization. The framework is structured into five sequential stages (Figure-1).

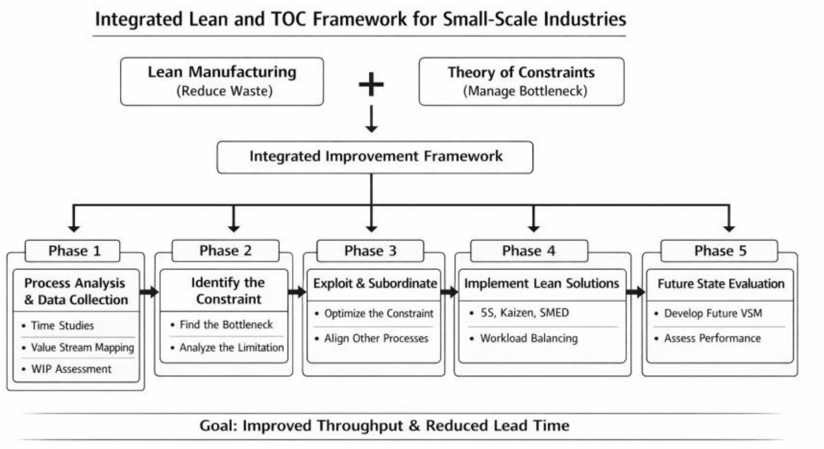

Figure-1: Conceptual Lean–TOC integration framework

First, the current system performance is evaluated using Lean diagnostic techniques such as process flow analysis and Value Stream Mapping to understand material and information flows. Second, the primary system constraint is identified using TOC principles, supported by cycle time analysis and work-in-process accumulation patterns. Third, the constraint is exploited through focused Lean interventions, including tools such as SMED, 5S, and standardized work, aimed at maximizing constraint productivity. Fourth, non-constraint processes are subordinated to ensure synchronized flow toward the constraint and prevent excess inventory and overproduction. Finally, overall system performance is reviewed to identify emerging constraints, thereby reinforcing continuous improvement.

By integrating Lean and TOC in this structured manner, the framework ensures that waste elimination and flow improvements are not applied in isolation but are strategically aligned with system constraints. This alignment enhances the effectiveness and sustainability of improvement initiatives, providing a coherent foundation for the research methodology presented in the subsequent section.

Based on the proposed Lean–TOC conceptual framework, a structured research methodology is developed to systematically evaluate its applicability and effectiveness in a real manufacturing context. The methodology operationalizes the framework by translating its sequential stages—current state assessment, constraint identification, focused improvement, and performance evaluation—into measurable and replicable research steps. Both Lean diagnostic tools and TOC-based analytical techniques are employed to ensure a comprehensive understanding of system behavior, while simulation is used to assess post-improvement performance under realistic operating conditions. The following section details the research design, data collection procedures, analytical approach, and performance assessment methods adopted in this study.

5. RESEARCH METHODOLOGY

This study follows a case study–based research methodology appropriate for applied manufacturing system analysis. As the implementation phase is in progress, the emphasis is placed on systematic diagnosis, framework application, and simulation-based evaluation rather than empirical post-implementation results. Initially, process and performance data are collected through shop-floor observations, time studies, process routing analysis, and interactions with operators and supervisors. The collected data include cycle times, setup times, machine availability, work-in-process (WIP) levels, manpower deployment, and production rates, supplemented by historical production records.

The current production system is analyzed using an integrated Lean–TOC perspective. Lean tools, particularly Value Stream Mapping (VSM), are used to visualize material and information flows and identify value-added and non-value-added activities. Concurrently, TOC principles are applied to examine capacity imbalances and locate throughput-limiting processes based on cycle time comparisons and WIP accumulation. Following this analysis, system bottlenecks and dominant wastes are identified and prioritized. Improvement proposals are developed using TOC's focusing logic, while appropriate Lean tools—such as standardized work, SMED, layout refinement, and workload balancing—are selectively applied to exploit and stabilize the constraint. A future-state system configuration is then designed. Figure-2 depicts the Research Methodology Flowchart.

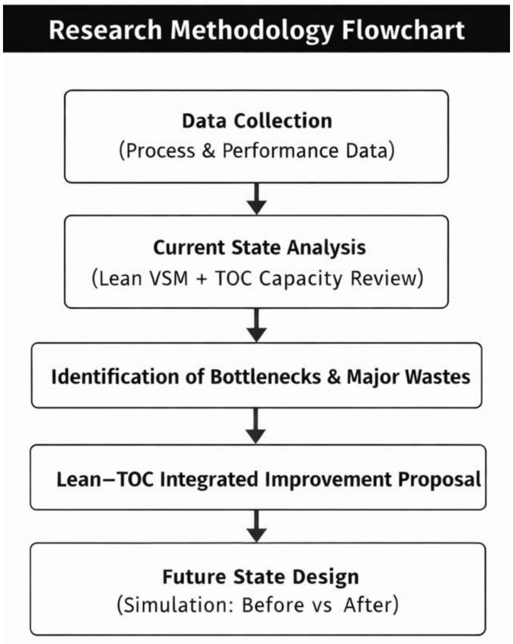

Figure-2: Research Methodology Flowchart

As physical implementation is constrained by time and cost, performance evaluation is conducted using simulation modeling. Key performance indicators, including throughput, lead time, WIP levels, and resource utilization, are compared between the current and proposed future states. This methodology provides a structured and replicable roadmap for future empirical validation.

6. EXPECTED OUTCOMES AND PRACTICAL IMPLICATIONS

The proposed Lean–TOC integration is expected to reduce lead time and work-in-process inventory while improving throughput and utilization of critical resources in small-scale manufacturing systems. By aligning Lean waste elimination with TOC's constraint-focused logic, the framework enables high-impact, targeted improvements without immediate capital investment. Simulation-based evaluation is anticipated to demonstrate improved flow stability and overall efficiency, while providing managerial support for performance-based decision-making and a structured continuous improvement culture.

7. CONCLUSION

This paper proposes a conceptual Lean–TOC integration framework tailored to the operational realities of small- scale industries. By combining Lean's flow and waste reduction focus with TOC's bottleneck-driven prioritization, the framework ensures system-level performance improvement. A structured research methodology, including current-state analysis, constraint identification, integrated improvement design, and simulation-based evaluation, was also outlined. Although empirical validation is in progress, the study offers a practical and coherent foundation for future application and research in resource-constrained manufacturing environments.

8. REFERENCES

[1]. Omar Bataineh, Tarek Al-Hawari, Hussam Alshraideh, Dorid Dalalah, "A sequential TPM-based scheme for improving production effectiveness presented with a case study", *Journal of Quality in Maintenance Engineering* , Vol. 25 No. 1, pp. 144-161, 2019

[2]. Shirin Begum, Md Abubakar Siddique Akash, Md Sanjid Khan, Minhazur Rahman Bhuiyan, "A Framework For Lean Manufacturing Implementation In The Textile Industry: A Research Study", *International Journal of Science and Engineering*, 1(4):17-31, 2024

[3]. Leandro L. Lorente Leyva, Edwin P. Curillo Perugachi, Ramiro V. Saraguro Piarpuezan, Carlos A. Machado

Orges and Edwin P. Ortega Montenegro, "Lean Manufacturing Application in Textile Industry ", *Proceedings of the International Conference on Industrial Engineering and Operations Management* Paris, France, July 26-27, 2018

[4]. P.G. Saleeshya and P. Raghuram, N. Vamsi, "Lean manufacturing practices in textile industries – a case study", *Int. J. Collaborative Enterprise*, 2012, Vol. 3, No. 1, 2012

[5]. Falah Abub, Hamed Gholami, Muhamad Zameri Mat Saman, Norhayati Zakuan, Dalia Streimikiene , "The implementation of lean manufacturing in the furniture industry: A review and analysis on the motives, barriers, challenges, and the applications", *Journal of Cleaner Production*, 234 (2013) 660-680, 234, 660-680, 2013

[6]. Dima A., Dinulescu R., "A Lean Management Approach For The Romanian Textile And Clothing Industry ", *Business Excellence and Management*, Volume 9 Issue 2 , June 2019.

[7]. Jos A.C. Bokhorsta, Wilfred Knolb,C, Jannes Slompb, Thomas Bortolotti, "Assessing to what extent smart manufacturing builds on lean principles", *Int. J.Production Economics*, 253, 2022

[8]. Rachna Shah a, Peter T. Ward b, "Lean manufacturing: context, practice bundles, and performance", *Journal of Operations Management*, 21 (2003) 129–149, 2003

[9]. R.Sundara, A.N.Balajib, R.M.SatheeshKumar, "A Review on Lean Manufacturing Implementation Techniques", *Procedia Engineering*, 97 (2014) 1875 – 1885, 2014

[10]. Md. Monir Hossain, "A Study to Reduce the Lead Time of a Bakery Factory by Using Lean Tools: A Case Study", *International Journal of Scientific and Research Publications*, Volume 5, Issue 11, November, 2015 [11]. S. A. Salah and N. Sobhi, "Productivity Enhancement Through Lean Implementation – A Case Study", *Proceedings of the 18 th Int. AMME Conference*, 3-5 April, 2018 , 43-56, 2018

[12]. Upadhye, N., Deshmukh, S.G. and Garg, S., "Lean manufacturing in biscuit manufacturing plant: a case", *Int. J. Advanced Operations Management*, Vol. 2, Nos. 1/2, pp.108–139, 2010

[13]. Paul A. Ozor Chibuike L. Orji-Oko Chimaobi K. Olua, "Productivity Improvement of Small and Medium Scale Enterprises using Lean Concept: Case Study of a Bread Factory ", *European Journal of Business and Management*, Vol.7, No.32, 2015

[14]. N. R. Rajhans Fellow, IEI. S.M Mehta, .T.M Jawale, D.R Shah, P.V Maharnwar, "Productivity Improvement in a Bakery", *Researchgate*, researchgate.net/publication/260658163, December 2013

[15]. Panagiotis Tsarouhas, "Implementation of total productive maintenance in food industry: a case study", *Journal of Quality in Maintenance Engineering*, Vol. 13 No. 1, pp. 5-18, 2007

[16]. Goldratt, E. M., & Cox, J. (1992). *The goal: A Process of ongoing improvement*. Great Barrington, MA: North River Press Publishing Company.

[17]. Nitza Geri Æ Niv Ahituv, "A Theory of Constraints approach to interorganizational systems implementation", *Inf Syst E-Bus Manage*, (2008) 6:341–360.

[18]. Seung-Hyun Rhee & Nam Wook Cho & Hyerim Bae, "Increasing the efficiency of business processes using a theory of constraints", *Inf Syst Front*, (2010) 12:443–455.

[19]. Somayeh Sadat & Michael W. Carter & Brian Golden, "Theory of constraints for publicly funded health systems", *Health Care Manag Sci*, (2013) 16:62–74.

[20]. Zeynep Tuğçe Şimşita , Noyan Sebla Günayb , Özalp Vayvay, "Theory of Constraints: A Literature Review", *Procedia - Social and Behavioral Sciences* , 150 (2014) 930 – 936.

[21]. Diego Augusto de Jesus Pacheco, "TOC, lean and six sigma: The missing link to increase productivity?", *African Journal of Business Management*, Vol 9(12), pp. 513-520, 28 June, 2015.

[22]. Guilherme Venanzi de Almeida, Fernando Bernardi de Souza, Humberto Rossetti Baptista, Mahesh Chander Gupta, Renato de Campos, "Fundamental principles of the Toyota Way and the Theory of Constraints: comparative analysis and synthesis", *Int. J. Services and Operations Management*, Vol. 30, No. 1, 2018.

[23]. J. Rajini, Dega Nagaraju, S. Narayanan, "Integration of lean, Six Sigma and theory of constraints for productivity improvement of mining industry", *International Journal of Productivity and Quality Management*, January 2018, Vol. 24, No. 3.

[24]. Yrlanda de Oliveira dos Santos, Carlos Alberto Oliveira de Freitas , Renato Souza de Lira, Cristiano Coimbra Goes, Reginaldo Jackson dos Santos Braga, Vandermi João da Silva, "Application of the overall equipment efficiency technique and theory of constraints to minimize Bottlenecks in a production line", *International Journal of Advanced Engineering Research and Science (IJAERS)*, Vol-7, Issue-7, Jul- 2020.