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A CRITICAL REVIEW OF THE CONTEMPORARY STUDY ON LEAN 4.0 IMPLEMENTATION IN INDIAN MSMES COMPARED TO LARGE INDUSTRIES

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ABSTRACT: This paper reviews the literature to examine the current status of research on the practical use of Lean 4.0 techniques in Indian MSMEs compared to large industries. The study mainly focuses on the research work done in recent years since 2022. The review aims to identify the research gaps in Indian MSMEs in using Lean 4.0 practices compared to Large Manufacturing industries and make important recommendations for future research, including the reasons for roadblocks in Lean 4.0 implementation in Indian MSMEs.

Study methodology: **–**

The present plethora of research on the integration of Industry 4.0 with Lean Manufacturing, often referred to as Lean 4.0, is thematically analyzed and synthesized using a systematic review of the literature. In this study, over 100 publications from peer-reviewed journals are subjected to a thorough literature review and content analysis.

Findings:

A thematic map was made to explore the following.

i) Lean 4.0 Tools/Techniques for improving operational performance.

ii) Lean 4/0 tools trend in the manufacturing industry in and outside India

iii) Determine if Indian MSMEs can implement Lean 4.0 solutions more readily than large manufacturing industries

iv) Challenges to the Use of Lean 4.0 Tools in Indian MSMEs

Keywords:
Lean manufacturing, Industry 4.0, Systematic literature review, MSMEs

I Introduction:

Lean Manufacturing (LM) reduces waste and non-value-added activities, improving productivity, quality, profitability, and competitiveness. However, sustaining LM can be challenging, and incorporating Industry 4.0 technologies can provide significant cost savings in implementation areas [1]. Most organizations struggle to transition to lean corporations, often attempting to use lean methodologies in inappropriate settings. Integrating I4.0 with lean can enhance lean management (LM) implementation to identify and reduce wastages, redefining manufacturing [2]. Industry 4.0 is a digital transformation focusing on automation, data interchange, and real-time monitoring. The primary goal is to automate production processes and improve energy efficiency and work conditions. Real-time information can help monitor, address, and predict events, improving machinery lifecycles and avoiding disturbances. Lean management aims to reduce waste across the entire value chain, and integrating enterprise, IT, equipment, operational systems, and devices yields a complete picture of the entire value [3].MSMEs are the backbone of developing nations like India, but to be market flag bearers, they must improve their operational, environmental, and social efficacy, so it becomes imperative for MSMEs to adopt sustainable business practices like Lean 4.0 [4].

The study aims to identify and categorize research topics related to the combination of "Lean Manufacturing" and "I4.0 technologies" from the years 2022-2024 only. Integrating Lean and I4.0 is crucial for understanding their interaction and developing more efficient deployment techniques. This research field is of great importance for scholars and practitioners to identify research gaps for further study.

This paper is further organized as follows: Section II explains the research methodology, and Section III summarizes the primary results from several research streams. Section IV provides essential recommendations for future research. Finally, the article concludes by emphasizing the significance of integrating lean and I4.0 technologies and the industrial community's recognition of the use of digital technologies in lean organizations and limitations in section V.

II. Research methodology

A systematic literature review (SLR) is a planned way to look at and combine a lot of research papers. It involves finding and evaluating the work of many experts. In the Systematic literature review, the steps followed are to frame research questions and relevant articles collected from credible sources like Google Scholar, identify and evaluate refined articles after inclusion and exclusion, analyze and synthesize relevant articles, and summarise the literature.

As a part of the first step, the research questions are framed by identifying the research gap in Lean 4.0 integration in the manufacturing sector, as in the objectives in the abstract.132 articles were downloaded with the keywords Lean 4.0, MSMEs, integration of lean manufacturing and Industry 4.0, critical success factors, and operational performance and studied critically. The articles were selected from 2022 -2024(until April). In the end, 51 articles related to Lean 4.0 were only cited for writing this paper. All related articles are collected and segregated based on factors such as Year, source, journal, and publication. The articles are then thematically analyzed to provide clear findings based on common themes for qualitative data analysis to generate reports of consistent findings. Finally, the review paper summarises conclusions, limitations and future scope.

III. Results and Implications

3.1 Lean 4.0 Tools/Techniques

In light of the emergence of Industry 4.0 (I4.0), researchers have focused on determining the correlation between Lean Manufacturing and I4.0 integration. Limited studies have also identified barriers to integrating I4.0 and Lean Manufacturing. Various tools have been identified from the systematic literature review and presented in Table 1.

3.2 Integration of Industry 4.0 and Lean integration

Lean and Industry 4.0 in a "Smart" ecosystem. It mainly focuses on three components: operational, financial and environmental performance factors [5]. More research is needed in implementing Lean 4.0 in Small and medium-sized companies to identify challenges [6]. The author explains that I4.0 digital technologies significantly integrate with lean tools in the manufacturing industry, and 93% of these tools are used. They propose a baseline propose model to determine their hierarchy [2].

The author introduces a multi-method approach to designing and understanding a new Lean 4.0 framework, including scoping review and qualitative methods [7]. A SAREL Schneider Electric case study studies the integration of Lean Management and Industry 4.0 in organizations, analyzing 38 Lean tools and 15 Industry 4.0 technologies and highlighting the importance of successful implementation [8]. Another article focuses on sustainable practices and waste management and suggests Lean management tools for a circular economy in agribusiness [9]. According to the author, the Greek food manufacturing sector faces financial, energy, health, and globalization challenges. Lean Manufacturing practices and IoT technologies also improve safety and quality [10]. The author integrates I4.0 with Lean methodologies like e-VMB and e-SMED, showing the benefits and effectiveness [11]. The author suggests the MMSO model, combining Industry 4.0, Lean Philosophy, and Total Productive Maintenance, and enables real-time monitoring of machines and equipment, possibly with top management and maintenance technicians' dedication and training [12]. The author emphasizes the significance of integrating Lean Manufacturing and Industry 4.0 principles in enhancing Product Development (PDP) in manufacturing firms, enabling informed decision-making, improving market performance, and eliminating the "chicken-and-egg problem" of sequential adoption [13].

Table 1: Lean 4.0 tools from literature (author's work)

Article Citation	Lean 4.0 tools identified
[14]	Lean Six Sigma, Lean and Internet of Things, VSM, radio frequency identification, Lean and smart manufacturing
[15]	Financial capability, Government support, Top management support and commitment, Customer focus, Change management and organizational culture, Employee attitude, motivation and involvement, Training and education
[16]	AI Chatbot
[17]	IoT, Big data, Robotics, Virtual Reality, Cloud AI, CPS Integration, RFID, Simulation
[18]	Top management leadership, Customer focus, Employee training and learning, Total productive maintenance, Statistical process control, Operational, Managerial and Technological readiness
[19]	Work-on-screen solutions, Product tracking, MES systems, Flexible automation
[20]	JIT With CPS, JIT with AGVs, TPM 4.0, TPM with analytics, e-Kanban with IIoT, Kanban with Simulation, VSM with CPS, VSM with simulation, SMED with additive manufacturing, Jidoka with sensors and actuators, Heijunka with H&V and data analytics Over
[21]	Project charter, VOC, VOB, EVSM, LCA, 5 whys, Pareto chart, Cause and Effect diagram, Environmental impact analysis, Green Scoreboard, 7S, OCAP, Kaizen, Big Data, IoT, Cyber security, CPS, Cloud computing, RFID, Sensors, VSM 4.0, 3 D Printing, 6R, COBOT, AR
[22]	5S, Cause and Effect matrix, Control chart/SPC, Partial least squares, Poka-Yoke, Regression, Root cause analysis, Response surface method, Simulation, SIPOC, SMED, Statistical analysis, Taguchi design, Taguchi loss function, Voice of the customer, Voice of stream mapping
[23]	Autonomous kanban, E-Kanban, Poka-Yoke, Traceability in VSM, VSM/JIT optimization, Intelligent cards release, Real-time tracking in Andon, Jidoka.
Article Citation	Lean 4.0 tools identified
[24]	Sustainable VSM, Extended SMED, Digital Poka-Yoke
[25]	Smart 5S, VSM, KANBAN, POKE-YOKE, JIDOKA, JIT, TPM, KAIZEN, Digital Andon, Heijunka, e-SMED
[26]	Autonomous robots, JIT, Industry4.0 & agility, LSM, Poke-Yoke, , E-Kanban, AQMS, Green manufacturing, Cyber-physical system, IIOT, 5S, Hybrid simulation-based VSM, SMED, AI, Machine learning, Digital manufacturing system, RFID), LSS 4.0, Cloud computing, Circular economy
[27]	Intelligent Processes, Real-time process monitoring, Avoiding digital waste
[28]	Agile manufacturing, Just-in-time, Jidoka, LSS 4.0, TPM, Kanban, Waste elimination, Kanban, Andon, Big data
[29]	Kanban, Workplace management, Total productive maintenance, Mistake proofing, 5 S practice, Visual Management, Value stream mapping, Takt time analysis, Just-in-time, Kaizen, Cellular manufacturing, 5 why's, Cause and effect, Pareto analysis, Change management tools, Kanban, Workplace management

[30]	Value stream orientation, PDCA, LM and I4.0, Waterfall project management, CM approaches, Agile and Pilot-based approaches
[31]	Kaizen Improvement, People Management, Customer Focus, Simulation
[32]	IoT, Big data, Robotics, Virtual Reality, Cloud AI, CPS Integration, RFID, Simulation

3.3 Implementation of Lean 4.0 in MSMEs

The author identifies the integration of Industry 4.0 technologies, particularly the Internet of Things, into Small and Medium-sized Enterprises (SMEs). The major barrier identified is investment. Competitiveness and innovation are the factors that motivate SMEs to implement digital technologies to achieve organizational improvements. Government support and policies could increase implementation and the value chain [33]. The author reveals that MSMEs' with lean 4.0 transformation affect the firms significantly. It also supports the resource-based theory of firms to seize opportunities in crisis that were digitally shifted before COVID-19 and Porter's five forces; the experience curve is a much-discussed barrier to entry and exit [34]. Also, the author finds the impact of digital technologies on operational efficiency in Pakistani SMEs and proposes a positive correlation with employee engagement [35].

3.4 Implementation of Lean 4.0 Critical Success Factors & Barriers and Operational Performance

Lean manufacturing model for Industry 4.0, aims to improve productivity, reduce lead time, increase capacity, and enhance operational excellence and profitability tested in two industries [36]. The author suggests factors that influence integration of cloud computing with 415 Malaysian SMEs using the TOE model to find advantages, complexity, compatibility, top management support, cost reduction, and government support significantly impact integration, suggesting SMEs can improve their financial, environmental, and social performance [37]. The author [38] proposed a barrier-solution framework using the FAHP-PROMETHEE technique, identifying 21 barriers, with economic and organizational dimensions being the most significant from the Indian perspective. The author suggests Key I4.0 technologies include BDA, IoT, cloud computing, and RFID in combination with Lean tools with case studies focusing on the DMAIC approach of SS [39]. To conclude the implications of the literature review, a set of Lean 4.0 tools has been identified. Each tool, if understood and applied in a fair manner, has its own capability of changing the future of Indian MSMEs.

IV. Key recommendations for future research:

In total, 132 relevant journal articles have been identified during the review during the last two years (i.e.,2022-2024), and 51 articles were critically reviewed to propose key recommendations for future research based on the current literature:

4.1 Integration of Lean manufacturing and industry 4.0 in Indian MSMEs

Lean Manufacturing has become a widely adopted approach in many Micro, small, and medium-sized enterprises (MSMEs). However, the amount of implementation of Industry 4.0 technology in these MSMEs differs due to its recent introduction. The technologies of the fourth industrial revolution (I4.0) will create equal opportunities for everyone, regardless of the size or scope of their activities, and will minimize economic dependencies. To remain competitive, Micro, small and medium-sized enterprises (MSMEs) must acquire the skills to utilize the capabilities of Industry 4.0 technology. While most technologies of the Fourth Industrial Revolution (I4.0) may be effectively adopted in large-scale firms, using them in Micro, small and medium-sized enterprises (MSMEs) poses a significant challenge.

According to [40][41], the main roadblocks to Lean 4.0 implementation are location, focus group, industrial development, and government policies in India. Future research with larger samples and application-based real case studies with structured models with an index to guide Lean 4.0 initiatives is suggested [2]. According to [42][43], Future research needs to explore internal factors, excluding

external factors. Future research should focus on broader systematic reviews and bibliographic analysis to address social and environmental concerns [44][45].

4.2 Integration of Lean 4.0 with Operational Performance

The adoption of Lean 4.0 in manufacturing companies enhances operational excellence. The study suggests empirical testing for smart manufacturing [46]. Proper DSP scenarios and X Reality visual analytics should focus on efficiency and social sustainability impacts [47]. However, there is a lack of research on the impact of I4.0 on Lean practices and performance implications [27].

4.3 Integration of Lean 4.0 in and outside Countries

The authors [48][49][50][13] research work from Brazil and Spain suggest focusing on the collection of data like a broader sample, more articles, and selecting data from emerging countries. A case study in Taiwan on Dynamic Lean 4.0 tools in SSMS suggests further research on Sustainable VSM and Extended SMED for continuous improvement in social, economic, and environmental performance [51].

V. Conclusions, research gaps, and limitations:

In the current competitive world, manufacturing companies face diverse competition characterized by changing customer expectations, intense competition, globalization, financial crisis, and economic downturn. Under these challenging environments, for companies to be competitive, they must constantly adapt to the latest technologies and processes to maintain the sustainability of the process. I4.0 is the latest advancement in the industrial process, which has been presented as a solution to ensure the productive sector's success in the digital area but must be aligned with organizational process improvement to guarantee such sustainability. Hence, different aspects of Lean Manufacturing and I4.0 integration have been explored in this paper as a potential approach to achieving such alignment. However, development in this area is still in its infancy, and most articles considered in this area have been published in the last two years.

5.1 Emerging tools in the integration of Lean and Industry 4.0

After a thorough literature review of articles related to Lean 4.0 (integration of lean principles and Industry 4.0), Almost 32 emerging tools were suggested. Though various lean 4.0 tools vary in their requirements to be installed in the manufacturing organization, they improve productivity with reduced cost and waste. Lean 4.0 integration has been researched exclusively in almost 51 articles in various organizations, and most of the articles used tools like Digital Poka-Yoke, TPM, VSM, and many statistical and mathematical approaches. Out of all the tools, Top management support and Employee training play a major role in the acceptance of the integration of Lean and Industry 4.0 at the grassroots level of any manufacturing organization. As most lean 4.0 tools are not understood in concept and application, comparatively, few companies are interested in adding new technologies besides benefits. Table 2 shows lean tools, their process and operational factors. Though many companies are in the name of Lean 4.0 implementation, they are nascent. Thus, much exposure is needed for implementing Lean 4.0 tools, not theoretical implications. Figure 1 is a mind map drawn to present the Lean 4.0 tools. Along with the Lean 4.0 tools, various Statistical methods like MIC MAC, ISM, Delphi, Fuzzy, etc., are identified in the literature survey.

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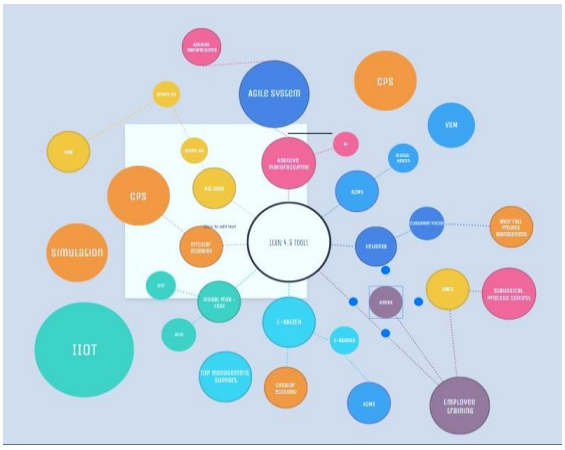

Figure 1: Lean 4.0 tools mind map (author's work)

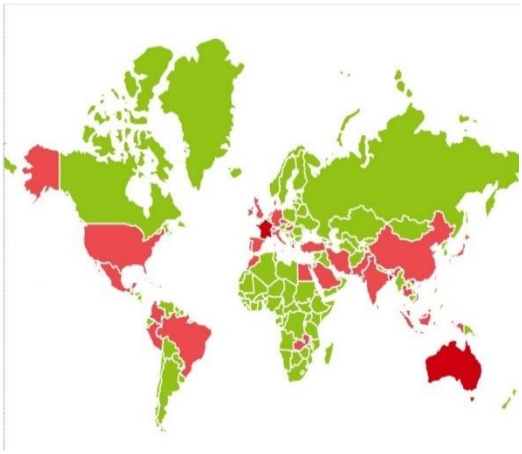

Figure 2: Lean 4.0 Country-wise research

5.2 Lean 4.0 tools trend in the manufacturing industry in and outside India

A thorough literature survey contributes to rigorous research in Lean 4.0 integration in India and other countries, covering the maximum share of research. This paper focuses on the Indian perspective, but most countries worldwide, like Brazil, Malaysia, Germany, Portugal, and Italy, also show interest in implementing Lean 4.0 and rigorously checking their effect on operational performance. This is evident from the Case study and survey methods chosen for Lean 4.0 implementation. Around the globe, various researchers have tried to implement Lean 4.0 technologies in manufacturing companies, mining, leather, agriculture, food processing, supply chain, and healthcare services. Definitely, this encourages researchers from various streams to conduct many more studies in various streams and benefit from Lean 4.0 strategies in depth. Figure 2 depicts the country-wise efforts in the research with the help of a map.

5.3 Can Indian MSMEs implement Lean 4.0 solutions compared to other manufacturing companies

After conducting a systematic literature review of available research articles, Various authors' contributions clearly mention the challenges in implementing Lean 4.0 in manufacturing organizations. Indian MSMEs are not particularly interested in using Lean 4.0 technologies compared to large manufacturing companies because they fear roadblocks in their implementation. Comparatively, MSMEs have a more competitive edge and flexibility in realizing the benefits of Lean 4.0 implementation with low investment and acquiring new skills. Even the government supports lean schemes to enhance productivity.

5.4 Challenges faced by Indian MSMEs in the use of Lean 4.0 tools

The available research articles indicate that Indian MSMEs are expected to face many challenges in implementing Lean 4.0. Some identified challenges are resistance to change, lack of technical expertise, time-consuming with limited resources, and government regulations to adopt and implement lean 4.0 tools.

5.5 Limitations and Future Scope

This is a limitation as the research was carried out based on a Systematic Literature review of the articles collected from 2022 -2024 only. There is a possibility of overlooking or missing a few articles and their implications from the source. This paper covers only the implications and considerations of selected articles. In addition, the articles collected were from a mix of various lean technologies, which concludes that the inbounded results cannot be generalized to all. This review paper contributes to and motivates future researchers to research this stream of Lean 4.0 in different MSMEs, with diverse lean tools and solutions to provide a competitive advantage in sustaining and making India more self and digital-reliant. The future scope is to choose the proper Lean 4.0 tool concerned with the specific requirements of the manufacturing industries and incorporate more case studies and observations on the technologies with validation. Another gap needs to be focussed on social, economic, and

environmental performance with the integration of Lean and Industry 4.0. There is a need for more research on the role of human factors in Lean 4.0 implementation.

Table 2: Lean tools and relation to Operational performance (author's work)

Lean 4.0 tools	Process involved	Operational Performance factors
Smart 5S	Organizing the workplace	Reduces waste
Additive manufacturing (3D Printing)	Construction of items by adding material	Reduces waste and Cost effective
Agile system	Strong focus on rapid response to customer	Reduced waste and shorter lead time
AI Machine learning	Helps manufacturers to identify inefficiencies	Increased productivity
Andon-Digital	Automated alert system	Reduced costs and Increased safety
Autonomous quality management system(AQMS)	Eliminates human errors	Reduced Costs
Big data	Helps in data collection from machines	Reduces Time waste
Circular Economy	Novel concept of reutilization of material	Reduces waste and Cost effective
Creative Problem solving (CPS)	To overcome problems and improve work processes	Reduced Time waste
Customer focus	Maximise customer value	Reduces waste
Cyber physical system	Connects the sensors and communication	Reduces defects
Lean 4.0 tool	Process involved	Operational performance
Employee training	Covers organizations needs	Continuous improvement
Heijunka with data analytics	Levels type and quantity of production	Reduced costs
Industrial Internet of Things (IIoT)	Provides high-value data	Improved efficiency and reduces waste
Jidoka with sensors and actuators	Automatically stops machines on detection of abnormality	Reduced defects
Just in time (JIT)	Produces what is needed	Improves productivity and reduces waste
e-Kaizen	Continuous improvement and employee participation	Improves productivity and quality
e-Kanban	Maintains optimum inventory	Shorter Lead time
Plan do act check (PDCA)	Production and continuous improvement	Reduces defects and delivery time
Digital Poka-Yoke	Error proofing and continuous improvement	Reduces defects
Radio Frequency Identification (RFID)	Improves inventory management	Improves operation time
Simulation	Animates display of processes	Workers change
Smart Manufacturing	Production enhancement within available resources	Reduces cost

Extended Single minute exchange of die (SMED)	Performs many changeover steps in the machine	Reduced change over time
Takt time analysis	Synchronizes production with customer demand	Improves flow and reduces waste
Top management Support	Guides manufacturing processes	Reduced waste and increased efficiency
Total productive maintenance (TPM)	Focuses on equipment maintenance	Increased Productivity
Value stream mapping (VSM)	Process of product and service creation	Reduced cycle time
Waterfall project management	Sequential task completion	Reduced Time waste

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