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DEVELOPMENT OF INTEGRATED LEAN AND GREEN FRAMEWORK FOR SMALL SCALE MANUFACTURING INDUSTRY

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Abstract
Small-scale industries (SSIs) play a crucial role in the Indian economy and are key contributors to employment generation. Lean manufacturing has been shown to enhance operational and economic performance, while green manufacturing practices improve social and environmental outcomes. Integrating Lean and Green manufacturing practices offers a promising solution for minimizing the environmental impact of manufacturing industries. This research aims to develop a framework that integrates Lean and Green practices specifically for SSIs in India. The proposed framework is comprehensive yet simple, designed to be easily adopted by SSIs to improve their sustainability and efficiency. The framework includes Assessment Phase, Planning Phase, Implementation Phase and Evaluation Phase. Assessment Phase includes evaluating current processes, gathering input from stakeholders, creating process maps, identifying waste, and selecting Lean and Green tools. Planning Phase includes setting clear goals, determining key performance indicators (KPIs), developing implementation plans, organizing training sessions, and forming dedicated Lean and Green (LnG) teams. Implementation Phase includes implementing techniques such as Value Stream Mapping, 5S, and 3R (Reduce, Reuse, Recycle), and establishing standard operating procedures (SOPs). Evaluation Phase includes continuously monitoring performance against KPIs, conducting regular reviews and audits, and making ongoing improvements. This structured approach is designed to help SSIs effectively adopt Lean-Green practices, ultimately contributing to their sustainable development and operational efficiency.

Keywords:
Lean manufacturing, green manufacturing, Integrated LnG framework, implementation framework, small-scale manufacturing industry.

I. Introduction

The small scale industries are the lifeline of the economy, specifically in developing countries like India. Small Scale Industries (SSIs) works in manufacturing, production, and rendering of services are done on a small or micro scale. These industries make a one-time investment in machinery, plant, and equipment, but it does not exceed Rs.10 crore and annual turnover does not exceed Rs.50 crore. These industries are generally labour-intensive, and hence they play a pivotal role in employment creation. Small scale industries are a crucial sector of the economy both from a financial and social point of view, as they help with the per capita income and resource utilization in the economy. SSIs are one of the main reasons for the growth and strengthening of the economy.

Table 1: Major problems faced by Small Scale Industries in India: [34, 35]

1. Lack of management commitment and leadership	9. More manufacturing lead time
2. Lack of communication	10. Poor inventory control
3. Lack of resources	11. No maintenance policy available
4. Resistant to change	12. Incompetent management
5. Lack of Employee involvement	13. Inadequate Finance
6. Lack of training and skills	14. Raw material shortages
	15. Lack of technology up-gradation
	16. Inability to meet environmental standards

7. Lack of cooperation and mutual trust between management and employees
8. Poor capacity utilization

To address these problems and to improve the organizational performance lean manufacturing and green manufacturing practices both can be implemented. Lean Manufacturing deals with the idea of eliminating waste from the processes and operational systems. The basic essence is to pull out the maximum output from minimum inputs without influencing the output in any negative way. Waste may be considered to be anything that is not minimum equipment, materials, parts, and working time, which absolutely are vital to production. Green Manufacturing is a process of manufacturing that minimizes waste and pollution. It aims at using minimum natural resources so as to conserve them for future generations. Also, the purpose is to create a substantially better image in the public, to save unnecessary cost, and to promote extensive research, engineering, and redesign to improve efficiency in greener ways. Thus, green manufacturing emphasizes manufacturing goods and services with minimal impact on the environment under present technological and economic challenges. The purpose of the research is to explore as well as to reflect the scope of integrating lean and green manufacturing to eliminate waste and to adapt environmental protection into business performance in small-scale Industries.

II. Literature Survey

2.1 Lean Manufacturing and its practices

Toyota production system first introduced Lean manufacturing in the 1950s. It mainly focuses on eliminating all kinds of non-value adding activities and process which are considered as waste and create no value for customers. Russell and Taylor (1999) define waste as anything other than the minimum amount of equipment, effort, materials, parts, space and time that is essential to add value to the product. To remove all kinds of lean waste has numbers of techniques and practices. 5S, Kaizen, takt time, poka yoke, error-proofing techniques, Value Stream Mapping, inventory minimization, high resource utilization, Cellular layout, Total Productive Maintenance [TPM], shorter lead time, work standardization, Just in Time [JIT] and Total Quality Management [TQM] are among the lean techniques. Different types of problems need different lean practices to be implemented. Various researchers have studied the implementation of the lean strategy.

Singh et al. (2013) show the role of lean manufacturing and JIT principle in supply chain management in small Manufacturing companies. In this study, the principle is used to eliminate waste, improve quality, increase production flow and reduce cost. [1]. Krisztina Demeter et al. (2011) studied the effect of lean manufacturing and contingency factors affect inventory turnover. The result of the study shows a significant relationship between lean manufacturing and inventory turnover [2]. A study by Hemanand et al. (2012) focused on waste reduction on an automotive industry, and the result of the study shows 11.95% improvement in productivity by modifying the layout. Time study and motion study was done to do the analysis [3]. Shah and Ward (2003) investigate how just in time, total quality management, total prevention maintenance, and human resource management result in 23% variation on operational performance [4]. Chakrabortty et al. (2011), use value stream mapping and layout design as their main lean tool and present a framework for the industries to improve their capacity. The result of the study shows 45%, 10 and 14% improvement in productivity of different buyers respectively [5]. A study by Mo et al. (2009), shows 30% increase in productivity by applying lean manufacturing principles in a small furniture company [6]. Dal Pont et al. (2008) used JIT, TQM and human resource management in 9 companies. The results indicate that JIT and TQM has a positive effect on operational performance while human resource management has mediated the effect [7].

Different studies haves been done on the effectiveness of implementing lean practices in manufacturing systems. The benefits of applying this strategy are:

- Reduction in cost [1]

- Reduction in lead time [5]
- Waste reduction [3]
- Improvement in productivity [3, 6]
- Operational performance and quality [4, 7]
- Cycle time reduction [5]
- Capacity improvement [5]
- Better labor, space and equipment utilization [3, 5]
- Reduction in work in process [WIP] Inventory [11]

2.2 Green Manufacturing and its practices

Green manufacturing strategies considers the whole life cycle of a product, from material requirement and specification, manufacturing and disposal of the product to reduce the environmental impacts. [8, 9] Green manufacturing practices focuses on the processing of producing a product and also disposal of the material without considering the manufacturing process. The practices focus on reducing the usage of resources such as energy, water, raw material, air emission, hazardous waste and non-product output and increasing the possibility of using recyclable or reusable material to reduce the environmental impacts [10]. The majority of these reductions cannot be optimized by only utilizing lean practices. Sarkis (2003) shows that JIT, TQM and introduction of a new process can help in reduction of resources [10]. Luttropp et al. (2006) provide golden rules for greening a product:

The summary of the rules to have a green product based on Luttropp et al. (2006) is as follow:

- Toxic materials should be eliminated.
- Energy and resource consumption in production and use phase should be minimized.
- High-quality materials and material cleaning are necessary to reduce maintenance
- Regular upgrading and repairing schedule for system is another way of greening the products.
- Use long-life products
- Organize upgrading, repair and recycling through access ability, labeling, modules, breaking points and manuals or recycled, simple, not blended materials and no alloys, whenever practical.
- Prevent using the joint as far as it possible and used them by considering their life cycle assessment. [11]

Investigating the energy consumption of machine tools provides important information that can be applied in the use phase of machine tools, as well as the manufacturing phase of the products that are made. Reducing the energy consumption of machines based on idle and busy time, identifying disruption based on power usage will help to reduce the environmental impacts associated manufacturing processes and systems. It will also help to track maintenance and providing beneficial reports [12, 13] The level of CO2 emissions that are imposed on developing countries and especially on India and China, two of the world's fastest-growing economies, creates the necessity of shifting the concentration towards environment-friendly ways of production and manufacturing. This also makes us think about sustainable development (UN Report, 2010). Deif (2011) presents the model which can capture various planning activities to migrate from a less green for the new green manufacturing paradigm into a greener and more eco-efficient manufacturing. According to Rahma et al. (2009) cleaner production (CP) can reduce cost, based on competitive advantage and environmental aspect approaches. The approach towards the CP practices is to: reduce, reuse, recycle, and reproduce and recovery (i.e., 5R). Selinger et al. (2008) identify a research and development plan for sustainable manufacturing focusing on enhancing use-productivity. Hosseini (2007) discusses the basic factors and a conceptual model in the adoption and maintenance of green management system. It is anticipated that if organizations ensure these factors, they will experience less resistance from their stakeholders and consequently they will have a successful GM (green management) and GP (green productivity) implementation. Huiy et al. (2002) presents a case study that demonstrates that the fuzzy set-based model can effectively account for the vagueness and uncertainty of information being used for the environmental impact of a manufacturing process.

Advantages of Green Manufacturing:

- Save valuable resources
- Economic incentives [13]
- Energy efficiency
- Benefits environment by reducing waste and harmful emissions
- Competitive advantages [13, 14]
- Higher quality and reliability

2.3 Linking lean with green manufacturing

Lean and green manufacturing sometimes used interchangeably. However, they have different end goals. Lean focuses on eliminating non-value adding activities by considering seven kinds of waste. Many different researchers studied the combination of lean and green strategies. Manufacturers can be green and highly profitable at the same time. Profits do not have to be sacrificed to environmental responsibility, or vice versa. The two strategies (lean and green) can be integrated and offered simultaneously that will reduce environmental or productivity inefficiencies (Pacific Northwest Pollution Prevention Resource Centre, 2008). According to Black et al. (2010) green manufacturing has the goal of zero waste. Yang et al. (2011) explores relationships between lean manufacturing practices, environmental management (e.g., environmental management practices and environmental performance), and business performance outcomes (e.g., market and financial performance). Bergmiller et al. (2009) suggests that "Lean and Green Programs" are synergistic and correlated. According to Bergmiller et al. (2009) the philosophical and structural similarities between models of leanness and greenness suggest that the reverse may also be true; i.e., those firms seeking minimal environmental impact from their operation may naturally adopt some methods of lean production in order to reduce wastage. According to Pacific Northwest Pollution Prevention Resource Center (2008), even without explicitly targeting environmental outcomes, lean efforts can yield substantial environmental benefits. Helper et al. (1997) explores how firms can be both profitable and environmentally conscious and how they can be both innovators in manufacturing and leaders in emissions reduction.

Pampanelli et al. (2014), implement the lean and green strategy by application of Kaizen with the aim of reducing waste and environmental impacts. The result of the study indicates that by applying the combination of these two approaches, there will be a reduction in resource usage from 30 to 50%. There is also a potential reduction in mass and energy flow from 5 to 10 %. In this study reduction in energy, water, metallic and contaminated waste, oil and chemicals usage were considered [15]. Galeazzoa et al. (2014), analyzed the performance of lean and green strategies in three projects in two manufacturing plants. This study used, 5-why approaches, material change, resizing the machines and removal of the bottleneck and buffer tools. They discovered that the lean and green practices can be implemented either sequentially or simultaneously. In all the cases the environmental emissions were minimized, speed, flexibility and quality improved in 2 of 3 projects because of the concept of the projects [16]. Chiarini (2014) applied two lean and green strategies in five motorcycle manufacturer. The result shows that value stream mapping, 5S, cellular manufacturing and total productive maintenance will improve the environmental impacts while the minute exchange of die does not change the environmental impacts. Ammonia and isocyanate emissions were measured in this study [17]. Kurdve et al. (2014) considered the integration of lean and green strategies. This study applied Toyota Production System, environmental management system, safety quality management systems and Occupational Health and Safety.

The result of the study shows that there is a lack of sustainability metrics and improvement methods to improve the operational performance [18]. Diaz et al. (2013) used lean and green strategies in a production parts for a powertrain. Batch reduction, Kanban systems, and defect reduction, total quality management, total productive maintenance, process integration for shorter waiting time and green scheduling by power reduction were the tools that used. The result caused in 10.8 % reduction in costs

of representative parts [19]. Dues et al. (2013) studied on the benefits, similarities and difference of lean and green strategies suggested that lean and green have two-way positive effect on each other results. Their result shows that lean manufacturing acts as a catalyst for reducing environmental impacts, and they have overlaps on tools and practices, lead time reduction and their focus on people and organizations [20]. Lean and Green integrated approach aims to achieve improvements in financial or operational and environment-oriented (Leong et al., 2019). The integration of Green and Lean can be seen as a new opportunity for organizations to improve their sustainability performance. According to Cherrafi et al. (2017), organizations that have simultaneously implemented lean and green practices have achieved better results than those organizations that have only focused on either of the initiatives.

2.4 Conclusion from literature review

Lean manufacturing focuses on eliminating the defects in terms of reducing cost and non-value added activities based on customers' point of view. However, green manufacturing focuses on reducing all types of waste including solid waste to reduce environmental impact. Reducing all kinds of waste not only improve the environmental performance of the processes, it also decreases cost and social impacts associated with those types of waste. As it was stated before lean practices focus on reducing time and cost, but they do not consider employee's satisfaction and result in poor quality of the employees' life.

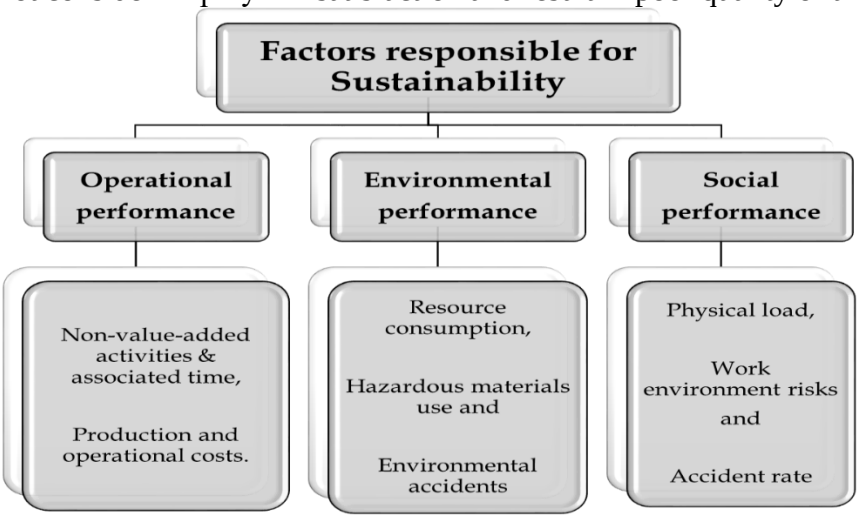

Figure 1: Lean and Green manufacturing for the sustainable performance

The (Figure 1) shows the operational, environmental and social performance parameter for the organizational sustainable performance.

Table 2: Outcomes of Lean and Green implementation

Results	Lean manufacturing	Green manufacturing
Financial improvement	√	√
Cycle time reduction	√	√
Improve productivity	√	√
Improve capacity	√	
Decrease work in progress	√	
Save resources	√	√
Energy efficiency	√	√
Waste reduction	√	√
Emission reduction		√
Company reputation	√	√
Customer satisfaction	√	√
Product quality	√	√
Improve safety	√	√
Improve health		√

2.5 Gaps in existing research

Through the literature survey, it is concluded that, Lean manufacturing has proven its positive effects on operational and economic performance in multiple cases. The implementation of green manufacturing practices improves the social and environmental performance of the SMEs along with enhancement of economic performance in the long run by reducing raw material and energy costs. Environmental factors should be incorporated for the overall performance of the organization. [1, 4] A number of business and environmental factors need to be integrated. [10] There is a general need to focus on environmentally sustainable practices and outcomes in the manufacturing and service industries. [14] Environmentally sustainable practices can be treated as an extension of lean philosophy. [15] Academicians could investigate whether it is possible to shape a general Lean Green model for improving environmental performance. For instance, the model should propose different categories of environmental impacts in different sectors, linking them with the specific Lean tools which can reduce them. [17] The integration of Lean and Green practices will bring benefits to companies. [20] Author concluded that only some researchers have focused on the integration of Green-Lean and Sustainability as a joint approach and to take a holistic view of the inter-related factors in the context of SMEs. [22] Due to their restricted size and resources, SMEs struggle to effectively integrate lean management with green management. Lack of management support and missing metrics are the main factors that prevent companies from implementing lean management and green management. Employee involvement has been proven to be a crucial condition to allow integration to succeed. [22]

The literature review also demonstrates that significant shortcomings in regards to the understanding and application of Green-Lean and Sustainability still exist. These can be overcome by promoting their integration through a comprehensive, simplified and generic implementation framework. A toolkit for Green-Lean and Sustainability has also yet to be developed, as many tools have either not been adapted, are not mature enough or are frequently not recognized by the industry. The authors additionally recognize a need for a greater focus on the context of SMEs to assist them in effectively integrating both paradigms. [22] Through extensive literature survey it is found that, there is barely any exploratory research focused upon the implementation of lean and green manufacturing practices for sustainable organizational performance of Indian small scale industries. Moreover, considering the contribution of Indian small scale industries to the economic and industrial growth, it is interesting to investigate the degree of lean-green adoption in Indian small scale industries. Here, Integration of green and lean manufacturing have been proposed as a solution for manufacturing industries in minimizing adverse environmental impact. This research will aim to integrate lean and green manufacturing practices, develop a lean and green manufacturing implementation framework and implementation of the framework at small scale manufacturing industries.

III. Development of Framework of Integrated Lean and Green (LnG) methodologies

Developing a framework for the integration of Lean and Green manufacturing practices in small-scale manufacturing industries involves creating a structured approach that aligns with the goals of improving efficiency, reducing waste, and enhancing environmental sustainability.

3.1. Literature related to the Lean and Green (LnG) Framework

Siegel et al. (2019) discussed on Green-Lean in the context of manufacturing SMEs. The findings indicate that the most common challenge to Green-Lean implementation is a lack of metrics and measurement. 5S is the most used tool. Author have identified and analysed, through a systematic review, data on the challenges, success factors, tools and techniques, sustainability aspects, frameworks and benefits of Green-Lean in manufacturing SMEs. A systemic model representing the relationship among the determinants to implement a Green-Lean initiative for manufacturing SMEs is also presented (Figure 2) and discussed. [45]

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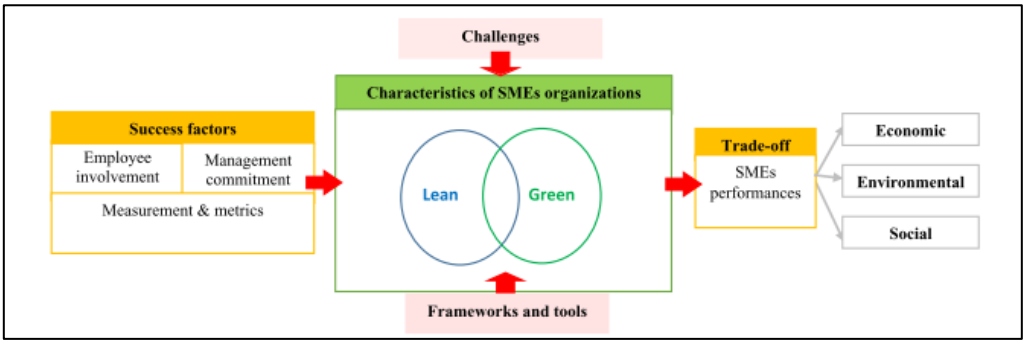

Figure 2: Framework for Green-Lean approach for SMEs [45]

The of Green-Lean tools based on literature survey has depicted (Figure 3) using radar chart. Through this 5S, TPM, VSM, Visual control, pull systems are the most common tool used by the researcher for the LnG implementation. [45]

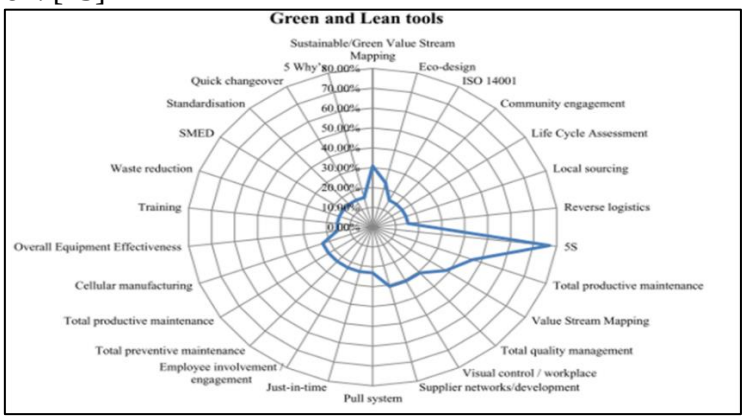

Figure 3: Green and Lean tools – radar chart [45]

Rafique et al. (2019) developed implementation framework of lean linked with technology (Figure 4) incorporating inputs from the literature. Value Stream Mapping (VSM) for lean implementation and Technology-Organisation-Environment (TOE) framework was considered as the most appropriate methodology. [46]

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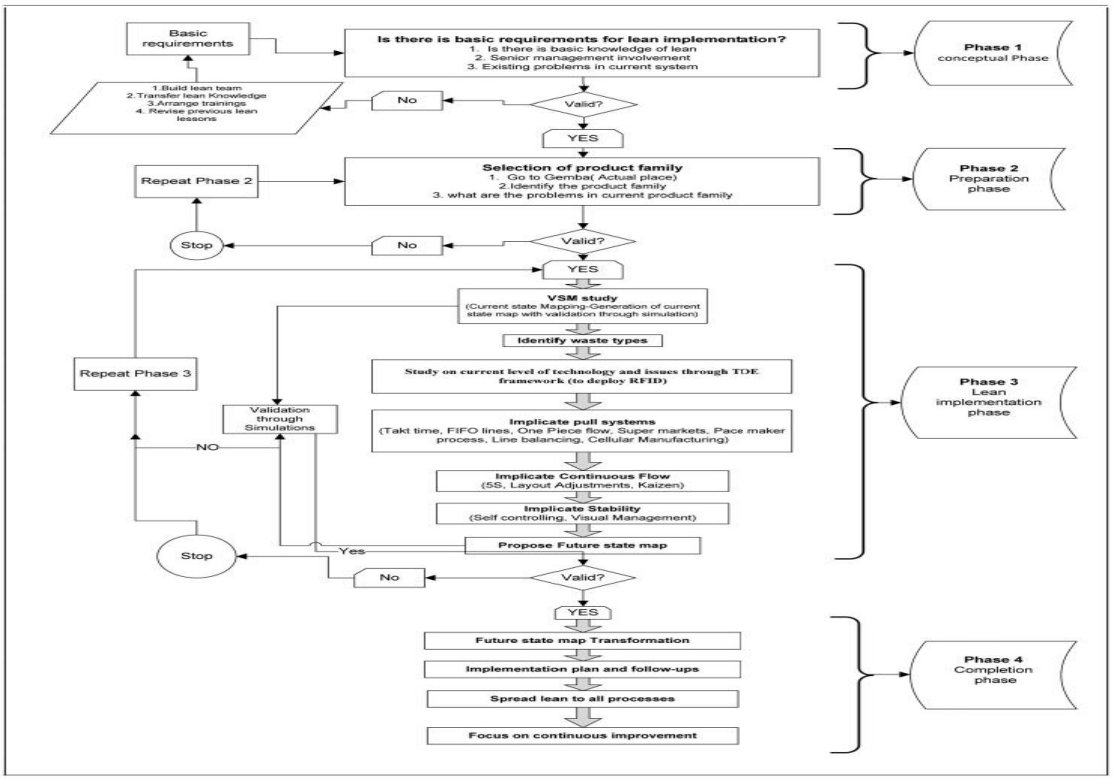

Figure 4: Implementation framework technology linked with lean [46]

David et al. (2016) have developed a methodological framework using a qualitative research approach to the implementation of Lean and Green principles in various industries. In implementing the methodology, the authors encountered obstacles such as low maturity. This lack of maturity could have created problems in adoption and implementation. [35] Cherraf et al. (2017) used a combination of methods to investigate barriers to the implementation of Green Lean practices and understand their contextual relationships. Using a systematic literature review (SLR), they identified and analyzed existing research on barriers to green lean adoption. These barriers involved many complex factors, including political, managerial, behavioral and technical factors. Main issues highlighted in their research included lack of environmental awareness, insufficient government support, financial constraints and various human factors. [36]

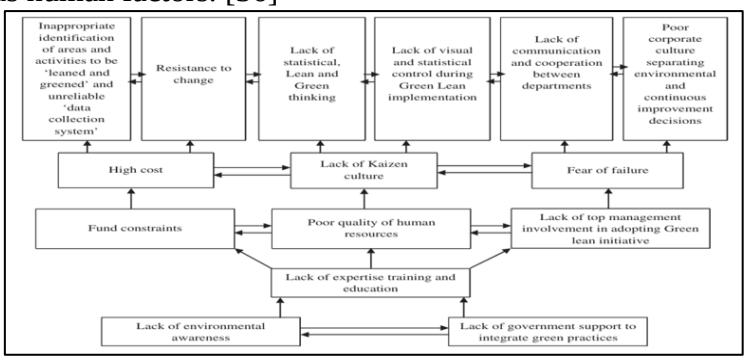

Figure 5: Barriers of Lean and Green adoption [36]

Duarte and Cruz Machado (2017) developed a conceptual framework to integrate green and lean management into organizational supply chains, they faced challenges related to the complexity of combining these two management models. [37] Belhadi, Touriki, and El Fezazi (2018) used a case study methodology to investigate the relationship between lean practices and environmental performance in small and medium-sized enterprises (SMEs), focusing on a pump manufacturing company. They adopted a lean and green integration framework (Figure 6) to investigate the relationship between improved operational and environmental resources in a company. The authors

encountered various obstacles in the implementation of their methodology. These barriers can be challenges related to changing the organizational culture to embrace lean and green principles, employee resistance to change, limited resources and difficulties in matching lean practices with environmental sustainability goals. The study showed a strong relationship between the adoptions of key lean practices such as 5S, Kanban, SMED, independent maintenance and quality control, and improvements to both operational and environmental metrics. [38]

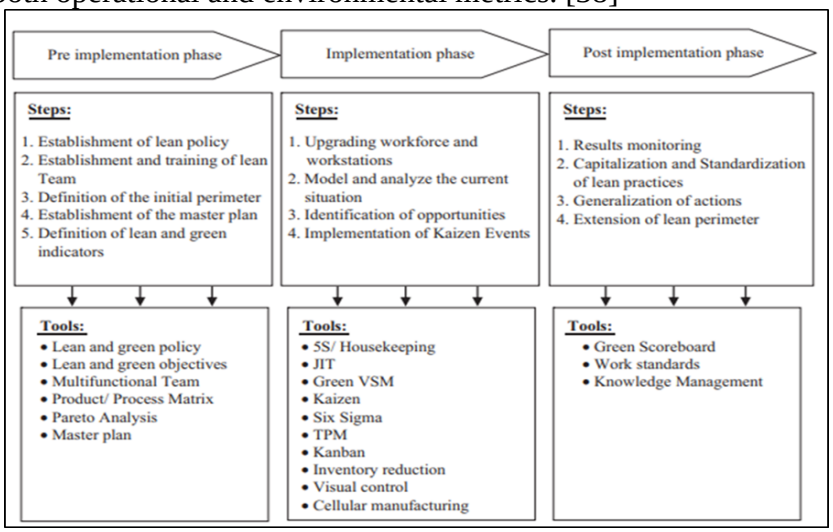

Figure 6: Methodology of lean and green implementation in SMEs [38]

Jamwal et al. (2019) used Total Interpretive Structural Modelling (TISM) as a method to study the adoption of Lean Manufacturing (LM) in a small-scale industry. They focused on identifying both barriers and facilitators to the adoption of LM in these sectors. After applying the methodology, the authors encountered various barriers to LM adoption. Cost has emerged as a crucial factor affecting industry practices and market dynamics. Other barriers include challenges related to resource limitations, lack of awareness or expertise, reluctance to change and difficulties in actually implementing LM principles. Despite these barriers, the study by Jamwal et al. provides valuable information on LM implementation. By identifying the barriers and using TISM to understand their relationships, the study contributes to strategic decision-making and helps to overcome the challenges of implementing LM in industry in the region. [39] Choudhary et al. (2019) initiated a study that aims to respond to the challenges faced by manufacturing SMEs in aligning operational efficiency and environmental sustainability. To address the specific challenges of SMEs implementing lean and eco-friendly practices, authors followed a systematic approach by conducting an extensive literature review. They developed a framework adapted to the unique context of SMEs, emphasizing the integration of lean and green strategies. This framework (Figure 7) served as a blueprint to effectively guide SMEs in solving the complex problems of integrating lean and green practices. Author suggested Green Integrated Value Stream Mapping (GIVSM), which aims to simplify carbon footprint measurement and waste visualization in SMEs. These tools aimed to provide SMEs with practical knowledge to promote sustainable practices. [40]

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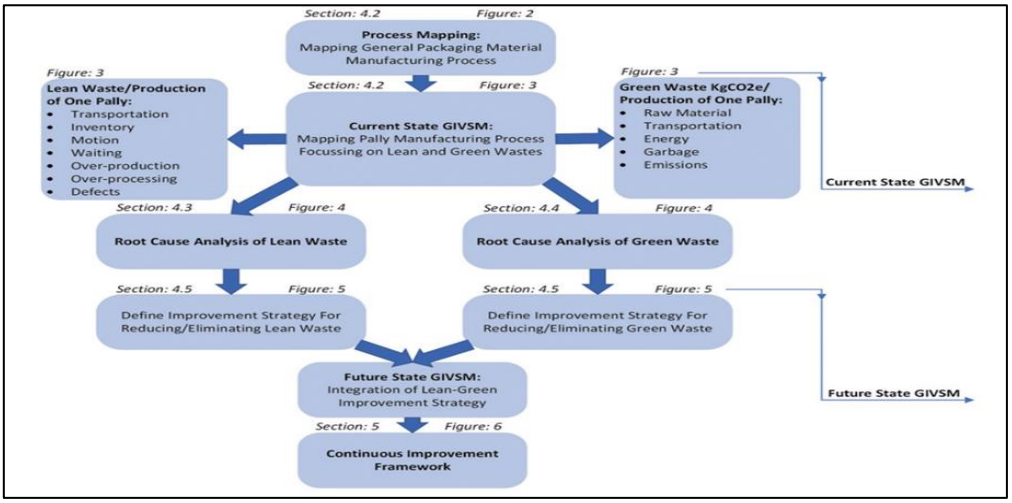

Figure 7: Integrated Lean and Green framework, GIVSM methodology [40]

Farias et al. (2019) used a systematic literature review (SLR) as a method to investigate the performance of lean and green production methods. Author proposed a conceptual framework (Figure 8) that helps in understanding the concepts and relationships involved in the lean and green performance assessment system [41]

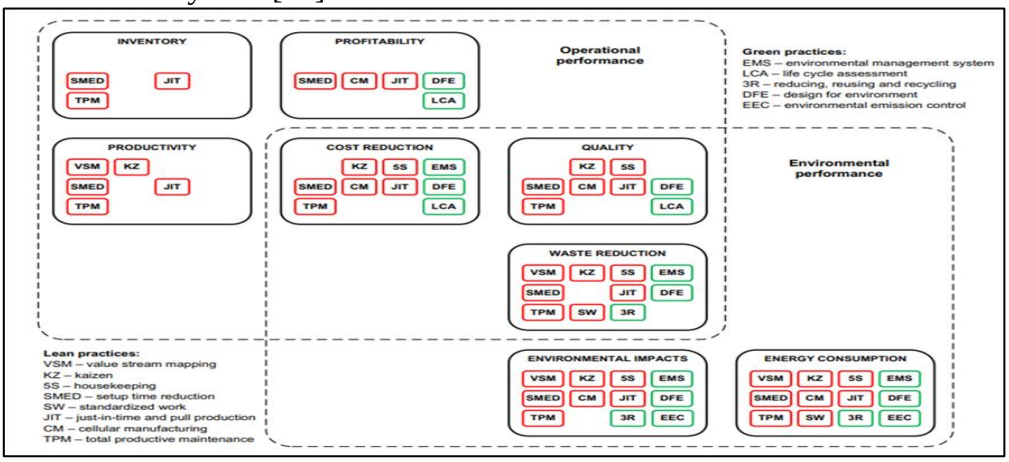

Figure 8: Lean and Green practices for Operational and Environmental performance [41]

Touriki et al. (2021) used a systematic literature review (SLR) methodology to investigate the integration of smart, green, resilient and lean (SGRL) paradigms in manufacturing specifically in the context of challenges such as COVID-19. The authors proposed two frameworks (Figure 9): one for integrating SGRL and one for future research directions. [42]

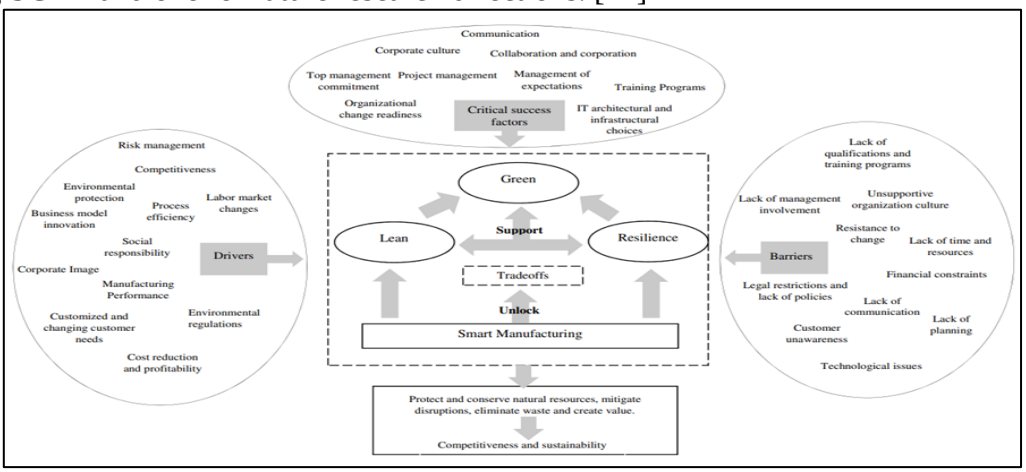

Figure 9: Integration of Smart, Green, Resilient and Lean (SGRL) paradigms [42]

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Kaswan et al. (2023) integrated Lean, Green and Six Sigma (Figure 10) and developed a Green Lean Six Sigma (GLSS) implementation framework (Figure 11) for manufacturing firms. [43]

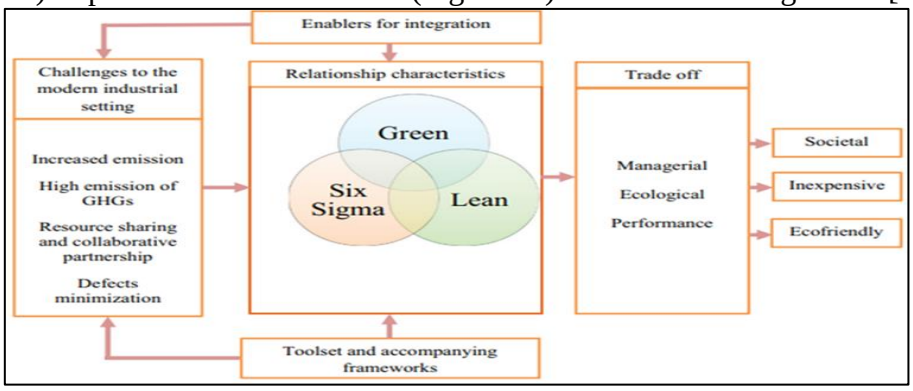

Figure 10: Integration of green lean and six sigma [43]

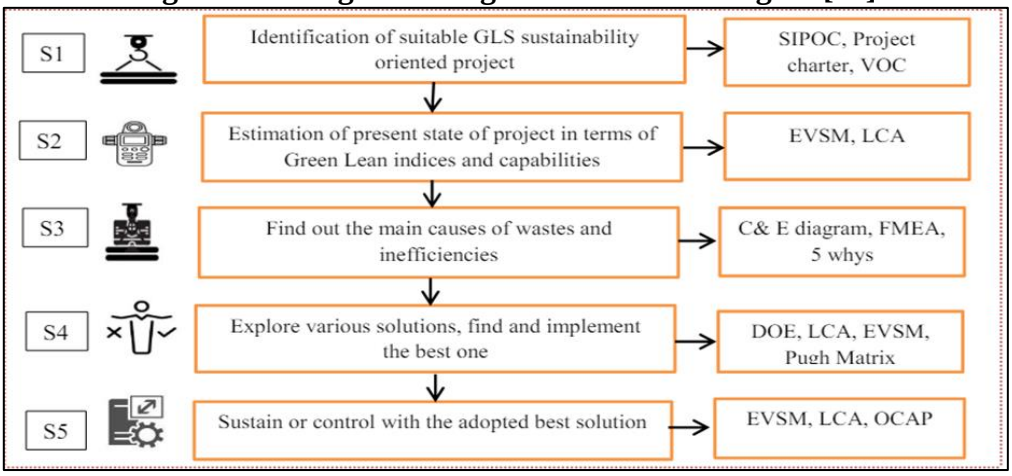

Figure 11: Green Lean Six Sigma (GLSS) implementation in manufacturing [43]

Siegel et al. (2022) conducted a comprehensive literature review to determine the importance of Green Lean practices, especially in SMEs. This method was the basis for identifying existing challenges and gaps in the literature. The authors have utilized surveys, conducted interviews with SME stakeholders to identify the specific barriers faced in implementing Green Lean methods. [44]

3.2. Development of Lean and Green Framework

The Lean and Green (LnG) Implementation Framework (Figure 12) provides a comprehensive, structured approach to enhance operational efficiency and environmental stewardship. This framework is meticulously designed to help small-scale manufacturers systematically assess, plan, implement, and evaluate Lean and Green practices, thereby fostering continuous improvement and long-term success.

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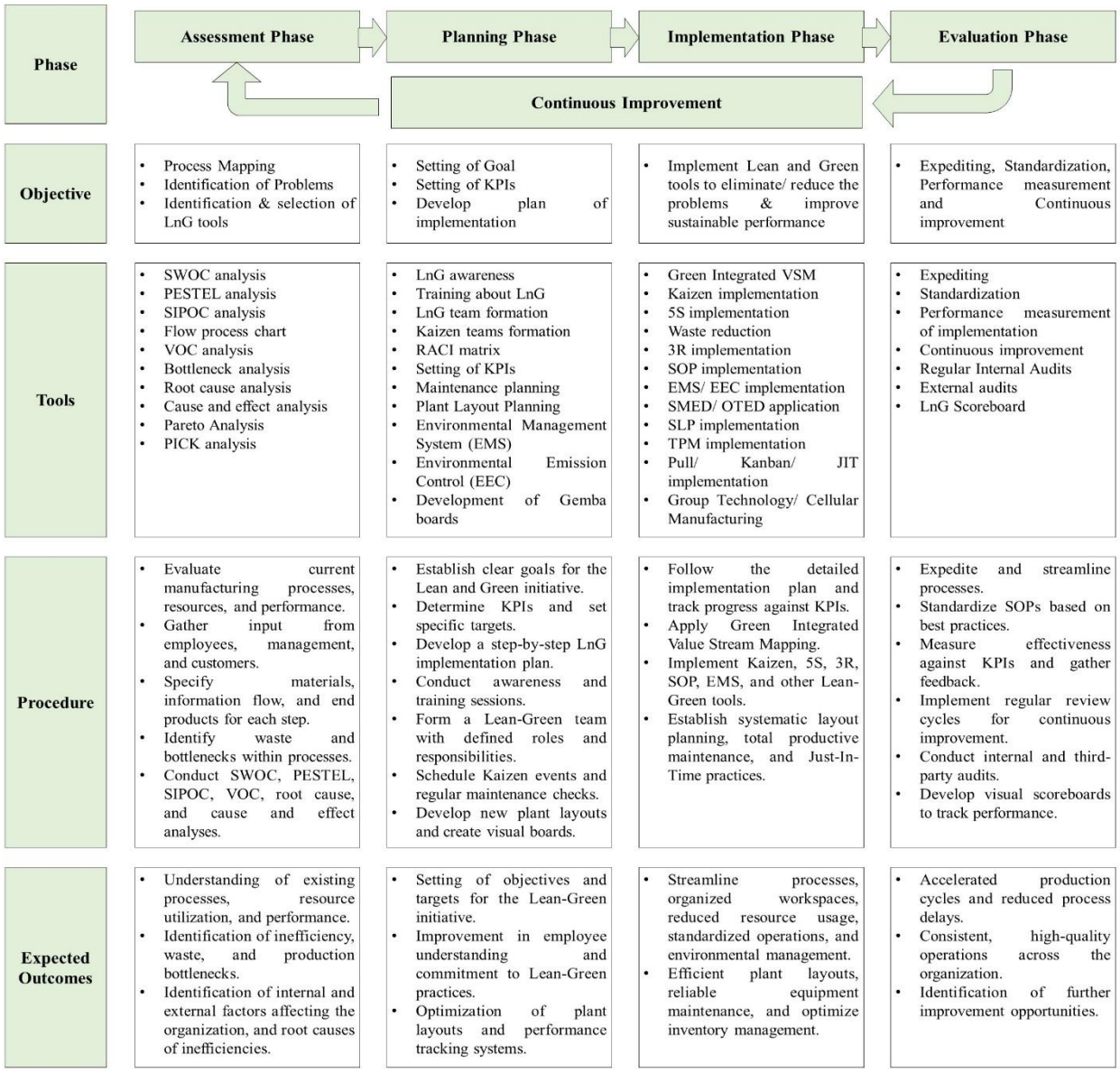

Figure 12: Suggested Integrated Lean & Green Framework

IV. Discussion on the Implementation of Lean and Green Framework

The proposed Lean-Green implementation framework provides a practical and effective approach for SSIs in India to enhance their sustainability and efficiency. By following the structured phases of assessment, planning, implementation, and evaluation, SSIs can systematically integrate Lean and Green practices into their operations. This framework not only addresses the current challenges faced by SSIs but also paves the way for sustainable growth and development in the manufacturing sector.

PHASE I: ASSESSMENT PHASE

By following these steps, small-scale manufacturing industries can systematically assess their processes, identify issues, select appropriate tools, and implement improvements to enhance efficiency and sustainability.

Step 1: Evaluate current manufacturing processes, resources, and performance.
Step 2: Gather input from employees, management, and customers to understand their perspectives.
Step 3: Create Detailed Process Maps of each step of the manufacturing process.
Step 4: Specify materials, information flow, and end products for each step.
Step 5: Identification of waste, and bottlenecks within the processes.

Step 5: Identification & Selection of LnG Tools
Step 6: SWOC Analysis: Identify internal strengths, weaknesses, external opportunities and challenges facing the organization.
Step 7: PESTEL Analysis: Government policies and regulations, economic factors, societal trends, technological advancements, sustainability initiatives and compliance issues.
Step 8: SIPOC Analysis: Identify key suppliers, list all inputs, Outline the process, Define the final products or services and identify the customers.
Step 9: Develop Flow Process Chart
Step 10: Voice of Customer (VOC) Analysis
Step 11: Conduct Root Cause Analysis: Using techniques like the 5 Whys to determine underlying causes of problems.
Step 12: Cause and Effect Analysis using Fishbone Diagram to map out potential causes of problems in categories (e.g., methods, materials, manpower).
Step 13: Pareto Analysis to identify the most significant causes of problems.
Step 14: PICK Analysis to Categorize actions into Possible, Implement, Challenge, and Kill based on impact and feasibility and to choose actions with high impact and ease of implementation.

PHASE II: PLANNING PHASE

By following these steps, small-scale manufacturing industries can systematically plan and prepare for the implementation of Lean and Green practices, ensuring a structured and effective approach to achieving sustainability and operational efficiency.
Step 1: Establish clear, specific, and measurable goals for the Lean and Green (LnG) initiative.
Step 2: Determine key performance indicators (KPIs) relevant to LnG goals and Define specific targets for each KPI to measure progress and success.
Step 3: Develop a step-by-step implementation plan outlining activities, timelines, and responsibilities.
Step 4: Organize workshops, seminars, and informational sessions to introduce LnG concepts.
Step 5: Conduct regular training sessions for all employees at different levels.
Step 5: LnG Team Formation: Choose employees from various departments with relevant expertise and define Roles and Responsibilities
Step 6: Make small, diverse Kaizen teams to focus on specific projects.
Step 7: Schedule regular Kaizen events to implement improvements.
Step 8: RACI Matrix: List all tasks involved in the LnG implementation, Assign Roles using the RACI (Responsible, Accountable, Consulted, Informed) framework.
Step 9: Create a timetable for regular maintenance checks and tasks and Assign personnel and budget for maintenance activities.
Step 10: Evaluate the existing plant layout for inefficiencies, develop a new layout to improve workflow and reduce waste and gradually transition to the new layout with minimal disruption.
Step 11: Create visual boards (Gemba Boards**)** to display key performance indicators and project status, Place Gemba boards in prominent locations within the plant and Update Regularly.

PHASE III: IMPLEMENTATION PHASE

By following these steps, small-scale manufacturing industries can systematically implement Lean and Green tools to enhance efficiency, reduce waste, and improve overall sustainability and performance.
Step 1: Follow the detailed implementation plan developed during the planning phase and continuously track progress against the set KPIs.
Step 2: Green Integrated Value Stream Mapping (VSM) : Map current processes (material flows, and energy usage), Identify areas of waste and high environmental impact, Develop an improved process map integrating Lean and Green practices and Implement the new process map and monitor improvements.
Step 3: Kaizen Implementation**:** Identify Improvement Areas, Conduct Kaizen Events and implement the Kaizen.

Step 4: 5S Implementation: Remove unnecessary items from the workspace, organize remaining items for easy access, Clean the workspace thoroughly, establish standards for maintaining organization and cleanliness and Ensure ongoing adherence to the 5S principles through regular audits.
Step 5: 3R Implementation (Reduce, Reuse, Recycle): Implement practices to minimize resource usage and waste generation, identify opportunities to reuse materials within the production process and establish systems for recycling waste materials.
Step 5: SOP Implementation: Create detailed standard operating procedures for key processes, Train staff on following SOPs accurately and regularly review and update SOPs to ensure they remain effective.
Step 6: Environmental Management System (EMS): Evaluate existing environmental practices and compliance, create a comprehensive plan, Execute the plan and train employees and regularly monitor environmental performance and conduct audits.
Step 7: Environmental Emission Control: Identify all sources of emissions within the facility, set targets for reducing emissions, apply technologies and practices to control and reduce emissions and regularly monitor emission levels and ensure compliance with regulations.
Step 8: SMED/ OTED Application: Evaluate the current changeover process and identify delays, Implement SMED (Single-Minute Exchange of Die) or OTED (One-Touch Exchange of Die) techniques to reduce changeover time, Train staff on new quick-changeover methods and continuously monitor changeover times and make improvements.
Step 9: Systematic Layout Planning (SLP) Implementation: Evaluate current workflow and layout, develop a new layout to improve efficiency and reduce movement, gradually transition to the new layout and Monitor the impact of layout changes on efficiency and adjust as needed.
Step 10: Total Productive Maintenance (TPM) Implementation: Evaluate existing maintenance practices and equipment reliability, create a plan incorporating preventive, predictive, and autonomous maintenance, Train staff on TPM practices and responsibilities and Continuously monitor equipment performance and refine maintenance practices.
Step 11: Pull/ Kanban/ Just-In-Time (JIT) Implementation: Evaluate existing inventory levels and production scheduling, introduce a Kanban system to signal demand and manage inventory flow, align production schedules closely with customer demand to minimize inventory and Continuously monitor inventory levels and production efficiency, adjusting as needed.
Step 12: Group Technology/ Cellular Manufacturing: Group similar processes and products into families, create manufacturing cells for each product family and regularly evaluate the performance of cells and make improvements.

PHASE IV: EVALUATION PHASE

By following these steps, small-scale manufacturing industries can effectively evaluate the success of Lean and Green implementations, ensure continuous improvement, and maintain high standards of performance and sustainability.
Step 1: Apply strategies to expedite and streamline processes and Track the effectiveness of expediting measures and make adjustments as necessary.
Step 2: Develop SOPs based on documented best practices, standardize and ensure all staff are trained on new SOPs to maintain consistency.
Step 3: Measure the effectiveness of implemented LnG tools against set KPIs through feedback from employees and stakeholders on the implementation process and Compare actual performance against targets and goals.
Step 4: Implement regular cycles for reviewing and improving processes (e.g., PDCA - Plan, Do, Check, Act) where employees can suggest improvements and continuously track improvement.
Step 5: Plan regular internal audits to evaluate compliance with SOPs and LnG practices, and address any non-conformities or issues identified during audits.
Step 6: Conduct third-party audit to review LnG practices and performance, analyze findings from external audits and take necessary actions for improvement.

Step 7: Develop a visual scoreboard to track and display key LnG performance indicators, Place scoreboards in prominent locations within the facility and Keep the scoreboard updated.

V. Conclusion

Integrating Lean and Green manufacturing practices offers a powerful way to boost the sustainability and efficiency of small-scale manufacturing industries. Research shows that Lean practices can improve how businesses operate and perform economically, while Green practices bring social, environmental, and economic benefits. However, small-scale industries often face challenges in adopting these practices due to limited resources and insufficient management support. The proposed Lean-Green implementation framework is designed to overcome these obstacles. It provides a step-by-step guide for small-scale manufacturers, starting with process mapping and waste identification, moving through the selection of appropriate tools, and ensuring continuous performance monitoring. By following this structured approach, small-scale industries can more effectively adopt Lean-Green practices, leading to sustainable growth and development in the manufacturing sector.

References

[1] Singh, C.D., R. Singh, and S. Singh, Application of Lean and JIT Principles in Supply Chain Management. Journal of Regional & Socio-Economic, 2013.
[2] Demeter, K. and Z. Matyusz, The impact of lean practices on inventory turnover. International Journal of Production Economics, 2011. 133(1): p. 154-163.
[3] Hemanand, K. and D. Amuthuselvan, Improving productivity of manufacturing division using lean concepts and development of material gravity feeder–a case study. International Journal of lean thinking, 2012. 3(2): p. 117-134.
[4] Shah, R. and P.T. Ward, Lean manufacturing: context, practice bundles, and performance. Journal of operations management, 2003. 21(2): p. 129-149.
[5] Kumar Chakrabortty, R. and S. Kumar Paul, Study and implementation of lean manufacturing in a garment manufacturing company: Bangladesh perspective. Journal of Optimization in Industrial Engineering, 2011: p. 11-22.
[6] Mo, J.P., The role of lean in the application of information technology to manufacturing. Computers in industry, 2009. 60(4): p. 266-276.
[7] Dal Pont, G., A. Furlan, and A. Vinelli, Interrelationships among lean bundles and their effects on operational performance. Operations Management Research, 2008. 1(2): p. 150-158.
[8] Melnyk, S.A. and R.T. Smith, Green manufacturing. 1993: Computer Automated Systems of the Society of Manufacturing Engineers.
[9] Tan, X., et al., A decision-making framework model of cutting fluid selection for green manufacturing and a case study. Journal of Materials processing technology, 2002. 129(1): p. 467-470.
[10] Sarkis, J., A strategic decision framework for green supply chain management. Journal of cleaner production, 2003. 11(4): p. 397-409.
[11] Luttropp, C. and J. Lagerstedt, EcoDesign and The Ten Golden Rules: generic advice for merging environmental aspects into product development. Journal of Cleaner Production, 2006. 14(15): p. 1396-1408.
[12] Vijayaraghavan, A. and D. Dornfeld, Automated energy monitoring of machine tools. CIRP Annals-Manufacturing Technology, 2010. 59(1): p. 21-24.
[13] Dornfeld, D.A., Green manufacturing: fundamentals and applications. 2012: Springer Science & Business Media.
[14] Rusinko, C., Green manufacturing: an evaluation of environmentally sustainable manufacturing practices and their impact on competitive outcomes. Engineering Management, IEEE Transactions on, 2007. 54(3): p. 445-454.
[15] Pampanelli, A.B., P. Found, and A.M. Bernardes, A Lean & Green Model for a production cell. Journal of cleaner production, 2014. 85: p. 19-30.

[16] Galeazzo, A., A. Furlan, and A. Vinelli, Lean and green in action: interdependencies and performance of pollution prevention projects. Journal of Cleaner Production, 2014. 85: p. 191-200.
[17] Chiarini, A., Sustainable manufacturing-greening processes using specific Lean Production tools: an empirical observation from European motorcycle component manufacturers. Journal of Cleaner Production, 2014. 85: p. 226-233.
[18] Kurdve, M., et al., Lean and Green integration into production system models– Experiences from Swedish industry. Journal of Cleaner Production, 2014. 85: p. 180-190.
[19] Diaz-Elsayed, N., et al., Assessment of lean and green strategies by simulation of manufacturing systems in discrete production environments. CIRP AnnalsManufacturing Technology, 2013. 62(1): p. 475-478.
[20] Dües, C.M., K.H. Tan, and M. Lim, Green as the new Lean: how to use Lean practices as a catalyst to greening your supply chain. Journal of cleaner production, 2013. 40: p. 93-100
[21] Amrik Sohal, Alka Ashwini Nand, Preeti Goyal, Ananya Bhattacharya (2022), Developing a circular economy: An examination of SME's role in India, Journal of Business Research, Volume 142, 2022, Pages 435-447, ISSN 0148-2963, https://doi.org/10.1016/j.jbusres.2021.12.072.
[22] Rebecca Siegel, Jiju Antony, Jose Arturo Garza-Reyes, Anass Cherrafi, Bart Lameijer (2019), Integrated green lean approach and sustainability for SMEs: From literature review to a conceptual framework, Journal of Cleaner Production, Volume 240, 2019, 118205, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2019.118205.
[23] V. Ramakrishnan, J. Jayaprakash, C. Elanchezhian, B. Vijaya Ramnath (2019), Implementation of Lean Manufacturing in Indian SMEs-A case study, Materials Today: Proceedings, Volume 16, Part 2, 2019, Pages 1244-1250, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2019.05.221.
[24] Antony Pearce, Dirk Pons, Thomas Neitzert (2018), Implementing lean—Outcomes from SME case studies, Operations Research Perspectives, Volume 5, 2018, Pages 94-104, ISSN 2214-7160, https://doi.org/10.1016/j.orp.2018.02.002.
[25] Mahadeo M. Narke, C.T. Jayadeva (2020), Value Stream Mapping: Effective Lean Tool for SMEs, Materials Today: Proceedings, Volume 24, Part 2, 2020, Pages 1263-1272, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2020.04.441.
[26] Mohammed AlManei, Konstantinos Salonitis, Yuchun Xu (2017), Lean Implementation Frameworks: The Challenges for SMEs, Procedia CIRP, Volume 63, 2017, Pages 750-755, ISSN 2212-8271, https://doi.org/10.1016/j.procir.2017.03.170.
[27] Katarzyna Antosz, Dorota Stadnicka (2017), Lean Philosophy Implementation in SMEs – Study Results, Procedia Engineering, Volume 182, 2017, Pages 25-32, ISSN 1877-7058, https://doi.org/10.1016/j.proeng.2017.03.107.
[28] Manjeet Kharub, Bandi Ruchitha, Shashank Hariharan, N. Shanmukha Vamsi (2021), Profit enhancement for small, medium scale enterprises using Lean Six Sigma, Materials Today: Proceedings, 2021, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2021.09.159.
[29] Felix Sieckmann, Hien Nguyen Ngoc, René Helm, Holger Kohl (2018), Implementation of lean production systems in small and medium-sized pharmaceutical enterprises, Procedia Manufacturing, Volume 21, 2018, Pages 814-821, ISSN 2351-9789, https://doi.org/10.1016/j.promfg.2018.02.188.
[30] Gilson Adamczuk Oliveira, Kim Hua Tan, Bruno Turmina Guedes (2018), Lean and green approach: An evaluation tool for new product development focused on small and medium enterprises, International Journal of Production Economics, Volume 205, 2018, Pages 62-73, ISSN 0925-5273, https://doi.org/10.1016/j.ijpe.2018.08.026.
[31] Afonso Amaral, Paulo Peças (2021), SMEs and Industry 4.0: Two case studies of digitalization for a smoother integration, Computers in Industry, Volume 125, 2021, 103333, ISSN 0166-3615, https://doi.org/10.1016/j.compind.2020.103333.
[32] Koppiahraj Karuppiah, Bathrinath Sankaranarayanan, Syed Mithun Ali, Priyabrata Chowdhury, Sanjoy Kumar Paul (2020), An integrated approach to modeling the barriers in implementing green

manufacturing practices in SMEs, Journal of Cleaner Production, Volume 265, 2020, 121737, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2020.121737.
[33] P. Teixeira, J.C. Sá, F.J.G. Silva, L.P. Ferreira, G. Santos, P. Fontoura (2021), Connecting lean and green with sustainability towards a conceptual model, Journal of Cleaner Production, Volume 322, 2021, 129047, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2021.129047.
[34] What are the problems faced by Small Scale Industries in India?, https://accountlearning.com/what-are-the-problems-faced-by-small-scale-industries-in-india/ (2020)
[35] David, S.M. and Found, P. (2015) 'An implementation model for lean and green', Measuring Operations Performance, pp. 1–29. doi:10.1007/978-3-319-19995-5_1.
[36] Cherrafi, A. et al. (2017) 'Barriers in green lean implementation: A combined systematic literature review and interpretive structural modelling approach', Production Planning & Control, 28(10), pp. 829–842. doi:10.1080/09537287.2017.1324184.
[37] Duarte, S. and Cruz Machado, V. (2017) 'Green and lean implementation: An assessment in the automotive industry', International Journal of Lean Six Sigma, 8(1), pp. 65–88. doi:10.1108/ijlss-11-2015-0041.
[38] Belhadi, A., Touriki, F.E. and El Fezazi, S. (2018) 'Benefits of adopting lean production on green performance of smes: A case study', Production Planning & Control, 29(11), pp. 873–894. doi:10.1080/09537287.2018.1490971.
[39] Jamwal, A. et al. (2019) 'A study on the barriers to lean manufacturing implementation for small-scale industries in Himachal Region (India)', International Journal of Intelligent Enterprise, 6(2/3/4), p. 393. doi:10.1504/ijie.2019.101129.
[40] Choudhary, S. et al. (2019) 'An integrated lean and green approach for improving sustainability performance: A case study of a packaging manufacturing SME in the U.K.', Production Planning & Control, 30(5–6), pp. 353–368. doi:10.1080/09537287.2018.1501811.
[41] Farias, L.M. et al. (2019) 'Criteria and practices for Lean and Green Performance Assessment: Systematic Review and conceptual framework', Journal of Cleaner Production, 218, pp. 746–762. doi:10.1016/j.jclepro.2019.02.042.
[42] Touriki, F.E. et al. (2021) 'An integrated smart, Green, resilient, and Lean Manufacturing Framework: A literature review and future research directions', Journal of Cleaner Production, 319, p. 128691. doi:10.1016/j.jclepro.2021.128691.
[43] Kaswan, M.S. et al. (2023) 'Exploration and investigation of Green Lean Six sigma adoption barriers for manufacturing sustainability', IEEE Transactions on Engineering Management, 70(12), pp. 4079–4093. doi:10.1109/tem.2021.3108171.
[44] Cherrafi, A. et al. (2017) 'Barriers in green lean implementation: A combined systematic literature review and interpretive structural modelling approach', Production Planning & Control, 28(10), pp. 829–842. doi:10.1080/09537287.2017.1324184.
[45] R. Siegel, J. Antony, J. A. Garza-Reyes, A. Cherrafi, and B. Lameijer, "Integrated green lean approach and sustainability for SMEs: From literature review to a conceptual framework," Journal of Cleaner Production. 2019. doi: 10.1016/j.jclepro.2019.118205.
[46] M. Z. Rafique, M. N. Ab Rahman, N. Saibani, and N. Arsad, "A systematic review of lean implementation approaches: a proposed technology combined lean implementation framework," Total Qual. Manag. Bus. Excell., vol. 30, no. 3–4, pp. 386–421, 2019, doi: 10.1080/14783363.2017.1308818.