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The Implementation of Lean and Green Approaches (G&L) to Enhance the Operational and Environmental Performance of a Manufacturing Plant –A Review

BY

D.Saber[1,2], Ghala Alzaydani[1], Jood Alali[1], Leen Alnemari[1], Ghadi Alwadee[1], Razan Alnemari[1]

[1]Industrial Engineering program, Department of Mechanical Engineering, College of Engineering, Taif University, P.O. Box 11099, Taif 21944, Saudi Arabia

[2]Materials Engineering Department, Faculty of Engineering, Zagazig University, P.O. Box 44519, Zagazig, Egypt.

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Abstract:
This review focuses on the application of Lean and green approaches within a manufacturing plant to improve both operational efficiency and environmental sustainability. By integrating Lean methodologies, which aim to eliminate waste and improve efficiency, with green practices that prioritize sustainability and environmental responsibility. This study identifies areas for improvement and develops tailored strategies to optimize performance. By implementing Lean and green initiatives, such as waste reduction, energy efficiency, resource conservation, and enhance operational efficiency while minimizing the plant's ecological footprint. This study provide valuable insights for organizations seeking to align their operations with environmental goals and contribute to the country's economic growth and diversification efforts. The study has emphasized the significance of synergies and potential trade-offs between lean and green practices in operations strategies. By examining the impacts of lean-green practices on manufacturing processes, the study has developed a framework that can enhance the performance of manufacturing plants. By implementing waste reduction, energy efficiency, and resource conservation initiatives, and enhance operational efficiency while minimizing the ecological footprint of the manufacturing plant.

Keywords: *Lean, green, sustainability, innovation, environmental responsibility, manufacturing and efficiency*

Introduction

Lean practices are celebrated in manufacturing for their ability to identify, reduce, and eliminate waste in production processes. Its various principles aim to eliminate overproduction, excess inventory, defects, time wastages, and many more. In addition, lean practices facilitate continuous improvement, focusing on incremental changes to enhance production processes. Green is a concept that deals with supply chains and production in the environment and handling in the environment consisting of air, energy, air, solid and hazardous waste [1-3]. Green Manufacturing aims to continue the integration of industrial processes and products, to reduce or avoid pollution in air, water, and soil, to reduce waste at its source, and to minimize risks to humans and other species. Green Manufacturing includes several practices namely pollution prevention and reduction of toxic use and design for the environment. Pollution prevention focuses on avoiding or minimizing waste or emissions through source reduction or on-site recycling. [4]. The interesting thing when discussing green manufacturing is how to distinguish green from lean manufacturing. The two terms are sometimes used interchangeably even though they actually have different end goals. Lean and green practices are complementary. Lean manufacturing focuses on how to create greater value for consumers with less work [5]. Researches that discuss green and lean manufacturing include research on the concepts of green and lean manufacturing [6]. A systematic literature review is done to answer several questions: what decision area(s) are affected by the implementation of each lean-green practice, and what are the impacts of lean-green practices on the performance of manufacturing processes? Lean-green practices for the production field are first identified and discussed, then trade-offs, synergies, and adjustments to key decision areas are discussed. The result is a lean-green framework that can be further validated and applied to enhance the performance of manufacturing plants.

Literature Review

Most manufacturers assign' cost' the biggest priority when assessing performance enhancement in manufacturing plants.

*Corresponding Author: D.Saber

The factor is related to lean manufacturing with cost reduction motivating companies to go green and reduce expenses associated with energy and material consumption [7-9]. When it comes to the environment, priority is given to reducing adverse implications arising from production processes. Studies on the environment emphasize competitive rivalries, thus presenting lean manufacturing as technique for enhancing one's competitive position through environmental sustainability. The aim of the studies on the environment is to reduce energy consumption, carbon emissions, water use, and the generation of toxic substances. The next factor assessed in lean manufacturing is quality and delivery. Quality in manufacturing is strictly defined by eliminating defects that can result in legal liabilities, increased costs of implementation, or the increased consumption of raw materials. Other priorities in lean production in the manufacturing sector were associated with social outcomes. Examples include worker and community safety considerations, motivation, and health[9]. Service is described as improvements in customer satisfaction, which in this case could comprise various factors, including building design, aesthetics, time of delivery, total cost, and occupancy rate, among many others [10].

It is important to note that performance management systems represent the most frequented decision area in lean-green manufacturing in the assessed pieces of literature. For instance, Leong et al. discuss integrating environmental performance indicators in industrial operations[11]. According to the authors, the performance management system is important for supporting technologies and decisions that require the operationalization of data to facilitate effective improvement processes. The authors found that implementing an L&G checklist results in a 12.4% average improvement in managerial decision-making.[12,13]Therefore, PMS is key to addressing supply chain gaps, including supplier relationships and project logistics improvements. Quality management is another area heavily studied in the integration of lean-green practices. The most common approaches to lean quality management are the Six Sigma and Total Quality Control standards. While the mentioned approaches focus on cost reduction, competition, and social outcomes, quality management emphasizes integrating technology and equipment to reduce consumption. Information systems are referred to several times in facilitating quality management as a decision area. Technology is also applied to enhance product development, which is enhancing the design and usability of a product. Little empirical evidence is provided on the integration of lean-green practices in issues related to the leadership structure. There is mention of planning and scheduling control discussions, but minimal information on how lean-green practices streamline corporate or project leadership. The gap implies inefficiencies in the lean-green principles when it comes to addressing human factors related to production processes [9,14].

Studies suggest there is a correlational relationship between lean practices and going green. In simpler words, lean practices facilitate sustainability, whereas the pursuit of sustainability promotes the adoption of lean techniques [15-17]. In a case review of manufacturing companies, Indah et al [9]. found that most of the participant companies combine lean and green practices. In others, the intended move was from focusing on lean practices alone (cost-effectiveness) to sustainability. Going green is becoming accepted as a concept that facilitates long-term cost-effectiveness, making it an essential pursuit for lean practices. The suggestion is that lean and green practices must co-exist in manufacturing. There is no implementation of one concept without the other since they are complementary. Failure to do so results in the implemented concept failing to achieve its full potential and impact on manufacturing. By aligning the two concepts, manufacturing plants can become efficient and environmentally accountable. Lean and green practices are growing in popularity due to their positive implications on internal innovation and adaptability. One of the shared insights about lean practices is that they foster the establishment of innovative cultures within organizations [9]. Due to the need to satisfy continuous improvement, companies have no other option but to develop new solutions and alternatives. This pursuit of alternative solutions is what fosters the establishment of innovative cultures.

Implementing green practices demands innovative solutions due to the distinctiveness of businesses and operating environments. The process can result in the design and development of new technologies and processes, in turn fostering long-term sustainability. A company that can innovate becomes adaptable to changes in the business environment. The company benefits from remaining competitive in a rapidly changing global business environment[17].

Theoretical Work

5M of Lean manufacturing

The 5Ms, namely money, manpower, machine, material, and method. The 5M model can be designed for different industrial applications, making it the go-to option for industrialists. Manpower (MP) was considered the organization's backbone, meaning lean practices were used to ensure the company realigned its human resource strategy with changes in the external business environment. Lean practices focused on creating and strengthening a dedicated talent pool. At the time, the key performance indicators for manpower were the number of employees, the competency rate, safety indicators, time management, and the key performance index[18].

In manufacturing, machine (MC) refers to the main equipment used to transform raw materials into products. Lean manufacturing argues that the quality and performance of the machine will have a direct impact on the financial health of an organization. The objective when it comes to MC is to improve the quality of production by reducing or eliminating performance inefficiencies. Material (MT), in the manufacturing context, refers to the number of resources that are being consumed and produced throughout the product development process. Lean manufacturing, at this point, emphasizes responsible consumption as per set SDG goals, encouraging the industrialist to assess and optimize the

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performance of the supply chain. The objective is to use inventory to improve the quality of production while reducing overall production costs. The fourth component, money (MT), focuses on assessing the value of facilities and the future value of earnings. Industrialists use the component to address challenges in the global market associated with fluctuations in currency values. Research informs that the average manufacturing plant generates roughly 800 hours of downtime per year. The statistic highlights the relationship between the performance of manufacturing plants and global financial markets. Any manufacturing facility's sustainability will depend on its financial statements' health. The last component in the traditional lean approach was the environment (EV). Under this component, companies focus on mitigating their carbon footprint, meaning waste management is prioritized.

The development of a lean and green model under the 5M model followed a systematic approach. The process begins with quantitative and qualitative data collection to understand the industrialist approach used in a manufacturing plant for continuous improvement. With a clear understanding of the operations, critical equipment, and process requirements, the next step is to determine the level of lean and green practices implemented using a lean and green index. The index also demonstrates periodic improvements associated with the implemented action plan. Fig (1) shows the diagram below provides a rough representation of the 5M model [7].

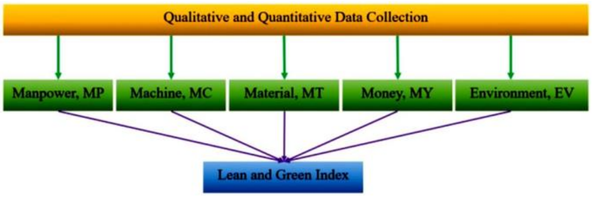

Figure 1:Relationship between the 5M components: Ref.[7]

Analytic Hierarchy Process (AHP)

Another traditional approach to lean and green manufacturing was the Analytic Hierarchy Process (AHP). The decision tool is applied to measure and transform qualitative judgments and quantitative values. The AHP process negates the complexity of managerial decision-making by dividing a problem into a series of pairwise comparisons. The decision maker models the complex problem using multiple criteria and alternatives arranged in a hierarchy structure. [19]. The judgments made from the comparisons mainly rely on expertise, experience, and the respondent's state of mind. The reliance on human integrity and honesty in determining areas of continuous improvement was one of the largest limitations of the AHP process.

The AHP process also followed a systematic approach to continuous improvement with the process beginning with data collection. The plant manager and plant personnel were interviewed to provide a comprehensive understanding of personnel, operations, and process management. The second step was to develop a model for decision-making based on a company's goals and performance criteria. Questionnaires are then sent to industry experts to gain professional insight into the development of the pairwise comparison matrix. Fig.(2) below provides a broken-down representation of the AHP process as applied in manufacturing[7].

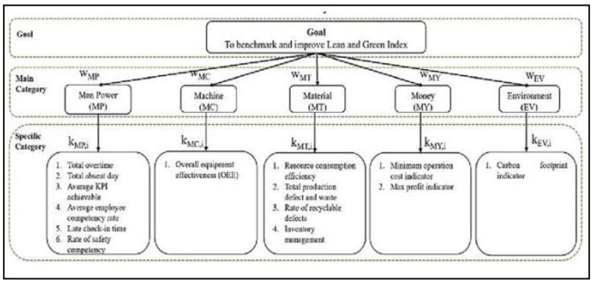

Figure 2: The AHP model structure: Ref[7]

Current approach to the lean and green model.

Present approaches combine the simultaneous application of lean and green approaches to demonstrate a strong commitment to reducing operational and environmental waste. The primary industry objective is to strike a balance between the environment and operations, resulting in the capture of optimum and sustainable output. Therefore, it is anticipated that there are overlaps in lean and green concepts, including community involvement, waste reduction, key performance indexes, and supply chain relationships. Lean and green concepts are perceived to share the same objectives: to improve production and production quality while reducing lead time and environmental emissions. Dues et al[20] created a Venn diagram summarizing the current understanding of the relationship between lean and green approaches Fig(3).

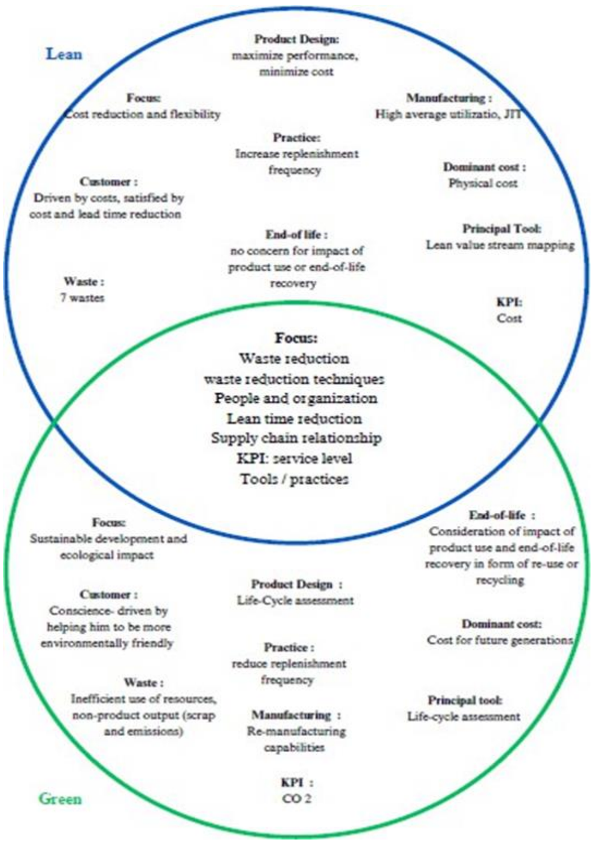

Figure 3: Relationship between lean and green concepts. Ref [20]

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The main hurdle in the present approaches to L&G is the degree of experience, expertise, and time required for successful implementation. Most organizations are faced with the challenge of not securing competent personnel to oversee the transformations. Nevertheless, modern approaches to L&G understand the importance of having a systematic analytic framework to assist industrialists in improving the accuracy and impact of their decisions. The framework is used as a means for adaptations with the information used to address the dynamic challenges identified in an industry. The modern approach, like the tradition, follows a systematic approach to implementing lean and green concepts in manufacturing. As shown in Fig (4), the process begins with information collection using a set of questionnaires. The data collection process aims to identify and understand the priorities and behaviours of the subject organization under review. The data collection process follows a pre-determined checklist to collect suitable and sufficient data to inform the lean and green index. A propagation analysis is then performed to compare the results of the expected and actual performance outcomes.

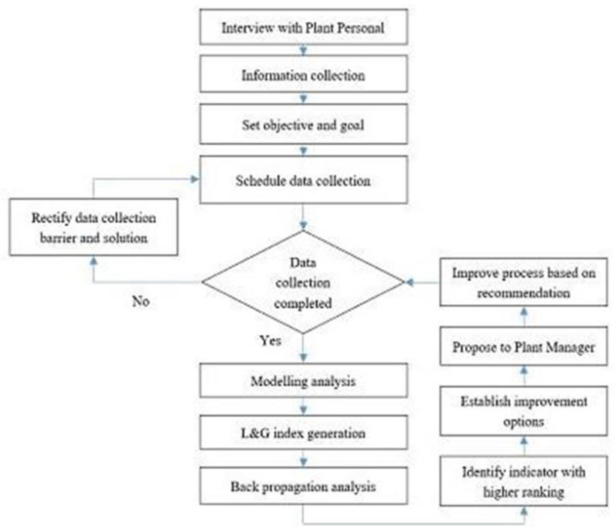

Figure 4: Current approach to the lean and green model. Ref [7]

Back-propagation analysis refers to an algorithm based on the reverse mode of differentiation applied to overcome the limitations of statistical models. The static analytic model is good at predicting events, but it is challenged in coping with the dynamic challenges of the real-world business environment. back-propagation analysis, modern lean and green practices can achieve continuous improvements in dynamic situations. The role of the industrialist becomes the need to regularly update the algorithm. An adaptive approach to L&G will compare the results of the manufacturing plant to the expected improvement criteria. Subsequently, the approach will adjust the priorities for improvement per the organization's changing needs[7,20].

Tools and methodologies

A diverse range of tools and methodologies exists to facilitate the implementation of lean and green approaches. These tools and methodologies offer structured frameworks for waste identification, process improvement, employee engagement, and environmental impact management. They resulting in enhanced operational efficiency, waste reduction, and reduced environmental footprints. These tools are widely recognized and have been commonly employed to successfully implement lean and green approaches.

Value Stream Mapping (VSM) is a visual tool employed for the analysis and enhancement of material and information flow within a process. Its primary objective is to identify sources of waste, bottlenecks, and potential areas for improvement. By meticulously mapping the existing state of the process and envisioning an optimized future state, VSM facilitates the identification and implementation of lean and green practices to streamline operations. The 5S Methodology is a systematic approach to workplace organization that encompasses five key principles: Sort, Set in Order, Shine, Standardize, and Sustain. This methodology is designed to establish and maintain an organized, clean, and efficient work environment. By adhering to the principles of 5S, we can effectively reduce waste, enhance productivity, and cultivate a safer and more environmentally conscious workspace.Lean Six Sigma combines lean principles with Six Sigma methodologies to eliminate waste and reduce process variation. It provides a structured approach for continuous improvement and problem-solving.

The Single-Minute-Exchange-of-Die (SMED) technique is a method-employed to minimize the duration of equipment changeovers, particularly in processes involving dies or molds. Its primary objective is to streamline the changeover process and effectively reduce downtime between successive product runs. By implementing SMED, organizations can optimize operational efficiency and enhance productivity by swiftly transitioning between different production setups. Why-Why Analysis, commonly referred to as the Five Whys, is a problem-solving methodology employed to ascertain the fundamental causes of issues or defects. This technique involves iteratively posing the question "why" to delve into deeper layers of causation. By systematically uncovering the underlying factors, Why-Why Analysis will enables us to effectively address root causes and implement preventive measures, thereby mitigating the likelihood of issue recurrence. Total Productive Maintenance (TPM) is a maintenance strategy designed to optimize equipment effectiveness and minimize downtime. It encompasses a proactive approach to maintenance, active employee engagement, and a commitment to continuous improvement. By implementing TPM, we can significantly reduce equipment failures, curtail energy waste, and mitigate environmental impacts. This comprehensive approach ensures enhanced equipment reliability, increased operational efficiency, and improved sustainability performance. Environmental Management Systems (EMS) provide us with a structured framework to systematically manage their environmental impacts. This comprehensive system encompasses processes for establishing environmental objectives, monitoring performance, and ensuring compliance

*Corresponding Author: D.Saber

with regulatory requirements. By implementing an EMS, such as ISO 14001, we can effectively integrate green practices into our project while adhering to established environmental standards. This approach fosters environmental responsibility, facilitates sustainable decision-making, and demonstrates a commitment to environmental stewardship. Just-in-Time (JIT) Production is a manufacturing strategy that aims to produce items only when they are needed, minimizing inventory and reducing waste. It can be applied to project management by optimizing resource allocation and scheduling [21,22].

Selected Case Studies

This section looks at the previous work done by other researchers implementing L&G in manufacturing. In study by Retrieved from Habib et al.,[23], They seek to improve the efficiency and performance of digital department engaged in labelling and packaging. Graphic tags and paper packaging items were the main products. According to the authors, it had been observed that the internal speed of the production processes did not match, which created unnecessary inventory on the production floor. It was also observed that much time was wasted as employees waited for the right tools or materials. Idle time did not generate value for the company and translated into lost income through reduced productivity.

In response, the researchers first employed value stream mapping (VSM), a lean model, to identify problematic processes in the greater operation. The VSM identified several issues, as outlined in Fig(5,6).

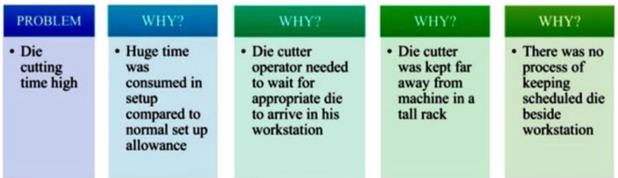

Fig. 5: Die cutting, Ref[23].

Figure 6: Finishing, Ref[23]

Die cutting was slow because it took a lot of time to set up and configure the machine for customized packaging designs. The entire process also included the combination of several activities that made it slower. On the other hand, finishing was slower also because it entailed several activities. In addition, the process had not been streamlined using a polar machine. Finishing also included processes considered not adding value to the finished product. The researchers devised a statistical index that calculated the amount of waiting time reduction with the implementation of each lean and green suggestion. The first step was to reduce the waiting time in the die-cutting setup by integrating a new Kanban dies cutter rack. The machine had more design configurations and took less time adjusting to each, thus enhancing productivity in terms of reduced waiting time and a higher number of packaging designs. The results are depicted in Fig. (7) (a, b, c, d, and e) for different die styles for better visibility Fig. (8) shows that not only the productivity in the later months had been increased but also it was sustaining.

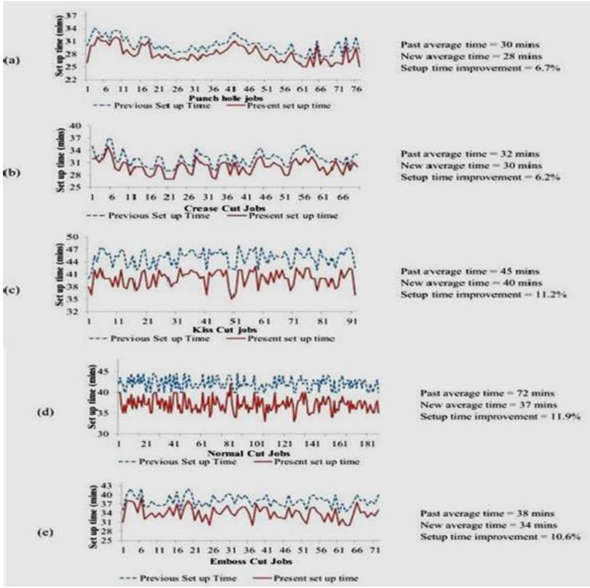

Figure 7: Set up time Improvement before and after lean tools, Ref[23]

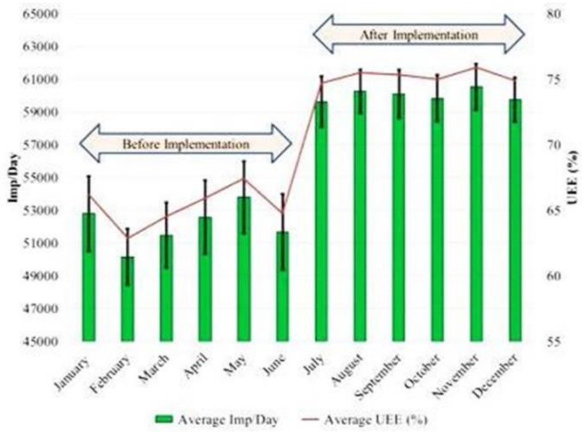

Figure 8: Average UEE before and after lean tools, Ref[23]

In another investigation by Choudhary et al. [10], the case study involving a manufacturing plant for packaging in the United Kingdom, the researcher also used VSM to differentiate value-adding and non-value-adding activities in the production process. However, in this case, they used an updated version of the VSM, Green Integrated Value Stream Mapping (GIVSM), which combines lean and green principles in fostering operational performance improvements. The combined approach meant an emphasis on reducing waste from the production process. The researchers also introduced an index for calculating the company's carbon footprint to determine its reduction with every improvement made. Waste in the form of time was also identified and monitored in the study. The contribution of this study is threefold. Firstly, it provides a systematic approach to identify lean and green

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wastes by applying lean tools such as VSM and Root cause analysis (RCA) in a real-case packaging manufacturing SME. Secondly, it integrates lean and green paradigm through a systematic methodology and proposes a novel tool called the GIVSM allowing simultaneous deployment of lean and green initiatives to improve both operational and environmental performance in a pilot study in the case company. Under the lean approach, a continuous strategy improvement, using PDCA cycle, was deployed during the pilot test, Fig.9. This shows that the integration of lean and green approaches within the traditional VSM has efficiently improved the case company's lean and green performance, which further illustrates its potential usage to derive benefits for many cash-starved SMEs who are unable to afford advanced manufacturing machines or large consultancy services to achieve desired improvements in their operations.

Thirdly, this study demonstrates practical benefits of using the GIVSM in a manufacturing SME and proposes its successful implementation through continuous improvement cycle within SMEs in manufacturing and other industry sectors that are faced with lack of funds and other constraints. Kaizen, visual management, SOPs, quality control, and supplier selection were few key improvement steps that were taken for yielding the synergistic effect of integrated lean-green implementation during the pilot run. The implementation of the above-described strategies was validated in the pilot run (future state GIVSM) and is currently underway for full consideration within the case company. The GIVSM helped in increasing the overall operational efficiency by decreasing the lead-time by 63%, and at the same time enhanced the environmental performance by decreasing the average carbon footprint by 77%.

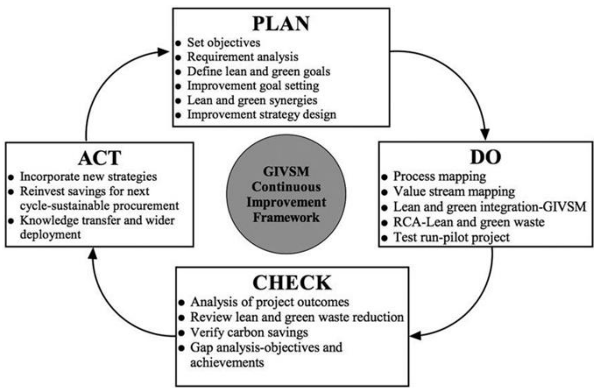

Figure 9. Future state GIVSM of pally manufacturing process Ref.[10]

Developed Framework and Future Work

This section proposes the developed framework for the implementation of lean and green practices, which is built upon previously mentioned work studies and research. This framework aims to provide organizations with a structured and comprehensive approach to integrating lean principles with environmental sustainability initiatives. By leveraging insights from previous implementations and drawing upon relevant research, our framework offers a systematic methodology to identify areas for improvement, analyze current processes, and design tailored solutions that optimize efficiency while minimizing environmental impact. Through this framework, organizations can effectively align their operational excellence goals with their sustainability objectives, fostering a more environmentally conscious and resource-efficient approach to business operations.

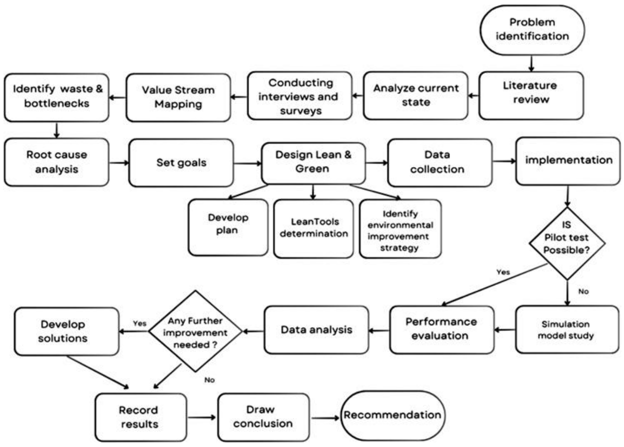

Figure10: Developed lean and green implementation framework

Conclusion

This review is done to answer several questions: what decision area(s) are affected by the implementation of each lean-green practice, and what are the impacts of lean-green practices on the performance of manufacturing processes? Lean-green practices for the production field are first identified and discussed, then trade-offs, synergies, and adjustments to key decision areas are discussed. A lean-green framework has been proposed that can be further validated and applied to enhance the performance of manufacturing plants. The developed framework involves a systematic and detailed framework. It begins with problem identification, where the specific issues or areas for improvement within a process or system are identified. Next, the current state of the process is analyzed in detail, taking into account the information gathered from the literature review. Value stream mapping is then performed to analyze and visualize the current state of the process. Based on the value stream mapping, specific types of waste and bottlenecks are identified, which hinder the flow and efficiency of the process. To address the identified issues, a root cause analysis is conducted. This analysis helps uncover the underlying causes of the waste and bottlenecks, enabling the development of effective and sustainable solutions. Additionally, goals and objectives are set to provide clear direction and measurement framework for the lean and green initiatives. The design phase involves three key steps. First, a plan is developed, second, the appropriate lean tools and techniques are determined and selected. Finally, an environmental improvement strategy is identified. Data collection is an essential step to assess the current state, track progress, and evaluate the impact of the implemented solutions. Data analysis is performed to compare the data collected before and after the implementation, measuring the impact and effectiveness of the solutions. Based on the evaluation and data analysis, further

*Corresponding Author: D.Saber

improvements may be identified. This detailed framework ensures a comprehensive and systematic approach to implementing lean and green approach, enabling organizations to optimize processes, reduce waste, and minimize environmental impact.

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