We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,300

Open access books available

172,000

International authors and editors

190M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Lean Manufacturing towards Green Manufacturing Practices and Its Implementation in SME's

J.P. Rishi

Abstract

The manufacturing SMEs are facing the burden of non-equilibrium of the supply–demand chain along with the global change in the climate. Several SMEs are looking for a substitute that can create a balance between performance and the environment. In spite of numerous studies related to green and lean that has been evolved, none of them is able to clearly define the spheres of green and lean. Here in this chapter, there is an exploration of advancement of lean and green manufacturing and its impact on other sectors. It also highlights the methodology adopted in implementing the same. This chapter recognizes the commonalities between lean and green approaches, the collaboration and impact, techniques involved. Also, the impediments and perplexities confronted by the manufacturing sector are examined. Further, this gives a better understanding of the challenges before implementing lean with green. This chapter also recognizes possible gaps in the literature that will help to eliminate the barrier toward this Neo manufacturing.

Keywords: Lean, Green, Manufacturing, Operation, Management

1. Introduction

Liberalization Privatization Globalization (LPG) has created market possibilities for manufacturing businesses around the Globe. This encourages competition worldwide for quality products, thereby leading to different ways to enhance their competency. A global phenomenon like financial instability, political imbalance, technology revolution, stringent regulation and global climate changes are affecting the competition [1]. Both energy and resources cost are always escalating due to non-equilibrium between supply and demand this is effecting the operation cost and economics of manufacturing directly. One vital strategy for SMEs to face competition to diminish the waste of resources by inefficient operation and production methods.

Numerous big Industries have implemented the lean-to step up competition worldwide [1]. This idea of lean is exceptionally well known and embraced in numerous businesses including Toyota, Boeing and Ford. With numerous elucidations for defining lean that have come to perplexity to recognize its effect. The description of lean itself is tricky. Some expressed lean has philosophy than a plethora of tools. On the other side, a viable and system approach depicts lean is an

assortment of waste diminishment approaches. Also lean is a framework with the primary objective to dispense waste. In any case, the common lean plan centres on the diminishment of waste. The lean tactics offer technique, tools, practices, and methodologies which can be useful to the manufacturing framework resulting in fewer resources utilization and fewer wastes. Lean manufacturing is actualized within manufacturing facilities since the effective usage by the Toyota Production System (TPS). Lean Manufacturing is characterized as an approach that disposes of all non-value added activities in production. Whereas lean centres the operational part, green looks into environmental perspective. Green addresses ecological balance and includes distinctive apprehensions like a waste, air, water and land pollution along with recycling management to enhance productivity [2]. The European Commission expressed the principles and practice of green in liaison with other buffer zones thus creating green economy which enhances the product value with lesser utilization of environmental-friendly resources everywhere conceivable. The green economy is an imperative way to propel financial development in the advancement of reducing carbon emission in process and products. From the green development point of view, the World Bank (2012) characterized green growth as a development effective in utilizing normal resources, limit contamination and natural impacts and resilient towards normal risks. Green development underscores worldwide maintainability that empowers the world's poorest and most powerless to take advantage of proficient, clean and buoyant progress. Green also additionally branded as the modern Lean wherein businesses have begun to provide support [3]. It is proved that green component primarily centres on cutting down contamination by increasing the value using resources judiciously [4, 5].

Green manufacturing has numerous acknowledgements in the literature study. Green Manufacturing is a trading technique that centres on productivity by the responsive and active environmentally friendly process. It is also seen as a rejuvenation of the manufacturing sector [6]. It alludes to any Manufacturing unit which employs innovation and renewable sources of energy whereas "Green" refers to activity to decrease contamination and waste by the reduction in the resource. The study reveals that industries that have implemented innovative green management, not only progress but also fulfil the requests of the buyer to enhance reputation among controllers and the public [7].

The collaboration within lean and green will encourage and improve performance by creating valuable products and waste diminishment. This combination has blended and intrigued many analysts. Numerous rudiments drive the accomplishment of Lean Green Manufacturing are examined within this chapter. Its usage is a major challenge due to the want of a Lean green domain expert, thereby deferring its execution and decrease in industry competitiveness. This chapter surveys standard of Lean Green manufacturing and its execution strategies. Also covers their metrics and determinants, challenges and future prospectus about Lean Green manufacturing.

2. Lean Manufacturing

2.1 Introduction

Lean Manufacturing considered an important component of modern manufacturing units, subsequent to industrial revolutions. It removes activities/events that don't add to the product value. **Figure 1** depicts the milestones of Lean Manufacturing. With the onset of first industrial revolution in the UK in early 1800

1800	1890	1900	1910	1950	1990
E. Whitney	F. W. Taylor	F. B. Gilbreth, L. M. Gilbreth.	H. Ford	T. Ohno	J. P. Womack, D. T. Jones, D. Roos.
Interchangeable Parts	Time Study	Motion Study & Chart	Flow Process and Mass Production	Toyota Production System	Lean Manufacturing

Figure 1.
The road map of Lean Manufacturing post-Industrial Revolution.

by Eli Whitney where machines were for the first time used in manufacturing. He conceived the idea of interchangeability which permitted a huge number of unskilled labours to be employed in musket manufacturing which was considered as a skilful job done by craftsman only during that time. This substantially enhanced the scale of economics in the production units. The manufacturing units intensively relied upon specific technologies till the late 1890's when one F.W. Taylor brought time study to reduce processing time. This approach measures and examines the quantum of time essential for an operator to finish the given job by means of a stopwatch thus establishing "Standard time" to complete a definite task. Subsequently, Process control chart by Frank and Lilian Gilbreth and followed by Motion Study during early 1900. The process control chart is drawn to give an actual picture of the manufacturing process and is used to take corrective and remedial actions to improve the process. The motion study is a methodology adopted to reduce unnecessary motions required to perform the task. Now both Motion study and time study are improved further and integrated and to be called method engineering. It assesses the engrossment of human beings with devices and guides human beings to effectively accomplish the given task. These innovations are the originators of waste elimination in terms of motion and idleness which are considered as forms of waste in Lean Manufacturing.

2.2 Lean Manufacturing practices, principles and tools

Progress of Lean Manufacturing technique has a positive effect on the overall performance of manufacturing SMEs. This evolution in manufacturing from a traditional to lean method makes the SMEs have good productivity and in a modest manner. Lean itself is a philosophy that encapsulates productivity. Any Lean manufacturing principles are based on five principles constituting a systematic framework to effect lean implementation as shown in **Table 1** and pictorially in **Figure 2**. These principles identify non-value added activities in a production process using a variety of lean tools [8].

In short Lean Manufacturing, methodology improves productivity by creating value and reduces 7 types of common wastes encountered in a production scenario shown in **Figure 3**. In order to easily implement Lean manufacturing effectively in SMEs, a variety of Lean tools are available to support SMEs in order to implement lean. A variety of Lean tools are available as shown in **Figure 5** and their selection plays a very important role in improving the moral of SMEs in order to effectively implement the Lean Manufacturing technique. Few lean tools at an outset look to be similar in the name like process mapping or value stream mapping. Also, These Lean tools can be adopted in any SMEs situated in any country with suitable

Lean Attributes	Functions	References
Value	To recognize the customer’s need for the product. This determines the willingness of the customer to purchase the product/service.	BMA (2008);
Recognize Value Stream	It makes the production department comprehend the Product life cycle and recognize the process or stages that don’t add value to a product.	
Ensure Smooth flow	In order to smoothen the value flow, identify and eliminate the non-value-added process. Thereby raw material flows interruptedly and the end-user receives the products smoothly.	
Implementation of Pull-Based Production	Here production is based on demand. Production will be scheduled only based upon receipt of the Client order. This system requires flexible manufacturing systems and an agile supply chain network.	Crawford (2016)
Continuous Improvement	Aim towards perfection constantly improving the process.	

Table 1.
Five principle functions of Lean.

Figure 2.
The Five Principles of Lean and Green.

adjustments. Also, applying the wrong lean tools may cause additional resource consumption. In order to apply the correct lean tool, it is required to reclassify criteria for selecting lean Tool and map it with a particular type of waste that needs to be eliminated. So it requires a roadmap for implementing lean and it cannot be done overnight.

On successful implementation of Lean tools in SMEs resulted in enhanced Performance, Quality improvement, cycle time reduction. Lean tools enable smooth, well-organized layout yielding a high-quality product with low waste in SMEs Green factory shown in **Figure 4**. These tools have impacted significantly on manufacturing cost performance, waste reduction and improved performance [6].

Wastes	Descriptions	References
Over-production	Product that is produced without or beyond demand. Over-production is described as the main waste that will trigger and contribute to the remaining of 7 wastes.	Berg and Ohlsson(2005)
Waiting	Waiting for further product processing due to want of information and resources can cause waiting. Manpower is the main reason for waiting. Production flow interrupted is also considered has waste.	Bach (2017); McBride (2013).
Inventory	Inventory is a necessary evil in any manufacturing unit. High inventory results in locking up of cash flow. Also storage cost escalates.	Bach (2017); McBride (2013)
Motion	Motion is defined as an excessive movement of employee or machine that does not add value to the product Excessive motion might result from lack of standard operating procedure (SOP), poor layout design, etc. This will relate to employee health issue.	Abe (2015); McBride (2013)
Defect	A product that does not satisfy the end-users need. Defects can be resulted from poor quality control, poor inventory control or from machine breakdown.	
Transportation	Transportation is deemed as waste if it does not add value to the product, it might cause damage to the product or extra manpower to manage transportation. Transportation factor is normally caused by poorly designed layout, improvement can be done by simplifying the process and improve the layout.	Abe (2015)
Over-Processing	Over-processing is defined as manufacturing the product at the specification higher than customer's requirement.	

Figure 3.
Waste list according to Lean Manufacturing.

Figure 4.
Green factory.

2.3 Systematic implementation of Lean Manufacturing

Lean Manufacturing can improve existing productivity by eliminating non-value-added activity in the production chain. **Figure 5** enumerates vital lean tools used in any industry. Even though there are benefits with effective implementation of lean but still there will be few challenges left. Few lean tools incline towards similar intent of value making and they complement one another. For illustration, bottlenecking analysis, value stream mapping, continuous flow tools and Gemba analysis are used for analyzing block diagram for upgrading the value [9]. Many assortments of lean tools are available but due to poor guidance in mapping, the appropriate lean tool to beset non-value-added activity is tedious.

Normally Lean experts use a blend of different lean tools to formulate combined methods like Value stream mappings and kaizens. In the year 2015 a new model which integrate lean with the Green concept and Six Sigma using Define, Measure, Analyze, Improve, Control (DMAIC), which is parallely implemented along with

Lean tools. To implement Lean Manufacturing the main basis is organizations culture and leadership to influence the follower's attitude and behaviour. Also, it is required to overcome inhibitors and identify critical success factors that are critical for implementing the integrated Lean Green model. Many studies discovered that human resources management is a very important critical success factor to implement successfully Lean Manufacturing in any organization. For this to happen a systematic top-down approach inside the SMEs is required [10].

3. Green Manufacturing

3.1 Introduction to Green Manufacturing

Global warming is escalating and people concerned are paying more attention to a clean and green environment. Even though Lean enhances performance in the

Top 25 Lean Tools

Lean Tool	What Is It?	How Does It Help?
5S	Organize the work area: <ul style="list-style-type: none"> Sort (eliminate that which is not needed) Set In Order (organize remaining items) Shine (clean and inspect work area) Standardize (write standards for above) Sustain (regularly apply the standards) 	Eliminates waste that results from a poorly organized work area (e.g. wasting time looking for a tool).
Andon	Visual feedback system for the plant floor that indicates production status, alerts when assistance is needed, and empowers operators to stop the production process.	Acts as a real-time communication tool for the plant floor that brings immediate attention to problems as they occur – so they can be instantly addressed.
Bottleneck Analysis	Identify which part of the manufacturing process limits the overall throughput and improve the performance of that part of the process.	Improves throughput by strengthening the weakest link in the manufacturing process.
Continuous Flow	Manufacturing where work-in-process smoothly flows through production with minimal (or no) buffers between steps of the manufacturing process.	Eliminates many forms of waste (e.g. inventory, waiting time, and transport).
Gemba (The Real Place)	A philosophy that reminds us to get out of our offices and spend time on the plant floor – the place where real action occurs.	Promotes a deep and thorough understanding of real-world manufacturing issues – by first-hand observation and by talking with plant floor employees.
Heijunka (Level Scheduling)	A form of production scheduling that purposely manufactures in much smaller batches by sequencing (mixing) product variants within the same process.	Reduces lead times (since each product or variant is manufactured more frequently) and inventory (since batches are smaller).
Hoshin Kanri (Policy Deployment)	Align the goals of the company (Strategy), with the plans of middle management (Tactics) and the work performed on the plant floor (Action).	Ensures that progress towards strategic goals is consistent and thorough – eliminating the waste that comes from poor communication and inconsistent direction.
Jidoka (Automation)	Design equipment to partially automate the manufacturing process (partial automation is typically much less expensive than full automation) and to automatically stop when defects are detected.	After Jidoka, workers can frequently monitor multiple stations (reducing labor costs) and many quality issues can be detected immediately (improving quality).
Just-In-Time (JIT)	Pull parts through production based on customer demand instead of pushing parts through production based on projected demand. Relies on many lean tools, such as Continuous Flow, Heijunka, Kanban, Standardized Work and Takt Time.	Highly effective in reducing inventory levels. Improves cash flow and reduces space requirements.
Kaizen (Continuous Improvement)	A strategy where employees work together proactively to achieve regular, incremental improvements in the manufacturing process.	Combines the collective talents of a company to create an engine for continually eliminating waste from manufacturing processes.
Kanban (Pull System)	A method of regulating the flow of goods both within the factory and with outside suppliers and customers. Based on automatic replenishment through signal cards that indicate when more goods are needed.	Eliminates waste from inventory and overproduction. Can eliminate the need for physical inventories (instead relying on signal cards to indicate when more goods need to be ordered).
KPI (Key Performance Indicator)	Metrics designed to track and encourage progress towards critical goals of the organization. Strongly promoted KPIs can be extremely powerful drivers of behavior – so it is important to carefully select KPIs that will drive desired behavior.	The best manufacturing KPIs: <ul style="list-style-type: none"> Are aligned with top-level strategic goals (thus helping to achieve those goals) Are effective at exposing and quantifying waste (OEE is a good example) Are readily influenced by plant floor employees (so they can drive results)
Muda (Waste)	Anything in the manufacturing process that does not add value from the customer's perspective.	Eliminating muda (waste) is the primary focus of lean manufacturing.

Lean Tool	What Is It?	How Does It Help?
Overall Equipment Effectiveness (OEE)	Framework for measuring productivity loss for a given manufacturing process. Three categories of loss are tracked: <ul style="list-style-type: none">• Availability (e.g. down time)• Performance (e.g. slow cycles)• Quality (e.g. rejects)	Provides a benchmark/baseline and a means to track progress in eliminating waste from a manufacturing process. 100% OEE means perfect production (manufacturing only good parts, as fast as possible, with no downtime).
PDCA (Plan, Do, Check, Act)	Iterative methodology for implementing improvements: <ul style="list-style-type: none">• Plan (establish plan and expected results)• Do (implement plan)• Check (verify expected results achieved)• Act (review and assess; do it again)	Applies a scientific approach to making improvements: <ul style="list-style-type: none">• Plan (develop a hypothesis)• Do (run experiment)• Check (evaluate results)• Act (refine your experiment; try again)
Poka-Yoke (Error Proofing)	Design error detection and prevention into production processes with the goal of achieving zero defects.	It is difficult (and expensive) to find all defects through inspection, and correcting defects typically gets significantly more expensive at each stage of production.
Root Cause Analysis	A problem solving methodology that focuses on resolving the underlying problem instead of applying quick fixes that only treat immediate symptoms of the problem. A common approach is to ask why five times – each time moving a step closer to discovering the true underlying problem.	Helps to ensure that a problem is truly eliminated by applying corrective action to the “root cause” of the problem.
Single Minute Exchange of Die (SMED)	Reduce setup (changeover) time to less than 10 minutes. Techniques include: <ul style="list-style-type: none">• Convert setup steps to be external (performed while the process is running)• Simplify internal setup (e.g. replace bolts with knobs and levers)• Eliminate non-essential operations• Create standardized work instructions	Enables manufacturing in smaller lots, reduces inventory, and improves customer responsiveness.
Six Big Losses	Six categories of productivity loss that are almost universally experienced in manufacturing: <ul style="list-style-type: none">• Breakdowns• Setup/Adjustments• Small Stops• Reduced Speed• Startup Rejects• Production Rejects	Provides a framework for attacking the most common causes of waste in manufacturing.
SMART Goals	Goals that are: Specific, Measurable, Attainable, Relevant, and Time-Specific.	Helps to ensure that goals are effective.
Standardized Work	Documented procedures for manufacturing that capture best practices (including the time to complete each task). Must be “living” documentation that is easy to change.	Eliminates waste by consistently applying best practices. Forms a baseline for future improvement activities.
Takt Time	The pace of production (e.g. manufacturing one piece every 34 seconds) that aligns production with customer demand. Calculated as $\text{Planned Production Time} / \text{Customer Demand}$.	Provides a simple, consistent and intuitive method of pacing production. Is easily extended to provide an efficiency goal for the plant floor ($\text{Actual Pieces} / \text{Target Pieces}$).
Total Productive Maintenance (TPM)	A holistic approach to maintenance that focuses on proactive and preventative maintenance to maximize the operational time of equipment. TPM blurs the distinction between maintenance and production by placing a strong emphasis on empowering operators to help maintain their equipment.	Creates a shared responsibility for equipment that encourages greater involvement by plant floor workers. In the right environment this can be very effective in improving productivity (increasing up time, reducing cycle times, and eliminating defects).
Value Stream Mapping	A tool used to visually map the flow of production. Shows the current and future state of processes in a way that highlights opportunities for improvement.	Exposes waste in the current processes and provides a roadmap for improvement through the future state.
Visual Factory	Visual indicators, displays and controls used throughout manufacturing plants to improve communication of information.	Makes the state and condition of manufacturing processes easily accessible and very clear – to everyone.

Figure 5.
Top 25 Lean Tools with their applications.

SMEs but does not consider any environmental factors during its implementation. Green Manufacturing is popularly known as sustainable manufacturing, it is a business strategy yielding profit through proactive environmental friendly operating methods.

Green Manufacturing originated at the beginning of the 1990s by eco-innovation is a novel production method leading to mitigating environmental pollution and negative effects of resources utilized. Numerous research work has been done to discover the green approach in SMEs. It is considered as an environmental and economical-driven method to minimalize waste by designing an efficient process

and selecting materials without compromising the environment factors. Only Best practice should be adopted so that Green Manufacturing becomes effective. The International Standard Organization (ISO) came up with an international standard for Environmental Management System known as ISO14001 during the year 2013. These standards act like a systematic continuous improvement tool to implement Green Manufacturing.

3.2 Green Manufacturing Philosophies

In order to accomplish Green Manufacturing, there is a prerequisite to set up a suitable method to achieve it. For this, there are one dozen Principles used as strategies for designing a green manufacturing process as depicted in **Figure 6**. Also, there is a need for assessment of product lifecycle, types of Energy and material used. After further developments, a basic framework consisting of five principles of Green Manufacturing was evolved as shown in **Figure 7**. The objectivity of both approaches highlights assessment in a manufacturing SME considering Product life cycle (PLC), by offering deep importance to eco-friendly resources [11].

No.	Definitions	Descriptions
Principle 1	Non-hazardous inherent rather than circumstantial.	Strive to ensure all material and energy input and output are inherently non-hazardous as possible.
Principle 2	Prevention instead of treatment.	Better to prevent waste than treat or clean up waste after it is formed. Waste correlates to a process or an energy that is not being used efficiently in an operation.
Principle 3	Design for separation.	Product separation and purification process in manufacturing process consume a large amount of energy and material. Minimum energy consumption and material use design consideration should be incorporated in separation and purification operation.
Principle 4	Maximize mass, energy, space and time efficiencies.	A process is considered not efficient when mass, energy, space and time are utilized below maximum efficiency. Space and time can be utilized along with mass and energy to eliminate waste. Product, process and system should be designed to maximize mass, energy, space and time efficiencies.
Principle 5	Output-pull.	The production is based on client demand where material or energy will only be consumed when there is a demand.
Principle 6	Conserve complexity.	High complexity should correspond to reuse. The material used should have the complexity benefit without the need of modifying existing manufacturing process. Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse, or beneficial disposition.
Principle 7	Durability rather than immortality.	A product that lasts well beyond its commercial life will normally cause an environmental problem. Product design should consider the expected lifespan of the product. Design goal should be targeted at durability, not immortality.
Principle 8	Meet need, minimize excess.	The operation cost for material and energy cost can be high for an overdesign system. Design for unnecessary capacity or capability should be considered as a design flaw.
Principle 9	Minimize material diversity.	Material diversity in multicomponent products should be minimized to promote disassembly and value retention.
Principle 10	Integrate local material and energy flow.	This focuses on heat and material recovery on existing process. Design of products, processes, and systems must include integration and interconnectivity with available energy and materials flows.
Principle 11	Design for commercial "afterlife".	The recycling element should be incorporated into product design. This enables the current product to be utilized.
Principle 12	Renewable rather than depleting.	Taking waste product from a process and utilised as a feedstock into other process is a recycle/renewable source. The renewable resources can be utilized for recycling. Material and energy inputs should be renewable rather than depleting.

Figure 6.
Green Principles and their scope.

No.	Definitions	Descriptions
Principle 1	A comprehensive systems approach must be used to evaluate and improve manufacturing process from a green perspective.	Principle 1 takes environmental impact into consideration as the impact may have resulted from the process itself.
Principle 2	The system should be wholly viewed across both the vertical and horizontal directions.	Vertical refers to system varying level of detail from the enterprise down to the process while horizontal refers to the system at the same level of detail. This approach is important as environmental impact can occur depending on the level of detail.
Principle 3	Harmful input and output of the system to the environment and humans should be reduced or removed.	Identify harmful input and output to be replaced with material that has a lower impact. An alternative way is to implement recycle, reuse and remanufacture to reduce harmful input required.
Principle 4	Net resource use should be lowered.	Ideally, net resources should be zero so that resources may be used at a rate equal to the rate of replenishment in the environment. Aside from being practically impossible, the system will be deemed as inefficient in minimizing environmental impact.
Principle 5	Temporal effect on the system should always be considered.	Temporal effect is referred to effect that is time-based. Environmental impact should be considered in the design stage to allow better ability to consider for an alternative in reducing the future effect.

Figure 7.
Refined Green Principles.

The product lifecycle (PLC) rudiments viz., designing, procuring, manufacturing, package and delivery, old product disposal and reuse, need to have Green Manufacturing ingredients. After extending the further analysis of product lifecycle stages, a more refined framework is evolved by polishing principles, practice and tools involved in lifecycle design. The proposed framework has three main segments viz., design, development, manufacturing and services. This framework emphasis on resource utilization, Production Planning and Control (PPC), product assembly and warehousing, packaging. A environmental-based study reveals that about 80% impact on social, economic and environmental is found out in the design of the Product/Process. Therefore a new study Design for Environment (DfE) is presented which includes elements of green technology in designing process/product based on its impact on the Product life cycle. One more analysis called life cycle assessment (LCA) on a product is comparatively vital in the first stage of product design by analyzing key environmental factors that influence the complete product life cycle [12]. These two analyses are closely related to emission/waste and are important in assessing the product features leading to environmental pollution.

In a Product Along with DfE and LCA, energy consumption pattern plays a vital role in SMEs. Nowadays Green Ideology is no longer a new word to the entire world. It is defined as the “usage of science in the environment to preserve the resource and environment to control the negative impact of human activity”. Few Energy-efficient technologies viz., co-generation, photovoltaic, biogas, etc. can enhance the green quotient of any SMEs. Even though settled green technologies are available they are not utilized to their full potential. So a lot of changes are required in terms

of technology and knowledge in order to achieve complete Green Manufacturing. Screening of new technologies to lessen pollution is a must-have a positive effect on the Management of Energy by optimization of resources in SMEs. Example Gas Turbine (GT) co-generation plant can cut operation cost by developing two or more forms of energy from a single source [13].

A Material requirement planning system (MRP) should consider material identification, selection procurement and consumption to help in understanding both quantitative and financial term. Also, an analytical model to assess and analyze the effect of environmental risk factors during manufacturing which can produce different types of waste. Industrial collaboration lets SMEs acquire quality resources having low waste deposition. This type of transformation process will involve adaptation, replacement and circumvention steps.

- The adaptation steps involve collecting waste material from a collaborators area and fed it as an energy source.
- The replacement steps will replace stock by adjusting the alternate stock.
- The circumvention step stresses reducing/eliminating waste generation that may cause environmental pollution.

3.3 Enablers of Green Manufacturing

Green Manufacturing as similar waste reduction resourcefulness as Lean Manufacturing. So it is important to bring into line green and lean waste in order to bridge the void between both approaches and also correlate them to improve performance. Typical green wastes like greenhouse gases, high resource consumption like energy, water etc., pollutant, rubbish, and Safety and health [13].

An interview conducted with SMEs in Indian Industrial clusters (i.e. Foundry, garments and printing press etc.) on green technology and it was found out impediments for implementing Lean and green approach. The productivity of the workforce and lack of Lean and Green expert in SMEs results from sluggish implementations of Lean and Green. Also, Low or No cost improvement in SMEs is always welcomed because the management of these SMEs are not keen on huge investment in new technology, since they don't possess the required expertise and proficient employee to lead the team. Also return on investment is also important to convince the management. If SMEs focus on smaller energy-efficient equipment it can pay substantially towards overall growth. One main observation in SMEs is if any wing in a manufacturing SMEs if initiated with green technology will go on to complete the implementation.

According to a survey on the Energy consumption pattern by International Energy Outlook (2016), it was found that industry alone is consuming 55% of the world energy, and consumption is increasing by 2.1% in 2018. This Energy production and consumption of fossil fuel is the main reason for global warming. The main factors which can control this undesirable consumption rate are the legislature, corporate image, competition, and tax holiday. Also, stakeholders of SMEs can create an urge towards Green Manufacturing. Government play a pivotal role in encouraging and backing the SMEs in implementing Green Manufacturing. To achieve these mandate, the government has offered tax holidays for SMEs who have gone green and funding's and the incentive is given to Green SMEs will augment Green Manufacturing. One such case is of the Japanese government, which have shown commitment and zeal in realizing the green approach by introducing the Joint Crediting Mechanism (JCM) to have low-carbon technology collaboration

with few developing countries. In return, Japan will have reduced total Green House Gas (GHG) emissions. Green technology like cogeneration/tri-generation can step up energy generation capability.

Today, educated customers have more awareness of global climate change and they can put pressure on the SMEs to include Green Manufacturing technology in their units. The customers are often pressurized and demand manufacturer which is directly related to competitor pressure. Many companies have improved their image and public perception by adopting green manufacturing technologies through their corporate social responsibility. Along with ISO 9000 certification for design and manufacturing company have to adopt green manufacturing technologies in order to acquire ISO14000 certification related to an environmental management system. ISO 14001 certified companies assess their supplier's environmental performances and compel their suppliers to adopt environmental practices [14].

Research unveils that Green Manufacturing mainly focuses on pollution, energy and waste management. Many SMEs around the globe have prioritized Green Manufacturing technologies and subsidy/incentives are given for their successful implementation. In facts, some SMEs have started green in their organizations without comprehending its actual benefits.

4. Lean integrated with Green Manufacturing

The objective of both the approach is same i.e. minimizing non-value-added activities they can very effective when unified and implemented simultaneously. The growth of Lean and Green manufacturing approach is recently initiated and not more than the past decade mainly both by researchers and Industrialist as shown in **Figure 8**.

Both Lean and Green Manufacture are similar and effective approaches that can improvise global competition by improving productivity with zero-waste. Various apps have been developed for Lean Manufacturing that can support SMEs to integrate smart systems in their up and downstream processes thereby completely reducing waste and later it Green Manufacture can be accomplished with a positive vibe on operational and environmental performances.

Figure 8.
Commonalities between Green and Lean Manufacturing.

Research shows that Lean Manufacturing creates a positive impact on the environment because these lean SMEs possess the ability to cut environmental pollution. SMEs who have adopted Lean Manufacturing for continuous improvement in their facilities resulted in high efficiency and better environment-friendly performance. Especially lean tools can be used to achieve Green Manufacture.

Implementation of Green Manufacturing has impacted positively on many SMEs by allowing the production utilities to perform better. It develops compatibility between environment and operation Management. The lean and Green approach is mutually complementary and augments the capability and efficacy of operations when related individually [15]. Both have the same objectives i.e. to enhance performance, quality, Lead time thereby reducing operation cost and creating a product with high values. This reveals the cross association between both manufacturing systems.

The integration of both approaches based on attributes like public and organization, waste, lead time, supply chain, tools, practices, performance indicators. **Figure 9** depicts the connection and lapping of Lean and Green, at an outset, both have the same traits but differently defined. The main similarity is in their objectives of waste reduction. It is seen that lean can maximize profit by reducing cost while green reduces environmental hazards thereby maintain ecological balance. Even though in **Figure 3** different objectives are stated for the lean and green approach, the Lean approach guarantees effective resource utilization by eliminating waste while the green approach reduces environmental pollution. So it can be said that both having different waste elimination approach but the same waste is targeted. This illustrates the symbiosis relation between the two approaches.

4.1 Impediments in the path of Lean and Green Manufacturing

Various Lean and Green tools are developed for its implementation but there is no validation of these method/model for an application in **Figure 10**. Manufacturing and Industrial engineering attract the attention of researchers in this area’s

Figure 9.
Opportunities for Green manufacturing.

Figure 10.
Lean vs. Green.

leading to advancement. Also, management commitment is a key factor in implementing Lean and Green manufacturing and wherever there is a lack of organizational responsibility it becomes the main impediments for its implementation. Using the Management strategy and direction, the Lean and Green approach can be used as a continuous improvement program [16].

Lean and Green model can correlate waste data by using a systematic approach to support and realize d the benefit of this approach. Lean handles aids SMEs to transfer lean knowledge to the employee. From the operations perspective total productive maintenance (TPM) with root cause analysis are capable of smoothening production operation and from the green perspective, consumption can be

controlled by optimization approach. By adopting energy management total operation cost can be cut off using energy saving opportunities. Environmental emission are continuously monitored and controlled by regulators in place. Today's SMEs is market demand driven, thus they need to adapt rapidly to latest technologies and performance boosters.

Figure 11 list trials faced while implementation of Lean green. The first step towards a green economy is the importance of endorsing teaching and training to the top management for their commitments towards implementing Lean and Green. For this Stake, holders are SMEs, NGOs, lean experts, Lean practitioners and academicians who can inculcate lean as well as green culture. Along with this, strong government backing is a must. Many SMEs are facing financial constraints in

Figure 11.
Affiliation amid lean -green methods.

No.	Barriers in implementing L&G	Importance
1	Lack of environmental awareness	High
2	Fear of failure	High
3	Poor quality of human resources	High
4	Lack of expertise training and education	High
5	Fund constraints	High
6	Lack of statistical, lean and green thinking	High
7	Inappropriate identification of areas and activities to be Leaned and greened.	High
8	Lack of Kaizen culture	High
9	Lack of visual and statistical control during L&G implementation	High
10	Lack of government support to integrate green practices	High
11	High cost	High
12	Lack of communication and cooperation between departments	Moderate
13	Lack of top management involvement in adopting L&G initiative	High
14	Resistance to change	High
15	Poor corporate culture separating environmental and continuous improvement decisions	High
16	unreliable data collection system	

Figure 12.
Impediments of lean -green implementation.

implementing the Lean Green approach in their setup, so government policies play a vital role in facilitating funds through financial institution's. An important utility is the Management Information System (MIS) for the collection of Data and performance index, this enables SMEs to categorize problems and assess the efficacy of solution [17]. Also employing a capable individual to implement and progress Lean and Green is a big challenge. After reviewing the literature it is observed that there is no organized framework and analytical model to guide SMEs in refining their overall performances as shown in **Figure 12**.

5. Future work

The necessity to meet demands globally without harming the Environment.is the order of the day for many SMEs. Industry 4.0 posed challenges for SMEs in acquiring advanced technologies to be competitive. The digitalization of manufacturing has led the shift in industrial Engineering popularly recognized as industrial revolution 4.0 and resulted in smart factories, smart products and smart services embedded with the Internet of Thing (IoT). It integrates the production system with intelligence and creates new technology [18].

Today researchers have formulated guidelines for SMEs for implementing Lean and Green manufacturing. Collecting Data is the key to enhance SMEs performance. Using this data one can analyze operation parameters to step up productivity, quality and efficiency. To accomplish this SMEs need to embrace Industry 4.0, wherein the variety of smart sensors, expert system, advance solver, intelligent devices and data acquisition systems are a must. This requires huge investment by SMEs, who are not in the position to afford this upgradient. Therefore there exist a void in implementing Industry 4.0 with a confidence level within SMEs, with respect to the huge investment cost and global competition. To fill this void a model depicting flow in implementing Lean and green process of Industry 4.0 compliant is shown in **Figure 4**. This model can be implemented with confidence by SMEs at an

Figure 13.
Planned Process chart for Lean and Green.

affordable price. In order to adopt and implement Industry 4.0 an efficient data management system for further analysis permits continuous improvement.

A Lean and Green framework is proposed with collecting data and Lean and Green agenda as shown in **Figure 13**. This proposed framework primarily comprises five key elements such as manpower, money, machine, material and environment (5me). This proposed L&G framework alters 5me with the amalgamation of the green element. “Manpower” is the main element in SMEs, it has to adapt to the latest manufacturing technology, so a positive environment is a must for adapting rapidly. On the other hand, employee retention and capacity building are vital to

Figure 14.
Proposed Lean and Green manufacturing framework.

any SMEs functioning globally. There is relationship between cost-saving, efficiency and sustainability, the Money factor is a direct indicator of the performance index of an SME. Next is “machine”, SMEs depends on a machine for manufacturing, so optimization of machine performance will improve production efficiency and create a continuous improvement environment for the employee to strive for better performance [19]. The element “material” includes resources like raw materials, products, logistic and storage, quality are considered. Finally, “environment” is involved to signify the green facet of the framework and it contributes severely to global warming and climate change.

These five major elements will help SMEs to implement the Lean and Green approach by giving direction regarding decision making by creating a multiple-criteria decision making (MCDM) tool which can help the organization to take the right decision based on their operational behaviour.

Also by using this proposed framework SMEs will be able to bridge the gap between an implementation using simulation technique used in implementing Industry 4.0. by combined development and analysis of process automation. The framework aims to overcome the barrier in implementing Lean and Green in the industry as shown in **Figure 14**.

6. Conclusion

The essentials of the Lean and Green facet has a foundation for beginners to comprehend the concepts of both is made. This integration leads to the synergy between Lean and Green yielding good result benefiting both environmental and operational performances. This chapter outlines the principles of Lean and Green manufacturing, tools for its application, enablers and inhibitors of this technology. The study reveals that due to ignorance, poor planning and no government policy to support and industries in implementing this approach. Total involvement of management within SMEs is a must for successful implementation. After identifying impediments of this integrated management still cannot implement effectively due to the shortage of experts in this domain. This chapter has reviewed the literature and identified the research gap amongst the barriers and implementation tools adopted, to fill this gap, a Lean Green framework model is developed to overcome the barriers of implementation. The ingredients of this proposed Lean and Green model are Men, Material, Machine, Money and Environment [20]. This model through simulation can fill the research gap to enhance the rate of implementation of this Lean and Green approach. This chapter can act as a primer to SMEs for a better understanding of Lean and Green, also to aid them to effectively implement sustainability in their manufacturing facilities. This chapter motivates and inspires SMEs to adopt Lean and Green manufacturing and to become Industry 4.0 compliant.

Abbreviations

DfE	Design of Environment
FPS	Ford Production System
GM	Green Manufacturing
IoT	Internet of Things
ISO	International Standard Organization
JCM	Joint Credit Mechanism
JIT	Just in Time

L&G	Lean and Green
LCA	Life Cycle Analysis
LM	Lean Manufacturing
MCDM	Multiple-Criteria Decision Making
NGO	Non-Governmental Organization
SMED	Single minute exchange die
TPS	Toyota Production System
UNEP	United Nations Environmental Program
WWII	World War II

IntechOpen

Author details

J.P. Rishi
Department of Mechanical Engineering, VidyaVardhaka College of Engineering
Mysuru, Karnataka, India

*Address all correspondence to: rishijp@vvce.ac.in

IntechOpen

© 2021 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

- [1] Anastas, P. and Zimmerman, J. (2003). Peer-Reviewed: Design Through the 12 Principles of Green Engineering. *Environmental Science & Technology*, 37(5), pp.94A-101A.
- [2] BP.(2018). BP Statistical review of world energy. London: BP.
- [3] Buesa, R. J. (2009). Adapting lean-to histology laboratories. *Annals of Diagnostic Pathology*, 13(5), 322–333. doi:10.1016/j.anndiagpath.2009.06.005
- [4] Business, B. (2018). 5 Ways How Globalization Impacts Small Businesses | BusinessBlogs Hub. [online] BusinessBlogs Hub. Available at: <https://www.businessblogshub.com/2017/05/5-ways-how-globalization-impacts-small-businesses/> [Accessed 16 Jun. 2018].
- [5] Carvalho, H., Azevedo, S. and Machado, V. (2010). Supply chain performance management: lean and green paradigms. *International Journal of Business Performance and Supply Chain Modelling*, 2(3/4), p.304.
- [6] De Ron, A. and Rooda, J. (2006). OEE and equipment effectiveness: an evaluation. *International Journal of Production Research*, 44(23), pp.4987–5003.
- [7] Frank B, G. (2016). *Process Charts*. Wentworth Press.
- [8] Galeazzo, A., Furlan, A. and Vinelli, A. (2014). Lean and green in action: interdependencies and performance of pollution prevention projects. *Journal of Cleaner Production*, 85, pp.191–200.
- [9] Handfield, R., Walton, S., Seegers, L. and Melnyk, S. (1997). 'Green' value chain practices in the furniture industry. *Journal of Operations Management*, 15 (4), pp.293–315.
- [10] Japan, G. (2017). Recent Development of the Joint Crediting Mechanism (JCM). Available at: https://www.carbon-markets.go.jp/document/20170522_JCM_goj_eng.pdf
- [11] Jin Kim S. and Kara S. (2012). Impact of Technology on Product Life Cycle Design: Functional and Environmental Perspective. Berkeley. p. 1, 2
- [12] Kochnev, I. (2007). WHAT, IF ANY, ARE THE DIFFERENCES BETWEEN THE TOYOTA PRODUCTION SYSTEM AND LEAN?. innovationlighthouse.com.
- [13] McBride, D. (2013). The 7 Wastes in Manufacturing. Retrieved November 20, 2017, from a. <http://www.emsstrategies.com/dm090203article2.html>
- [14] McGrath, W. (2007). Impact Analysis of Large Scale Lean Manufacturing Initiatives Upon Manufacturing a. Process Innovation In Irish Companies, Master thesis, Waterford Institute of Technology.
- [15] Paul, I., Bhole, G. and Chaudhari, J. (2014). A Review on Green Manufacturing: It's Important, Methodology and its Application. *Procedia Materials Science*, 6, pp.1644–1649.
- [16] Pettersen, J. (2009). Defining lean production: some conceptual and practical issues. *The TQM Journal*, 21 (2), pp.127–142.
- [17] Qin, S. (2014). Process data analytics in the era of big data. *AIChE Journal*, 60(9), pp.3092–3100.
- [18] Rouse, M. (2015). What is just-in-time manufacturing (JIT manufacturing)?. [online] WhatIs.com. Available at: <https://whatis.techtarget.com/definition/just-in-time-manufacturing-JIT-manufacturing> [Accessed 13 Jun.. 2018].

[19] Sezen, B. and Çankaya, S. (2013). Effects of Green Manufacturing and Eco-innovation on Sustainability Performance. *Procedia - Social and Behavioral Sciences*, 99, pp.154–163.

[20] TOYOTA. C. (2018). Toyota Global Site | Jidoka. [online] Toyota Motor Corporation Global Website. Available philosophy/toyota_production_system/jidoka.html.

IntechOpen

IntechOpen