Lean Manufacturing and Environment

Rajesh Goel
Research Scholar
MRIU, Faridabad
rajeshgoel07@yahoo.co.in

Ranvijay Singh
Professor and HOD,
Mech. Engg (FET),
MRIU, Faridabad

Abstract: *"Lean manufacturing" is a leading manufacturing paradigm being applied in many sectors, where improving product quality, reducing production costs, and being "first to market" and quick to respond to customer needs are critical to competitiveness and success. Lean principles and methods focus on creating a continual improvement culture that engages employees in reducing the intensity of time, materials, and capital necessary for meeting a customer's needs. While lean production's fundamental focus is on the systematic elimination of non-value added activity and waste from the production process, the implementation of lean principles and methods also results in improved environmental performance. At the heart of successful lean implementation efforts lies an operations-based, employee-involved, continual improvement-focused waste elimination culture. While environmental wastes (e.g., solid waste, hazardous wastes, air emissions, wastewater discharges) are seldom the explicit targets of or drivers for lean implementation efforts, case study and empirical evidence shows that the environmental benefits resulting from lean initiatives are typically substantial. The cumulative effect makes lean manufacturing a powerful vehicle for reducing the overall environmental footprint of manufacturing and business operations, while creating an engine for sustained and continual environmental improvement.*

Keyword: *Lean Manufacturing, Environment, Waste elimination.*

I. INTRODUCTION

James Womack, Daniel Jones, and Daniel Roos coined the term "lean production" in their 1990 book *The Machine that Changed the World* to describe the manufacturing paradigm established by the Toyota

Production System.6 In the 1950s, the Toyota Motor Company pioneered a collection of advanced manufacturing methods that aimed to minimize the resources it takes for a single product to flow through the entire production process. Inspired by the waste elimination concepts developed by Henry Ford in the early

1900s, Toyota created an organizational culture focused on the systematic identification and elimination of all waste from the production process. In its most basic form, lean manufacturing is the systematic elimination of waste from all aspects of an organization's operations, where waste is viewed as any use or loss of resources that does not lead directly to creating the product or service a customer wants when they want it. In many industrial processes, such non-value added activity can comprise more than 90 percent of a factory's total activity.

Nationwide, numerous companies of varying size across multiple industry sectors, primarily in the manufacturing and service sectors, are implementing such lean production systems, and experts report that the rate of lean adoption is accelerating. Companies primarily choose to engage in lean manufacturing for three reasons: to reduce production resource requirements and costs; to increase customer responsiveness; and to improve product quality, all which combine to boost company profits and competitiveness. To help accomplish these improvements and associated waste reduction, lean involves a fundamental paradigm shift from conventional "batch and queue" mass production to product-aligned "one-piece flow" pull production. Whereas "batch and queue" involves mass production of large lots of products in advance based on potential or predicted customer demands, a "one-piece flow" system rearranges production activities in a way that processing steps of different types are conducted immediately adjacent to each other in a continuous flow.

This shift requires highly controlled processes operated in a well maintained, ordered, and clean environment that incorporates principles of employee-involved, system-wide, continual improvement. Common methods used in lean manufacturing include: Kaizen; 5S; Total Productive Maintenance (TPM); Cellular Manufacturing; Just-in-Time Production; Six Sigma; Pre-Production Planning (3P); and Lean Enterprise Supplier Networks.

Lean methods typically target eight types of waste. These waste types are listed in Table 1. It is interesting to note that the "wastes" typically targeted by environmental management agencies, such as non-product output and raw material wastes, are not explicitly included in the list of manufacturing wastes that lean practitioners routinely target.

II. METHODS USED FOR LEAN IMPLEMENTATION

There are numerous methods and tools that organizations use to implement lean production systems. Eight core lean methods are described briefly below. The methods include:

1. Kaizen Rapid Improvement Process
2. 5S
3. Total Productive Maintenance (TPM)
4. Cellular Manufacturing / One-piece Flow
5. Just-in-time Production / Kanban
6. Six Sigma
7. Pre-Production Planning (3P)
8. Lean Enterprise Supplier Networks

While most of these lean methods are interrelated and can occur concurrently, their implementation is often sequenced in the order they are presented below. Most organizations begin by implementing lean techniques in a particular production area or at a "pilot" facility, and then expand use of the methods over time.

Fig. 1 illustrates the production flow in a conventional batch and queue system, where the process begins with a large batch of units from the parts supplier. The parts make their way through the various functional departments in large "lots," until the assembled products eventually are shipped to the customer. Rather than processing multiple parts before sending them on to the next machine or process step (as is the case in batch-and-queue, or large-lot production), cellular manufacturing aims to move products through the manufacturing process one-piece at a time, at a rate determined by customer demand (the *pull*).

Table 1: Eight Types of Manufacturing Waste Targeted by Lean Methods

Waste Type	Examples
Defects	Production of off-specification products, components or services that result in scrap, rework, replacement production, inspection, and/or defective materials.
Waiting	Delays associated with stock-outs, lot processing delays, equipment downtime, capacity bottlenecks.
Unnecessary Processing	Process steps that are not required to produce the product.
Overproduction	Manufacturing items for which there are no orders.
Movement	Human motions that are unnecessary or staining, and work-in-process (WIP).
Inventory	Excess raw material, WIP, or finished good.
Unused Employee Creativity	Failure to tap employees for process improvement suggestions.
Complexity	More parts, process steps, or time than necessary to meet customer needs.

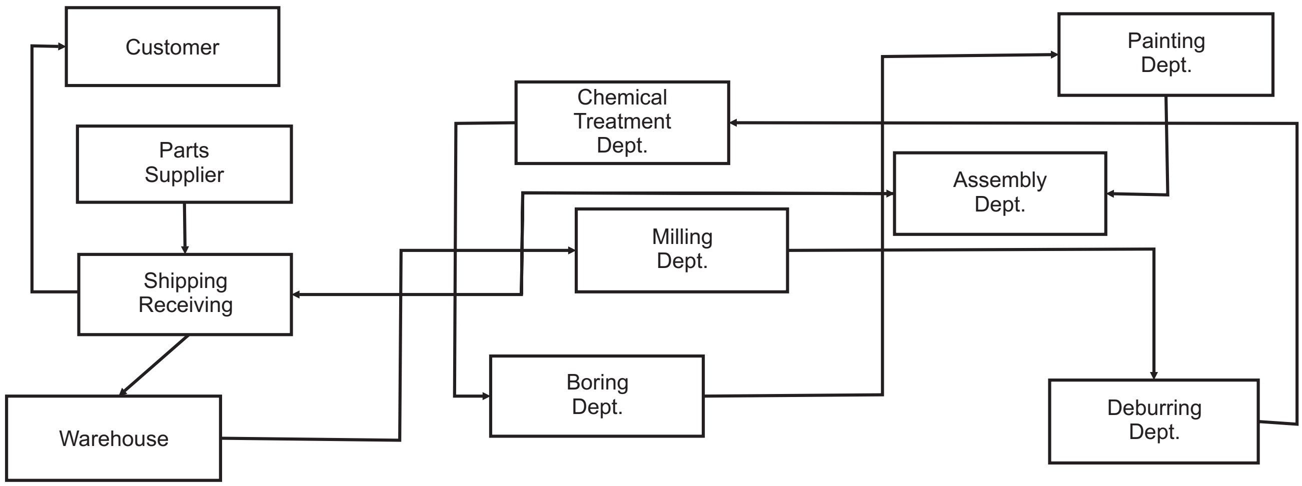

Fig. 1: Functionally-Allgned, Batch and Queue, Mass Production

Cellular manufacturing can also provide companies with the flexibility to make quick "changeovers" to vary product type or features on the production line in response to specific customer demands. This can eliminate the need for uncertain forecasting as well as the waste associated with unsuccessful forecasting.

Fig. 2 illustrates production in this product-aligned, one-piece flow, pull production approach.

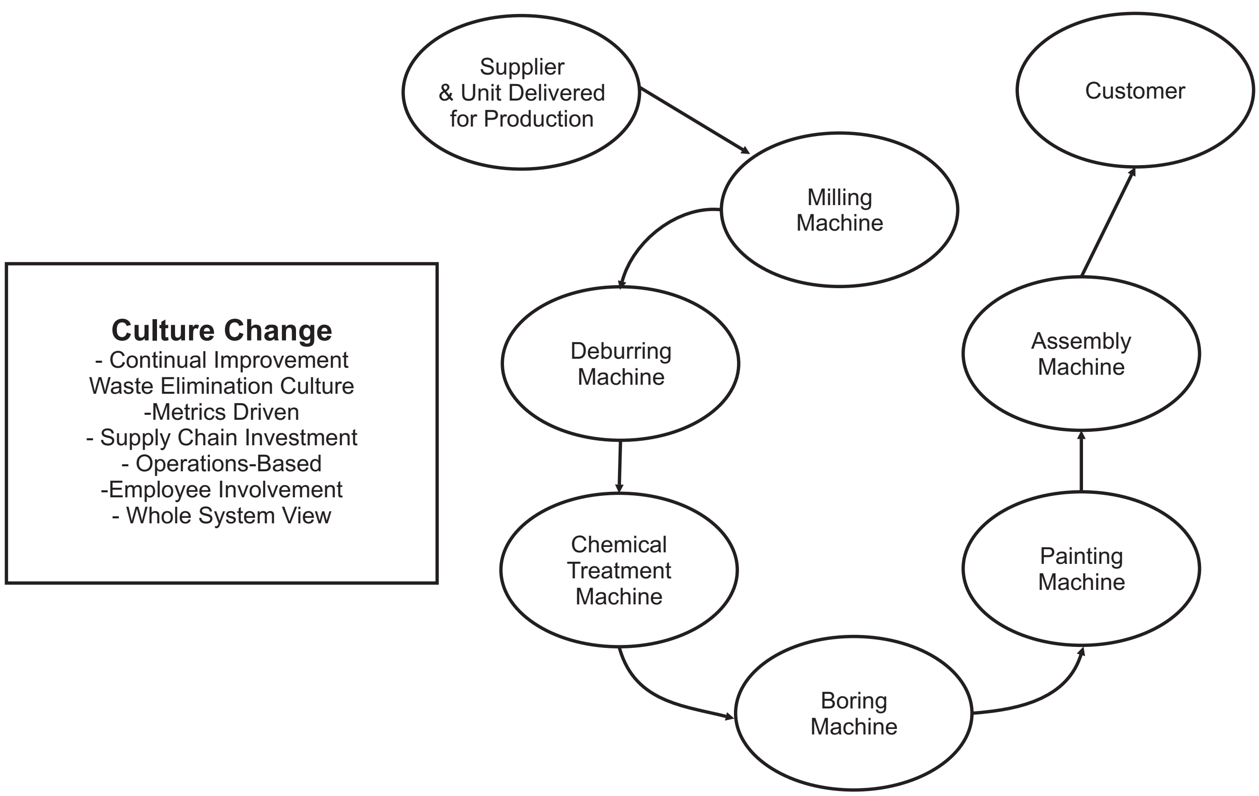

Fig. 2: Product-Aligned, One-Piece Flow, Pull Production

III. MECHANISMS FOR ENVIRONMENTAL IMPROVEMENT THROUGH LEAN IMPLEMENTATION

With the expanding evidence consistently demonstrating that lean implementations yield environmental improvements, it seems appropriate to ask what are the mechanisms by which these improvements are being achieved. Conceptually, the link between lean production and environmental improvement is strong. As discussed this paper, the fundamental objective of lean systems is the systematic elimination of waste by focusing on production costs, product quality and delivery, and worker involvement. At a whole systems level, advanced manufacturing methods work to lower the resource intensity necessary to deliver a product or service to meet customer needs. This means that organizations implementing lean methods continually seek to reduce the materials, energy, water, space, and equipment needed per unit of production.

Even though environmental endpoints, such as hazardous waste, air emissions, and wastewater discharges, are frequently not directly identified in the types of manufacturing wastes targeted by lean initiatives, improvements in these areas are deeply embedded in the other types of manufacturing wastes.

Table 2 lists seven common types of waste that lean works to eliminate, along with the environmental impacts that are often associated with each of them. An analysis of advanced manufacturing methods, accomplished through a review of publications documenting lean methods supplemented by input from lean experts, reveals multiple ways in which each of the lean methods has implications for environmental performance. Each of the lean methods examined for this analysis have multiple ways in which they can produce environmental benefits.

Table 2: Environmental Impacts Linked with Manufacturing Waste

Waste Type	Examples	Environmental Impacts
Defects	Scrap, rework, replacement production, inspection	• Raw materials consumed in making defective productrs • Defective components require recycling or disposal • More space required for rework and repair, increasing energy use for healting, cooling, and lighting
Waiting	Stock-outs, lot processing delays, equipment downtime, capacity bottlenecks	• Potential material spoilage or component damage caushing waste • Wasted energy from heating, cooling, and lighting during production downtime
Overproduction	Manufacturing items for which there are no orders	• More raw materials consumed in making the unneeded products • Extra products may spil or become obsolete requiring disposal
Movement	Human motions that are unnecessary or straining, carrying work in process (WIP) long distances, transport	• More energy use for transport • Emissions from transport • More space required for WIP movement, increasing lighting, heating, and cooling demand and energy consumption • More packaging required to product components during movement
Inventory	Excess raw material, WIP, or finished goods	• More packaging to store work-in-process • Waste from deterioration or demage to stored WIP • More materials needed to replace damaged WIP • More energy used to heat, cool, and light inventory space
Complexity	More parts, process steps, or time than necessary to meet customer needs	• More parts and raw materials consumed per unit of production • Unnecessary processing increases wastes, energy use, and emissions
Unused	Lost time, ideas, skills, improvements, and suggestions from employees	• Fewer suggestions of P2 and waste minimization opportunities

IV. LEAN MANUFACTURING COATTAILS FOR ENVIRONMENTAL IMPROVEMENT

In many cases, it appears that the environmental improvements resulting from lean implementation are improvements for which there would not likely have been a strong business case in the absence of the lean initiative. For example, Goodrich representatives indicated that had the business case for developing right-sized parts washers, paint booths, and chemical treatment baths been based on environmental improvement factors such as reduced chemical use, hazardous waste generation, and air emissions, they would not have been undertaken. In reality, the environmental benefits were not calculated in making the business case.

Improving "flow and linkage" in the production process, and reducing the capital and time intensity of production, overshadowed other benefits, creating a compelling case for the conversion to a right-sized, cellular manufacturing environment. Savings in operational costs, such as reduced chemical or material use and reduced waste disposal costs may be significant, but they are significantly smaller than business benefits achieved from reduced capital and time intensity of production. In other words, the business case for change did not enter through the "green door".

Lean implementation efforts, on the other hand, are typically central to an organization's competitiveness and operational strategy. Several of the companies have moved away from traditional project evaluation processes that rely on calculating a project's return on investment (ROI) and comparing it with a hurdle rate.

They indicated that many lean implementation projects focused on particular process steps would not compete effectively on these grounds, since the real benefits arise from the optimization of the overall system's flow and linkage. This is consistent with Joseph Romm's findings in *Lean and Clean Management* that conventional project evaluation techniques often turn a blind eye to life cycle costs or the impacts on the whole production system. If the operational change is already being made, then pollution prevention can "pay" even more, and, at times, pollution prevention that does not "pay" can be adopted because it contributes to overall lower systems cost. In effect, lean can help pollution prevention to better compete.

V. BRIDGING ENVIRONMENTAL BLIND SPOTS AND GAPS IN LEAN METHODS

As illustrated in Fig. 3, lean methods have a low attentiveness to environmental risks—such as the toxicity of substances—in the production process and in products. While lean implementation often reduces environmental risks (e.g., productivity improvements that reduce chemical use and hazardous waste generation), environmental risk factors are not routinely examined by lean methods. Similarly, lean methods do not typically identify or consider the environmental impacts or costs associated with the extraction of materials used in the manufacturing process, the disposal of non-product output or waste generated during production, or the use or disposal of the resulting product.

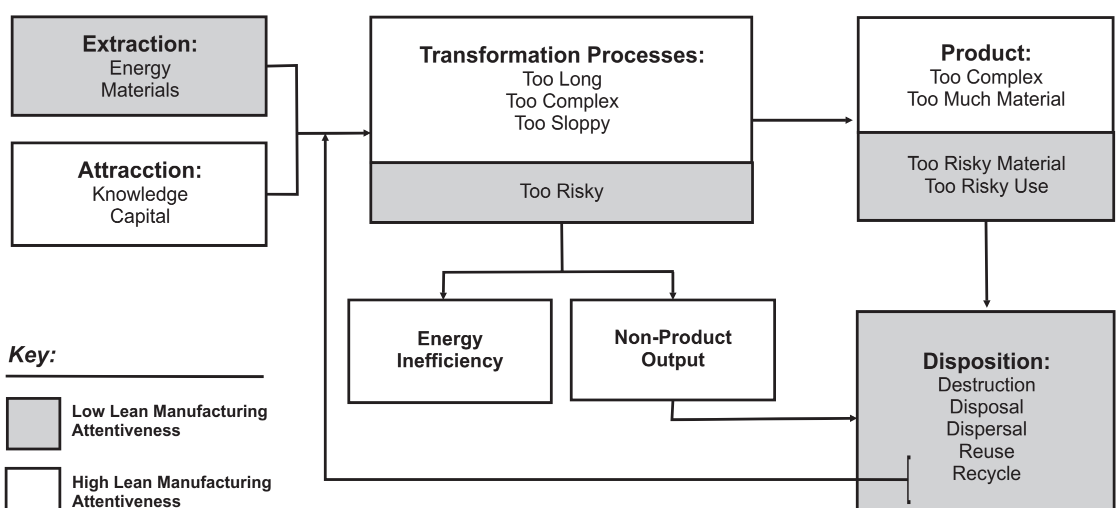

Fig. 3: Lean "Blind Spots": Risk and Lifecycle impacts

Fig. 3 also highlights several areas in the product or service lifecycle where lean methods do address characteristics that align with the preferences of public environmental regulatory agencies, such as reducing energy inefficiency and decreasing the complexity and material in products.

VI. LEAN AS A PLATFORM FOR SUSTAINABILITY

Over time, lean implementation can create an effective platform for addressing sustainability objectives, such as eliminating environmental risk and addressing environmental impacts throughout the product or service lifecycle. After firmly establishing lean methods and processes in their organizations, several companies have found benefits from closing the gaps identified above. The initial lean resource productivity (efficiency) drive established organizational cultures and methods that enabled a smooth transition to what is, in effect, "eco-effectiveness" thinking. Once environmental personnel gain familiarity and proficiency with lean methods and processes, there is evidence that lean tools can be used to explicitly address environmental objectives such as waste minimization and risk reduction.

Lean implementation can also reduce the marginal effort and cost of implementing sustainability activities, such as Design for Environment and Extended Producer Responsibility, to eliminate environmental impacts at the product design stage and to manage products at the end of their productive use. One company found that its lean implementation activities, including 3P "design for manufacturability" techniques, drove many environmental impacts out of its production process, while simplifying its product line to a small number of parts made from recyclable materials.

Much to the company's surprise, when it assessed its product lines using the new standard, it found that one fully met the standard, and the second barely missed meeting the standard due to formaldehyde off-gassing. The company worked to address the off-gassing and subsequently landed a multi-year contract with the state that is valued at over $60 million. This experience has led the company to integrate Design for Environment tools and practices into its lean design processes. Company executives now see advanced manufacturing and environmental management tools as complementary and integral to the company's competitive advantage.

VII. RECOMMENDATIONS

1. Work with lean experts to identify and address the environmental "blind spots" that typically arise in lean methods. By addressing the few environmental blind spots and gaps in lean manuals, publications, training, and lean implementation, environmental regulatory agencies have an opportunity to harness even greater environmental improvement from industry lean implementation efforts.

   More specific actions can take to facilitate this process include:

   - Develop an action plan for raising awareness among companies of opportunities to achieve further environmental improvements during lean implementation;
   - Partner with lean promoters to develop and modify lean tools, manuals, training, and conference sessions to address environmental performance topics;
   - Develop and disseminate resources and tools for environmental practitioners to help them better understand lean manufacturing techniques and benefits;
   - Develop resources, fact sheets, and website materials that highlight important environmental questions and criteria that can be incorporated into lean methods; and
   - Conduct explicit outreach (e.g., materials, conference presentations, workshops) to corporate environment, health, and safety (EHS) managers to raise awareness about techniques they can use to integrate environmental considerations into their companies' lean initiatives.

2. Develop a pilot/demonstration program to encourage companies who are implementing lean to achieve more waste reduction and P2 by explicitly incorporating environmental considerations and tools into their lean initiatives. Build the bridge between lean manufacturing initiatives and environmental management by assisting companies who are implementing lean to achieve more waste reduction and P2 through the explicit incorporation of environmental considerations and tools into their lean initiatives.

Beginning a pilot / demonstration program with specific companies could open avenues for putting the wealth of pollution prevention expertise, techniques, and technologies developed in recent decades for driving waste and risk out of these processes into the hands of lean practitioners who are engaged in process innovation. By building such a "bridge," environmental agencies will be better positioned to understand lean implementation processes and to realize greater environmental improvement result from lean initiatives. Specific pilot/demonstration activities could include:

- Work with companies to document and disseminate case study examples of companies that have successfully integrated environmental activities into lean. In addition, EPA could explore and highlight case study examples that illustrate how companies have effectively used lean as a platform for implementing environmentally sustainable tools (e.g., life-cycle analyses, Design for Environment);
- Partner with selected industry sectors and associated organizations in which there is large amount of lean activity to improve the environmental benefits associated with lean. For example, EPA could explore partnership opportunities with the Lean Aerospace Initiative or the Society for Automotive Engineers to bridge lean and the environment in these sectors; and
- This effort could include conducting a pilot project with a hospital implementing lean, designed to integrate waste reduction and product stewardship techniques into its lean initiatives. The resulting lessons could then be publicized for the benefit of other hospitals.

3. Use pilot projects and resulting documentation to clarify specific areas of environmental regulatory uncertainty associated with lean implementation and improve regulatory responsiveness to lean implementation. This research suggests that public environmental management agencies have an important opportunity to align the environmental regulatory system to address key business competitiveness needs in a manner that improves environmental performance.

Lack of regulatory precedent associated with mobile, "right-sized" equipment begs the need for environmental agencies to articulate acceptable compliance strategies for addressing applicable requirements in the lean operating environment. At the same time, regulatory "friction"—cost, delay, uncertainty—can often arise when regulatory "lead times" (e.g., time to secure applicability determinations, permits, and approval) slow the fast-paced, iterative operational change that is typically associated with lean implementation. More specific actions can take to facilitate this process include:

- Developing guidance on acceptable compliance strategies for implementing lean techniques around environmentally sensitive processes
- Developing acceptable compliance strategies and permitting tools that can accommodate the implementation of mobile, right-sized equipment around environmentally sensitive processes; and
- Identifying and documenting guidance regarding acceptable strategies for applying lean to other environmentally sensitive processes, including painting and metal finishing.

REFERENCES

[1]. Florida, R. "Lean and Green: The Move to Environmentally Conscious Manufacturing." *California Management Review* 39, no.1 (1996) 80-105.

[2]. Hawken, Paul, Amory Lovins, and L. Hunter Lovins. *Natural Capitalism: Creating the Next Industrial Revolution* (New York: Little, Brown and Company, 1999).

[3]. Hart, S.L. "Beyond Greening: Strategies for a Sustainable World." *Harvard Business Review* 75, no.1 (1997) 66.

[4]. Maxwell, James, Sandra Rothenberg and B. Schenk. *Does Lean Mean Green? The mplications of Lean Production for the Environmental Management*. MIT Working Paper (1993).

[5]. Womack, James P. and Daniel T. Jones. L*ean Thinking: Banish Waste and Create Wealth in Your Corporation* (New York: Simon & Schuster, 1996).

[6]. Pojasek, Robert B. "Zeroing In". *Environmental Quality Management* (Summer 1999) 93-97.

❒