LEAN MANUFACTURING: THEORY AND PRACTICE

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crossref http://dx.doi.org/10.5755/j01.em.17.2.2205

Abstract

Lean manufacturing began as the Toyota Production System in the Japanese auto industry of the 1970s and 1980s. Its main goals were to eliminate waste, reduce the need for managing large inventories, and provide optimum quality at the least cost by making quality control decisions an immediate part of the manufacturing process. Lean manufacturing is a management philosophy derived mostly from the Toyota Production System (TPS) to address their specific needs in a restricted market in times of economic trouble. Lean manufacturing, lean enterprise, lean production, or often simply, "Lean," is a practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination. Lean can be described at different levels of abstraction: it can be defined as a philosophy, as a set of principles and as bundles of practices. Lean as one of the popular concepts has been studied and practiced in many companies. It has been proven to be transferrable and applicable to a wide variety of industries and services.

The paper aims to identify the main principles of Lean and disclose success factors in Lean implementation. Authors of this paper present the model of Lean implementation process.

Keywords: Lean manufacturing, Toyota production system, manufacturing performance.
JEL Classification: M11, L23, M54.

Introduction

The concept of Lean incorporates important works of Ohno (1978) and Deming (1986). Lean production, evolved from the Toyota Production System (TPS) over a period of several decades, and is considered to improve firm performance through elimination of waste (Holweg, 2007; Shah & Ward, 2007).

Lean production is a prominent manufacturing philosophy that is based on customer-focused process improvements. The key idea is to increase value to customers while reducing the number of resources consumed and cycle times via waste elimination.

Lean is a philosophy of manufacturing that incorporates a collection of principles, tools and techniques into the business processes to optimize time, human resources, assets, and productivity, while improving the quality level of products and services to their customers (Ronald, 2001). Applying lean manufacturing philosophy is one of the most important concepts that help enterprises to gain competitive advantage in the world market. Lean manufacturing or lean production is a production practice, which regards the use of resources for any work other than the creation of value for the end customer, as waste. Lean manufacturing is a multi-dimensional management practice including just in time, quality systems, work teams, cellular manufacturing, supplier management, etc. in an integrated system (Singh *et al.*, 2011).

Although a lot of companies started implementing lean concept, according to Bhasin and Burcher (2006), only 10 percent or less of the companies succeed in implementing lean manufacturing practices. Even though number of lean tools, techniques and technologies available to improve operational performance is growing rapidly, however a few companies that put effort to use them failed to produce significant results.

Despite significant studies and works on Lean manufacturing, this field has struggled with a lack of clarity about what lean production is and what it is not; what are the main principles, techniques and success factors of Lean implementation; advantages and risks of Lean production.

The purpose of this paper is to identify the main principles of lean and success factors in Lean implementation.

Research methods are the analysis of scientific literature, logical analysis and conclusion formulating.

The paper is divided into four main parts. The first part analyses the background of Lean concept. The second part reports on the general principles of Lean manufacturing. Success factors and model of Lean implementation process are presented in the third part. Finally, advantages and risks of Lean Production are highlighted.

Historical development of Lean concept

The concept and roots of Lean are based on foundational ideas that date back to W. F. Taylor (1911) and to H. Ford, who put in place an impressive production system in the Highland Park manufacturing plant, in 1913. There, a set of practices and tools (interchangeable parts, standard work and the assembly flow line) was put in place in such an integrated way that allowed them to turn out products at incredible speeds, with very short flow times and high consistency. This system was not very flexible, though. The Model T was manufactured virtually unchanged during 19 years under this system, and there was no need for setups or changeovers since there was only one product being processed in that line. Increased demand for shorter product cycles and more variety, as well as the market demands after World War II, changed the competitive marketplace in such a way that Ford's early "Leanness" was not sustained in the long run (Duque & Cadavid, 2007).

K. Toyoda (member of the founding family of Toyota) and T. Ohno (Toyota's leading manufacturing engineer) visited Ford factories right after World War II and observed their operation. They were convinced that with some elements from the Ford system, their adaptation to their scale and reality and a lot of ingenuity they could make Toyota a competitive force in the automotive market. Essentially, they changed the emphasis from machine and workstation optimization to product flow through the total process, implementing some ideas like dimensioning the manufacturing resources according to actual demand (rightsizing), improving the self-monitoring capabilities of equipment to ensure quality, designing the process layout to facilitate the sequence of the operations, studying and improving quick setups to enable rapid changeovers and the use of kanbans to coordinate the production pull from and link one workstation to its predecessors and successors, and also to link the company with its suppliers and enable Just-in-time supply (Womack, 2002). These processing improvements made possible to offer a wide variety of products in a sequence that reflected more closely the market's demands, reducing lead times and eliminating the need for large volumes of inventory (which, with the space constraints for manufacturing and warehousing facilities in Japan, was critical for the financial success of any business). Also, a management system was developed to reflect and support all these changes in focus and style, which is now known as the "Toyota Production System" (TPS) (Duque & Cadavid, 2007).

Toyota's successful journey of more than 50 years to become the world's most profitable auto company (Taylor, 2007) is often credited to the company's manufacturing prowess resulting from the TPS (Hino, 2006; Liker, 2004). Rather, it developed gradually over many years as the accumulation of a series of small innovations (Fujimoto, 1999). Early on, Toyota leaders did not have the economies of scale enjoyed by Ford or General Motors and believed they could not attain these, so they tried to develop a system that they imagined Henry Ford might have used in their situation (Ohno, 1988).

In the early 1980s, as Toyota and other Japanese manufacturers made inroads into global markets, the call was sounded to study these Japanese companies in depth. In an attempt to generalize the work of Toyota for other manufacturing settings, Krafcik (1988) coined the term "lean" to highlight the principles of limiting inventory and excess workers, or "waste", as opposed to other auto manufacturers' "buffered" approaches (Hopp & Spearman, 2004; Staats *et al*., 2011).

Lean production can be described at different levels of abstraction: it can be defined as a philosophy, as a set of principles and as bundles of practices. For instance, Womack et al. (1996) define Lean production as a business and production philosophy that shortens the time between order placement and product delivery by eliminating waste from a product's value-stream. The principle view of Lean production rests on a set of tenets such as those outlined by Spear and Bowen (1999) and Womack and Jones (1996). However, the dominant view in describing and measuring Lean production rests on a set of practices and tools used in eliminating waste (Shah & Ward, 2003; Narasimhan *et al*., 2006). While researchers disagree with the exact practices and their number, there is general consensus that there are four main aspects of Lean production and frequently group related practices together into bundles. These are practices associated with quality management, pull production, preventive maintenance, and human resource management (Cua *et al*., 2001; Shah *et al.*, 2008).

General principles of Lean manufacturing

Two basic concepts in Lean thinking are to eliminate waste and create value. According to Womack and Jones (1996), Emiliani (1998), Spear (2004), Murman *et al*., (2002), Hopp and Spearman, (2004) Lean manufacturing is underpinned by 5 principles.

1. Identify Customers and Specify Value. The starting point is to recognise that only a small fraction of the total time and effort in any organisation actually adds value for the end customer. By clearly defining value for a specific product or service from the end customer's perspective, all the non value activities - or waste - can be targeted for removal. Value defines the use that a product offers a customer, and works backward to build the production process. Identifying customers' value it is important to answer following questions: What do customers want? When and how do they want it? What combination of features, capabilities, availability and price will be preferred by them?

2. Identify and Map the Value Stream. Firms map production (create a value stream) to ensure that each step provides value. The Value Stream is the collection of processes and activities across all parts of the organisation involved in jointly delivering the product or service. This represents the end-to-end process that delivers the value to the customer. Once you understand what your customers want the next step is to identify how you are delivering (or not) that to them. The Value Stream is not limited by boundaries between companies; that is the reason to strive to integrate suppliers, manufacturers, distributors and even retailers in the efforts to recognize and analyze the Value Stream. Also, three main categories of activities are distinguished:

a) Those that add value;

b) Those that do not add value but cannot be currently avoided;

c) And those that do not add value and should therefore be eliminated.

3. Create Flow by Eliminating Waste. Flow reorganizes processes so products move smoothly through the value-creating steps. Typically when you first map the Value Stream you will find that only 5% of activities add value, this can rise to 45% in a service environment. Eliminating this waste ensures that your product or service "flows" to the customer without any interruption, detour or waiting. In lean manufacturing, waste is not the object that is tossed into the scrap barrel, but rather defined by what the customer will and won't pay for and planning production around making the best part in the least amount of time. Processes that do not add value, according to a customer's definition, are eliminated.

According to Rawabdeh (2005) and Carter (2011) there are at least seven areas that can be looked at for ways to reduce waste or excess of a product (see figure 1).

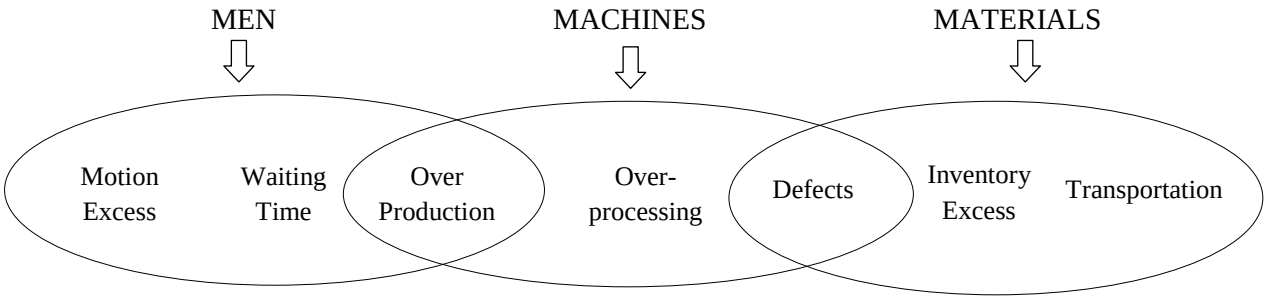

Figure 1. Wastes to be eliminated

Overproduction of an item creates trash or selling at a reduced price. Inventory or stockpiling of items is wasteful and ties up cash that could be used elsewhere. Conveyance is normal in production, but considering if some of the movement is unnecessary may save time and money. Reworking parts is a huge source of excess spending. Redesigning the production in order to produce the part in only one, specific way is a lean savings. If movement of the part causes stress on a person, reworking or redesigning the operator motions could save lost time due to injury. Adding unnecessary processes, which have no value to the customer, increase the cost and reduce the effectiveness of production. An operator should not be idle during the machining process as that is a waste of time.

4. Respond to Customer Pull. This is about understanding the customer demand on your service and then creating your process to respond to this. Such that you produce only what the customer wants when the customer wants it. Companies should not push their products to customers, and rather let them pull "value" (products or services) and link all the production chain (even with suppliers) in such a way that materials are not released and activities are not done until they are needed. The discipline of pull is established and enforced by using kanbans, which are physical or electronic mechanisms to transmit the need for parts and subassemblies from one point in the process to the preceding one.

5. Pursue Perfection. Perfection requires constant striving to meet customer needs and improve one's process with zero defects. Creating flow and pull starts with radically reorganising individual process steps, but the gains become truly significant as the entire steps link together. As this happens more and more layers of waste become visible and the process continues towards the theoretical end point of perfection, where every asset and every action adds value for the end customer. It is the conviction that improvement efforts are never finished, and it is the consistency to keep the discipline for improvement in place (kaizen).

In following these five principles of Lean you will implement a philosophy that will become "just the way things are done". You are ensuring that you are driving towards the overall organisational strategy by constant review of your processes to ensure that they are constantly and consistently delivering value to your customer. This allows the organisation to maintain its high level of service whilst being able to grow and flex with a changing environment and it does this through implementing sustainable change.

Success Factors in Lean Implementation

Implementation of Lean philosophy and principles can be described as a set of actions and processes starting from planning the change, defining the success factors and finishing by implementation and measuring the progress. Summarizing Martinez & Perez (2001), Anchanga (2006), Pettersen (2009), Sim & Rogers (2009), and Duque & Cadavid (2007) authors of this paper present the model of Lean implementation process (see figure 2).

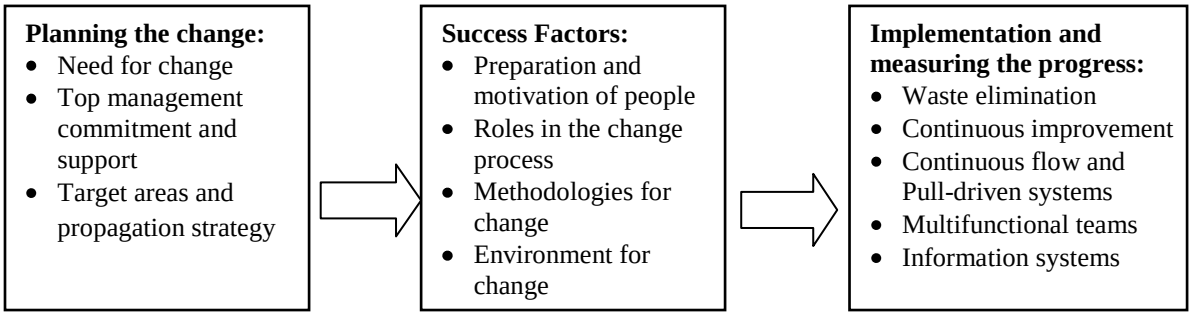

Figure 2. Model of Lean implementation process

1. Planning the change. The first step of Lean philosophy implementation process is planning the change. Three things should be present at the very beginning:

1) Define the need for change. It is essential to understand and communicate continuously what is the motivation for a Lean transformation effort. This should provide guidance and clarity to everybody in the company.

2) Top management commitment and support. If employees don't see, feel and believe in a real commitment from upper management, nothing much will happen. Involvement and support should be not only verbal but also factual, with managers participating in shop floor activities and kaizen events.

3) Identify target areas and propagation strategy. A plan should be crafted, indicating which processes and production lines will be transformed to Lean, in what sequence and time frame.

2. Success Factors. There are four key factors for success in the implementation of a Lean effort:

1) Preparation and motivation of people. It includes intense communication, clarification of expectations, emphasize the need for change and, essentially, letting people know what's ahead.

2) Roles in the change process. The need for an informed and active leadership, the involvement of the employees in all aspects of the project, experts acting as coaches and support from management and the other functional areas are required roles that need to be filled for the success of a lean implementation.

3) Methodologies for change. Here all the technical tools that sometimes are thought to be "the Lean things" come into play, like the use of model lines, the right sizing of equipment and the change of the physical line layout, kaizen events as a way to participate and show quick and visible improvements, the orientation to action, focus on flow, the work in focused teams problem solving and practical training.

4) Environment for change. As in any transformation effort, the environment that upper management facilitates and puts in place is critical for success. In Lean implementations is important to provide job security, constant reinforcement of the guiding principles, a safe environment for experimentation and a climate of mutual trust between workers and management.

These success factors have to be taken into account in the planning of the process, so the implementation phase can begin.

3. Implementation and monitoring the progress of a Lean implementation. It is necessary to show progress and to assess the effectiveness of the different changes, tools and techniques that are implemented. For each of the improvement dimensions, several indicators can show the progress. These implementation activities should lead to improvement in five dimensions: elimination of waste; continuous improvement; continuous flow and pull-driven systems; multifunctional teams and information systems.

The degree to which these goals are reached will lead to the proposal of indicators that reflect the advancement of a team or line in the implementation of Lean Manufacturing. Once different tools are implemented, these indicators will serve as the input to build control charts and to establish improvement goals for report periods (Duque & Cadavid, 2007).

Advantages and Risks of Lean Production

The key idea of Lean manufacturing is to increase value to customers while reducing the number of resources consumed and cycle times via waste elimination. As with any business management theory, there are a number of advantages and risks that must be balance for each organization (Holweg, 2007; Sim & Rogers, 2009; Kropf, 2008; Wood, 2012 and Kelly, 2012) and the main of them are presented in Table 1.

Table 1. Advantages and Risks of Lean Production

Advantages		Risks	
Customer satisfaction	By reducing waste, the final product is delivered to a customer with value. The advantage of this is increased customer satisfaction.	**Customer Dissatisfaction Problems**	Because lean manufacturing processes are so dependent on supplier efficiency, any disruption in the supply chain and therefore, on production can be a problem that adversely affects customers. Delivery delays can cause long-lasting marketing problems.
Productivity	Productivity is increased because of the focused improvements made to processes with the intent of eliminating waste.	**Productivity Costs**	In order to achieve such productivity, there is a significant upfront investment in achieving a level of standardized processing which can be a disadvantage during the implementation process.
Change of Attitude	Implementing lean production often demands a significant change in an organization's attitude, which can be very challenging if an organization is not well slated to deal with the changes.	**Lack of Acceptance by Employees**	Lean manufacturing processes require a complete overhaul of manufacturing systems that may cause stress and rejection by employees. Lean manufacturing requires constant employee input on quality control, which some employees may feel disinclined or unqualified to do. There may also be some difficulty finding managers with sufficient leadership and persuasion skills to overcome this.
Quality	As a result of process improvement initiatives, the overall quality of a company's product is also improved in the process	**High Cost of Implementation**	Implementing lean manufacturing often means completely dismantling previous physical plant setups and systems. The purchase of efficient machinery and training employees can add considerably to companies' payroll expenses.
Delivery times	Another fundamental element of lean production is just in time production, which is the idea that excess inventory will not be maintained in order to fulfil customer orders.	**Supply Problems**	Because only a small amount of inventory is kept on hand, lean manufacturing depends heavily on suppliers. Problems like employee strikes, transportation delays and quality errors on the part of suppliers can create manufacturing holdups that can be fatal. Vendors may be unable or unwilling to supply parts or products on a tighter schedule or in smaller amounts.

Unsuccessful implementation of lean manufacturing. One of the major reasons for unsuccessful implementing Lean manufacturing is the typical behaviours exhibited by people in the workplace, which are known to be deficient trust and gain commitment. Orr (2005) stated that the term "Lean" manufacturing seems to have forgotten the debate on human motivation, and has focused on techniques, where the emphasis has been on deploying new methods, rather than understanding how work is organized and lead.

The practice of Lean behaviour is shown to be an essential element for producing healthy work environments that can lead to economic lean produces. Emiliani & Stec (2004) stated lean behaviour practices must apply all the lean principles where most companies failed to apply all the lean principles together to get significance result. In order for the business to enjoy the full benefits of lean, it is essential for the right behaviour to exist amongst the organization's employees (Sanjay & Peter, 2006).

Lean is as much about establishing a "lean corporate culture" as it is about lean manufacturing and production processes. A lean culture seeks to motivate workers to participate and even initiate lean initiatives to improve the corporate bottom line. For this reason, companies need to develop a lean corporate culture along with lean manufacturing initiatives to maximize the effectiveness of lean solutions.

Implementation of Lean philosophy and principles is a long journey process and not easy implemented. To fully benefit the company for Lean implementation, both the concept and techniques should be considered.

Conclusions

Lean production can be described at different levels of abstraction: it can be defined as a philosophy, as a set of principles and as bundles of practices.

Implementation of Lean philosophy and principles can be described as a set of actions and processes starting from planning the change, defining the success factors and finishing by implementation and measuring the progress. Lean Manufacturing implementations require the establishment of an environment that makes the rest of the elements of the process possible. This environment will ensure that employees feel empowered and have the necessary tools to gain product and process ownership, focused teams work and autonomy in the development of solutions and process improvements.

Five main dimensions can be measured to assess the progress in a Lean transformation: Elimination of Waste, Continuous Improvement, Continuous Flow and Pull Driven Systems, Multifunctional Teams and Information Systems.

Like most management systems, lean manufacturing does not come without its own set of disadvantages, including possible customer dissatisfaction problems, productivity costs, supply problems, high cost of implementation and lack of acceptance by employees. One of the major reasons for unsuccessful implementing of lean manufacturing is the typical behaviours exhibited by people in the workplace, which are known to be deficient trust and gain commitment.

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