A Detailed Review on Lean Manufacturing Processes for Industrial Productivity Optimization

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Abstract – One of the most significant research areas in modern time is the need, potentials and possibility of building the methods and application tools and techniques aims for the improvement of machine tool manufacturing processes. The idea of lean manufacturing was created to maximise resource efficiency by reducing waste; however, lean was further adapted in reaction to the changing and dynamic market world. The comparison of before and after LP programmes in determining managers' future advantages, such as shorter manufacturing lead times and lower work-in-process inventory. The aim of this paper is to synthesise the literature with a focus on defining the potential for lean in the process industry and the benefits that come with it. The study further examines lean production methods that have been used or may be used in the process sector, as well as the complexities of implementing lean. Even, how using Lean tools can be extremely beneficial in increasing efficiency. Productivity enhancement is important in most production and process sectors because it aids in the elimination or minimization of waste.

Key Words – Lean manufacturing, Production, Waste Reduction, Productivity Optimization and Review

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1. INTRODUCTION

Manufacturing industries [1] - [3] are the major drivers of a nation's economy. Competitive economic growth of a nation is based on the Gross Domestic Product (GDP) [4]. Indian industries are not exceptional to this norm. Manufacturing sector in Indian industries needs to be reinforced to attain faster economic growth. Capability of industries to sustain long-term competitiveness relies on their performance. It also depends on the capability of introducing, adopting or developing new technologies. Improving the performance of manufacturing industries against the global challenges like speedy globalization, resource utilization, advanced technologies, increased competition, and protection of innovations is an important issue. In recent times, India has progressed in various phases of science and technology with strong worldwide network, quality manpower and innovations. Even though India"s potential is identified globally, still there is a gap in promoting interactions between organizations and research establishments.

The structural reforms in India have propelled service sector to contribute to 50% of GDP [5]. Other than agriculture, India needs to create more job opportunities to stop the increasing level of unemployment. As it requires educated and highly skilled professionals, service sector cannot completely offer jobs to all the remaining unemployed ones. This shows the importance of manufacturing industries both in employment and GDP.

The major reason for manufacturing organizations not being much competitive at the global level is the existence of non-registered Small and Medium sized Enterprises (SMEs). The investments for these industries are low and demands for their products in market are distorted; hence no advanced technologies are followed by these industries. Other reasons for this kind of scenario are poor quality of infrastructure facilities, high rate of power consumption and high capital cost. Special attempts to upgrade infrastructure and to create good financial climate are required to promote the manufacturing sector in India. On the other side of these preparations, individual organizations should focus on improving their operational performance and cost effectiveness by making some internal changes. These could be done by imparting the following aspects [6]:

- Upgradation of manufacturing technology
- Revamping the existing infrastructure to improve responsibility and accountability of industries.
- Modification of business policies to retain skilled and talented resources.
- Exporting the products to global markets.
- Concentrating on quality products for customer satisfaction.
- Advancing the core processes for better utilization of resources, minimized inputs and improved organizational performance.

2. LEAN MANUFACTURING

2.1. History of Lean Production System

The manufacturing organizations in Japan are confronted with extreme scarcity of human resources, material and finance after the Second World War. Problems faced by Japanese manufacturers induced the formation of lean manufacturing principles [7]. Toyota motor company run by its leader Kiichiro Toyoda noticed that the auto manufacturers of United States of America were their counterparts. In the mid-1940s, Toyota was producing at the factor of ten from Japan. Hence to improve the existing system and to overcome the crisis of manufacturing, the leaders Taiichi Ohno, Shigeo Shingo and Kiichiro Toyoda developed a process-focused and well-organized system which is called Lean production system or Toyota production system. Taiichi Ohno took the responsibility of developing a new system to improve productivity of the Toyota motor company. Hendry ford"s book Today and tomorrow was referred by Ohno and drew a few ideas to improve productivity. Continuously moving assembly line in fords system was the basis for Toyota production system. Then with the continuous reform, developments and experiments, the Toyota production system was transformed towards a highly optimized production system from 1945 to 1970. The development of optimized production system did not end there but researches have been going on worldwide [8] – [11]. The primary objective of this system is to consume minimum resources and to eliminate the activities which do not add value to the product or process.

2.2. Lean Manufacturing Concepts

Elimination of wastes, reduction of cost and empowerment of employees are the basic passions behind the lean philosophy and these have been followed by many Japanese manufacturers. The earlier mind set in western manufacturers to increase the profit for their products is to decrease the manufacturing cost to the selling price [12], but in contrast, Japanese manufacturers believe that the quality product would make the customers to pay more and this could be accomplished by reducing or tightening the consumption of resources. It has certainly reduced the actual manufacturing cost without compromising the quality. Five principles of by which lean manufacturing can be adopted by any organization are value, value stream, flow, pull and perfection. The lean manufacturing concept is to work with complete phase of value stream by eliminating Non-Value Added (NVA) activities for cost reduction, capital generation and promotion of more sales. The definition of value stream is specific activities inside the supply chain obligatory to design, order and deliver a specific product or value [13].

The term lean represents the, production of the same quantity with the traditional mass manufacturing system, but with less consumption of resources and satisfying a variety of customer requirements [14]. Lean manufacturing is the term used in parallel to the other names like agile manufacturing, synchronous manufacturing, continuous flow, Just-In-Time (JIT) manufacturing and world-class manufacturing. Hence decisive principle of lean system is to increase profit by reducing input cost through continuous process improvement and eventually with reduced service and product cost. Muda is the Japanese word for wastes which are targeted to be minimized by highly utilizing all the inputs to give only Value Added (VA) products and services. The value is anything that adds worth to the product for which a customer is willing to pay. Hence the waste elimination is the main principle behind lean manufacturing. The elimination of wastes in industries could include any of the following [15]:

1. **Material:** Convert most of the materials into product, thereby scrap and excess raw material requirements can be avoided.
2. **Inventory:** Try not to store more materials than that required and keep continuous flow of materials to end customers based on their needs.
3. **Overproduction:** Produce only the required quantity of products needed by customers. Produce it only when needed.
4. **Labour:** Reduce unnecessary movements and activities of labour.
5. **Complexity:** Try to solve the problems in an easier way rather in a complex way; otherwise it would be tough to manage then and this would create wastes.
6. **Energy:** Avoid unwanted power consumption by eliminating unnecessary

operations. Use the resources effectively in productive manner.

7. **Space:** Arrange the people, resources and equipment in an organized way and reduce the space requirement.

8. **Defects:** Try all possible ways to reduce defects in products.

9. **Transportation:** Avoid unnecessary transportation of materials and information which are NVA.

10. **Time:** Reduce setup time, avoid delays and uncertain downtime.

11. **Unnecessary motion:** Eliminate the unnecessary motions like bending, stretching and ineffective movements.

In recent years, wastes are categorized into seven types such as transportation, inventory, motion, waiting, overproduction, overprocessing and defects. In paper [16], the authors have added two more categories of wastes in this list such as underutilization of people and underutilization of resources. The elimination or reduction of one type of waste may lead to the reduction or elimination of the other.

Transportation inside the factory is considered as a waste as it does not add any value to the product. Time consumed for transporting parts between stations should be minimized. A significant way to reduce transportation within the process is continuous flow of parts by adapting cellular layout. Non-productive activities and processes are reduced by grouping machines and people into cells to form dedicated work stations. They run only to produce similar kind of products. Therefore transportation can be reduced greatly in addition to setup time. Ineffective utilization of resources can also be avoided. The defective products and scraps along with the important wastes should also be reduced. It is found that reduced defect levels and scraps have positive influence on productivity [17].

Inventory is the major waste in an organization. There are three types of inventories in the organization, namely raw material inventory, work-in-process inventory and finished goods inventory. Lot size reduction is one of the ways for reducing the inventory levels. Famous economic order quantity states, setup time reduction should be followed after reduction of lot size to have reduced constant price of a unit [18]. Single Minute Exchange of Dies (SMED) is developed at Toyota by Shingo & Dillon [19] for reductions in setup time. For example, in large press working machine, setup time can be reduced to ten minutes or less. This could make very high impact upon lot size. Reduction of machine downtime is another way to reduce setup time [19]. Preventive maintenance is the best practice for reducing machine downtime. Hence one after other, the wastes are reduced by reducing inventory. This could save the total time and resource spent on production. This can further boost up production rate. It can also save energy and space; hence the capacity and utilization of system can be increased considerably.

Overproduction and overprocessing are considered as wastes because they do not necessarily add up the requirements on the products. Overproduction refers to the excess quantity of production than that needed by customers. This incurs additional storage, overstaffing, unnecessary transportation and excessive expenses. Incorrect processing or overprocessing is the unnecessary processing step carried out on the product. This may be due to improper design and tool selection and lack of tool mentoring system. The increased number of defects, reworks and rejections are the results of incorrect processing. Moreover, producing very high quality products than that is necessary is also regarded as unnecessary processing. This can cause purchasing of extra duty tools than needed and additional time consumption than required [20].

The activities or movements performed by the labourers such as reaching for tools/work parts, stretching due to ineffective ergonomic working conditions, storing and retrieving parts from long distances and unnecessary walking are considered as unnecessary movements. This would largely create operator fatigue and lead to less labour participation. There are many ways to reduce these wastes like facility location solutions, work study and so on. The time spent by the labour on waiting for the parts, tools, operations and resources is regarded as waiting which is a waste. The time spent by a labour without doing any work, looking / waiting for the activity to do is an ideal time for which also he/she is accounted. This may be caused due to uncertain shutdown of machine or component, planned downtime, delays due to lot processing and bottlenecks due to capacity. Defects are the obvious wastes that would result in rework cost, material cost, operation and maintenance cost, processing time, scrap, handling time, effort and production replacement time spent on the defective products. In addition, the creativity of employee, which remains unused, would tend to lose time, improvements, ideas, innovations and job. Hence a management policy to listen to employees is important for a healthy organization [20].

3. LEAN MANUFACTURING TOOLS AND TECHNIQUES

Various tools and techniques have been proposed by industrialists and researchers to deal with wastes. They include cellular manufacturing, JIT, continuous improvement, production smoothing, Total Productive Maintenance (TPM), standardization of work, kanban, one piece flow, Overall Equipment Effectiveness (OEE), poka-yoke, SMED, Value Stream Mapping (VSM) and other waste reduction techniques. For existing companies, once the wastes are identified, then suitable waste reduction techniques can be adopted.

3.1. Cellular Manufacturing

Cellular manufacturing is one of the bases for an industry to become a lean organization. The resources like men, machine and equipment are arranged inside a cell which is dedicated for a specific operation. This ensures smooth flow of parts, components and materials throughout the process. Great reductions in operating costs and high utilization of resources can be achieved along with the floating volume and mixed variety of products [21]. This can be attained by clustering similar kind of products and processes with similar operation sequence. Hence there would be a reduction in changeover time.

3.2. Kaizen and 5S

Continuous improvement is one of the primary techniques in lean manufacturing. Kaizen is a Japanese word for continuous improvement and has become the globally accepted management principle. There are many opportunities in manufacturing organizations for continuous improvement programs like reducing inventory, defects and NVA activities. 5S is a primary tool of continuous improvement for waste reduction attempts. It is coined using five Japanese words Seiri, Seiton, Seiso, Seiketsu and Shitsuke which mean sort, set-in-order, shine, standardize and sustain correspondingly [22]. The primary objective of 5S is to eliminate wastes. Some forms of wastes are surplus raw materials, inventory, defects, scrap, defective tools and outdated holding and guiding equipment [23].

Seiri (sort) deals with the items which are not frequently used. Moving away such items from continuously used items would smooth the production, material flow and other resources to work effectively. This would also reduce collisions of materials and equipment within the station.

Seiton (set-in-order) emphasizes to keep right stuff in right area. It requires the workplace to be set orderly for keeping all the items like raw material, Work in Process (WIP), equipment, tools, jigs and fixtures, components and other essentials in a properly labelled location. This should be done in such a way that the flow of production is not affected. The orderly arrangement of tools and equipment should ensure the proximity between tools and workstations.

Seiso (Shine) involves keeping the workplace clean. Any form of dust or wastes should be cleared from the workplace. Hygiene environment plays a major role in creating interest among the employees to work. Regular maintenance of the workplace should be adopted ensuring that none of the tools and items are missing from the right place.

Seiketsu (Standardize) is a practice of standardizing the workplace all the time. Regular audits should be made in maintaining a standardized workplace and housekeeping. Everyone from that workplace should be educated to do standardized activities since they are responsible for their workplace. For example, colour coding system can help distinguishing usable items with non-usable items and scraps with WIP (Feld 2000) [24].

Similarly, Shitsuke (Sustain) is a management practice of training the employees to maintain the workplace. Regular audits and meetings should be conducted by the management to express what they expect from the labour. Management should have a regular visit to the workplace to check whether everything is in right place and to motivate the labour to work without being instructed and to be in discipline. People who are doing well in housekeeping and maintaining standards should be properly rewarded.

3.3. Just-In-Time (JIT)

JIT is a management philosophy that focuses mainly on eliminating wastes. The wastes like WIP inventory, defects and unplanned delivery of parts are addressed by it [25]. JIT is the modification of internal processes to deliver right material at right time with right quantity to meet the sudden changes in demand patterns.

The backbone of lean manufacturing is JIT production system [26]. JIT production emphasizes not to have more quantity of raw materials, WIP or other items than required. JIT uses a system called pull system which starts from customer end. Based on demand, orders are placed to the assembly stations to produce only required quantity which means goods are pulled from the assembly station. Assembly line starves for required number of parts, which is to be dragged from the previous station when required. The upstream process pulls the required number of parts at right time from previous station. This entire chain-like process needs a control system to communicate the information about the quantity of parts being processed between stations. Since the system pulls parts from production lines, shipments are small and at regular lots. Management of this system is done by kanban card which holds the information about the number of items to be produced in each station [27]. There are three types of kanbans, namely withdrawal kanban, production kanban and supplier kanban.

The major wastes eliminated by JIT system are inventory and overproduction. The parts are transported and produced in smaller lots based on the customer need, thus it avoids stagnation of raw material, WIP and finished goods inventory within the stations of shop floor. The parts are produced only in requirements based on numbers; hence overproduction could be avoided under JIT system.

3.4. Production Smoothing

To reduce the wastes through lean manufacturing, it is essential to have control over the processes at higher level. Production smoothing is one of the techniques to meet this objective. Japanese use the word Heijunka for production smoothing wherein the production is maintained at constant level as much as possible by the continuous efforts of product manufacturers [7]. This technique is followed in Toyota production system with an aim of keeping the production cost down by producing cars not more than the actual requirement. To produce the right number of parts or products with effective utilization of resources, the production schedule must be made as smooth as possible. In a workplace, if parts are not kept at constant levels, it may lead to wastes like WIP inventory.

3.5. Standardization of Work

Standardization of work emphasizes the regulations of the actions of workers. Standardizing the physical work ensures that each job is organized and carried out in the most effective way. Uniform quality of products should be achieved irrespective of the labour. Standardization in processing consists of time required to finish a job, the sequence for every job and the parts in process. By standardization in processing, it is possible to achieve balanced lines, minimized WIP inventory and reduced NVA activities. Takt time is a simple tool and a calculated value to standardize a work. „Takt" is a German word to express the beat or rhythm and it refers to the frequency of parts to be produced based on the actual demand from customers. The goal is to keep the production pace not more than Takt time. Takt time is expressed as follows [28]:

Takt time (TT) = Available production time / required production quantity

3.6. Total Productive Maintenance (TPM)

TPM program consists of three main elements. First one is preventive maintenance and it deals with planned periodical and regular maintenance of all the equipment. It avoids random check-ups. Whenever the variance or irregularity occurs in any equipment, it can be easily detected by having regular maintenance. This would avoid major accidents/breakdowns of machines and components during production and would improve the throughput of each equipment and machine. The second is corrective maintenance and it deals with the decisions to repair or to buy new equipment. It is better to replace an old part with newer one if it undergoes breakdown all the time and incurs heavier maintenance cost. The new substitute part would increase the uptime and reliability of machine. Third is the maintenance prevention and it involves the buying of a new machine. Machines with less maintenance are used to avoid the investment of a huge amount of money. Machines that are hard to maintain like very frequent lubrication and hard to tight up are to be avoided. This also creates fatigue on labour which would reduce the labour productivity.

3.7. Other Waste Elimination Techniques

Zero defects, line balancing and setup time reduction are the other waste elimination tools. The purpose of zero defects tool is to ensure that the produced product is completely defect-free in the continuous improvement environment [29]. It is quite common for humans to make mistakes during work. If their mistakes on products during processes are not detected, then it will reflect in the final product. It is possible to avoid them before the occurrence. Zero defects use the poka-yoke tool which is one of the important tools accepted and proven for its effectiveness in avoiding the defective products. Shingo has developed the tool poka-yoke and when this autonomous tool is installed on a machine, it will inspect all the ways to ensure that the product is free from defects. The main goal of poka-yoke is to make a complete observation to find the source of defective parts, identify the causes of defects and avoid mixing of defective parts with accepted parts or stop the defective parts moving to a next station [28]. Line balancing is a technique for high labour utilization. It is considered to be an effective tool for waste elimination, specifically the time wasted by workers. The idea is to send the right quantity of products to the next workstation continuously without being stopped. This would ensure that all the workstations are being operated at the same pace not faster or slower than one another.

Setup time reduction is another technique to improve production process by reducing the setup times of machines. Ohno, during 1950s developed a tool named as SMED at Toyota to reduce the setup time. The idea is to develop a method for speedy exchange of dies during production of a variety of products or processes. As a result, he developed a system to reduce the die exchanging time from few days to few minutes. Internal and external setups are the two types of setups in operations. Internal setup in the machine can be performed only when the machine is stopped, but external setup can be done either when the machine is stopped or on the run. The main purpose is to transfer as many as internal setups to external setups. If all these activities are found, then further stage is to make the activities as simple as possible (e.g. use of self-locking nuts rather than conventional bolt and nuts in addition to setup standardization). This can yield many benefits to the organization. Highly skilled labours or experts are not needed for die setup. Inventory can be greatly reduced.

3.8. Value Stream Mapping (VSM)

A value stream is a compilation of all the VA and NVA activities required to produce a product or set of products using the same resource through the entire flow starting from raw materials to finished goods (Rother & Shook 2003) [30]. Activities in the whole supply chain consist of both process flow and information flow which are essential for lean implementation. VSM is an important tool for an organization to visualize the whole production process along with the material and information flow.

The objective of VSM is to discover all the types of wastes either open or hidden from the overall value stream and to identify possible opportunities to eliminate them. Working on VSM would improve the overall flow of the processes rather an individual process alone. It is viewed as a common understandable communication in production process that aids important management decisions on production flow [31]. The main difficulty in industrial engineering is linking of information in overall supply chain. This is addressed by VSM through creating material and information flow in the entire supply chain of an individual organization in a picture. VSM can provide a basic platform for any organization interested to become lean enterprise. The benefits offered by VSM are listed as follow [30]:

- Better visualization of the entire process flow than that of individual process level (e.g. machining, inspection).
- This process mapping tool helps to identify the sources of wastes also in the value stream.
- It is a generic communication of manufacturing processes.
- It helps to incorporate Lean Tools (LTs) to foresee the benefits.
- It serves as a blue print to design a lean organization.

4. REVIEW OF WORKS

As a lean manufacturing is a technique to reduce human efforts and produce defect free product. According to Jafri Mohd Rohani et.al. [38] are production line analysis via value stream mapping for colour industry, in this article identify and eliminate waste by using team formation, product selection, conceptual design, and time frame formulation through takt time calculation. And use the some lean techniques change over time and 5s and decreased lead time from 8.5 days to 6 days and value aided time decrease from 68 minutes to 37 minutes.

Productivity improvement has evolved through various stages since early 1980s. Initial stages of evaluation of manufacturing industries have focused only on traditional improvements like return on investment, profit per unit sale, productivity and profit per unit production. Among these traditional focuses, productivity has been regarded as a key performance indicator for any manufacturing industry"s performance [33]. Among the many available approaches, lean manufacturing is the best practice to improve productivity and performance of manufacturing industries by eliminating wastes [34]. Lean manufacturing principles are also proven to improve performance in many sectors other than manufacturing sector [35]. Though being a lean organization is highly advantageous, Hines *et al.* [36] have found that, it is critical to differentiate lean thinking at strategic level from operational level. It is also argued that, complete understanding of lean thinking is critical to provide appropriate strategies. Limitations of lean manufacturing are also pointed out by researchers. They are listed below:

► On the perspective of design and manufacturing processes, still batch production is suffering from significant attention [37]

Tomas Rohac [39] to demonstration with value stream mapping on the plastic product of health care to applying lean tools are 5-why & Ishikawa chart, and reduce the lead time and inventory control. Pravin shaswatat, el. [40] apply the value stream mapping on bearing industry and reduce the work in process inventory and lead time. This article gives the information about value stream mapping and gives the methodology for the implementation of VSM. According to Taho yang yiyo kag [41] suggested and implement lean production system for fishing net manufacturing, use the various lean tools and Simulation method and make to order (MTO) process are apply for the regular shipment. And It also use the VSM tool and produce future state map and increase service level and reduce lead time, also gives the guideline for the implementation of the value stream mapping. Santosh kumar et, al. [42] apply the lean tool by method time measurement and line balance efficiency and reduce the cycle time in a truck body assembly line and improve efficiency in that product line. Also says that lean manufacturing is a business philosophy that continuously improves the process involve in manufacturing.

5. COMPARATIVE TABLE

Lean implementation practices are still confronting issues due to many fundamental reasons which are the causes of its reduced rate of successfulness. A few of these frameworks are shown in Table 1.

Table 1: Frameworks/tools

Sl. No.	Author(s)	Data Type	Frameworks/Tools used	Application industries
1.	Arnhetter & Maleyeff	Crisp	Lean Six sigma	Manufacturing organizations
2.	Singh *et al*	Fuzzy	FAHP	Steel industry
3.	Anand & Kodali	Crisp	Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE)	Valve manufacturing enterprise
4.	Anand & Kodali	Crisp	Analytic Hierarchy Process (AHP)	Medium sized valve manufacturer
5.	Sawhney *et al.*	Crisp	Failure Mode and Effects Analysis (FMEA)	Manufacturing industries
6.	Vinodh *et al.*	Crisp	AHP	Modular switch manufacturing organization
7.	Boran *et al.*	Fuzzy	Fuzzy-Analytic Network Process (ANP)	Suppliers of automobile components
8.	Vinodh & Kumar Chintha	Fuzzy	FQFD	Electronic switch manufacturing company
9.	Mohanraj *et al.*	Crisp	VSM-Quality Function Deployment (QFD)	Indian pump manufacturing industry
10.	Yu et al.	Fuzzy	Fuzzy-AHP	Stereo manufacturers
11.	Cil & Turkan	Crisp	ANP	Cylinders, locks and other industrial component manufacturing company
12.	Wong et. *al*	Crisp	ANP	Semiconductor manufacturing company
13.	Souza & Carpinetti	Crisp	FMEA	Wooden door and window manufacturer
14.	Roghanian & *Alipour*	Fuzzy	Fuzzy-AHP- QFD-Promethee	Automotive part manufacturers

6. CONCLUSION

After the study of various articles, we came to the conclusion that a robust introduction of a Lean Manufacturing System necessitates certain data collection, which in turn necessitates the use of modelling and alignment of some lean tools in appropriate sequences. It may also be used in small-scale factories to enhance man, machine, process, and climate, which are all important components of manufacturing. We can also recommend any changes to the steps of processes when using VSM by software, which could make it more convenient for staff to use. Excess inventory can be reduced by incorporating Lean production practises, allowing them to better handle inventory. We examined all of the research papers in order to learn more about lean production tools that can be used to boost the competitiveness of an Indian industrial machinery manufacturer. To summarise, Lean manufacturing has shifted the model of productivity enhancement by using rigorous and thorough analysing methods that necessitate ongoing management and worker activities.

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