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An Analysis upon Various Improvements and Benefits of Lean Manufacturing: A Case Study of Indian Manufacturing Industries

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Abstract – The design of a lean production system is also proposed in this thesis. The lean production system includes a newly designed layout for the manufacturing cell as well as the "operating system" for the cell. The layout is based on the principles of cellular manufacturing in order to promote flow and improve quality. The operating system includes such things as production batch sizes, product routings, and strategic inventory locations. Based on the future state value stream map and supported by a discrete-event simulation, the new operating system is designed to align the lean strategy with the technical capabilities of the manufacturing line.

The lean manufacturing system has helped many companies to improve operational performance, mainly in the automotive and electronic supply chains. Although lean manufacturing revealed to be effective for repetitive systems, some small and medium suppliers, faced with high mix and low volume production, have had difficulty to implement the lean manufacturing. The main objective of this study is to analyze lean manufacturing applicability to MTO companies. The results achieved from the case study conducted reveal that lean manufacturing principles, combined with a proper pull mechanism, can be appropriate to MTO, promoting better due date performance and cycle time reduction.

As today's manufacturers face increasing pressure to improve costs and compete globally, many are turning to the philosophy of Lean Manufacturing as exemplified by the Om Components Pvt. Ltd. Pune. Lean is most successful when production is characterized by a few high-volume products, but may not be the answer as the production mix increases and volume decreases.

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INTRODUCTION

Lean is a systematic approach to eliminating waste and creating flow within an organization to improve overall customer value. Learn to produce more and be more efficient by eliminating non-value-added activities. Our Lean manufacturing training employs the proven techniques pioneered by Toyota to improve any process -- from manufacturing, to service industries, to medical organizations. Our training can assist companies in saving time, money, and precious resources through creating the most efficient work force possible. Benefits of implementing these techniques include savings on turnover expenses, increased profitability, reduction in inventory, increased productivity, reduced set up and lead times, improved costs, and increased employee involvement.

One of the biggest challenges in implementing Lean Manufacturing (LM) is convincing both management and staff at all different levels of the power of Lean Manufacturing tools. Many of the staff at Fabrinet envisioned lean concepts as very complicated mathematical modeling of the process using complex math equations to find the optimal conditions and solutions for lowest cost, best quality and best STC. Others viewed lean manufacturing to be more applicable for optimizing manufacturing shop processes. The problems in supply chain were seen to be insurmountable and beyond the scope of lean manufacturing practices.

We had to get past the initial cynicism and notion that lean concepts were very complicated and only suitable for high volume products, required special skill sets and were outside the scope of rank and file.

A series of classes including staff from all levels of the supply chain staff were held. Class material was designed without involving any mathematics to demonstrate that the overall concepts are simple and easy to understand. Different components of lean manufacturing were reviewed and each component was explained in the simplest terms to ensure everybody understood the basics. The training and education initiative was also intended to show that not all of the LM tools are always applicable in all cases and that many are not always necessary.

To ensure everyone was on board, several small working groups were set up during working hours to encourage interactive discussion, ask questions and debate the pros and cons of the LM practices. The primary goal was to create team work, improve the confidence level of each individual and demonstrate that everyone can contribute to continuous process improvements.

As soon as employees realized Lean stands for waste reduction and not for eliminating people and jobs, Fabrinet accomplished a major milestone toward accepting and adopting Lean Manufacturing practices throughout the Supply Chain organization. With practice, Fabrinet employees realized that Lean Manufacturing was about cost and cycle time reduction and was a means toward providing the best value proposition to customers.

Over the past 10 years or so, lean manufacturing has been receiving an increasing amount of attention as one source for productivity improvements and cost reductions in manufacturing. Hailed by its proponents as a breakthrough means to analyze and improve production and the factory floor environment, lean manufacturing is a broad collection of principles and practices that can improve corporate performance. The argument is that lean manufacturing offers revolutionary rather than evolutionary efficiency improvements.

While lean manufacturing has received a lot of publicity since the term was coined as part of a study analyzing world automobile production, it is very difficult to find a concise definition of the term that describes all aspects of the system. Lean manufacturing is very closely related to Total Quality Management and derives from the Toyota production model. It involves a reconceptualization of the entire production process as a closely interconnected system from which buffers are removed. All the different activities that are part of the production process must be carefully coordinated to maximize the benefits of lean; the associated organizational and coordination requirements make implementing lean production a difficult and complex endeavor.

A systematic and continuing search for non-value-added activities and sources of waste forces a focus on quality and cost. New tools and techniques are incorporated as part of the continual effort to cut costs and improve quality and to enable reduced inventories and other lean practices.

Although lean manufacturing has its origins in the automobile manufacturing sector, other industries have adopted the practices to improve their own operations. Womack and Jones (1996) offer several case studies of firms making radically different products, including stretch-wrapping machines, wire management systems and power protection devices, and aircraft engines, among others. Liker (1998) reports improvements for a tannery, a maker of sealing components, a scientific products company, a maker of outdoor cedar products (including birdhouses), a manufacturer of seismic exploration equipment, and companies in the automobile supply chain.

Many other adoptions of lean principles have been reported as well, although hard quantitative data on proven savings is unfortunately limited.

The search for improvements in production processes is by no means new. The eighteenth century economist Adam Smith is not usually thought of as an industrial engineer. However, his 1776 discussion in *An Inquiry into the Nature and Causes of the Wealth of Nations* regarding the division of labor in the manufacture of pins was one of the first formal examples of how to improve efficiency in production. Rather than having one worker make the pin from start to finish (drawing out the wire, straightening it, cutting it, sharpening it, putting the head on), he suggested that by dividing up the tasks involved in the production of pins and having a different worker perform each separate task, many more pins could be produced in a day. The process of dividing tasks into components and assigning different workers to complete each task was one of the enablers of the efficiency improvements in the industrial revolution, which was also driven by new sources of energy, new types of machine tools, population growth, broader changes in social structure, and many other factors.

Proponents of the lean system claim that it offers the potential for nothing less than revolutionary improvements in performance and cost. Womack et al. (1990) claim that with the entire system in place, production will involve "one-half the human effort in factory, one half the manufacturing space, one-half the investment tools, one half the engineering hours, one-half the time to develop new products." The authors also insist that unless the entire group of practices is adopted as a system, performance improvements will be negligible.

Japanese automobile manufacturers achieved high quality and low costs by removing buffers and impediments from the system, hence the term "lean." Eliminating excess inventory, for example, drives closer linkages between assemblers and suppliers, reshapes the factory floor, forces greater attention to first-time quality, and so on.

Excess inventory means that manufacturing mistakes or broken equipment will not halt production because downstream processes can draw on inventories to keep going while the mistakes are remedied or the equipment is fixed. However, excess inventory costs money and can hide production problems that lead to greater problems later on. Mass production allows for excess inventory to provide a buffer against mistakes, while lean manufacturing aims to eliminate mistakes and hence the need for costly buffers. Removing inventory buffers requires very tightly coupled processes that closely link different functions within the organization. Further, Womack et al. have contended that the lean system must be adopted wholesale to see improvements. The synergies from applying lean to different areas of the manufacturing process are so significant that new processes cannot be properly understood alone or adopted singly. Such piecemeal efforts could only result in small improvements at best, a fraction of what full-scale implementation would offer.

The practices involve improvements on the manufacturing floor, in supplier management, in inventory management, in design and development, in human resources, and so forth. Attention to quality and flow drives costs down throughout the production process, from the design phase through final delivery to the customer. The authors of *The Machine that Changed the World* take a functional approach to lean processes in the plant and then make the connections across the different functions. In their construct, beginning in the design stage, products are developed to meet customer needs and to be easy to produce out of readily available components. This process requires the input of experts from all different areas on integrated product teams (IPTs).

On the factory floor, components of the product are manufactured one at a time ("single piece flow") in dedicated areas ("cells"). Attention is paid to decreasing setup times and improving first-time quality. Careful inventory management involving minimal or nonexistent inventory stocks keeps costs down, reduces required floor space, and drives the attention to first-time quality so that defects do not halt the flow of production. Similarly, close partnering relationships with suppliers contribute to lower costs and higher quality as suppliers deliver perfect parts and assemblies to the factory floor right before they are needed and continuously work to improve their own quality and reduce their costs. A trained and flexible workforce can play a role in continuous improvement and quality enhancement in a structure that allows workers to have jobs that are comparatively enriched. Close links with customers make sure their needs are met and final product delivery occurs when required.

Overhead and other indirect costs are carefully managed as well, with attention paid to which procedures truly add value and which are not necessary (i.e., the collection of data for metrics that are never used), and levels of management structure are kept to a minimum.

Lean manufacturing is relatively easy to simplify, as it generally appears in most articles and books, including this one. In small plants, producing simple products, it may be easy to identify all the areas that must be changed to create a lean system. However, a single factory tour in a more complex industry, such as aircraft production, will make the analyst realize the challenges and complexities of any large-scale organizational changes, such as those presented by the implementation of lean manufacturing.

A related complexity arises from how lean principles cut across the whole enterprise but must be disaggregated and flowed down to different functional areas within organizations to get work done. Proper supplier management, inventory management, design and development, human resources,4 and manufacturing operations are critical to lean production, but responsibility for managing these tasks are found in different departments throughout the firm.

Implementing a truly lean system across a firm requires an intensive effort to tightly couple related tasks across functional departments.

And lean implementation in different functional areas is closely related. For example, issues of concern during design and development can directly affect the manufacturing process, such as the ease of assembling parts into the final configuration. Just-in-time delivery requires the development of close ties with suppliers, keeps inventory low, and has significant effects on the factory floor. Truly lean manufacturing occurs when functions are tightly coupled across the organization to ensure that relevant issues for other functions are raised within each individual function.

Another set of complexities of lean manufacturing regards the cross functional nature of many of the lean best practices in manufacturing plants.

These complexities make capturing cost improvements related to any one lean initiative or new lean best practice very difficult. Figure 1 shows the interrelationships of the various activities needed to manufacture a product and how all must be managed to improve overall operating efficiency.

It is not necessarily a given, in spite of what its proponents suggest, that lean production is the best way to do business. It offers a powerful package, but uncritically accepting all lean tenets, originally based on a high-volume industry, and could lead to problems in low volume situations. For example, aircraft manufacturing involves the production of relatively low volumes over a number of years. Some parts become obsolete and may be unavailable for the entire production run unless purchased at the beginning. This runs directly counter to JIT delivery of parts and is a particular danger in sectors characterized by rapid technological change, such as avionics.

(However, Spear and Bowen [1999] report that at Toyota there is flexibility about the “no inventory” rule depending on circumstances.) Also, trade studies must be done to compare the costs of buying a couple of units a year with the costs of buying all required units up front when there are possibilities of volume discounts.

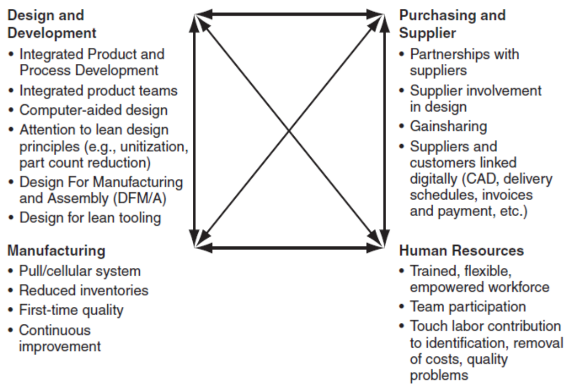

Figure 1—Lean Production Is an Enterprise Approach: Linked Functions Affect One Another.

Another concern raised by researchers on human resources and industrial relations issues is the danger that lean production may be just another way to stress workers into producing “more with less,” without giving them true input into how the work is done.

Complete implementation of the lean manufacturing system involves considerable organizational change. Aerospace manufacturers have shown that they can take the first steps, but they have not totally transformed themselves. Organizational change of any sort is a long and difficult process, and a transition to lean practices involves cultural and process transformations throughout the entire organization. Successful pilot projects limited to a few cells on the factory floor do not provide sufficient proof that this larger-scale change will occur.

Continuing interest, pressure, and/or incentives from the government for process improvements at manufacturers is required to keep their management focused on continuous improvement and could, over time, result in lower costs and higher-quality products. Without such actions by DoD, a very real danger exists that aerospace manufacturers will fail to take either the initial or follow-on actions required by the continuous process improvement focus of lean manufacturing.

THEORETICAL BACKGROUND

Lean Manufacturing is a philosophy that aims to maintain smooth production flow by continuously identifying and eliminating waste resulting in increasing value of activities in the production process. Lean manufacturing approach makes an organization able to sustain market competition by improving its competence for better quality; on time delivery with lower cost Lean Manufacturing aims for Identification and elimination of waste (any activity that does not add value to customer).

Lean Manufacturing aims for the accomplishment of unidirectional and continuous material movement known as production flow. Processes should be free from bottlenecks, waiting, disruption, and backflow. Lean manufacturing aims to produce only what is needed, when it is needed. Production is pulled by the downstream workstation so that each workstation should only produce what is requested by the next workstation. Lean Manufacturing focuses on defect free production lines. It aims for defects to be eliminated at the source and for quality inspection to be performed by the workers as part of the in-line production process. Lean Manufacturing requires striving for perfection by continually removing layers of waste as they are uncovered. This in turn requires a high level of worker involvement in the continual improvement process.

Business management strategies has been around for a long time, at least from the beginning of the last century and much of what is referred to as tools are originally common sense employed in a scientifically way.

Six Sigma is a quality orientated improvement method originally derived by Motorola in 1981. More specifically it was an engineer called William Smith who is known as the father of Six Sigma, although many more have been working on the problems with reducing variability and improving quality1 (essentials of lean six sigma). Six Sigma focuses on identifying causes for defects and removing them, always with the customer in focus. The underlying assumption is that every process can be described with a statistical distribution curve which can be used to measure the variability and behavior of the process.

Lean manufacturing is another production practice that has been developed from the Toyota Production System in the 1960s which in turn has origins from the beginning of the 20th century. Lean manufacturing differs between value adding activities and waste, everything not considered to add value to the product is considered to be waste. Another viewpoint is that value added is everything the customer is prepared to pay for, all the rest is waste. Fundamental approaches in Lean is to remove or at least minimize all stocks such as inventories and finished goods, this forces everyone involved to do their best in order to avoid costly mistakes as they will incur complete stops in production. Since there is no room for errors all problems are laid bare and can be dealt with.

One approach in both Six Sigma and Lean is to reduce variability in processes, to increase flow and smoothness. Recently these two manufacturing philosophies have been combined into Lean Six Sigma where tools from both Lean and Six Sigma are used together. This thesis will use tools from Lean Six Sigma in the empirical part of the study.

In the beginning of 1980 the western automobile industry began to realize that the Japanese way of manufacturing vehicle far exceeded the methods that were used in European and American industries. Japanese Companies achieved higher productivity and better quality using less resources (Metall 2002). A major research project was initiated thereafter at the end of 1980 by Womack, Jones and Roos at Massachusetts Institute of Technology. The project was called “The international Motor Vehicle Programme (IMVP) and the aim was to investigate the Japanese automobile industry and compare it to the western automobiles industries. The IMVP Study showed a significant gap in productivity and quality between the Japanese vehicle assemblers and the rest of the vehicle assemblers in the world. The term Lean Production was coined in the report as a description of victorious Japanese production philosophy. The IMVP research describes Lean production is lean because it uses less of everything compared with mass production half of human effort in the factory, half of manufacturing space, half of investment in tools and half of engineering hours to develop a new product . Also it required keeping far less than half the needed inventory on site, resulting in many fewer defects , and produces a greater and ever growing variety of products The IMVP report was recognized all over the world and ended up in the famous book “The machine that changed the world”. Lean Production is not confined to the activities that take place in the manufacturing company, rather it relates to activities ranging from the product development, procurement and manufacturing over to distribution. Together all these areas found the lean enterprises. The ultimate goal of implementing lean production in an organization is to have the customer in focus when improving productivity, enhancing quality, shortening lead times, reducing costs etc...These factors indicate the performance of Lean production system. The determinants of a lean production system are the action taken, the principles implemented, and the changes made to the organization to achieve the desired performance.

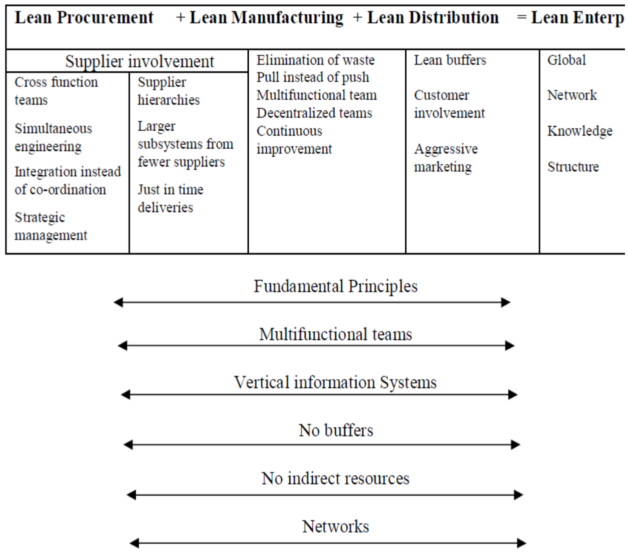

Figure 2 Concept of lean production.

While many researchers and practitioners have studied and commented on lean manufacturing, it is very difficult to find a concise definition which everyone agrees (Yu cheng et al 2009). Different authors define it distinctively. According to Drew et al (2004) lean is an alternative to mass production (that is the Henry Ford way), not a complement to it. Lean calls for a completely different way of operating, and for a completely different way of thinking about operations. Lean is not compatible with large-batch production; instead the pace, mix and quality of production are set by the customer. Whereas mass producers set themselves limited goals, an acceptable number of defects, a tolerable level of inventories, and a narrow range of standardized products. Lean producers, on the other hand, aim for perfection, continually declining costs, zero defects, zero inventories and endless product variety.

ELEMENTS OF LEAN MANUFACTURING

To convert a conventional organization into a lean organization numerous and continual efforts are essential. Certain elements are discussed by researchers and are adopted by the manufacturing organizations to improve competitiveness in the market by reducing product manufacturing cost, reducing response time to customers and improving quality and productivity.

Followings are the key elements which have been recognized in different research papers.

1. **SMED/setup time Reduction -** Lean Manufacturing targets reduction of setup time

and changeover time because it consumes critical working time and reduces proper utilization of machine and operator time. This can be achieved by sequenced and structured work instructions to perform the job. The operator will follow the instruction and should be able to finish the job within minimum possible time. The work instruction is based on time and motion study during changeover, analysis of the waste and modification with the aim to eliminate the waste.

2. **Kanban –** Kanban is a shop floor tool which communicates customer requirement from downstream to upstream worker. Once product is withdrawn from finished goods against customer demands to replenish the moved quantity it is replaced with colored card (or electronically). This becomes a production order for the internal supplier in the upstream value chain.

3. **Total Productive Maintenance –** Total Productive Maintenance (TPM) promotes basic preventative maintenance job to operator itself so that break down time of machines is reduced. It also enhances operational efficiency of machine as worker does cleaning, lubricating, inspection, tightening activity of his machine.

4. **Batch Size Reduction –** Lean Manufacturing calls for smaller batch size production. The word single piece flow means it tends to one part at a time to be produced when operating for various types of product. In practical case it is not possible in some cases so minimum possible batch size should be selected. It helps in reducing waiting inventory of part. Lesser idle inventory means lesser working capital requirement and better financial efficiency.

5. **Cellular Layout –** In cellular production layouts, equipment and workstations are arranged into a large number of small tightly connected cells so that many stages or all stages of a production process can occur within a single cell or a series of cells. Cellular layout helps to achieve many of the objectives of Lean Manufacturing due to its ability to help eliminate many non-value-added activities from the production process such as waiting times, bottlenecks, transport and works-in-progress. Another benefit of cellular manufacturing is that responsibility for quality is clearly assigned to the worker in a particular cell and he/she therefore cannot blame workers at upstream stages for quality problems.

6. **Poka Yoke –** Poka Yoke means mistake proofing. This involves bringing a system which eliminates human mistakes in term of quality, safety and other process parameters to ensure quality and safety in the manufacturing lines.

7. **The Five S's –** The 5S is a lean tool which consists of five steps Seiri, Seiton, Seiso, Seiketsu, Shitsuke and taken from Japanese language which aims to improve work place efficiency.

Seiri: It refers to the action of sorting out wanted and unwanted material in and around workplace. Unwanted material should throw away and material which needs with lesser frequency should be place near to workplace and material which is required more frequently must be kept at a defined place very near to point of use. Seiri ensures in reduction of material searching time waste.

Seiton: Seiton or set in order means every object (material, tool or instrument) must have a designated place to keep and every place have is the same object. The correct place, position, or holder for every tool, item, or material must be chosen carefully in relation to how the work will be performed and who will use them Seiso: Seiso, is the third step in "5S", speaks about clean and shine. Everybody is caretaker of its workstation and should see to clean all the commodities in and around workplace and make it shine.

Seiketsu: The forth S of "5S", is seiketsu, it means standardization. It consists of defining the standards by which personnel must measure and maintain 'cleanliness'. Color coding can be used for standardization which can enable to visualize between current level and desired level.

Shitsuke: The S of "5S" is Shitsuke, which means 'Self Discipline.' It stands for promise to maintain the first 4 S as a way of life. The importance of shitsuke is taking away of bad habits of disorderliness and regular practice of good ones.

8. **Quality at the Source –** Quality at the Source means that quality should be built into the production process in such a way that defects are identified and eliminated at the source. The main responsibility for quality inspection is done in-line by workers, not by separate quality inspectors who inspect sample lots. In lean manufacturing primary job of a quality control team is to troubleshoot the root cause of defects, implement preventive measures and provide training to workers to make sure that the defects are not produced.

9. **Worker Involvement –** In Lean Manufacturing, workers are assigned clear responsibility to identify sources of non-value-added activities and to propose solutions to those. Lean Manufacturers typically believe that the majority of useful ideas for eliminating non value-added activities typically originate with workers involved in those processes. In order to ensure that ideas for eliminating non value-added activities are acted upon, the power to decide on changes to the production processes are pushed down to the lowest level possible (i.e. normal workers) but any such changes are required to meet certain requirements. For example, at Toyota workers are encouraged to implement improvements to the production processes but the improvement must have a clear logic which is in accordance with the scientific method, the improvement must be implemented under the supervision of an authorized manager and the new process must be documented in a high level of detail covering content, sequence, timing and improvement is effective, Toyota will implement the change across its manufacturing operations.

10. **Continual Improvement -**A company can never be perfectly efficient. Lean Manufacturing requires a commitment to continual improvement, and preferably a systematic process for ensuring continuous improvement, whereby the company constantly searches for non-value-added activities and ways to eliminate those. The focus of continual improvement should be on identifying the root causes of non-value-added activities and eliminating those by improving the production process.

11. **Kaizen –**Kaizen means small improvement. To maintain continuous improvement activities throughout the organization Kaizen culture should be created and maintained. Kaizen is done by the individuals mainly by operators for improvement in working condition, safety, quality, productivity, set up time reduction or any other small change for betterment.

12. **Standard Work -**Standardized work means defining work and process instructions are well defined with full details of operation or process and parameters. It will reduce variation in repeated work cycles All the work instructions should contain standard worker movement, actions, checkpoints for quality, safety along with machine time, standard inventory.

13. **Visual Management-**Visual Management facilitate everyone to be known about manufacturing targets, current status, deviations etc. It makes information available for all regarding status of production lines, down time and also controls the process by defining limits of tolerance. Good and not good parts are also defined with different colors .Location of not good parts are generally defined by red color.

14. **Value Stream Mapping -**Value stream mapping is a set of methods to visually display the flow of materials and information through the production process. The objective of value stream mapping is to identify value-added activities and non-value-added activities. Value stream maps should reflect what actually happens rather than what is supposed to happen so that opportunities for improvement can be identified. Value Stream Mapping is often used in process cycle-time improvement projects since it demonstrates exactly how a process operates with detailed timing of step-by-step activities. It is also used for process analysis and improvement by identifying and eliminating time spent on non-value-added activities.

15. **Production Leveling (Heijunka**) -Production leveling, also called production smoothing, aims to distribute production volumes and product mix evenly over time so as to minimize peaks and valleys in the workload. Any changes to volumes should be smoothed so that they occur gradually and therefore in the most non-disruptive way possible. This will also allow the company to operate at higher average capacity utilization while also minimizing changeovers. A key element of production leveling is that the person(s) responsible for placing orders to the factory floor should have a system for automatically smoothing out the orders so that any increases or decreases are gradual and not disruptive. This makes it easier to correctly allocate the necessary equipment and people.

LEAN MANUFACTURING IMPLEMENTATION STRATEGIES

Lean manufacturing is a philosophy which cannot be implemented instantly so it requires tolerantly developing understanding within the organization about lean, starting with smaller projects of lean at tool level, taking guidelines of an expert, making and following the strategy with due course correction in strategy while implementing lean throughout the organization. Some of the steps are as follows:

1. **Senior Management Involvement –** For any major change, support and commitment from top management is vital. It is very much possible that problems will arise when lean implementation will progress and these issues must be understood and solved by top management without effecting lean implementation process.

2. **Initiate with smaller projects –** Initial project must be small so that more resources are utilized and more chances are for better results with lesser risk moreover people working on project and around will learn while doing project. The results will motivate other to follow the same and people will start having faith in lean techniques. So recommendation is to start with smaller project at tool level.

3. **Start with limited execution –** Lean implementation should be within limited area during start so that it can be monitored, corrected and directed for further implementation starting lean all-around the organization will reduce control and mentoring of people involved in lean implementation. Once movement is gained it should be spread in other areas.

4. **Employ a professional –** Services of a professional mentor should be taken at least at the start. During conversion of a conventional organization to a lean organization lots of issue will arise and should be handled professionally they can be taken care with the use of expert.

LEAN MANUFACTURING TOOLS AND TECHNIQUES

There are numbers of lean manufacturing tools which, when used in proper ways will give the best results. Once the source of the waste is identified it is easier to use the suitable lean tool to reduce or eliminate them and try to make waste free systems. Some of these tools are discussed in this study.

1. Cellular Manufacturing

A cell is a combination of people, equipment and workstations organized in the order of process to flow, to manufacture all or part of a production unit (Wilson, 2009). Following are the characteristics of effective cellular manufacturing practice.

1. Should have one-piece or very small lot of flow.

2. The equipment should be right-sized and very specific for the cell operations.

3. Is usually arranged in a C or U shape so the incoming raw materials and outgoing finished goods are easily monitored.

4. Should have cross-trained people within the cell for flexibility of operation.

5. Generally, the cell is arranged in C or U shape and covers less space than the long assembly lines.

There are lots of benefits of cellular manufacturing over long assembly lines. Some of them are as follows (Heizer and Render, 2000).

1. Reduced work in process inventory because the work cell is set up to provide a balanced flow from machine to machine.

2. Reduced direct labor cost because of improved communication between employees, better material flow, and improved scheduling.

3. High employee participation is achieved due to added responsibility of product quality monitored by themselves rather than separate quality persons.

4. Increased use of equipment and machinery, because of better scheduling and faster material flow.

5. Allows the company higher degrees of flexibility to accommodate changes in customer demand.

6. Promotes continuous improvement as problems are exposed to surface due to low WIP and better communication.

7. Reduces throughput time and increases velocity for customer orders from order receipt through production and shipment.

8. Enhances the employee's productive capability through multi-skilled multimachine operators.

Apart from these tangible benefits, there is the very important advantage of cellular manufacturing over the linear flow model. Due to the closed loop arrangement of machines, the operators inside the cell are familiar with each other's operations and they understand each other better. This improves the relation between the operators and helps to improve productivity. Whereas in long assembly line one operator knows only two operators (before and after his operation in the line) it seems that operators are working independently in the line.

2. Continuous Improvement

According to (Gersten and Riss, 2002) Continuous improvement (CI) can be defined as the planned, organized and systematic process of ongoing, incremental and company-wide change of existing practices aimed at improving company performance.

Activities and behaviors that facilitate and enable the development of CI include problem-solving, plan-do-check-act (PDCA) and other CI tools, policy deployment, cross-functional teams, a formal CI planning and management group, and formal systems for evaluating CI activities. Successful CI implementation involves not only the training and development of employees in the use of tools and processes, but also the establishment of a learning environment conducive to future continuous learning.

Thus continuous improvement is an ongoing and never ending process; it measures only the achievements gained from the application of one process over the existing. So while selecting the continuous improvement plan one should concentrate on the area which needs more attention and which adds more value to our products. There are seven different kinds of continuous improvement tools they can be described as follows. The use of these tools varies from case to case depending on the requirement of the process to be monitored.

Pareto Diagram: The Pareto diagram is a graphical overview of the process problems, in ranking order from the most frequent, down to the least frequent, in descending order from left to right. Thus, the Pareto diagram illustrates the frequency of fault types. Using a Pareto, one can decide which fault is the most serious or most frequent offender.

Fishbone Diagram: A framework used to identify potential root causes leading to poor quality.

Check Sheet: A check sheet is a structured, prepared form for collecting and analyzing data. This is a generic tool that can be adapted for a wide variety of purposes.

Histogram: A graph of variable data providing a pictorial view of the distribution of data around a desired target value.

Stratification: A method of sorting data to identify whether defects are the result of a special cause, such as an individual employee or specific machine.

Scatter Diagram: A graph used to display the effect of changes in one input variable on the output of an operation.

Charting: A graph that tracks the performance of an operation over time, usually used to monitor the effectiveness of improvement programs.

3. Just in Time

Just in time is an integrated set of activities designed to achieve high volume production using the minimal inventories of raw materials, work in process and finished goods. Just in time is also based on the logic that nothing will be produced until it is needed (Shivanand, 2006).

Just-in-time manufacturing is a Japanese management philosophy applied in manufacturing. It involves having the right items with the right quality and quantity in the right place at the right time. The ability to manage inventory (which often accounts for as much as 80 percent of product cost) to coincide with market demand or changing product specifications can substantially boost profits and improve a manufacturer's competitive position by reducing inventories and waste. In general, Just in Time (JIT) helps to optimize company resources like capital, equipment, and labor. The goal of JIT is the total elimination of waste in the manufacturing process. Although JIT system is applied mostly to manufacturing environment, the concepts are not limited to this area of business only. The philosophy of JIT is a continuous improvement that puts emphasis on prevention rather than correction, and demands a companywide focus on quality. The requirement of JIT is that equipment, resources and labor are made available only in the amount required and at the time required to do the work. It is based on producing only the necessary units in the necessary quantities at the necessary time by bringing production rates exactly in line with market demand. In short, JIT means making what the market wants, when it wants, by using a minimum of facilities, equipment, materials, and human resources (Roy, 2005).

Pull and Push System - In push system, when work is finished at a workstation, the output is pushed to the next station; or, in the case of the final operation, it is pushed on to the final inventory. In this system, work is pushed on as it is completed, with no regard for whether the next station is ready for the work or not. In this way, the WIP is unbalanced in all operations throughout the shop floor.

Description	Push System	Pull System
Signal to produce more	Schedule or plan	Customer signal
Timing of signal	Advance of the need	At the time of the need
Planning horizon	Fairly long	Very short
Leveling of demand	No	Generally yes
Negatives about the system	Too much inventory, no visual control, long and planned lead times, requires more information	Does not planned ahead, missed customer demand at the beginning of product life cycle, too much inventory at the last
Best for	Non repetitive, batch, short product lifecycle, long lead time purchasing	Repetitive, high volume manufacturing and stable demand
Problem visibility	Not visible	Visible
Stress to improve	Little	Much

TABLE 1: Difference between push and pull manufacturing system.

The push system is also known as the Materials Requirements Planning (MRP) system. This system is based on the planning department setting up a long-term production schedule, which is then dissected to give a detailed schedule for making or buying parts. This detailed schedule then pushes the production people to make a part and push it forward to the next station. The major weakness of this system is that it relies on guessing the future customer demand to develop the schedule that production is based on and guessing the time it takes to produce each part. Overestimation and underestimation may lead to excess inventory or part shortages, respectively.

4. Total Productive Maintenance

Machine breakdown is one of the major headaches for people related to production. The reliability of the equipment on the shop floor is very important because if any one of the machines is down the entire shop floor productivity may be nil. The tool that takes care of these sudden breakdowns and awakes maintenance as well as production workers to minimize these unplanned breakdowns is called total productive maintenance. Total Productive Maintenance (TPM) is a maintenance program, which involves a newly defined concept for maintaining plants and equipment. The goal of the TPM program is to increase production, increase employee morale and job satisfaction. (Bisen and Srivastava, 2009)

TPM is set of tools, which when implemented in an organization as a whole gives the best utilization of machines with least disruption of production. The set of tools are called pillars of TPM and they are shortly described here and illustrated in a TPM diagram (Figure 3).

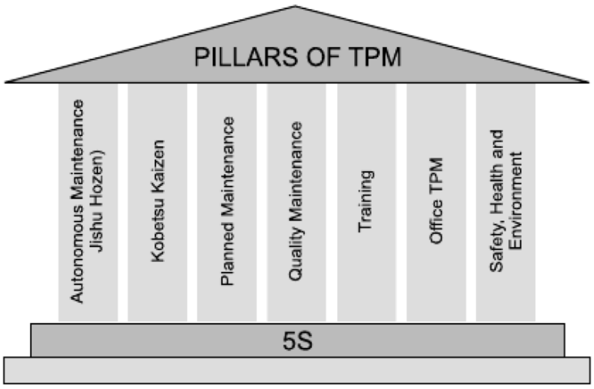

FIGURE 3: TPM diagram - Pillars of TPM

5. Work Standardization

A very important principle of waste reduction is the standardization of work. Standardized work basically ensures that each job is organized and carried out in the same manner; irrespective of the people working on it. In this way if the work is standardized the same quality output will be received even if the worker is changed in process. At Toyota, every worker follows the same processing steps all the time. This includes the time needed to finish a job, the order of steps to follow for each job, and the parts on hand. By doing this one ensures that line balancing is achieved, unwanted work in process inventory is minimized and non-value added activities are reduced. A tool that is used to standardize work is called takt time.

6. Waste Reduction Techniques

Some of the waste reduction tools include zero defects, setup time reduction, and line balancing. The goal of zero defects is to ensure that products are fault free all the way, through continuous improvement of the manufacturing process. Human beings almost invariably will make errors. When errors are made and are not caught then defective parts will appear at the end of the process. However, if the errors can be prevented before they happen then defective parts can be avoided. One of the tools that the zero defect principle uses is Poka Yoke. Poka-Yoke, which was developed by Shingo, is an autonomous defect control system that is put on a machine that inspects all parts to make sure that there are zero defects. The goal of Poka-Yoke is to observe the defective parts at the source, detect the cause of the defect, and to avoid moving the defective part to the next workstation (Feld, 2000).

Single Minute Exchange of Die (SMED) is another technique of waste reduction.

During 1950's Ohno devised this system; and was able to reduce the die changing time from 1 day to three minutes. The basic idea of SMED is to reduce the setup time on a machine. There are two types of setups: internal and external. Internal setup activities are those that can be carried out only when the machine is stopped while external setup activities are those that can be done during machining. The idea is to move as many activities as possible from internal to external. Once all activities are identified than the next step is to try to simplify these activities (e.g. standardize setup, use fewer bolts). By reducing the setup time many benefits can be realized. First, die-changing specialists are not needed. Second, inventory can be reduced by producing small batches and more variety of product mix can be run.

Line balancing is considered a great weapon against waste, especially the wasted time of workers. The idea is to make every workstation produce the right volume of work that is sent to upstream workstations without any stoppage. This will guarantee that each workstation is working in a synchronized manner, neither faster nor slower than other workstations.

7. Value Stream mapping

Value Stream Mapping (VSM) is a technique that was originally developed by Toyota and then popularized by the book, Learning to See (The Lean Enterprise Institute, 1998), by Rother and Shook. VSM is used to find waste in the value stream of a product. Once waste is identified, then it is easier to make plan to eliminate it. The purpose of VSM is process improvement at the system level. Value stream maps show the process in a normal flow format. However, in addition to the information normally found on a process flow diagram, value stream maps show the information flow necessary to plan and meet the customer's normal demands. Other process information includes cycle times, inventories, changeover times, staffing and modes of transportation etc. VSMs can be made for the entire business process or part of it depending upon necessity. The key benefit to value stream mapping is that it focuses on the entire value stream to find system wastes and try to eliminate the pitfall. Generally, the value stream maps are of three types. Present State Value Stream Map (PSVSM) tells about the current situation, Future State Value Stream Map (FSVSM) can be obtained by removing wastes (which can be eliminated in the short time like three to six months) from PSVSM and Ideal State Value Stream Mapping (ISVSM) is obtained by removing all the wastes from the stream. The VSM is designed to be a tool for highlighting activities. In lean terminology they are called kaizen activities, for waste reduction. Once the wastes are highlighted, the purpose of a VSM is to communicate the opportunities so they may be prioritized and acted upon. Hence, the prioritization and action must follow the VSM, otherwise it is just a waste like other wastes.

CONCLUSION

The design and implementation of a lean production system is a complex task requiring an intimate understanding of the fundamental lean principles. This thesis develops a series of management tools derived from these principles to assist with lean implementation in a complex, highly constrained system. Nonetheless, these tools alone are not sufficient for a successful implementation. Successful lean implementation requires a series of complementary proficiencies. These include, but are not limited to, a systems level perspective, solid analytical skills, high level management buy-in and support, effective leadership, and, most importantly, the ability to continually adapt. No two lean implementations are the same. Although the skills and experience developed in one implementation environment can and should be drawn upon to assist with the next, there is rarely a cookie cutter solution. Leaders must be flexible and learn to adapt to their environment in order to be effective organizational change agents.

Organizationally, Lean has ramifications at all levels in the company. It is often initiated at the tactical level where it involves production decisions, run rules and supply chain improvements. But an enterprise is a dynamic system, and long term solutions in complex product environments inevitably have ramifications at the strategic level.

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