

Lean and Six Sigma approach for Manufacturing SMEs

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Abstract

Lean manufacturing as a production methodology aims at elimination of waste, simplification of procedures and speeding up of operations. Six Sigma, on the other hand, is a business improvement strategy which aims at drastic reduction in the number of defects occurring in manufacturing or service operations. Indian small and medium component manufacturing enterprises sector needs cost effective methods and techniques to handle critical to quality and productivity problems. In this paper an attempt has been made to explain the relevance and benefits of Six Sigma and Lean Manufacturing approach to this sector.

Keywords: Six Sigma, Lean Manufacturing, SME

Introduction

Six Sigma is a business strategy that enables organizations to increase their profits by optimizing their operations, improving quality and eliminating defects (Harry and Crawford, 2005). Six-Sigma theme pivots on drastic reduction of variability in the processes. The companies that adopt Six Sigma approach will have to reduce the process variation to such a level that the number of defective parts per a million of produced parts would be less than 3.4. Embarking on a Six Sigma program means delivering top-quality products and service while virtually eliminating all internal deficiencies (Rotondaro R, 2002).

Six Sigma projects and activities are linked to the top level goals of the organization. The goals of any organization come from its three major constituencies: customers, investors and employees. Senior management translates these stakeholder based goals in to proper metrics. These goals and metrics are then mapped to a strategy for achieving them.

By addressing all business processes and treating manufacturing as part of a larger system Six Sigma provides multiple benefits to customers. When product design cycle shortens and operations become more cost-effective, the owners or investors will automatically reap more benefits. When employees become more productive naturally their monetary package will get better. So, adoption of Six Sigma means higher benefits to all stakeholders in the organization (Thomos Pyzdek, 2003).

Six Sigma implementation uses five step DMAIC (Define, Measure, Analyze, Improve and Control) methodology, somewhat similar to Plan-Do-Check-Act problem solving methodology defined by Deming. DMADV (Define, Measure, Analyze, Design and Verify) methodology is adopted for new product developments.

From the viewpoint of the customer of a product or service, 'value' can be defined as any action or process that the customer would be willing to pay for. Taiichi Ohno, developer of the

Toyota “just-in-time” Production System in the 1950s, defined waste as any human activity which absorbs resources but creates no value. Lean is a production practice that eliminates waste.

At the beginning of the twentieth century the automobile industry started mass production as an alternative to craft production. The mass production had many advantages like high volume, low cost, less skilled operators, etc. But, it also had some disadvantages like very high cost of machinery, less variety, excess supplies, need of more workers, need of extra space to ensure smooth production, etc. Lean production came as an alternative to mass production combining the advantages of both craft and mass production. James P.Womack, et al. in their book ‘The Machine That Changed The World’ (1990) say: Lean production should be viewed as a strategy for achieving value leadership. It goes well beyond cost cutting. First, lean production dramatically raises the threshold of acceptable quality to a level that mass production, cannot easily match. Second, lean production offers over-expanding product variety and rapid responses to changing consumer tastes, something low-wage mass production finds hard to counter except through lower prices. Lean production dramatically lowers the amount of high-wage work needed to produce a product and keeps on reducing it through continuous incremental improvement. Lean production can fully utilize automation in many ways which mass production cannot.

Lean Six Sigma is the combination of Lean production and Six Sigma approach. It draws the philosophies, principles and tools of both in its approach. Lean focuses on elimination of waste and non-value added activities by process optimization while Six Sigma focuses on reduction of process variation and hence drastic reduction of defects and meeting the requirements of all the stakeholders. Lean and Six Sigma compliment and reinforce one another. Only lean will not bring the process under statistical control to meet the quality targets whilst Six Sigma alone will not reduce waste in the processes. Currently, Lean Six Sigma is an internationally established methodology for improving the organizational effectiveness.

Six Sigma approach

In 1985 an Engineer by name Bill Smith working for Motorola presented a paper strongly recommending production of defect free parts in production processes. That was the beginning of Six Sigma approach by the production companies. Later the world-class companies such as General Electric, Johnson & Johnson, Honeywell, and many others have adopted Six Sigma. They claim that Six Sigma helped them to transform their organizations in a number of ways. Six Sigma is a business system with many statistical aspects, and it naturally fits the business systems of most companies. It is an operational system that speeds up improvement by getting the right projects conducted in the right way. It drives out fear by making employees agents of change rather than resisters to change (James M Lucas, 2002).

Implementation of Six Sigma is done by taking up a number of small projects using five-step DMAIC (Define, Measure, Analyze, Improve and Control) methodology. DMAIC is somewhat similar to Plan-Do-Check-Act problem solving methodology defined by Walter Shewhart and W. Edward Deming. Six Sigma projects and practices will later become part of the organizational culture and functional routine.

Details of the activities conducted and tools used within each phase of DMAIC process of a Six Sigma project are:

Define Phase:

- Identify the critical customer requirements

- Select projects, set initial goals or targets, and identify the project metrics using VOC tools, Process Map, QFD, SIPOC and Bench Marking.
- Implement a balanced score card considering the cost of poor quality (COPQ) and rolled through yield (RTY) (Forrest W Breyfogle, 2003)
- Setup the Six Sigma project team
- Develop Six Sigma roadmap and implementation plan with clear-cut deliverables
- Prepare the schedules for periodic meetings to discuss the progress of the Six Sigma initiative

Measure Phase:

- Create run charts and control charts of key process output variables. Start compiling project metrics in time series format.
- Determine the long term process capability.
- Determine the baseline performance. Pareto diagrams and controls charts are the commonly used tools.
- Develop a flowchart/process map
- Carryout measurement system analysis
- Strategic deliverables for the measure step are baseline figures, measurement system analysis results, process capability, an improvement goal, a refined process map, and a refined project charter (Eckes, 2001; Pande et al., 2002).

Analysis Phase

- Develop a Cause and Effect diagram to identify the variables that affect the process output.
- Create a cause and effect matrix assessing the strength of relationships that are thought to exist between key process input variables and the key process output variables (Forrest W Breyfogle, 2003)
- Conduct Failure Mode and Effects Analysis (FMEA)
- Collect data to assess the relationship between key process input and output variables
- Create multi-vari charts and box plots
- Conduct correlation studies
- Validate the causes using statistical tools such as scatter plots, hypothesis testing, ANOVA, regression analysis design of experiments (DOE) and Response Surface Methods analyses
- Root causes of the problems are the deliverables of the analysis phase

Improve Phase

- Brainstorm to determine the possible countermeasures and long-term process improvements that address the root causes. Force field diagrams, 7M tools and project planning and management tools are used for the study.
- Determine the optimum operating levels of the key input variables using full and fractional factorial DOEs and response surface methodology.

Control Phase

- Update the control plan.
- Implement statistical process control
- Verify the process improvements, process capability and stability.

The Six Sigma project team consists of Champion & Sponsors, Master Black Belts, Black Belts, Green Belts and Yellow Belts. The support and active involvement of the top management is very essential for successful implementation of Six Sigma. For a Six Sigma initiative the top

management establishes quantifiable and verifiable measures of success. A champion will be in-charge of each Six Sigma initiative who directly reports to the top management. The Six sigma champion should have adequate education, leadership qualities and sufficient analytical, communication, presentation and persuasion skills. A champion is responsible for the success of a Six Sigma project who possesses authority to provide the necessary resources, breaking down the department barriers, etc.

Black Belts, the backbone of a Six Sigma initiative, are considered to be technically strong and proficient with statistical software packages. Typically Black Belts comprise 1 or 2 % of the company's total population. Each BB is expected to achieve a financial target as a result of the process improvement through a Six Sigma initiative. They work under the guidance of a Master Black Belt (MBB). MBBs provide technical leadership and are trainers, facilitators and coaches in a Six Sigma process. Both MBB and BB are full time on Six Sigma projects. Green Belts (GB) are Six Sigma project leaders who facilitate Six Sigma project team from concept to completion. Normally, Green Belts number 5-10 % of the organization population and work on part time basis in Six Sigma projects. Yellow Belts are the team members that support Green Belts and Black Belts. The Yellow Belts are technical and non-technical personnel, who gather data, participate in problem solving process and add their expertise to the Six Sigma projects.

People at all levels involved in a Six Sigma initiative should be trained. Leadership should be trained on Six Sigma concepts and methodology. Top management and senior managers participate in a 2-3 day workshop on Six Sigma. Black Belts undergo 4week in four month training on Six Sigma. Master Black Belts undergo BB training Plus 2 weeks of additional training on mentoring Six Sigma projects. Green Belts undergo a 2week in two month Six Sigma training. Yellow Belts undergo 1 week over 1month training.

Measurement of Six Sigma performance should be conducted on a regular basis. Selection of the appropriate performance metrics is very important for effective measurements such that any bad effect is noticed in the initial stage itself instead of waiting till it becomes too costly to rectify. Organizations should maintain proper perspective by having performance metrics in four areas: Customers, Finance, Processes and Improvement.

For successful completion of the projects an employee recognition program is established. After the completion of each project it is verified against established goals. Savings due to the process improvements of each Six Sigma project is corroborated by the accounts department. Corporate score card is updated and assessed to determine the increase in profitability and growth. The results are reported to all employees. Successful completion of the projects is documented by the employees and the project leaders. A platform or framework for the employees and the project leaders to share the success stories is created.

When there is no process in existence or an existing process is to be completely redesigned, design for Six Sigma (DFSS) methodology is used. DFSS focuses on Define – Measure – Analyze – Design – Verify (DMADV) approach.

Lean manufacturing

Lean Manufacturing is a management philosophy derived mostly from the Toyota Production System (TPS). Many a times Lean is considered as a set of tools that assist in the identification and elimination of waste. The main objective of Lean is not mere use of tools, but the reduction of three types of waste: muda (non-value-adding work), muri (overburden) and mura (unevenness).

Companies that have mastered lean design will offer a wider variety of products and replace them more frequently than mass-production competitors. The Japanese lean producers exercised

extreme care not to detach the advanced technologies from the day-to-day workings of the company and the demands of the market. Based on their observations of U.S. and European mass-producers, they concluded that, to be effective, even advanced engineering, must be tied into the key market-driven activities of the company (James P.Womack, et al. 1990).

The manufacturing system developed by Toyota, the Japanese automobile giant, using lean principles from 1945 to 1975 later became quite popular as Toyota Production System (TPS). During the early 1950s, Eiji Toyoda of Toyota Motor Corporation went to Ford's car manufacturing plant at Detroit, USA to study how the cars were being manufactured. He observed that there were many possibilities for improvement in the production system. Later Taiichi Ohno visited Detroit several times and studied the mass production system at Ford. They both realized that there were too much of waste everywhere in the mass production unit of Ford. There were wastes of man power, material, time, space and efforts. As a result they developed the Toyota Production System using which Toyota was able to significantly reduce the lead time and cost, while greatly improving the quality.

There are following seven kinds of muda (waste) that are addressed in the Toyota Production System:

1. Overproduction
 - Producing more than the internal or external customer needs and producing sooner than the internal or external customer needs
2. Waiting
 - People waiting for machinery, tooling, maintenance, raw materials, etc. and machinery waiting for maintenance, people, materials, tooling etc.
3. Transportation
 - Moving materials or people over long distances
4. Inappropriate Processing
 - Unnecessary (non-value added) or inefficient processing
5. Work-In-Process (WIP)
 - Process inventory causes extra handling, extra space and extra cost
6. Excess Motions
 - Any motion of people or machines which does not add value to the product or service
7. Defective products
 - Scrap, rework, customer returns, customer dissatisfaction

Later 'defective design' was added as one more waste to the list by Womack et al. (2003). But, according to some people 'underutilization of employees' is the eighth waste. 'Defective Design' is defined as designs which do not meet needs of customers, unnecessary extra features and 'Underutilization of employees' is defined as not using human resources productively with proper motivation and reward system.

A famous system invented by Ohno to reduce muda is known as Just-In-time (JIT). In JIT, the process relies on signals or Kanban between different points in the process, which tell production when to make the next part. By implementing JIT or Kanban system much muda could be reduced. First of all, a large space was not necessary to keep a large number of parts. Second, only the needed quantity of parts was produced. Third, if defects were produced, it was immediately discovered, thus the system prevented a large number of defects to be produced (Jens J. Dahlgaard & Su Mi Dahlgaard-Park, 2006). Just-In-time became popular in the western world when it was

documented in the book 'The machine that changed the world' written by James Womack, et al. in 1990. They gave the name 'Lean Manufacturing' to this system. This was the eye opener for the western world about this system. Thereafter the concepts were practiced all over the world (Aza Badurdeen, 2007).

Principles of Lean include: No waiting time, No inventory, Pull system instead of a push system, Reduced batch sizes, Line balancing and Reduced process cycle times. Womack & Jones (Lean Thinking, 1996) argue that a lean way of thinking allows companies to:

- Specify value
 - According to the authors 'Value' is defined as a capability provided to the customer at the right time at an appropriate price as defined in each case by the customer.
- Identify the value stream for each product
 - 'Value stream' is defined as specific activities required to design, order and provide a specific product, from concept to launch, order to delivery, and raw materials to products.
- Make the value flow without interruptions
 - 'Flow' is defined as the progressive achievement of tasks along the value stream so that a product proceeds from design to launch, order to delivery and raw materials into the hands of the customer with no stoppages, scrap or backflows.
- Whenever customer pulls them
 - 'Pull' is defined by the authors as a system of cascading production and delivery instructions from downstream to upstream in which nothing is produced by the upstream supplier until the downstream customer signals a need.
- Pursue perfection
 - 'Perfection' is defined as the complete elimination of muda so that all activities along a value stream create value.

Lean tools used in manufacturing are: Value Stream Mapping, Quick Changeover/Setup Reduction, Single Minutes Exchange of Dies (SMED), Kaizen, Cellular/Flow Manufacturing, Total Productive Maintenance (TPM), Pull/Kanban Systems and Visual Workplace/Five S.

Lean environment begins with the discipline of '5-S' namely:

- Organization (Seiei)
 - keeping on hand only what is needed for the process – the rest is red-tagged & removed, making it easy to see the bare process in its orderly state.
- Orderliness (Seiton)
 - a place for everything in its place for immediate retrieval and use.
- Cleanliness (seiso)
 - Keep the workplace clean, spotless, and shining.
- Standardized (Seitetsu)
 - It is the condition we achieve when we take care of the first three. Everyone plays a role.
- Discipline (Shitsuke)
 - Through the strength of personal discipline make a habit of maintaining the established procedures every day.

Set-up time is the time taken from the last good piece of the previous run until good piece comes off the machine again. Reduction of set-up time directly impacts inventory levels, lead times, linked continuous flow, quality improvements and more. Fish-bone or Ishikawa or 'Cause and Effect' (C-E) diagram makes it easy to see how a certain effect results from many root causes. Its use focuses everyone's attention in a structured way on the real root causes of a problem and avoids getting distracted onto symptoms. Companies and organizations employing the lean tools report significant gains in productivity and overall effectiveness. Lean Manufacturing uses less of everything compared with mass production. Lean manufacturing system works with the interconnected processes. Improvement in one area will improve the system as a whole.

Lean Manufacturing and Six Sigma approach for Indian component manufacturing SMEs:

Manufacturing companies should have effective operations and continuously improve their services, markets, etc. Companies need to learn not just doing things better, but a way of doing better things. When companies are not doing well financially the only way forward is a thorough restructuring of the business. They should focus not just on cost reduction but growth of the company. Companies may have to compete, respond well, react faster and so forth. Essentially companies will have to learn to do more with less using techniques like Six Sigma and Lean manufacturing.

In India, till recently, the Six Sigma has been confined to be the domain of only the large OEM companies. In recent times a small section of the small and medium size enterprises are opening up to the new challenges and have started thinking of adopting the Six Sigma and lean approach for improving their effectiveness. This is a welcome trend for this sector but quite a long way to go. The major problem is that most of the small and medium scale industries are driven by the customers for any improvement in operations and quality system instead of taking initiative on their own. Many feel that Six Sigma, Lean, etc. will only add to their cost without much return on the investments. There is also a perception that it is applicable only for large companies with better manpower and financial resources. The industries across the world offer a wider variety of products and replace them more frequently. So, the Indian component suppliers, to be effective, not only have to use advanced engineering but also respond well to the market-driven issues.

Practitioners across the world have realized that the two methodologies, Lean and Six Sigma, compliment with each other and when used together yield greater success. Lean Six Sigma, an integrated system for managing projects, is the latest generation of improvement approaches. But, for Indian SME sector where both Six Sigma and Lean are yet to be adopted in a bigger scale the introduction of the integrated approach directly may not be a recommended option. Our study of the Indian component manufacturing SMEs indicates that there are many hindrances for this sector. So, initially Lean and Six Sigma approaches should be separately suggested to the industries based on their operations. For example, if individual process steps of components themselves are highly variable it is not possible to run a process with minimum waste or at a steady capacity. On the other hand, even if the processes are complex but stable, reduction in cycle-time or productivity improvement cannot be obtained without lean tools. The order of application of the tools to solve these problems varies. If the problem is related to reducing lead time or increasing productivity, Lean should be implemented first and complex problems can be solved by the subsequent application of the Six Sigma tools.

According to our assessment, based on the preliminary results of our study, in general, Indian SMEs are adopting Lean approach to certain extent. They have started realizing that 'Lean' is all about elimination of waste, but a deeper understanding and adoption of the techniques is yet to take place. Waste includes any effort or outlay that doesn't contribute directly to the value received

by the customer. The purchaser will pay for installation of a part in an assembly, but not for a technician's time searching for a tool. Extra movements, idle workers waiting for parts or machines, disorganized work and storage areas, and stacks of parts and inventory are all waste and should be eliminated. Targeting these will result in improvements in lead times, inventory, productivity, warehouse space and material costs. It takes almost 4-5 years for an organization to create a Lean culture. It is not an overnight transformation. Companies, having decided to have lean culture should persist with their efforts till they reach the expected level. The continuous supporting role of the management and the consultants is very essential, especially in the case of Indian SMEs.

Once the companies master the lean design it is important for them to adopt advanced technologies for the day-to-day workings of the company and also to meet the changing demands of the market. Our SMEs should aim to reach the level of the best lean production companies who deliver components directly to the assembly line, often hourly, certainly several times a day, with no inspection at all of incoming parts. This procedure is the famous just-in-time system, the invention of Taiichi Ohno. For this, the parts supplier should be fully aware of what faulty parts mean and should take pains not to let it happen. If a defective part is found, both the supplier and the customer need to trace every defective part to its ultimate cause and to ensure that a solution is devised that prevents this error from ever happening again. So, the cooperation and continuous support of the customer is the vital requirement of the entire component manufacturing SMEs. Indian OEM companies have started to realise this and they are involving their SME suppliers in the training programs of their quality improvement efforts and also supporting the initiatives of their suppliers as well.

Some of the companies in India are focusing on improving process efficiency and speed using Lean tools such as 5S, value stream mapping, cycle time analysis, pull system (Kanban), etc. But, the Six Sigma implementation efforts by the companies are not up to the same level. Six Sigma as a business system with many statistical aspects should naturally fit the business systems of most of the companies for solving process problems, improving performance, reducing defects, improving sigma levels, etc. However, during our study we found that implementation of Six Sigma by taking up a number of small projects using the entire Six Sigma DMAIC toolkit is not being done by many of the big manufacturing companies themselves. So, it may be too much to ask for SMEs to estimate cost of poor quality (COPQ) and go for full implementation of Six Sigma using five-step DMAIC (Define, Measure, Analyze, Improve and Control) methodology. Having said that we also should make it clear that many of the Six Sigma tools like Pareto diagrams, flowchart/process map, Failure Mode and Effects Analysis (FMEA), design of experiments (DOE), measurement system analysis, estimation of process capability (C_p and C_{pk}) are being used by many industries for different purposes. Probably what is lacking with the most of the companies is the understanding of Six Sigma in the real sense. If the companies realize that Six Sigma is an operational system that speeds up improvement by getting the right projects conducted in the right way with the benefits like increased profit and reduced cost, automatically they would be interested in it. But, there are many hindrances for this to happen. One of the major hindrances of Six Sigma implementation is need of skilled manpower and their training. SMEs cannot afford to have the Six Sigma project team consisting Champion, Master Black Belts, Black Belts, etc. Based on our observations of the situation prevalent in many SMEs the other barriers because of which the companies are not able to effectively implement Six Sigma can be listed as: Lack of resources, Internal resistance; Lack of leadership from top executives; Lack of knowledge about Six Sigma; Insufficient organizational alignment; Cultural barriers; Poor training and coaching; False notion

that Six Sigma is too complex to use; Wrong identification of the process parameters; Lacunae in data collection; Poor Six Sigma project selection, etc.

Through this article we have attempted to lessen one of the hindrances i.e. Lack of knowledge about Six Sigma and lean manufacturing. As an output of our study of the small and medium enterprises regarding their present status of application of Six Sigma we intend to come out with a simple Six Sigma implementation model for SMEs driving out the many of apprehensions in their mind, clarifying the doubts about managerial and financial implications of the implementation, the overall benefits that all the stake holders are going to reap, etc.

Once the companies mature in the Six Sigma and Lean applications individually, gradually Lean Six Sigma concepts can be introduced. The companies would adopt it automatically because by eliminating the non-value added activities in the process, Lean Six Sigma helps to reduce the number of opportunities itself for occurrence of defects in production of the product which in turn results in lesser DPO (defects per opportunity) and thus increases the sigma level of the process.

Conclusion:

The small and medium enterprises, especially component manufacturing industries, need to supply large variety and varying quantities of parts in line with the changing demands of their OEM customers. It is something traditional mass production systems find hard to counter. Six Sigma and Lean offers solutions to these problems raising the acceptable quality to a level that mass production cannot easily match. Lean production also significantly lowers the amount of high skill effort needed to produce a product of a given specification. It reduces the cost of production through continuous incremental improvement. Thus it offsets the low cost advantage of mass production system. Six Sigma fully utilizes advanced technology and automation in ways mass production cannot. It can be stated that lean and Six Sigma approach are not only very much relevant for auto component manufacturing industries it is the need of the hour. At an advanced stage Lean Six Sigma strategy can be adopted by the companies to achieve value leadership along with cost cutting and high yield. A study has been under taken to understand the present level of application of Six Sigma by small and medium component manufacturing industries in India, the common hindrances faced by them, the critical success factors for implementation, etc. The purpose of the study is to bring out a model for implementation of Six Sigma by SMEs in simple way along with lean manufacturing techniques which will ultimately lead to Lean Six Sigma Companies.

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