

# Applications of Lean Six Sigma

Swati Sabale<sup>1</sup>, Santosh Thorat<sup>2</sup>

<sup>1</sup>Swati Sabale, Chemical Engineering Department, Pune University, Pune, India.

<sup>2</sup>Santosh Thorat, National Institute of Pharmaceutical Education & Research, Hyderabad, India.

\*\*\*

**Abstract:** This paper elaborates a comprehensive assessment of the literature on lean six sigma concept, for its significance, feasibility and need for organizations to sustain in the global market. This article is focused on methodology and tools of lean six sigma process and how it can improve the industrial and production environment. Lean manufacturing is a concept of improving the speed and efficiency of an organization by eliminating wastes. Whereas six sigma is a continuous up-gradation plan that is applied to reduce unevenness. Here, tried to develop a lean procedure by studying technical papers for the companies to implement the lean six sigma system.

**Keywords:** Lean manufacturing, Six Sigma, quality, process improvement.

## I. INTRODUCTION

Current business competition raises the constant demand for profitable solutions that allow organizations to gain competitive advantage. For this reason, more and more companies search for management methodologies that allow them to improve their products and/or service characteristics, perfect their processes, decrease costs, improve the capital's profitability and customers' satisfaction. This has been achieved by applying Lean Management and Six Sigma integrated system in their managerial and manufacturing processes. The Lean Six Sigma ( $L6\sigma$ ) is a combination of two methodologies, Lean and Six Sigma that focus on continuous process improvement without raising the cost. Lean mostly works on the waste nullification, using easy and visual methodologies and Six Sigma on the control and processes differentiations elimination, using various tools. (1)

The Lean production system is also known as the **Toyota Production System** (TPS) which became well-known in the 1980's as Toyota began its growth to supremacy in the US car market by producing less expensive cars with higher quality than their US Manufacturers. (2)

Six Sigma was established by Motorola in the 1980s to improve their quality by minimizing variability in their manufacturing process as they competed in the semiconductor sector. (3)

This article explains a Lean Six Sigma project management improvement model supported by the DMAIC cycle and integrating an enlarged and adapted set of statistical tools, given the characteristic of the project management main changeable factors and the included operations.

## II. LITERATURE REVIEW

### The concept of Lean-

The concept of lean manufacturing is simply performing better productivity in eliminating waste from the manufacturing process. Lean works on operation format to make it earlier with no longer time and valuable with no waste generation. Lean aims to maximize value to the customer while using a few resources as possible.

So waste is any activity that does not add value from the customer's point of view. As per a research report generated by the Lean Enterprise Research Centre (LERC), completely 60% of production processes in a common manufacturing operation are waste – they add zero value for the customer. Figure 1. elaborates five principles of lean, are value, the value stream, flow, pull and perfection. These are known as the lean implementation basis.

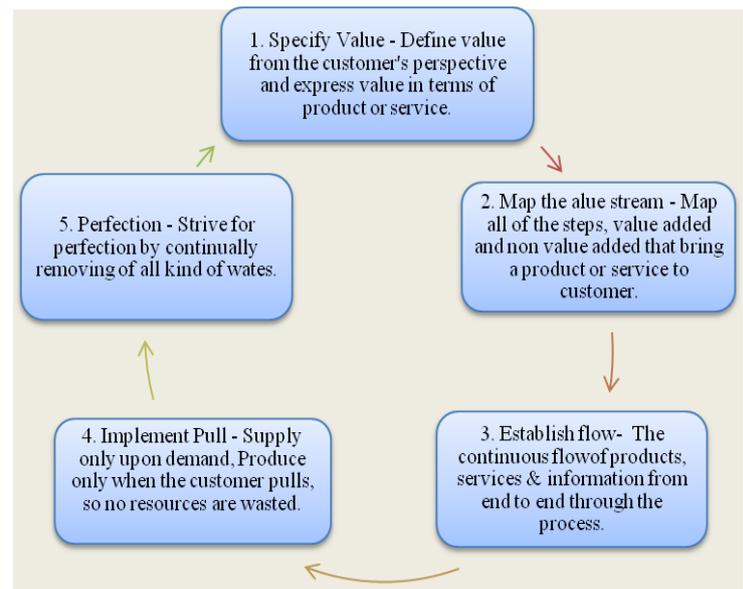


Fig. 1. Principles of lean manufacturing (4)

### Principles of Lean manufacturing (5)

1. Specify a value from the customer's perspective - Value is defined by the customer even though it is produced by the producer. The company must focus on to remove waste and cost from its working processes so that the customer's optimal price can be achieved at the highest profit to the company.

2. Map the value stream. - The value stream consists of the product's entire lifecycle, from raw materials through to disposal. Companies must work on each stage of the cycle

for waste. Anything that does not add value must be eliminated.

3. Establish flow. - Add the value-generating steps in the process flow. Eliminate the barriers and identify ways to improve lead time to ensure the smooth processes in order to on-time delivery. Lean manufacturing works on preventing intervention in production operations.

4. Implement the pull system. - You start new assignment only when there is requirement for it. Lean manufacturing is based on a pull system in which nothing is bought or made until there is demand. Pull relies on flexibility and communication.

5. Pursue work perfection with continual process improvement, or kaizen. - Lean manufacturing builds on the concept of continuous improvement and perfection, which entails targeting the root causes of quality issues and eliminating waste across the value stream.

### The eight wastes of lean production (6)

There are eight wastes, or processes and resources, that don't add value for the customer, as given below.

- unnecessary transportation;
- excess inventory;
- the unnecessary motion of people, equipment or machinery;
- waiting, it may be people waiting or unrequired equipment;
- over-production of a product;
- investing more time into a product than a customer needs, such as designs that need high-tech machinery or much cost for unrequired features; and
- defects, which needs more work and cost for corrections.
- waste of unused talent and ingenuity.

### Lean manufacturing tools and concepts (7)

The most important lean management tools such as 5S, Andon, Bottleneck Analysis, Continuous Flow, Gemba, Heijunka, Hoshin Kanri, Jidoka, Just-In-Time, Kaizen, Kanban, KPI, Overall Equipment Effectiveness, PDCA, PokaYoke, Root Cause Analysis, Single Minute Exchange of Die (SMED), Six Big Losses, SMART Goals, Standardized Work, TaktTime, Total Productive Maintenance, Value Stream Mapping and Visual Factory used for productivity improvement in manufacturing industries. Some of the important methodologies are explained below.

• Value Stream Mapping (VSM): VSM is the process of mapping the material and information flows required to coordinate the activities performed by manufacturers, suppliers and distributors to deliver products to customers.

• One-piece flow: One piece flow is a method used to manufacture the components in a hustle free process area. The manufacturing area where all required items to process the part is within easy reach, and no part is allowed to go to the next operation until the earlier operation has been completed.

• Visual Management: The intent of a visual factory is that the whole workplace is set-up with signs, labels, color coded markings, etc. which helps the person who is unfamiliar with the process can analyze the process flow and activity and can know what is being done correctly and what is out of place.

• Kaizen: Kaizen (ki-zen) is a Japanese word, the "ki" represents change and the "zen" goodness or virtue. Kaizen is commonly used to indicate continuous improvement. Kaizen focus on to give more production value with least wastes, to achieve better work culture and develop a stable process by standardization.

• Heijunka: This means production leveling or smoothing that seeks to produce a continuous flow of production, releasing work to the plant at the required rate and avoiding interruptions.

• Kanban: Is a signal either physical, such as tag or empty bin, or electronically sent through a system used to streamline processes and create just in time delivery.

• Jidoka: This is a method of providing machines and humans with the ability to detect an abnormality and stop work until it can be corrected.

• Andon: A visual aid, such as a flashing light, that alerts workers to a problem.

• Pokayoke: A mechanism that safeguards against human error, such as an indicator light that turns on if a necessary step was missed, as an example when a bolt was tightened the correct number of times a sign indicates or a system doesn't allow to process next step until all the previous steps are completed.

• Continuous Improvements (5S): One of the most effective tools of continuous improvement is 5S, which is the starting point for an effective lean company. 5S is a most starting step towards waste reduction. 5S is made up of five Japanese words Seiri (Sort), Seiton (Straighten), Seiso (Sweep and Clean), Seiketsu (Systemize), and Shitsuke (Standardize). Seiri: Deals with moving those items that are unused or not needed on a continuous basis. Seiton: Deals with having the correct items at the correct place. Items which are not related to that area should not be in that area. Seiso: Deals with cleaning and sweeping the work place methodically. The workplace should always have to keep neat and clean and ready to use for the later work shift. Seiketsu: Is to maintain a high standard of housekeeping and workplace arrangement. Shitsuke: Is in account of management to train people to follow basic housekeeping rules. And at times the sixth S for Safety is added though 5 S

purists say that an effective implementation of 5 S will eventually result in safety.

- Cycle time: How much time is require to produce a part or complete a process.

**The concept of Six Sigma-**

The philosophy of Six-Sigma is to satisfy the customer by offering the defect-free product or service delivering on time at a lower cost. Six Sigma is aimed to identify and nullify the root causes of errors or defects, termed as anything which could lead to customer dissatisfaction or business failures processes by working on resulting products that are critical to end users. The methodology of Six-Sigma does not only improve the quality of a product or service but it also focuses upon the cost of goods sold and the return on investment.

Six Sigma at many industries termed as a measure of quality that aimed to near perfection. It also can be called as "Operational Excellence," "Zero Defects," or "Customer Perfection."

**The two perspectives of Six-Sigma processes (8)**

1) Statistical perspective: The statistical representation of Six Sigma describes as a quality improvement approach that aims to reduce the number of defects up to 3.4 parts per million. Ie. 3.4 defective products on a sample of 1 million, which corresponds to a quality rate of 99.9997%,

Sigma Level	Defects per million	Yield
6	3.4	99.99966%
5	230	99.977%
4	6,210	99.38%
3	66,800	93.32%
2	308,000	69.15%
1	690,000	30.85%

2) Business perspective: Six-Sigma is a business strategy that is used to increase the profitability of the business to enhance the efficiency and effectiveness of all processes to meet or go beyond the customer’s needs and expectations. In an organisation initially, it applied in manufacturing processes and then later expanded to different functional areas like engineering, marketing, purchasing and servicing etc.

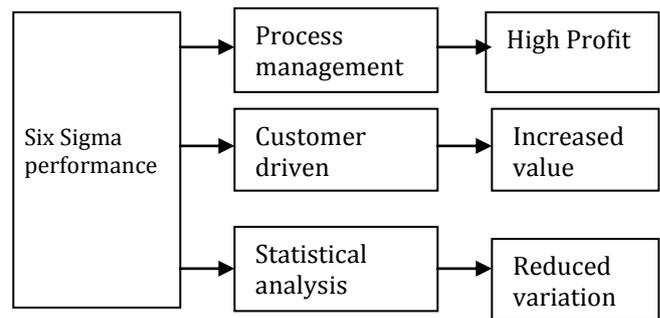


Fig. 2. Essentials of Lean Six-Sigma.

**Six-Sigma methodologies: (9)**

Business executives and Six Sigma professionals widely use two models to advance and improve quality levels within the organisation. These are DMAIC and DMADV methods.

**DMAIC (Define, Measure, Analyze, Improve and Control) :**

DMAIC the framework of Six Sigma methodology has been a well-established tool for process improvement and customer satisfaction helps in solving the problems related to the Manufacturing Process. When a product or a process is in existence in our company but that is not meeting customer specification or not performing adequately in this situation DMAIC methodology is used. It is as follows:

- D as Define – Define the issues of the project to identify customer expectations, to set goals.
- M as Measure – Measure the critical parameter to quality of product mainly those whose influence on the result is the largest.
- A as Analyze - Analyzing data obtained during the previous step and identify the opportunities for better improvement.
- I as Improve - Identify, evaluate, select & implement the right improvement solution.
- C as Control - This last step is to control the process to ensure that the problem is solved and stay in quality level achieved.

**DMADV (Define, Measure, Analyze, Design, Verify):**

When a product or a process is not in existence in our company and one needs to be developed (if we want to produce a new product) then in this situation "DMADV" methodology is used as similar to DMAIC,

- D as Define - Define the goals as per the customer requirements.
- M as Measure - Measure all parameters that are correspond with the process.
- A as Analyze - Analyze the parameters and the data collected during measurement, and create a design that suits the goals best.
- D as Design - Design the process.
- V as Verify - Verify that the process runs according to set goals.

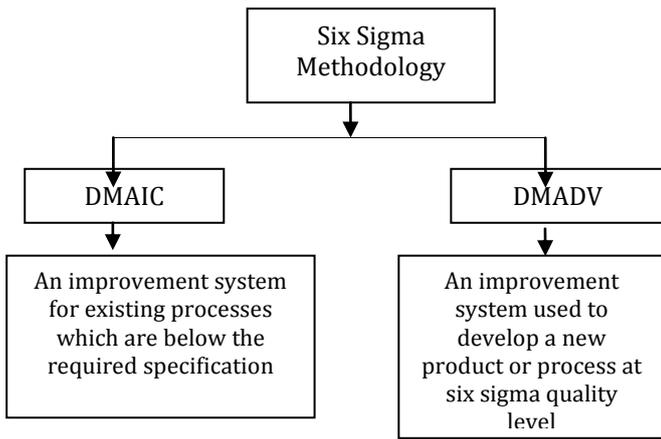


Fig. 3: Methodology of Six-Sigma. [9]

**Six Sigma Tools and techniques [10]:**

- **Check sheet:** Check sheet is used in the measuring phase of Six-Sigma which narrates in tabular form. This tool is used in data collection of required characteristics of any workflow which has to be improved. It is the most sensitive tool as if the collected data is wrong then the most suitable methods will be resulting in failure.
- **Histogram:** This is the second Six-Sigma tool used in the analyzing phase. Collected data from measuring phase is to be divided into different classes by using the histogram. The histogram made in such a way that the area of each rectangle is proportional to a number of calculation and observation within every class. Hence, the addition of areas of all the rectangles will be equal to the total number of the observations. The suitable number of classes in a histogram should be in between 6-12.
- **Cause and effect diagram:** It is applied in defining and analysis phases of Six-Sigma. Dr Kaoru Ishikawa introduced this Six-Sigma tool in 1943 It is also called the fishbone or the Ishikawa diagram. It is used as a first step in solving any problem by listing all the possible causes.
- **Pareto chart:** The Pareto chart introduced by Joseph M. Juran in 1940. It is also known as 80/20 rule; it means that 80% of the problems are due to the 20% of causes.
- **Control chart:** Shewhart introduced the control chart in 1924 and is using in industry. This tool is used in mainly 3 phases of six sigma system as analysis, improvement and control. In the analysis phase, this tool is very helpful for identifying whether or not the process is predictable, in the improvement phase it identifies a special cause of variation and in the control phase, it clarifies that there is improved process performance.

**III. METHODOLOGY**

**Lean Six Sigma Framework by Combining Lean Manufacturing and Six Sigma Tools [11]**

In the development of Lean Six Sigma framework, the phases of Lean Manufacturing and Six Sigma combined with

the aim that the company simultaneously tackles both the 'waste reduction' element and, the critical quality element of the business.

The Lean Six Sigma framework has five phases as shown in Figure 4. Each phase providing an easy and structural solution towards root-cause identification of a problem, hence proposing and implementing a feasible solution to eliminate the root cause through continuous improvement.

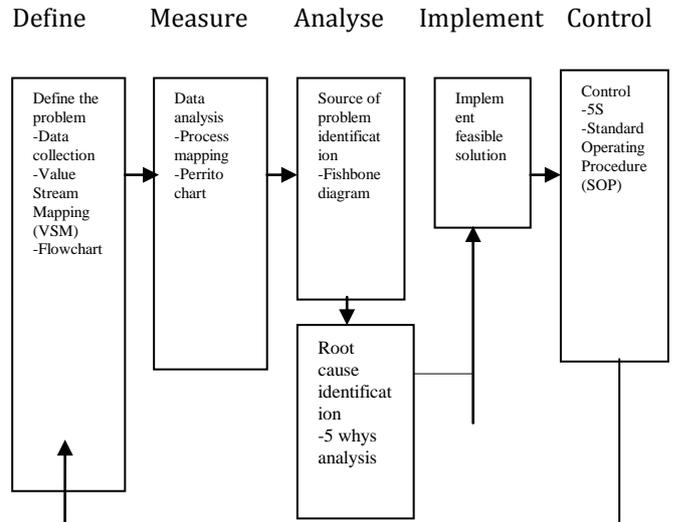


Fig. 4: Methodology of Lean Six-Sigma. [1]

The Lean Six Sigma framework as shown is simply an easy form of DMAIC methodology with using certain lean tools in each phase to analyze the problem and to find out improvement opportunities.

**A. Define the problem**

Collect the data using suitable sources for understanding the current scenario, perform Value Stream Mapping (VSM) which will help in understanding which stages of the process actually add value to the product and go through the Flowchart thoroughly in order to find the stages where attention is to be drawn.

**B. Measuring by data analysis and identification of problem source**

Data collected in the previous stage should be analyzed using tools such as process mapping and Pareto analysis.

**C. Analyze the problem**

At this stage identification of root cause of the problem is essential. This can be achieved by using tools such as Fishbone diagram and 5 Why analysis.

**D. Improve the process**

This stage aims at implementing a feasible solution. Under the Indian Industrial scenario, the most important stage is the involvement of employees for Brainstorming sessions

for achieving smooth implementation of the improved process.

#### E. Control

It is essential to ensure that the improved process is not only followed but the final product attains the improved levels of quality. This can be achieved by controlling the process and more importantly continuously optimizing it to constantly reduce the process variations. Use of tools such as Standard Operating Procedures (SOP), 5S and Kaizen play a vital role.

#### • Implementation of Lean Six Sigma(LSS) [12]

Every customer values the product with quality, speed and low cost. If any business wants to achieve the highest levels of quality for their product or service, it must follow the path which contributes to the speed of the process as no. of defects results in lengthen the process. Low quality and low speed is what makes the processes and thereby also products and services costly.

For the implementation of LSS methodology the key part is all departments' employees & management. The successful implementation of Six Sigma quality management in an organization leads to process variations, quality and productivity improvement.

Lean Six Sigma (LSS) strategy can be applied in all process areas such as production, design, sales, marketing, services and procurement with quite many advantages. Some of these advantages are 1) to reduce costs 2) to reduce delivery time 3) to reduce inventory levels 4) to improve customer satisfaction 5) to reduce product cost (10 to 25 percent) and more powerful and robust designs. Another point to note is that the increase in the level of each Sigma level means a 5% increase in the net profit of the company.

#### • Case Study

In the automobile sector, Bajaj Auto is one of the biggest company in India. In the period of 1980 to 90, the company's manufacturing model gave output in form of inefficiencies, higher costs and a large inventory with quality issues. Then in 90- 2000s, because of rising competition in the market and growing customer expectations make the company adapt lean manufacturing and statistical process control (SPC) techniques in manufacturing operations.

The lean manufacturing began reorganization and redesigning of the company. With the objective to create a high performing organization by restructuring, re-staffing and establishing a performance management system and to reduce purchasing and conversion costs. The major aim was to boost the top line 100 per cent and bottom line 10 per cent.

The action taken to a lean manufacturing process resulted in significant gains for the company. Company's

productivity rose 10 times. The company could to minimize the inventory for raw materials from one week to half a shift stock. The material required for final products was cut down from one month to three days. The number of rejected items was reduced from 20,000 parts per million (PPM) to less than 2,000 PPM. ([www.ibef.org](http://www.ibef.org)).

#### IV. CONCLUSION

Lean is performance through continuous improvement and continuous improvement by waste elimination. Six-Sigma is a quality improvement approach that aims to reduce the number of defects up to 3.4 parts per million. In the last some decades, lean six sigma helped many companies to enhance the capability of their processes and to increase the level of quality of their product or service. In this paper, the concept and methodologies of lean manufacturing, six sigma tools were discussed. Which when combined turn into an even powerful tool called lean six sigma. Lean six sigma methodology is a powerful tool for improving the quality, output of the process and the design of the product. Therefore, it can be concluded that the manufacturing industry needs to give more attention to implement lean six sigma in all the key areas. Hence, with adequate lean education, training, in association with manufacturing industries are to stimulate the lean awareness in all type of manufacturing industries.

#### REFERENCES

1. Mr. Harun Pinjari, Dr. S.N.Teli, Mr. Lokpriya Gaikwad "Lean Six Sigma Applications" Research gate, <https://www.researchgate.net/publication/322499581>
2. Christopher Fritze "The Toyota Production System", January 2016, pp. 1-13.
3. Luca Cagnazzo, Paolo Taticchi, "Six Sigma: a literature review analysis", December 2009, Research gate, pp. 1-7, <https://www.researchgate.net/publication/262354890>
4. [https://www.ibm.com/developerworks/bpm/bpmjournal/1308\\_col\\_schume/1308\\_schume.html](https://www.ibm.com/developerworks/bpm/bpmjournal/1308_col_schume/1308_schume.html)
5. Rahul S. Mor, Sarbjit Singh, Arvind Bhardwaj, "Learning on Lean Production: A Review of Opinion and Research within Environmental Constraints", Operations and Supply Chain Management, Vol. 9, No. 1, 2016, pp. 61 – 72
6. Virender Chahal, M.S. Narwal, "An empirical review of lean manufacturing and their strategies", Management Science Letters 7 (2017) pp. 321–336
7. Dr. Ashish Thakur, "A Review on Lean Manufacturing Implementation Techniques: A Conceptual Model of Lean Manufacturing Dimensions", REST Journal on Emerging Trends in Modelling and Manufacturing 2(3) 2016, pp. 62-72
8. Mr. Ganesh P. Jadhav, Mr. Sandeep B. Jadhav, Mr. Amol Bhagat, "Six Sigma DMAIC Literature Review", International

Journal of Scientific & Engineering Research, Volume 6, Issue 12, December-2015.

9. 1Lakkamaneni Venkatesh, 2Dr. K. Ravindranath, "An Application of Six Sigma DMAIC and DMADV Methodologies in a Two-wheeler Lead Acid Battery Manufacturing Industry", International Journal for Research in Engineering Application & Management (IJREAM),

10. Rohail Hassan, Maran Marimuthu and Manmeet Mahinderjit-Singh, "Application of Six-Sigma for Process Improvement in Manufacturing Industries: A Case Study", International Business Management 10 (5), © Medwell Journals, 2016.

11. J. Hill, A. J. Thomas, R. K. Mason-Jones & S. El-Kateb, "The implementation of a Lean Six Sigma framework to enhance operational performance in an MRO facility", ISSN: (Print) 2169-3277 [Online]. Available: Journal homepage: <https://www.tandfonline.com/loi/tpmr20>

12. Marta Kučerová, Miroslava Ml̄kva, Dagmar Rusková, "Lean six sigma implementation in industrial companies", ISSN 2029-9575 Quality Issues and Insights in the 21st Century Vol. 2, No. 1, 2013.

#### AUTHORS PROFILE



**Swati Sabale**, Chemical Engineer, I'm working as an engineer in Hypro engineering Pvt. Ltd, Pune, India. I have 5 years of experience in the engineering field.



**Santosh Thorat**, M.S. (Pharm), I'm working as a specialist in Deva Holding, Turkey. I have completed B. Pharm and M.S.Pharm and have 5 years experience in the research field.