International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Lean Six Sigma: An integrative approach of Lean and Six Sigma methodology

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Accepted 01 Nov 2015, Available online 05 Nov 2015, **Vol.5, No.6 (Dec 2015)**

Abstract

In this cutthroat competition the aim of every organization is to achieve excellence in terms of quality, delivery and customer satisfaction. Most of organizations have applied either lean or six sigma. But adopting any one can reach only a state of diminishing return and beyond that integration is only the option. Lean focuses on eliminating waste and so ensure smooth and uninterrupted flow which offer speed and flexibility. On the flip, six sigma is extensive data driven methodology which mainly focus on reduction of variation and deliver product of superior quality as defined by the customer. Integrative approach called as Lean Six Sigma (LSS) overcoming limitation and retaining most of strength of each strategy, which integrate human and process aspect in which lean effectively work with flow of material and information and six sigma address poorly performing value adding transformations. By this organization can create win -win situation.

Keywords: *Lean, Six sigma, Lean six sigma, Lean tools, DMAIC, Road map for LSS*

1. Introduction to Lean

Definition

Lean is defined as identifying activities, bifurcating it into value added and non-value added, try to eliminate non value added activities through eliminating waste and continuous improvement so product/process/service can flow seamlessly.

Objective

1. Improve product flow or reduce lead time through eliminating waste (Muda) by continuous improvement (Kaizen) or radical improvement (Kaikaku)
2. Do the right thing right the first time that means focus on mistake proofing (pokayoke) by adopting technique of source inspection.
3. Improve productivity, reduce inventory

History and Background

Lean manufacturing, also known as the Toyota Production System (TPS), was originated by Taiichi Ohno and Shigeo Shingo at Toyota. The concept was originated in 1950'S,but not become documented and popular till 1990,when the book The Machine that Changed the World was published it compare various Japanese system with western culture system and then around the globe different lean manufacturing system become familiar and gain attraction towards implementation for becoming a part of cutthroat competition.

Overview

Lean manufacturing believes the simple fact that customers will pay for the value of services they receive, but will not pay for mistakes. (K. Venkataraman et. al ,2014)

Lean focus on efficiency aiming to produce product/service as fast as possible and at lowest cost, For that it use set of tools and techniques which identify waste and eliminate it so that make benefits like reduce lead time, set up time, equipment down time.(J. Antony,2011)

S. J. Pavnaskar *et al*. (2003) discussed classification scheme for lean tools. He proposed one scheme in which according to 7 criteria any lean tool (approx. from 101) can easily classify and one can studied how to use, where and when to use these different types of tools according to its classification.

Two basic lines of lean manufacturing are "respect to the workforce" and "waste elimination. Simultaneous application of both principles results in the elimination of waste, called "muda" in Japanese. Lean means "manufacturing without waste"(Taj & Berro, 2006). Waste is defined as: activities and behaviours that add cost but do not add value.8 waste (Womack & Jones, 2003), (M. Taleghani,2010)

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(1) Motion: movement of people that does not add value
(2) Waiting: idle time created when material, information, people or equipment is not ready.
(3) Correction: work that contains defects, errors, reworks mistakes or lacks something necessary.
(4) Over – processing: effort that adds no value from the customer's viewpoint.
(5) Over – production: Producing more than the customer needs right now.
(6) Transportation: movement of product that does not add value.
(7) Inventory: more materials, parts or products on hand than the customer needs
(8) Knowledge: workforce is not confident about the best way to perform tasks.
Lean manufacturing combines the best features of both mass production and craft production that means it is suitable for mass production and one can achieve benefit of low cost at same time it can provide wide range of product. (S. J. Pavnaskar *et al*.,2003)

Lean Tools

There exists a plethora of different tools and techniques from easiest one 5'S to complex kanban, kaizen, pokayoke, cellular manufacturing, single piece flow, inventory management, standardization of work etc.

Survey of J. V Kovach *et al*. (2011) on US industries shows that companies using 75% of times lean tools to solve their problem and in manufacturing the use of tools is approximately double than in service sector. Order of preference of lean tools :(1) 5'S (2)VSM (3)standardization of work (4) Kanban (5) Pokayoke (6) SMED. T. Melton(2005) also discusses key tools of Lean and that are similar to this so we are going to discuss each of this six tools in this review.

5S

It is series of activities designed by Japanese to organise the work environment so that everything is visual and problems are not covered up.it is expressed by 5 Japanese words which are starting with S that are,
Seiri: Sort (eliminate unnecessary item from workplace, if you don't use it, move it)
Seiton: Set in Order/Straighten (focus on effective and efficient storage method, concept of PEEP that is a place for everything and everything in its place is applicable here)
Seison: Shine/Sweep (thoroughly clean the work area, Daily follow up cleaning is necessary)
Seiketsu: Standardize (establish best manufacturing practise in your work area)
Shitsuke: Sustain/Self-discipline (Most difficult S out of 5, generally human are reluctant to change)
The greatest feature of 5S approach is that it is simple; for that reason it easily finds area of application. Forming a ground for the other improvement activities, 5S is an important term that carries priority in improvement at a company.it is useful in simplifying work environment, reduce waste, improving quality and safety.

VSM (Value Stream mapping)

Lean employee VSM as central tool which is a paper pencil approach to map current state by analytical method, Nowadays it has also incorporate various software to made work easy. Value Stream Mapping (VSM) is the visual process of mapping the material and information flows required to coordinate the activities performed by manufacturers, suppliers and distributors to deliver products to customers. First and foremost step of any improvement should be drawing VSM. Current state map describe flow of process as well indicate process time, lead time, inventory, waiting time etc. so by visualizing it one can easily identified value added and non-value added activity, this NVA is source of waste and gives idea about next step that is which tools should be used to eliminate it and provide basis for implementation plan. Next step in VSM is to draw a future state map based on improvement plan. The availability of the information in the VSM facilitates and validates the decision to implement lean tool and can also motivate the organization during the actual implementation in order to obtain the desired results.

Standardization of work

By effective utilization of resources carry out job in safest mode and in shortest time efficiently (R. Sundar *et al*.,2014). Develop SOP (standard operating procedure) that document all necessary detail related to job. Like process, standard time, safely moves etc. It is also considered as basic tool for continuous improvement.

Kanban

Kanban is a Japanese word which means visible record or part. (N. Azian *et al*.,2013) Kanban as a tool may control the levels of buffer inventories in the system to regulate production. When a buffer reaches its pre-set maximum level, the upstream machine is told to stop producing that particular part type.it can be considered as a visual signal to support flow by 'pulling' product through the manufacturing process as required by the customer. The Kanban system requires production only when the demand of products is available that means it is working on concept of pull and it can be consider as one part of JIT. Kanban system provide mixed model production along with optimal inventory level which results in less lead time in product delivery and effective utilization of resources such as man, machine etc.

Pokayoke

Poka-Yoke method was introduced by Shigeo Shingo in 1961(M. Dudek-burlikowska,2015) to prevent mistake or error before it becomes waste. Design system such

that by mistake even one could not do mistake.it is one of the principles of ZQC (Zero Quality Control) Poka-yoke has three basic functions to prevent or reduce defects: shutdown, control, and warning.

There are two approaches of pokayoke

1. Control method: defect is already occurred and it is calling for defect detection and controls it, otherwise there is chance of producing more defects and scrap.
2. Warning method: defect is about to occur so predict as soon as possible, so error resolved quickly before it is converted in to mistake.

Single minute exchange of die (SMED)

Due to increasing demand of variable parts industry has pressure to produce part in small size and it is only possible when set up time is less. Do not interpret that it means die should be changed over in one minute it should be in single digit. 5'S in context of SMED helps to reduce searching time during change over.

Shingo defines 3 stage of SMED (Y. Dave,2012)

(1) Identify internal (internal means when machine is stopped) and external activity (external means when machine is running)
(2) Try to convert internal activities in to external one
(3) Stream line the process of change over.

Shortcomings of lean

1. Many a times it fails in giving bottom line results.
2. For achieving high capability lean is not useful
3. People misconceptualize by its name and understood as layoff at that time it is very hard to take support of them in lean activities.
4. It is not used extensive data rather culture transition.

2. Six Sigma

A brief history and overview

The origin of six sigma methodology lies in problem solving method of Motorola which is developed by Bill Smith in mid-1980's who was engineer and statistician at Motorola. As per them they have applied MAIC (measure, analysis, improve, control) to solve the problem, later on GE applied the same method and add D (D stands for definition) and named as DMAIC methodology which is very popular methodology nowadays for problem solving and achieving bottom line results.(A. Shahin,2008)

According to A. Mousa(2013), six sigma can be considered as new management strategy under the leadership of top management, by applying this company can improve their bottom line drastically.
Six sigma is a well-established approach that seeks to identify and eliminate defects,

Mistakes or failures in business processes or systems by focusing on those process performance characteristics that are of critical importance to customers (Snee, 2004), (A. J. Thomas *et al*.,2009) he has discussed 4 aspect of this strategy which are adding to any other previous strategy and which make this one more popular: clear focus to bottom line, well defined road map, integrating human and process aspect and linking power to apply tools and technique in sequential manner.

There are two perspective of six sigma

Statistical view point

Sigma is statistical major which denotes variation and symbolize as "σ". When defects produce are less than 3.4 per million opportunities then it can be said process is operating at six sigma level under the assumption that the process average may shift over the long term by as much as 1.5 standard deviation. (D. A. Desai and M. B. Patel,2013)

Business view point

In context of business world, it can be consider as business strategy to satisfy costumer in fullest way and parallely improve business profitability. (Y. Hoon and F. T. Anbari,2004)

Need to operate at six sigma level

Suppose assume that company is operating at 3 sigma level that means it is producing approx. 3000 defect per millions of product. Now assume that the component is very tiny and so important as if it is not working then model is not working and 1 model needs 1000 of component.in this condition by operating at three sigma means only 5% products are defect free probably.so three sigma is considered as minimum design standard and companies are striking to achieve level of six sigma.(E. D. Arnheiter and J. Maleyeff,2005)

A six sigma is good initiative by top management which is designed to change the culture via break through improvements by focusing on thinking out of the box in order to achieve strategic goals. When successfully applied, it results in to gain of knowledge and capital which finally transform into shared bottom line result.

Based on simple statistics six sigma gives discipline, structure and foundation for solid decision making. The real power of six sigma is simple because it combines people power with process power. Mostly it focus on improving quality and process capability by minimizing defects and variation in manufacturing process (E. Kabir *et al*.,2013)

Y. Hoon and F. T. Anbari (2004) said that wide spread application of six sigma is possible because one can draw benefits in term of financial cost saving as well as process improvements.

Not all process necessary to operate at six sigma level. If process is operating at lower sigma level that is 2 or 3 sigma level than it is easy to achieve goal of 4 sigma by adopting simple tools but when one want two go beyond 4 or 5 than much more efforts and more statistical tools are become prerequisite and effort and difficulty increase exponentially as the process sigma increase.(K. Linderman *et al*.,2003)

Approaches of Six sigma

There are mainly 2 Roadmap for six sigma methodology:

1. DMAIC: This approach was originated at Motorola but coined by GE by adding D in MAIC methodology.(R. Banuelas,2005)
D: Define: (1) define the scope and boundaries of the project (2) Define Project charter which includes various details such as Process definition, Business critical i.e. how it is related with goal, benefit impact, describe the scope and boundaries of the project., list the key milestones activities with dates, support required (3) estimate the impact of the project in monetary term.
M: Measure: Mapping the current process, in general this phase measure current sigma level of the industry and mostly DPMO approach is used for this measurement.
A: Analyses: Data collection at measure phase serves input for analysis phase. Main aim of this is to identify root cause of the problem. Many techniques such as cause and effect diagram, Tree diagram, why- why analysis is popular in this context.
I: improve: identification of alternative improvement; implementation of the best alternative for improving the process; validation of the improvement. Use statistical tools such as DOE (design of experiment), Robust design concept etc.
C: Control: The intent of an effective control plan strategy is to operate the temporal or sustained solutions consistently, on target, with minimum variation and while minimizing process over-adjustment. Use of control charts is beneficial here. It also helps to assure the identified and implemented process improvements become institutionalized by providing adequate training in all procedures. Provide SOP (how to do operations), Reaction plan (if setting failed how to readjust) and once again measure performance.

2. DFSS

This approach is used when existing product does not satisfy the customer and for achieving strategic objective of business it is mandatory to develop new method or product. The methodology is known as Design for Six Sigma.

Versions of DFSS (A. Shahin,2008)

DMADV (Define, Measure, analyze, Design, Verify)
IDOV (Identify, Design, Optimize, Validate)
DCOV (Define, Characterize, Optimize, Verify)

Although names are different but basic tools and fundamentals are same.

There are many version of DFSS are popular but in general DMADV is used. DMADV is similar to DMAIC. (A. Shahin,2008)

D: Initiate and plan project by using Team charter
M: Capture need: QFD (Quality function deployment)
A: Developing design concept
D: Detail design
V: implement full screen project after pilot product

IDOV suggested by GE and many company are using this E.g. Samsung, Ford. In this methodology after each stage there is design review to decide to go for next step or not. (A. Shahin,2008)
I: identify CTQ (critical to quality) by VOC (voice of customer), QFD, Benchmarking
D: Design: Robust design, DOE (design of experiment), CAD
O: Optimize: verification of technology: FMEA (failure mode effect analysis)
V: Verification of mass production

Boundary of six sigma

1. Only top level people are involve in decision making so facilitator may be disconnected from shop floor and many decision practically not work over shop floor.
2. Eliminate defect in the process but will not say how to optimize process.
3. People misinterpret that it is alike as TQM, features are same only test is new and so not adopt properly.
4. Many a time industries achieve highest level of quality but fail in delivery management.

3. Lean Six Sigma

Evolution of Lean Six Sigma

Until 1990, Lean and Six Sigma treated individually. Many firms has applied either lean or Six Sigma successfully and achieved great benefits ,but company, using just one approach can reach a point of diminishing return and if they want to go beyond it they have to use this integration approach in which reduction in process variation achieve by six sigma and elimination of non-value adding activity by lean.so this integrative approach came into picture which is called as “Lean Six Sigma Approach” and it can be considered as latest generation improvement approach. In more precise term LSS can be defined as business strategy and methodology which increase process performance and so improve bottom line result (R. D. Snee,2010).

Literature Review

Lean six sigma helps company in a new world where customer expect defect free product at earliest time with minimum cost. Six sigma involve few specific individual ,mostly top level people, where as lean involves each and every people from shop floor level to top level to participate in lean program and identify, eliminate waste. So by integration of two methodologies employee can feel ownership of process (A. Mousa,2013)

According to B. Smith(2003), Using lean tool create one piece flow, this issue is referred as "low hanging fruit", picking that fruits clear the branches so that one can easily visualize the challenges that require six sigma approach using statistical tools to uncover the unseen roots of the problem.

By integration model companies across the entire world found most efficient way to eliminate flows that leads to rejection, rework or scrap and create united idea of continuous improvement that address many of weakness and use most of strength of each fundamental concept that is lean as well as six sigma.

M. P. J. Pepper and T. A. Spedding (2010) Said that aligning the cultural aspects of lean with the data driven statistics of sig sigma hold huge potential in a bid for a genuine and sustainable approach to organizational change and process improvement. The integration of these two aspects addresses every type of opportunity for improvement within an organization. If any one of them only implemented in organization then outcome can result in neither being done effectively; constrained by one another's needs in the organization.

Which approach should apply first or in which sequence is depending on and choice of organization. In many case lean apply first and then six sigma, like lean evaluate option than in six sigma, cause and effect dia. on contrary, in some case reverse is also possible.
Lean and six-sigma complementing each other in order to improve enterprises processes and achieves goals. This integration has been achieved blending their methods and principles using the DMAIC cycle as the conjoint continuous improvement framework and conjointly making efforts to reduce production defects and process variability along with process simplification, standardization and waste reduction. (A. Tenera and L. C. Pinto,2014)

Synergy between Lean and six sigma

Parameter	Lean	Six sigma
Process improvement	Reduce variation	Improve flow in process
Primary objective	Cost reduction	Lead time reduction
Secondary objective	Customer satisfaction, Achieve business goal	Reduce WIP(Work in process) inventory, improve productivity
Road map	Define, Measure, Analysis, Improve, Control or Define, Measure, Analysis, Design, Verify	Define value, identify value, Value stream mapping, pull, perfection
Fundamental Theory	No defect	Eliminate waste
Involvement of People	Only fewer top level	From shop floor to Top level
Aspect	Cultural	Data driven

Comparing Lean and Six Sigma

Lean can be considered typically as an approach for inter process improvement, i.e. lean principle are most effective when deal with flow of information and material while six Sigma used for intra process improvement, i.e. it address poorly performing activity and by reducing variation improve quality.

Lean with Six sigma

Lean can take decision on basis of extensive data by incorporating ix sigma. E. D. Arnheiter and J. Maleyeff (2005) discussed one example in which company using lean manufacturing method to control process, and on basis of go no go gauge passes the products, Product made in this plan are according to conformance but when it is placed at assembly many are not fit due to close tolerance problem.in other plant they are using control charts and process are nearer to target and it is better than the previous one. So it proved that by collecting and analyzing variable measurements using control charting methods, processes can be effectively kept on target. A comparison of control charts and pre-control shows that under most conditions, control charts are better suited for keeping processes on target.

Six sigma with Lean

In this cutthroat competition only high quality goods cannot help to win the market but high quality of service is also mandatory. When company are ready to work on batch mode and provide quality at six sigma level, risk of poor customer service can reduce by implementation of lean management which identify waste by incorporation of various lean tools and reduce lead time which will improve inventory turnover leads to improve revenue and enhance competitiveness by meeting promise date and giving fast delivery.

Road map for integration model

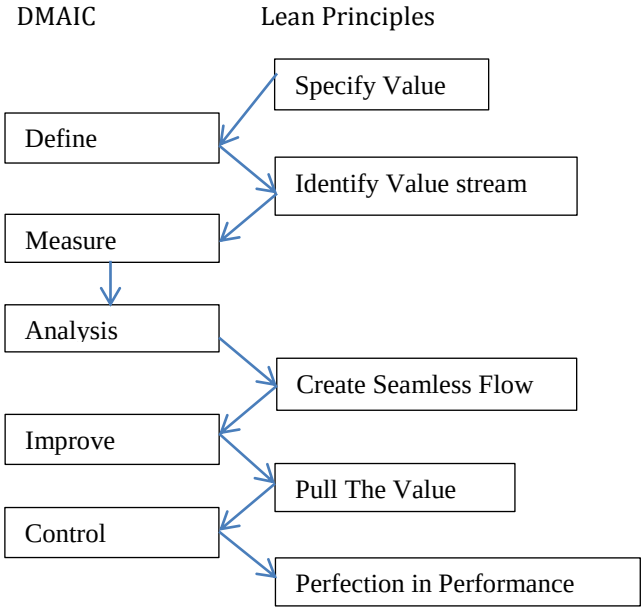
Literature review focus on the fact that integration of two systems can achieve better result than either system could not achieve alone. If sig sigma is applied only than facilitator is not in constant touch with shop

floor people and take decision on basis of historical data only while by incorporation of lean, facilitator go on shop floor, understand actual condition, do mapping and then take decision and it is always more practical rather to take by only observation of data.

Literature review focus on the fact that till now there is no generic integrative model which gives step by step implementation plan, Many gives LSS model according to their requirement but not a generic one.in next step we are going to discuss one such a model which use DMAIC methodology of six sigma with principles and tools of lean.

Steps

1. Specify value: Identify value for customer by VOC (Voice of Customer) or by applying QFD (Quality function deployment) because customer finally wants value for his money and aim of integration model is to satisfy customer by providing high quality product with fast delivery at minimum cost.
2. Define: Identify Problem, Use pareto analysis, Brainstorming conducted to identify CTQ (critical to Quality) based on VOC and develop Project charter which state scope and boundary of the projects.
3. Value stream mapping: A value stream map is a visual representation which enables one to determine where the waste occurs. Value stream maps are utilised to assess current manufacturing processes which will give opportunity of improvement. It is also called as process mapping



4. Measure: Measure current state by identifying value adding and non-value adding activity, bottlenecks, defects. Use some statistical tools and derive current sigma level of process. (E.g. DPMO approach)
5. Analyze: Objective is to determine the root causes of defects and identify the significant process parameters causing the defect .Brain storming session followed by cause and effect diagram helps to identify root cause then draw pareto chart and use prioritization matrix.
6. Create value flow: Apply some lean principle such as 5'S, Kaizen etc. to eliminate waste and make value flow seamlessly.
7. Improve: Apply some statistical tool such as DOE (Design of Experiment) and identified different solution, prioritize and implement one or combinations of solution to improve current state.
8. Concept of pull: Improved solution must add value in the product and must satisfy customer need that is excellent in quality as well as per need customer can get the products in less span and lean principle reduce lead time so made JIT possible means conformance to pull concept.
9. Control: If organization want to sustain this culture of excellence than this step is very important in that concern. Control activity such as control chart, process capability index etc. helps to visualize variation and take corrective action before error become defect.
10. Perfection: Adding some lean technique such as line stopping whenever mistake made or pokayoke helps to identify error even at first time and perfection in performance.

Requirement for successful Deployment of Lean Six Sigma

If company want to achieve maximum shares that is better position in the market than it is mandatory to have some assets, resources and skills. For successful deployment of lean six sigma company require personal and corporate competencies

1. Personal competency: it means company need to have work force with sound technical knowledge.

2. Corporate competency: combinations of skills, knowledge, experience that enable firm to implement change program successfully.

How to ensure success of Lean Six Sigma project?

1) Lean Six Sigma deployment success: if project is succeed then it reflects success of Lean Six Sigma programme. Another way to represent success is by stock price. Companies defined success by many different ways like, in terms of customer satisfaction, financial gain, reducing cost, improving quality etc.
2) Using technical and interpersonal skills of deployment facilitator i.e. Master Black belt
3) Using technical and interpersonal skills of Project leader i.e. Black belt
4) The organizational competence measured by the adherence to the various critical success factors.

Conclusion

Integration of two most popular programs helps organization to survive in market (financial crisis) which helps to reduce costs and keep the cash flowing. Both methodologies focused on quality and process

improvement, six sigma gives clear road map while lean gives direction for the road map. There is little work has been done so far in this area, but in upcoming years it will developed at its fullest. Many companies have followed lean six sigma methodology and also achieved drastic improvement. From the literature review done and authors' knowledge, till now there is no generic model available to describe step wise process for implementation of LSS program, so this model can be useful for organization who wants to apply LSS approach and become base model for future research. Although Validation of model is still on progress but in further research we can apply this model on any case and measure improvement will suggest its validation

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