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Integrating Lean and Six-Sigma framework for Process Improvement

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Abstract - The purpose of this conceptual paper is to provide the key tools of Lean and Six-Sigma and their implementation into both manufacturing and service organizations. Lean is a principle-based management philosophy focused on customer value, planned elimination of all waste, and continuous improvement of productivity and cycle time. Six-Sigma is a management philosophy that targets reducing variation and defects in a process. Lean Six-Sigma (LSS) is a combination of the two process improvement methods. Lean, focused on reducing lead time by removing waste and non-value added steps and Six-Sigma, focused on reducing variability and defects by identifying and controlling its causes. Employed together, you can increase speed, process capability, and customer satisfaction.
Keywords – Lean, Six-Sigma, Customer Satisfaction.

I. INTRODUCTION

Lean is a set of problem solving tools to reduce or eliminate activities that don't add value to the process. It emphasizes removing wasteful steps in a process and taking only value added steps. The Lean method ensures high quality and customer satisfaction. It is a never ending process of waste removal. Six-Sigma is a data driven problem solving methodology. The focus is on process variations and emphasis is given to customer satisfaction. Continuous process improvement with low defects is the goal of this method. Lean Six-Sigma (LSS) combines the strategies of Lean and Six-Sigma. The principles of Lean Six-Sigma help to improve the efficiency and quality of the process.

In this management approach, the lean methodology is used first to remove the waste in a process. After this is complete, the Six-Sigma tools are used to improve process variations. The combination of these two methods helps to develop streamlined processes with high quality.

The LSS management approach finds wide application across industries. It leads to rapid changes in an organization's performance. It has become popular in various companies in the world. They can be product or service oriented companies. The LSS method has improved processes making them efficient. This is possible because of total employee involvement and commitment to customer satisfaction.

II. LEAN & LEAN TOOLS

Lean is popular for its methodical approach to streamlining both manufacturing and service processes by eliminating waste while continuing to deliver value to customers. Lean is a set of problem solving tools to reduce or eliminate activities that don't add value to the process. It emphasizes removing wasteful steps in a process and taking only value added steps. The Lean method ensures high quality and customer satisfaction. It is a never ending process of waste removal.

Waste is any step or action in a process that is not required to complete a process (called "Non Value-Adding") successfully. When Waste is removed, only the steps that are required (called "Value-Adding") to deliver a satisfactory product or service to the customer remain in the process. Here are several ways that resources can be wasted. The Lean approach divides these into eight key areas of potential waste that might occur in any process. Once identified, they can be reduced or eliminated.

Defects – Products or services that are out of specification that require resources to correct.

Overproduction – Producing too much of a product before it is ready to be sold.

Waiting – Waiting for the previous step in the process to complete.

Non-Utilized Talent – Employees that are not effectively engaged in the process

Transportation – Transporting items or information that is not required to perform the process from one location to another.

Inventory – Inventory or information that is sitting idle (not being processed).

Motion – People, information or equipment making unnecessary motion due to workspace layout, ergonomic issues or searching for misplaced items.

Extra Processing – Performing any activity that is not necessary to produce a functioning product or service

When Japanese companies talk about waste they usually talk about the three M's; Mura, Muri and Muda. While most people who have had contact with lean manufacturing will have been made aware of the 7 wastes and Muda

they often have not been introduced to Muri and Mura at all. Yet these wastes are often far more important to tackle than Muda and often are the underlying causes of the Muda that you observe within your processes. While Muda is the non-value adding actions within your processes; Muri is to overburden or be unreasonable while Mura is unevenness.

III. M'S (MUDA; MURI; MURA) –

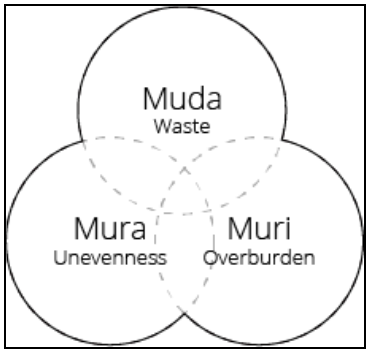
Any activity in your process that does not add value is known as Muda. Muda is not creating value for the customer. In short: WASTE.

Type I Muda: Non-value-added tasks which seem to be essential. Business conditions need to be changed to eliminate this type of waste.

Type II Muda: Non-value-added tasks which can be eliminated immediately.

Any variation leading to unbalanced situations is known as Muri. In short: UNEVENNESS, inconsistent, irregular. Mura exists when workflow is out of balance and workload is inconsistent and not incompliance with the standard.

Any activity asking unreasonable stress or effort from personnel, material or equipment is known as Mura. In short: OVERBURDEN. For people, Muri means: a too heavy mental- or physical burden. For machinery Muri means: expecting a machine to do more than it is capable of- or has been designed to do. Usually the three of them cannot be seen separate. When a process is not balanced (Mura), this leads to an overburden on equipment, facilities and people (Muri) which will cause all kinds of non value adding activities (Waiting is also an activity!!) thus leads to Muda. To eliminate Mura and Muri, larger parts of the system need to be looked upon, not only a process or process step or operation, but at an entire Value Stream. VSM or 'Process Kaizen' eliminates Muda.



3.1Muda, Mura and Muri

5 S (Seiri, Seiton, Seiso, Seiketsu and Shitsuke) –

5 S is one of the most powerful Lean Manufacturing Tools. It is split into 5 phases, each named after a different Japanese term beginning with the letter "S"; hence the name 5 S. It is a simple tool for organizing your workplace in a clean, efficient and safe manner to enhance your productivity, visual management and to ensure the introduction of standardized working. It was developed in Japan and was identified as one of the techniques that enabled Just in Time manufacturing.

Sort (Seiri) – Distinguishing between necessary and unnecessary things, and getting rid of what you do not need.

Set in Order/Straighten (Seiton) – The practice of orderly storage so the right item can be picked efficiently (without waste) at the right time, easy to access for everyone. A place for everything and everything in its place.

Shine (Seiso) – Create a clean worksite without garbage, dirt and dust, so problems can be more easily identified (leaks, spills, excess, damage, etc).

Standardize (Seiketsu) – Setting up standards for a neat, clean, workplace.

Sustain (Shitsuke) – Implementing behaviors and habits to maintain the established standards over the long term, and making the workplace organization the key to managing the process for success.

5 S (Seiri, Seiton, Seiso, Seiketsu and Shitsuke)

3.2 Andon Cord –

Andon means 'Sign' or 'Signal'. It is a visual aid which alerts and highlights where action is required. Think, for example, a flashing light in a manufacturing plant that indicates the line has been stopped by one of the operators due to some irregularity. The Andon is activated usually by a pull-chord or button, which automatically halts production so that the team can gather, apply PDCA and root cause analysis, and then quickly apply a solution. The warning lights are incorporated into an easily visible, overhead signboard, which also identifies the area or specific workstation that has the problem.

3.3 One-Piece Flow –

One-Piece Flow is also known by various other names such as the following: One-piece Flow; Make-one, Move-one; Single-piece Flow; Continuous Flow; Flow Manufacturing. One-Piece Flow comes from the Toyota Production System (TPS). TPS emphasizes right-sizing your batches because batches that aren't the right size leads to queues, which leads to waiting time, which leads to poor space or resource utilization, increased Work-in-Process (WIP) or Things-in-Process (TIP), longer cycle times, which are all forms of wastes or muda.

On the other hand, the Batch-and-Queue approach teaches us to build stuff, let it queue in front of the next step, all throughout the system. Batch-and-Queue systems lead to poor space utilization because of the batches of work waiting to be served that take up space on the production floor, longer cycle times, a higher probability of defects because you build stuff and let it sit and, lower morale because batch-and-queue leads to large sizes of work-in-process, not finished goods — the psychological message is that you've created a bunch of unfinished stuff, further burdening the team with thoughts of "man, we have so much more to do."

Moving products through a production system without separating them into lots is known as One Piece Flow. This approach is much better because there's no waiting involved, cycle time is shorter because I'm completing job at each motion, and I feel better because I can visually see what I have completed.

3.4 Poka-yoke –

It is a Japanese term that means mistake-proofing. A poka-yoke is any mechanism in a lean manufacturing process that helps an equipment operator avoid (yokeru) mistakes (poka). Its purpose is to eliminate product defects by preventing, correcting, or drawing attention to human errors as they occur. In other words, once the root causes are known through root cause analysis and the 5 Whys, then Poka-Yoke can be an applied countermeasure to make sure the error doesn't happen again. The concept was formalized, and the term adopted, by Shigeo Shingo as part of the Toyota Production System. It was originally described as baka-yoke, but as this means "fool-proofing" (or "idiot-proofing") the name was changed to the milder poka-yoke.

3.5 Kaizen –

Kaizen (Continuous Improvement) is a strategy where employees at all levels of a company work together proactively to achieve regular, incremental improvements to the manufacturing process. In a sense, it combines the collective talents within a company to create a powerful engine for improvement. Kaizen is part action plan and part philosophy.

a) As an action plan, Kaizen is about organizing events focused on improving specific areas within the company. These events involve teams of employees at all levels, with an especially strong emphasis on involving plant floor employees

b) As a philosophy, Kaizen is about building a culture where all employees are actively engaged in suggesting and implementing improvements to the company. In truly lean companies, it becomes a natural way of thinking for both managers and plant floor employees.

Kaizen works hand-in-hand with Standardized Work. Standardized Work captures the current best practices for a process, and Kaizen aims to find improvements for those processes.

3.6 Kanban –

Kanban is Japanese for "visual signal" or "card." Toyota line-workers used a kanban (i.e., an actual card) to signal steps in their manufacturing process. The system's highly visual nature allowed teams to communicate more easily on what work needed to be done and when. It also standardized cues and refined processes, which helped to reduce waste and maximize value.

3.7 Just In Time –

Just-in-time (JIT) is an inventory strategy companies employ to increase efficiency and decrease waste by receiving goods only as they are needed in the production process, thereby reducing inventory costs. This method requires producers to forecast demand accurately. It ideally controls the entire value chain from the supplier to the end consumer. In this way, it helps avoid supply disruption and overstocking of goods at various stages of the manufacturing process. Kanban requires continuous monitoring of the process. Particular attention needs to be given to avoid bottlenecks that could slow down the production process. The aim is to achieve higher throughput with lower delivery lead times. Over time, Kanban has become an efficient way in a variety of production systems.

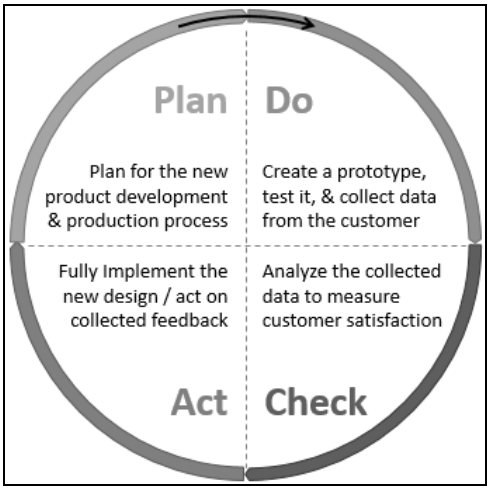
3.8 PDCA (Plan, Do, Check, Act) –

PDCA, sometimes seen as plan-do-check-adjust, is a continuous quality improvement model consisting out of a logical sequence of four repetitive steps for continuous improvement and learning: Plan, Do, Study (Check) and Act. The PDCA model is also known as the Deming circle/cycle/wheel, Shewhart cycle, control circle/cycle, or plan–do–study–act (PDSA).

During,

a) Plan - It recognizes an opportunity and plans a change.
b) Do - Test the change. Carry out a small-scale study.
c) Check - Review the test, analyze the results and identify what you've learned.
d) Act - Take action based on what you learned in the study step:

If the change did not work, go through the cycle again with a different plan. If you were successful, incorporate what you learned from the test into wider changes. Use what you learned to plan new improvements, beginning the cycle again.



PDCA Cycle

3.9 Heijunka –

Heijunka is a Japanese word for levelling. It is part of the lean methodology of process improvement that helps organizations match unpredictable customer demand patterns and eliminate manufacturing waste by levelling the type and quantity of production output over a fixed period of time.

The objective of 'Heijunka' is to keep up the production lines with the variations and fluctuations in market and customer demand. It functions in both ways: 1) To avoid over-production and piling up inventory which increases the storage cost; 2) To avoid shortage in supply of produced goods on time by keeping an optimum buffer of

produced goods. To implement 'Heijunka' an organization should have a fair 'Demand Prediction' system in place, if not perfect. In today's scenario, a perfect 'Demand Prediction' is really tough but completely ignoring it can lead to business disasters.

Heijunka depends on the below three ways to achieve its objective. They are:

a) Flexibility: In production sequences it is the sharing of an equipment/resource between one or more product/service. The changeover time that a machine takes to switch from manufacturing one product to other is a critical criterion. The faster the machine switches, easier is the production time and changeover.

b) Stability: Averaging out the number of products in each type to be produced in every single lot (between change-over) is also an important criterion. Often the batch size determines the buffer availability and is directly related to product availability.

c) Predictability: As we already saw, much required for an organization to devise its schedules, batch sizes and also product type orders in changeover. Moreover, some organizations level up and have tried to do Demand leveling (influencing customer demand by means of product offers, discounts etc).

Thus Heijunka tries to level the volume and types of products to meet customer demand, without keeping too much inventory.

3.10 Gemba Walk –

Gemba walk is the term used to describe personal observation of work – where the work is happening. The original Japanese term comes from gembutsu, which means real thing. It also sometimes refers to the "real place." This concept stresses:

a) Observation: In-person observation, the core principle of the tool

b) Value-add location: Observing where the work is being done.

c) Teaming: Interacting with the people and process in a spirit of Kaizen

A gemba walk is not an opportunity to find fault in others while they are being observed. It is also not a time to enforce policy adherence. If a gemba walk is used punitively, employees will shut down and resistance to change will rise rapidly. A gemba walk needs to be approached from a place of mutual respect and interest in making things faster, safer, easier and just plain better.

A gemba walk is also not the time to solve problems and make changes. This is a time of observation, input and reflection. That does not mean it is the time to ignore operator ideas for improvements or stifle brainstorming, but rather to be open and observe the "real thing" – see what is really happening. If ideas or complaints arise, note them and make sure they are followed up on after the walk. Be mindful not to focus on the details too quickly without seeing the whole.

3.11 Jidoka –

Jidoka is also a Japanese term which means Autonomation (Automation with human touch). The concept of Jidoka is "Automatic detection of problems or defects at an early stage and proceed with the production only after resolving the problem at its root cause". This means, the machines and operation will stop automatically without any human intervention or supervision, once a problem is detected or a defect is found.

By implementing 'Jidoka' or 'Autonomation', the human intervention and supervision to detect and identify defective units or defects get considerably reduced. This is a direct cost saving, and companies can also use this manpower for more productive work. The production stops when a machine detects a bad product and resumes only after correction of the root cause of the problem. This improves the quality of the products in first hand, and improves the efficiency of the production system also.

The problems and defects are identified and resolved then and there rather than accumulating the errors till the end of production line. This saves a huge amount of rework, inspection time, time and effort of the labor and helps in early delivery of goods, in turn the adherence to the cycle time. Correction and Prevention of errors during production cycle itself, restricts the defective units to reach the customer and hence reduces dissatisfaction, and wins customer confidence.

3.12 KPI's (Key Performance Indicators) –

A Key Performance Indicator is a measurable value that demonstrates how effectively a company is achieving key business objectives. Organizations use KPIs to evaluate their success at reaching targets. KPIs differ from organization to organization based on business priorities. The KPIs followed most closely by different people in the same organization can also vary depending on their roles.

Key performance indicators shine a light on how well a business is doing. Without KPIs, it would be difficult for a company's leaders to evaluate that in a meaningful way, and to then make operational changes to address performance problems. Keeping employees focused on business initiatives and tasks that are central to

organizational success could also be challenging without designated KPIs to reinforce the importance and value of those activities.

3.13 Bottleneck Analysis –
Bottleneck analysis helps in identifying which part of the manufacturing process limits the overall throughput and improve the performance of that part of the process. It eliminates many forms of waste such as inventory, waiting time, and transport.

3.14 Root Cause Analysis –
Root cause analysis (RCA) is a systematic process for identifying "root causes" of problems or events and an approach for responding to them. RCA is based on the basic idea that effective management requires more than merely "putting out fires" for problems that develop, but finding a way to prevent them. The nature of RCA is to identify all and multiple contributing factors to a problem or event. This is most effectively accomplished through an analysis method. Some methods used in RCA include: "5-Whys" Analysis, Barrier Analysis, Change Analysis, Causal Factor Tree Analysis, Failure Mode and Effects Analysis, Fish Bone diagram, Pareto Analysis and Fault Tree Analysis.

3.15 SMART Goals –
SMART is a mnemonic used in setting targets and or objectives. The SMART goal setting method is used in many different forms of project management, strategic initiatives and tactical projects. SMART stands for:
a) Specific - The goal should be defined as much as possible with no unclear language or vague references used.
b) Measurable - Can you measure the progress of your goal?
c) Attainable - Is the goal reasonable? Can your team or you reach the goal?
d) Relevant - Will the goal meet your needs? Does the goal align with the long term vision?
e) Time Based - What is the time frame?
It helps in describing what needs to be done to work toward a specific change, ultimately creating success and improvement.

3.16 Standardized Work –
Standardized work is one of the most powerful but least used lean tools. By documenting the current best practice, standardized work forms the baseline for kaizen or continuous improvement. As the standard is improved, the new standard becomes the baseline for further improvements, and so on. Improving standardized work is a never-ending process. Basically, standardized work consists of three elements:
a) Takt time, which is the rate at which products must be made in a process to meet customer demand.
b) The precise work sequence in which an operator performs tasks within takt time.
c) The standard inventory, including units in machines, required to keep the process operating smoothly.

3.17 Takt Time –
Takt time is the maximum amount of time in which a product needs to be produced in order to satisfy customer demand. The term comes from the German word "takt," which means "pulse." Set by customer demand, takt creates the pulse or rhythm across all processes in a business to ensure continuous flow and utilization of capacities (e.g., man and machine). Takt time is more than a metric of time — it's a whole different way of thinking for running your operations.
First, takt ensures that all the capacity in a business is planned and utilized and still meets overall customer demand. By and large, takt will help to deliver the right product (RP) at the right time (RT) in the right quantity (RQ) to the customer. You can achieve RP, RT, and RQ without implementing takt; however, this could lead to much waste of man and machine.
Second, takt creates a constant pulse across your processes, which will immediately highlight capacity issues, synchronization issues among processes, quality issues and many others. Takt time can be expressed mathematically as a ratio of Available Work Time to the Customer Demand Rate.

3.18 Value Stream Mapping –
Value stream mapping is a lean-management method for analyzing the current state and designing a future state for the series of events that take a product or service from its beginning through to the customer. This tool seeks to map your process from supplier to customer, highlighting the flows of product and information and identifying delays

and non-value adding processes. It is a team process that should take place at the gemba (the workplace), not within an office by an expert using data from written procedures about what should happen. Your value stream map should reflect exactly what does happen along with real current data regarding stock levels, delays, change over times, quality levels and so forth. It is this map that will form the basis for your improvements. It exposes waste in the current processes and provides a roadmap for improvement through the future state.

IV. SIX-SIGMA & SIX-SIGMA TOOLS

Six-Sigma is a smarter way to manage a business or a department. Six-Sigma puts the customer first and uses facts and data to drive better solutions. Six-Sigma efforts target three main areas: Improving customer satisfaction; reducing cycle time and reducing defects. The key characteristics of Six-Sigma are

a) Six-Sigma is customer focused.
b) Six-Sigma projects produce major returns on investment.
c) Six-Sigma changes how management operates.

Six-Sigma can be defined in many ways. It can be defined as a statistical measure of the performance of a process or a product (or) a goal that reaches near perfection for performance improvement (or) a system of management to achieve lasting business leadership and world-class performance.

Six-Sigma is usually related to the magic number of 3.4 defects per million opportunities. People often view Six-Sigma as yet another rigorous statistical quality control mechanism. Pioneered at Motorola in the mid-1980s, Six-Sigma was initially targeted to quantify the defects occurred during manufacturing processes, and to reduce those defects to a very small level. Motorola claimed to have saved several million dollars. Another very popular success was at GE. Six-Sigma contributed over US $ 300 million to GE's 1997 operating income. Today Six-Sigma is delivering business excellence, higher customer satisfaction, and superior profits by dramatically improving every process in an enterprise.

The term sigma (σ) is taken from a letter in the Greek alphabet and is used in statistics as a measure of how far a given process deviates from perfection (variation). For a business process, the sigma value is a metric that indicates how well that process is performing. The higher the sigma value, the better. More specifically, sigma measures the capability of the process to perform defect or error free work as defined by the customer. A defect or error is anything that has the potential to result in customer dissatisfaction. With Six-Sigma, the common measurement is "defects per unit," where a unit can be virtually anything, for example: a part within a larger component, a component, a raw material, an entry in a form or document, a clerical error, a telephone enquiry, etc.

A sigma value or level is an indicator of how often defects or errors are likely to occur. As this value increases and approaches Six-Sigma, customer satisfaction levels increase with costs and cycle times decreasing. Six-Sigma is the goal, which equates to 3.4 defects per million opportunities or a yield of 99.99966%. So in simple terms, a Sigma Level represents the number of deviations from the mean. The table below demonstrates these Sigma Levels.

Table -1 Sigma Levels

Sigma Level	Defects Per Million Opportunities	Yield
1σ	6,90,000	30.85%
2σ	3,08,000	69.15%
3σ	66,800	93.32%
4σ	6,210	99.38%
5σ	230	99.977%
6σ	3.4	99.99966%

It is important to note that the need for a process to be at a Six-Sigma level will depend on a number of factors, e.g. customer needs, cost, competitive environment, legislative requirements, etc. The driving force behind any Six-Sigma project comes from its primary focus - "bringing breakthrough improvements in a systematic manner by managing variation and reducing defects". This requires us to ask tougher questions, raise the bar significantly, and force people to think out of the box and to be innovative. The objective is to stretch and stretch mentally not physically. To make this journey successful there is a methodology(s) to support Six-Sigma implementations.

Six-Sigma projects follow two project methodologies inspired by Deming's Plan-Do-Check-Act Cycle. These methodologies composed of five phases each, bear the acronyms DMAIC (is used for projects aimed at improving an existing business process) and DMADV (is used for projects aimed at creating new product or process designs).

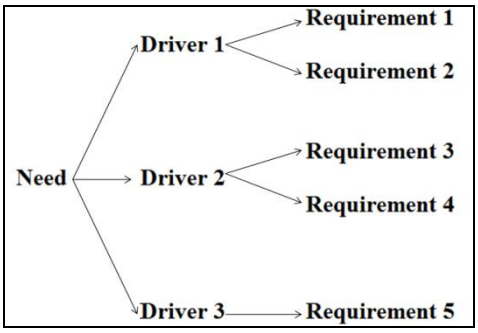
The DMAIC project methodology has five phases:

Define the system, the voice of the customer and their requirements, and the project goals, specifically.

Measure key aspects of the current process and collect relevant data; calculate the 'as-is' Process Capability.

Analyze the data to investigate and verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered. Seek out root cause of the defect under investigation.
Improve or optimize the current process based upon data analysis using techniques such as design of experiments, poka yoke or mistake proofing, and standard work to create a new, future state process. Set up pilot runs to establish process capability.
Control the future state process to ensure that any deviations from the target are corrected before they result in defects. Implement control systems such as statistical process control, production boards, visual workplaces, and continuously monitor the process. This process is repeated until the desired quality level is obtained.
The DMADV project methodology, known as DFSS ("Design for Six-Sigma"), features five phases:
Define design goals that are consistent with customer demands and the enterprise strategy.
Measure and identify CTQs (characteristics that are Critical To Quality), measure product capabilities, production process capability, and measure risks.
Analyze to develop and design alternatives
Design an improved alternative, best suited per analysis in the previous step
Verify the design, set up pilot runs, implement the production process and hand it over to the process owner(s).
For convenience, we have grouped the tools into five categories.
Tools for generating ideas and organizing information.
Tools for gathering data.
Tools for process and data analysis.
Tools for statistical analysis.
Tools for implementation and process management.

Tools for generating ideas and organizing information –
Brainstorming –
Brainstorming is the name given to a situation when a group of people meet to generate new ideas around a specific area of interest. Using rules which remove inhibitions, people are able to think more freely and move into new areas of thought and so create numerous new ideas and solutions. The participants shout out ideas as they occur to them and then build on the ideas raised by others. All the ideas are noted down and are not criticized. Only when the brainstorming session is over are the ideas evaluated.
Affinity Diagram –
The affinity diagram is a business tool used to organize ideas and data. The purpose of an affinity diagram is to generate, organize, and consolidate information concerning a product, process, complex issue, or problem. Constructing an affinity diagram is a creative process that expresses ideas without quantifying them.
The affinity diagram helps a group to develop its own system of thought about a complex issue or problem. A group can use an affinity diagram at any stage where it needs to generate and organize a large amount of information.
The affinity diagram organizes ideas with following steps:
Record each idea on cards or notes.
Look for ideas that seem to be related.
Sort cards into groups until all cards have been used.
Once the cards have been sorted into groups the team may sort large clusters into subgroups for easier management and analysis. Once completed, the affinity diagram may be used to create a cause and effect diagram.
Multi-voting –
Teams use multi-voting to narrow down a list of ideas or options. It's also often used as a follow-up to brainstorming. Each participant gets a certain number of votes. The options getting the most votes overall are then given further analysis or consideration.
Tree Diagram –
A Tree Diagram is a chart that begins with one central item and then branches into more items and keeps branching until the line of inquiry begun with the central item has been exhausted. The tree diagram, with its branching steps, motivates the team to move from the general to the more specific in a systematic way. The tree diagram is useful to organize a team's thinking about an issue so that the main ideas and relationships are immediately apparent.

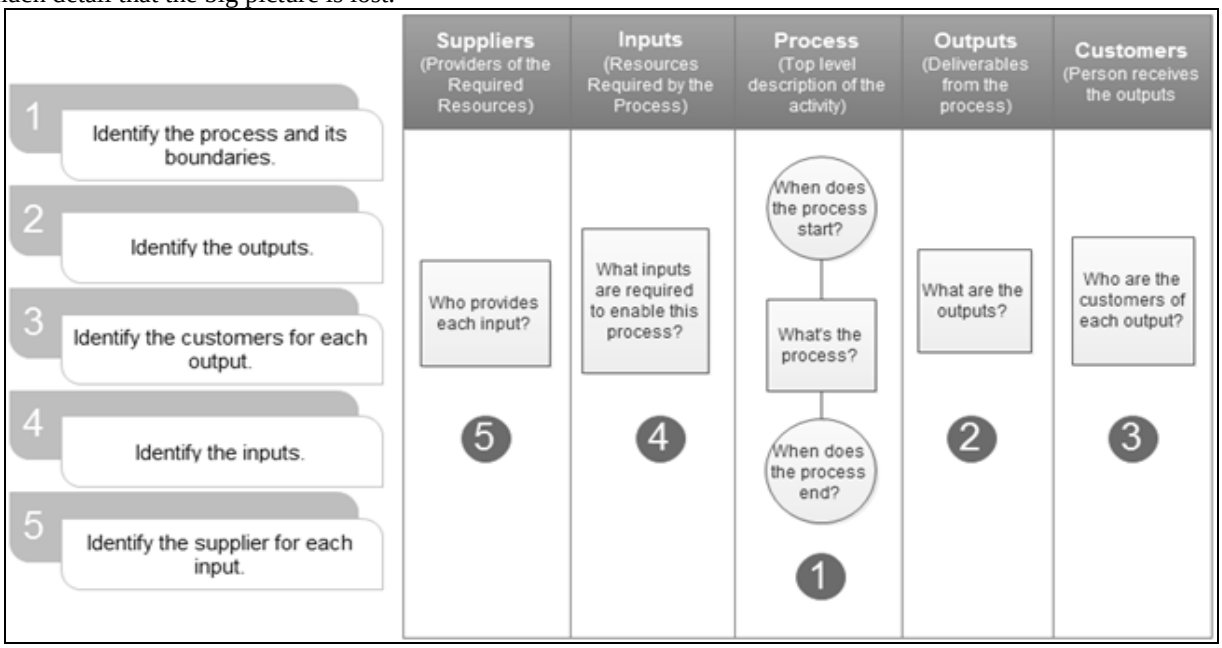


Tree Diagram

High Level Process Map (SIPOC Diagram) –

In process improvement, a SIPOC (sometimes COPIS) is a tool that summarizes the inputs and outputs of one or more processes in table form. The acronym SIPOC stands for suppliers, inputs, process, outputs, and customers which form the columns of the table. It was in use at least as early as the total quality management programs of the late 1980's and continues to be used today in Six-Sigma, lean manufacturing, and business process management.

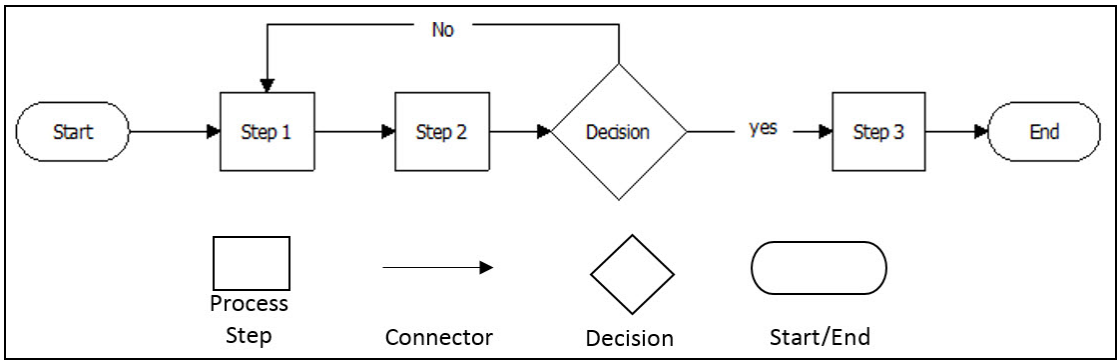
A SIPOC diagram is used to help define the boundaries and critical elements of a process without getting into so much detail that the big picture is lost.



SIPOC

Process Map (Flow Chart) –

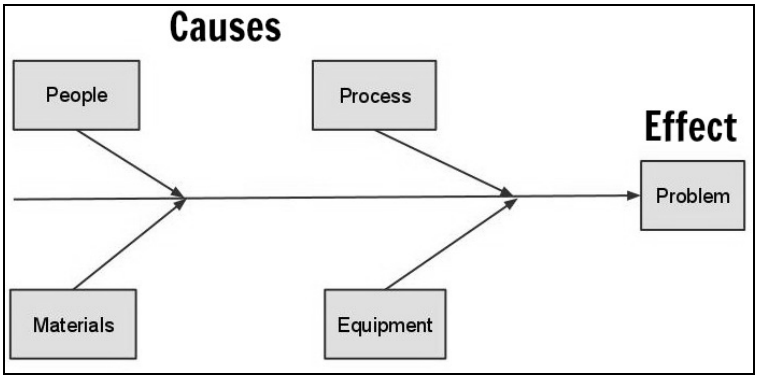
Process mapping is the graphic display of steps, events and operations that constitute a process. It's a pictorial illustration which identifies the steps, inputs and outputs, and other related details of a process by providing a step-by-step picture of the process "as-is". It's a graphics technique for dissecting a process by capturing and integrating the combined knowledge of all persons associated with the process. It's is a team effort and is documented by everyone who contributes to the process and/or is a part of the process. Process maps helps in characterizing the functional relationships between various inputs and outputs.



Process Map

Fish Bone Diagram (Cause & Effect Diagram) –

A fishbone diagram also known as a "cause and effect diagram", can help in brainstorming to identify possible causes of a problem and in sorting ideas into useful categories, which is a common tool using in Six-Sigma program for root cause analysis. The fishbone will help to visually display the many potential causes for a specific problem or effect. It's particularly useful when capturing different ideas when there are many opinions in root cause identification.



Fish Bone Diagram

Tools for gathering data –

Voice of Customer (VOC) –

Voice of Customer is the customer's voice, expectations, preferences, comments, of a product or service in discussion. It is the statement made by the customer on a particular product or service. This process is all about being proactive and constantly innovative to capture the changing requirements of the customers with time. The voice of the customer can be captured in a variety of ways: Direct discussion or interviews, surveys, focus groups, customer specifications, observation, warranty data, field reports, complaint logs, etc. This data is used to identify the quality attributes needed for a supplied component or material to incorporate in the process or product.

Sampling –

Sampling is the process of selecting a small number of elements from a larger defined target group of elements. Population is the total group of elements we want to study. Sample is the subgroup of the population we actually study. Sample would mean a group of 'n' employees chosen randomly from organization of population "N".

Check sheets –

The check sheet is another simple and effective tool useful in Lean Six-Sigma projects. It is sometimes referred to as a concentration diagram or location plot. It is a handy tool for both qualitative and quantitative data gathering and analysis. Check sheets help to systematically collect and organize data and is useful in the all phases of the Lean Six-Sigma DMAIC (define, measure, analyze, improve and control) framework.

Defect	Tallies	Total
Defect 1	𝍸 ///	8
Defect 2	///	3
Defect 3	𝍸	5
Defect 4	𝍸 𝍸 ///	13

Checksheets

Tools for process and data analysis –

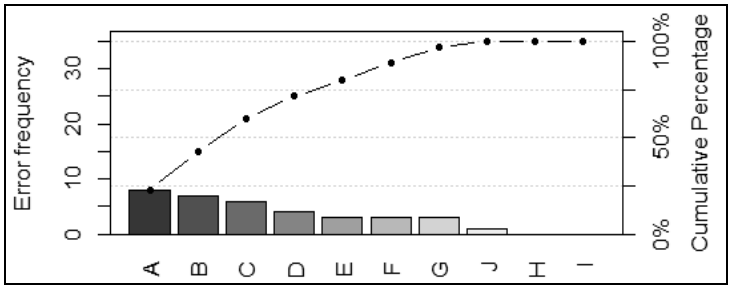
Value Analysis –

It is a process in which the essential benefits and attributes of a product or service are realized. Those attributes or benefits which are more customer-appealing are retained and improved, while the others are eliminated or reduced. The main goal of value added analysis is to obtain a value for end product which is higher than its production cost. The production cost includes all the resources which are required to produce the product or service, like labor, raw material, transportation, storage and overhead costs. For value added analysis of a particular process, all the activities involved in that process, need to be examined carefully. The value added by any activity to the whole process should be positive and is calculated as:

Value Added = (Product's value after the activity) - (Product's value before the activity)

Pareto Chart –

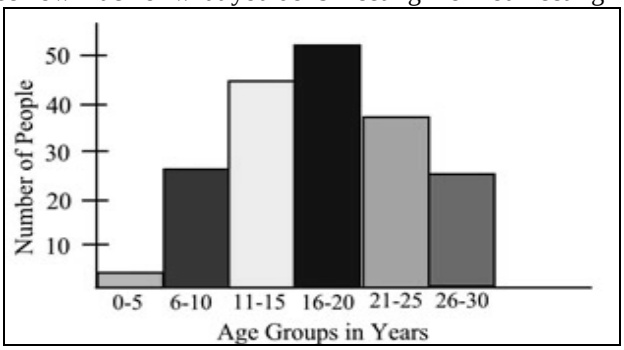
A Pareto chart is a bar graph. The lengths of the bars represent frequency or cost (time or money), and are arranged with longest bars on the left and the shortest to the right. In this way the chart visually depicts which situations are more significant. It is used when analyzing data about the frequency of problems (or) focusing on a significant problem among many problems.



Pareto Chart

Histogram –

A histogram is a plot that lets you discover, and show, the underlying frequency distribution (shape) of a set of continuous data. In analyzing histograms, you can look for the shape of the bars or the curve, the width of the spread, or range, from top to bottom, or the number of "humps" in the bars. If you plot customer requirements on a histogram, you can quickly see how much of what you do is meeting—or not meeting—customers' needs.

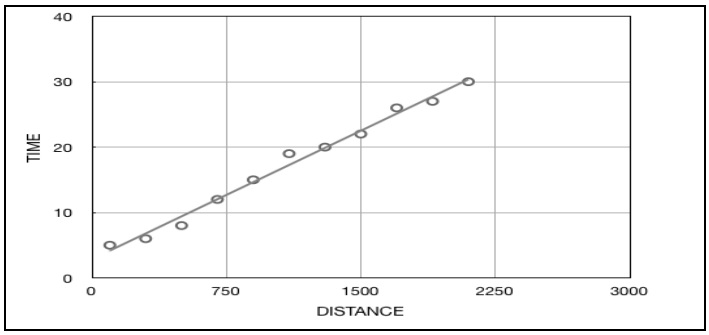


Histogram

Scatter Plot –

A scatter plot is also known as scatter diagram. It is a basic graphic tool that illustrates the relationship between two variables. The dots on the scatter plot represent data points. Scatter plots are used with variable data to study

possible relationships between two different variables. Even though a scatter plot depicts a relationship between variables, it does not indicate a cause and effect relationship. Use Scatter plots to determine what happens to one variable when another variable changes value. It is a tool used to visually determine whether a potential relationship exists between an input and an outcome.



Scatter Plot

Tools for statistical analysis –

Tests for statistical significance –

These tools look for differences in groups of data to see whether they are meaningful. These tests include Chi-square, t-tests, and analysis of variance (ANOVA).

Correlation & Regression –

Correlation is a measure of association between two variables. The variables are not designated as dependent or independent. The two most popular correlation coefficients are: Spearman's correlation coefficient rho and Pearson's product-moment correlation coefficient. Simple regression is used to examine the relationship between one dependent and one independent variable. After performing an analysis, the regression statistics can be used to predict the dependent variable when the independent variable is known. Regression goes beyond correlation by adding prediction capabilities.

Design of Experiments (DOE) –

DOE is a collection of methods for developing and conducting controlled assessments of how process or a product performs, usually testing two or more characteristics under different conditions. In addition to helping target causes of a problem, DOE can be essential to get maximum benefit out of solutions (called “optimizing” results).

Tools for implementation and process management –

Project Management Methods –

Just because we can analyze a problem, it doesn’t mean that you can put a solution in place. Six-Sigma companies recognize early on the importance of strong project management skills: planning, budgeting, scheduling, communication, people management. Technical project management tools (E.g.: Gantt charts or timelines) are also important.

Potential Problem Analysis and Failure Mode and Effects Analysis –

These are two of the key problem-prevention methods that are applied both in implementing new processes and in running them every day. Both start with listing (brainstorming) the many things that could go wrong. Then, the potential problems are prioritized. Finally, the biggest risks are protected by looking for ways to prevent them from happening, as well as ways to limit the damage if they do occur (called “contingencies”).

Process Documentation –

As a DMAIC project reaches conclusion with solutions in place and results in hand the time comes to turn over responsibility to those who will manage the process on an ongoing basis. Creating effective, clear, not overly complex process documentation process maps, task instructions, measures, and so on is the last and most important element of the DMAIC Control step.

Balanced Scorecards and Process Dashboards –

Six-Sigma has placed new attention on the ability of people throughout an organization to keep tabs on current performance, trends, and issues on key indicators in a process. Balanced scorecards and process dashboards provide a summary of critical measures that, ideally, give real-time feedback and promote prompt attention to issues and opportunities. These tools typically feature both output (Y) and process and input (X) measures and go well beyond traditional financial data.

V.CONCLUSION

For achieving operational and service excellence in any organization, Lean and Six-Sigma are the two most powerful strategies. By integrating tools and techniques of Lean and Six-Sigma, it improves the efficiency of your organization by: Maximizing your organization's efforts toward delivering a satisfactory product or service to your customers and allowing your organization to allocate resources/revenue produced from your newly improved processes towards growing your business.

VI. REFERENCES

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