UNIT I - Lean and Six Sigma
Background and Fundamentals

Syllabus

Historical Overview – Definition of quality – What is six sigma -TQM and Six sigma - lean manufacturing and six sigma- six sigma and process tolerance – Six sigma and cultural changes – six sigma capability – six sigma need assessments - implications of quality levels, Cost of Poor Quality (COPQ), Cost of Doing Nothing – assessment questions.

1. Introduction

Lean Six Sigma comprises of two philosophies namely :

- Lean : This addresses waste removal from organizational processes in order to improve efficiency.
- Six Sigma : This addresses reduction of defects or variations during the production process.

The idea behind Lean Six Sigma is that if wasteful activities (such as idle time and misuse of resources) that are reduced, then the overall quality of the production process will get improved.

The Lean Six Sigma methodology is based on the idea that organizations must learn from past mistakes and that it is necessary for organizations to have strong quality management initiatives that are based on continuous improvement (CI).

The Lean Six Sigma approach has a number of philosophies that it uses. These philosophies act as the framework or skeleton from which Lean Six Sigma operates. These include customer focus, understanding the process, focusing on business results and data driven decision making.

Historical Overview

The **history of lean** involves luminaries such as **Toyoda, Ford, Ohno, Taylor** and many others. It all started way back in **1450s** in Venice, and subsequently the first person who integrated the concept of lean in the manufacturing system was **Henry Ford.**

The **history of Six Sigma** was developed by **Motorola** in United States in **1986** to compete with the Kaizen (or lean manufacturing) business model in Japan. In the 1990s, **Allied Signal** hired **Larry Bossidy** and introduced Six Sigma in heavy manufacturing. A few years later he began Six Sigma at General Electric and widely accepted in the manufacturing world.

During the **2000s** Lean Six Sigma cleft from Six Sigma and became its own unique process. It also incorporated the ideas from lean manufacturing, which was developed as a part of the Toyota Production System earlier.

The first concept of Lean Six Sigma was created in **2001** by a book titled - Leaning into Six Sigma : The Path to Integration of Lean Enterprise and Six Sigma by Barbara Wheat, Chuck Mills, Mike Carnell. The book was developed as a guide for managers of manufacturing plants on how to merge lean manufacturing and Six Sigma in order to significantly improve quality and cycle time in the plant.

In the early **2000s** Six Sigma principles expanded into other sectors of the economy, such as Healthcare, Finance, Supply Chain, etc. While different sectors of the economy sell different products and have different customers, Lean Six Sigma principles can still be applied with slight alterations in wording and processes.

Definition of Quality

"Quality" in a manufacturing organization has so many meanings, there are Quality Management Systems, Quality Managers, statistical process controls and older one termed as Quality Circles. The focus in the manufacturing is now turning from Quality to Lean.

Quality is still needed in every manufacturing environment and "Quality at source" is fundamental for a flowing production system. Quality at source, builds the quality requirements into each step of the process and has controls, so known problems are highlighted and not passed on. As a Lean improvement system is reducing the wastes in the production system, wasted materials and time due to poor quality needs attention.

Having Inspectors at the end of a line is no longer an acceptable way to try and control the quality of your product leaving your factory. At each step of the process the product specifications and tolerances need to be known and checked they are correct, at each "value adding" step of the product that changes its form, fit or function.

These checks need to be built into the process and the quality requirements clearly defined : At this step, I check the length of the section, or the weld quality or the surface finish. If it's good, it goes here, if it's not, then what happens also needs to be clearly defined.

Visual management tools and error proofing are great ways to clearly define the quality aspects that are important at each step and make it easy to determine if the part is acceptable or needs attention.

Statistical process controls (SPC) is needed on processes where the variability of a process is influencing the final level of quality.

The key to accomplishment in implementing Quality principles in any organization is to cultivate a culture of continuous improvement where there is a focus on quality, lean thinking, and customer satisfaction as the organization's main goal.

What is Six Sigma

Six Sigma **(6σ)** is a set of techniques and tools for process improvement. It was introduced by American engineer **Bill Smith** while working at Motorola in **1986.** A six sigma process is one in which 99.99966 % of all opportunities to generate some feature of a part are statistically expected to be free of defects.

Six Sigma strategies seek to improve the quality of the Output of the process, by identifying and removing the causes of defects and also minimizing the impact variability in the manufacturing and business processes.

Each Six Sigma project, carried out within an organization follows a distinct sequence of steps with a specific value targets, for example: reduce process cycle time, reduce pollution, reduce costs, increase customer satisfaction, and increase profits.

Six Sigma relies on tried and true methods that have been used for decades. By some measures, Six Sigma discards a great deal of the complexity that characterizes Total Quality Management (TQM).

It takes measure with a handful of proven methods and trains a small cadre of in- house technical leaders, known as Six Sigma Black Belts, to a high level of proficiency in the application of these techniques.

The tools of this methodology are applied within a simple performance improvement model known as **D**efine-**M**easure-**A**nalyze-**I**mprove-**C**ontrol, or DMAIC.

DMAIC is described briefly as follows :

D - Define the goals of the improvement activity.

M - Measure the existing system.

A - Analyze the system to identify ways to eliminate the gap between the current performance of the system or process and the desired goal.

I - Improve the system.

C - Control the new system.

The philosophical perspective of Six Sigma, views all work as processes that can be defined, measured, analyzed, improved, and controlled. Processes require inputs (x) and produce outputs (y). If you control the inputs, you will control the outputs. This is generally expressed as $y = f(x)$.

Set of tools/techniques: The Six Sigma expert uses qualitative and quantitative techniques or tools to coerce process improvement. Such tools include **S**tatistical **P**rocess **C**ontrol (SPC), control charts, **F**ailure **M**ode and **E**ffects **A**nalysis **(FMEA)** and process mapping.

Methodology: This view of Six Sigma recognizes the underlying and rigorous DMAIC approach. DMAIC defines the steps a Six Sigma practitioner is expected to follow, starting with identifying the problem and ending with the implementation of long-lasting solutions. While DMAIC is not the only Six Sigma methodology in use, it is certainly the most widely adopted and acknowledged.

Metrics: In simple terms, Six Sigma quality performance means 3.4 defects per million opportunities (accounting for a 1.5-sigma shift in the mean).

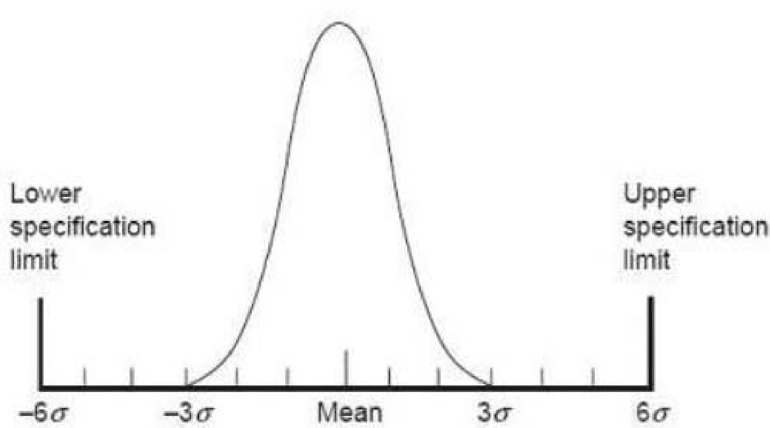


Fig 1.3.1 Six Sigma quality performance

TQM and Six Sigma

Total Quality Management (TQM) is a management style that involves :

- Commitment from everyone in the organization.
- Dedication to a high level of quality in every process.
- A focus on customer satisfaction.
- TQM has a significant focus on **continual improvement**. It integrates all functions within an organization.
- Planning, sales, marketing, production, technology, design, and finance are all included under its umbrella.
- Accordingly, in every department, improvements can be made to meet customer expectations and achieve organizational goals.

The 8 Principles of TQM

There are eight basic principles in Total Quality Management. These principles work together to improve processes and end results for customer and business alike.

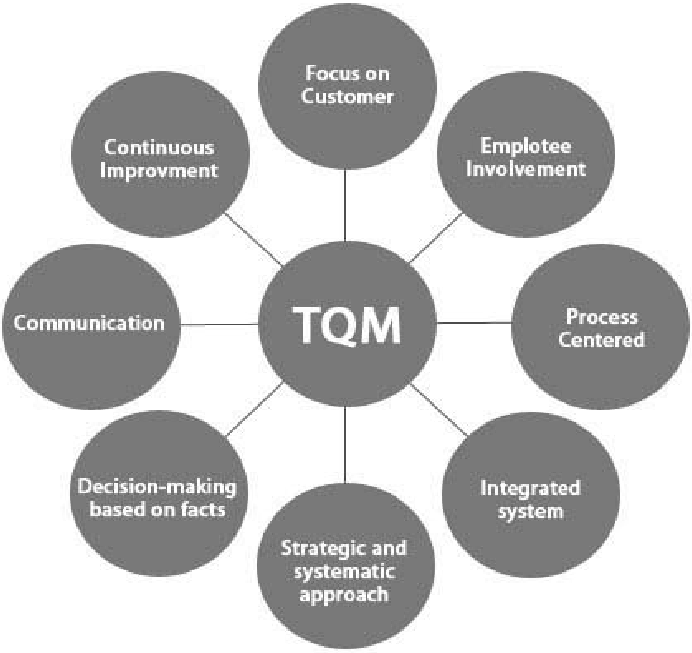


Fig 1.4.1 Eight principles of TQM

1. **Customer focus :** The success of an organization depends on customer satisfaction. Therefore all improvements must focus on customers and their needs.
2. **Total employee involvement:** All employees - from high level through to the lowest paid worker - need to be involved. Everyone works to increase quality and meet customer expectations.
3. **Centered on processes:** If the processes are improved, its output will be improved eventually. Furthermore, if the out is improved, automatically customer satisfaction goes to the hike. That's why TQM has such a strong focus on processes. Define, monitor and control the processes to assure quality.
4. **Integrated business processes:** As different departments evolve in a company, they often develop their own processes. Significantly, it's very difficult to oversee multiple departments using different processes. Instead TQM requires that all key business processes be implemented across the entire company.
5. **Systematic, strategic approach:** TQM emphasizes implementing a strategy in a systematic way. To begin with, a strategic plan is needed. This plan needs a strong focus on quality improvements. Next, a system needs to be framed for implementing the plan. This may seem like a simple approach, but many organizations find themselves lacking one of these aspects in their planning.
6. **Continual improvement:** Look for opportunities to improve. This is a key ideology of TQM. Basically, everyone in a business should be identifying potential improvements. Then, once these have been identified, incorporate them into the strategic plan. The organization needs a strong focus on 'how can we be better ?' rather than 'this is good enough'.
7. **Fact based decisions:** Strategic decisions need to be based on facts, not assumptions. Subsequently, metrics are in need to provide objective and measurable results. That way, it can be witnessed exactly what effect various choices have had. Additionally, a road map can be designed to perceive the progress toward business goals. When progress is not satisfactory, you can change strategy accordingly.
8. **Communication :** Two-way communication is essential in TQM. Employees must understand the company's goals and strategy. For that to

happen, effective downward lines of communication need to be in place. However, management also must be aware of issues, concerns, and opportunities identified by staff. Therefore, effective upward lines of communication are equally important.

Benefits of TQM :

TQM focus is to improve the quality of products and services offered to customers.

Few benefits are as follows,

- Boosts employee morale
- Increases productivity
- Decreases production costs
- Raises profits
- Makes processes more efficient and reliable
- Engages employees
- Improves general work environment

TQM Tools :

There are a lot of tools that can be used with TQM. Mainly they can help you to,

- Identify problems with quality
- Analyze issues
- Evaluate data
- Identify root causes of problems
- Measure results

Some of the standard tools used are described diagrammatically in the Fig 1.4.2.

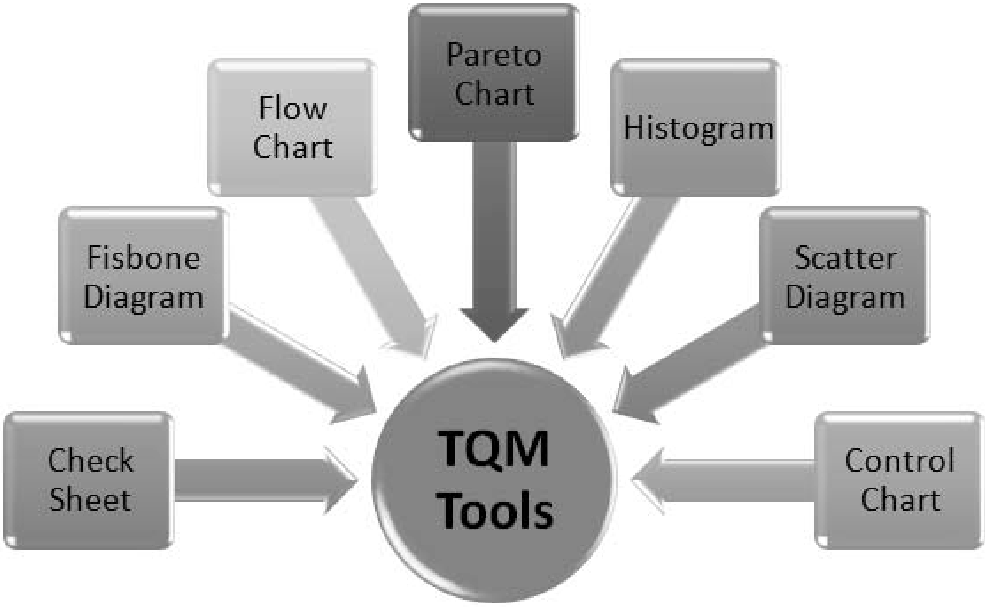


Fig 1.4.2 Standard TQM tools

Similarities between Six Sigma and Total Quality Management

- Six Sigma and TQM both methods are used to monitor quality of products, processes, and services.
- TQM is an application of quantitative methods and human resources to improve all the processes within the organization.
- Six Sigma is a problem solving approach and the main aim is defect reduction and variation management. While both aim to decrease the number of defects and errors created.

Differences between Six Sigma and Total Quality Management

- To implement Six Sigma, certified professionals are required like Green belt, Black Belt and Master Black belts where as TQM does not required any certified professionals, however training to be provided to all the employees on TQM principles.
- Six Sigma : Defect focused. Looks for causes of defects and, where appropriate, amends processes.
- TQM : Process focused. Looks for improvements that can be made to processes, assuming that better processes will cause fewer errors.

- Total Quality Management (TQM) methodology is in practice much before the Six Sigma.
- TQM and Six Sigma do not have to be mutually exclusive to meet the organizational objectives.
- It is a good idea to identify the relationship between Six Sigma and TQM which will help to improve the quality of business processes, products and services.
- Moreover Six Sigma has the potential to improve the process in a more focused approach.

Lean Manufacturing and Six Sigma

Lean manufacturing and Six Sigma principals are used to improve processes and create efficiencies in the overall manufacturing process.

Lean manufacturing or lean production, usually referred to simply as "lean" is an enterprise methodology developed by Toyota Motor Corp in the 1990s.

It is an organized process of eliminating waste from various activities in the organization, providing maximum value to customers with the lowest possible amount of investment.

Advantages of lean

- Lean's main strength is its fast implementation, and almost immediately visible results.
- Short term benefits include:
  - A rise in productivity
  - Error reduction
  - Shorter customer lead times.
- With better planning and execution, Lean can improve financial performance, customer satisfaction, and staff morale.

Difference between the Lean manufacturing and Six Sigma

- Mainly, the difference is in the approach toward this goal, and each system's definition of the root cause of waste.
- While Lean is traditionally manufacturing-oriented, and is quicker to

implement, Six Sigma is armed with the power of data for decision making, and is consumer- centric at its core.

- Six Sigma is a broader process that easily adapts to the application of manufacturing processes, but it also serves as a big picture approach to strategy in business by using statistical models.
- When applied to manufacturing, Six Sigma is an evaluation process used to identify weaknesses and improve the overall process.
- Lean manufacturing is similar, but it works in a very narrow scope that's focused heavily on waste and production. Use *less*, do *more* is the essential backbone of lean manufacturing methodology.

Lean Manufacturing Processes

- The entire lean manufacturing process requires maximizing production, while minimizing waste. The goal is to create the highest possible output without sacrificing quality.
- Toyota pioneered the process by identifying seven specific common wastes that are removed from the production process to add value and reduce costs.
- While Lean Manufacturing is not necessarily the best approach for every business, it has proven effective at a large scale for numerous manufacturing based companies
- It is not an exact science but is more of a set of a guidelines and principals for management teams.
- Many leaders choose to modify definitions and adjust the process to fit within their specific business model.

Choosing a Method

- While Six Sigma and Lean Manufacturing are both effective approaches, they are not necessarily used by every manufacturer and do not have set in stone guidelines.
- A company could effectively combine both processes and evaluate their production models, using intensive statistical analysis, while communicating directly with the workforce and identifying issues at the source.
- A company heavily dependent on machinery and robotics really stands to benefit more from Six Sigma principals, whereas a labor heavy

manufacturing process can benefit from lean principals.

- A new manufacturing facility that is fresh, and ready to evolve and grow over time, stands to benefit from implementing an existing, proven model immediately, while leaving the option open to reevaluate and adjust, as needed, over time.

Six Sigma and Process Tolerance

- Process tolerance is a value that sets the standard by which the capability of your process is determined. It is defined as a multiple of a process standard deviation (sigma). Usually, 6*sigma is used as a tolerance. Some processes require a higher, stricter tolerance than others.
  - For example, passenger safety depends on the components of an airplane. Therefore, the process that produces these parts must have a high tolerance. But if your process does not affect the safety of people and resources, a lower tolerance is permissible.
  - For example, the manager of a company that makes feed for livestock may set a low tolerance on the length of food pellets because no serious consequences exist if they are misshapen, and it will waste company resources to hold the dimensions of livestock feed to the same tolerance as airplane parts.
- When you have a properly defined process tolerance for each part of your organization, you can easily account for every possible problem that can come up, and deal with those issues before they have had a chance to grow into something bigger.
- Proper market analysis and ensuring that you understand the fundamental requirements of your project is obviously important.
- Two different levels related to the process tolerance are the upper and lower limits as mentioned previously. Anything that falls between these two levels will be treated as acceptable, and you should additionally strive for a situation where the majority of products coming out of your organization are right around the average between the two.
- The most popular metrics used in assessing Six Sigma projects, both **DMAIC** (Define, Measure, Analyze, Improve, Control) and Design for Six Sigma **(DFSS)**, is defects per million opportunities **(DPMO)**.

  DPMO - This measurement is the average number of defects per unit observed during an average production run divided by the number of opportunities for making a defect on the product. Then the number is normalized to one million. A defect is defined as a failure to conform to requirements. Those requirements are articulated in the specification or tolerance of the products or processes.

- Tolerances should be determined in product or process development. Properly designed specifications can reduce the DPMO.
- A too-tight tolerance specification can ensure functional requirements, but it is not cost effective. A too-loose tolerance specification will bring low assembly process, but frequent rework would likely be required to maintain performance.

The importance of the average

- Here the attention is directed towards the middle ground between the two tolerance points, i.e., the Average, where most of the output should be around, for the better results to be attained overall.
- It is important to apply a proper statistical analysis tools here. If you simply take the average of all the products to check how much they are deviating from the expected average, you are probably we get nearly an identical value. This makes sense if the upper and lower deviations are within the norm and not too far from the expected values.
- This means that it should be kept track of the actual numbers of the products that deviate from the average and the value of their deviations.
- There are different statistical analysis tools that can help to get a good overview of the true situation within your plant, and it is important to master them as quickly as possible if you want to be a responsible leader in your organization.
- Most people look at just the average (mean) value of their product or service, but fail to evaluate the variation (calculated as the standard deviation).
- **"If the variation exceeds the limits (called "capability"), then the goal is to reduce variation and/or shift the average closer to the center of the limits"** This is the heart of Six Sigma, to understand how the average and standard deviation compares to the tolerance limits, and identify what factors are causing the variation.

Shrinking of the tolerance limits

- When it comes to shrinking the tolerance limit, should we do it ? Unless your client or customer specifically requests it, you probably should not be putting any additional effort into trying to shrink the gap between the tolerance limits.
- The goal should be to continuously reduce the variation, so you can achieve results closer to the average, which improves customer satisfaction and reduces reliability issues.
- In case if there is a complaint that you are deviating from the expected norms, then there should be some consideration on immediate changes, such as tightening the tolerance limits.
- There is no need to necessarily shrink the process tolerance from both ends, if products are primarily jumping over the limit. For example, you can lower the upper level but keep the other one in place. So that it can be prevented from the unnecessary repetition of work within the organization.
- Understanding process tolerance and its implications for an organization is a critical skill for any responsible leader.

Six Sigma and Cultural Changes

The power of Six Sigma to create a culture of continuous improvement lies in the combination of changing the way work gets done by changing processes, plus educating people in new ways of understanding processes and solving problems.

The differences between a traditional and a Six Sigma culture can be characterized as shown

Sr. No.	Aspects of Culture	Traditional	Six Sigma
1	Work orientation	Departmental, functional and/or task	Process flow and customer-output related

2	Who defines what needs improving ?	Senior managers and department managers	Senior and department managers plus bottom-up suggestions from project leaders and team members
3	Leadership for improvem ent	Functional managers or designated project leaders	Champions and improvement specialist (Belts)
4	Who has skills to develop and implement solutions ?	Specialists (e.g., engineers) and managers	Specialists plus project leaders, team members and managers
5	Improvement methods/tools used	The most familiar ones	Common, state-of-the-art approach and tools
6	Degree of operator involvement	Ad hoc	Widespread through Yellow Belt training
7	Project management discipline related to improvement	Variable	Gate reviews at each step of DMAIC
8	How performance is measured ?	Actual versus budget	Impact on X's (causal measures) that affect Y's (outcomes)

Table 1.7.1 Differences between traditional and six sigma cultures

- In a Six Sigma culture, knowledge of processes and improvement is widespread throughout the organization. However, while training in Six Sigma methods and tools and applying them to projects are important, these alone are insufficient to create a sustainable Six Sigma culture.
- The companies that have succeeded in creating a Six Sigma culture also have in place the following :
  - Leaders with first-hand experience in applying Six Sigma to strategic issues.
  - Dashboards of predictive, process-oriented measures that are used regularly to review and improve operations performance.
- A Six Sigma culture has the potential to literally transform employees. Those with Six Sigma certification are cultured to see themselves and the work they do differently than traditional employees. They are taught to :
  - See work in terms of process flow, and not just departments and functions.
  - Take an active role in defining improvements and identifying solutions, instead of relying on management.
  - Utilize the appropriate skills to create and implement solutions.
  - Actively involve themselves in continuous improvement efforts.

Change Management : The Key to Creating a New Culture

- Change management can help solidify a new culture in individuals and organizations. The four ways that change management can be used to instill Six Sigma culture into an organization,
- Create Awareness and Desire
- **Expose the Organization to Change**
  - Move Ahead, and Be Prepared for Surprises
  - Reward Generously

1. Create Awareness and Desire :

This process starts at the top, as executive management communicates the benefits of using Six Sigma methodology, down through the organization. This can provide four important benefits :

- Projects are better able to stay on time and budget

- Management can support Six Sigma projects by allocating the proper resources
- Management's support for Six Sigma projects can decrease resistance from employees and other stakeholders
- Employee productivity may be less impacted by the change

2. Expose the Organization to Change :

Once upper management has laid the groundwork for a change in culture by placing its support behind Six Sigma, the methodology can be disbursed throughout the organization. The best way to infuse Six Sigma into the organization is through education, training and certification. The more employees exposed to Six Sigma through online and offline training, the more entrenched it can become in the company culture.

3. Move Ahead, and Be prepared for surprises :

Following your change management plan is critical for creating a climate where Six Sigma culture can thrive. However, change agents may encounter hidden obstacles that threaten to derail change, such as strongly held traditions or an attachment to outdated practices. Managing change means being prepared for the unexpected.

4. Reward Generously :

What you reward, you typically get more of. When leaders and employees show behavior that promotes a Six Sigma culture, recognize their contributions. Be sure to explain how behavior that supports Six Sigma benefits the company.

- Six Sigma can lead to profound changes in an organization's culture - the beliefs and behaviors accepted as normal. By integrating education with hands-on problem- solving, how work gets done starts to change. Knowledge of processes and improvement becomes more and more widespread
- As more and more Six Sigma "graduates" assume line management roles, they naturally apply Six Sigma approaches in their daily work. Using dashboards in

  regular operations review sessions, they involve everyone in reviewing process- related performance and committing to improvement.

Six Sigma Capability

Six Sigma is a broad business approach to drive defects produced by all processes down into parts per million levels of performance.

- This means it's really about improving the process capability for all Critical-To- Quality **(CTQ)** characteristics from all processes in the organization.
- The goal in a Six Sigma organization is to achieve defect levels of less than 3.4 parts per million for every process in the organization and for every CTQ characteristic produced by those processes.

Before knowing about the six sigma capability, process capability must be recognized.

Process capability

- Process capability compares the process output with the customer's specification.
- The purpose of a process capability study is to compare the process specification to the process output and determine statistically if the process can meet the customer's specification.
- A capable process is the one which is stable and can fit within the customer specification.
- The less variation there is in a process, the more capable it will be of meeting the customer's specification.

Measuring process capability

- The primary measures of process capability used are the process Capability Ratio, the process Capability Index, and the Cpk.
- Some organizations also use Process Performance Indicators (Pp and Ppk), which are related to Cp and Cpk.

Process capability ratio (Cr)

It describes what portion of the specification the process is taking up. The Cr should be no greater than 75 % in order for the process to be considered capable.

Process Capability Index (Cp)

It is the inverse of the Capability Ratio(Cr). The Cp should be at least 1.33 in order for the process to be considered capable.

Cpk

This capability measure is preferred by most industries because it indicates whether it is capable and how well-centered the process is. The **Cpk** is the smaller of the **Cpu** (capability of the upper half of the process) and the **Cpl** (capability of the lower half of the process).

$$Cpk = \text{smaller of } \{Cpu, Cpl\}$$

Process Capability Study

The steps for conducting a process capability study are :

1. Preparing for the study
2. Determining the process output
3. Comparing the output to the spec
4. Taking action to improve the process

- A process capability study measures the capability of a specific piece of equipment or a process under specific operating conditions.
- It is important to identify and record this information prior to the beginning of the process capability study.

Step 1 : Preparing for the Study

- Define the processing conditions
- Select a representative operator
- Assure sufficient raw materials are available
- Make sure the measurement system is reliable

Step 2 : Determining the Process Output

To determine the process output, run the process and collect data, if you were setting up a control chart.

- Make sure the process is stable using the same methods for setting up a control chart.
- Since common process capability calculations are based on a stable,

normally distributed process, if the process is not stable, process capability study cannot be conducted.

- Calculate the process mean and process variation for the measured output.

Step 3 : Comparing Process Output to the Spec

A specification normally consists of the nominal, or ideal, measure for the product and the tolerance, which is the amount of variation acceptable to the customer. It is often referred to as **“the spec”.**

- The distance between the Upper Spec Limit **(USL)** and the Lower Spec Limit **(LSL)**

  is called the Total Tolerance, or **T.T.**

- The Cpk for a process is determined by calculating the Cpu and the Cpl. The Cpk is the lower of those two numbers.

Step 4 : Taking Action to Improve the Process

There are a variety of activities that can be undertaken to improve the process such as 8D problem solving & mistake-proofing.

- Six Sigma has been accepted to mean a 4.5-sigma process, not “true six sigma” process.
  - A process that operates with “true six sigma” performance takes up 50 % of the specification if centered. This gives it a Cpk and a Cp of 2.0. A process such as this will produce defects at a rate of only ~2 parts per billion.
  - Six Sigma professionals have allowed for the process to drift by up to 1.5 standard deviations from the mean. So if we have a process with a Cp = 2.0 but allow for a 1.5s drift, then we have the equivalent of a 4.5 sigma process. That is, the mean will be 4.5s from the specification limit at the edges of the drift. A

    4.5 sigma process yields a 3.4 ppm defect level.

- Instead of Cp and Cpk, some Six Sigma organizations report capability in terms of

  Z-values.

  - The Z-values represent the number of standard deviation units the mean is away from the specification limits.

- **Zl** is the distance from the mean to the Lower Spec and **Zu** is the distance from the mean to the Upper Spec.

- **Zl** equals 3 times Cpl and Zu equals 3 times Cpu. For example, if the Cpl of a process was 1.5, the Zl would be 4.5.

Six Sigma Need Assessments

- First and simply, Six Sigma is a quality improvement methodology.
- Six Sigma has also become a generic 'brand' for a set of concepts that many organizations have used, and continue to use, to improve quality, and to provide quality and performance improvement services and training.
- The assessment process helps to identify and validate initial project clusters for consideration as Six Sigma projects. These will need to be qualified, quantified, scoped and prioritized accordingly as the program rolls out.
- Six Sigma was then simply a statistical term that specifically referred to a performance target of 3.4 defects per million operations or 'opportunities' (DPMO).
- Six Sigma grew quickly from a statistical process for reducing defects in production, to become a 'branded' and yet generic management methodology, whose elements extend far beyond the meaning of the original Six Sigma expression.

Implications of Quality Levels

- A well-designed **quality improvement plan** has all it takes to survive and rise above the competition.
- The Six Sigma quality improvement plan template has seriously saved millions of dollars for many businesses. This has been achieved simply by reducing the defects and errors in product development procedures. It is something that can improve customer satisfaction as well. All that is needed is a basic understanding of the Six Sigma quality improvement approach and principles.
- Over the years, businesses adopted different methods in order to improve, control and manage the quality of their products and services, but none of the quality management methods could rival Six Sigma. It has surpassed all the other methods in growing popularity as it emphasizes more on utilization of statistical methods.
- The major Implications of quality levels are,

- In order to improve the entire process, Six Sigma does the required things better and faster, that too at a much lower cost.
- This can be employed in various facets of business, right from human resource to production and order entry to technical support with utmost ease and convenience.
- The best part of adopting Six Sigma approach is getting a clear focus on quality improvement methods that are extremely crucial to the valuable customers.
- It can wonderfully eliminate the process variation and also inconsistency.
- This is known to bring about active participation of top management.

- The Quality system suggested by Six Sigma has created quite a buzz in almost every industry, including healthcare, retail, BPO, etc. Such state-of-the-art methods are developed with the sole objective of testing crucial products and services.
- To ensure that they are fulfilling the criteria of desired standards and customer's expectations about the products are successfully met. With the ever-increasing demand for quality products, Six Sigma quality management has become the prime concern for organizations all over the world for survival and profitability.

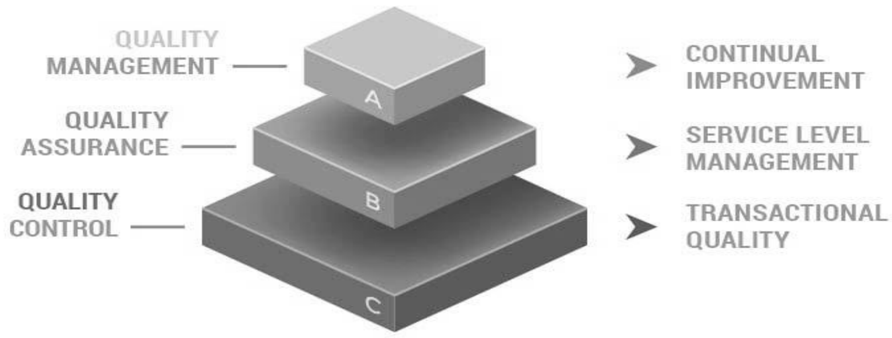


Fig. 1.9.1 Six Sigma Quality Levels

Quality Control (QC) :

- Quality control is a system. It comprises of routine processes and activities, which are specifically aimed to measure and control the overall quality of the concerned product and service.
- It also involves an accuracy check to ensure zero-error in data calculations and estimating the uncertainties.
- The quality assurance check should be regular. This is how the QC system can guarantee data correctness, completeness, and also integrity.
- One major part of QC is to distinguish errors and rectify them.

Quality Assurance (QA) :

- QA is a process, which is executed to meet the expectations of customers. There is a set of steps which are followed to attain the quality management goals.
- Six Sigma QA approach and quality infrastructure are gaining skyrocketing popularity in this domain.
- It is known to make use of a planned and systematic process for quality checks. It is done to prevent defects.
- As there are a lot of emphasis laid and will continue to be laid, on the pursuit of perfection, is to improve quality. Also the businesses are heading towards a zero- defect world.
- In achieving this perfection, a quality assurance officer will play a crucial part, directly or indirectly.

Quality Management (QM) :

- Quality management is the act of overseeing all activities and tasks that must be accomplished to maintain a desired level of excellence.
- This includes the determination of a quality policy, creating and implementing quality planning and assurance, and quality control and quality improvement. It is also referred to as Total Quality Management **(TQM).**
- As per the quality management,
  - Quality control has more emphasis on the product concerned.

- Quality Assurance is all about focusing on the process of developing it.

Cost of Poor Quality (COPQ)

- Cost Of Quality (COQ) is defined as a methodology that allows an organization to determine the extent to which its resources are used for activities that prevent poor quality, that appraise the quality of the organization's products or services, and that result from internal and external failures.
- This cost includes the cost involved in fulfilling the gap between the desired and actual product/service quality. It also includes the cost of lost opportunity due to the loss of resources used in rectifying the defect.
- This cost includes all the labor cost, rework cost, disposition costs, and material costs that have been added to the unit up to the point of rejection.
- COPQ does not include detection and prevention cost.
- Cost of poor quality (COPQ) can be simply defined as the costs associated with providing poor quality products or services.
- There are three categories :
  - **Appraisal costs :** Costs incurred to determine the degree of conformance to quality requirements.
  - **Internal failure costs :** Costs associated with defects found before the customer receives the product or service.
  - **External failure costs :** Costs associated with defects found after the customer receives the product or service.

Quality-related activities that incur costs may be divided into prevention costs, appraisal costs, and internal and external failure costs.

Appraisal costs

Appraisal costs are associated with measuring and monitoring activities related to quality. These costs are associated with the suppliers' and customers' evaluation of purchased materials, processes, products, and services to ensure that they conform to specifications.

They could include :

- **Verification :** Checking of incoming material, process setup, and products against agreed specifications
- **Quality audits :** Confirmation that the quality system is functioning correctly
- **Supplier rating :** Assessment and approval of suppliers of products and services

Internal failure costs

Internal failure costs are incurred to remedy defects discovered before the product or service is delivered to the customer. These costs occur when the results of work fail to reach design quality standards and are detected before they are transferred to the customer.

They could include :

- **Waste :** Performance of unnecessary work or holding of stock as a result of errors, poor organization, or communication
- **Scrap :** Defective product or material that cannot be repaired, used, or sold
- **Rework or rectification :** Correction of defective material or errors
- **Failure analysis :** Activity required establishing the causes of internal product or service failure

External failure costs

External failure costs are incurred to remedy defects discovered by customers. These costs occur when products or services that fail to reach design quality standards are not detected until after transfer to the customer.

They could include :

- **Repairs and servicing :** Of both returned products and those in the field
- **Warranty claims :** Failed products that are replaced or services that are re-performed under a guarantee
- **Complaints :** All work and costs associated with handling and servicing customers' complaints
- **Returns :** Handling and investigation of rejected or recalled products, including transport costs

Prevention Costs

Prevention costs are incurred to prevent or avoid quality problems. These costs are associated with the design, implementation, and maintenance of the quality management system. They are planned and incurred before actual operation, and they include :

Product or service requirements: Establishment of specifications for incoming materials, processes, finished products, and services

Quality planning: Creation of plans for quality, reliability, operations, production, and inspection

Quality assurance: Creation and maintenance of the quality system

Training: Development, preparation, and maintenance of programs

Cost of Quality and Organizational Objectives

The costs of doing a quality job, conducting quality improvements, and achieving goals must be carefully managed so that the long-term effect of quality on the organization is a desirable one.

These costs must be a true measure of the quality effort, and they are best determined from an analysis of the costs of quality. Such an analysis provides a method of assessing the effectiveness of the management of quality and a means of determining problem areas, opportunities, savings, and action priorities.

The quality cost system, once established, should become dynamic and have a positive impact on the achievement of the organization's mission, goals, and objectives.

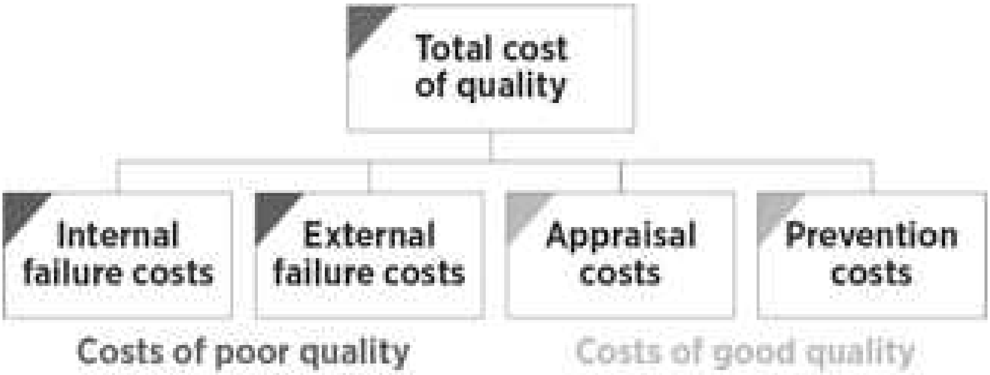


Fig.1.9.2 Classification of Cost of Quality

Cost of Doing Nothing (CODN)

- **"It takes money to make money"** In the world of Six Sigma quality, the saying also holds true: it takes money to save money using the Six Sigma quality methodology.
- We cannot expect to significantly reduce costs and increase sales using Six Sigma without investing in training, organizational infrastructure and culture evolution.
- If there is a need to produce a culture shift within the organization, a shift that causes every employee to think about how their actions impact the customer and to communicate within the business using a consistent language, it's going to require a resource commitment. It takes money to save money.
- We come across a concept, what if we do nothing instead of applying six sigma ? What is the cost of doing nothing ? When the leaders who assess Sig sigma must consider certain other options like :
  - Doing nothing
  - Creating Six sigma strategy
  - Creating six sigma Initiatives within the organization.

Doing nothing : This option can be the right choice for an organization, if they compare the cost of doing noting and cost of doing something (applying Six sigma methodology) and if the result is better with doing nothing.

Creating Six sigma strategy: This option will be more beneficial if they are applied wisely. The organization must be given good knowledge about the six sigma approach that they can decide whether or not to spend their money and time in serious investigation of this approach **Creating six sigma initiatives :** This option is less advantageous, when applied. This can be viewed by the organization as risks early rejection without much benefit. When the risks are abandoned the initiative is dropped with lot of money, time and other resources spent on it.

- Six Sigma is not a "get rich quick" methodology. It is a get rich slow methodology - the point is get rich and save money if you plan properly and execute consistently.

Assessment Questions

- Whenever you are using Lean Six Sigma to make improvements to your facility and eliminate waste, you need to make sure you take the time up front to plan it out properly. In fact, the planning stage is often considered the most important of the entire Lean Six Sigma process.
- One great way to ensure you complete the planning properly, and then go through the entire process without overlooking any of the essential steps as defined by the Six Sigma methodologies, is to use a Six Sigma Assessment.
- The Assessment checklist will be used throughout the process improvement initiative, but especially in the beginning phases during the planning process.
- Often there will be situations when people might have difficulty in seeing how six sigma techniques are directly applicable to their situation. Hence they want to see a specific example of a six sigma technique that is closely related to their own situation so that they can see how they will benefit.
- Consider a person who wants to apply six sigma techniques in his organization to get benefited but his fellow employees are not sure about how this is going to work on. Hence the person might ask questions to the management and his fellow employees.
- These questions can be addressed based on six sigma thinking. Six sigma methodologies provide appropriate metrics for the questions and resolve the situation when needed.

Unit II - The Scope of Tools and Techniques

Syllabus

Tools for definition – IPO diagram, SIPOC diagram, Flow diagram, CTQ Tree, Project Charter – Tools for measurement – Check sheets, Histograms, Run Charts, Scatter Diagrams, Cause and effect diagram, Pareto charts, Control charts, Flow process charts, Process Capability Measurement, Tools for analysis – Process Mapping, Regression analysis, RU/CS analysis, SWOT, PESTLE, Five Whys, interrelationship diagram, overall equipment effectiveness, TRIZ innovative problem solving – Tools for improvement – Affinity diagram, Normal group technique, SMED, 5S, mistake proofing, Value stream Mapping, forced field analysis – Tools for control – Gantt chart, Activity network diagram, Radar chart, PDCA cycle, Milestone tracker diagram, Earned value management.

Six Sigma tools are defined as the problem-solving tools used to support Six Sigma and other process improvement efforts. The Six Sigma expert uses qualitative and quantitative techniques to drive process improvement. Although the tools themselves are not unique, the way they are applied and integrated as part of a system is unique. The Six Sigma steps for process improvement, also referred to as **DMAIC**, are fairly direct and straightforward.

- Define the problem. Craft a problem statement, goal statement, project charter, customer requirement, and process map.
- Measure the current process.
- Analyze the cause of issues.
- Improve the process.
- Control.

Define, Measure, Analyze, Improve, and Control (DMAIC) is a data-driven quality strategy used to improve processes. The letters in the acronym represent the five phases that make up the process, including the tools to use to complete those phases.

It is an integral part of a Six Sigma initiative, but in general can be implemented as a standalone quality improvement procedure or as part of other process improvement initiatives such as lean.

DMAIC is a five-phase cycle focused on the ability to define, measure, analyze, improve, and control processes. It is designed to help a project run more efficiently and provide structure. Using this method, each change throughout a project is carefully analyzed based on relevant data. If a new change or opportunity arises during a project, the DMAIC cycle is repeated.

IPO Diagram

A diagram that visually (usually best) represents the process (center box) with inputs shown on the left and outputs shown on the right. This diagram assists in understanding proactive and reactive improvement, and also strives for addressing the inputs to a process.

A visual representation of a process or system where inputs are represented by input arrows to a box (representing the process or system) and outputs are shown using arrows emanating out of the box.

The input data shows that will be used by the process. The process itself is the steps used to solve problems that illustrate the working of the function. While output is a data item produced or modified by the steps in the process.

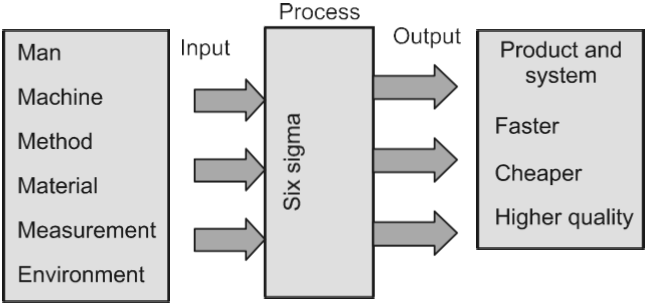


Fig. 2.2.1 IPO Diagram

The diagram has a standard IPO called 1E and 5M (Man, Machine, Method, Materials, Measurement and Environment), which describe the ways and factors that affect the manufacturing system in general. While the expected output is the productivity and quality are better aligned with the main objective of Six Sigma to deliver goods more quickly in the presentation, cheaper price and better quality.

SIPOC Diagram

SIPOC stands for Suppliers, Inputs, Process, Outputs and Customer.

A SIPOC diagram is a form of process mapping. Process mapping is a term used to describe the task of putting a project's goals and, in some cases, detailed steps on how those goals will be accomplished. It's a simple but effective method for ensuring every project team member as well as executive leadership is on the same page.

Supplier - The provider of inputs into a process

Input - Materials, information and other resources needed to complete a process

Process - Structured steps used to convert inputs into outputs

Outputs - Products or services resulting from the process

Customer - Recipient of the outputs

Steps to Create SIPOC Diagram

- The first step is to establish a name or title for the process
- The second step is to define the starting point and the ending point of the process to be improved. These should already be listed in the scope section of the team charter
- The third step is to state the top-level process steps of the process. Keep the list to four to eight main steps. These steps do not contain any decision points or feedback loops
- The fourth step is to list the key outputs of the process. Usually, this list includes up to three or four main outputs even though the process may produce more
- The fifth step is to define who receives those outputs, i.e. the customers. These customers may be internal (part of the business) or external
- The sixth step is to list the inputs to process. Stick with one to four main inputs
- In seventh step, define who supplies the inputs to the process

An Example - A lemonade stand

Supplier : Grocery store, home store, customer requests

Inputs : Lemon juice, water, sugar, ice, cups, stirring spoon, large pitcher, wood from home store, money jar, a busy pedestrian area, people to operate stand

Process : Construct lemonade stand, combine ingredients to make lemonade in pitcher, take customer orders, pour lemonade from pitcher to cup

Outputs : Chilled glass of lemonade, money placed in jar

Customer : Thirsty pedestrians

Supplier	Inputs	Process	Outputs	Customers
• Grocery store • Home store • Customer request	• Lemon juice • Water • Sugar • Ice • Cups • Stirring spoon • Large pitcher • Money jar	• Stand construction • Combining ingredients • Take orders • Pouring lemonade to cup	• Chilled glass of lemonade • Money placed in jar	• Thirsty pedestrians

Fig 2.3.1 SIPOC Diagram

Flow Diagram

Process flow charts or flow diagrams are simple and effective plans that can help resolve a lot of process improvement issues with very little work. They can be designed on a computer, on paper, or on a whiteboard using whatever tools we want.

The basic procedure for how to design process flow diagram is :

Define the process. Simply write the title at the top of the chart area. Again, this can be either on a computer, paper, or a whiteboard. You can do this alone or as a group.

Discuss the boundaries. Answer the following : Where and when does the process begin and end ? Is it a basic outline of the procedure, or is it a complicated, in-depth analysis of the process ?

Look at the process stages that take place and write them down. This can be on sticky notes, cards, or text boxes/shapes on your computer.

Put them in order. Now you can work together if in a group, to place them in sequence. Consider which stages rely on others to take effect when putting the activities in order. Identify processes that are fundamental, as well as those that are less important, if not redundant.

Use arrows to show the direction of flow. This is where you will link each stage, showing where the process diagram begins, ends, and everything in between.

Review the process. Work with your group and those involved in the relevant process (i.e. supervisors, workers, suppliers, customers) to assess the diagram. If working alone, show your work to someone else who is knowledgeable about the subject. This ensures all information displayed is accurate and valid.

Example Process Flow Diagram

Below is a basic diagram, which can be used for simple processes that don't possess complicated procedures. This basic design can be modified for diagrams that require more in-depth presentations of data.

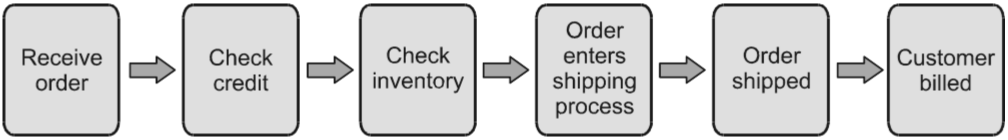


Fig. 2.4.1 Flow diagram for Online CoD orders

CTQ Tree

Critical to Quality Tree (also known as a CTQ Tree) is a Six Sigma tool used to identify the needs of the customer and translate that information into measurable product and process requirements. It allows organizations to understand the characteristics of a product or service that most drives quality for customers.

Before initiating any process improvement project, it's important for a business to determine the characteristics of the product or service that are critical to quality as judged by customers – this is known as CTQ. Creating a CTQ Tree determines the drivers behind those characteristics and helps companies find ways to meet them.

Components of a CTQ Tree

The first step to create a CTQ Tree involves listing the customer's needs. Data in this area is typically attained through interaction with the customer. Six Sigma calls for breaking down these needs into three component areas.

Need - What customer need are you fulfilling with your product or service ?

Drivers - What elements or characteristics will your customers mostly likely consider when judging the quality of your product or service ?

Requirements - What process or product requirements are needed to make those drivers meet customer standards ?

Steps to Create a CTQ Tree

- **Determine the need -** It may be helpful to ask customers directly, or consult with customer service representatives or salespeople who frequently interact with customers.
- **Determine at least three drivers -** These are the elements that drive quality for customers who have the need you want to satisfy. Keep in mind that these are elements that must be present to satisfy customers.
- **Create the requirements -** These are the standards that must be met to meet customers' expectations for each driver.

Example - Cupcake Shop CTQ Tree

The critical requirements for a cupcake shop

Need

Quality cupcakes and good service.

Drivers

1. Variety of products
2. Speed of service
3. Quality of ingredients

Requirements

For Variety of Toppings

1. At least a dozen different cupcake toppings
2. In addition to usual toppings, also include seasonal decoration options
3. Identify non-cupcake products to offer, such as cocoa or coffee

For Speed of Service

1. All customers waited on within a minute of entering shop
2. All orders fulfilled within five minutes

3. Deliver option offered for customers within certain miles of the shop

For Quality Ingredients

1. All ingredients listed on menu
2. Calories for each item listed
3. All ingredients used are locally sourced where possible

Project Charter

The project charter is a sponsor document. The Six Sigma project charter essentially is a contract for work between the project sponsor and the project team. The project charter is a set of a documents that provide purpose and motivation for the initiative, serves as a working document for the team. The project charter should also clearly state what the intended goals are and how success will be measured.

The project charter

- Clarifies what is expected of the team
- Keeps the team focused
- Keep the team aligned with process priorities The Six Sigma project charter includes :
- Measurable or quantifiable objectives to be achieved
- Organizational and Operational boundaries or scope
- Top management support commitment

Elements of Project Charter

Each organization has a standardized way to present a Six Sigma project charter. Therefore, the Six Sigma project charter can take many forms. But as explained in the lean training course some of the common elements, which are found in every Six Sigma project charter, are as follows :

1. Business Case
2. Problem / Opportunity Statement
3. Goals / Projected Benefits
4. Goal statement

5. Project Scope
6. Project Plan
7. Team Structure

Business case :

The first element in the Six Sigma project charter is the business case. The business case contains a description of the Big Y, i.e., the reason for taking up the project. It defines the quantifiable benefit of the project and how it aligns with business strategy or goals in the Six Sigma project charter. The business case identifies the dollars to be saved and establishes how the project aligns with the organization's strategies.

Problem statement :

The problem statement in the Six Sigma project charter may refer to business problem or pain, and an opportunity statement refers to improvement opportunity.

The problem statement should answer three questions :

- What is wrong ? A brief and quantified description of the problem along with the metric
- Where is the problem appearing ? Here we need a process step or process name and location
- How big is the problem ? The size, magnitude, and criticality of the business problem

The problem statement has to follow S-M- A-R- T mechanism.

Example for a poorly drafted problem statement and a properly drafted problem statement.

Poorly drafted – "Inventory levels are too high and must be reduced"

It is a poorly drafted problem statement. Having high inventory levels is a problem but a problem statement containing so little information significantly reduces your ability to take specific action and obtain improvement. This is not sufficient for the Six Sigma project charter.

The revised problem statement is :

"Inventory levels at the XYZ inventory storage process in ABC country are consuming space, taking up asset management time and creating cash flow issues. The average inventory levels are 35 days, with a high of 48 days. These levels have exceeded the target of 29 days 92 % of the time since August 2014. We could save USD 530,000 on an annualized basis subject to the condition that inventory level meets the target of 29 days”

Goals :

The third element of the Six Sigma project charter is goals or projected benefits. This part refers to the objective of the improvement idea in quantified terms.

An example of a well-defined goal is as follows :

Reducing turnaround time, which is abbreviated as TAT, from 48 hours to 24 hours concurrently increasing the daily volume coverage from 90 % in 48 hours to 93 % in 24 hours ? The estimated soft or notional savings, on account of more than 50 % reduction in TAT, are equivalent to 257,000 USD. The savings computation is enclosed herewith.

Goal statement :

The goal statement describes what success looks like. It describes the approach to solve the problem statement defined in the Six Sigma project charter but does not provide the answer or the solution.

The goal statement does not say how the goal will be achieved. If the project team knows how to achieve the goal, then they do not need to work on a Six Sigma project. They cannot have the solution in the beginning of the project. It would defeat the purpose of the project. The goal statement defines the relief expected from the team’s work.

A goal statement would always have 3 elements :

- What is to be targeted or accomplished as a result of the implementation of the project
- A measurable target for the desired result
- A projected completion date to reach the Goal

Project Scope :

The fifth element of the Six Sigma project charter is the project scope. It describes the boundary conditions and identifies key parameters covered or not covered by the project.

Project Plan :

The project plan usually contains a chart with the major milestones of the project. Often, the chart will contain the steps of DMAIC (Define, Measure, Analyze, Improve, Control) as a start. The team will need to follow the chart with a more detailed project plan.

A project plan should answer the key questions of "Who, What, Where, When, How, and How much." This covers the resources which are : People, Facilities, Equipment, and Materials that will be needed. The plan also identifies project activities with a schedule that includes an estimate of when each activity will take place, and what resources are required to finish the tasks the project plan document is expected to change over time as more information about the project becomes available.

Team Structure :

The seventh element of the Six Sigma project charter is the team structure. The team structure refers to project resources. Normally, the resources are Project Managers, Leaders and Project Team Members who are involved in the project.

The tools for measurement phase are

- Check Sheets
- Histograms
- Run Charts
- Scatter Diagrams
- Cause and Effect Diagram
- Pareto Charts
- Control Charts
- Flow Process Charts
- Process Capability Measurement

Project Name/Title : Order Processing Efficiency Start Date : 9/17/07
Problem/Project Description : Current capacity in Sales/Customer Support area is constrained while there are untapped opportunities for increased sales. We should limit, wherever possible, Sales involvement in order

- **Project charter**

processing to free up resource for active lead follow-up and sales generation, errors and/or gaps in information acquired during Order Processing procedure have a negative impact on time required to generate and/or receipt rate of, email marketing and software renewals to existing clients. This has an especially large potential impact, since it requires correction by senior sales staff, who might otherwise have more time to engage with clients, develop marketing efforts or work with product development staff.			
Project Scape (Process, Product functional areas) : Limited to software a products.			
Project objectives a Goals : To decrease cycle time and costs of specific Sale Department activities :	**Matrix**	**Baseline**	**Goal**
- Order Processing by 50 % + - Marketing to existing clients by 80 + % - Software renewals by 80 + %	Cost/Order Time/campaign Time/update	$32 download $40 shipped 2-4 hours 2-4 hours	$16 download $20 shipped 20 minutes 20 minutes
Business Need	Customer Impact : Improved notification rate for renewals and upgrades; reduction in total cycle time as procedure more streamlined.		
	Shareholder Impact : Increased sales potential, immediately on upgrades, but also for future sales with availability of sales staff; Reduced cost for order processing. Reduced costs for marketing and renewal campaigns.		

	Employee Impact : Clearer responsibilities; Less interruption in process flow.	
Project Sponsor : Pater Keene, VP	Stakeholder Group : Sales and Operations	Signature/Date
Team Black Belt : Patrick Killihan		
Team Members : Don Debuski	Customer Support	
Helen Winkleham	Shipping and Packaging	
Anne Sheppard	Accounting	

DEFINE	**MEASURE**	**ANALYZE**	**IMPROVE**	**CONTROL**
Objective and Date Complete	Objective and Date Complete	Objective and Date Complete	Objective and Date Complete	Objective and Date Complete
· Project Def. 9/17/07	· Process Definition____	· Value Stream Analysis ____	· Implement process ____	· Standard Methods ____
· Top level process Def. 9/19/07	· Metric Def.	· Analyze Variation	· Assess Benefits	· Control Plan
· Team Formation 9/19/07	· Estimate Baseline	· Determine Drivers	· Evaluate Failure Mode	· Lessons Learned

Check Sheets

The Check Sheet is a simple document that is used for collecting data in real time and at the location where the data is generated. The document is typically a blank form that is designed for the quick, easy and efficient recording of the desired information, which can be either quantitative or qualitative. When the information is quantitative, the check sheet is sometimes called a tally sheet.

A defining characteristic of a check sheet is that data is recorded by making marks ("checks") on it. A typical check sheet is divided into regions, and marks made in different regions have different significance. Data is read by observing the location and number of marks on the sheet.

Useful for all phases of DMAIC, Check Sheets are best used when the data can be collected by the same person or in the same location. It is particularly effective for identifying defect frequency, patterns of events, and possible defect causes.

A Check Sheet is a simple tally sheet used to systematically collect data on the frequency of an occurrence (e.g., the frequency of defects).

Types

Five basic types of check sheets include :

Classification check sheet : A trait such as a defect must be classified into a category. If you just kept track of the total defects, you would know that you had 101 total defects. That is somewhat useful but that, in and of itself, does not provide much insight as to which day is the worst day or which source of defects is in the worst shape, etc. With a classification check sheet, it provides a visual overview of the problem areas.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Wrong orders	///	𝍸	𝍸 𝍸 𝍸 𝍸 //	/	//	////	𝍸 //
Reworked orders		/	//	///		/	//
Late deliveries	𝍸 ///	/	///	//		///	//
Shipping damage						𝍸 𝍸 𝍸 𝍸	𝍸 ///
Late payments		/					
Totals	**11**	**8**	**27**	**6**	**2**	**28**	**19**

Fig. 2.7.1 Classification check sheet

Histograms

A Histogram is a bar chart showing the frequency of an outcome. In Six Sigma, we can use a histogram to visualize what is going on. A Histogram can reflect the voice of the process.

Histogram represents the frequency (count) of items falling into different categories of a given population or sample. It looks similar to a bar graph. It has vertical bars with different heights (Height of the bar signifying the frequency of that group). Each group has a corresponding bar representing it in the graph.

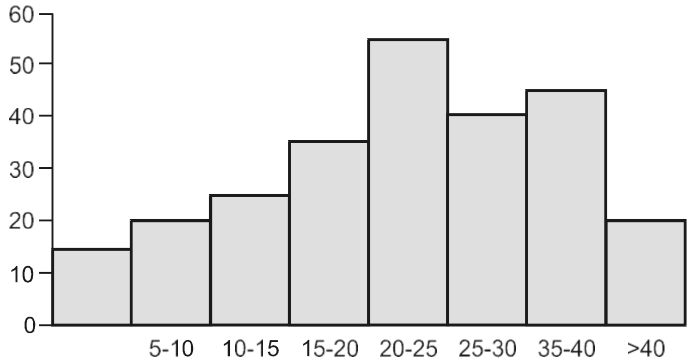
Characteristics of a Histogram

- Histogram is used to represent categorization of Continuous data.
- There is no gap between the bars unlike Bar graph, to signify that the data is continuous.
- The width of the groups is equal.

$$\text{Width} = \frac{\text{Total range of population}}{\text{No. of categories}}$$

Applications of Histogram

- There are numerous places and situations where one can use a Histogram. Let us discuss about the most frequently used fields. In Stock exchange to identify the trade in different areas or different group of investors
- In Medical and Clinical Research, to identify the presence or absence of a condition among different categories of people.
- In photography for Image processing and digitization
- In Six Sigma, Quality improvement – to study the defect pattern across different categories of samples



Run Charts

A run chart displays observed data as they evolve over time. Just a basic graph that displays data values in a time order. Can be useful for identifying trends or shifts in process but also allows you to test for randomness in the process.

A run chart can reveal shifts and trends, but not points out of control (A run chart does not have control limits; therefore, it cannot detect out of control conditions.) You can turn a run chart into a control chart by adding upper and lower control limits.

Use it to :

- Track improvements (and determine success)
- Display outputs to look for stability or instability

A run chart may be used to study observed data for trends or patterns over a specified period of time and focus attention on vital changes in the process. The run chart is useful for tracking information and predicting trends or patterns. It can determine if a process has common cause or special cause variation. It can also reveal whether a process is stable by looking for a consistent central tendency, variation and randomness of pattern. This is important because processes fall into one of four states:

1. Ideal
2. Threshold
3. Brink of chaos
4. State of chaos

Creation of Run Charts

There are seven steps to creating a run chart.

1. Decide on the measure to be analyzed (assuming there is a reliable measurement system in place).
2. Gather the data – have a minimum of 10 data points.
3. Draw a graph with a vertical line and a horizontal line.
4. On the vertical line, or the y-axis, draw the scale relative to the variable you are measuring.
5. On the horizontal line, or the x-axis, draw the time or sequence scale.
6. Calculate the mean/median (whichever the data set indicates to be appropriate) and draw a horizontal line at that value – going across the graph.
7. Plot the data in the sequence, or the time order, in which the data was collected.

Interpretation of Run Charts

A run is a sequence of consecutive points which all lie on the same side of the mean/median line. Mean or median can be used depending upon the data. If the data is symmetrical, use mean; otherwise median is a better choice. A run can be a single point if both the previous and subsequent points are on the opposite side of the mean/median line. Ignore points that lie exactly on the line. Simply count the number of runs. Having more or fewer runs than expected indicates that there is non-random variation in the process.

A shift is nine or more consecutive points above or below the central line. This is an indication that special cause variation exists in the process. After shifts, look for trends. Trends are six or more consecutively increasing or decreasing points indicating that special cause variation exists in the process.

Then check for alternating points - points alternating up and down indicates special cause variation exists in the process. Next it is time to check for outliers, any dramatically different values indicating special cause variation in the process. In addition to these formal checks, it is important to determine if the current data looks different than the older data (if available).

Parts 1-25

Fig. 2.9.1 Run Chart - Trends Example

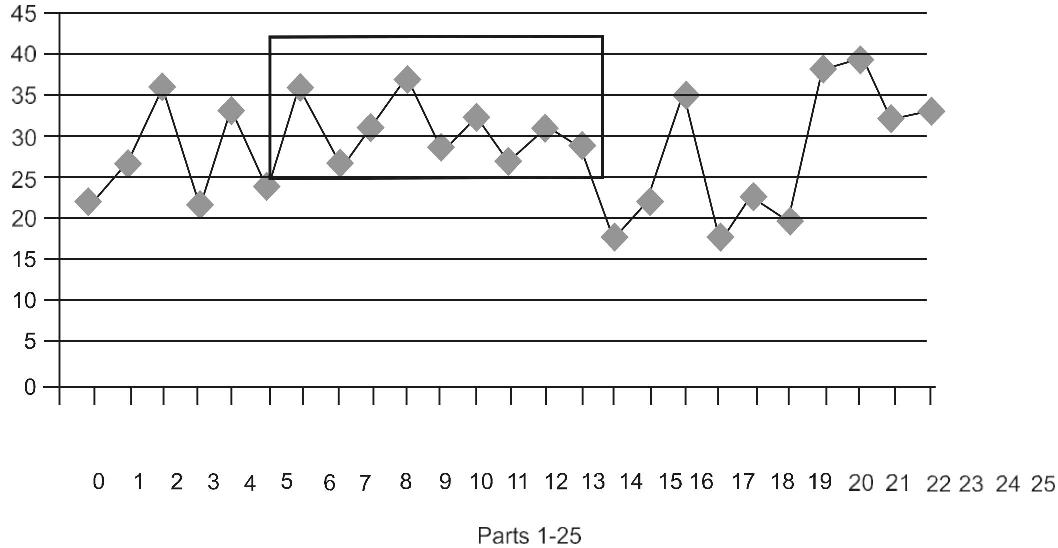


Fig. 2.9.2 Run Chart - Shifts Example

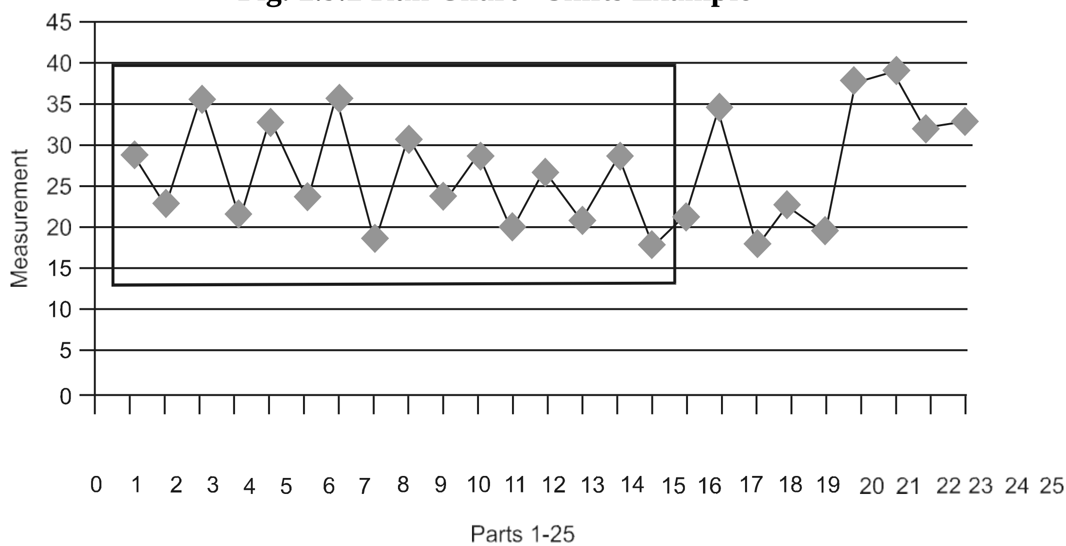


Fig. 13

Fig. 2.9.3 Run Chart - Alternating Example

Guidelines for interpretation :

1. Look at data representing a long enough period of time so that a "usual" range of variation is experienced. (This requires some process knowledge.)
2. Is the recent data within the usual range of variation ?
3. Is there a cyclical pattern ? Weekly ? Monthly ? Yearly ?
4. Draw a best-fit trend line from the beginning to the end of the data on the run chart. If the line is approximately horizontal, then the mean of the process can be considered stationary over this time interval. If not, then the process mean is

   considered non-stationary, or unstable. Drawing this inference requires sufficient data, usually 50 or more observations (i.e., two points are not sufficient).

Scatter Diagrams

A scatter diagram is a graphical tool that shows whether or not there is a correlation between two variables. A Scatter Analysis is used when you need to compare two data sets against each other to see if there is a relationship. Scatter plots are a way of visualizing the relationship; by plotting the data points you get a scattering of points on a graph. The analysis comes in when trying to discern what kind of pattern – if any – is present.

When using a scatter diagram there are two types of variables – a dependent variable and an independent variable. The **independent variable** is usually a plotted along the horizontal axis. **The dependent variable** is usually plotted along the vertical axis. If no dependent variable exists, either type of variable can be plotted on either axis. If the clustering of intersecting dots in the paired comparisons shows a pattern that extends from lower-left to upper-right, the scatter diagram shows evidence of a **positive correlation.** If the pattern of dots tends to go from the upper-left to the bottom-right, there is evidence of a **negative correlation.**

1. Correlation does not mean causation. There might be a correlation suggesting that ice cream sales causes more shark attacks, but clearly there is a third variable – the weather outside means that when the

weather is warmer, more people tend to eat ice cream and more people tend to go swimming.

2. The second thing to remember is that a negative correlation does not mean a bad thing. It simply means that as the vertical axis decreases, the horizontal axis increases. That's all it means. Sometimes people think that a negative correlation is bad. It has nothing to do with good or bad. It has everything to do with whether or not there is a positive or negative correlation. Also know that if there is no pattern of evidence of a trend in either direction, there is evidence of no correlation, which is good to know as well.

Correlation Coefficient (R) and Coefficient of determination (R Squared)

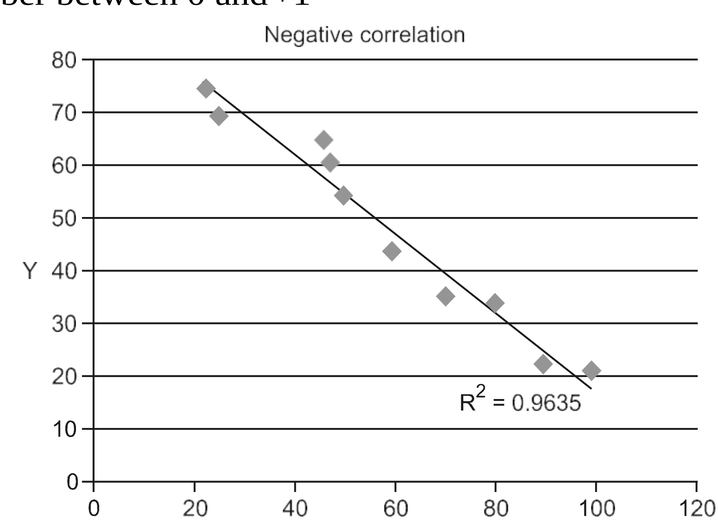
A scatter diagram is a graphical representation of two variables, one on X axis and the other on Y axis. Hence they are also known as XY plots. A Scatter plot depicts the relationship between the two variables and determines if there is a correlation between those two variables. When one variable changes when changing the other variable, then a correlation is said to exist between those two variables.

Correlation Coefficient is measured as :

$$\text{Correlation Coefficient (R)} = \frac{N\sum XY - \sum X \sum Y}{\sqrt{N(\sum X^2) - (\sum X)^2}\sqrt{N(\sum Y^2) - (\sum Y)^2}}$$

R is always between -1 and $+1$

Coefficient of determination is the square of R or R squared. This is always a positive number between 0 and +1



X

Fig. 2.10.1

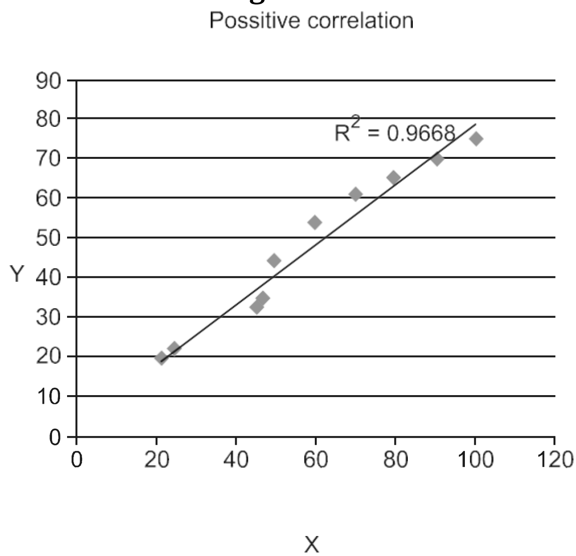


Fig 2.10.2

Scatter Plots and Correlation

Scatter plots only show correlation. They do not prove causation. The example often used is shark attacks and ice cream sales. There may be a correlation between the two, but ice cream does not cause shark attacks - the heat of the day does. In other words, more people are in the water on hot days equaling more shark attacks, and more people buy ice cream on hot days.

Making of Scatter Diagram

1. Collect sets of data where a relationship is present.
2. Draw a graph in the shape of an “L,” and make the scale even multiples (i.e., 10, 20).
   - Place the independent variable on the horizontal (X) axis.
   - Place the dependent variable on the vertical (Y) axis.
   - Place a dot or a symbol where the x-axis value intersects the y-axis value.
   - If two dots fall together, place them side by side, so they are touching,

and both are visible.

3. Review the pattern of points to determine if a relationship is present:
    - Stop if the data forms a line or a curve, as the variables are considered correlated.
    - Use regression or correlation analysis, if necessary. If regression or correlation analysis are not needed, complete steps four through seven below.
4. Divide points on the graph into four equal sections. If X points are present on the graph :
    - Count X/2 points from top to bottom and draw a horizontal line.
    - Count X/2 points from left to right and draw a vertical line.
    - If the number of points is odd, draw a line through the middle point.
5. Count the points in each quadrant.

Cause and Effect Diagram

A Cause and Effect Diagram is a graphical tool for displaying a list of causes associated with a specific effect. It is also known as a fishbone diagram or an Ishikawa diagram (created by Dr. Kaoru Ishikawa, an influential quality management innovator). The graph organizes a list of potential causes into categories.

Commonly used in brainstorming and in the "open" phase of root cause analysis.

Each cause or reason for imperfection is a source of variation. Causes are usually grouped into major categories (5Ms and 1E) to identify these sources of variation.

- Man : Anyone involved with the process
- Methods : How the process is performed and the specific requirements for doing it, such as policies, procedures, rules, regulations and laws
- Machines : Any equipment, computers, tools, etc. required to accomplish the job
- Materials : Raw materials, parts, pens, paper, etc. used to produce the final product
- Measurements : Data generated from the process that are used to evaluate

its quality

- Environment : The conditions, such as location, time, temperature, and culture in which the process operates

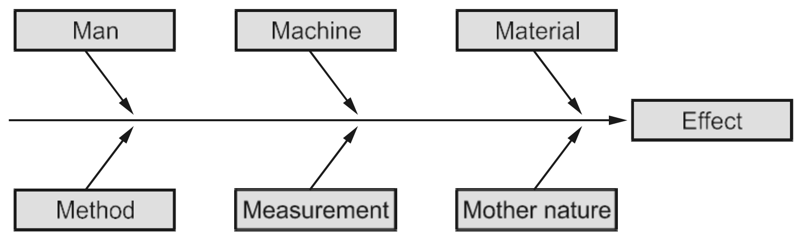


Fig. 2.11.1 Cause and Effect diagram

Example of Cause and Effect Diagram

A company has experienced problems with a particular machine. The drilling operation is producing an excessively large size of burr. What's a burr ? If you were to drill a hole in metal; then, if you were to run your finger across the hole and it cuts your finger, the cut was caused by a burr. It's virtually impossible to drill a hole without a burr, but it isn't impossible to minimize the size of them. The team chose to use a Cause and Effect Diagram to list as many causes as possible that might have an effect – which in this case is the burr.

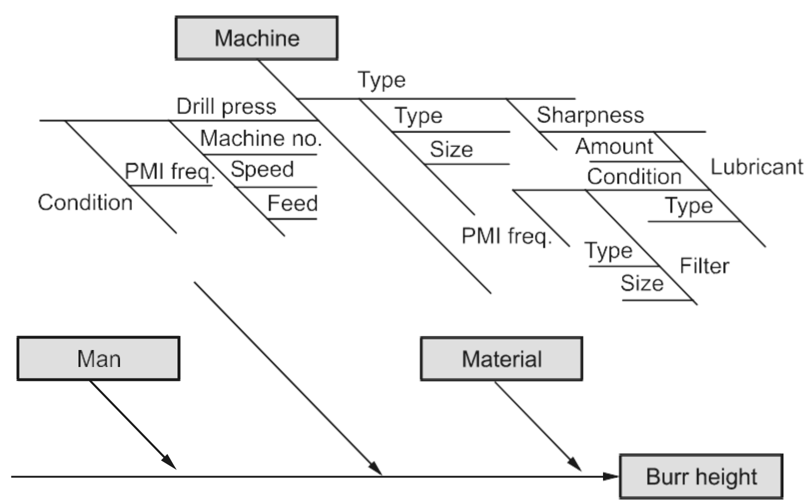


Fig. 2.11.2 Cause and Effect diagram - Example

Pareto Charts

Pareto Analysis is a way of looking for the most common contributing causes to a situation. Using a Pareto chart to perform graphical analysis on your data can help you identify the biggest drivers to your process and appropriately prioritize your actions.

Pareto Principle :

Often called the 80-20 rule, the Pareto Principle is a common 'rule of thumb' that

"80 % of the effects of something can be attributed to 20 % of the drivers."

Pareto Analysis Principle Example :

Profits - Many businesses discover that 80 % of their profits are driven by 20 % of their products. Thus it makes sense for them to focus on that 20 % of those customers because that gives them the best chance to drive profits.

Errors - Sometimes you can see that one aspect of your process is responsible for delivering 80% of your errors. If you fix that one process, you can achieve outsized results.

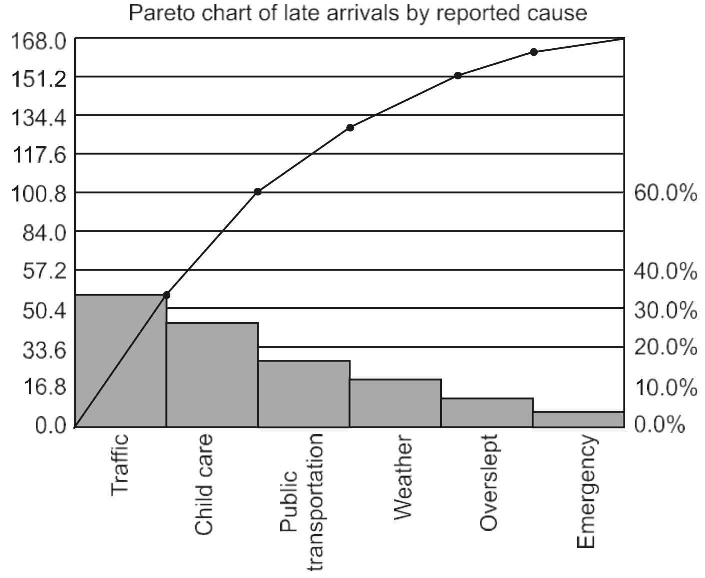


Fig. 2.12.1 Pareto Chart – Example

Steps for Building a Pareto Chart

1. Identify the problem under investigation.
2. List the potential causes – Use existing data or brainstorm new ideas.
3. Measure the problem with an easy-to-understand unit – The most common are frequency and cost.
4. Choose the right period of time – Measure performance over a time period long enough to capture the situation. Select a period of time that is long enough to balance out seasonality and shorter weekly fluctuations.
5. Collect data for each type of problem – This data can be current or historical.
6. Measure the cost or frequency of each problem
7. Display problems and their costs on a graph

For graph : Plot the problems on the horizontal line of the graph and frequencies or costs on the vertical line. Plot the problems in descending order from left to right on the horizontal line. The problem with the highest frequency or cost is displayed at the far left of the horizontal line followed by the next most costly or frequent problem and so on.

Presenting a Pareto Chart in graphical form displays the types of problems that afflict the process and illustrates the relative significance of these problems. Using the Pareto Chart as a guide, project teams can decide which problems to address first. Six Sigma teaches project teams to address problems that impact customers and profitability first.

The Pareto Principle teaches that most of the problems in the process have just a few causes. The Six Sigma technique of creating a Pareto Chart takes this principle one step further and illustrates what these causes are and how much impact they have on the process.

Control Charts

A Six Sigma control chart is a simple yet powerful tool for evaluating the stability of a process or operation over time. Creating a control chart requires a graph that covers a period of time, a center line that shows the results of a process during that time, and upper and lower control limits that indicate whether process variation is within an accepted range.

A control chart offers a way of taking the details involved in creating and improving a process and having one chart that shows the outcome. That's vital information because processes fall under four states : ideal, threshold of ideal, on the brink of chaos and in a state of chaos.

A control chart is an extension of a run chart. The control chart includes everything a run chart does but adds upper control limits and lower control limits at a distance of 3 Standard Deviations away from the process mean. This shows process capability and helps you monitor a process to see if it is within acceptable parameters or not.

Tips for Control Chart

- Specification lines should NEVER be included on a control chart
- You should gather data for a control chart in the order of production
- The ease of data collection is not a major consideration.
- It is more important to collect data that relates to a critical product or process parameter.
- Never gather data from inspection records, because it is too late - the cause for a point out of control, shift, or trend is lost because it happened hours earlier.
- Put at least 6 points in the range of a control chart to ensure adequate discrimination.
- A control chart can be used to identify the following assignable causes
    - Shifts
    - Trends
    - A point outside control limits
    - NOT anything to do with specification limits.

For example, construction of cars, trucks and planes involves thousands of parts and tasks. Constructing a chart to map out subgroups such as construction of individual parts might be required.

When constructing a control chart, it's important to keep the following in mind :

- Gather and record data in the order of production.
- Collect data sets over a period of time that help you establish the upper and lower control ranges using averages.

- Plot and connect dots that indicate, from left to right, the data over a period of time
- Act on what the chart tells you.

A run chart can reveal shifts and trends, but not points out of control (A run chart does not have control limits; therefore, it cannot detect out of control conditions.) You can turn a run chart into a control chart by adding upper and lower control limits.

Control limits :

Control limits are the voice of the process (different from specification limits, which are the voice of the customer.) They show what the process is doing and act as a guide for what it should be doing. Control limits also indicate that a process event or measurement is likely to fall within that limit.

Control limits are calculated by :

- Estimating the standard deviation, σ, of the sample data
- Multiplying that number by three
- Adding (3 x σ to the average) for the UCL and subtracting (3 x σ from the average) for the LCL

Mathematically, the calculation of control limits looks

like : CL = average 3 *

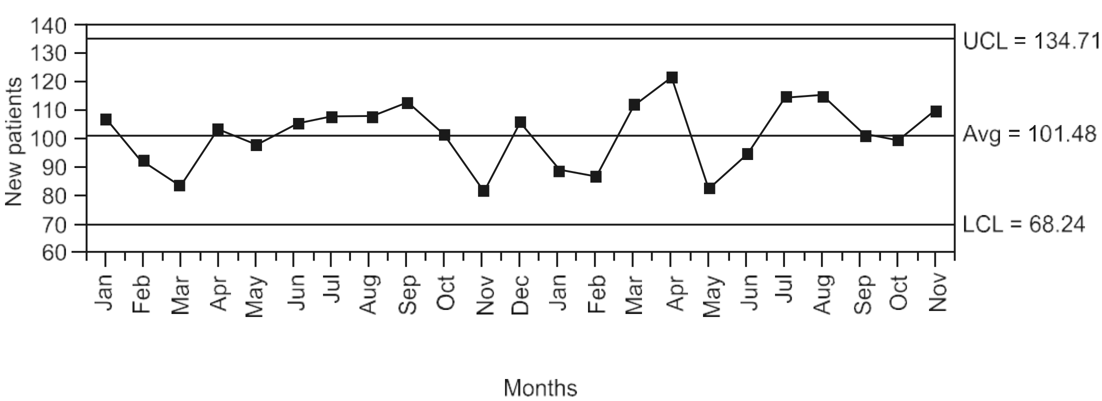


Fig. 2.13.1 Control chart - Example

A Control Chart Indicates a Process is Out of Control When :

- Six consecutive points, increasing or decreasing.

- Fourteen consecutive points that alternate up and down.
- One or more points outside the control limits.

The Four Process States in Control Chart :

Processes fall into one of four states.

1) The ideal,

2) The threshold,

3) The brink of chaos and

4) The state of chaos

When a process operates in the **ideal state,** that process is in statistical control and produces 100 percent conformance. This process has proven stability and target performance over time. This process is predictable and its output meets customer expectations.

A process that is in the **threshold state** is characterized by being in statistical control but still producing the occasional nonconformance. This type of process will produce a constant level of nonconformance and exhibits low capability. Although predictable, this process does not consistently meet customer needs.

The **brink of chaos state** reflects a process that is not in statistical control, but also is not producing defects. In other words, the process is unpredictable, but the outputs of the process still meet customer requirements. The lack of defects leads to a false sense of security, however, as such a process can produce nonconformance at any moment. It is only a matter of time.

The fourth process state is the **state of chaos.** Here, the process is not in statistical control and produces unpredictable levels of nonconformance.

Usage and Terms of Control Chart :

Trend : Seven points in a row in either an upward or downward direction.

Shift : Seven points in a row either above or below the center line

Extreme shift : Seven points in a row that are beyond the control limits, not a trend

Drift : A process is expected to drift, for no particular reason, about 1.5 standard deviations over the long run

Flow Process Charts

Flow process or process mapping is a technique utilized in a Six Sigma project to visualize the steps involved in a certain activity or process. In its basic form, Six Sigma process mapping is a flowchart that illustrates all of the inputs and outputs of an event, process, or activity in an easy to read, step-by-step format.

The process flow map is created to get an understanding of the process to be improved, and to ensure that all team members have a solid grasp on the steps involved in the process. Further, it marks the baseline, 'as-is' condition of the process for your project.

1. The visualization of a particular workflow that **Utilize the right symbols -** Most Six Sigma process maps feature the same set of symbols, and each symbol represents a different action or point. Draw these symbols around each step of the process and be sure the entire team understands the meaning of each symbol. The most common symbols and their meanings are as follows :
   a. Terminator : Both the start and end of the process
   b. Rectangle : A step or task that must be performed as part of the process
   c. Oval : The inputs and outputs of a step or the entire process (commonly found at the beginning and end of the process)
   d. D : "D" symbols indicate delays in the process
   e. Arrow : Movement in the process—an indication of where the process flows from step to step
   f. Diamond : A point in the process where a decision must be made
2. **Check your work -** Review the map to ensure every step of the current process is listed and described correctly. Have someone outside the project team-but involved in the process-to analyze the map from their perspective to make sure nothing is missing.

Process Capability Measurement

Process Capability (Cp) is a measure of the relationship between the voice of the process and the Voice Of Customer (VOC). It is essentially a ratio of the customer requirement (specification) and the expected process variation.

Process capability = Voice of the customer / Voice of the process

Cp is an expression of how well your process performs relative to the VOC. And it is a prediction of how well your process will meet customer requirements in the future. A capable process is one in which almost all measurements of a feature produced by the process fall inside specification limits. There are several indices that are commonly used.

Example of Cp Measurement

Let's use a car and garage example to drive home the concept of Cp. The garage defines the specification limits. The car size represents the process limits.

we are working to improve is called as **Process Flow Map.**

Benefits of Process Mapping

- See the entire process in one view.
- Detect waste faster.
- Deliver on promised expectations.
- Store for future reference and training.

The type of process map you choose will depend on the complexity of your project, but each map should be completed as follows :

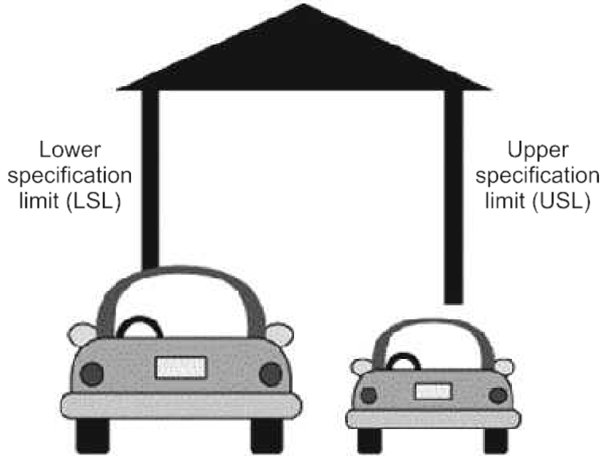


Fig. 2.15.1. Cp

If the car is smaller than the garage, it means Cp > 1; the car will fit inside the garage. When you find that your data (car) is smaller than the specification limits (garage), your process is capable. It is, therefore, safe to conclude that you will not have problems meeting the specifications. In other words, you will not have problems parking the car in the garage. Cp is the specification width divided by the process width.

Process Capability Assumptions

When calculating process capability Cp or Cpk, there are three key assumptions :

- Large sample size
- Stable process
- Normal distribution

When these assumptions are not met, the values are not valid.

Most capability index estimates are valid only if the sample size used is "large enough," which is generally thought to be about 30 or more independent data values.

Tools for Analysis :

The Analysis phase of DMAIC helps project teams identify problems in the productionprocess that cause product defects. This phase of Six Sigma methodology is loaded with tools to help spot the problems in the production process and to determine if these problems are the root causes of defects.

Some of the tools for analysis are

- Process Mapping
- Regression analysis
- RU/CS analysis
- SWOT
- PESTLE
- Five Whys
- Interrelationship diagram
- Overall equipment effectiveness
- TRIZ innovative problem solving

Process Mapping

The process map is a tool that graphically shows the inputs, actions and outputs of a process in a clear, step-by-step map of the process. The purpose of process mapping is to help team members and others within the process to understand the process.

Process mapping is the graphical representation with illustrative descriptions of how things get done. It helps the participants to visualize the details of the process closely and guides decision making. One can identify the major areas of strengths and weaknesses in the existing process, such that the contribution of individual steps in the process are recognized. Further, it helps to reduce the cycle times and defects in the process and enhances its productivity.

The major components of a process map include the inputs, outputs and the steps in the process. A good process map should illustrate the flow of the work and the interaction with the organization. It should make use of common language (symbols) that are easily understood by everyone. An ideal process map should contain proper detail with respect to multiple paths, decisions and rework loops.

Need for Process Mapping

1. Pictures guide better than words. The use of graphs, charts, tables and images guides better than a big compiled report with lot of data fixation issues in it.
2. Process maps facilitate improvements in the process, since it becomes easy to pin point the specific areas that need changes, like bottlenecks, delays, capacity constraints etc. in the light of efficiency and effectiveness of the process.
3. Decision making becomes fast as it deals with the ‘show me’ aspect and not the ‘tell me’ aspect of the process and the problem areas.
4. The improvements made in the process can easily be tracked using process maps since it becomes possible to audit and understand different areas in the process as well as the organization.
5. Visual illustration for training would be much more effective than any oral tools explained, as the visual examples register faster in human brains and helps them understand the things better and fast.
6. In the need of change, when the organization moves on making the changes without understanding the current working process, it is likely to commit more mistakes or deploy its resources in creating more troubles. Process maps provide a detailed outlook of the current process and guides the effective management of change.
7. Process maps serves as a measurement tool for a process that is very much necessary to manage and finally improve it.

Process Maps - Types

There are two major types of process maps - that are process flowchart and deployment flowchart.

Process flowchart :

A process flowchart is a simple process map that provides the visual representation of the sequence of activities along with their points of decisions. These flowcharts provide the basic details of the process, which can later be augmented by adding the roles of different staffs.

Deployment flowchart :

These process maps provide the interactions between different departments and the roles performed by different people in the organization. Also termed as 'swim- lane' charts, these process maps have vertical lines showing the movement of process from person to person.

Advantages

- Process Maps Help You Uncover Waste
- Process Maps Help You Deliver to Expectations

Steps in Developing the Process Map

Step 1 : Select the process - identify the reason for creating the process map.

Step 2 : Identify the scope of the process steps - observe the entire process and collect data and information.

Step 3 : Plan and schedule resources - identify the systems that are involved in the process.

Step 4 : Select Mapping techniques - select the mapping technique, like process flowchart or deployment flowchart.

Step 5 : Conducting interviews - plan and conduct the interviews in the sequence of roles established in the process map.

Step 6 : As-Is process - describe the activities that help to transform inputs to outputs.

Analyze, evaluate and Sign- off - Process map should be reviewed thoroughly to learn any redundancies, delays, unnecessary steps, ambiguous roles, cycle time, activity lapse, repeated activity flows, bottlenecks and rework loops. Performance can be measured using Pareto Charts, Cause and Effect diagram, process behavior charts and process modeling and simulation.

Regression Analysis

Analysis is one of the most important phases within Six Sigma. During analysis, project teams seek to map out an operation in detail and identify problems that are leading to defects, errors or waste.

Regression Analysis is a tool that identifies root causes of defects, errors and waste. Regression analysis estimates the impact variables have on each other as well as the final product. It allows for measurement of how well a theory fits the real-world data.

Project teams that use regression analysis make predictions and measure outcomes by using data to plot the relationship between an independent and dependent variable. This is known as linear regression.

Advantages

- Decreased work-in-progress
- Improved process flow
- Increased productivity
- Improved inventory turns
- Reduced cycle time

Terminologies in Regression Analysis

1. **Coefficients :** These are the intercept (b0) and slopes (b1, b2,….,bn) of individual input variables. The values of these coefficients are extremely important in determining the Regression Equation. They are also, one of the key outputs of a Regression Analysis.
2. **Standard Error (SE) :** Most software packages provide this value SE, when performing a Regression Analysis. It denotes the standard deviation of the Residual values from the Regression line. A good model should try to reduce the Standard Error.
3. **Coefficient of Determination (r2) :** This value denotes how good and efficient

the regression equation is, in predicting the y value. Typically, r2 values range from 0 to 1; 0 denoting a worst model and 1 denoting the best model. Higher is the r2

value, better is the prediction. Often, for Multiple Regression, another value known as r2adj is calculated. This value is different from r2 by eliminating the effect of multiple interrelated variables (Multicollinearity).

4. **Multicollinearity :** It is a condition denoting the input variables being strongly correlated. In such a condition, this correlation may mask another input variable's significance in the prediction. So, to avoid this, before proceeding to Regression, a Correlation Matrix for all the input variables is plotted and the masking effect is identified. Any one of the pair of variables with strong correlation is removed based on the business knowledge of the problem.

Simple Regression Analysis - Example

A statistical measurement of correlation can be calculated using the least squares method to quantify the strength of the relationship between two variables. The output of that calculation is the Correlation Coefficient, or (r), which ranges between □1 and 1.

A value of 1 indicates perfect **positive correlation** - as one variable increases, the second increases in a linear fashion. Likewise, a value of □1 indicates perfect **negative correlation** - as one variable increases, the second decreases. A value of zero indicates **zero correlation**.

Following is a scatter plot chart example based on an automobile manufacturer.

In this case, the process improvement team is analyzing door closing efforts to understand what the causes could be. The Y-axis represents the width of the gap between the sealing flange of a car door and the sealing flange on the body - a measure of how tight the door is set to the body. The fishbone diagram indicated that variability in the seal gap could be a cause of variability in door closing efforts.

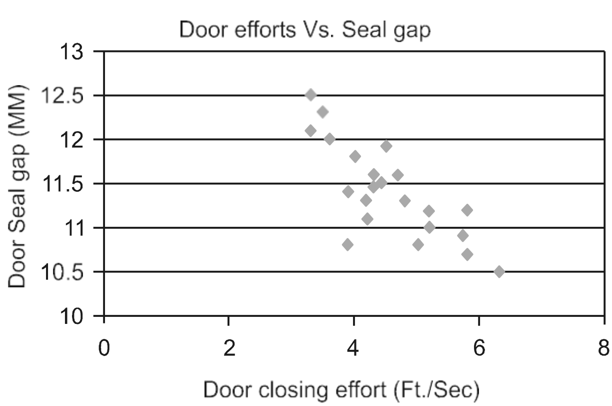


Fig. 2.17.1 Correlation

In this case, you can see a pattern in the data indicating a negative correlation (negative slope) between the two variables. In fact, the Correlation Coefficient is 0.78, indicating a strong inverse or negative relationship.

Regression Analysis assumes that one variable is dependent upon :

A) Another single independent variable (Simple Regression) , or

B) Multiple independent variables (Multiple Regression).

RU/CS Analysis

Resource Utilization (RU) / Customer Satisfaction (CS) analysis is a tool to establish thekey parameters of both RU and CS.

The parameters of RU may be

1. Machines
2. Materials and
3. Labour

The parameters of CS may be

1. Specification
2. Cost and
3. Time

The customer expects the goods or service to be delivered according to the acceptable standards, to be an affordable price and that they arrive on time. Hence the parameters we chosen are specification, cost and time and which also varied with respect to the market condition.

Basic Steps

- Identify the key parameters of Resource Utilization (RU) and prioritize the top 3parameters.
- For CS parameters, we have already chosen specification, cost and time.
- Draw two matrices for CS and RU showing 6 parameters as below.
- Allocate the rating of 1, 2 and 3 (keeping 3 being most important). The ratings areinfluenced by internal process.
- Rate separately what is actually achieved for RU and CS.
- Compare the two sets of figures and identifies the shortfalls.

- Review the criticality of the shortfalls and examine the resources.
- Draw a combined RU/CS matrix, with the allocated ratings and identify the conflicts.
- Have identified the conflicts, examine the relative importance of parameter to minimize the conflicts.

RU

	1	2	3
1	✓	✓	✓
2	✓	?	✓
3	✓	?	X

RU

	1	2	3
1	✓	✓	?
2	?	✓	✓
3	X	?	✓

CS (Cost)

Fig. 2.18.1 Matrices of key parameters

SWOT

SWOT Analysis is a methodology for the team to explore the Strengths, Weaknesses, Opportunities, and Threats of an item, or area of interest.

A technique used in Six Sigma to evaluate a project or an entire company and identifies the four facets of the situation.

- S - Strengths
- W - Weaknesses
- O - Opportunities
- T - Threats

The first two categories are internal. They exist within the organization.

- Strengths are things that you do well.
- Weaknesses are things that you don't do so well.

The last two categories are external. They exist in the environment. In other words, themarket place in which the organization operates.

- Opportunities are elements that your org could use to improve its situation.
- Threats are elements that could cause harm to your org.

Need for SWOT

A SWOT analysis is good for giving a high level view of your company or a project. Itcan help to :

- Work to your strengths
- Shore up or make allowances for your flaws
- Take advantage of changes in the marketplace
- Minimize risk by defending against known threats.

Stakeholders of SWOT Analysis

- Subject matter experts
- Team members
- Business planners
- Product owners
- Managers
- Marketing team

Factors to be Considered

Step 1 : Assemble your group - Get the stakeholders together for a brainstorming session. A person acting as a group leader will guide the process.

Step 2 : Run through your objectives - Make sure everyone understands the business objectives.

Step 3 : Explain the categories - Ensure that the categories (strengths, weaknesses, opportunities, threats) are clear to all.

Step 4 : Write down suggestions - Avoid judging ideas as they come in. Keep the pacebrisk and write them down.

Step 5 : Groups pick their top tens - Separate the people into groups based on their stakeholder types and ask each group to discuss and decide on a list of their topten suggestions in each category.

Step 6 : Consolidate the data - Put together a small group of representatives from each group and go over each group's top tens and consolidate into a final top ten ineach category.

SWOT Example

Objective : TO INCREASE OF NURSERY IN A NEW MARKET	
Internal Factors	
Strengths (+)	**Weaknesses (□)**
1) Consistent Quality : - Consistently product plants with high activebotanical %	1) Lack of Funding : - We need to borrow some amount of money in 1^{st} year
2) Saleable Plants : - Produce high ratio of healthy plants 3) Experience : - Combination of Business and Horticultureexperience	2) No reputation yet : - Haven't established yet as a reputable Nursery
External Factors	
Opportunities (+)	**Threats (□)**

1) Customer loyalty : - Customer are looking for ongoing relationships 2) Growing market : - Market for supplement is huge and growing	1) Weather : - Changes in weather can seriously affect production 2) Pest : - A threat to our ability to produce healthy plants 3) Similar-sized farms : - Some similar farms are in bu

PESTLE

PESTLE - Political, Economic, Social, Technological, Legal, Environmental

The PESTEL or PESTLE Analysis is a tool that is used to identify and analyze the key drivers of change in the strategic or business environment. The tool allows the assessing of the current environment and potential changes. The idea is, if the project is better placed than its competitors, it would be able to respond to changes more effectively.

PESTLE - The Tool

Political : Every project has both internal politics and external politics. The internal politics like team jealousies, cohesive projects, and personal interests occur in all projects and must be considered and managed by stakeholders. The external politics refer to those which the stakeholders do not control. These events include all political events like employment laws, tax policies, trade restrictions, trade reforms, environmental regulations, political stability, tariffs, etc.

Economic : This factor takes into consideration all events that affect the internal and external economic environment. The internal or micro-economic events relate to the project viability and internal soundness of the project. The external or macro-economic events include interstate taxes, embargoes, interest rates, economic growth, recession, inflation rate, exchange rate, minimum wage, wage rates, unemployment, cost of living, working hours, credit availability, financing availability, etc.

Sociological : The sociological factor takes into consideration all events that affect the market and community socially. Thus, the advantages and disadvantages to the people ofthe area in which the project is taking place also need to be considered. These events include cultural expectations, norms, population dynamics, healthy consciousness, career altitudes, global warming, etc.

Technological : This factor takes into consideration all events that affect technology. Since technology often becomes outdated within a few months after it is launched, it is important to consider this. This factor could also take into consideration all barriers to entry in certain markets and changes to financial decisions.

Legal : This factor takes into consideration all legal aspects like employment, quotas, taxation, resources, imports and exports, etc.

Environmental : This factor takes into consideration ecological and environmental aspects that could be either economic or social in nature. These include temperature, monsoons, natural calamities, access by rail, air, and road, ground conditions, ground contamination, nearby water sources, and so forth.

Advantages and Disadvantages

The advantages of using the PESTLE analysis tool are :

- The tool is simple and easy to understand and use.
- The tool helps understand the business environment better.
- The tool encourages the development of strategic thinking.
- The tool helps reduce the effect of future business threats.
- The tool enables projects to spot new opportunities and exploit them effectively.The disadvantages of using the PESTLE tool are :
- The tool allows users to over-simplify the data that is used. It is easily possible tomiss important data.
- The tool needs to be updated regularly to be effective.
- The tool is most effective when users come from different perspectives and departments.
- The tool requires users to have access to data sources which could be time consuming and expensive.
- Much of the data used by the tool is on an assumption basis.
- The business environment is changing drastically. Thus, it is becoming increasinglydifficult for projects to anticipate developments.

Five Whys

A technique used in the analysis phase of the Six Sigma DMAIC (Define, Measure,Analyze, Improve, Control) methodology. It is a great Six Sigma tool that does not involve data segmentation, hypothesis testing, regression or other advanced statistical tools, and in many cases can be completed without a data collection plan.

By repeatedly asking the question "Why" (five is a good rule of thumb), we can peelaway the layers of symptoms which can lead to the root cause of a problem.

Benefits

- Help identify the root cause of a problem.
- Determine the relationship between different root causes of a problem.
- One of the simplest tools; easy to complete without statistical analysis.

Steps

- Write down the specific problem. Writing the issue helps you formalize the problemand describe it completely. It also helps a team focus on the same problem.
- Ask Why the problem happens and write the answer down below the problem.
- If the answer you just provided doesn't identify the root cause of the problem thatyou wrote down in Step 1, ask Why again and write that answer down.
- Loop back to step 3 until the team is in agreement that the problem's root cause isidentified. Again, this may take fewer or more times than five Whys.

Example of Five Whys

Problem Statement : You are on your way home from work and your car stops in themiddle of the road.

1. Why did your car stop ?

– Because it ran out of gas.

2. Why did it run out of gas ?

– Because I didn't buy any gas on my way to work.

3. Why didn't you buy any gas this morning ?

– Because I didn't have any money.

4. Why didn't you have any money ?

– Because I lost it all last night in a poker game.

5. Why did you lose your money in last night's poker game ?

– Because I'm not very good at "bluffing" when I don't have a good hand.

Interrelationship Diagram

A tool analyzing the links of the causes and effects of a problematic situation when presented in a complex way.

An Interrelationship Diagram shows graphically the cause-and-effect relationships that exist among a group of items, issues, problems, or opportunities. It is particularly useful in helping to identify the potential causal relationships that might lie behind a problem that continues to recur despite attempts to resolve it.

Example of Interrelationship Diagram

A local physicians' group is experiencing a relatively high number of patient complaints regarding the lack of returned phone calls following a patient visit where some kind of test was ordered. In particular, the patients are frustrated that the promised call notifying them of the test results is either delayed or must be initiated by the patient. The office manager of the group conducts a brainstorming session to generate potential reasons for the lack of effective and timely follow-up calls. The group then takes the brainstormed list and organizes the potential reasons using an interrelationship diagram.

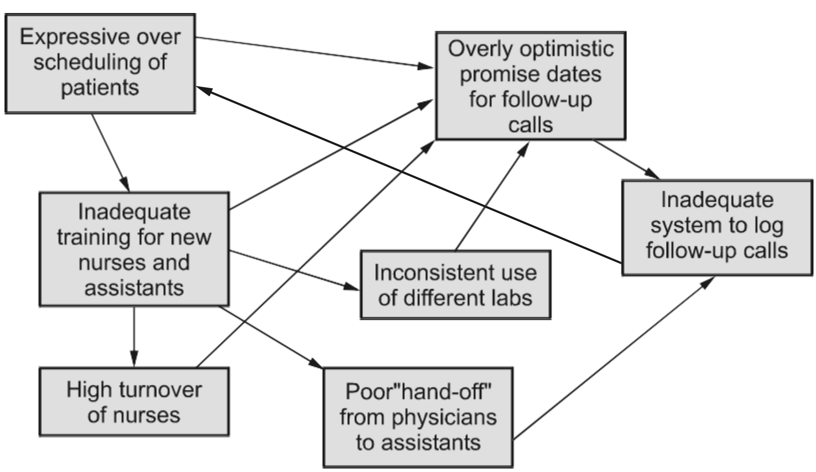


Fig. 2.22.1 Interrelationship Diagram

The basic idea is to count the number of "in" and "out" arrows to and from a particular issue and to use these counts to assist you in prioritizing the issues. In the interrelationship diagram above, "Overly optimistic promise dates for follow-up calls" is a key issue and, of course, would cause patients to expect a phone call faster than the group believes it can deliver it.

Uses of Interrelationship Diagram

- Analyzing any kind of relationship, besides cause-and-effect relationships.
- Analyzing complex issues involving several interrelated issues.
- Determining areas of improvement that will have the greatest impact.
- Analyzing logical relationships.
- Analyzing problems where causes cannot be organized as hierarchies or matrices.
- Analyzing a problem that is believed to be caused by another problem.
- And, developing a better understanding of the relations identified using tools suchas affinity diagrams.

Interrelationship Diagram Example

A small hospital was concerned about the productivity of its doctors because they were the most expensive employees and critical for the treatment of the patients. Having taken numerous steps toward ensuring high productivity, hospital management wasbaffled when productivity steadily declined month after month.

The following factors are used to create an interrelationship diagram.

- The number of scheduled appointments per doctor
- The number of emergency appointments per doctor
- Administrative workload per doctor
- The number of changes in scheduled appointments
- Equipment quality and reliability
- Nurse availability
- Availability of other support functions

- The doctors' pay levels

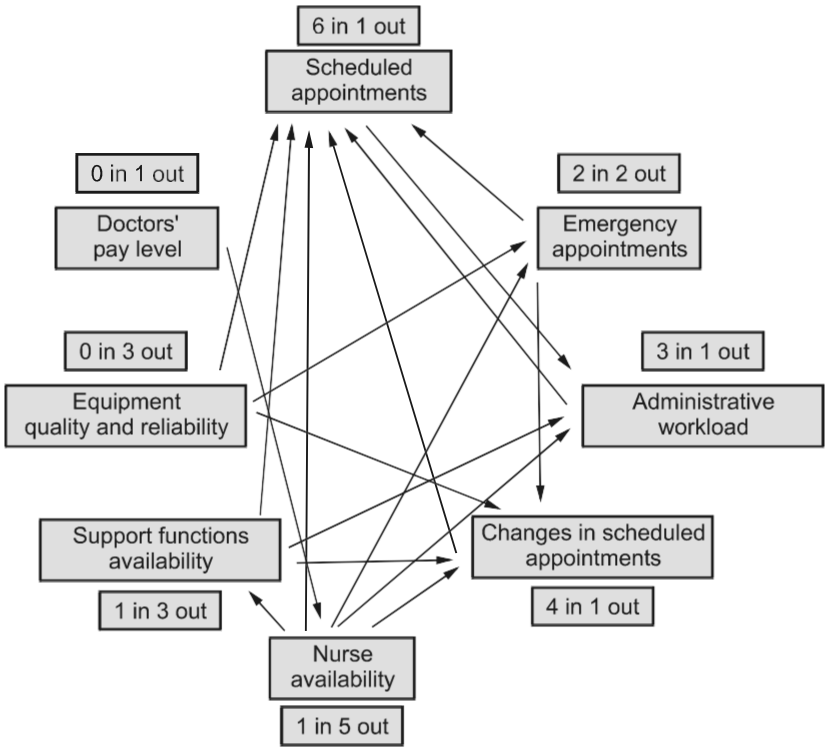


Fig. 2.22.2 Example

Overall Equipment Effectiveness

Abbreviated as OEE. A standard machine performance measurement that encompasses all loss of time on a machine or process that is not contributing to good partsor outputs.

It is equal to the combined effect of Availability □ Performance □ Quality.

OEE can be described by six metrics, called the "Six Big Losses," which is broken out into each of the three categories.

Availability (Uptime) : percentage of scheduled time that the operation is available to operate. Often referred to as Uptime.

Big Loss #1: Planned downtime Big Loss #2: Breakdowns

OEE Availability is calculated as the actual time the process is producing product (or service) divided by the amount of time that is planned for production. The planned time, by definition, excludes all scheduled shutdowns when equipment is not operational, which may include lunches, breaks, plant shutdowns for holidays, etc. The remaining portion of the planned time includes the available time for production, and the down- time. Down time is the loss in production time due to shift changeovers, part changeovers, waiting for material, equipment failures, and so on. It is any measurable time where the process is not available for production, when production had been planned. 100 % Availability implies that the process is operational 100 % of the time.

Performance (Speed) : speed at which the Work Center runs as a percentage of its designed speed.

Big Loss #3 : Minor
stops Big Loss #4 :
Speed loss

OEE Performance is the efficiency of the process in minimizing its Operating Time. Performance is an OEE metric that is calculated by dividing the ideal process cycle time by the actual cycle time. It accounts for process inefficiencies, such as due to poor quality materials, operator inefficiencies, equipment slowdown, etc. 100 % Performance implies the process is running at maximum velocity

Quality (Yield) : Good units as a percentage of the total units produced. It is also known as First Pass Yield (FPY).

Big Loss #5 : Rejects

Big Loss #6 : Rejects on Startup

OEE Quality is the percent of total output that meets the requirement without need for any repair or rework. It might otherwise be called the first pass quality. 100 % Quality implies the process is producing no errors.

A - Availability

- Takes into account all events that stop planned production long enough where it makes sense to track a reason for being town
- Availability = Run time / Planned production time

P - Performance

- Takes into anything that causes the manufacturing process to run at less than the maximum possible speed when it is running.
- Performance = (Ideal cycle time × Total count) / Run time

Q - Quality

- Takes into account manufactured parts that do not meet quality standards, including parts that need rework.
- Quality = Good count / Total count

Fig. 2.23.1 Formulae

As an example, to calculate OEE :

OEE = Availability = 86.6 % * Performance = 93 % * Quality = 91.3 % = 73.6 %

TRIZ Innovative Problem Solving

TRIZ, also known as the theory of inventive problem solving, is a technique that fosters invention for project teams who have become stuck while trying to solve a business challenge. It provides data on similar past projects that can help teams find anew path forward.

TRIZ (pronounced "trees") started in Russia. It involves a technique for problem solving created by observing the commonalities in solutions discovered in the past. Created by Genrich Altshuller in the former Soviet Union, the Six Sigma technique recognizes that certain patterns emerge whenever inventions are made.

TRIZ operates on a abstraction process that transfers the problem from specific to general or to a higher level of abstraction then was tried to solve the general problem. Using this process shows the universal principle for a group of problems.

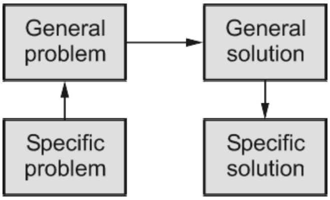


Fig. 2.24.1 Abstractionmethod

Tools for Improvement :

The Improve Phase is where the team gets to solve the problem. They develop solutions, pilot the process changes, implement their ideas and collect data to confirmthey made a measurable difference. This is where their hard work pays off.

The focus of this stage is to determine a solution which is based on the uncovered problem in the first three phases.

Some of the tools used in this improvement phase are :

- Affinity diagram
- Normal Group Technique
- SMED
- 5S
- Mistake Proofing
- Value Stream Mapping
- Forced Field Analysis

Affinity Diagram

An Affinity Diagram is an analytical tool used to organize a large number of ideas, opinions, and issues and group them based on their relationships. Affinity diagrams are generally used for categorizing ideas that are generated during brainstorming sessions and can be particularly useful for analyzing complex issues. The method is reported to have been developed by Jiro Kawakita and so is sometimes referred to as the K-J method.

Creation of Affinity Diagram

1. Generating ideas through brainstorming.
2. Displaying the ideas randomly.
3. Sorting the ideas into groups.
4. Creating header cards for each group to capture the essential links among the ideas in each group.
5. And, drawing the affinity diagram by writing the problem statement at the top and the headers with their respective groups of ideas below the problem statement.
6. An affinity diagram helps in sorting and grouping customer requirements.

Example

Several members of a small company have just returned from a workshop on the methods of Six Sigma. On the trip back from the seminar, the group engaged in a vigorous discussion of the challenges they would confront if they attempted to implement the Six Sigma approach. One person quickly jotted down the list of challenges they generated. The list of brainstormed challenges is given below.

• Cost accounting discourage other measures	• Performance measures discourage cooperation
• Culture does not encourage quality at the source	• Poor cooperation among departments
• Distrust of "new initiatives"	• Poor opinion of team-based projects
• Inadequate performance reporting tools	• Reward systems do not accommodate teams

• No current process champions	• Supervisors resistant to required time to train
• Operators not well trained in quality	• Suppliers not held accountable for quality

An affinity diagram for this example might look as follows.

Manageme nt	**Trainin g**
Poor cooperation among departments Performance measures discourage cooperation Poor opinion of team-based projects Inadequate performance reporting tools	Operators not well trained in quality Supervisors resistant to required time to train Culture does not encourage quality at the source Distrust of "new Initiatives" No current process champions
Systems	
Cost accounting discourage other measures Reward systems do not accommodate teams Suppliers not held accountable for quality	

After the affinity diagram, it is easy to visualize the homogeneous groupings and therefore might help to guide the team towards a viable project.

Need for Affinity Diagram

The affinity diagram will be used when

1. Group agreement for a discussing conclusion
2. A complicated issue with copious divisions
3. Plenty of disordered information and data
4. After analyzing verbal data

Nominal Group Technique

A decision-making method used by teams to separate the vital few from the trivial many. Separation of the important items from the not-as-important items can be made using various techniques. One technique is majority rule. The decision made by majority rule is quick, but those in the minority feel alienated because they lose. It is better to get a win-win decision.

A popular Nominal Group Technique (NGT) is to give everyone on the team five votes. Some use Post-it notes where one note equals one vote. Each member can vote on one item and use all of their five votes on that one idea. The team member may choose to split his or her votes among a few different ideas. For example, they might want to put three votes on one idea and two votes on another idea. They might even want to put one vote on each of the five items.

Ranking Method of NGT

With the ranking method, all of the items are listed down the left side of the whiteboard. Across the top of the whiteboard going from left to right, the facilitator places the initials of each of the team members. Listed along the vertical axis on the left- hand side of the board is a listing of each of the items being evaluated.

Starting with the first item at the top, each person states out loud to the group how important they feel that particular item is on the scale of 1 to 10. (1= low, 10 = high) Note that it is a good idea to rotate who starts the voting each time to minimize the effect of stronger-willed team members influencing the weaker members.

The facilitator checks for internal validity meaning that if there is a range greater than three (3) for any of the items being evaluated, the facilitator will ask each of the members who think that something is very important (e.g., rated 8, 9, or 10) why they feel that a particular item is so important.

When to Use Nominal Group Technique

- When you have shy team members.
- When the team tends to defer to a single person or group of people.
- When a team member hasn't felt like their voice is being heard.
- When teams think better in silence.
- When there are controversial items to discuss.

Example of NGT

Table 2.26.1 lists possible user requirements for a library card system. Three team members have assigned each user requirement a points value based on the estimated work involved.

User requirement	Estimated points		
	Person 1	**Person 2**	**Person 3**
Borrow books from the library system.	21	13	21
Borrow books by first reserving them online.	13	21	13
Check the due date of time from an online library application.	13	8	8
Receive email notification regarding library items that are due.	13	13	13
Receive a short text message notification regarding library items that are due.	8	8	8

Table 2.26.1 List of requirements

Sum all the ranks given by individual persons with respect to the requirements. Pick up top one or two requirements to find out solutions. In the above table, the requirements "borrow books from the library system" and "borrow books by first reserving them online" are in the top two ranks and selected to find with the solutions.

Considerations of NGT

- The primary purpose of the discussion is clarification, not to resolve differences of opinion.
- Discussion should be equally balanced among all ideas.
- Keep all ideas visible. When ideas overflow to additional flipchart pages, post previous pages around the room so all ideas are still visible to everyone.
- See brainstorming for other suggestions to use with this tool.

SMED

SMED - Single Minute Exchange of Die. Also known as a Quick Changeover.

SMED is a tool in Lean used to reduce the amount of time it takes to change from running one process in an operation to running another. In addition to improving cycle time in a process, SMED can help reduce costs and increase flexibility within a process.

The "single minute" title refers to the goal of reducing the changeover time to single-digit minutes, from a maximum of nine minutes down to one (if possible).

Example of SMED

Many restaurants offer three menus - breakfast, lunch and dinner. Changing from one to the other can take as long as an hour as kitchens prepare for different meals and (in some cases) one serving staff clocks out while another clocks in. Speeding up this process allows for a smoother transition between serving times. In some cases, restaurants have gotten so good at it that they offer items from two menus - sometimes all three - at any time of the day.

Principles of SMED

SMED steps take place within one of two areas : external and internal setup components.

Internal steps happen while the equipment or process is stopped.External steps occur while the equipment or process is running. Both are important in accomplishing SMED.

External

With external components, one of the focuses is on having supplies and tools ready fora changeover. For example, in the above restaurant example, chefs don't suddenly have tofind choice ground beef for the lunch burgers just as the clock strikes noon.

Internal

This is where the videotaping of a process proves especially valuable. Any operation that can be done before the actual changeover takes place should be identified. This helps speed up the process significantly.

Steps to Implement SMED

Identify The Process - In this first step, the focus area for improving changeover times is identified.

Identify Elements - Each element of the process should be quantified by the amount of time it takes as well as the cost. The process is then mapped out by each individual element, those involving both human and machine activities.

Separate External Elements - All elements of the operation that are external should be separated. This includes elements that are currently internal but can be made external. On

each element, it should be asked: can this be done while the equipment or process is running ? If so, it can be accomplished before the actual changeover takes place.

Convert Internal to External - Any element that can be moved to external should now be moved. Prioritize the list so that the elements with the most potential impact on reducing time and cost are acted on first. This involves advanced preparation on many elements.

Streamline - The internal elements should be simplified to take less time. Every single element must be considered. This also can involve new equipment or modification of existing equipment to make changeovers run smoother and faster. Also keep in mind to eliminate wasted motion or time spent waiting.

Putting it all together can lead to operations that run faster while also producing quality products.

5S

5S : Sort, Set, Shine, Standardize, Sustain

5S represents a way of focusing and thinking in order to better organize and manage workspace, specifically by eliminating the 8 Wastes as defined by the Lean Manufacturing system. It is one of the most widely used component of Lean Manufacturing. Its simple, common-sense application is highly effective and reliable as a stabilizing force in Lean strategies.

Sort - Distinguishing between necessary and unnecessary things, and getting rid of what you do not need.

- Remove items not used in area – outdated materials, broken equipment, redundantequipment, files on the computer, measurements which you no longer use
- Ask staff to tag all items which they don’t think are needed – this improves understanding about need and use
- Classify all equipment and materials by frequency of use to help decide if it shouldbe removed – place ‘Red Tag’ on items to be removed
- Establish a ‘holding area’ for items that are difficult to classify – hold item for allotted period to enable others not on 5S team to review

Set - 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.

- Identify and allocate a place for all the materials needed for your work.
- Assign fixed places and fixed quantity.
- Make it compact.
- Place heavy objects at a height where they are easy to pick from.
- Decide how things should be put away, and obey those rules.

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

- Identify root causes of dirtiness, and correct process
- Only one work activity on a workspace at any given time
- Keep tools and equipment clean and in top condition, ready for use at any time
- Cleanliness should be a daily activity – at least 5 minutes per day
- Use chart with signatures/initials shows that the action or review has taken place
- Ensure proper lighting – it can be hard to see dirt and dust

Standardize - Setting up standards for a neat, clean, workplace

- Standardization of best practices through 'visual management'
- Make abnormalities visible to management
- Keep each area consistent with one another
- Standards make it easy to move workers into different areas
- Create process of how to maintain the standard with defined roles and responsibilities
- Make it easy for everyone to identify the state of normal or abnormal conditions –place photos on the walls, to provide visual reminder

Sustain - 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

- Toughest phase is to Sustain – many fall short of this goal
- Establish and maintain responsibilities – requires leader commitment to follow through
- Every one sticks to the rules and makes it a habit
- Participation of everyone in developing good habits and buy-in
- Regular audits and reviews

- Get to root cause of issues

Aim for higher 5S levels – continuous improvement

Things to Consider in Implementation of 5S

- In order to be effective, the 5S should be made visual by using colors, shadowboards, and taped- off identification lines
- 5S should be designed for every task or process uniquely
- 5S should be implemented not just in manufacturing or production units, but also for the office areas
- The management should participate, audit and review regularly the 5S such that it remains productive and an improvement oriented culture can be facilitated

5S Example

Fig. 2.28.1 Storage unit in an office before and after implementing 5S

Mistake Proofing

Mistake Proofing is about adding techniques to prevent defects and detect defects as soon as possible, if one does occur.

Also called as **Poka-Yoke**

Poka-Yoke is often used as a synonymous term but its meaning is to eliminate product defects by preventing human errors (that are unintentional). The concept was first put to widespread use by Shigeo Shingo within the Toyota Production System (TPS).

When an error cannot practically be 100 % prevented or detected, then the next best option is to try to reduce the severity of the error and defect.

2.29.1 Varieties of Mistake Proofing

1. Warnings/Alarms – provides information
2. Controls – prevents and/or stops the process

Inspection itself is not considered a viable technique of mistake proofing. The technique or mechanism that prevents or detects errors or deviations is mistake proofing.

Types

There are three types of poka-yokes.

1. Contact method – Contact with the part in the process highlights the errors
2. Fixed-value method – Errors are detected in the process through counting
3. Motion-step method – Errors are detected by a motion or lack of it in the process

2.29.3 Techniques

The key mistake proofing techniques are :

- Shutdown – Shutdown or stop a process immediately on occurrence of a failure
- Control – Eliminate the occurrence of failure in a process
- Warning – Proactively notify the occurrence of failure in a process before it occurs

Steps to Implement Mistake Proofing

Step 1 : The process or operation that needs improvement needs to be identified using Pareto chart and analysis.

Step 2 : Assess and understand the defects in the process that may lead to failure. Atthis stage, the 5- whys should be thoroughly analyzed.

Step 3 : Decision about the strategy to be used for effective Poka- Yoke. Some of the strategies include

- Shut out strategy that is, prevention strategy that the error is not committed
- Attention strategy that is, pinpointing the defect when it is being committed
- Comprehensive approaches

Step 4 : Determine the appropriateness of the strategy being decided. This can be done by using a contact, that is any physical attribution for detection of error;constant number, in case the trigger behind the error is the absence of certainnumber of actions; and sequence method, that is to check and tally using a checklist that all the steps in the process are undertaken appropriately and effectively.

Step 5 : Run a trial test to ensure that the method chosen is appropriate and effective.

Step 6 : Once ensured that the method chosen is good, train the operators for the same, review the performance and measure the success to verify and validate the Poka- Yoke strategy.

Example of Mistake Proofing

Suppose a newly installed shut off valve on the coffee maker functions to prevent spilling below onto the base or countertop when the coffee pot is removed.

This is a very pleasant mistake proofing device, but if the hot water pump doesn't get a feedback signal and continues filling the filter compartment then this could overflow. Essentially, the spill failure mode has been moved from one location to another.

Value Stream Mapping

A technique used to document, analyze and improve the flow of information or materials required to produce a product or service for a customer.

Value Stream Mapping (VSM) is a paper and pencil tool that helps you to see and understand the flow of material and information as a product or service makes its way through the value stream.

VSM is especially useful to find and eliminate waste. Items are mapped as adding value or not adding value from the customer’s standpoint, with the purpose of rooting out items that don’t add value.

A value stream map is typically created as a one-page flow chart depicting the current production path. In lean production, value is the ultimate goal for customers. Processes that do not provide any value are called **waste.** Value stream has been embraced as a great methodology for identifying the inherent waste, and plan to eliminate it, which is an indispensable tool in your six sigma program.

Value stream mapping is typically used in Lean, it differs from the process mapping of Six Sigma in four ways :

1. It gathers and displays a far broader range of information than a typical process map.
2. It tends to be at a higher level (5 - 10 boxes) than many process maps.
3. It tends to be used at a broader level, i.e. from receiving of raw material to

delivery of finished goods.

4. It tends to be used to identify where to focus future projects, subprojects, and/or kaizen events.

Uses

1. Graphically illustrate the flows of materials and information in a process. It displays the interaction between multiple organizational functions- both manufacturing as well as ancillary functions.
2. Pinpoint the problem areas, inefficiencies, defects, bottlenecks more efficiently as it integrates and maps the information flows, material flows along with the sequence of tasks. It even shows the cycle- times and lag- times between different tasks.
3. Involves all the stakeholders in each stage of the process and hence, it becomes easy to develop and implement countermeasures to facilitate cultural change in theorganization. It provides a proper presentation of all the limiting factors.
4. Continuous improvement is facilitated since the direction can be focused on lean transformation teams, front line supervision and upper management.

Creation of VSM

Step 1 : Select your sponsor and set expectations. Appoint someone who is responsible to make decisions, arbitrate solutions, and plan the project.

Step 2 : Select your team. Ensure that each area or stakeholder of the process isrepresented.

Step 3 : Consider Customer.

Step 4 : Collect data and produce current state map, including process times, inventory or materials information, customer (or demand) requirements.

Step 5 : Draw the customer near the top right of your value stream map and capturethe events or signals that trigger the start of the process.

Step 6 : Capture the process steps.

Step 7 : Add the process time line.

Step 8 : Identify improvement opportunities.

States in VSM

When value stream mapping, it is necessary for two maps created (possibly more).

One map represents the **CURRENT STATE** and the other map represents the desired **FUTURE STATE**. There may be a short term and long term future state map depending on the how detailed the team wants to proceed.

Most current state value stream paps find that < 5 % of the total lead time for a process is value-added ("value-added"means the customer is willing to pay for it or it is compliance/regulatory time).

Value Stream Mapping is more detailed than a Process Map since it is supported with numerical analysis. However; it also involves a **Gemba walk** to observe the actual process and document actual cycle times, actual inventory levels, quality, etc. This also could mean traveling to observe processes that occur outside of your location.

Current State :

Capture the current process despite how ugly it may be. There are often situations where cycle times vary, batch sizes vary for appropriate reasons, and it is difficult to come up with values for the map. It is important to prepare for this as a Green Belt/Black Belt (GB/BB) when leading the team so a consensus can be reached on all the "what-if" scenarios. Be consistent with how the values are obtained and used on the map.

Future State (longer term) :

Develop the desired future state and long-term vision. The team should get creative and develop the future state regardless of what they think can be accomplished with some discretion as to what is practical and economical. The future state should be aligned with company goals, mission, and vision. Of course, the company goals should have Customer Satisfaction as priority.

Forced Field Analysis

Force field analysis is a tool used to visualize the driving forces and the restraining forces that affect some area of interest. The team might use force field analysis to get an understanding of the forces that are helping something and the forces that are inhibiting something from being at the optimal level.

Force field analysis, this name sound so powerful as forces which can be positive or negative on anything. We can say positive is what we are looking for and negative iswhat we are trying to eliminate. That's it, you are into concept of force field analysis. It is used for planning, problem identification and resolution

Often in term of six sigma positive forces is known as "**Driving Force**" while negative forces are "**Restraining Force**".

Tools for Control :

The focus of the control phase is to make sure that the action item created in the improvement phase is well-implemented and maintained. Several tools are used in this stage to make sure that variables are within its limits. Activities such as checking the proper execution of initiative(s), control charts are being employed, and effectiveness of the initiatives are also evaluated.

Some of the tools used in the control phase are :

1. Gantt Chart
2. Activity Network Diagram
3. Radar Chart
4. PDCA Cycle
5. Milestone Tracker Diagram
6. Earned Value Management

Gantt Chart

A Gantt chart is a powerful and preferred visual reporting device used for conveying aproject's schedule.

A typical Gantt chart graphically displays the work breakdown, total duration needed to complete tasks, as well as % completion.

Gantt Charts may be integrated with other spreadsheet-type reporting devices that convey additional information related to project planning. Furthermore, Gantt Charts are often enhanced with functionality that includes the identification of relationships betweentasks, and the ability to dynamically change task attributes.

A Gantt chart is a planning method designed to show the tasks associated with a project, the personnel responsible for completing the tasks and the timelines allowed. A

bar chart named after Henry Gant that shows when tasks will complete and what needsto get done before other tasks begin.

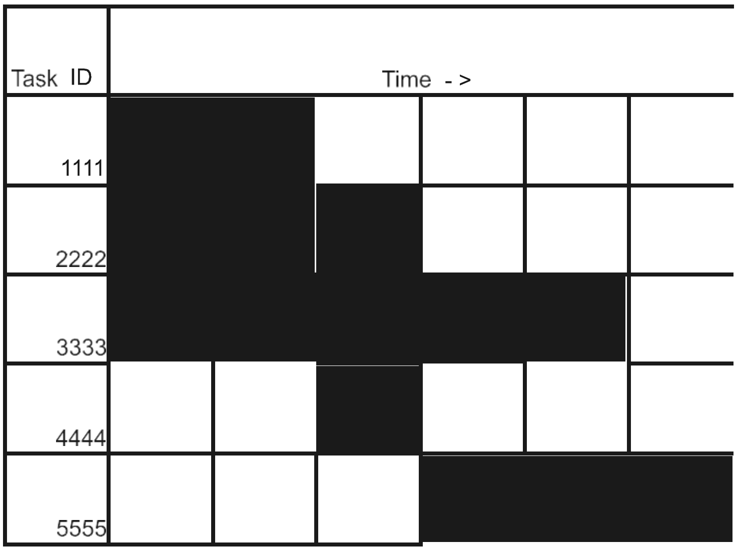


Fig. 2.32.1 Gantt chart

Note that 5555 cannot begin until 2222 and 3333 are completed.

Need for Gantt Chart

We may use a Gantt Chart if :

- When we want to display the activities against time
- When we want to compare the Plan Vs the Actual completion rate of the project
- When we want to know the overlapping time of parallel activities and plan theresources and schedule accordingly.

Creation of Gantt Chart

- Plot the time in X axis (Start and End dates of the project)
- Plot bars of each activities in the project one below the other in parallel lines. Use thestart and end dates of each activity to mark the respective bar
- Similarly plot the actual time taken for each activity (If needed and available)
- Use color indicators to differentiate various activities, and also to denote plan adherence (Green, Amber, Red etc).

Advantages of Gantt Chart

- Easy to understand.
- Each bar represents a single activity.
- Very easy to change the chart.
- Can be constructed with minimal data.
- Shows task progress vs date.

Disadvantages of Gantt Chart

- Does NOT show interdependence of activities.
- The effects of starting a task earlier or later are not shown.
- No way to indicate variations in expected time to completion.
- No details of a task are listed.
- Cannot be used for predictive analysis.

Example - Customer Complaints Resolving Chart

#	Activity	Start date	End date
1	Identify top 5 complaints from customer	9-Oct-17	15-Oct-17
2	Audit 20 samples for each complaint type	16-Oct-17	29-Oct-17
3	Analyse and brain storm to list down probable root causes	30-Oct-17	5-Nov-17
4	Data analyse to identify actual causes	6-Nov-17	26-Nov-17
5	Analyse and brain storm to list down probable solutions	27-Nov-17	3-Dect-17
6	Cost benefit analyse of solution	4-Dec-17	17-Oct-17

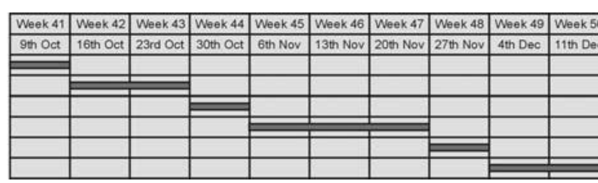


Fig. 2.32.2 Gantt Chart for resolving complaints from customers

Activity Network Diagram

An Activity Network Diagram is a diagram of project activities that shows the sequential relationships of activities using arrows and nodes. An activity network diagram tool is used extensively in and is necessary for the identification of a project's critical path (which is used to determine the expected completion time of the project).

Example : Suppose the team is tasked with improving the process of building a house. The team lists the major steps involved – everything from the excavation step through thelandscaping step.

A. Excavate	B. Foundation	C. Frame
D. Electrical	E. Roof	F. Masonry

G. Interior H.Exterior I. Landscape

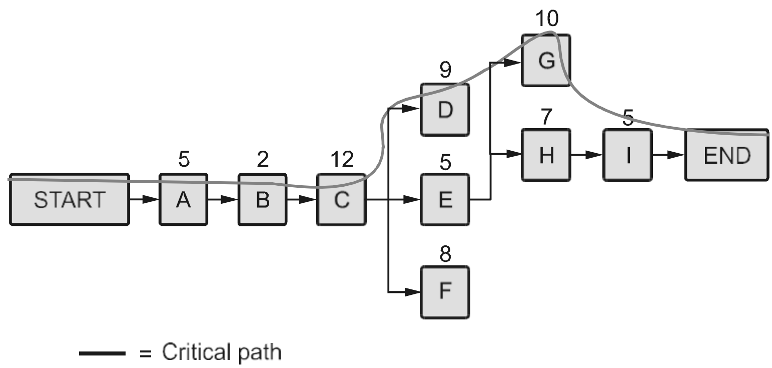


Fig. 2.33.1 Diagram of house building process

Some of the process steps (nodes A, B, and C) run in series, while other process steps (nodes D, E, and F) run in parallel. Notice that Step B cannot happen until step A has been completed. Likewise, step C cannot happen until step B has completed. Step H cannot

happen until steps D, E, and F have completed – and ALL need to be completed before Step H. So, nodes A, B, and C are running in series.

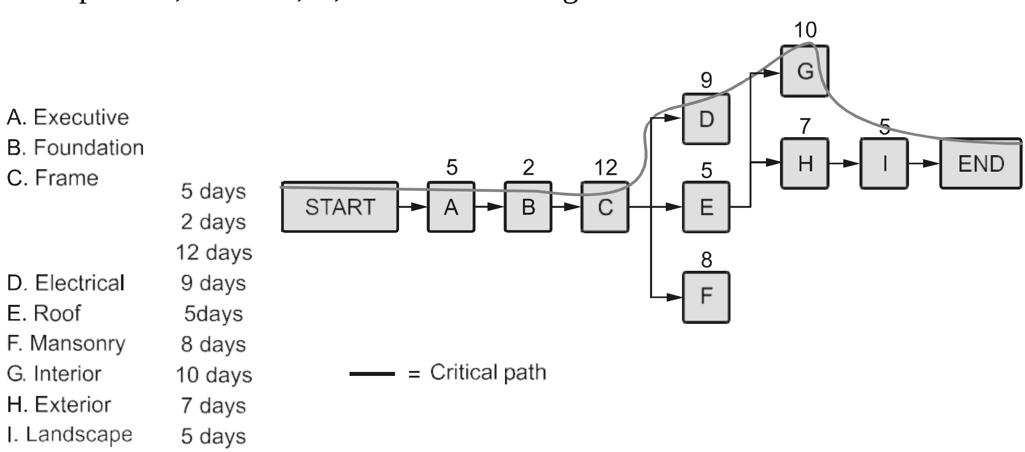


Fig. 2.33.1. Diagram of house building process with days completion

Critical Path

The team's job is to take note of which of the nodes D, E, and F, will be taking the most amount of time, and which of those nodes is expected to take the least amount of time. This is essential when creating the Critical Path. For instance, if node D is expected to take the most amount of time as compared with nodes E and F, it is not important that nodes D and E start at the exact same time as node F. Those steps can start later, but they have to be finished no later than the most time consuming of the three steps that run in parallel. The team evaluates the nine steps and come to a consensus on how many days each of the nine steps will take. The critical path is a line that goes through all of the nodes that have the longest expected completion times.

Most Likely Time :

Nodes A, B, and C run in series, so the critical path is straightforward. Notice that between the three nodes that run in parallel, (nodes D, E, and F) node D is expected to take the longest to complete as compared to the other two nodes. The critical path would run through nodes D and G because those particular nodes have the longest expected completion times. The line above shows the critical path. By looking at the Activity Network Diagram the team can easily see that the expected completion time as defined by the critical path is 50 days. (5+2+12+9+10+7+5 = 50 days) That's the MOST LIKELY time.

Optimistic Time

The team might want to know what the best case (Optimistic Time), in terms of time, would be. To come up with that number, the team would decide upon the shortest possible time for each of the nodes, and then add those up. The numbers in parenthesis are the most optimistic times. (4+2+10+8+8+7+4 = 43)

Pessimistic Time

The team also might want to know what the worst case (Pessimistic Time), in terms of time, would be. To come up with that number, the team would decide upon the longest possible time for each of the nodes, and then add those up. Note: To determine the best case or the worst case, the critical path line must be followed. The numbers in parentheses are the most pessimistic times. (7+3+14+10+11+8+6 = 59)

So what does all of this mean ? It means the project most likely will take 50 days, but it could take 59 days or it can be done as soon as 43 days.

Expected Time

$$\text{Expected Time} = \frac{\text{Optimistic + [(Most Likely)] + Pessimistic}}{6}$$

$$\text{Expected Time} = \frac{43 + 200 + 59}{6} = 50.3 \text{ days}$$

Control Bands :

We could calculate control bands around the average. Here’s how we do that :

$$\text{Limits of expected variation} = \frac{\text{Optimistic □ Pessimistic}}{6}$$

Limits of expected variation = $\frac{59}{6}$

□ 43 Limits of expected variation

6

= $\frac{16}{}$ = 2.7

For the critical path, we can expect the project to take from 47.6 days to 53.0 days

50.3 + 2.7 = 53 on the high side

50.3 □ 2.7 = 47.6 on the low side.

Radar Chart

A radar chart is a graph in which each data series has it’s own axis and ‘radiates’ out from a central point.

A radar chart is particularly useful when there are multiple characteristics that need to be compromised to a point (a ‘sweet spot’) that is most pleasing to most of the customers in a particular niche. For example, there really is no such thing as a perfect car that will please everyone.

A radar chart is a graphical display of the differences between actual and ideal performance. It is useful for defining performance and identifying strengths and weaknesses.

A radar chart is a graphical method of displaying multivariate data in the form of a two-dimensional chart of three or more quantitative variables represented on axes starting from the same point.

Radar charts can be used to display any number of business performance for example

- Comparing performance between suppliers
- Comparing performance between work cell teams or shifts in a manufacturing

centre

- Measuring performance against business strategies

Example of Radar Chart

HR managers can visualize employee performance data, based on rankings given by their respective seniors, on a single chart. This chart (commonly know as the Employee Chart) can also be used to plan employee training by grouping employees who lack a particular skill set (low in rank) and then designing suitable remedial procedures for the group.

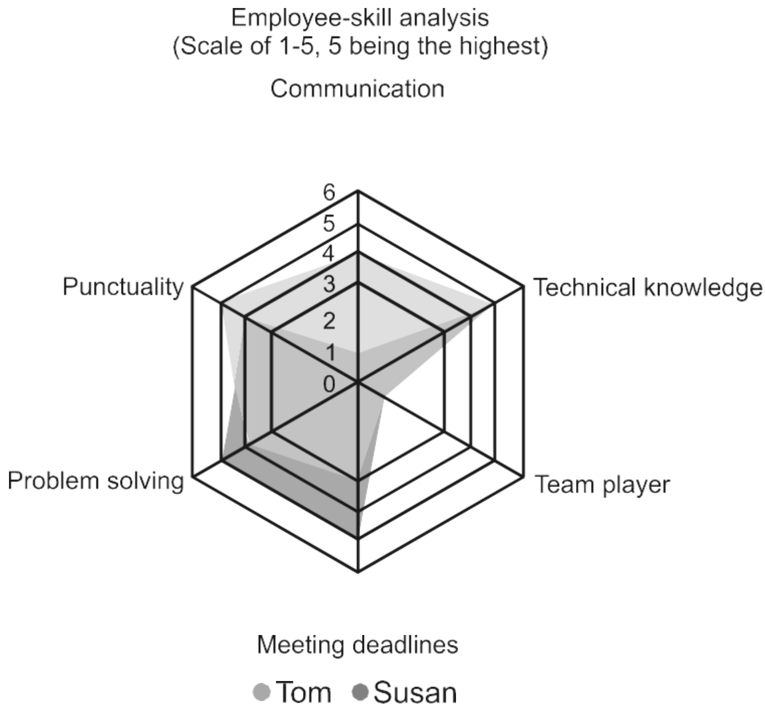


Fig. 2.34.1 Employee analysis using Radar

Advantages

- Shows data outliers and commonality strikingly.

Disadvantages

- They are ill-suited for making trade-off decisions.
- It is hard to compare lengths of different spokes, because radial distances are hardto judge visually.

PDCA Cycle

PDCA (Plan-Do-Check-Act)

The idea in the PLAN step is to define the process to improve. The DO step is implementing the plan and measuring its performance. The team then takes those measurements to assess whether they are getting the desired results. This is known as the CHECK step. The ACT step follows. The team decides on changes that need to be made to improve the process; then, the whole cycle starts again.

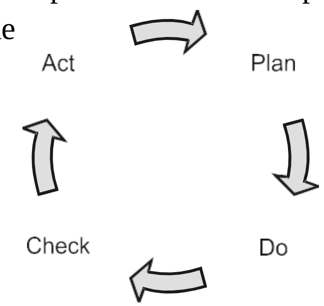


Fig. 2.35.1 PDCA

It is also called Deming's cycle or Shewhart cycle.

Plan

An opportunity for any improvement in the organization has been identified and establishes a plan for achieving the goal i.e. improvement. Here we consider the changes but don't actually implement them.

Do

In this phase we carry out a small-scale version of the improvement we want to see. Call it a pilot program. The idea is to test out our hypothesis in a way that limits risk but also allows us to see significant results. Enact the changes detailed in the Plan.

Check

Here we close the loop and verify if the improvement action we did had its intended effect. Measure and analyze the results.

Act

If our pilot was successful, we roll the changes out for full implementation. If not, we take a look at the data we did receive and challenge our previous assumptions in order to come up with a new, different plan.

Implement the necessary reforms when the results are not as expected.In either case the cycle repeats with the next experiment.

When to use PDCA

- For continuous improvement.
- When starting a new project or creating a new product or service.
- When defining a process.
- To verify the prioritization of data collection or root causes.
- When implementing a change.

Follow the four steps iteratively for problem-solving and continuous process improvement :

- **Plan :** Plan ahead for change. Analyze and predict the results.
- **Do :** Execute the plan, taking small steps in controlled circumstances.
- **Check :** Check or study the results.

- **Act :** Take action to standardize or improve the process.

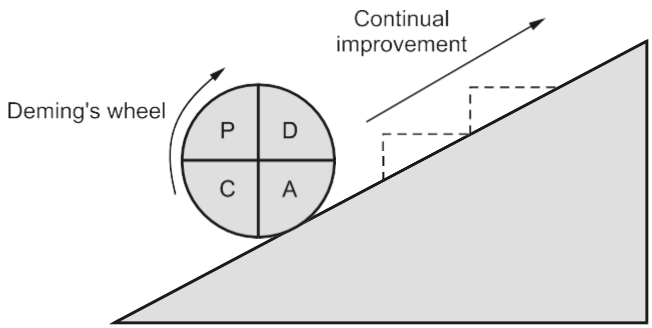


Fig. 2.35.2 PDCA Diagram

PDCA Applications

1. PDCA cycle is mainly used in software field for Software development lifecycle.
2. It is used in manufacturing and Service industries for new product development.
3. It also finds its place in Project Management of any nature.
4. Areas like Change Management also use PDCA cycle for their implementation.

Milestone Tracker Diagram

A milestones chart displays all activities (milestones) and their corresponding start and completion dates. It is used to manage and monitor a project and can serve as a supporting document when attached to a project status report.

Steps

STEP 1 The team first identifies all major activities of the project to be scheduled.

STEP 2 The team constructs a milestones chart and lists all identified activities in the order of completion. See the example below in the Figure 2.36.1.

STEP 3 The team estimates the time required to complete each activity and assigns a completion date to each.

STEP 4 Next, the team draws a horizontal bar for each activity, placing the bar in accordance with start and completion dates in sequential order along the milestones chart, as shown in the example.

STEP 5 The team then checks all information and dates the chart.

Example of Milestone Tracker

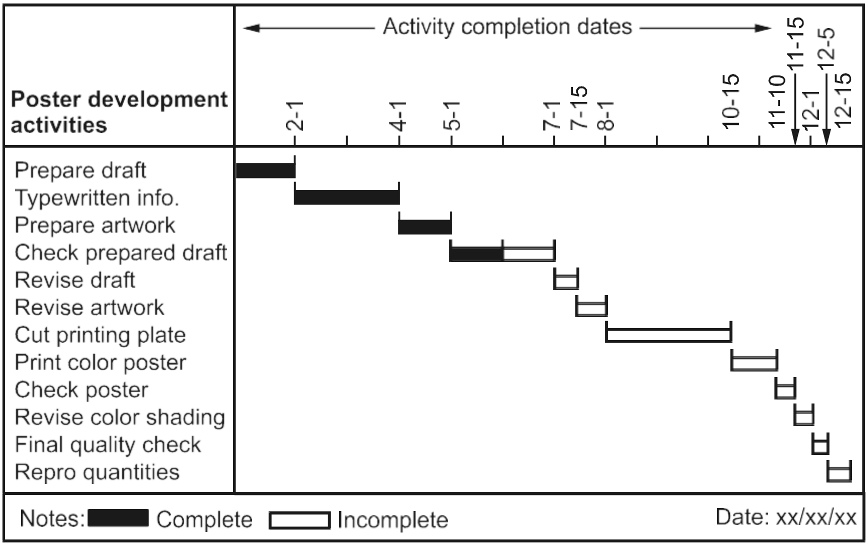


Fig. 2.36.1 Milestone tracker

Earned Value Management

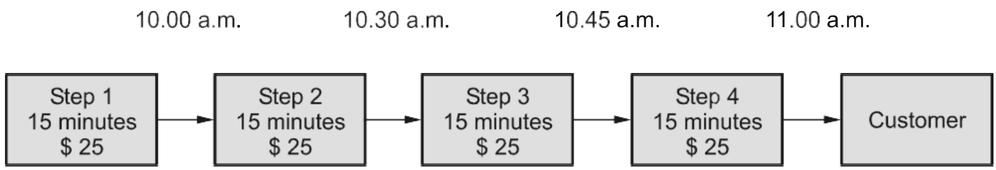
Whenever there is an issue in a process, attempts are made to identify the process step that is causing the problem, identify the root cause and come up with a corrective or preventive action. The time taken to identify the "right" process step is directly proportional to the number of process steps involved and it becomes vital to identify the root cause as quickly as possible in order to take action.

These process steps can be identified using Earned Value Management (EVM) without losing time by deep diving into the complete process.

Earned value management is a project management technique for measuring project performance and progress and it has the capacity to combine cost, scope and schedule. Earned Value (EV) is a measure of work performed expressed in terms of the budget authorized for that work; it is the budget associated with the authorized work that has been completed. Planned Value (PV) is the authorized budget assigned to scheduled work.

Example of EVM

Consider a process with four steps. Each step takes exactly 15 minutes (cycle time is 60 minutes) and the costs associated (e.g., resources and effort) with each step is $25 (planned value). As and when a process step is completed, $25 is added to the earned value. The budget at completion (BAC), therefore, is $100.



Scenario 1 :

If the process begins at 10 a.m., then by 10:30 a.m. Step 2 is complete and $50 has beenspent.

Cost variance = Earned value ($50) – Actual cost ($50) = $0

Schedule variance = Earned value ($50) – Planned value ($50) = $0

This is an ideal scenario with zero variance, which means the process is performing asplanned both on the cost and schedule perspectives.

Scenario 2 :

The process begins at 10 a.m. and by 10:30 a.m. only the first step has been completed. Twenty-five dollars has been spent. The earned value is $25 as 25 percent of the total effort has been earned through Step 1. Ideally by 10:30 a.m. Step 2 should have been completed, meaning the planned value is $50.

Cost variance = $25 – $25 = $0

Schedule variance = $25 – $50 = □ $25

The schedule variance is negative which means the process is lagging by $25 worth of work. The possible primary causes could be motion, wait time, defect or transportation.

Scenario 3 :

Work starts at 10 a.m. and by 10:30 a.m. the process is at Step 2. The actual cost,however, has been $60 and as Step 2 has been completed, the earned value is $50.

Cost variance = $50 – $60 = □ $10

Schedule variance = $50 – $50 = $0

The process consumed $10 worth of resources more than were required to deliver theproduct or service. The possible causes are overproduction or a defect in Steps 1 or 2.

Scenario 4 :

Step 1 begins at 10 a.m. and Step 3 is finished at 11 a.m.; $100 was spent.Cost variance = $75 – $100 = □ $25

Schedule variance = $75 – $100 = □ $25

Here there are both cost and schedule variances, which signify more cost has been consumed than should have been and that there is a lag of $25 worth of deliverables on a schedule standpoint. The possible causes could be any of the seven kinds of waste.

Unit – 3 Six Sigma Methodologies

Syllabus

Design For Six Sigma (DFSS),Design For Six Sigma Method - Failure Mode Effect Analysis (FMEA), FMEA process - Risk Priority Number (RPN)- Six Sigma and Leadership, committed leadership – Change Acceleration Process (CAP)- Developing communication plan – Stakeholder.

Introduction

In the current global marketplace, competition for products and services has never been higher. Consumers have multiple choices for many very similar products. Therefore, many manufacturing companies are continually striving to introduce completely new products or break into new markets. Sometimes the products meet the consumer's needs and expectations and sometimes they don't. The company will usually redesign the product, sometimes developing and testing multiple iterations prior to re-introducing the product to market. Multiple redesigns of a product are expensive and wasteful. It would be much more beneficial if the product met the actual needs and expectations of the customer, with a higher level of product quality the first time. Design for Six Sigma (DFSS) focuses on performing additional work up front to assure you fully understand the customer's needs and expectations prior to design completion. DFSS requires involvement by all stakeholders in every function. When following a DFSS methodology you can achieve higher levels of quality for new products or processes.

Design For Six Sigma (DFSS)

DFSS is the acronym for Design For Six Sigma. Unlike the DMAIC methodology, the phases or steps of DFSS are not universally recognized or defined and almost every company or training organization will define DFSS differently. Many times a company will implement DFSS to suit their business, industry and culture; other times they will implement the version of DFSS used by the consulting company assisting in the deployment. Because of this, DFSS is more of an approach than a defined methodology.

With DFSS, the goal is to design products and processes while minimizing defects and variations at their roots.

Need for DFSS

When the company designs a new product or process from the ground up it requires a sizable amount of time and resources. Many products today are highly complex, providing multiple opportunities for things to go wrong. If the design does not meet the customer's actual wants and expectations or the product does not provide the value the customer is willing to pay for, the product sales will suffer. Redesigning products and processes is expensive and increases the time to market. In contrast, by utilizing Design for Six Sigma methodologies, companies have reduced their time to market by 25 to 40 percent while providing a high quality product that meets the customer's requirements.

DFSS is a proactive approach to design with quantifiable data and proven design tools that can improve your chances of success.

When to Implement Design for Six Sigma

DFSS should be used when designing a completely new product or service. DFSS is intended for use when you must replace a product instead of redesigning. When the current product or process cannot be improved to meet customer requirements, it is time for replacement.

The DFSS methodologies are not meant to be applied to incremental changes in a process or design. DFSS is used for prevention of quality issues. Utilize the DFSS approach and its methodologies when your goal is to optimize your design to meet the customer's actual wants and expectations, shorten the time to market, provide a high level of initial product quality and succeed the first time.

How to Implement Design for Six Sigma

The DFSS project should involve a cross functional team from the entire organization. It is a team effort that should be focused on the customer requirements and Critical to Quality parameters (CTQs).

The DFSS team should invest time studying and understanding the issues with the existing systems prior to developing a new design. There are multiple methodologies being used for implementation of DFSS.

One of the most common techniques, **DMADV (Define, Measure, Analyze, Design, Verify)**, is detailed below.

Define :

The Define stage should include the Project Charter, Communication Plan and Risk Assessment / Management Plan.

The Project Charter

The team should develop a Project Charter, which should include :

- Purpose or reason for project - Preferably with quantifiable data or measurable targets.
- Voice of business - What the business expects to gain from completion of the project.
- Project scope - Establish the scope and parameters of the project and determine exactly what is in and out of scope for the project to prevent "project creep".
- Problem statement or identification of the gap between current and desired state
- Statement of the goals for improved revenue, customer satisfaction or market share stated in measurable, well-defined targets
- Project timeline or schedule with well-defined gates and deliverables for each gate review.
- Project Budget – Cost target for the project including any capital expenditures
- Identification of the project sponsor and key stakeholders
- Identification of the cross-functional team members
- Clarification of roles and responsibilities for the team members and other stakeholders

The Communication Plan

During the Define phase, the team should develop a strategy for proper communication throughout the life of the project. The Communication Plan should be designed to address different aspects and techniques for discussing the evaluation results. To develop the Communication Plan, answer the following questions :

- Who is the primary contact on the team that is responsible for communicating ?
- What are the main goals for the communication process ?
- Who are you communicating to ? (Identify target audience)
- When and how often will the communication occur ?
- What methods will be used for communication ?

The Risk Assessment or Risk Management Plan :

The project manager should prepare a Risk Assessment or Risk Management Plan that includes, but is not limited, to the following information :

- Risks associated with the project
- Impact of risks against the success of the project
- Outline / plan for managing any project risk

Measure

During the Measurement Phase, the project focus is on understanding customer needs and wants and then translating them into measurable design requirements. The team should not only focus on requirements or "Must Haves" but also on the "Would likes", which are features or functions that would excite the customer, something that would set your product apart from the competition.

The customer information may be obtained through various methods including :

- Customer surveys
- Dealer or site visits
- Warranty or customer service information
- Historical data
- Consumer Focus Groups

Analyze

In the Analyze Phase, the customer information should be captured and translated into measureable design performance or functional requirements. The Parameter (P) Diagram is often used to capture and translate this information. Those requirements should then be converted into System, Sub-system and Component level design requirements. The Quality Function Deployment (QFD) and Characteristic Matrix are effective tools for driving the needs of the customer from the machine level down to component level requirements.

The team should then use the information to develop multiple concept level design options. Various assessment tools like benchmarking or brainstorming can be used to evaluate how well each of the design concepts meet customer and business requirements and their potential for success. Then the team will evaluate the options and select a final design using decision-making tools such as a Pugh Matrix or a similar method.

Design

When the DFSS team has selected a single concept-level design, it is time to begin the detailed design work using 3D modeling, preliminary drawings, etc. The design team evaluates the physical product and other considerations including, but not limited to, the following :

- Manufacturing process
- Equipment requirements
- Supporting technology
- Material selection
- Manufacturing location
- Packaging

Verify

During the Verify Phase, the team introduces the design of the product or process and performs the validation testing to verify that it does meet customer and performance requirements. In addition, the team should develop a detailed process map, process documentation and instructions. Usually a prototype or pilot build is conducted. A pilot build can take the form of a limited product production run, service offering or possibly a test of a new process. The information or data collected during the prototype or pilot run is then used to improve the design of the product or process prior to a full roll-out or product launch. When the project is complete the team ensures the process is ready to hand-off to the business leaders and current production teams. The team should provide all required process documentation and a Process Control Plan. Finally, the project leaders, stakeholders and sponsors complete the project documentation and communicate the project results. The entire team should then celebrate project completion.

Design for Six Sigma (DFSS) Method

Various methods of DFSS are

- Finite Element Analysis (FEA)
- Failure Modes and Effects Analysis (FMEA)
- Tolerance Stack Analysis
- Design Of Experiment (DOE)

Failure Mode Effect Analysis (FMEA)

FMEA identifies all the probable failure modes for the product or process. It prioritizes the failure modes for focused attention by using a scoring model based on Severity (S), Occurrence (O) and Detect ability (D).

FMEA is a risk assessment tool, that evaluates the severity, occurrence and detection ofrisks to prioritize which ones are the most urgent.

Definition of Terms

- Failure Mode – The way in which a specific process input fails
- Effect – The impact the failure has on the Critical Quality Parameter
- Cause – The source of variation that caused the process to fail
- Current controls – Systemized devices in place to prevent or detect the failure
- Severity – Importance of an effect on critical quality parameter (1-Not severe;10 – very severe)
- Occurrence – Frequency with which a cause occurs (1-Not likely; 10-Very likely)
- Detection – Ability of current control to detect the cause before creating a failuremode (1-likely to detect; 10-not likely to detect)
- RPN is an acronym for **Risk Priority Number.** It is calculated by multiplying theSeverity, Occurrence and Detectability.

Each category i.e. severity, occurrence and detection, has a scoring matrix with a 1-10scale.

Severity of 1 denotes low risk to the end customer, and a score of 10 denotes high riskto the customer.

Occurrence of 1 denotes low probability of the risk happening, and a 10 denotes a veryhigh probability of the risk happening.

Detection of 1 denotes a process that WILL likely catch a failure, and a 10 means theprocess will likely NOT catch a failure.

Sample Scoring Tables for Severity, Occurrence and Detection

Severity Rankings			
Rankin	**Effect**	**Design FMEA Severity**	**Process FMEA**

g			Severity
10	Hazardous-nowarning	Affects safe operation withoutwarning	May endanger machine oroperator without warning
9	Hazardous -wwarning	Affects safe operation with warning	May endanger machine oroperator with warning
8	Very High	Makes product inoperable	major disruption in operations(100 % scrap)
7	High	Makes product operable at reducedperformance (customer dissatisfaction)	Minor disruption in operations (may require sorting and somescrap)
6	Moderate	Results in customer discomfort	Minor disruption in operations(no sorting but some scrap)
5	Low	Results in comfort and convenienceat a reduced level	Minor disruption in operations(portion may require network)
4	Very Low	Results in dissatisfaction by mostcustomers.	Minor disruption in operations (some sorting and portion may require rework)
3	Minor	Results in dissatisfaction by averagecustomer.	Minor disruption (some reworkbut little affect on production rate)
2	Very Minor	Results in dissatisfaction by fewcustomers.	Minor disruption (minimalaffect on production rate)
1	None	No effect	No effect

Fig. 3.3.1 Severity table

Occurrence Rankings				
Ranking	**Effect**	**Failure Rates**	**Percent Defective**	**Cpk**
10	Extremely High	> 1 in 2	50 %	Cpk < 0.33
9	Very High	1 in 3	33 %	Cpk ~ 0.5
8	Very High	1 in 8	10 – 15 %	Cpk ~ 0.75
7	High	1 in 20	5 %	
6	Marginal	1 in 100	1 %	
5	Marginal	1 in 400	0.25 %	Cpk ~ 1
4	Unlikely	1 in 2000	0.05 %	
3	Low	1 in 15,000	0.007 %	Cpk > 1.33
2	Very Low	1 in 150,000	0.0007 %	Cpk > 1.5
1	Remote	< 1 in 1,500,000	0.00007 %	Cpk > 1.67

Fig. 3.3.2 Occurence table

Detection Rankings			
Ranking	**Effect**	**Design FMEA Detection**	**Process FMEA Detection**
10	Absolute uncertainty	No chance that design control willdetect cause mechanism and subsequent failure.	No known process control to detect cause mechanism and subsequent failure.
9	Very remote	Very remote chance that design control will detect cause mechanism and	

		subsequent failure.	
8	Remote	Remote chance that design controlwill detect cause mechanism and subsequent failure.	Remote chance that processcontrol to detect cause mechanism and subsequentfailure.
7	Very Low	Very low chance that design control will detect cause mechanism and subsequent failure.	
6	Low	Low chance that design control willdetect cause mechanism and subsequent failure.	Low chance that process control to detect cause mechanism and subsequentfailure.
5	Moderate	Moderate chance that design control will detect cause mechanism and subsequent failure.	
4	Moderate lyHigh	Moderately high chance that designcontrol will detect cause mechanism and subsequent failure.	

Fig. 3.3.3. Detection table

After scoring of each category is complete for each risk, the three scores are multiplied together **(Severity □ Occurrence □ Detection) to determine the Risk Priority Number (RPN).** The RPNs are sorted from largest to smallest, and actions are taken on the top risks in order to reduce the overall risk.

Typically, the severity cannot be reduced, so the team should evaluate ways to reduce occurrence or increase detection. After actions are completed, the RPNs are recalculated and new risks are determined.

Steps of the Failure Mode Effects Analysis (FMEA) :

- Recognize and evaluate potential failure modes
    - Use Risk Priorities Numbers to evaluate the modes.
- Identify the cause of failure
- Identify the actions which could prevent failures
- Document ideas of the team

FMEA Process

Purpose :

- Improves the quality, reliability and safety of the evaluated process and products.
- Reduces process and product redevelopment timing and cost.
- Documents and tracks actions taken to reduce risk.
- Aids in the development of robust process and product control plans.
- Helps practitioners prioritize and focus on eliminating product and process concerns and/or helps prevent problems from occurring.
- Improves customer/consumer satisfaction.

Objectives :

FMEA reduces the risk of failures by :

- Aiding in the evaluation of design requirements and design alternatives.
- Increasing the probability that potential failure modes, ranked according to theireffect on the customer (CTQs), have been considered in the development process.
- Aiding in the development of thorough and efficient validation plans.
- Providing future reference for analyzing field concerns and evaluating design process changes.

Process FMEA :

- Started before or after the feasibility stage, prior to production tooling.
    - Usually after a Design FMEA, but it could be some time before productionactivities start up.
    - Should take place before manufacturing begins.
- Accounts for all manufacturing operations.

- If a defect does occur during manufacturing, you should check to see if there is anunaccounted for failure mode occurring.

Here’s an overview of the 10 steps to a Process FMEA.

STEP 1 : Review the process

- Use a process flowchart to identify each process component.
- List each process component in the FMEA table.
- If it starts feeling like the scope is too big, it probably is. This is a good time to breakthe Process Failure Mode and Effects Analysis into more manageable chunks.

STEP 2 : Brainstorm potential failure modes

- Review existing documentation and data for clues about all of the ways each component can failure.
- The list should be exhaustive – it can be paired down and items can be combinedafter this initial list is generated.
- There will likely be several potential failures for each component.

STEP 3 : List potential effects of each failure

- The effect is the impact the failure has on the end product or on subsequent steps inthe process.
- There will likely be more than one effect for each failure.

STEP 4 : Assign severity rankings

- Rankings will be issued based on the severity of the consequences of failure.

STEP 5 : Assign occurrence rankings

- Rate the severity of each effect using customized ranking scales as a guide.

STEP 6 : Assign detection rankings

- What are the chances the failure will be detected prior to it occuring.

STEP 7 : Calculate the RPN

- Severity X Occurrence X Detection

STEP 8 : Develop the action plan

- Decide which failures will be worked on based on the Risk Priority Numbers. Focuson the highest RPNs.
- Define who will do what by when.

STEP 9 : Take action

- Implement the improvements identified by your Process Failure Mode and EffectsAnalysis team.

STEP 10 : Calculate the resulting RPN

Re-evaluate each of the potential failures once improvements have been made anddetermine the impact of the improvements.

Risk Priority Number (RPN)

Risk Priority Number (RPN) is a measure to sort the risks from highest to lowest. The RPN is calculated by multiplying the three scoring columns :

Severity, Occurrence and Detection.

The Risk Priority Number (RPN) methodology is a technique for analyzing the risk associated with potential problems identified during a Failure Mode and Effects Analysis (FMEA).

- **Severity -** Rates the severity of the potential effect of the failure.
- **Occurrence -** Rates the likelihood that the failure will occur.
- **Detection -** Rates the likelihood that the problem will be detected before it reachesthe end-user/customer.

RPN = Severity * Occurrence * Detection

Rating scales usually range from 1 to 5 or from 1 to 10, with the higher number representing the higher seriousness or risk. For example, on a ten point Occurrence scale, 10 indicate that the failure is very likely to occur and is worse than 1, which indicates that the failure is very unlikely to occur.

Ratin g	Description	Criteri a
1	Very Low or None	Minor nuisance
2	Low or Minor	Product operable at reduced performable
3	Moderate or significant	Gradual performance degradation
4	High	Loss of function
5	Very High or Catastrophic	Safety-related catastrophic failures

Fig. 3.4.1 Generic five point severity scale

Revised RPNs and Percentage Reduction in RPNs

In some cases, it may be appropriate to revise the initial risk assessment based on the assumption (or the fact) that the recommended actions have been completed. This provides an indication of the effectiveness of corrective actions and can also be used to evaluate the value to the organization of performing the FMEA.

To calculate revised RPNs (RPNr), the analysis team assigns a second set of Severity, Occurrence and Detection ratings for each issue (using the same rating scales) and multiplies the revised ratings to calculate the revised RPNs. If both initial (RPN_i) and

revised RPNs have been assigned, the percent reduction in RPN can also be calculated as follows :

	Severity	Occurrence	Detection	RPN
Initial	7	8	5	280
Revised	7	6	4	168
% Reduction in RPN				40 %

RPN Calculation Example

From the Process FMEA analysis of a painting process, the RPN is 120 for failure mode of foreign body in the painting layer.

Functions	Requirement	Failure Mode	Effects	Severity	Class	Causes	Control Methods				RPN
							Prevention Control	Occurrence	Detection Control	Detection	
Automatically paint the door of the car	Fully cover the required area of the door with required color	Foreign body in painting layer of the door	Bad appearance	5		Contamination of the room	Check room cleanliness every day	6	Appearance check after painting 100%	4	120
		Door suface is not covered	Bad appearance of the door; Car surface is not protected.	6		Door is not set correctly in the painting machine	Door setting working instruction	8	Appearance check after painting 100%	4	192
						Painting machine with trav[illegible]	Painting		Appearance	4	192
	Paint thickness meet the required specification	Pain layer is too thin	Color is not good Durability of paiting layer is shorter than specification	8		Spraying parameter is incorrect	Painting parameter setting instruction	8	Check the thickness of the first piece sample	6	384

RPN = Severity x Occurrence x Detection
= 5 x 6 x 4 = **120**

RPN is not the only risk assessment number used with FMEA. Some companies use other indexes to assess risks, such as the **Critical Number (CN)** or Severity-Occurrence- Detection (SOD). However, they are rarely used.

3.4.3 Critical Number (CN)

Critical Number (CN) = Severity (S) x Occurrence (O)

Example :

Failure Mode	Severity	Occurrence	Detection	CN
Failure Mode 1	6	5	5	30
Failure Mode 2	5	7	6	35

3.5 Six Sigma and Leadership

Here are some guidelines for business and human resources professionals to integrate the six sigma and leadership.

Select the Right Talent - In order to ensure leadership success from the start, select for Black Belt training only those people who are assessed to be good potential leaders. Black Belts should be the best people in a company. Many companies therefore select employees who have been identified as having high potential and sometimes even management trainees as Black Belt candidates.

A Black Belt candidate should be :

- A self-starter who can work on their own initiative with minimum supervision.
- Able to lead, train, mentor and work in a team.
- An effective communicator, at all levels.
- Able to effectively work at multiple levels within the organization.

- Computer literate and competent in mathematics and elementary statistics.
- Energetic and enthusiastic and have a passion for excellence.

Develop Clear and Promising Pathways - Designated Black Belts should know from the beginning that their assignment is just temporary, typically for two or three years. They must be assured that, after this period, they can move into an attractive leadership position. A promising pathway helps retain Black Belts in the company.

Provide Additional Training and Coaching - In addition to the knowledge and skills Black Belts acquire when working as process improvement experts and change agents, to be a successful leader, they need know-how and competencies in such areas as :

- Developing and implementing strategy
- Financial planning and controlling
- International organization development
- Performance management
- Marketing and sales effectiveness

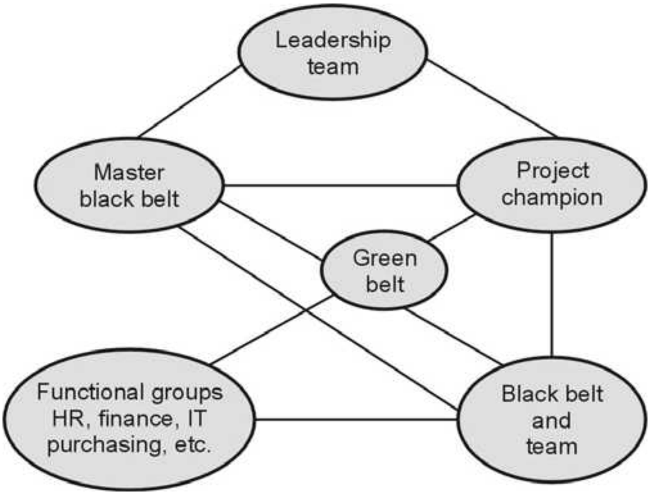


Fig. 3.5.1 Key players involved in a Six Sigma

The organization is defined as the unit that has responsibility for identifying the improvement opportunities and chartering the Six Sigma projects. This could be a

corporation, a division, a facility, or a function. The leadership team (often called the Six Sigma Council) leads the overall effort and has responsibility for approving the projects undertaken by the BBs. In the case of a finance function, the leadership team might be the Chief Financial Officer (CFO) and selected members of his or her staff.

The project Champion is typically a member of the leadership team and has the following responsibilities :

- Facilitating the selection of projects

- Drafting the initial project charters
- Selecting BBs and other resources needed to conduct the project
- Removing barriers to the successful completion of the project
- Holding short weekly progress reviews with the BBs

The functional support groups, such as human resources, finance, IT, and legal, assist the Six Sigma effort in four key ways, beyond improving their own processes through Six Sigma projects :

- They provide specialized data as needed by BBs, GBs, and teams outside their function.
- They provide expertise associated with their functional responsibilities.
- They provide members for the BB and GB project teams when appropriate.
- They help identify improvement opportunities for the organization to pursue.

3.5.1 Committed Leadership

The leadership qualities needed in a Lean Six Sigma team leader both universal and specific to the Lean Six Sigma process. Each quality is generally seen in good leaders across many different industries and applications, but also tends to be present at exceptional levels in a good Lean 6 Sigma team leader.

Lean 6 Sigma experts may vary somewhat in the specific words and labels they give to each quality, but they most often fit into one of the following categories :

- Project Management
- Problem Solving
- Team Dynamics
- Customer Focus
- Business Expertise
- Technical Expertise
- Integrity

The following table shows why each category is important.

Leadership Quality	Why It's Important
Project Management	• Deal with all aspects of a project from start to finish • Effective use of resources, time, team personnel, andSix Sigma processes
Problem Solving	• Anticipate probable obstacles and issues • Create solutions for emergent problems

Team Dynamics	• Facilitation • Motivation • Conflict resolution • Guide team through common stages of development (forming, storming, norming, performing)
Customer Focus	• Attention to needs of internal and external customers • Advocate for customer as final judge of quality
Business Expertise	• Understand and apply alignment between project results and overall business strategies • Attention to financial results • Attention to competitive issues
Technical Expertise	• Understand data and statistics • Analytical skills • Fluent in Six Sigma methodology
Integrity	• Trustworthy • Well-liked • Respected • Open, honest communication • Commitment to do the right thing

Success Strategies for Lean 6 Sigma Team Leaders :

All Lean 6 Sigma teams go through various stages and processes to get to the finalproject results. Each step along the way presents unique challenges and opportunities to the team leader, requiring ` leadership and management strategies to ensuresuccess.

Here are some of the most common situations a team leader faces, along withsuggested strategies for working through them.

Situation	Strategies
Team Development	• Team building exercises • Clarification of roles and expectations • Establish team ground rules • Ensure participation by all team members • Foster open and honest communication

Obstacles And Impediments	• Anticipate potential obstacles • Facilitate team actions for emergent obstacles • Foster problem solving skills and behavior among team members • Intervene on team behalf when necessary • Encourage creative solutions
Team Motivation	• Recognize what motivates each team member • Regularly recognize and reward team accomplishments • Foster culture of mutual support among team members • Call for breaks, down time, team building, motivational activities, etc. as necessary • Coach and counsel team members who become frustrated or discouraged along the way
Conflict Management And Resolution	• Establish communication and conflict resolution expectations • Provide conflict resolution tools • Manage team morale to anticipate and prevent conflict when possible • Facilitate conflict resolution activities • Recognize that team members have varying levels of comfort with conflict
Project Completion	• Facilitate gathering of "lessons learned" from team members • Ensure appropriate celebration of successful project completion • Ensure appropriate recognition for contributions of team members • Provide individual coaching and feedback to team members to support professional and/or personal growth

Change Acceleration Process

Change Acceleration Processes (CAP) represents a group of change management tools that are used to help the change effort to be accelerated towards a common goal.

In simple words, it is a set of principles and tools designed to accelerate implementation and increase the success of organizational change. It helps to gauge the political, strategic, cultural environment in the organization and plan for the action which will eventually estimate what a change initiative is capable of achieving with the existing operational processes.

Definition - A change management framework with a set of tools to gauge the political/strategic/cultural environment in the organization and plan for action which will eventually determine how much success a change initiative can bring in within the existing operating boundaries.

CAP addresses the following :

- How to create a shared need for the change ?
- How to understand and deal with resistance from the key stakeholders ?
- How to build an effective influencing strategy and communication plan for thechange ?

Steps of CAP

Leading Change : As the saying goes, 'Don't talk the talk if you don't walk the walk', the leader should demonstrate consistently showing strong commitment towards the change. Leaders should be cautious of their messages and their actions. From the project management perspective, there is a significant risk of failure if the organization lacks leadership commitment to the change initiatives.

Creating a Shared Need : Here one needs to answer the need for change, irrespective of the reason whether it has been derived from a threat or an opportunity. The need for change must be outweighed by the resistance by the organization. Reasons must be compelling and resonate not just for the leadership team but that it should appeal to all the stakeholders.

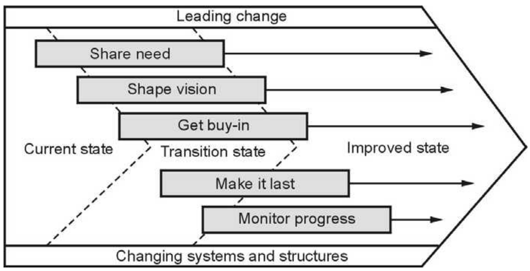
Shaping a Vision : It is the direction towards "how one is going to achieve the outcome of change initiatives". It is a clear statement which tells what, why, who and when the organization will address the changes. The desired outcome should be clearly understood, have genuine reasons and widely accepted.

Mobilizing Commitment : The strong commitment needs to be invested by business functions in the change to make it work and demand management support in order to support the changes. It also includes engaging, identifying, planning and analyzing the changes.

Making the Change Last : Once change is starts, the key is to sustain the change and transform it to a new norm, by allocating and adjusting the required funds and surviving through the competition.

Monitoring the Process of the Change Initiative : Measuring the progress of the CAP project by providing focus, direction and momentum throughout the change process. Ensures insight into level of acceptance throughout the change. It takes corrective action whenever necessary. To reward and encourage it tracks the key events and milestones of the change process

Changing the Overall Systems and Structures : Making sure management practices are used to complement and reinforce the change. It is to realign and leverage the way that the business functions has to organize, communicate, measure, train, reward and promote.



Six Sigma Change Acceleration Process (CAP)

CAP Analysis - Example - ARMI

ARMI is a project management tool used for doing stakeholder analysis for a project. It identifies the responsibilities of the personnel involved in the project. ARMI is an acronym of

- **A -** Approver / Sponsor, one who authorizes and approves the project and its progress
- **R -** Resource, a subject matter expert (SME) whose skills and knowledge are

required for specific duration

- **M -** Member, a full-time project team member
- **I -** Interested Party, someone who needs to be kept informed about the project statusIt is similar to the project management tool RACI (Responsible, Accountable,

Consulted, Informed) for categorizing the level of participation of project team members.

Advantages of ARMI :

- Gives a clear idea about the roles to play to the stake holders.
- Gives a clear Idea about how their role is going to change over the time with respectto different phases of a project
- Gives a clear glimpse of a project including impact analysis

Project Acceptability :

The Key Benefits of Project Acceptability is that it enables projects to be started and completed more quickly. It helps ensure that project solutions are supported. It helps ensure that customers and suppliers are getting involved appropriately. Team involvement ensures change sustenance. It reinforce change that is consistent, visible and tangible. It ensure a "baked-in" change – not just something on the surface that will be the first thing to be dropped in a pinch. And it helps drive change on a global/strategic basis.

Project Acceptability is based on the below equation :

Effectiveness of a solution = Quality of a solution * Acceptability of the solution.

Developing Communication Plan

It's important to keep the team, stakeholders and others informed throughout the DMAIC lean six sigma project.

The communication plan can be used as a structure to this, by defining what should becommunicated, the purpose, frequency, the audience and the communication method

A communication plan is document stating the goal for the project, how to achieve the end result and a list of objectives, strategies and procedures. A successful communication plan requires planning and coordination. An external Black Belt professional has the knowledge of the process improvement but will need to understand the culture of the company.

Brainstorming ideas with employees and staff will help develop a plan. Gaining perspective to the process already in action, gathering information and putting together an effective communication plan to give everyone an understanding of what the goal is, what steps will be taken, how this process will aid the departments in the short term and the long term benefit for the organization as a whole.

Communication Tactics

As an organization begins to build its communication plan, it must consider the variation in audiences and the methods that will be most appropriate for ensuring messages are received and understood. If, for example, there are many people in the organization without access to email or computers, reliance on web-based communications would not be a viable option.

The organization also must give thought to the messages that will be shared at different stages of deployment and establish a regular rhythm for communicating through a variety of channels.

Commonly used communication tactics include :

- Face-to-face meetings
- Town halls
- CEO memos to employees
- Presentations at staff/management meetings
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- Suggestion and question boxes
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- Quality quizzes or crossword puzzles
- Posters
- Shirts with special logos for team members.

Communication Plan Template

Different kinds of templates can be used as a communication plan that describes the information to the stakeholders.

Stakeholder/ Stakeholder Group	Objectives (Actions Desired)	Message Content	Delivery Method(s)/Venues	By When (Frequency)

Fig. 3.7.1 Communication Plan – Sample Template

A communication plan is made near the start of the project during the Define phase. It provides a structure for how the team will communicate with each other throughout the project.

The main methods of communication that are used are :

- Written; such as update forms with a set format
- Quick emails
- Meetings; gets attention but uses a lot of resource
- One-to-one catch ups; best for communication, but uses a lot of time

The output (plan) is a table with all the different communication methods that will be used in the project, along with who will be responsible, how frequently they will be used. This will then be distributed to the team.

Stakeholders

Stakeholders are people who will be affected by the project or can influence it but who are not directly involved with doing the project work.

Examples are Managers affected by the project, Process Owners, People who work with the process under study, internal departments that support the process, customers, suppliers, and financial department.

Alternative definition : People who are (or might be) affected by any action taken by an organization. Examples are : Customers, owners, employees, associates, partners, contractors, suppliers, related people or located nearby.

Categories of Stakeholders

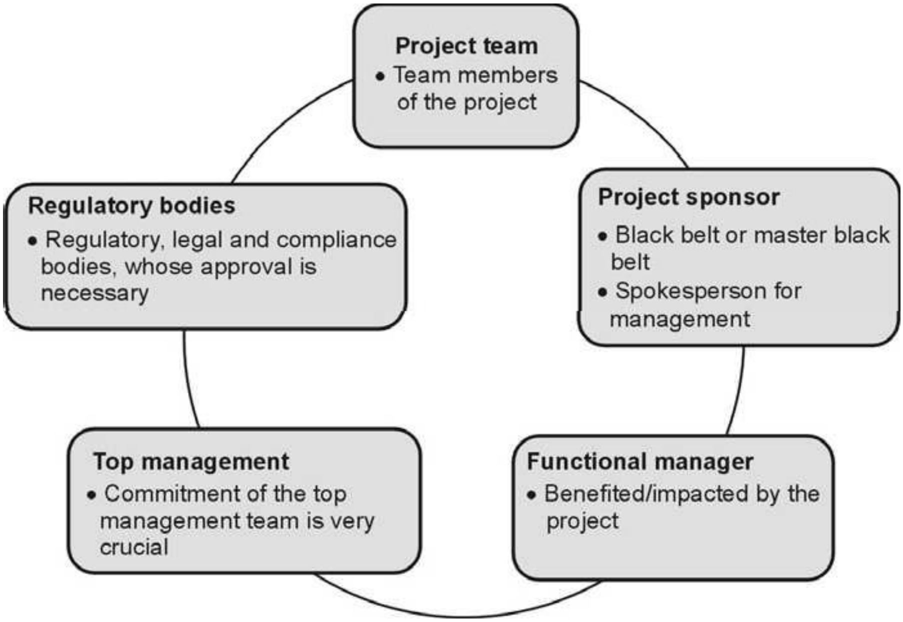

Fig. 3.8.1 Stakeholder categories

Stakeholder Analysis

The Stakeholder Analysis is a chart which gauges the positioning of stakeholders relative to change and commitment to the goals of the team.

Projects involve change and this often stirs emotions and encounters resistance. The higher the impact of the projected change the more important this tool becomes. The output of the Stakeholder Analysis is a representation of where the impacted people both inside and outside the system stands relative to change.

A sample template is shown below :

Stakeholder name	Current rating	Desired rating	Rationale for rating	Action plan	Date last revised
John	1	3	Runs downstream machine and has maintenance experience	Interview, go through Changetools	XX/XX/XX
Mary	4	4	Handles material to and from machines that Dave operates	OK	XX/XX/XX
Carol	5	5	Dave reports to Carol, former operator	OK	XX/XX/XX
Dave	3	5	Runs machine that produces this part	Explain gap and potential, interview, Change tools	XX/XX/XX
Mark	3	4	Quality control, inspects Dave's parts, make recommendations	Interview, go through Changetools	XX/XX/XX

Fig. 3.8.2 Sample template

Steps in Analysis :

1. List all stakeholder names on the team. Other stakeholders are the community, customers, stockholders, but are not included in this exercise.
2. Provide a number of 1-5 to indicate their CURRENT and DESIRED willingness to embrace change and make cultural commitment to advocate the change.

Note that not all members may need to be a 4 or 5, but since a major breakthrough, technical, or cultural change requires a team effort it is important to have the core team neutral or better before starting or proceeding to the next step.

- 1 = Strong Resistance
- 2 = Resistance

- 3 = Neutral
- 4 = Willing To Change
- 5 = Strong willingness to accept and embrace change

3. Document the roles and the relationships members that impact one another, boss, co-worker, material handler, and operators.
4. Develop a plan to get individuals to desired rating quickly. If the plan is notworking the person may need to be replaced before proceeding.
5. The Stakeholder Analysis tool (similar to the Pareto Diagram) may be used at any time during any phase to gauge the member's positioning. Overuse might indicate a trust issuewithin the team.

RPN_i □ RPN_r RPN_i

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Sigma Change Acceleration Process (CAP)

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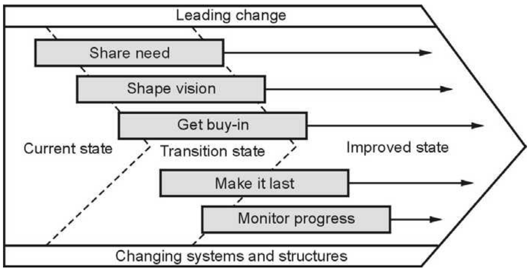

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Stakeholder/ Stakeholder Group	Objectives (Actions Desired)	Message Content	Delivery Method(s)/Venues	By When (Frequency)

Fig. 3.7.1 Communication Plan – Sample Template

A communication plan is made near the start of the project during the Define phase. It provides a structure for how the team will communicate with each other throughout the project.

The main methods of communication that are used are :

- Written; such as update forms with a set format
- Quick emails
- Meetings; gets attention but uses a lot of resource
- One-to-one catch ups; best for communication, but uses a lot of time

The output (plan) is a table with all the different communication methods that will be used in the project, along with who will be responsible, how frequently they will be used. This will then be distributed to the team.

Stakeholders

Stakeholders are people who will be affected by the project or can influence it but who are not directly involved with doing the project work.

Examples are Managers affected by the project, Process Owners, People who work with the process under study, internal departments that support the process, customers, suppliers, and financial department.

Alternative definition : People who are (or might be) affected by any action taken by an organization. Examples are : Customers, owners, employees, associates, partners, contractors, suppliers, related people or located nearby.

Categories of Stakeholders

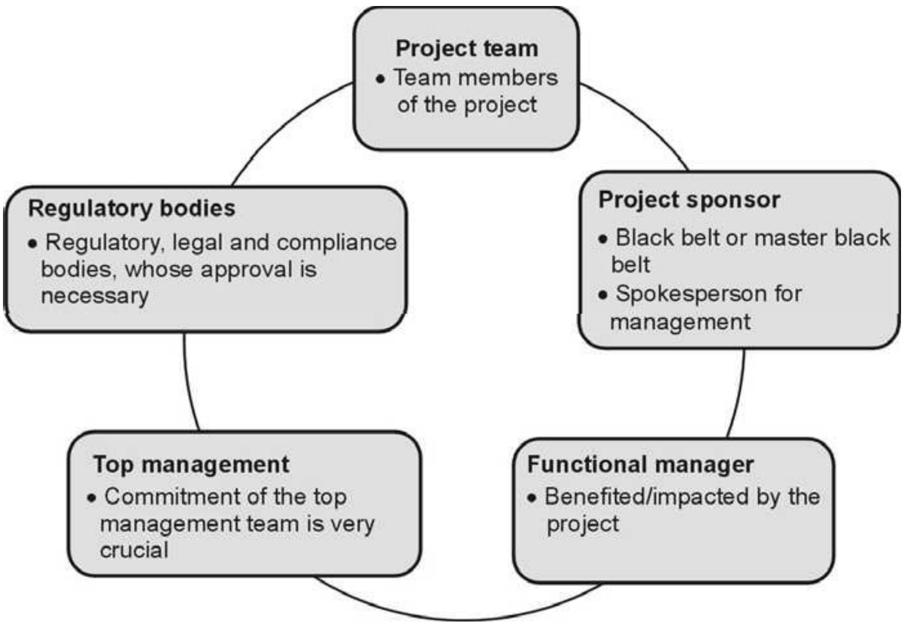

Fig. 3.8.1 Stakeholder categories

Stakeholder Analysis

The Stakeholder Analysis is a chart which gauges the positioning of stakeholders relative to change and commitment to the goals of the team.

Projects involve change and this often stirs emotions and encounters resistance. The higher the impact of the projected change the more important this tool becomes. The output of the Stakeholder Analysis is a representation of where the impacted people both inside and outside the system stands relative to change.

A sample template is shown below :

Stakeholder name	Current rating	Desired rating	Rationale for rating	Action plan	Date last revised
John	1	3	Runs downstream machine and has maintenance experience	Interview, go through Change tools	XX/XX/XX
Mary	4	4	Handles material to and from machines that Dave operates	OK	XX/XX/XX
Carol	5	5	Dave reports to Carol, former operator	OK	XX/XX/XX
Dave	3	5	Runs machine that produces this part	Explain gap and potential, interview, Change tools	XX/XX/XX
Mark	3	4	Quality control, inspects Dave's parts, make recommendations	Interview, go through Change tools	XX/XX/XX

Fig. 3.8.2 Sample template

Steps in Analysis :

6. List all stakeholder names on the team. Other stakeholders are the community, customers, stockholders, but are not included in this exercise.
7. Provide a number of 1-5 to indicate their CURRENT and DESIRED willingness to embrace change and make cultural commitment to advocate the change.

Note that not all members may need to be a 4 or 5, but since a major breakthrough, technical, or cultural change requires a team effort it is important to have the core team neutral or better before starting or proceeding to the next step.

- 1 = Strong Resistance

- 2 = Resistance
- 3 = Neutral
- 4 = Willing To Change
- 5 = Strong willingness to accept and embrace change

8. Document the roles and the relationships members that impact one another, boss, co-worker, material handler, and operators.
9. Develop a plan to get individuals to desired rating quickly. If the plan is not working the person may need to be replaced before proceeding.
10. The Stakeholder Analysis tool (similar to the Pareto Diagram) may be used at any time during any phase to gauge the member's positioning. Overuse might indicate a trust issue within the team.

Unit – 4 Six Sigma Implementation and Challenges

Syllabus

Tools for implementation – Supplier Input Process Output Customer (SIPOC) – Quality Function Deployment or House of Quality (QFD) – alternative approach –implementation – leadership training, close communication system, project selection – project management and team – champion training – customer quality index – challenges – program failure, CPQ vs six sigma, structure the deployment of six sigma – cultural challenge – customer/internal metrics.

Tools of Implementation

Six Sigma tools are defined as the problem-solving tools used to support Six Sigma and other process improvement efforts.

The Six Sigma expert uses qualitative and quantitative techniques to drive process improvement. Although the tools themselves are not unique, the way they are applied and integrated as part of a system is.

The main purpose of these tools was to guide the managers in planning, analysis and decision making. These tools were invented separately by different people for various purposes, but were organized and clubbed together during the course of time to achieve efficient planning and management of operations.

Affinity Diagram

Otherwise also called as KJ Method (Named after Jiro Kawatika). It is used to organize a large number of ideas or decision criteria into groups based on their underlying relationships and affinity (likeness). This method is used when the team is confronted with large number of different ideas or solutions and if the issue seems to be very complex and difficult to manage. The process followed herein is –

- Bring all the team members and domain experts in a room.
- Brainstorm all the ideas related to the problem and stick it on a board. This will ensure that ideas are free flowing and not interrupted or influenced.
- The Project Leader will then group the similar ideas and if there is a conflict in having any idea in a particular group, place it in both the groups and finally give a heading to each group.
- Discuss the relevance of the enlisted points and revise it as applicable.

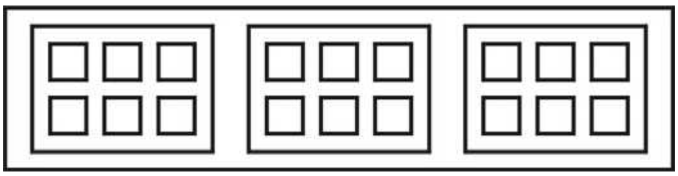

Fig. 4.1.1 Affinity diagram

Relationship Diagram

Otherwise it called as Interrelationship diagram. It is used to signify the strength of relationship between two processes or entities. It helps us to understand the causal relationship between variables/processes in a complex scenario. It establishes the linkages between variables/processes. The number of incoming and outgoing links indicates the importance of each process. The higher number of incoming arrows indicates the higher dependency of that process on other processes. Similarly, the more number of outgoing arrows from a particular process indicates the importance of that process on other dependent processes.

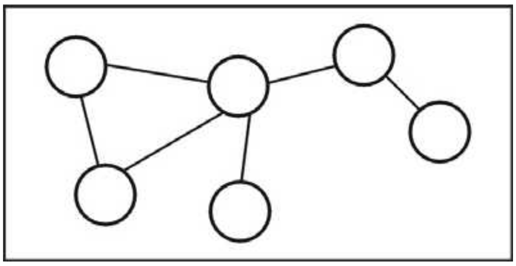

Fig. 4.1.2 Relationship diagram

Tree Diagram

This helps in understanding the process level-by-level by breaking down complex processes to the minute level of detail. It helps the team move down from broad process map to specific process details and requirements. It brings down and explores the finer details in any complex process. This is very helpful in decision making in a complex process with many business rules or in process that have huge financial implications.

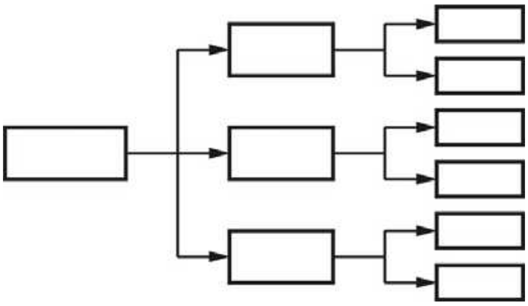

Fig. 4.1.3 Tree diagram

Matrix Diagram

This is another tool that helps in establishing relationship between variables. Variables are arranged in both Row & column and the strength of the relationship between each pair is marked in their corresponding cell. We can use this to measure relationship for one (Triangle), two (L shape), three (T shape, Y shape, C shape) and four set (X shape) of variables.

Process Decision Program Chart (PDPC)

This tool is based on the Decision tree but has other additional features like mapping the failure mode, risk involved, effect of failure with each decision node. It combines the aspects of FMEA - Failure mode, effect and risk of failure with the Decision tree. Thus it helps us to analyze all possible problems involved in making a decision. Thus, a corrective/preventive action can be planned for any step in the process.

Activity Network Diagram (AND)

This is also called as Arrow Diagram and is a tool used in PERT and by Project Management professionals to map their activities and sequential tasks in a visual format to understand and optimize the project duration. Plotting an AND makes you find the project duration, schedule tasks easily and identify the critical path.

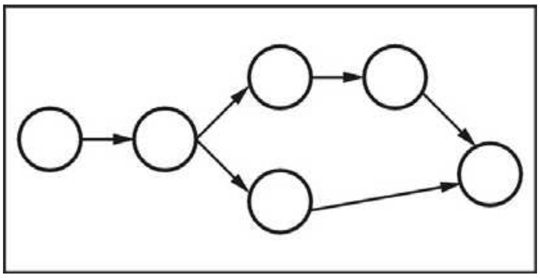

Fig. 4.1.5 Activity Network Diagram (AND)

Supplier Input Process Output Customer (SIPOC)

SIPOC is the acronym for **SUPPLIER** or the source of input, **INPUT** or the materials needed for the process, **PROCESS, OUTPUT,** what is produced by the process and **CUSTOMERS,** the end users of the output. By graphically plotting of all variables that affects the aspects of the whole process, managers are more able to see the bird's eye view of the process, thus affording a more comprehensive and effective decision making.

SIPOC is a high level management tool that simplifies the variables of any given process into five segments. SIPOC is the acronym of these five segments :

- S for suppliers,
- I for inputs,
- P for process,

- O for output and
- C for customers;

A basic SIPOC diagram would look like this :

Fig. 4.1.6 Basic SIPOC diagram

Each phase of the process is clearly defined. It shows the vital relationship of onephase to another and how they affect each other's performance. The diagram also shows the flow of the process, making the determination of a failure easier to pinpoint.

SIPOC is best accomplished in team work and brainstorming sessions. During sessions, team members will determine all the variables that are relevant to a given process. Let's use the baking process as an example for this discussion.

The first step of the process is to determine and list down the its variables. In our example, we can list the following as our suppliers, inputs, outputs and customers. This is just a short list intended to demonstrate the method. When working in a real setting, you have to list everything that is relevant:

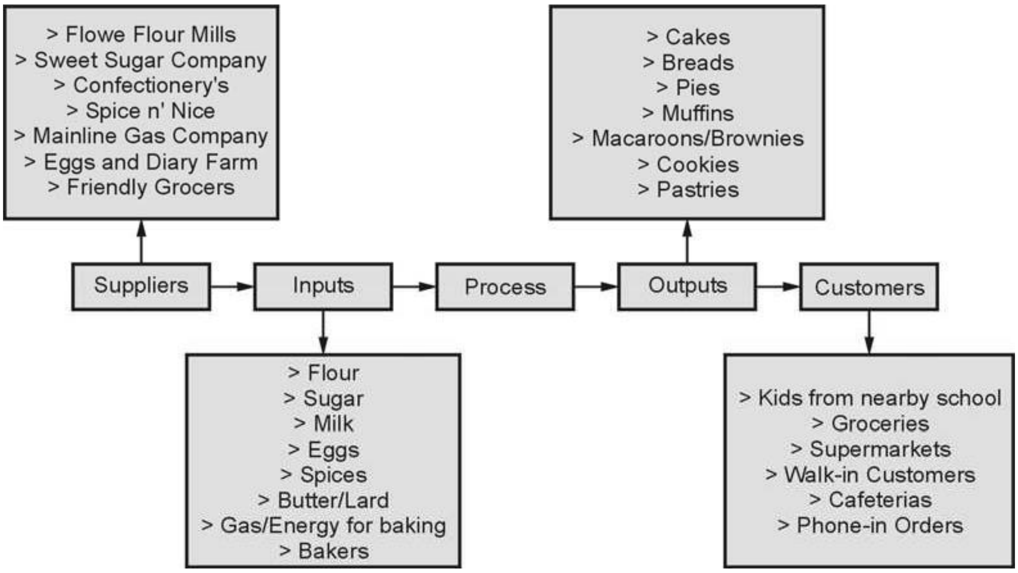

Fig. 4.1.7 SIPOC diagram variables

Next we establish the steps within the process. For this example, the process map willlook like this :

Process

- Determine the orders for the day
- Check if requirements and ingredients for the orders are available and complete. Send out orders to suppliers for needed supplies.
- Makes the dough for the breads. Let it stand.
- Mix cake batters.
    - Bake the cakes. Let it cool before decorations and icings.
- Knead the bread dough. Set aside to let rise.
- Mix and bake macaroons or brownies. Let cool before decorating.
- Decorate the cakes.
- Decorate brownies.
- Knead and cut the bread dough.
- Mix and bake muffins.
- Bake the bread and other pastries.
- Mix and bake cookies.
- Assistants will pack or box to deliver or send to the display counters.
- Counter sales or delivery of orders to customers.

Fig. 4.1.8 SIPOC Process Map

Before you can analyze your SIPOC diagram, you first have to establish the requirements for the inputs and outputs.

Inputs – Inputs are the raw materials used in the process and the main components of your output. Below is the list of input requirements for the baking process :

- Raw materials should be fresh.
- Should be reasonably priced.
- Available when needed.

Outputs – Outputs are the end product of the process. These are also the products that you will pass on to your customers. Your output should always mirror the company's goal and positioning in the market. Below are some possible output requirement of our sample process :

- Freshly baked.
- Delicious and well presented.
- Affordable.
- Easily accessible.

Now we can analyze if the suppliers are addressing the input requirements and compare if the customer's needs are aligned with the products that we are offering.

Suppliers - Your suppliers should be able to address the needs or specifications of your inputs. Some of the guiding questions to help you determine if you are working with the right suppliers are :

- Can the supplier provide adequate supply when needed ?
- Does the quality of supplies meet the input requirement ?
- Are the prices feasible ?
- Does the company have a backup supplier in case of default ?
- Is it financially and reputation-wise advantageous to be connected with the supplier's company ?

Customers - Customers or the end users of our products are the people or entities that are willing and able to pay for what we are offering. In this case, we listed walk-in customers as well as retailers. Using VOC (Voice of the Customer) we use the guide questions to determine our customers' needs and wants :

- What is the most important bread quality that you require ?
- How much are you willing to spend for a loaf of bread ? For a medium sized birthday cake ?
- Where do you buy your bread supply ? How do you buy specialty cakes ?
- How often do you buy pastries ?

Your customers' feedback or your projected customers' needs should be addressed by your output. In case of misalignment, go back to your process. You might need to modify the process.

It is not unusual to employ SIPOC on established processes if there's a low turnout on sales or output or if the expense ratio against income is high. SIPOC will help process auditors to determine if the process is still working for the business. From the analysis, managers will have a clearer idea of whether to streamline on expenses or infuse more resources to improve the efficiency of the process.

Quality Function Deployment or House of Quality (QFD)

Another Six Sigma tool that aims to get a hold of the voice of the customer is the Quality Function Deployment or QFD. Introduced in 1966 by 2 Japanese professors – Dr. Shigeru Mizuno and Dr. Yoji Akao, organizations all over the globe utilize this technique to market products and services faster, cheaper, and better. In the earlier years, manufacturers used QFD to assure that the end product is produced according to design.

Over the years, this Six Sigma tool has evolved and has been associated with the *House of Quality* to classify customer needs and convert them into definite product features that will satisfy specific needs. Unlike House of Quality, which focuses more on the engineering capacities of the product, QFD's focus is on what the consumer would say about the product.

The tool uncovers both *"unspoken"* and *"spoken"* consumer needs and maximizes the positive feature that makes value. The objective of minimizing or eliminating defects is done using the help of the product's end users' feedback.

This quality system uses both elements of psychology and systems thinking. Systems thinking represent the overall view of the product as a whole while psychology refers to understanding what the customer need and want is, what they mean by "value", their buying decision, and ultimately what makes them continue to buy the same product.

By using QFD, organizations are able to answer questions like :

- How do we know which consumer to ask ?
- How do we know the end user's specific product requirement ?
- What features do we need to include?

QFD's objective is for the organization to be on the competitive edge wherein there is the ability to maximize favorable features that add value and to satisfy the consumer all the way through the development, production, and business process.

To better understand the QFD tool, it is essential to distinguish it from the traditional systems of quality. QFD is different from long-established quality systems. When using conventional systems results tend to be limited because the focus is only to eliminate unfavorable factors and not to take full advantage of the favorable key features.

Using QFD generates *"value"* which eventually leads to good customer experience. Quality Function Development is the lone quality system which aims to satisfy the consumer. The method focuses on making the best use of customer satisfaction which is measured by parameters including repeat business.

Once determined the spoken and unspoken needs are converted into designs and solutions and later on communicated to the target group or to the whole organization if necessary. QFD also lets its consumers prioritize their needs and compare these needs against the needs of competitors. Once benchmarked, it is directed to optimize the product features which will eventually lead the company to a competitive edge.

To be able to satisfy the needs of the consumer, it is imperative to understand how consumer satisfaction will be affected by the means of meeting these needs. There are three general types of consumer requirements: the revealed requirement, exciting requirements, and the expected requirements.

- **Revealed requirements,** also known as the basic factors are needs verbally expressed by end users. These are responses written on feedback forms or answersto survey questions.
- **Expected requirements** or performance factors are those not explicitly mentioned by the consumers but may affect their buying decision. These are product features expected by a customer but not really included in the product. Often the result is dissatisfying but there are tendencies that customers fail to mention these factors in the surveys.
- **Exciting requirements** or expected factors, on the other hand, are needs that are not easy to realize. The absence of this need does not automatically merit dissatisfaction but the presence gives additional value to the product. These are the features that amaze the customer. Since these features are not expressed by the consumer it is the company's job to uncover what features should be added to the product for it to have additional customer merit.

The essentiality of using QFD is not limited to the factors which affect customer's satisfaction. For an organization to be always on the competitive advantage, it is a must to conduct frequent study on what satisfies the customer and what other factors can be added to their satisfaction. The process may require a lot of activity at first considering all the "what" and "how" questions that needs to be answered but the fruit in the end is veryrewarding.

Benefits of using these Management Tools :

- Rather than using ad-hoc and own methods for planning and decision making, use of these well-defined and proven methods will help the user complete the task faster and easily.
- Also, time spent on unnecessary analysis and research is reduced by using these tools.
- These tools guide the users to success on various aspects like planning, decision making, arriving at the root cause and other significant business activities.
- Using a standardized and universally accepted tools and techniques winsacceptance and confidence among clients and other business engagements.

Alternative Approach

There are some other approaches and technology to support Six Sigma and other process improvement efforts by not only considering the current tools we have discussed.

You can use approaches like,

- **The Autocorrelation Function (ACF)** is a tool for identifying dependence of current data on previous data points.
- **Benchmarking,** is defined as measuring your performance against best-in-class companies, determining how the best-in-class achieve those performance levels, and using the information as the basis for your own company's targets, strategies, and implementation.
- **A Box Whisker Chart** is a graphical tool that may be used with variables data (data that is both quantitative and continuous in measurement, such as a measured dimension or time). Box Whisker plots may be used to :
  1. Monitor the process location and variation over time.
  2. Compare the location and variation of various processes or categories of products or services.
- **A Bulls eye Chart** is a graphical tool that may be used with variables data (data that is both quantitative and continuous in measurement, such as a measured dimension or time). The Bulls eye chart may be used to estimate whether each of two parameters is within its desired or expected range (depending on input parameters).
- **Failure Mode, Effects, and Criticality Analysis :** Failure Modes and Effects Analysis (FMEA), also known as Failure Modes, Effects and Criticality Analysis (FMECA), is used to determine high risk functions or product features based on the impact of a failure and the likelihood that a failure could occur without detection.
- **Maintainability and Availability :** Maintainability is a measure of the difficulty to repair the system and Availability is a measure of the readiness of a system.
- Measurement Systems Analysis
- **PDCA Plan-Do-Check-Act,** is a flow chart for learning and process improvement.
- **Run Charts** are basic trend charts that may be used with both variables (data that is both

quantitative and continuous in measurement, such as a measured dimension or time) and attributes (count) data. The Run chart monitors the process location over time. Run Charts are NOT control charts, as they do not have statistical control limits. For that reason, they may not be used to establish statistical control of a process or to measure process capability.

Implementation

Six Sigma principles use statistical and numeric methods to reduce the number of defects in output to an insignificant level. They emphasize simplicity of process, quality of parts and supplies, and employee responsibility for achieving promised results. The direct involvement of employees in the introduction of Six Sigma strategies is a major factor for successful implementation. Training key employees in Six Sigma techniques is an important prerequisite. Businesses that successfully implement Six Sigma programs see an improvement in company performance and increased financial returns.

- **Project :** The best way to implement a Six Sigma program is to start with a pilot project. You can identify a company process that generates defects or has other problems, usually in production. The process of identifying a pilot project has to involve the people carrying out the work and consider their input. Six Sigma only works when everyone is involved.
- **Training :** The person leading the Six Sigma implementation project has to be knowledgeable about Six Sigma methods and principles. In Six Sigma terms, he must be a "black belt" expert. In small businesses, one black belt for a pilot project is usually enough. The business can hire a qualified new employee or can train within the ranks. Training for black belt certification and implementation of the pilot project may overlap.
- **Team :** Once the company has chosen the black belt team leader, it must assign team members who will help with the implementation. The company has to consult the workers involved in the pilot project. Some team members will become black belt leaders for other company implementations, and many will become green belt support workers who help the black belt leaders. Good workers are needed on the team, but also to run the Six Sigma pilot project after implementation.
- **Plan :** The team has to plan the implementation under the leadership of the black belt. The aim is to put in place an organizational structure that streamlines the target production process to reduce defects. The black belt identifies problem areas, and the workers who carry out the work help with solutions. The plan details the measures the team proposes to reduce waste, increase worker efficiency and eliminate bottlenecks.
- **Execute :** Six Sigma requires an initial effort and is then a continuous process. The pilot project has to set up the initial steps and put in place the organization for continued application. The team makes the necessary changes according to the plan and then puts in place a black belt to run it. Green belts help with operation according to the new plan and take responsibility for specific aspects.
- **Evaluate :** At the completion of the pilot project, an evaluation details what worked well and where there were problems. The workers involved are a key source for evaluation criteria and parameters. The company now has at least one qualified black belt and several

candidates. The evaluation is the basis for a continued application to other areas of company operations. In a small business, a second round can probably encompass all the remaining production activities.

Leadership Training

When organizations decide to deploy a Six Sigma initiative, there are several foundation stones required for a successful venture. One of those building blocks is leadership. From executive-level support to assigning champions and choosing the right projects, leadership is critical for Six Sigma success. But if it is so important, leadership training should be a core ingredient in any Six Sigma curriculum. The need for constant renewal and improvement can only be met when an organization has strong leaders.

Training begins at the executive level to help top managers understand the vision of how Six Sigma methodology impacts business success, so that Six Sigma projects can be connected to achieving business goals. Middle managers are trained to be Six Sigma champions and act as project sponsors to lead by example and demonstrate the organization's commitment to Six Sigma by conferring authority on project teams and allocating needed resources.

Close Communication System

Communication is a key factor in the success of any project. For Six Sigma leaders, maturity and experience can bring a balance between viewing individual "trees in the forest" and understanding how the whole forest full of trees can function together. When a leader starts adjusting processes in one area, changes can be felt in other areas, even if the perturbation was unintentional.

For a Six Sigma project to run smoothly, communication is essential. Hence the close communication system is incorporated among everyone across the organization, which enables to understand the basics of Six Sigma, then it is more likely there will be some understanding when improvements in one area bring about changes in others.

The savings and ingenuity reaped from an organization that can share meaningful insights and communicate more effectively across divisions may translate into significant profits over time.

Project Selection

Project selection is a critical part of the Six Sigma quality improvement process. It is quantifiable and based on objective data rather than subjective guesswork. A project is a problem that is scheduled for solution. A good Six Sigma project is connected to a company's strategic goals and will solve customers' problems. A successful project will lead to improvements in schedule, quality or cost and can be used to meet the needs of external customers, internal customers or shareholders.

The rigors of Six Sigma require that project selection be based on quantifiable metrics. Choosing a project based on quantifiable data helps the organization identify the project that provides the greatest savings relative to the time expended and cost of deployment.

Project Management and Team

Project management is the application of knowledge, skills, tools, and techniques to project activities to meet project requirements. Work breakdown analysis, schedule development, risk analysis, scope definition, status reporting and cost budgeting are common processes that project managers use to plan, execute, control and close projects. These processes and associated tools work for both transactional projects and manufacturing projects. The project management approach utilizes various tools and processes to complete a process improvement project.

The processes identified above are far from an exhaustive list of the processes available in the project management arsenal, but represent those most useful to a process improvement project. The strengths of project management include formal control of change, scope, time and money. These controls are important to any firm trying to improve its bottom line via process improvements.

Champion Training

Champion training focuses on providing you with the managerial and technical knowledge to facilitate the leadership and deployment of the Six Sigma strategy. Champions are upper-level managers who lead the execution of the Lean Six Sigma deployment plans for the company. That makes it one of the most critical roles in any successful Six Sigma improvement initiative. Guided by the direction set forth by the executive team, champions select the projects, determine who is trained as Black Belts/Green Belts, review progress, and mentor the Black Belts/Green Belts in order for the deployment to be effective.

Champions play a pivotal role in a successful Lean Six Sigma initiative. They serve as mentors to project teams and act as a bridge between black belts and organization management. Without champions, efforts can become entangled with internal obstacles, become misaligned with core business objectives, lose focus and track of time, and may not yield expected benefits. Champions are typically members of the executive or leadership group who sponsor projects and mentor teams working on those projects. To be effective, champions must be trained in the essentials of the Six Sigma Methodology. Champions do not need to be “expert” in Six Sigma tools and techniques but they do need to have proficient skills in facilitation, collaboration and conflict resolution.

This training enables learners to,

- Successfully support your staff’s lean six sigma efforts.
- Overcome challenges to successful lean six sigma implementation.
- Monitor and nurture lean six sigma projects.

Customer Quality Index

Quality Index : We can’t measure quality of a product that is performing well today, but can go down tomorrow because of changes in customer needs. Thus we define Quality Index (QI), as a measure of quality.

The need for Quality Index is,

- Customer satisfaction is one of the most critical things when it comes to quality ofthe application. Based on the QI, one can measure customer satisfaction.
- When the quality index is applied, it will be easy for the management to digest one number and drill down the other, if required. S
- The QI trend provides continuous feedback, which is required for control. It is easyto monitor when the process is going out-of-control.

Quality is a subjective term. Each type of 'customer' will have their own slant on 'quality' - the accounting department might define quality in terms of profits while an end-user might define quality as user-friendly and bug-free. Quality Index is a measure ofquality. The objective of calculating QI is to achieve customer satisfaction and also result in improved productivity, reduced errors, reduced training and improved acceptance.

The key to the success in the initial step is to accurately capturing the “Voice of the Customer” (VoC) which describes your customer’s feedback about their experiences with and expectations for your products or services. It focuses on customer needs, expectations, understandings, and product improvement.

VoC programs have gained traction over the years and are fast-growing segments of a core business strategy for organizations. Learning through customer feedback of what works and what does not work will help the organization to establish a continual process improvement.

Challenges

Some blame Six Sigma when an organization decides to put the methodology into action and things don’t improve. Or they simply think Six Sigma does not apply to their situation. Six Sigma is not some sort of magic incantation to chant that solves issues in a snap. It takes dedication, training and proper application.

Challenges arise not with Six Sigma itself, but with how it is applied and the people who apply it.

Challenges with People

Six Sigma is a collection of tools and techniques. They’ve been proven to work time and time again to make processes within a company more efficient. Those who doubt can call Motorola, Toyota, IBM and General Electric. They’ve all had a bit of success with Six Sigma.

Six Sigma or Lean, properly applied, can make any process more efficient. Feelings are not part of the equation. Any process can be improved when its measured, analyzed, defects and wastes are found and eliminated, and a plan is put into action to sustain the changes.

But things sometimes get in the way. They include many of the following.

- Low Information :

Some people simply do not learn the rules of Six Sigma before applying them. Without basic knowledge and training in the details of Six Sigma methodology, it will not work properly.

- Resistance to Change :

Many employees – and managers – are resistant to changing a process that has worked one way for many years, no matter how inefficient. This is an emotional response, not a logical one. In some cases, employees fear they will lose their jobs if Six Sigma is applied.

This is one of the biggest Six Sigma myths. That's not what Six Sigma does. It focuses on fixing defects, not eliminating jobs.

- No Management Buy-In :

Management doesn't always completely commit to Six Sigma. Or, if the benefit is not clear or immediately realized, they will lose interest and offer weak support. This short- term view is not the best approach. Six Sigma is a process that requires long-term commitment.

Challenges with Implementation

These areas are results of the issues listed above. They involve errors in implementing Six Sigma process improvement methodologies.

- Incorrect Scope :

The scope of a project is important as it defines the ultimate goal and sets parameters for what the project will encompass. However, once a project begins and issues are uncovered, scope creep can occur. This leads teams off onto tangents that don't necessarily benefit the stated project goal. Office politics and a lack of unclouded vision from management can also constrain a project.

- Not Using a Data-Driven Approach :

Knowing the correct data to collect on a project is difficult enough, as is analyzing it properly to reach conclusions that will benefit an organization. However, in many cases, managers and executives will still go with "gut instincts" no matter what the data shows. By ignoring the data, people ignore one of the basic principles of Six Sigma.

- Lack of Resources :

This ties in particularly with management buy-in. Without providing the proper tools to accomplish a project, a team can soon flounder.

- Change Is Hard :

Of everything listed above, fear of change is likely behind much of the issue.

Ultimately, the issue becomes one of vision. Any "agent of change" – such as a process improvement methodology – will be a cause of concern. There are five fundamental ideas to keep in mind that might be helpful to implementing Six Sigma.

The directives require each and every one in the organization, i.e., all the employees to participate in the course outlining 5 W's of six sigma. This course explains the Who, What, Where, When & Why of the organization's new way of doing business.

Program Failure

There are any numbers of reasons why some projects fail, and organization experiences at least some extent. By understanding the chief points of failure, managers can do a better job of anticipating potential trouble spots in their organizations and structuring their initiatives to most effectively offset the risks. These include:

- **Lack of senior management support and involvement :** It's not just support that makes a difference. Senior management also must take an active role in the improvement programs so they have a direct, unfiltered perspective of what it takes to succeed and how everyone will know it has been achieved.
- **Cutting short Six Sigma experts' involvement :** The Six Sigma leader's role must be consistent over time to keep projects from derailing. This is the person who monitors progress, ensures performance remains tied to demonstrable improvements over time, and establishes an environment where people continue learning, training is ongoing and resources are maintained.
- **Failure to link programs to financial objectives and adequately measure results :** The reality is that Six Sigma initiatives are defined by the value they create for an organization.
- **Lack of fit with DMAIC fundamentals :** Another issue is the one which revolves around DMAIC (define, measure analyze, improve and control) – the basic Six Sigma process improvement methodology. In some instances, the project was too small for the kind of rigor called for by the methodology. More of an issue was the tendency to force inappropriate projects into the DMAIC format – the selection of a software vendor, for example, or the installation of a finishing line on a factory floor.
- **Failure to launch :** If the solution is not implemented, it's a waste of time and resources and erodes the value that Six Sigma should ultimately create for the organization in the name of continuous improvement. But it happens too often. Improvements are not an easy or fast fix – and both management and the project team can get restless (or worse). Impatient managers may boycott projects – which is why it's critical to enlist senior executive involvement and encourage a culture where the Six Sigma leaders have the clout to keep projects from derailing.

Any one of these factors can spell trouble for organizations hoping to realize the Six Sigma promise of continuous improvement. Those that pay close attention to the people and project issues from the outset will benefit by experiencing Six Sigma initiatives that measure up and deliver.

CPQ vs Six Sigma

Cost of Poor Quality it is a term that is misconstrued badly in the Six Sigma fraternity. In fact the term Cost of Poor Quality (referred to hereafter as CPQ), is used so commonly even in Non-Six Sigma companies that this often deserves more than a merit or a discussion.

CPQ is the cost or price a company pays when all of its products are not perfect. The summation of three different costs,

- Costs of non-conformities
- Cost of inefficient processes
- Cost of lost opportunities for sales

Companies prefer categorizing CPQ in four different categories and until date, this is the best way how CPQ could be broken down as,

- Internal Failure Cost : Prior to delivery of the product or service
- External Failure Cost : After delivery.
- Prevention Cost : Incurred on prevention activities.
- Appraisal Cost : Incurred by testing, measuring, and auditing.

Example of Cost of Poor Quality (CPQ) vs Six sigma :

- Quality assurance is everything for an organization. By incorporating Six Sigma tools, this allows companies to decrease waste (Raw materials, Logistics costs, and unnecessary man hours) which increases their bottom line.
- Let us imagine we are running a DMAIC project. In the define phase, we want to quantify the cost of poor quality. We start by defining what a defect is, then measuring how many defects per million opportunities our process has.
- Imagine producing TVs and for every 1M produced 2 % were damaged. That's 20,000 TVs. If those damages were not salvageable, and it cost ` 7000/- to produce each unit, then it cost your company 20k * 7000 (approximately $2 Million)
- But that's not all. How many people would you have to staff to answer 20,000 calls, returns, inventory management etc.? Let us say that figure is an additional ` 700 per unit. At 20 K units, that is $200 K. The total cost to the company would be $2.2 Million!
- When six sigma is applied, and at a Six Sigma level you would only produce 3.4 defects per million opportunities. In the previous example the process was making 20,000 defects per million. Moving to a six sigma level of quality would mean 19,996.6 less defects per million units made! That's a savings of $2.2M – (3.4 * $110) =
$2.2M – $374. So, nearly $2.2 Million is saved.

Structure the Deployment of Six Sigma

Six Sigma deployments is not something new to the industry. We heard about Lean Six Sigma belters; Green, Black and Master Black Belt. But the belters are not the only role in Six Sigma organization structure. Most of organizations deploy the Lean Six Sigma are not run only by the belters. There are several different roles played by different individuals supporting the Six Sigma structure.

Below diagram is the generic Six Sigma structure in organization with several roles with explanation of their responsibilities in supporting the Six Sigma deployment.

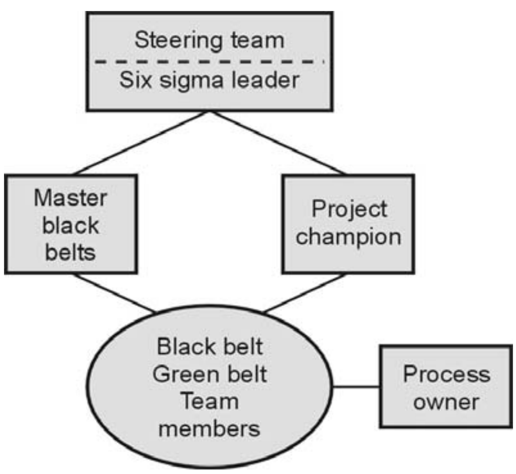

Fig. 4.12.1 Generic six sigma structure

1. **Steering Team -** These are the leadership team that foresees the Six Sigmainitiatives within the organization. They are responsible to:

- Review overall deployment progress
- Select and prioritize the projects
- Ensure strategic alignment between the lean six sigma initiatives and company'svision

2. **Six Sigma Leader -** The leader normally is one of the Six Sigma experts in the management team and they have the final accountability of the six sigma deployment. The responsibility of the lean six sigma leaders are to :

- Oversee deployment progress as custodian Lead Master Black Belts
- Facilitate Leadership Team on project selection
- To assess the project closure

3. **Project Champion -** The champions preferably are from the middle management team and above. They are the ice breaker for the belters to ensure the projects are progressing well. The other responsible of the champions are :

- Assess financial impact of projects
- Breaking project's barriers with the management's authority
- Support project selection and execution

4. **Process Owner -** The process owner is from the management team that owns the process of the projects. Sometime the process owner can be Project Champion; it will ease the process of breaking the barrier in the project. The responsible of project owner in supporting Six Sigma structure are to :

- Manage the improved process once team is done
- Maintain dashboard
- Support of the project audit process

5. **Master Black Belt (MBB) -** The Master Black Belt is the Six Sigma Jedi in the organization. Thus, normally the Master Black Belts are the Jedi Council in creating, advising and reviewing the technical parts (syllabus, tools etc) of Six Sigma to meet the organizational needs. The Master Black Belts also responsible to:

- Train and coach the Black Belts and Green Belts
- Help with advanced statistical tools

6. **Black Belt -** Since the MBB is the Jedi, the Black Belt supposedly the junior Jedi or Knight. Their technical skills might be on the par, but the 'people skill' is growing. Black Belts are the heart and soul of the Six Sigma organization. Their main purpose is to lead quality projects and work full time until they are complete. Other traits that differentiate between the Black Belts and Green Belts are,

- Black Belts require completing more complex projects that might involve across division projects and high impact.
- Black Belts supposed to complete more projects in a year (4-6 projects) in their KPI.

7. **Green Belt -** This is the learners of the Six Sigma, the part time project leader in the organization. They trained in Six Sigma who spend a portion of their time completing projects but maintain their regular work role and responsibilities. The Green Belts are required to :

- To complete the less complex projects those involve statistical tools. Normally the score of the project is within their department/division to avoid time consuming.
- Expected to complete at lease 1-2 projects per year in their KPI.

8. **Yellow Belt -** The Yellow Belt normally play roles as team member in Black Belt or Green Belt's projects. Sometimes, they can lead the small improvement projects within their areas (e.g. 5 S, Visual Control) and it is not expected in their KPI.

Cultural Challenge

The biggest benefit Six Sigma brings to the organizations that practice it is the way it converts employees from passive participants who often notice problems to active participants who possess the drive to solve them.

A Six Sigma culture has the potential to literally transform employees.

Those with Six Sigma certification are cultured to see themselves and the work they do differently than traditional employees. They are taught to :

- See work in terms of process flow, and not just departments and functions
- Take an active role in defining improvements and identifying solutions, instead of relying on management
- Utilize the appropriate skills to create and implement solutions
- Actively involve themselves in continuous improvement efforts

Once Six Sigma training has been instilled in employees and the transformation is complete, organizations need a company culture that sustains these attributes and prevents employees from reverting to their old behavior and mindset.

Change management can help solidify a new culture in individuals and organizations. Consider these four ways change management can be used to instill Six Sigma culture into an organization.

1. Create Awareness and Desire
2. Expose the Organization to Change
3. Move Ahead, and Be Prepared for Surprises
4. Reward Generously

Customer / Internal Metrics

Customer metrics need to be supported by a clear description of what it is measuring. They are non-ambiguous and straightforward. The definition, referred to as the constitutive definition, not only tells you what the customer metric is measuring, it also tells you what the customer metric is **not** measuring.

The complexity of the definition will match the complexity of the customer metric itself.

Depending on the customer metric, definitions can reflect a narrow concept or a more complex concept. For single-item metrics, definitions are fairly narrow. For example, a customer metric based on the satisfaction rating of a single overall product quality question would have the following definition: “Satisfaction with product quality”. For customer metrics that are made up of several items, a well-articulated definition is especially important. These customer metrics measure something more nuanced than single-item customer metrics. Try to capture the essence of the commonality shared across the different items. For example, if the ratings of five items about the call center experience (e.g., technical knowledge of rep, professionalism of rep, resolution) are combined into an overall metric, then the definition of the overall metric would be: “Overall satisfaction with call center experience.”

Unit – 5 Evaluation and Continuous Improvement Methods

Syllabus

Evaluation strategy – the economics of six sigma quality, Return on six Sigma (ROSS), ROI, poor project estimates – continuous improvement – lean manufacturing – value, customer focus, Perfection, focus on waste, overproduction – waiting, inventory in process (IIP), processing waste, transportation, motion, making defective products, underutilizing people – Kaizen – 5S.

Evaluation Strategy

At the completion of the project, an evaluation details what worked well and where there any problems occurred will be taken care of. The workers involved are a key source for evaluation criteria and parameters. The organization with six sigma implemented will have at least one qualified black belt and several other candidates. The evaluation is the basis for a continued application to other areas of organizational operations. In a small business, a second round can probably encompass all the remaining production activities. The third round can extend Six Sigma principles to services such as design and human resources.

Projects are the core of every Six Sigma initiative. Identifying the right projects, having skilled people on board, and providing a proper environment for project execution determines whether the intended process and business results can be achieved and whether Six Sigma will be perceived as a powerful approach to contribute to business success.

Is your strategy right for you ? There are six criteria on which to base an answer. These are :

1. Internal consistency.
2. Consistency with the environment.
3. Appropriateness in the light of available resources.
4. Satisfactory degree of risk.
5. Appropriate time horizon.
6. Workability.

If all of these criteria are met, you have a strategy that is right for you. This is as much as can be asked. There is no such thing as a good strategy in any absolute, objective sense. while a set of goals and major policies that meets the criteria listed above does not guarantee success, it can be of considerable value in giving management both the time and the room to maneuver.

The Economics of Six Sigma Quality

Six Sigma is a quality management methodology used to help businesses improve current processes, products or services by discovering and eliminating defects. The goal is to streamline quality control in manufacturing or business processes so there is little to no variance throughout.

Six Sigma is specifically designed to help large organizations with quality management. In 1998, Jack Welch, CEO of GE, helped thrust Six Sigma into the limelight by donating upwards of $1 million as a thank you to the company, recognizing how Six Sigma positively impacted GE's operations and promoting the process for large organizations. After that, Fortune 500 companies followed suit and Six Sigma has been popular with large organizations ever since.

The goal in any Six Sigma project is to identify and eliminate any defects that are causing variations in quality by defining a sequence of steps around a certain target. The most common examples you'll find use the targets "smaller is better, larger is better or nominal is best."

- **Smaller is Better** creates an "upper specification limit," such as having a target of zero for defects or rejected parts.
- **Larger is Better** involves a "lower specification limit," such as test scores — where the target is 100 percent.
- **Nominal is Best** looks at the middle ground — a customer service rep needs to spend enough time on the phone to troubleshoot a problem, but not so long that they lose productivity.

The process aims to bring data and statistics into the mesh to help objectively identify errors and defects that will impact quality. It's designed to fit a variety of business goals, allowing organizations to define objectives around specific industry needs.

A Six Sigma system quickly demonstrates the amount of variation customers and employees experience in a process. Keys to Successful Implementation "Implementing a Six Sigma quality improvement program is not a magic pill to instantly improve a business's performance, but instead is a structured way to improve the product or service delivered to customers while improving business efficiency,"

The United States Army provided a great example, announcing savings of nearly $2 billion after implementing Six Sigma principles across several units. The Army lowered costs by optimizing scheduling, communicating at all levels of service and focusing on task management. The U.S. Army continues to apply Six Sigma principles to improve performance and increase cost savings.

Nowadays, Six Sigma is getting more and more popular among organizations from various industries. It focuses mostly on improving production processes what leads to the increase of profitability of the company. Achieving Six Sigma level requires from organizations understanding the reasons of processes variability, performing their analysis of cause and effect and the assessment of their costs. The application of DMAIC, which is one of the methods of quality improvement used in Six Sigma concept, can increase the effectiveness while adequate reacting for the appearing problems.

Return on Six Sigma (ROSS) or Return On Investment (ROI)

Six Sigma can help make drastic changes to your organization, to improve the quality of processes and products. It is also an excellent measurement tool for return on investment. Return on Investment (ROI) or Return on Six Sigma (ROSS) is your profit on an investment expressed as a percentage.

Six Sigma focuses on bridging the gaps in an organization. Gaps in efficiency, productivity, and profit; where waste and variation can accumulate. Investment, when dealing with Six Sigma, requires a significant contribution of resources. Organization should make any investment decisions based on the likelihood of making a return.

Six Sigma is a proven cost-saving methodology that can enhance your shareholder value. Not only that, but it can also create positive effects for other areas of your company. Of all the organizations that implemented Six Sigma strategies in 2001, around 50 % believed their businesses experience resulting improvements. Furthermore, around an additional 60 % of Six Sigma companies stated that their customer satisfaction rates had seen vast improvements. As the years have gone on, these figures have increased significantly.

In 2006, research generated some even more promising results. Their study focused on whether Six Sigma improvement programs had met with success or not. The research demonstrated that over 70 % of respondents believed their Six Sigma programs to have achieved either complete or partial success.

Return On Investment (ROI) or Return On Six Sigma (ROSS) compares costs associated with investment over time, judging them against returns over time. The effectiveness of Six Sigma strategy means places particular importance on returns over costs. Company can separate their returns into hard savings and soft. Hard savings are easy to trace a line back to concrete profit, such as through waste or headcount reduction. On the other hand, soft savings are often considered less bankable, such as reductions in cycle times.

Soft savings are more subjective when compared to hard savings as their calculations tend to be similar for multiple projects. There are various simple and common errors that come with calculating soft savings, including quantifying gross sales improvements as opposed to net sales. But remember, even with room to interpret mistakes in soft savings, make sure to create a standardized strategy for assigning value.

Using Six Sigma to measure Return on Investment brings many benefits. It gives you the power to enhance shareholder value, improve rates of customer and employee satisfaction, minimize risk, and reduce timescales.

There are two basic types of financial measures we can use :

- Forward looking measures : These help us figure out whether a project will be worthwhile.
- Backward looking measures : These help us to measure the financial effect of ourrecent projects.

Returns :

This category of metrics look at the income received vs the effort made and the assets owned. They're backward looking measures. In other words, they're generally calculated after a project ends.

ROI or ROSS :

Return on Investment (ROI) = Gain realized / Effort spent.

This metric measure how efficient and profitable an endeavor (project, program, etc)is. You could be building a valuable product, but spending too much money to get it.

$$ROI = ((\text{end value} - \text{cost}) / \text{cost})$$

Where :

- ROI = Return On Investment.

- End value = Final value of the project.
- Cost = The amount of money spent on the project.

For example, a software company is creating a piece of software. It pays four developers and testers for a year to complete the product, at a cost of $250,000. It pays a marketer $50,000 for six months to create the marketing campaign. 300 customers subscribe to pay $200 a month for access to the software in the first year after the product is released.

$$ROI = (\text{end value} - \text{cost}) / \text{cost}$$

$$ROI = ((300 \times 200 \times 12) - 300000) / 300000$$

$$ROI = (720000 - 300000) / 300000$$

$$ROI = 420000 / 300000$$

$$ROI = 1.4 = 140\ \%$$

Quantifying the positive effects of the Design for Six Sigma strategy for introducing new products and services doesn't have to be difficult. Identifying the success of any new introductions is always tricky, but Six Sigma can help streamline the process and make it easier. Design for Six Sigma concerns the difficulties associated with commercialisation and reducing technological risk.

Poor Project Estimates

Very few organizations develop cost estimates which communicate at least three datapoints :

1. The value at which there is a 50 % chance of the project coming in above this costand a 50 % chance of it coming in below this cost (known as the P50 estimate).
2. The value at which there is only a 10 % chance of the project coming in at a lowercost (known as the P10 estimate), i.e. the lower bound.
3. The value at which there is a 90 % chance of the project coming in at a lower cost (known as the P90 estimate), i.e. the upper bound.

If a project is at an early stage, with little knowledge of the details, it's impossible to develop an accurate cost estimate as there's simply not enough detail known about the project. As a result, you'd expect the lower and upper bound to be far apart.

As the project concept is developed towards implementation, more detail is known and the cost estimate can be improved upon. Therefore, the range of cost outcomes will become narrower as the upper and lower bounds will move closer to the midpoint.

Causes for poor project estimates :

- Lack of experience
- Business pressure
- Poor communication
- Organizational dysfunction

Take steps to stop an unrealistic schedule from being chiseled in stone. Here are some ideas :

- **Do the research**. Prepare a list of the high-level tasks you believe will need to be accomplished on the project. Identify rough estimates of effort, schedule, and staffing requirements.

- **Collaborate with other developers** to get a better handle on the scope of the new project. If there are developers that have worked on similar projects, get their input on the actual effort and calendar time required for their projects. Carefully identify similarities and differences with these benchmarked projects.
- **Discuss the detailed information with your project manager** before he or she sets early expectations with senior executives. The more concrete information you can provide, the easier it will be for your manager to sell senior management on a realistic timeframe.
- **Act early.** Whatever the reason, the sooner you act, the better your chances of getting a schedule you can live with.

Continuous Improvement

Perhaps the most widely recognized version of Lean in business, Six Sigma is a continuous improvement model that focuses on eliminating variability and improving predictability in organizations. The goals of Six Sigma are to achieve stable and predictable process results, through clearly defined, measurable processes, and a commitment to sustained quality improvement.

Six Sigma is a disciplined, data-driven approach to continuous improvement. It uses a set of quality management methods rooted in statistical analysis, and relies on an infrastructure of people within the company who are trained experts in these methods to see them through.

Six Sigma experts have to work their way through a series of certifications, which are identified by different colored belts, as in karate or judo. Each role comes with specific responsibilities, so success with Six Sigma relies on having each role filled by a qualified expert.

With its statistical tools, certification programs, defined roles and responsibilities, Six Sigma is a highly structured continuous improvement model, ideal for organizations already organized in a structured, corporate way.

Among certain methods used, Lean manufacturing,5S and Kaizen are considered to be very popular and used by most of the successful organizations.

Lean Manufacturing

Lean manufacturing is a methodology that focuses on minimizing waste within manufacturing systems while simultaneously maximizing productivity. Waste is seen as anything that customers do not believe adds value and is not willing to pay for. Some of the benefits of lean manufacturing can include reduced lead times, reduced operating costs and improved product quality.

Lean manufacturing, also known as lean production, or lean, is a practice that organizations from numerous fields can enable. Some well-known companies that use lean include Toyota, Intel, John Deere and Nike. The approach is based on the Toyota Production System and is still used by that company, as well as myriad others.

Lean manufacturing is based on a number of specific principles, such as Kaizen, or continuous improvement.

Lean manufacturing was introduced to the Western world through the 1990 publication of

"*The Machine That Changed the World* ", based on an MIT study into the future of the automobile detailed by Toyota's lean production system. Since that time,
lean principles have profoundly influenced manufacturing concepts throughout the world, as well as industries outside of manufacturing, including healthcare, software development and service industries.

Five principles of lean manufacturing :

- Identify value from the customer's perspective.
- Map the value stream
- Create flow.
- Establish a pull system
- Pursue perfection with continual process improvement, or Kaizen

Value

The core objective of Lean is creating more value for customers while optimizing resources. It sounds simple, but it is truly effective.

The Lean thinking begins with one simple thing: identifying value. This will help you understand what your customers are ready to pay for.

In terms of Lean, the value should always be considered from a customer perspective. At the end of the day, it doesn't matter whether you came up with a great idea if the customer doesn't see any value and therefore they are not ready to pay for it.

It is important to remember that customers enjoy value in its entirety but not delivered piece by piece. It is tricky, but if you don't pay attention to this, you may end up with a bunch of unhappy customers and low brand equity.

Customer Focus

A Customer Focus is an emphasis on understanding the needs of a customer; in short, a Customer Focused organization understands what customers really care about. A proper Customer Focus results in increased satisfaction by identifying/anticipating their needs, adding value, and eliminating defects and waste.

At the center of a Lean manufacturing and key to success is customer focus. The more our daily actions and long term plans are driven by meeting customer expectations, and the more we evaluate our work based upon these expectations, the more we improve customer loyalty and advocacy. This relentless focus on the customer is the path to sustained growth and profitability.

In a customer focused organization, Leadership, Processes and People are customer- aligned. This requires that :

- Every action is shaped by a relentless commitment to meeting and exceeding customer expectations regarding product and service quality.
- Customer touch points and supporting internal processes are constantly evaluated and improved to meet or exceed those expectations.

- Every employee understands what he/she must do in order to maintain and add value to every relationship with both the paying customer and those within the organization that rely on them for the work they do.

Customer focus and service excellence is everyone's responsibility, not just those that have direct contact with them. Organizations that are recognized as exceptional providers of customer service are the ones that have incorporated these customer-focused behaviors into their daily operations.

Perfection

Each of the five principles of Lean manufacturing build on each other and then begin again to create a continuous cycle of improvement. Those 5 key Lean principles are :

- Value
- Value stream
- Flow
- Pull
- Perfection

The Lean manufacturing team identifies areas of improvement and implements meaningful change, seeking the most efficient processes to bring the greatest value to the customer. As the Lean team seeks perfection, they constantly analyze each process for the increase in value (reduced cost, time, resources used, space, etc.). They focus on the elements that add value and eliminate those that do not. They tighten the flow and deliver the value as the customer needs.

Ultimately, the goal is not perfection (which is unattainable), but rather, the pursuit of it, a concept otherwise known as continuous improvement.

The most important thing is making Lean manufacturing and process improvement part of the corporate culture. As gains continue to pile up, it is important to remember lean is not a static system and requires constant effort and vigilance to perfect. Every employee should be involved in implementing lean. Lean experts often say that a process is not truly lean until it has been through value-stream mapping at least half a dozen times.

Focus on Waste

Lean manufacturing, a management philosophy primarily derived from the Toyota Production System, focuses on eliminating waste—called "Muda"— within a manufacturing system. It takes into account many kinds of waste, including the waste of excessive human motion, and aims to integrate each step of production into a holistic, efficient process that reduces cost and improves overall revenue. Under the lean manufacturing system, seven wastes are identified: overproduction, inventory, motion, defects, over-processing, waiting, and transport.

So, what is waste ? It can take many forms, but the basic idea is to eliminate anything and everything that does not add value from the perspective of your customer.

Another way to look at lean manufacturing is as a collection of tips, tools, and techniques that have been proven effective for driving waste out of the manufacturing process.

Overproduction

Overproduction occurs when manufacturing a product or an element of the product before it is being asked for or required. It may be tempting to produce as many products as possible when there is idle worker or equipment time. However, rather than producing products just when they are needed under the 'Just In Time' philosophy, the 'Just In Case' way of working leads a host of problems including preventing smooth flow of work, higher storage costs, hiding defects inside the WIP, requiring more capital expenditure to fund the production process, and excessive lead-time.

Additionally, over-producing a product also leads to an increase in likelihood that the product or quantities of products produced are beyond the customer's requirements.

In an office environment, overproduction could include making extra copies, creating reports no one reads, providing more information than needed, and providing a service before the customer is ready. Manufacturing overproduction involves producing more products than demanded through a 'push production system' or producing products in higher batch sizes than needed.

There are three countermeasures for overproduction.

- Firstly, using a **'Takt Time'** ensures that the rates of manufacturing between stations are even. Whereas, Takt time is the average time between the start of production of one unit and the start of production of the next unit, when these production starts are set to match the rate of customer demand.
- Secondly, **reducing setup times** enables manufacturing small batches or single-piece flow.
- Thirdly, **using a pull** or 'Kanban' system can control the amount of WIP (Work In Process).

Waiting

The waste of waiting includes :

1. People waiting on material or equipment
2. Idle equipment. Waiting time is often caused by unevenness in the production stations and can result in excess inventory and overproduction.

In the office, waiting waste can include waiting for others to respond to an email, having files waiting for review, ineffective meetings, and waiting for the computer to load a program. In the manufacturing facility, waiting waste can include waiting for materials to arrive, waiting for the proper instructions to start manufacturing, and having equipment with insufficient capacity.

Some countermeasures for waiting include: designing processes to ensure continuous flow or single piece flow, leveling out the workload by using standardized work instructions, and developing flexible multi-skilled workers who can quickly adjust in the work demands.

Inventory in Process (IIP) or WIP (Work In Progress)

Often times it is difficult to think about excess inventory as waste. In accounting, inventory is seen as an asset and often time's suppliers give discount for bulk purchases. But having more inventory than necessary to sustain a steady flow of work can lead to problems including:

- Product defects or damage materials,
- Greater lead time in the production process,
- An inefficient allocation of capital, and
- Problems being hidden away in the inventory.

Excess inventory can be caused by over-purchasing, overproducing Work In Process (WIP), or producing more products than the customer needs. Excess inventory prevents detecting production-related problems since defects have time to accumulate before it is discovered. As a result, more work will be needed to correct the defects.

In-office inventory waste could be files waiting to be worked on, customers waiting for service, unused records in a database, or obsolete files. Manufacturing inventory waste could include broken machines sitting around, more finished products than demanded, and extra materials taking up work space, and finished products that cannot be sold.

Some countermeasures for inventory include: purchasing raw materials only when needed and in the quantity needed, reducing buffers between production steps, and creating a queue system to prevent overproduction.

Processing Waste

Over-processing refers to doing more work, adding more components, or having more steps in a product or service than what is required by the customer. In manufacturing this could include using a higher precision equipment than necessary, using components with capacities beyond what is required, running more analysis than needed, over-engineering a solution, adjusting a component after it has already been installed, and having more functionalities in a product than needed. In the office, over-processing can include generating more detailed reports than needed, having unnecessary steps in the purchasing process, requiring unnecessary signatures on a document, double entry of data, requiring more forms than needed, and having an extra step in a workflow.

One simple way to counter over-processing is to understand the work requirements from the standpoint of the customer. Always have a customer in mind before starting work, produce to the level of quality and expectation that the customer desires, and make only the quantities needed.

Transportation

Waste in transportation includes movement of people, tools, inventory, equipment, or products further than necessary. Excessive movement of materials can lead to product damage and defects. Additionally, excessive movement of people and equipment can lead to unnecessary work, greater wear and tear, and exhaustion.

In the office, workers who collaborate with each other often should be close together. In the factory, materials necessary for production should be easily accessible at the production location and double or triple handling of materials should be avoided.

Some of the countermeasures to transportation waste include developing a U-shape production line, creating flow between processes, and not over-producing Work In Process (WIP) items.

Motion

The waste in motion includes any unnecessary movement of people, equipment, or machinery. This includes walking, lifting, reaching, bending, stretching, and moving. Tasks that require excessive motion should be redesigned to enhance the work of personnel and increase the health and safety levels.

In the office, wasted motion can include walking; reaching to get materials, searching for files, sifting through inventory to find what is needed, excess mouse clicks, and double entry of data. Manufacturing motion waste can include repetitive movements that do not add value to the customer, reaching for materials, walking to get a tool or materials, and readjusting a component after it has been installed.

Some countermeasures for motion include making sure the workspace is well organized, placing equipment near the production location, and putting materials at an ergonomic position to reduce stretching and straining.

Making Defective Products

Defects occur when the product is not fit for use. This typically results in either reworking or scrapping the product. Both results are wasteful as they add additional costs to the operations without delivering any value to the customer.

Here are four countermeasures for defects.

- Firstly, look for the most frequent defect and focus on it.
- Secondly, design a process to detect abnormalities and do not pass any defective items along the production process.
- Thirdly, redesign the process so that does not lead to defects.
- Lastly, uses standardize work to ensure a consistent manufacturing process that is defect free.

Underutilizing People (8th waste)

Even though it was not part of the Toyota Production System (TPS), many people are well aware of the waste of human potential. This is also described as the waste of unused human talent and ingenuity. This waste occurs when organizations separate the role of management from employees. In some organizations, management's responsibility is planning, organizing, controlling, and innovate the production process. The employee's role is to simply follow orders and execute the work as planned. By not engaging the frontline worker's knowledge and expertise, it is difficult to improve processes. This is due to the fact that the people doing the work are the ones who are most capable of identifying problems and developing solutions for them.

In the office, non-utilized talent could include insufficient training, poor incentives, not asking for employee feedback, and placing employees in positions below their skills and qualifications. In manufacturing, this waste can be seen when employees are poorly trained, employees not knowing how to effectively operate equipment, when employees are given the wrong tool for the job, and when employees are not challenged to come up with ideas to improve the work.

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.

The Dual Nature of Kaizen

Kaizen is part action plan and part philosophy.

- 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
- 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. Note the emphasis on *current*; Standardized Work is living documentation (it continually evolves through Kaizen).

The Events that Takes Place in Kaizen

1. Set goals and provide any necessary background.
2. Review the current state and develop a plan for improvements.
3. Implement improvements.
4. Review and fix what doesn’t work.
5. Report results and determine any follow-up items.

When Kaizen is applied as an action plan through a consistent and sustained program of successful Kaizen events, it teaches employees to think differently about their work. In other words, consistent application of Kaizen as an action plan creates tremendous long- term value by developing the culture that is needed for truly effective continuous improvement.

5-S

There are five pillars in 5S in a continuous improvement program, which stand for :

1. Sort (Seiri)
2. Set in Order (Seiton),
3. Shine (Seiso),
4. Standardize (Seiketsu), and
5. Sustain (Shitsuke)

Fig.5-S Diagram

The Japanese translation is given in the bracket. The goal of a 5S program is to get products closer to operations and workers, organized and labeled, to eliminate wasted time and materials.

The 5S philosophy is "a place for everything and everything in its place," and helps to eliminate wasted time, wasted space, and wasted inventory. Implementing 5S raises product quality and improves work productivity, resulting in lower costs and higher efficiencies.

1. **Sort (Seiri) :** Start by removing all items from your work area. Inspect the equipment and identify those items that are critical to the success of the function performed at the workstation. Eliminate any duplicates, unnecessary equipment, infrequently used items, and trash. Identify the non-essential items as either waste or "valuable but not critical." Store the non-critical items outside of the workstation area. This saves time, space, and labor costs, while enhancing productivity.

2. **Set in Order (Seiton) :** Whatever equipment is deemed critical to the operation must now be organized. Assign positions for all equipment, work in progress, and raw materials, keeping ease of reach, identification, and proximity to work surface in mind as you do. The goal is to maximize the efficiency of the workstation layout. On a smaller scale, it's the same concept as warehouse layout. The most frequently used tools should be the most convenient to grab. This eliminates wasted time from excess motion and searching.
3. **Shine (Seiso) :** Keep everything clean, every day. Doing this keeps things ready to be used when needed. A clean workspace is a productive workspace, and Seiso literally means "to clean or shine." Clean the floors, the walls and the equipment, and ensure all items are restored to their designated place. Make sure the workstation is well lit. This should be a part of your daily tasks and should not be postponed until idle time is

available.

4. **Standardize (Seiketsu) :** Ensure conditions of work area do not return to the original, disorganized state. Make the previous three S's part of your standard procedures each day. Implement them with the help of signs, banners, shadow boards, tool holders, etc. Make sure all workers understand their responsibilities and are empowered to perform all of the tasks.
5. **Sustain (Shitsuke) :** Make a habit of properly maintaining correct procedures to avoid backsliding. Implementing these steps is a continuous process. It is important to ensure that they are done each day to prevent slipping into old habits. Commit to performing these steps every shift and make sure that any changes to your product or process are compensated for at your workstation and problems are alleviated as quickly as they are created.

The end result of a 5S implementation is a significant reduction in space needed for existing operations. Workers improve their workspaces by cleaning and organizing them. Tools and materials are labeled and stored in organized storage locations. Shelving and racks optimize the storage of items in a smaller footprint, helping to improve the order picking process by eliminating the need to search for items.