MEENAKSHI ENGINEERING COLLEGE
DEPARTMENT OF MANAGEMENT STUDIES
BA 7054 – LEAN SIX SIGMA
QUESTION BANK

UNIT 1-PART A

1. Define six sigma.

Six sigma is a disciplined, data-driven approach and methodology for eliminating defects (driving toward six standard deviations between the mean and the nearest specification limit) in any process – from manufacturing to transactional and from product to service. Six Sigma is named after a statistical concept where a process only produces 3.4 defects per million opportunities (DPMO).

2. What is DPMO?

Defects per million opportunities. Six Sigma is named after a statistical concept where a process only produces 3.4 defects per million opportunities (DPMO).

3. What is lean?

Lean is simply a method of streamlining a process, resulting in increased revenue, reduced costs and improved customer satisfaction. Lean is achieved by removing "waste", which is activity not required to complete a process.

4. What is lean manufacturing?

The term "lean" is used because Lean Manufacturing uses less:

• Human effort in the factory
• Manufacturing space
• Capital investment
• Materials

- Time between the customer order and the product shipment.

5. What are the basic goals of lean manufacturing?

- Fewer resources for the same output
- Minimising inventory at all stages of production
- Shortening product cycle times from raw materials to finished goods to eliminate waste

6. What are the benefits of using lean six sigma?

Organizations face rising costs and increasing competition every day. Lean six sigma allows you to combat these problems and grow their businesses the following ways:

- Increases revenue
- Decreases costs
- Improves efficiency
- Develops effective people/employees

7. what are the two methodologies in six sigma?

DMAIC

DMADV

8. What is DMAIC?

   Define, **M**easure, **A**nalyse, **I**mprove and **C**ontrol. This six sigma methodology is an improvement system used to develop existing process.

9. What is DMADV?

   Define, **M**easure, **A**nalyse, **D**esign and **V**erify. This six sigma methodology is an improvement system used to develop new process.

10. Define quality

    In manufacturing, a **measure of excellence** or a state of being free from defects, deficiencies and significant variations.

11. How ISO defines quality?

    ISO, an international body for formulating standards, has defined quality as: ***"Degree to which a set of inherent characteristics fulfils requirements".***

12. What is process tolerance?

    - A process tolerance is a tolerance that specifies requirements for a process producing large quantities of parts.
    - A process tolerance specifies a
      - *minimum average*
      - *maximum average and*
      - *maximum standard deviation*

13. What are the two approaches in process tolerance?

    a. statistical tolerances and

    b. worst-case tolerances

14. What do you meant by statistical tolerances?

    This approach assumes that there's a scenario for a process to specify requirements for variations while supposing that there's ***some centered process serving as the baseline*** for measuring tolerance of the first process

15. What do you meant by worst-case tolerances?

    This approach entails ***using minimum and maximum average values*** of variations for a process to determine the worst-case scenario and define the tolerance measure. It actually means that such a scenario brings zero standard deviations, allowing the process to be performed at the extreme level.

16. Define process capability index.

    The Cp index compares the tolerance to the specification spread. If the tolerance range is greater the specification spread, then your process needs improvement.

17. What do you meant by tolerance limits?

The bounds of the tolerance range are called tolerance limits.

18. What are the methods to determine process capability?

1. Histograms and probability plots,
2. Control charts, and
3. Design of experiments.

19. What is the relationship between Cp and Cpk?

The index Cp determines only the spread of the process. It does not take into account the shift in the process. Cpk determines both the spread and the shift in the process and the relationship between Cp and Cpk is given by

$$C_{pk} = (1-k)C_p$$

Note that Cpk never exceeds Cp. When Cpk=Cp, the process is centered midway between the specification limits.

20. How are six sigma & tqm related?

Tqm: It is based on a strategic approach that focuses on maintaining existing quality standards as well as making incremental quality improvements.

six sigma: Six Sigma is more than just a process improvement program as it is based on concepts that focus on continuous quality improvements for achieving near perfection by restricting the number of possible defects to less than 3.4 defects per million.

21. How are six sigma & lean manufacturing related?

Six Sigma works on the principle that reducing variation gets to the ***root of any problem***. And many people also see it as a technically superior way of working. On the other hand, Lean Manufacturing uses ***basic improvements*** to make business processes more effective.

22. How are six sigma & process tolerance related?

How are six sigma & process capability related?

23. What is cost of poor quality?

COPQ consists of those costs which are generated as a result of producing defective material. 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) or poor quality costs (PQC), are costs that would disappear if systems, processes, and products were perfect.

24. what is meant by short-term and long-term variation?

variability due to common causes is described as "short-term" variability, while the variability due to special causes is considered "long-term" variability.

25. Illustrate with examples cost of doing nothing.

The "doing nothing" option might be the right choice for an organization; however, an organization needs to make this decision after comparing the cost of doing nothing to the cost of doing something. Organizations don't require to spend more money, if they are not initiating for six sigma.

PART B

1. Give a detailed report on how six sigma is related to TQM.

TQM AND SIX SIGMA

Six Sigma is a relatively new concept as compared to Total Quality Management (TQM).However, when it was conceptualized, it was not intended to be a replacement for TQM. Both Six Sigma and TQM have many similarities and are compatible in varied business environments, including manufacturing and service industries. While TQM has helped many companies in improving the quality of manufactured goods or services rendered, Six Sigma has the potential of delivering even sharper results.

Total Quality Management

Total Quality Management is often associated with the development, deployment, and maintenance of organizational systems that are required for various business processes. It is based on a strategic approach that focuses on maintaining existing quality standards as well as making incremental quality improvements. It can also be described as a cultural initiative as the focus is on establishing a culture of collaboration among various functional departments within an organization for improving overall quality.

Comparison To Six Sigma

In comparison, Six Sigma is more than just a process improvement program as it is based on concepts that focus on continuous quality improvements for achieving near perfection by restricting the number of possible defects to less than 3.4 defects per million. It is complementary to Statistical Process Control (SPC), which uses statistical methods for monitoring and controlling business processes. Although both SPC and TQM help in improving quality, they often reach a stage after which no further quality improvements can be made. Six Sigma, on the other hand, is different as it focuses on taking quality improvement processes to the next level.

The basic difference between Six Sigma and TQM is the approach. While TQM views quality as conformance to internal requirements, Six Sigma focuses on improving quality by reducing the number of defects. The end result may be the same in both the concepts (i.e.

producing better quality products). Six Sigma helps organizations in reducing operational costs by focusing on defect reduction, cycle time reduction, and cost savings. It is different from conventional cost cutting measures that may reduce value and quality. It focuses on identifying and eliminating costs that provide no value to customers such as costs incurred due to waste

TQM initiatives focus on improving individual operations within unrelated business processes whereas Six Sigma program focus on improving all the operations within a single business process. Six Sigma projects require the skills of professionals that are certified as ‗black belts‘whereas TQM initiatives are usually a part-time activity that can be managed by non-dedicated managers.

Applications Where Six Sigma Is Better

Six Sigma initiatives are based on a preplanned project charter that outlines the scale of a project, financial targets, anticipated benefits and milestones. In comparison, organizations that have implemented TQM, work without fully knowing what the financial gains might be. Six Sigma is based on DMAIC (Define-Measure-Analyze-Improve-Control) that helps in making precise measurements, identifying exact problems, and providing solutions that can be measured.

Six sigma is also different from TQM in that it is fact based and data driven, result oriented, providing quantifiable and measurable bottom-line results, linked to strategy and related to customer requirements. It is applicable to all common business processes such as administration, sales, marketing and R & D. Although many tools and techniques used in Six Sigma may appear similar to TQM, they are often distinct as in Six Sigma, the focus is on the strategic and systematic application of the tools on targeted projects at the appropriate time. It is predicted that Six Sigma will outlast TQM as it has the potential of achieving more than TQM.

The Differences Between TQM & Six Sigma

Both TQM, total quality management, and Six Sigma are time tested tools to enhance quality of products as well as services. While there are numerous similarities, the subtleties within these systems are different. Traditionally, these systems have been utilized by large corporations. However, small businesses can successfully apply most of the key lessons.

Six Sigma and TQM Basics

Six Sigma and TQM are both quality-improvement systems and attempt to reduce defective products or poor service in an organization, while improving customer satisfaction. Both approaches first and foremost attempt to identify the fundamental sources of defects and provide lasting cures that will permanently enhance quality. If delivery trucks often arrive late at customers' stores, for example, both systems look far beyond the trucks, warehouses and loading docks. Six Sigma and TQM analyze large portions of the business, identifying problems that might not appear connected at first sight and review the culture that might be leading to quality issues. The scope as well applications of these systems, however, differ upon closer inspection.

1. Focus and Scope

One difference between the two systems lies in their areas of focus. While TQM concentrates on individual departments and more specific quantitative goals, TQM's ultimate focus is customer satisfaction. The path that takes the business toward that final goal is secondary. TQM must be redefined when the predetermined goals are accomplished. Six Sigma, however, aims at continuous improvements and is self-propelled. Six sigma, when correctly applied, will continue to yield benefits after the original goals have been realized as it instills a culture that forever aims to improve performance.

2. Application

Six Sigma projects are managed by "black belts" who have gone through formal training and have a proven track record in quality gains. These individuals work full time on Six Sigma in their departments but return to their previous jobs after a few years. TQM is run by the quality control department and professionals who specialize on quality improvements, usually, for their entire career. Six Sigma aims to spread the ownership of quality improvement to the entire organization while those who run TQM are more experienced in the quality field. Six Sigma is often driven by a focus on cutting costs and tends to work best if it has specific financial goals. TQM, however, pursues objectives that are harder to boil down to a single figure, such as customer satisfaction and long-term strategic excellence.

Lesson for the Small Business

Small businesses can use principles from these two systems, understanding that cost-cutting and increased customer satisfaction can go hand in hand. If cost-cutting also effectively targets the root causes of customer complaints and defects, the job will be done right the first time with as little waste as possible. Furthermore, every employee, even the delivery person working for you during her summer break, must focus on the end result: the quality of the final product and customer experience above all else. Doing exactly what you're told is good. Questioning whether the job can be done better and communicating ideas to co-workers is better.

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2. Give a detailed report on how six sigma is related to lean manufacturing.

LEAN MANUFACTURING AND SIX SIGMA

What are Lean and Six Sigma?

Many people are familiar with the terms ‘Lean Manufacturing’ and ‘Six Sigma’, but are unsure as to which approach is right for their business. Six Sigma works on the principle that reducing variation gets to the root of any problem. And many people also see it as a technically superior way of working. On the other hand, Lean Manufacturing uses basic improvements to make business processes more effective.

What is Lean Manufacturing?

The essence of lean thinking is grounded in the Toyota Production System (TPS), which considers people and processes to be the two main pillars of any business. Engineer Taiichi Ohno is credited with developing the principles of 'Lean' production after World War II. His philosophy, which focused on eliminating waste and empowering workers, reduced inventory and improved productivity.

The term 'lean' is used because Lean Manufacturing uses less:

• Human effort in the factory
• Manufacturing space
• Capital investment
• Materials
• Time between the customer order and the product shipment.

The basic goal is to get more done with less, by:

• Fewer resources for the same output
• Minimising inventory at all stages of production
• Shortening product cycle times from raw materials to finished goods to eliminate waste

Lean is a strategy for remaining competitive by identifying and eliminating wasteful steps in products and processes, using the following practices:

• Eliminating waste and loss
• Minimising inventories
• Maximising flow
• Pulling production from customer demand
• Meeting customer needs
• Doing it right the first time
• Empowering workers
• Designing for rapid changeover
• Creating a culture of continuous improvement
• Partnering with suppliers

What is Six Sigma?

Six Sigma was originally developed as a set of practices designed to improve manufacturing processes and eliminate defects. But its application was subsequently extended to other types of business processes as well. The particulars of the methodology were first formulated by Bill Smith at Motorola in 1986. Six Sigma was heavily inspired by six decades of quality improvement methodologies, such as quality control, TQM, and Zero Defects, based on the work of pioneers such as Shewhart, Deming, Juran, Ishikawa, Taguchi and others. In the Six Sigma approach, the view on waste is that “variation is waste". In practising Six Sigma, the DMAIC method is used to:

1. Define - goals and the scope of the improvement project
2. Measure - the performance of the current procedures or processes
3. Analyze - current performance in terms of the future requirements
4. Improve - current methods to the required level
5. Control - institutionalise the improvements

Six Sigma is a ‘problem-focused’ methodology, and the primary toolset of Six Sigma is maths and statistics.

Which is better - Lean or Six Sigma?

Lean thinkers believe that using resources for any goal other than value for the customer, is wasteful, and should be eliminated. ‘Value’ is defined as any action or process that a customer would be willing to pay for.

Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects and variation in manufacturing and business processes. It uses a set of quality management methods, including statistical methods, and creates a special infrastructure for people within the organisation ("Black Belts" etc.), who are experts in these methods. Six Sigma can be used to solve specific problems, where the root causes are complex and correlated.

Similarities between Lean and Six Sigma

In summary, there are several similarities between these two improvement practices:

- Both approaches require the use of teams, be they Kaizen teams or Six Sigma project teams.
- Both approaches function best if they are managed by experienced (certified) people, such as black belts, green belts, or lean consultants.
- Both approaches require behaviour change and systems change, if you want to see true improvement.
- And both approaches can save you significant time and money if they are effectively implemented.

Six Sigma and Lean go together hand in hand, even though they are different. Despite any distinctions, the two go very well together. For example, it could be logical to focus on Lean to achieve process improvement, and at the same time develop a deeper understanding of the process. If more work is needed, Six Sigma could be used to reduce process variation.

A Chinese proverb says "I forget what I hear, I remember what I see, I know what I do". Since the best way to learn about Lean or Six Sigma is by doing it, we apply these models routinely to different situations, but please remember: like any skill, these take both practice and discipline

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3. Give a detailed report on how six sigma is related to Process tolerance.

PROCESS TOLERANCE

A process tolerance is a tolerance that specifies requirements for a process producing large quantities of parts. A process tolerance specifies a minimum and maximum average and a maximum standard deviation. Equivalently, a process tolerance can be defined by specifying values for Cp and Cc.

The minimum and maximum average represent an operating window for the average. Suppose that a capability study has been performed to demonstrate that the process is stable. This does not prove the process is perfectly centered. But it is good evidence that the process is holding a +/- 1.5 standard deviation operating window. In this case on might specify a minimum average of the target minus 1.5 standard deviations and a maximum average of the target plus 1.5 standard deviations. For unstable processes or uncontrolled inputs, wider operating windows are required.

Process tolerances represents a unified approach to specifying tolerances as the two commonly used approaches, worst-case tolerances and statistical tolerances, represent special cases. Process tolerances allow statistical tolerances and worst-case tolerances to be combined together as well as allows behaviors to be modelled that are not adequately described by either of the previous two approaches.

• **Statistical tolerance.** This approach assumes that there's a scenario for a process to specify requirements for variations while supposing that there's some centered process serving as the baseline for measuring tolerance of the first process.

• **Worst-case tolerance.** This approach entails using minimum and maximum average values of variations for a process to determine the worst-case scenario and define the tolerance measure. It actually means that such a scenario brings zero standard deviations, allowing the process to be performed at the extreme level.

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 lenient 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.

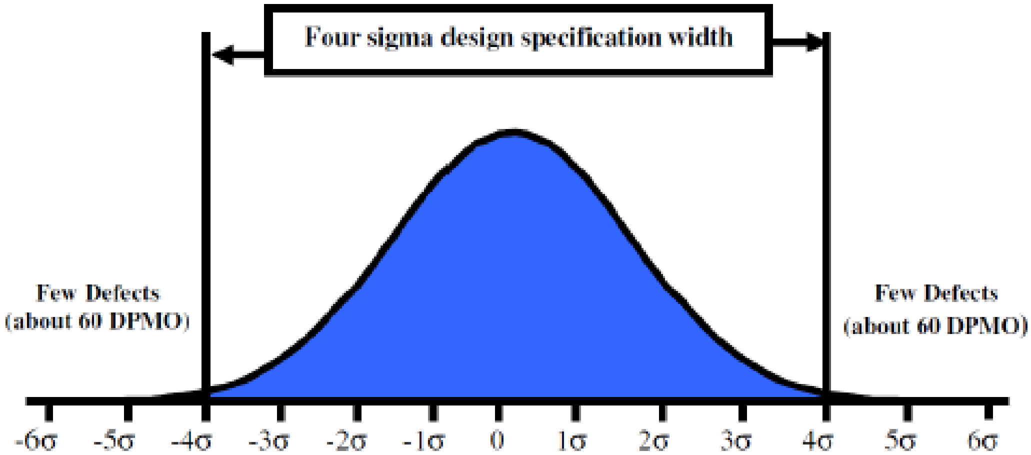
Minitab uses the tolerance to calculate capability indices such as the Cp index, which compares the tolerance to the specification spread. If the tolerance range is greater the specification spread, then your process needs improvement.

The bounds of the tolerance range are called tolerance limits.

Tolerance Vs Six Sigma

Distribution curves tell us not only how well our processes have done; they also tell us the probability of what our process will do next. Statisticians group those probabilities in segments of the distribution curve called standard deviations from the mean. The symbol they use for standard deviation is the lower-case Greek letter sigma.

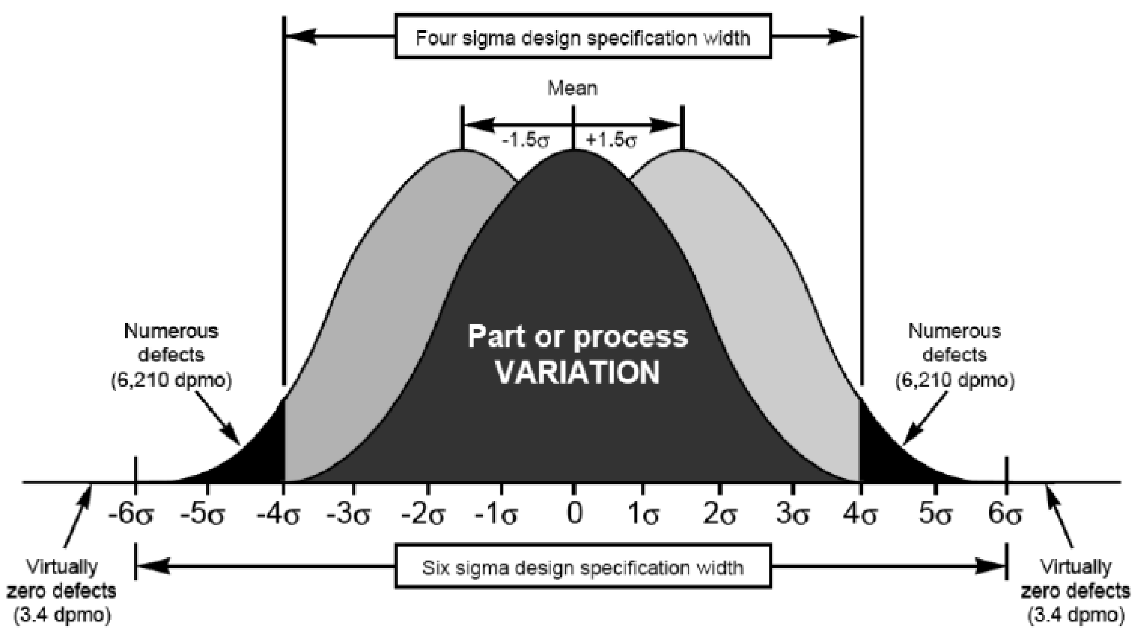
For any process with a standard distribution (something that looks like a bell-shaped curve), the probability is 68.26% that the next value will be within one standard deviation from the mean. The probability is 95.44% that the same next value will fall within two standard deviations. The probability is 99.73% that it will be within three sigma; and 99.994% that it will be within four sigma.



Standard distribution curve with mean, sigma values and four sigma tolerances.
DPMO = Defect Per Million Opportunities

If the range of acceptability, or tolerance limit, for your product is at or outside the four sigma point on the distribution curve for your process, you are virtually assured of producing acceptable material every time–provided, of course, that your process is centered and stays centered on your target value. Unfortunately, even if you can center your process once, it will tend to drift.

Experimental data show that most processes that are in control still drift about 1.5 sigma on either side of their center point over time.



For a product to be virtually defect free, it must be designed with both normal process variation and process drift in mind. With these things considered, a Six Sigma design specification width would produce a yield of 99.99966%–3.4 defects per million opportunities or virtually zero defects.

This means that the real probability of a process with tolerance limits at four sigma, producing acceptable material is actually more like 98.76%, not 99.994%. To reach near-perfect process output, the process capability curve must fit inside the tolerances such that the tolerances are at or beyond six standard deviations, or Six Sigma, on the distribution curve. That is why we call our goal Six Sigma quality.

Quality makes us strong

In the past, conventional wisdom said that high levels of quality cost more in the long run than poorer quality, raising the price you had to ask for your product and making you less competitive. Balancing quality with cost was thought to be the key to economic survival. The surprising discovery of companies which initially developed Six Sigma, or world-class, quality is that the best quality does not cost more. It actually costs less. The reason for this is something called cost of- quality. Cost-of-quality is actually the cost of deviating from quality– paying for things like rework, scrap and warranty claims. Making things right the first time– even if it takes more effort to get to that level of performance–actually costs much less than creating then finding and fixing defects.

4.Explain in detail how cultural changes affect six sigma.

SIX SIGMA THINKING FOR CULTURAL CHANGE

Is six sigma philosophy new? If we want to answer this question, we should try to remember the contribution of many great quality gurus in the quality journey. Principles and tools of six sigma are not new. Some champions of the progress in the journey of quality and six sigma are shown here.

	Six Sigma Roadmap				
Tools	Define	Measure	Analyze	Improve	Control
Charter	●				
Gantt Chart	●				
Pareto Analysis	●				
Process Mapping		●			
Value Stream Mapping		●			
FMEA		●	●		●
Cause and Effects Matrix		●	●		
MSA		●			●
Process Capability		●		●	
Exploratory Data Analysis	●		●	●	
Life Data Analysis		●		●	
Multi-Vari Analysis			●		
Hypothesis Testing			●	●	
Confidence Intervals			●	●	
Power and Sample Size			●	●	
Analysis of Variance		●	●	●	
Correlation and Regression			●		
Multiple Regression			●	●	
Design of Experiments				●	
Response Surface Methods				●	
Evolutionary Operation				●	
Statistical Process Control	●	●		●	●
PPAP					●

Shewhart did not propose theory of control charts for implementing six sigma projects! Fisher did not invent the statistical procedures to support six sigma approach. Similarly, Crosby‘s zero defect approach was meant to be implemented across the organization in everything that is being done in the company. Shingo‘s Poka Yoke (mistake proofing) was to prevent defects from being produced! He did not call it six sigma. Thus the philosophies and concepts were meant for application wherever appropriate, generally across the company. As a matter of fact, if there was a “copyright‖ on some of these concepts, six sigma would not have taken its form the way we see it. As such the phrase ”six Sigma” came in to existence much later during the 1980s when Bill Smith coined it and Bob Galvin, the CEO of Motorola embraced it. (Interestingly, it is said that it took quite a bit of effort to sell the six sigma concept to Bob!).

If the philosophy and tools are not new, why should we restrict its application to only identified projects? We should constantly look for potential applications to improve performance to our customers. Most six sigma training programs require belts to take up a project before start of the program. This is an excellent idea as it forces belts in applying the concepts and tool immediately after the training before the tools are forgotten! However, this does not mean that the concepts and tools are useful only for projects where benefits are quantified in financial terms. I have observed in many organizations that after barely completing one project, the belts neither undertake the next project, nor do they apply the superb tools in their regular work. If we know for sure that there is an urgent need to improve and we see an application of some of the tools, we need not wait till the project charter is signed off and approved. Most organizations implementing six sigma require approvals of sponsors, master black belts (MBB), champions and financial controllers. The approval cycle time may be few days. There is also some cost associated with approval process! There are many opportunities where waiting for a week may not be acceptable. The other consideration for belts would be after completion of their projects. They should not stop applying the concepts and tools just because their projects are over! Six sigma belts are considered as future leaders of the organization and usually take important business positions after completion of their tenures as black belts. Thus they must inculcate the fact based decision making process as a part of work culture.

Till 1980s, the statistical tools were primarily used by statisticians. These required lot of manual calculations. Few DOS based softwares were available but these were not very user friendly and required statisticians to manage input and interpret output. With user-friendly softwares and large number of managers, engineers and professionals trained for six sigma, many of tools could be applied by these trained professionals. If the tools can be easily applied, these must be used. If the trained belts do not use these, there will be waste of ―underutilized people‖ according to Masaki Imai, the great Kaizen Guru.

Some examples to illustrate ―cultural change‖ examples are showed here. These are not six sigma projects but part of regular work of engineers and managers.

• Parts for a new source are being tested for comparing wear with that on parts from current source. The new source may save a lot of money for the company. The decision can be taken using hypothesis tests ensuring adequate power in the test.

• We want to confirm whether corrective action is effective or not. Compare performance of before and after corrective action

• We want to establish process parameters for a process. We can map the process and optimize the parameters using designed experiments

• Historical data of process is available for process parameters and performance. We can analyze the data using regression or other tools to find opportunities for improving the process.

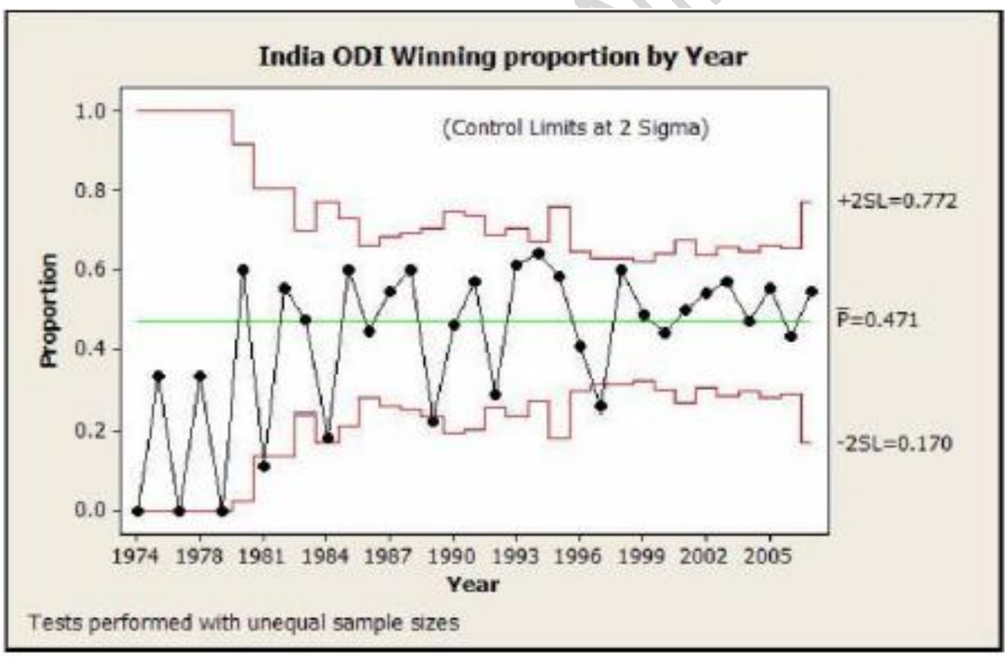
• Performance data of various call centers is available. We may use some of the tools to compare the performance to conclude whether some centers are better or worse.

• Sales team wants to develop a forecasting model based on past data.

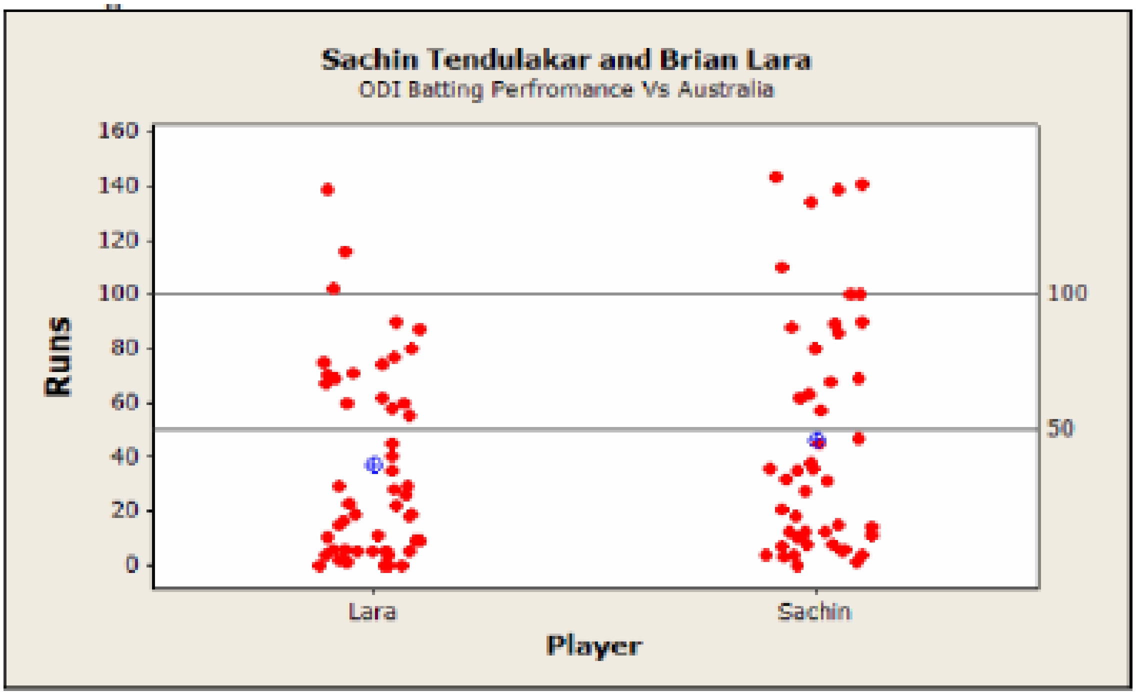
• Marketing wants to find out which advertisement results in higher sales.

• Service manager wants to assess dealers‘ service performance in terms of service time for various types of service calls.

The tools can be used in many applications other than business. To illustrate the point, following control chart shows India‘s winning performance in one day cricket matches till 2007.



Another example is comparison of performance of Sachin Tendulkar and Brian Lara‘s batting.



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5. Briefly describe process capability and how to measure cp and cpk, with practical Examples.

PROCESS CAPABILITY

Process Capability is the ability of the process to meet specifications. The capability analysis determines how the product specifications compare with the inherent variability in a process. The inherent variability of the process is the part of process variation due to common causes. The other type of process variability is due to the special causes of variation.

It is a common practice to take the six-sigma spread of a process‘s inherent variation as a measure of process capability when the process is stable. Thus, the process spread is the process capability, which is equal to six sigma.

Process Capability Analysis: An Important Part of an Overall Quality Improvement Program

The purpose of the process capability analysis involves assessing and quantifying variability before and after the product is released for production, analyzing the variability relative to product specifications, and improving the product design and manufacturing process to reduce the variability. Variation reduction is the key to product improvement and product consistency.

The process capability analysis is useful in determining how well the process will hold the tolerances (the difference between specifications). The analysis can also be useful in selecting or modifying the process during product design and development, selecting the process requirements for machines and equipment, and above all, reducing the variability in production processes.

Determining Process Capability

The following points should be noted before conducting a process capability analysis.

• Process capability should be assessed once the process has attained statistical control. This means that the special causes of variation have been identified and eliminated.

• In calculating process capability, the specification limits are required in most cases. Unrealistic or inaccurate specification limits may not provide correct process capability.

• Process capability analysis using a histogram or a control chart is based on the assumption that the process characteristics follow a normal distribution. While the assumption of normality holds in many situations, there are cases where the processes do not follow a normal distribution. Extreme care should be exercised where normality does not hold. In cases where the data are not normal, it is important to determine the appropriate distribution to perform process capability analysis. In case of non-normal data, appropriate data transformation techniques should be used to bring the data to normality.

SHORT-TERM AND LONG-TERM VARIATION

The standard deviation that describes the process variation is an integral part of process capability analysis. In general, the standard deviation is not known and must be estimated from the process data. There are differences of opinion on how to estimate the standard deviation in different situations. The estimated standard deviation used in process capability calculations may address "short-term" or "long-term" variability. The variability due to common causes is described as "short-term" variability, while the variability due to special causes is considered "long-term" variability.

Some examples of "long-term" variability may be lot-to-lot variation, operator-to-operator variation, day-to-day variation or shift-to-shift variation. Short- term variability may be within-part variation, part-to-part variation, variations within a machine, etc. However, the literature differs on what is "long-term" and what is "short-term" variation. In process capability analysis, both "short-term" and "long-term" indexes are calculated and are not considered separately in assessing process capability. The indexes Cp and Cpk are "short-term" capability indexes and are calculated using "short-term" standard deviation whereas, Pp and Ppk are "long-term" capability and are calculated using "long-term" standard deviation estimate. These are discussed in more detail later.

DETERMINING PROCESS CAPABILITY

Following are some of the methods used to determine the process capability. The first two are very common and are described below.

1. Histograms and probability plots,
2. Control charts, and
3. Design of experiments.

PROCESS CAPABILITY USING HISTOGRAMS: SPECIFICATION LIMITS KNOWN

Suppose that the specification limits on the length is 6.00±0.05. We now want to determine the percentage of the parts outside of the specification limits. Since the measurements are very close to normal, we can use the normal distribution to calculate the nonconforming percentage. Figure 6.2 shows the histogram of the length data with the target value and specifications limits. To do this plot, follow the instructions

HISTOGRAM WITH SPECIFICATION LIMITS	Open the worksheet **PCA1.MTW** From the main menu, select **Graph** ➢ **Histogram** Click on **With Fit** then click **OK** For **Graph variables,** ……………Click the **Scale** then click the **Reference Lines** tab In the Show **reference lines at data values** type **5.95 6.0 6.05** Click **OK** in all dialog boxes.

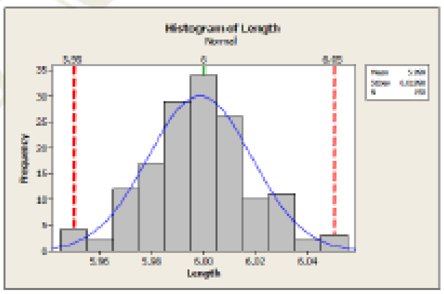


Figure 6.2: Histogram of the Length Data with Specification Limits and Target

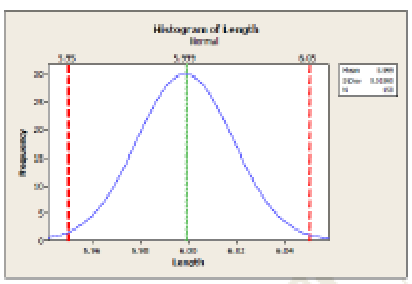


Figure 6.3: Fitted Normal Curve with Reference Line for the Length Data

Table 6.4

Cumulative Distribution Function

Normal with mean = 5.999 and standard deviation = 0.0199

x	P(X <= x)
5.95	0.0069022
6.05	0.994809

From the above table, the percent conforming can be calculated as 0.994809 - 0.0069022 = 0.98790 or, 98.79%. Therefore, the percent outside of the specification limits is 1-0.98790 or, 0.0121 (1.21%). This value is close to what we obtained using manual calculations. The calculations using the computer are more accurate.

PROCESS CAPABILITY USING PROBABILITY PLOTS

A probability plot can be used in place of a histogram to determine the process capability. Recall that a probability plot can be used to determine the distribution and shape of the data. If the probability plot indicates that the distribution is normal, the mean and standard deviation can be estimated from the plot.

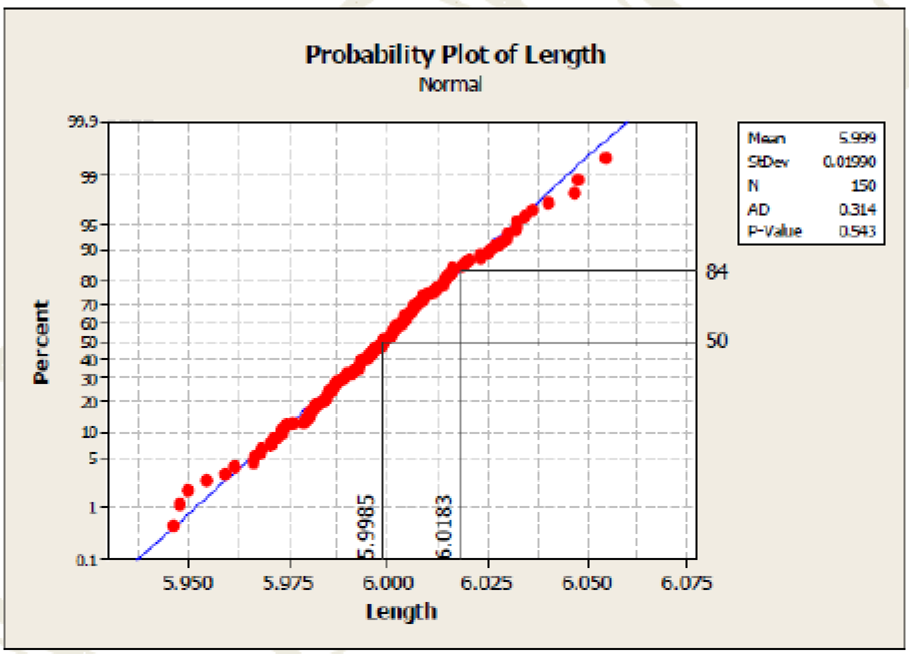
For the length data discussed above, we know that the distribution is normal. We will construct a probability plot (or perform a Normality test)

NORMALITY TEST USING PROBABILITY PLOT	Open the worksheet **PCA1.MTW** From the main menu, select **Stat ➢ Basic Statistics ➢Normality Test** For **Variable**, Select **C1 Length** Under **Percentile Line**, ...type **5 0 84** in the box Under **Test for Normality**, ...**Anderson Darling** Click **OK**

For a normal distribution, the mean equals median, which is 50th percentile, and the standard deviation is the difference between the 84th and 50th percentile. From Figure 6.4, the estimated mean is 5.9985 or 5.999 and the estimated standard deviation is

$$\hat{\sigma} = 84^{th} \text{ percentile} - 50^{th} \text{ percentile} = 6.0183 - 5.9985 = 0.0198$$

Note that the estimated standard deviation is very close to what we got from earlier analysis. The process capability can now be determined as explained in the previous example.



DETERMINING PROCESS CAPABILITIES USING NORMAL DISTRIBUTION

The capability indexes in this case are calculated based on the assumption that the process data are normally distributed, and the process is stable and within control. Two sets of capability indexes are calculated: Potential (within) Capability and Overall Capability.

Potential Capability

- The potential or within capability indexes are: Cp, Cpl, Cpu, Cpk, and Ccpk

• These capability indexes are calculated based on the estimate of or the variation within each subgroup. If the data are in one column and the subgroup size is 1, this standard deviation is calculated based on the moving range (the adjacent observations are treated as subgroups). If the subgroup size is greater than 1, the within standard deviation is calculated using the range or standard deviation control chart (you can specify the method you want).

• According to the MINITAB help screen, the potential capability of the process tells what the process would be capable of producing if the process did not have shifts and drifts; or, how the process could perform relative to the specification limits (if the shifts in the process mean could be eliminated).

Overall Capability

• The overall capability indexes are: Pp, Ppl, Ppu, Ppk, and Cpm

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6. Explain the evolution of TQM and six sigma.

The roots of Six Sigma as a measurement standard can be traced back to Carl Friedrich Gauss (1777-1855) who introduced the concept of the normal curve. Six Sigma as a measurement standard in product variation can be traced back to the 1920's when Walter Shewhart showed that three sigma from the mean is the point where a process requires correction. Many measurement standards (Cpk,Zero Defects, etc.) later came on the scene but credit for coining the term "Six Sigma‖ goes to a Motorola engineer named Bill Smith. (Incidentally, "Six Sigma‖ is a federally registered trademark of Motorola).

In the early and mid-1980s with Chairman Bob Galvin at the helm, Motorola engineers decided that the traditional quality levels — measuring defects in thousands of opportunities – didn't provide enough granularity. Instead, they wanted to measure the defects per million opportunities. Motorola developed this new standard and created the methodology and needed cultural change associated with it. Six Sigma helped Motorola realize powerful bottom-line results in their organization – in fact, they documented more than $16 Billion in savings as a result of our Six Sigma efforts.

Since then, hundreds of companies around the world have adopted Six Sigma as a way of doing business. This is a direct result of many of America's leaders openly praising the benefits of Six Sigma. Leaders such as Larry Bossidy of Allied Signal (now Honeywell), and Jack Welch of General Electric Company. Rumor has it that Larry and Jack were playing golf one day and Jack bet Larry that he could implement Six Sigma faster and with greater results at GE than Larry did at Allied Signal. The results speak for themselves.

Six Sigma has evolved over time. It‘s more than just a quality system like TQM or ISO. It‘s a way of doing business. As Geoff Tennant describes in his book Six Sigma: SPC and TQM in Manufacturing and Services: “Six Sigma is many things, and it would perhaps be easier to list all the things that Six Sigma quality is not. Six Sigma can be seen as: a vision; a philosophy; a symbol; a metric; a goal; a methodology.”

The Evolution of Six Sigma

Before, January 15, 1987, Six Sigma was solely a statistical term. Since then, the Six Sigma crusade, which began at Motorola, has spread to other companies who are continually striving for excellence. While it is progressing, it has extended and evolved from a problem-solving technique to a quality strategy and ultimately into a sophisticated quality philosophy. However, this unique philosophy only became well known after GE‘s Jack Welch made it a central focus of his business strategy in 1995. Today, Six Sigma is the fastest growing business management system in industry.

To elaborate the evolution of Six Sigma, one Six Sigma authority has to be introduced: Mikel Harry, who is called the “godfather‖ of Six Sigma and is acknowledged as the leading authority on theory and practice. Even though he did not invent the concept, the way that it is currently practiced bears the unmistakable marks of Harry‘s personality and personal history. Harry's history path is followed here to reveal the evolution of Six Sigma.

The evolution began in the late 1970s, when a Japanese firm took over a Motorola factory that manufactured television sets in the United States and the Japanese promptly set about making drastic changes to the way the factory operated. Under Japanese management, the factory was soon producing TV sets with 1/20th the number of defects they had produced under Motorola management. Finally, Motorola recognized its quality was awful. Since then, Motorola management decided to take quality seriously. When Bob Galvin became Motorola's CEO in 1981, he challenged his company to achieve a tenfold improvement in performance over a five-year period.

In 1984, after Harry was awarded a doctorate from Arizona State University, he joined Motorola where he worked with Bill Smith, a veteran engineer who was in Mikel Harry's words, “the father of Six Sigma‖. During 1985, Smith wrote an internal quality research report which caught the attention of Bob Galvin. Smith discovered the correlation between how well a product did in its field life and how much rework had been required during the manufacturing process. He also found that products that were built with fewer nonconformities were the ones that performed the best after delivery to the customer. Although Motorola executives agreed with Smith's supposition, the challenge then became how to create practical ways to eliminate the defects. With the concept of “logic filter‖, one of Harry's papers at Arizona State University, together with Smith, Harry developed a four-stage problem-solving approach: Measure, Analyze, Improve, Control (MAIC). Later, the MAIC discipline became the road map for achieving Six Sigma quality.

On January 15, 1987, Galvin launched a long term quality program, called "The Six Sigma Quality Program‖. The program was a corporate program which established Six Sigma as the required capability level to approach the standard of 3.4 DPMO. This new standard was to be used in everything, that is, in products, processes, services and administration. The Corporate Policy Committee of Motorola then updated their quality goal as follows:

"Improve product and service quality ten times by 1989, and at least one hundred fold by 1991. Achieve Six Sigma capability by 1992. With a deep sense of urgency, Galvin spread dedication to quality to every facet of the corporation, and achieve a culture of continual improvement to assure Total Customer Satisfaction. There is only one ultimate goal: zero defects in everything we do."

The revised corporate quality goal stated that everyone was responsible for and to each other regarding this objective. In addition, it affirmed that no one could assume she or he had done enough until the entire goal of Six Sigma was achieved company-wide. After implementing Six Sigma, in 1988, Motorola was among the first recipients of the Malcolm Baldrige National Quality Award. Since then, Six Sigma has constantly caught the attention of industry. However, at Motorola, Six Sigma was only a disciplined problem-solving methodology.

In 1988, at Unisys Corp. Harry discussed with Cliff Ames, one of Unisys‘ plant managers, about how to leverage the Six Sigma technique throughout an organization and how to recognize the people who were equipped with Six Sigma tools. Since Ames was a lover of karate and Harry himself was a martial arts enthusiast, in some respects, they shared the same eastern martial arts philosophy. People in martial arts are incredibly skilled, have a precise command of tools, are very dedicated, and are very humble to learn. Based on this insight, Harry decided to designate those with Six Sigma skills as "Black Belt".

In 1989, Galvin invited Harry to head up Motorola's Six Sigma Research Institute and challenged him to do "short cycle quality knowledge transfer and rapid dissemination of quality knowledge into a world-wide company‖. Harry answered the challenge with Six Sigma implementation strategy that attempted to put quality tools into the hands of large numbers of workers and managers throughout the organization. From that moment, Six Sigma skills were not solely owned by quality engineers, but began to transfer from the quality department to the entire organization.

In 1993, at Asea Brown Boveri (ABB), Harry teamed with Richard Schroeder who later joined him to found Six Sigma Academy. Inspired by Kjell Magnuson, one of ABB‘s business unit presidents, Harry realized that high level executives only focused on clear and quantifiable gains. Further, Harry recognized that it should not be quality first, but business first which will lead to the realization of quality. In addition, from his Marine Corps experience, he understood the importance of tactics. To exploit the full power of Six Sigma by focusing on bottom-line results, Harry refined Six Sigma deployment tactics which included: Champion, Master Black Belt, Black Belt, and Green Belt.

At that time, enamored by Motorola's success, several other companies, such as Texas Instruments, began a similar pursuit. But, it wasn't until late 1993 that Six Sigma really began to transform business. That's the year that Harry and Schroeder moved to Allied Signal and its CEO, Larry Bossidy, decided to adopt Six Sigma.

By adequately selecting the right Six Sigma projects and promptly providing the right support for them, Bossidy suggested that high level executives should also understand Six Sigma tools. To respond to that, Harry developed a methodology for a leadership team to select high financial leverage projects. At Allied Signal, an entire system of leadership and support systems began to form around the statistical problem solving tools of Six Sigma.

Not long after Allied Signal began its pursuit of Six Sigma quality, Jack Welch, then Chairman and CEO of General Electric, influenced by Bossidy, then began to get interested in Six Sigma. In fact, before Six Sigma, according to Welch, neither he nor Bossidy quality enthusiasts. They felt the earlier quality programs were too heavy on slogans and light on results. In June 1995, Welch invited Bossidy to attend GE‘s Corporate Executive Council meeting and share his experience with Six Sigma. After that meeting, GE conducted a cost-benefit analysis on Six Sigma implementation. The analysis showed that if GE, then running at three to four sigma quality level, were to raise its quality to six Sigma, the cost saving opportunity was somewhere between $7 billion and $10 billion. This amounted to a huge number - 10 to 15 percent of sales.

Then, in January 1996, teaming with Six Sigma Academy, Welch announced the launch of Six Sigma at GE. At that time, he called Six Sigma the most ambitious undertaking the company had ever taken on. He stated: “Quality can truly change GE from one of the great companies to absolutely the greatest company in world business.‖ Needless to say that when GE does something, it does it all the way. Welch said to GE‘s Corporate Executives: “Everyone in this room must lead the quality charge. There can be no spectators on this. What took Motorola ten years, we must do in five – not through shortcuts, but in learning from others‖. From that moment, Jack Welch became the global promoter of Six Sigma.

There are two important contributions from GE‘s way of implementation to the evolution of Six Sigma. First, Welch demonstrated the great paradigm of leadership. Second, Welch backed the Six Sigma program up with a strong rewards system to show his commitment to it. GE changed its incentive compensation plan for the entire company so that 60 percent of the bonus was based on financials and 40 percent on Six Sigma results. The new system successfully attracted GE employees‘attentions to Six Sigma. Moreover, Six Sigma training had become a prerequisite for advancement up GE's corporate ladder. Welch insisted that no one would be considered for a management job without at least a Green Belt training by the end of 1998.

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7. Enumerate the benefits of using six sigma.

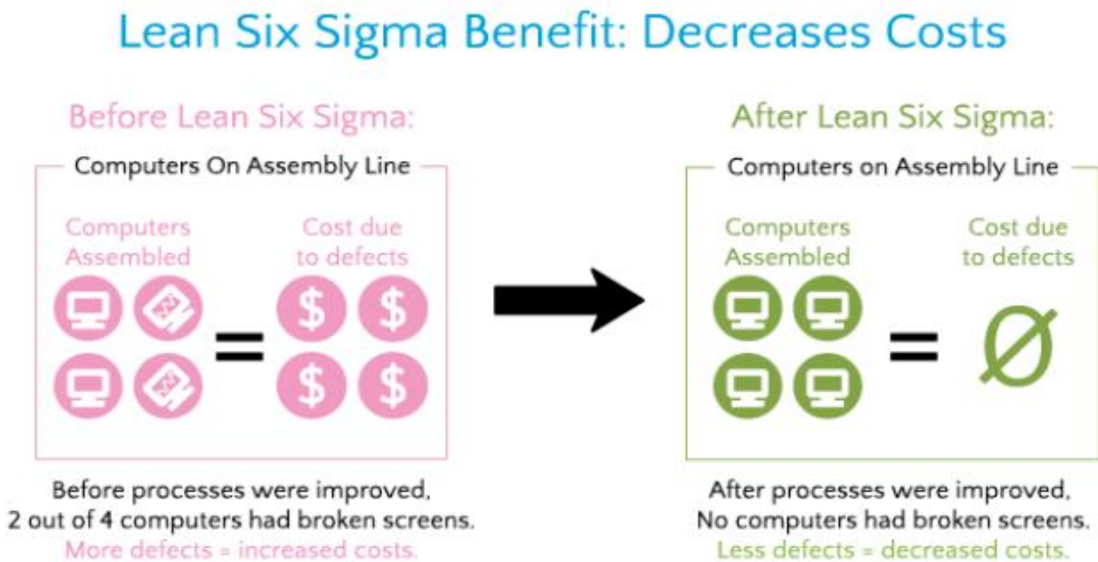
The Benefits of Using Lean Six Sigma

Organizations face rising costs and increasing competition every day. Lean Six Sigma allows you to combat these problems and grow their businesses the following ways:

- Increases revenue
- Decreases costs
- Improves efficiency
- Develops effective people/employees

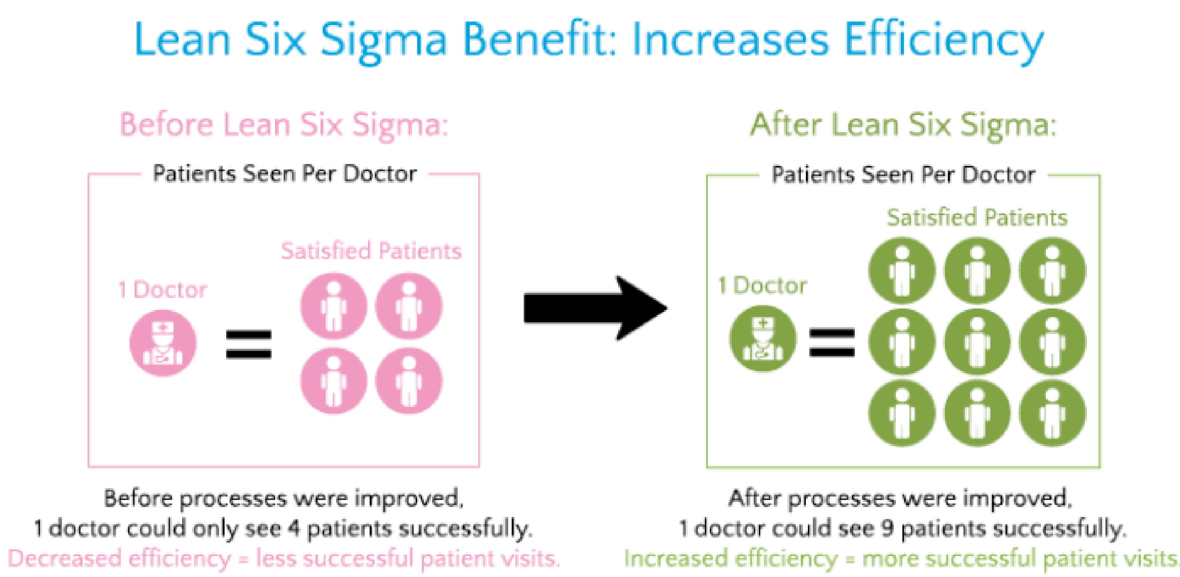
Lean Six Sigma increases your organization's revenue by streamlining processes.

- Streamlined processes result in products or services that are completed faster and more efficiently at no cost to quality.
- Simply put, Lean Six Sigma increases revenue by enabling your organization to do more with less – Sell, manufacture and provide more products or services using fewer resources.



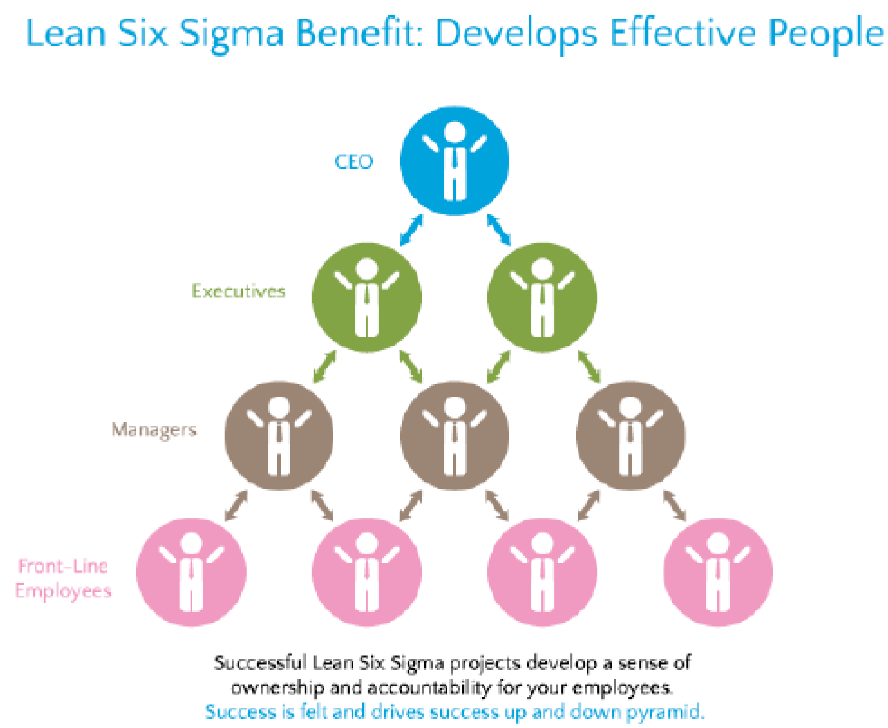
Lean Six Sigma decreases your organization's costs by:

- Removing "Waste" from a process. Waste is any activity within a process that isn't required to manufacture a product or provide a service that is up to specification.
- Solving problems caused by a process. Problems are defects in a product or service that cost your organization money



Lean Six Sigma improves the efficiency of your organization by:

- Maximizing your organization's efforts toward delivering a satisfactory* product or service to your customers
- Allowing your organization to allocate resources/revenue produced from your newly improved processes towards growing your business



Lean Six Sigma develops effective employees within your organization by:

- ❖ Involving employees in the improvement process. This promotes active participation and results in an engaged, accountable team.
- ❖ Building trust. Transparency throughout all levels of the organization promotes a shared understanding of how each person is important to the organization's success.

8.Prepare Assessment question regarding any manufacturing industry. **(Case study)**

9.Discuss about lean manufacturing and explain how it can be applied in manufacturing with real time problems. **(Case study)**

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10. What are the methods to determine process capability? explain in detail

(Refer Q.No.5)

Determining process capability

Following are some of the methods used to determine the process capability. The first two are very common and are described below.

1. Histograms and probability plots,
2. Control charts, and
3. Design of experiments.
