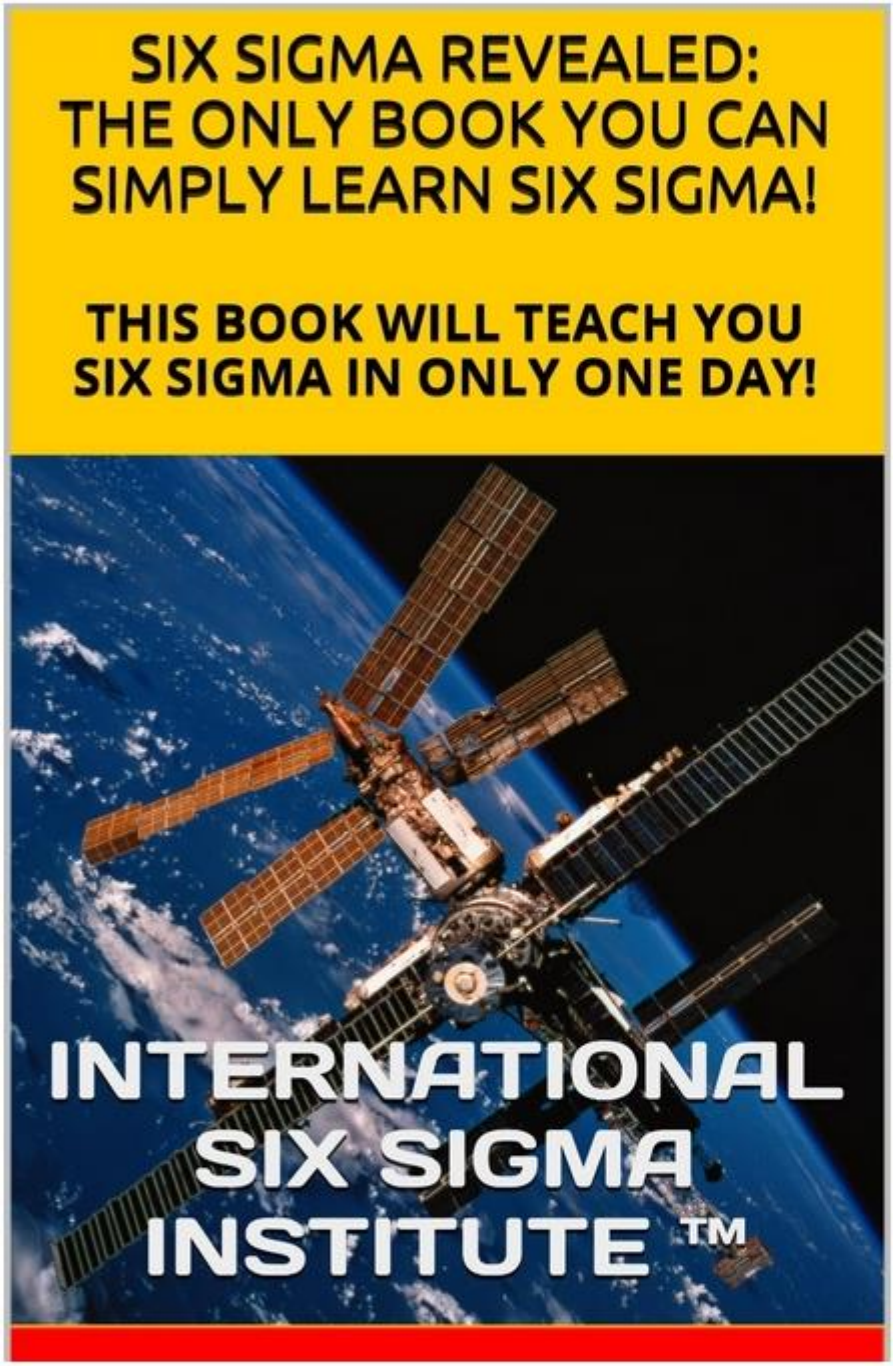
SIX SIGMA REVEALED:
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THIS BOOK WILL TEACH YOU
SIX SIGMA IN ONLY ONE DAY!
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INSTITUTE ™

Contents

ABOUT THE AUTHOR

International Six Sigma™ Institute is an independent Institute which helps Organizations and Professionals worldwide prove their competence and knowhow in Six Sigma Methodology and get them certified with our Six Sigma Certification Programs. Our Certified Six Sigma Champion, Master Black Belt, Deployment Leader, Black Belt, Green Belt and Yellow Belt Programs have proven their worldwide Acceptance and Reputation by being the choice of more than 175'000 Six Sigma Practitioners in 143 Countries.

Six Sigma is an open Problem Solving and Quality Improvement Framework, and yet before International Six Sigma Institute was established, there used to be no reasonable way for Six Sigma Professionals to obtain Six Sigma Certifications and to prove their competence in Six Sigma domain. Six Sigma Professionals had to pay expensive fees for the money-driven Six Sigma Certification Programs of other Certification Entities.

International Six Sigma Institute aims to remove the barriers set in front of the Six Sigma Professionals in developed and emerging markets by saving them from paying unreasonable fees for Six Sigma Classroom Trainings and Six Sigma Certification Examinations before they certify their knowhow in Six Sigma.

International Six Sigma Institute provides six major Online Six Sigma Certification Programs which are designed by our consortium of renowned Six Sigma Experts and Coaches participated from all major Industries. These certification programs are:

- Certified Six Sigma Master Black Belt (CSSMBB™)
- Certified Six Sigma Black Belt (CSSBB™)
- Certified Six Sigma Green Belt (CSSGB™)
- Certified Six Sigma Yellow Belt (CSSYB™)
- Certified Six Sigma Champion (CSSC™)
- Certified Six Sigma Deployment Leader (CSSDL™)

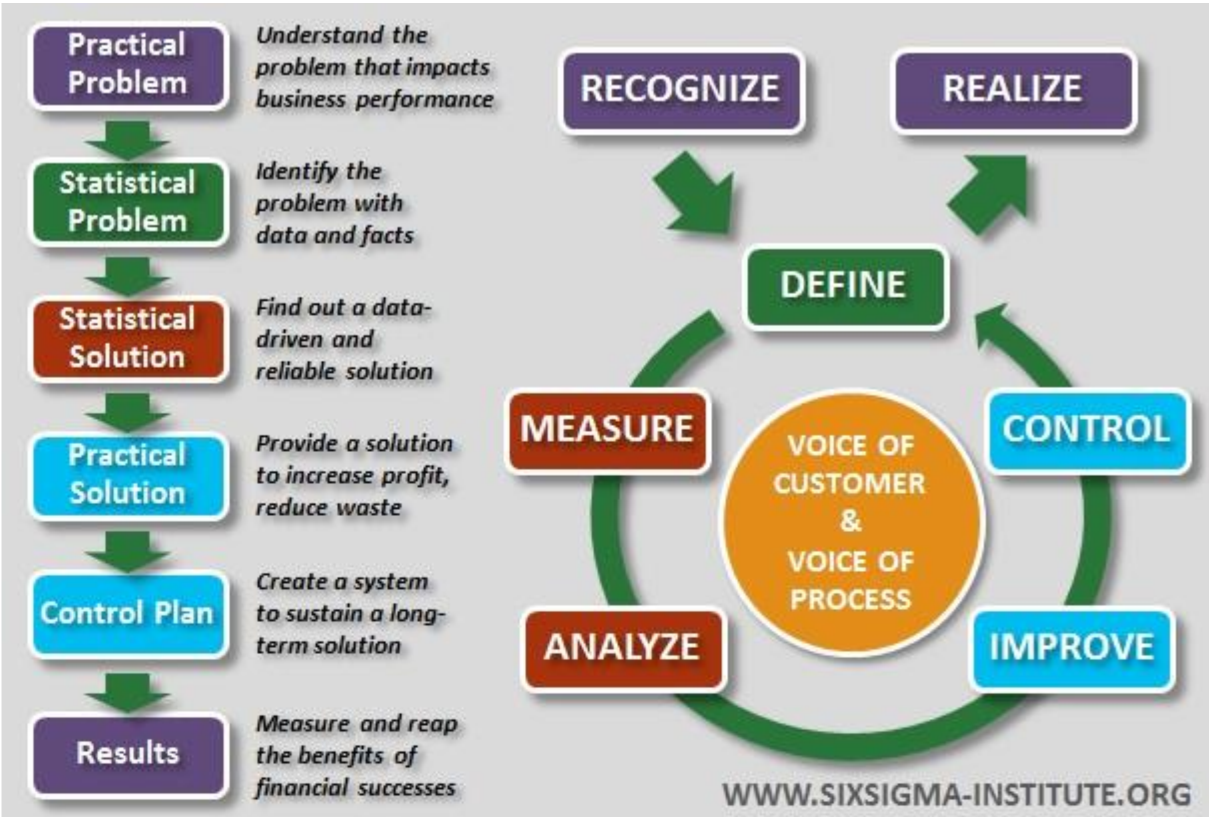
Our one-of-a-kind industry leading registration, examination and certification process is very simple, quick and completely online. You can find all details under the following link: http://www.sixsigma-institute.org/Certified_Six_Sigma_Master_Black_Belt_CSSMBB_Program.php

Afterwards, please feel free to do your registration from the following link: http://www.sixsigma-institute.org/Register_Six_Sigma_Certification_Program.php

All the Best and Happy Reading!

WHAT IS SIX SIGMA?

Six Sigma is a defined and disciplined business methodology to increase customer satisfaction and profitability by streamlining operations, improving quality and eliminating defects in every organization-wide process.



Six Sigma and DMAIC Methodology Overview

What is Six Sigma?

Six Sigma is:

- **A Business Strategy:** Using Six Sigma Methodology, a business can strategize its plan of action and drive revenue increase, cost reduction and process improvements in all parts of the organization.

- **A Vision:** Six Sigma Methodology helps the Senior Management create a vision to provide defect free, positive environment to the organization.

- **A Benchmark:** Six Sigma Methodology helps in improving process metrics. Once the improved process metrics achieve stability; we can use Six Sigma methodology again to improve the newly stabilized process metrics. For example: The Cycle Time of Pizza Delivery is improved from 60 minutes to 45 minutes in a Pizza Delivery process by using Six Sigma methodology. Once the Pizza Delivery process stabilizes at 45 minutes, we could carry out another Six Sigma project to improve its cycle time from 45 minutes to 30 minutes. Thus, it is a benchmark.

- **A Goal:** Using Six Sigma methodology, organizations can keep a stringent goal for themselves and work towards achieving them during the course of the year. Right use of the methodology often leads these organizations to achieve these goals.

- **A Statistical Measure:** Six Sigma is a data driven methodology. Statistical Analysis is used to identify root-causes of the problem. Additionally, Six Sigma methodology calculates the process performance using its own unit known as Sigma unit.

- **A Robust Methodology:** Six Sigma is the only methodology available in the market today which is a documented methodology for problem solving. If used in the right manner, Six Sigma improvements are bullet-proof and they give high yielding returns.

WHAT IS QUALITY?

Different individuals and organizations have given different definitions for Quality. Let's study some of those definitions:

- **Deming:** "Quality is defined from the customer's point of view as anything that enhances their satisfaction".
- **Juran:** "Fitness for use. Those product features which meet the needs of customers and thereby provide product satisfaction. Freedom from deficiencies".
- **ASQC:** "The totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs".
- **COPC:** "Quality is defined as knowledge of agents that would enable them to provide accurate and consistent solution to the customer at the very first attempt".
- **ISO:** "Degree to which a set of inherent characteristics, of a product or service, fulfill requirements".

Simply stated, quality comes from meeting customer expectations. This occurs as a result of four activities:

- **Understanding** customer requirements.
- **Designing** products and services that satisfy those requirements.
- **Developing** processes that are capable of producing those products and services.
- **Controlling** and managing those processes so they consistently deliver to their capabilities.

WHAT IS THE HIDDEN FACTORY?

The Hidden Factory is the set of activity (or activities) in the process that result in reduction of quality or efficiency of a business process or manufacturing department, and is not known to managers or others seeking to improve the process. Six Sigma focuses on identifying "hidden factory" activities to eliminate the root-causes.

One of the examples of Hidden Factory will be creating multiple versions of a status update presentation by the Project Management team because all of the requested information was not received by the due date from all the departments.

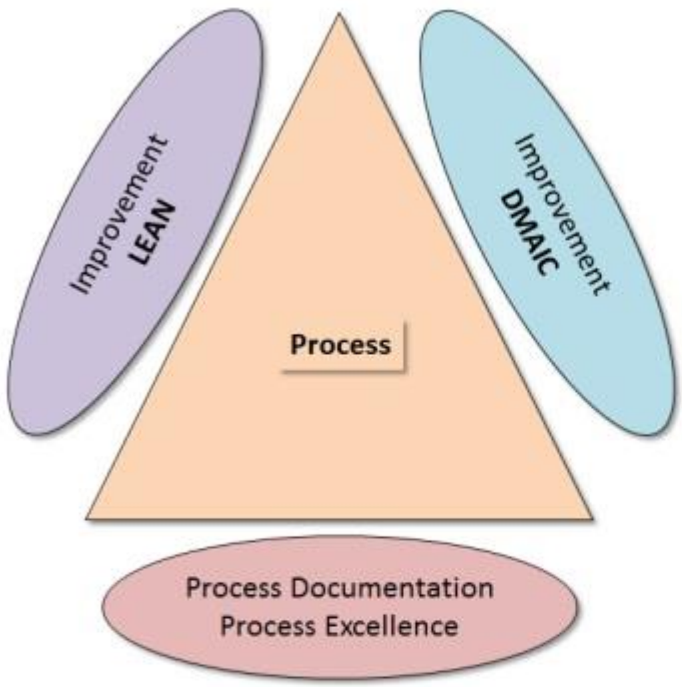
Six Sigma works effectively to identify the hidden factory situations, questions the status quo, removes it and thus it improves business profits and reduces wastes.

SIX SIGMA PROCESS EXCELLENCE DISCIPLINES

Process Excellence/Process Documentation:
Process Excellence and Process Documentation helps the project team to define, measure and control the business processes. Six Sigma and Lean tools are used for both Process Excellence and Process Documentation.

Process Excellence and Process Documentation ensures:

- Standardization across different processes in the same organization/department.
- Allows business continuity in case of non-availability of Key Subject Matter Experts (SME's).
- Helps to understand the current state of the process and also to measure the performance of the future state of the project.



Six Sigma Process Excellence Disciplines

Process Improvement (DMAIC):
Process Improvement is an effort to identify high priority problems in business processes and to train teams to tackle those problems. The methodology used is called DMAIC. It is an acronym for Define-Measure-Analyze-Improve-Control.

In the Define phase, the project is defined. In Measure phase, data is collected, Measurement System is validated and current performance is identified. In Analyze phase, root causes are identified. In Improve, solutions are created and implemented and in Control phase, new performance is sustained).

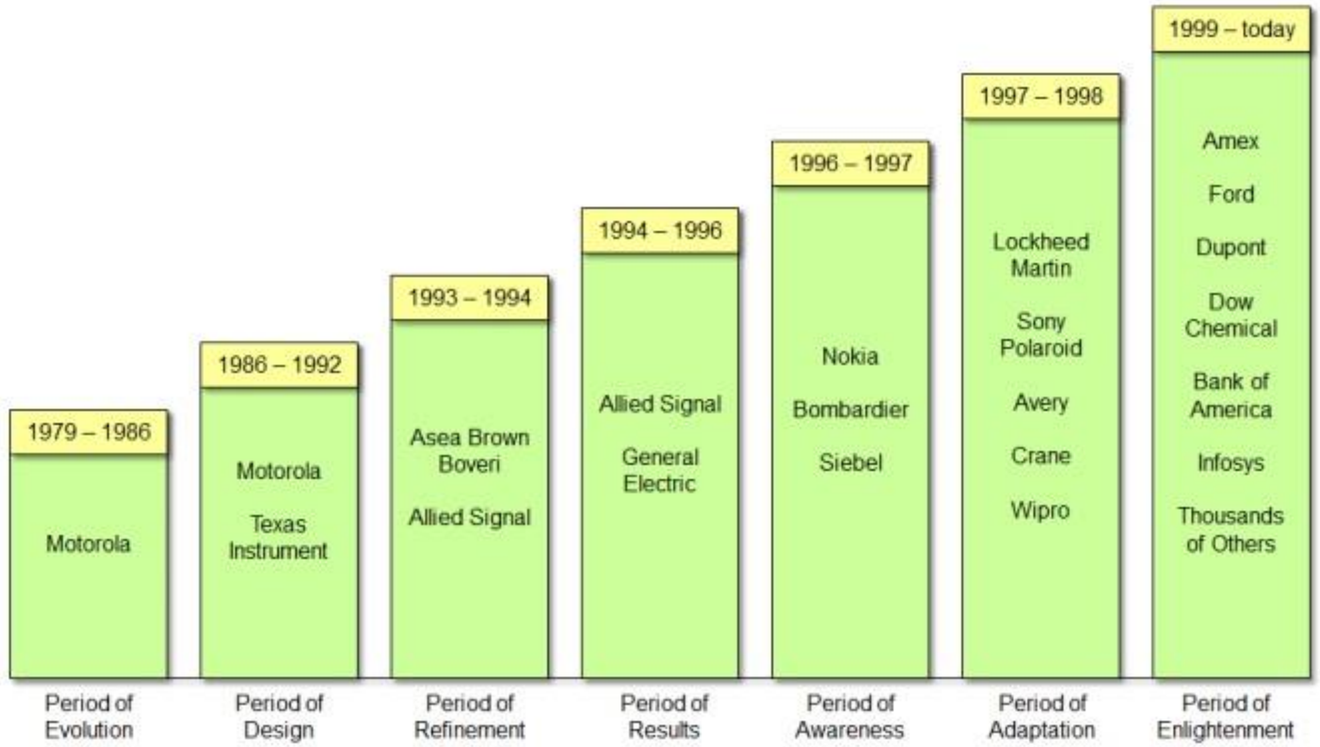
Lean tools such as Value Stream Map (VSM), Pull and Kaizen are leveraged too.

Process Improvement (Lean):
"Lean" is the set of management practices based on the Toyota Production System (TPS). This methodology is deployed in selected processes to identify and eliminate Non-value added activities and hence increase the operational efficiency. Lean is quick and avoids rigorous data analysis.

There are two critical factors of Lean – Value Added and Non-Value Added. Value is what the customer cares for. It is doing the right things the first time. When we say Value Added, our product or service should add value to the process. Similarly, we should focus on removing non-value added activities from the process.

HISTORY OF SIX SIGMA

- Developed by Mikel Harry and Bill Smith, Motorola.
- Motorola was amongst the first recipients of the Malcolm Baldrige Award.
- National Quality Award in 1988.



Six Sigma History

Throughout its history and evolution, Six Sigma turned into a business driven, multi-dimensional structured approach to reinforce Business Strategies into various aspects such as:

1. Improving Processes
2. Lowering Defects
3. Reducing Process Variability
4. Reducing Costs
5. Increasing Customer Satisfaction
6. Increasing Profit

HOW DOES SIX SIGMA WORK?

Step 1 - Business Problem: At the beginning of a Six Sigma project, the Business Problem is defined. Questions such as What, When, Where are addressed in a problem statement. Magnitude and Consequence of the problem is also discussed. Project Scope is identified.

Step 2 - Statistical Problem: Root causes for the business problems are identified. Those root causes are converted into statistical problems using Hypothesis testing methods. **Trivial Many Causes:** These are all the possible causes of the given problem. They may cause impact to the problem. **Vital Few Causes:** These are the few critical causes which cause maximum impact over the problem.

Step 3 - Statistical Solution: Identification of only 3-4 vital root causes using statistical analysis is achieved. These root causes are vital because they have maximum impact on the problem. Any given problem follows a Pareto principle which states that 80% of the problems are caused due to 20% of the root-causes. Solutions to these root causes are studied and an optimal value for each solution is identified.

Step 4 - Business Solution: These statistical solutions are then converted to implementable practical solutions. Implementation of these business solutions is carried out in the process. Improvements are observed and sustained.

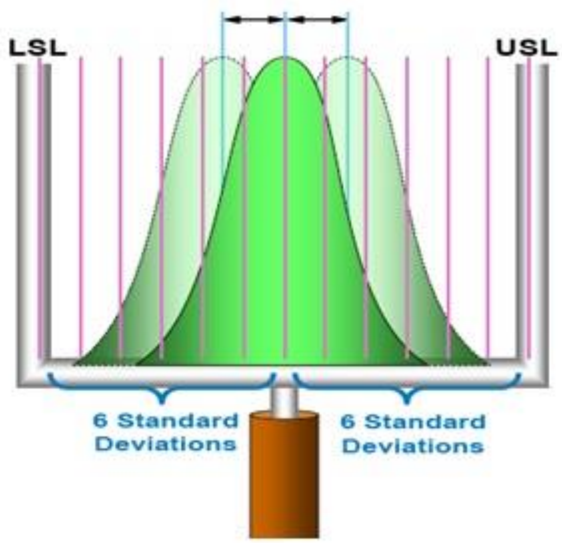
Six Sigma applies statistical tools to business problems. The key is data-driven decision making.

WHAT IS SIGMA AND WHY IS IT SIX SIGMA?

Mean is the arithmetic average of a process data set.
Central tendency is the tendency of data to be around this mean.
Standard Deviation (also known as Sigma or σ) determines the spread around this mean/central tendency.

The more number of standard deviations between process average and acceptable process limits fits, the less likely that the process performs beyond the acceptable process limits, and it causes a defect. This is the reason why a 6σ (Six Sigma) process performs better than 1σ, 2σ, 3σ, 4σ, 5σ processes.

Obviously 7 or more σ processes are even better than a 6σ (Six Sigma) process, and yet throughout the evaluation and history of Six Sigma process, the practitioners gained the belief that a 6σ process is good enough to be reliable in almost all major situations except some systems whose defects can cause unrepairable consequences.

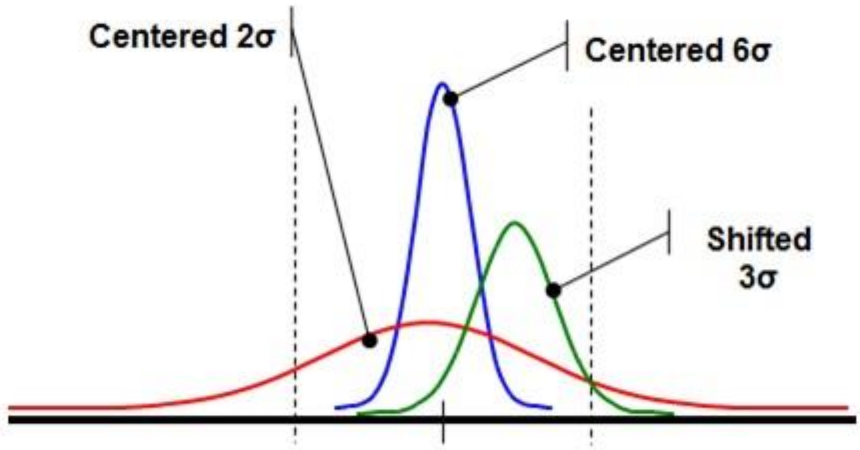


Six Sigma stands for 6 standard deviations (6σ) between avarage and acceptable limits

LSL and USL stand for "Lower Specification Limit" and "Upper Specification Limit" respectively. Specification Limits are derived from the customer requirements, and they specify the minimum and maximum acceptable limits of a process.

For instance in a car manufacturing system the desired average length (Mean length) of car door can be 1.37185 meter. In order to smoothly assemble the door into the car, LSL can be 1.37179 meter, and USL can be 1.37191 meter. To reach a 6σ quality level in such a process, the standard deviation of car door length must be at most 0.00001 meter around the mean length.

Sigma is also the capability of the process to produce defect free work. Higher the capability, lower the defects.



Processes in various Sigma Levels

In the above figure, the red curve indicates a 2σ level of performance where we observe that its peak is very low (fewer outputs are around the desired average) and the variation is from extreme left to extreme right of the figure. If the process improves from 2σ to 3σ (green curve), you will observe that the process variation reduces and the process has a larger peak (more outputs are around the desired average, but a different average than red curve). As the process performance increases from 3σ to 6σ (blue curve), the process becomes centered between the upper and lower specification limits and does not have much variation. Here with blue curve the majority of process outputs are around the desired average. This is why it is good and it causes less defects beyond the lower and upper specification limits.

Sigma Level	DPMO Defects per Million Opportunities
2 σ	308’537.0
3 σ	66’807.0
4 σ	6’210.0
5 σ	233.0
6 σ	3.4

Sigma Level vs DPMO Defects per Million Opportunities

In the above table, you will observe that as the Sigma level increase the Defects decrease. For example, for a 2σ process the Defects are as high as 308,537 in one million opportunities. Similarly, for a 6σ process the Defects is as low as 3.4 in one million opportunities. The 2σ performance level will have more defects than a system in 6σ performance level as the standard deviation for a 2σ process is much larger than the standard deviation for a 6σ process.

Can we have any process which has 6σ level of performance?

The answer is yes. Pharmaceutical Companies, Airline Manufacturing Organizations, Automobile Manufacturers, among others are bound to work at a sigma level which is either 6σ or more than that. If they are not able to perform at this efficiency, the organization cannot exist. Think about it, you are in the air, 5000 feet above the ground, flying in a Boeing 777 Aircraft and suddenly a nut-bolt in the wing of the plane loosens (probably due to manufacturing defect) making it difficult for the pilot to steer the flight! This is the only reason why defects are not welcome and organizations try to achieve higher Sigma levels.

Sigma	Spelling	Money	Time	DPMO
3 σ	1.5 misspelled words per page in a book	$ 2.7 Million Indebtedness per $1 Billion in Assets	3 ½ Months per century	66,807
4 σ	1 misspelled word per 30 pages in a book	$63,000 Indebtedness per $1 Billion in Assets	2 ½ Days per century	6,210
5 σ	1 misspelled word in a set of encyclopedias	$ 570 Indebtedness per $1 Billion in Assets	30 Minutes Per Century	233
6 σ	1 misspelled word in all the books in a small library	$ 2 Indebtedness per $1 Billion in Assets	6 Seconds Per Century	3.4

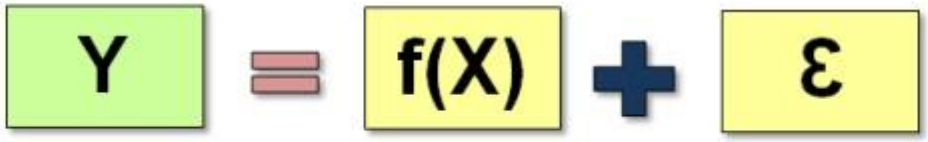
Six Sigma vs DPMO Examples

In the above examples,

- Sigma indicates the Sigma level.
- Spelling indicates the total spelling errors.
- Money indicates the amount of fine/indebtedness that can occur due to the misspellings.
- Time indicates the total time it takes to correct those misspellings.
- DPMO indicates the total Defects in One Million Opportunities.

We can clearly observe that as the Sigma Level increase, the defects (misspellings) decrease, the indebtedness reduce and the time for rework also reduces, thus it reduces the DPMO-Defects per Million Opportunities.

WHAT IS THE FOCUS OF SIX SIGMA?



Focus of Six Sigma

Y is outcome(s) or result(s) you desire and need from a process. This is a dependent factor and it depends on the X's.
X represents the input factors that could result in Y. There could be multiple X's. These are independent factors.
Ɛ represents the presence of error, or uncertainty surrounding how accurately the X's are transformed to create the outcome.

In other words, the input variable(s) are transformed by a function (or process) and combined with error to form the output. The Y results from, or is a function of the Xs. To determine a desired outcome, you apply a transformation process or function, f, on the inputs.

For example, the formation of a thin sheet of iron undergoes several processes. The input variables are Iron Ore (Wrought Iron), charcoal, other chemicals and a furnace. This wrought iron is transformed through use of all of the input raw materials in the right proportion and heating in the furnace into a desired outcome. The raw materials and furnace is the X's, the mixing of raw materials and heating are the transformation process function f, and the resulting Iron sheet is the Y. Ɛ can be the varying degree of temperature throughout the furnace resulting in non-uniform sheet of metal (errors in the process).

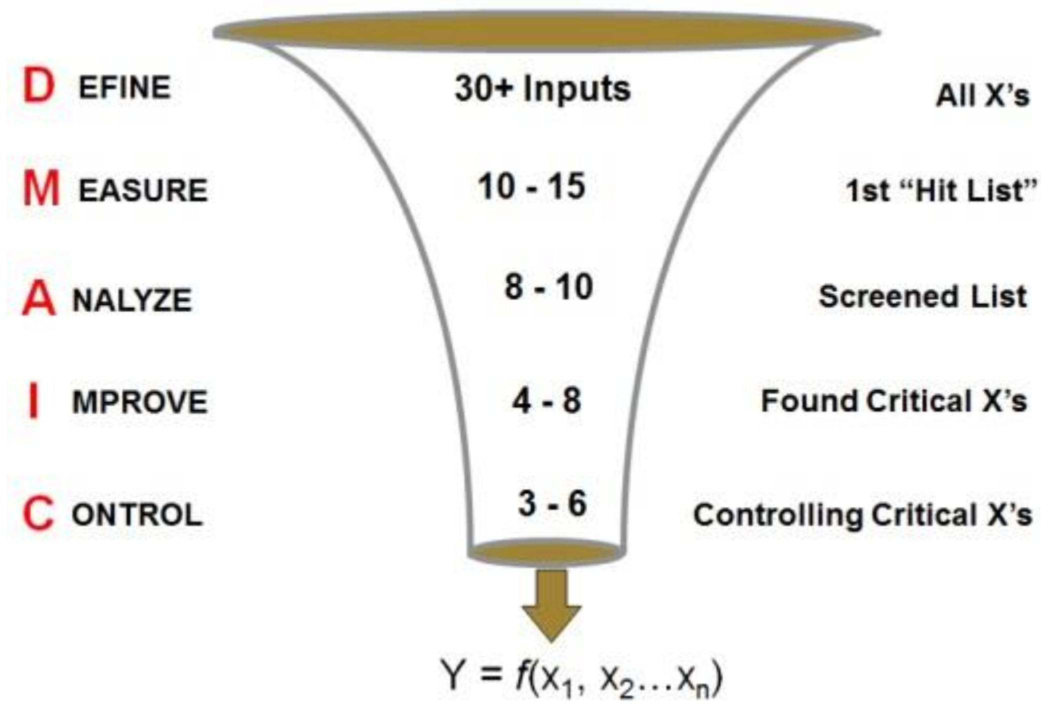
In the Pizza delivery example, some of the reasons for not meeting the pizza delivery time of 30 minutes could be Heavy Traffic, Delivery Driver did not know the delivery address, Pizza was not prepared in-time, among others. Thus, in this example, Delivery time of Pizza is "Y" and the reasons for not delivering the pizza on-time are "X's".

After understanding the two examples described above, in order to get results, should we focus on "Y" or "X"?

Focus the Causes (X) and NOT the Result (Y): Whenever you do a Six Sigma project, the focus of the project team needs to be on identifying of causes and mitigating them. The Result will automatically improve if the causes are dealt correctly. In the above example, formation of an iron sheet is the result and all the input materials are the causes. Thus, focus on the Causes and NOT the Result.

HOW DOES SIX SIGMA DMAIC PROCESS WORK?

Let us now understand how the DMAIC process works. DMAIC is an acronym for its five phases – Define, Measure, Analyze, Improve and Control. DMAIC is a Six Sigma methodology which helps in achieving process improvements by reducing variation. Each phase of has its own significance and we will understand how DMAIC process reduces many root causes to only a few vital root causes. Let's look at the below diagram:



Six Sigma DMAIC Process

As we see above, the Define phase looks at all the X's (here X is an independent variable as discussed in the previous section). In the Measure phase, we get the 1st "Hit List" where the root causes (X's) are reduced to just 10 – 15. In Analyze phase, we screen the available list and reduce the root causes to 8 – 10. In Improve phase, we identify just 4 – 8 critical X's and in Control phase, we are controlling only 3 – 6 root causes (X's). Thus, by controlling just 3 – 6 root causes we are able to positively impact the project Y.

Characteristics of a successful project:

- Should be related to your day to day work
- Should be manageable in terms of time-frame
- Should be aligned with business goals and results
- Should preferably address only one CTQ (Critical To Quality) parameter
- Should address issues which are important to the customer
- The improvements that you do should be locally actionable

In the above characteristics, we have a CTQ parameter. Here, CTQ stands for Critical To Quality. In layman's language, CTQ is nothing but a metric that helps in measuring the extent of performance. CTQ can be of various types such as CTD (Critical to Delivery), CTP (Critical to Process), among others. Some of the examples of CTQ's are Cycle Time in a process, Quality Scores, Yield%, among others.

Projects must be tightly bound and must not focus on solving broad issue such as global warming or world's pollution.

When a Six Sigma project is initiated, it generally happens that we do not scope the project appropriately. During the course of the project, we keep adding additional parts to the project and the team has to manage these additional items which were not considered earlier. This phenomenon of including additions to the project is termed as "scope creep" and leads to challenges in project execution at a later stage. Projects which lead to scope creep are termed as projects which are trying to solve "global warming". In order for the projects to achieve the desired results, they must be tightly bound and must not focus on solving broad issues.

A process-focused business constantly realigns processes to remain capable of meeting changing market demands. Only by gaining predictability can an enterprise truly maintain capable processes to changing customer demands.

Here, we should focus on getting the Voice of Process to understand the real nuances that it may face during the course of its operations. Voice of Process helps in understanding the metrics and the inherent fluctuations of these metrics. Three key terms that help us define process capability are:

- Process Baseline
- Process Entitlement
- Process Benchmark

Six Sigma facilitates in understanding variation in our business processes!

Let's understand the three key terms:

Process Baseline:
Process baseline is the average long-term performance level of a process when all the input variables in the process are running in an unconstrained fashion. Long term performance is the performance of the process over a period of time.

Process Entitlement:
Process entitlement is the best case short-term performance level of a process when all the input variables in the process are centered and in control. Short term performance is the performance of the process at any given point of time.

Process Benchmark:

Process benchmark is the performance level of the process deemed by comparison to the best process possible. It takes us to the best that anyone has ever done. In practical terms this means researching and finding the best that has ever been done in the industry.

SIX SIGMA ROLES AND RESPONSIBILITIES

Six Sigma roles are primarily divided into two segments:

1. Initiative Leadership
2. Project Leadership

Apart from the above two segments, the overall Six Sigma methodology require the following roles:

1. Six Sigma Deployment Leader
2. Six Sigma Champion
3. Six Sigma Master Black Belt (MBB)
4. Six Sigma Black Belt (BB)
5. Six Sigma Green Belt (GB)
6. Six Sigma Yellow Belt (YB)

Let's look at how Six Sigma roles are bifurcated into the required segments:

	Initiative Leadership	Project Leadership
Six Sigma Deployment Leader	X	
Six Sigma Champion	X (within specified area)	X
Six Sigma Master Black Belt (MBB)	X (within specified area)	X
Six Sigma Black Belt (BB)		X
Six Sigma Green Belt (GB)		X
Six Sigma Yellow Belt (YB)		X

Six Sigma Project Roles

SIX SIGMA DEPLOYMENT LEADER:

As a group, business leaders must own and drive Six Sigma by doing the following:

- Establish business objectives and the role of Six Sigma to achieve those goals.
- Create an environment which enables success including goals, measures, coaching, and communication, among others.
- Actively participate in Six Sigma activities and projects.

Success of the effort is very highly correlated to the interest and time invested by business leaders.

Deliverables of a Six Sigma Deployment Leader:

- Six sigma strategy and roll-out plan for the overall organization
- Hire team of Master Black Belt, Black Belts, among others
- Work with MBB to identify organization vision and mission
- Provide a goal for the organization to drive Six Sigma at all levels

Benefits of being a Six Sigma Deployment Leader for Organization and for self-career:

- Six Sigma Deployment Leader helps the organization to develop the Six Sigma culture and helps nurture a culture of continuous process improvement.
- Driving Six Sigma in the organization allows the deployment leader to run the company to its full potential, thus, leveraging him/her the additional budget for taking more initiatives.

SIX SIGMA CHAMPION:

Project Champions (Sponsors) are the managers of the business, function, or value stream which has been identified as high priority for a Six Sigma team. They play a pivotal role in that they own the processes of the business and, therefore, must ensure process improvements are captured and sustained.

They typically also manage Six Sigma Green Belts (GB's) and must understand the challenges faced by GB associates (for example, removing roadblocks). They also must work with BB's and MBB's to ensure that their business area has developed, and is implementing, a long-term vision of a Six Sigma operating environment across the entire operative base.

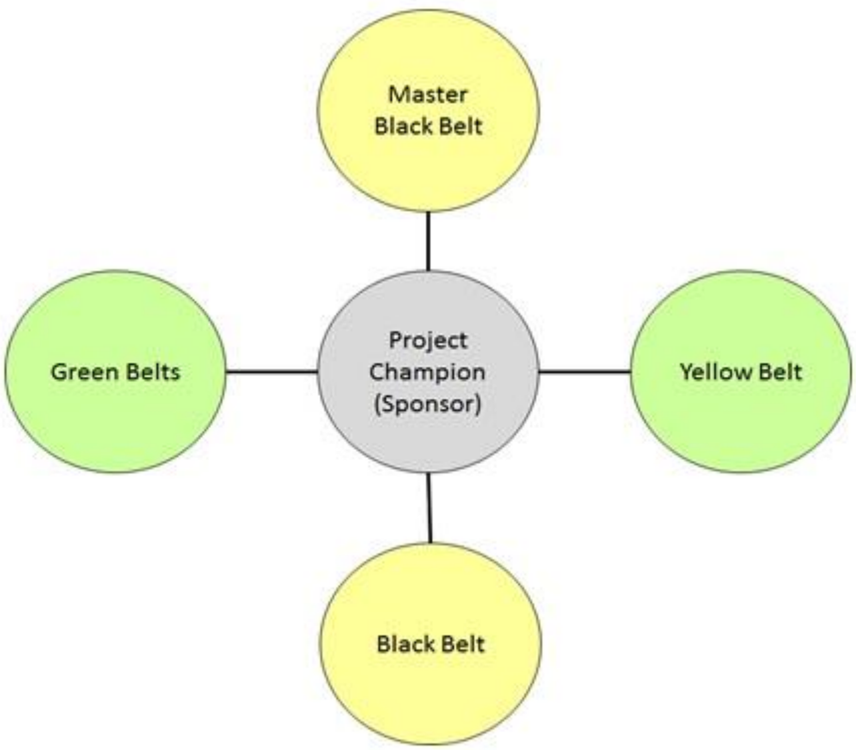
Some more details and associated deliverables on the role of Six Sigma Champion (Sponsor):

- **Training:** Sponsors must participate in available Six Sigma trainings.
- **Support:** Provide visible support for Six Sigma MBB, BB and GB's and provide access to resources needed to conduct the project.
- **Scope:** Set very clear scope for all Six Sigma projects. Ensure that the project is clearly defined, has a scope which can be managed within 4-6 months, and which has high likelihood of success. Watch the project as it progresses to ensure that the scope stays strictly within the bounds originally set.
- **Expectations:** Set high expectations on the value of the results. Ensure the goals are not sub-optimized. The Six Sigma process has proven in many cases to deliver value far beyond initial estimates. Less-than-aggressive goals will yield less-than-aggressive results.
- **Facts:** Challenge Experts on their Knowledge of facts and the basis of their conclusions.
- **Involvement:** Sponsors are expected to interact with project teams on a regular basis to participate in problem solving, make decisions, and allocate resources. Plan to spend at least 2 hours every other week with the project team.

- **Hand-over:** Sponsors will be responsible for ensuring that the business takes ownership of the implementation and delivers the value indicated in the Control phase. This requires a specific individual who will own the delivery of the project metrics.
- **Results:** Sponsors, as well as 6sigma mentors and business controllers, are responsible for ensuring that project results hit the bottom line of the organization.

Benefits of being a Six Sigma Champion (Sponsor) for Organization and for self-career:

- Champions set the direction of process improvements in the organization. They link the benefits of the project to organizational priorities.
- Champions can create a portfolio of projects which could range from projects in Customer Satisfaction, Service, Cost and Quality. It provides the Champions the visibility in the process and also showcases his abilities to top-management to manage varied portfolio of projects.



Six Sigma Interacting Roles

SIX SIGMA MASTER BLACK BELT (MBB):

These individuals are responsible for translating the high level business goals into a Six Sigma strategy for the division and the supporting tactics. They work with the deployment leader to achieve the former. They also lead the development of the Six Sigma skills in the organization, for Black Belts, Green Belts, and the general associate base. MBB's have ultimate responsibility to ensure the quality, value, and sustainability of Six Sigma projects under their guidance.

MBB's are responsible, together, for the success of the overall Division's Six Sigma effort. They coordinate and lead activity on key cross-division value streams (e.g. Customer Service, Cycle Time, Research, etc). They also ensure that a culture that values openness, creativity and challenging the status quo develops in the organization.

Deliverables of a Master Black Belt:

- Six sigma strategy and roll-out plan in the organization/function
- Manage Project of the function
- Mentor Teams
- Achieve Lean Six Sigma Results
- Cross-Functional Leadership
- Project Execution and Removing Roadblocks

Benefits of being a Master Black Belt for Organization and for self-career:

- MBB helps to set the culture of Six Sigma right from the grass-root level in the organization.
- Black Belts are benefited due to the mentoring and statistical skills of MBB.
- MBB can grow up the ladder and become the Chief Quality Officer as he gains experience and expertise in the field of Six Sigma.

SIX SIGMA BLACK BELT (BB):

Six Sigma BB's are full-time/part time project leaders and mentors of the business, including Green Belts and other associates. They have tactical responsibility for executing specific projects and ensuring that the results are captured, the changes are owned by the Champions (Sponsors), and the changes are sustained. They will also lead Six Sigma knowledge transfer to both full- and part-time participants.

BB's are expected to create an environment of open, honest debate of facts. They challenge the status quo where appropriate and share (and seek) ideas across boundaries.

Deliverables of a Black Belt:

- Six sigma strategy and roll-out plan for the given process/area
- Execute Projects
- Help and guide Project Resources/ Help remove project level Barriers
- Team and Project Structuring
- 6 sigma Project Results
- Mentor Green Belts
- Share Best Practices

Benefits of being a Black Belt for Organization and for self-career:

- BB's are responsible for taking the process improvements to the next level in the organization.
- BB's are highly trained on improving results for the organization using statistical analysis and Six Sigma tools. Hence, they have a very lucrative career path ranging from Business Analysts to Process Improvement experts.

SIX SIGMA GREEN BELT (GB):

Six Sigma Green Belts are the engine of Six Sigma projects. Black Belt's support the efforts of the broader business teams to identify and implement change. The GB's are part-time Six Sigma Project Leaders. They are responsible for scoping the projects, leading the project team, calling for help when needed, managing interfaces with business leaders, and ensuring sustainable results.

The goal of GB's is to translate the value of Six Sigma to the specific work environment and problems.

Deliverables of a Green Belt:

- Project Execution
- Team and Project Structuring
- Six Sigma Project Results
- Share Best Practices

Benefits of being a Green Belt for Organization and for self-career:

- GB's have authority in their respective processes and can get the work done effectively. This is a very critical aspect for the organization as it builds its process improvement structure within each process.
- For self-career, GB's receive exposure to senior management directly by virtue of the projects and get the opportunity to make a difference in the organization.

SIX SIGMA YELLOW BELT (YB):

These are the project-specific, full-or part-time resources that provide process and cross-functional knowledge, as well as help to sustain the gains. They have co-ownership of the project with the Six Sigma Experts and are responsible for the quality of the work and results.

This team also plays the critical role of translating the process gains from Six Sigma to other areas of the business after the specific project has been completed. This is the true leverage of Six Sigma methodology!

Deliverables of a Yellow Belt:

- A Yellow Belt has basic knowledge of Six Sigma
- They do not lead projects on their own, as does a Green Belt or Black Belt.
- YB participates as a core team member or subject matter expert (SME) on DMAIC project or projects. Supports Green Belt or Black Belt in developing process maps, helping with data capture, facilitating simulation, and improvements.
- YBs may often be responsible for driving smaller process improvement projects using Lean tools or best practice sharing in their processes.

Benefits of being a Yellow Belt for Organization and for self-career:

- For any project, Yellow Belts are those individuals who are the Subject Matter Experts (SME's) of their respective processes and also have the basic know-how of Six Sigma. They are the spokes of a wheel and can help drive any Six Sigma process to closure by using their process expertise. Organizations can greatly benefit by choosing the right YB's for the right projects.
- For self-career, YB's get exposure of channelizing their Subject knowledge to process improvement opportunities yielding tremendous benefits for self understanding.

Example of a Mobile Phone factory which intends to transition to Six Sigma methodology in a mobile phone factory:

	Functional Role in Organization	Six Sigma Role in a Six Sigma Project
1	Managing Director (M.D.)	Six Sigma Deployment Leader
2	General Manager	Six Sigma Champion (Sponsor)
3	Service Delivery Leader – Operations	Six Sigma Champion (Sponsor)
4	Head – Quality	Six Sigma Master Black Belt (MBB)
5	Manager – Quality	Six Sigma Black Belt (BB)
6	Manager – Operations	Six Sigma Green Belt (GB)
7	Asst. Manager - Operations	Six Sigma Green Belt (GB)
8	Team Leader – Operations	Six Sigma Green Belt (GB)
9	Associates – Operations	Six Sigma Yellow Belt (YB)

Functional Roles vs Six Sigma Roles

SIX SIGMA VS BUSINESS PROCESS REENGINEERING (BPR) - A COMPARISON

What is Business Process Reengineering (BPR)?
BPR is process of streamlining the processes by challenging the each step of the current process. The classic example of BPR is from the banking industry. In the late 1980's and late 1990's, if we wanted to withdraw money from our bank account, following steps were involved:

- Go to the bank during banking operation hours
- Fill in the withdrawal requisition slip
- Submit the slip and receive a token number
- Wait until our token number is announced by the Cash Teller
- Then receive the money

The above process had a lot of drawbacks. We could go to the bank only during their operational hours. Certain banks did not have many branches and thus, we had to go to the location of the bank. We had to fill the withdrawal requisition slip. We had to wait in a queue where others are also waiting to withdraw money and so on.

What did the banking industry do? They radically changed the entire process and in the early 2000's got in the ATM machines. Do we now need to go to our banks? Do we have to wait in queues? Do we need to fill any withdrawal slips? Everything's changed. This kind of a process improvement is called as Business Process Reengineering.

In contrast to BPR, Six Sigma is an approach which focuses on variation (or uncertainty) reduction in processes. It is the only methodology available which is a documented process improvement methodology. Unlike BPR, Six Sigma uses a five step method to identify root causes and provide world-class solutions. Six Sigma does not involve a complete overhaul of the process like BPR. However, it requires out-of-the-box thinking and questioning status-quo to identify and implement solutions. An example of a banking process will be as follows:

Consider that you are applying for an account opening process in a bank. You will need to go through the following steps:

- Meet the banks representative and fill out Account Opening Form
- Provide KYC (Know Your Customer) details and submit identification proofs
- Telephonic verification takes place
- Physical Home Address verification takes place
- Account is created and check book and ATM card is sent to customer address

The above process may have an Account Opening timeline target of 48 hours and the mean performance of the process may be 40 hours, however, the variation may be as high as 8 days. There may be multiple instances where the account opening took place as late as 8 days. That's a long time which is good enough to have angry customer!. And the customer does not look at the mean performance but looks at this specific variation just happened to him. **When a Six Sigma project is applied to above process, it focuses on reducing this variation and streamlining**

the processes to achieve customer satisfaction. It may not necessarily change the entire process flow like it takes place in BPR. This is the key difference between Six Sigma and BPR.

Below is a brief comparison of BPR and Six Sigma:

	Business Process Reengineering	Six Sigma
General Tendency	Radical Redesign	Align & Maintain
Business Drivers	Recession and Changing Market Needs	Service Bundling and Internet
Goals	Streamlining	Process Alignment
Tools	Process Maps	Statistical Analysis
Method	Challenge Process Fundamentals	Prioritize by COPQ (Cost Of Poor Quality) and Capability
Deployment	Top-Down	Top-Middle-Bottom
Key Feature	Outside Consultants	Internal Experts
Impact	Short and Medium-Term	Short, Medium and Long Term
Role of Technology	Enabler	Enabler
Risk/Return	High/Low	Medium/High

Six Sigma vs Business Process Reengineering - A Comparison

WHAT IS STATISTICS?

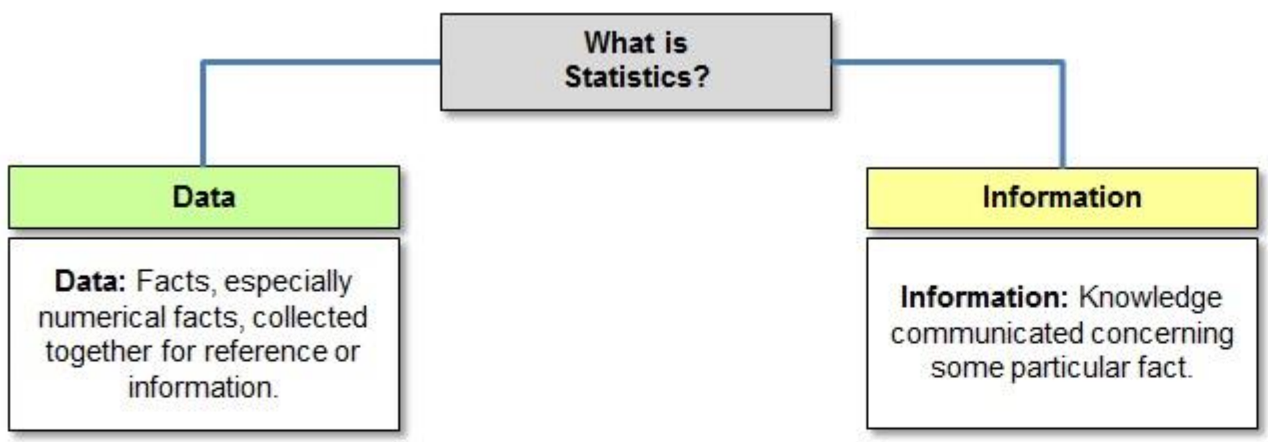
In today's world, we are constantly being bombarded with statistics and statistical information. For example: Customer Surveys, Transactional Data, Marketing Information, Personal Information, among others.

Key questions to answer are:
How can we make sense out of all this data?
How do we differentiate valid from flawed claims?

Let's take a scenario where you are working with a computer manufacturing organization and want to measure customer's satisfaction score for the purchased product. You have kept the target for satisfaction as 80%, and the result of the first thousand surveys is 82%. Have you really achieve customer satisfaction with this result? On doing statistical analysis, you may find your mean survey performance may be 82%, however, the variation within the survey questions is very high i.e. there are many customers who may have rated low on the survey questions (specifically for the product) and would have also not liked the product. Thus, even if you considered 82% as an achieved score for customer satisfaction, your product may not likely survive in the market for long.

Thus, knowing only some arbitrary measurements within or outside Specification Limits doesn't prove much about the real performance and quality. However, only statistics can reveal here the performance and quality and this is why Six Sigma is great, powerful and better than other gut-feeling oriented improvement methodologies.

So, what is statistics then? Statistics is a way to get reliable information from data.



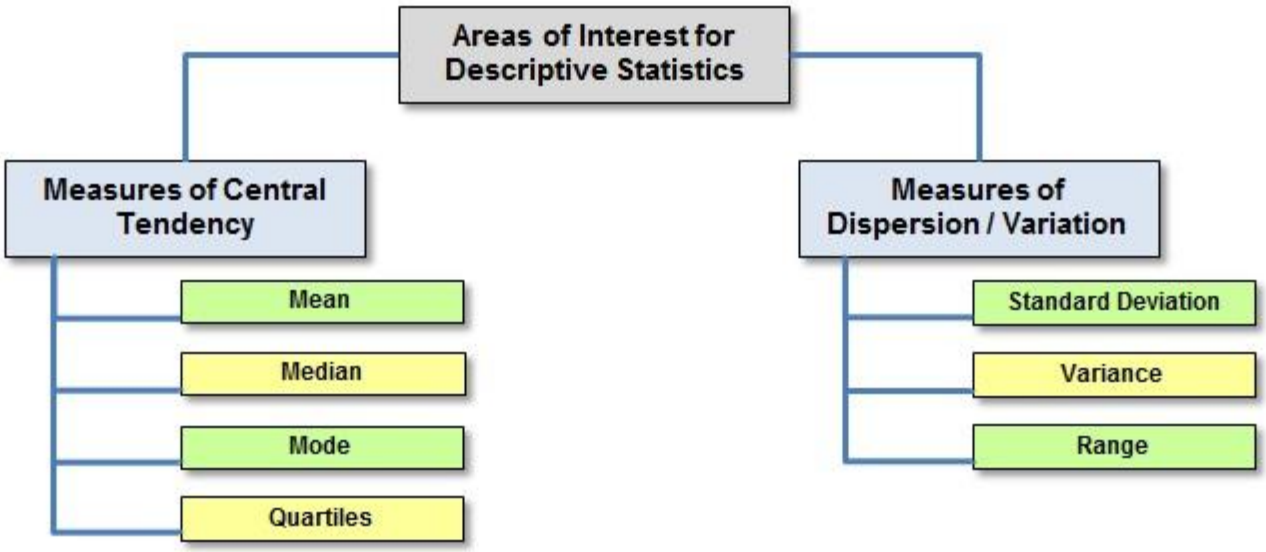
What is Statistics?

Statistics is a tool for creating new understanding from a set of numbers. Statistics can be better understood under two branches:

1. Descriptive Statistics
2. Inferential Statistics

WHAT IS DESCRIPTIVE STATISTICS?

Descriptive Statistics is a method of organizing, summarizing, and presenting data in a convenient and informative way.
The actual method used depends on what information we would like to extract.



Areas of Interest for Descriptive Statistics

MEASURES OF CENTRAL TENDENCY

MEAN (Arithmetic Average):
Mean is the arithmetic average computed by summing all the values in the dataset and dividing the sum by the number of data values. For a finite set of dataset with measurement values X1, X2, …., Xn (a set of n numbers), it is defined by the formula:

$$\mu_x = \sum_{i=1}^{N} \frac{x_i}{N} = \frac{x_1 + x_2 + \ldots + x_N}{N}$$

Mean Formula

The sample mean is represented by x-bar.
The population mean is represented by Greek letter μ.

For a given data set: 12, 14, 11, 12, 12, 12, 15, 17, 22, 15, 12
Sum of data points = (12+14+11+12+12+12+15+17+22+15+12) = 154
Number of data points = (take a total count of observations) = 11
Mean = (Divide sum of data points into total number of data points) = 154/11 = 14

MEDIAN:
The middle number in the data set (n/2), when arranged in ascending order (small to large). If there are odd numbers of observations then median is the (n+1)/2th ordered value. If there are even numbers of observations then median is average of the two middle values.

For a given data set: 12, 14, 11, 12, 12, 12, 15, 17, 22, 15, 12
Ascending Order: 11, 12, 12, 12, 12, 12, 14, 15, 15, 17, 22
Thus, the middle number in the data set **Median** = 12

MODE:
Mode is the data point having the highest frequency (maximum occurrences).

For a given data set: 12, 14, 11, 12, 12, 12, 15, 17, 22, 15, 12
Maximum occurring data point, **Mode** = 12

QUARTILES:
A quartile is any of the three values which divide the sorted data set into four equal parts, so that each part represents one fourth of the sampled population.

- First quartile (designated Q1) = lower quartile = cuts off lowest 25% of data = 25th percentile
- Second quartile (designated Q2) = median = cuts data set in half = 50th percentile
- Third quartile (designated Q3) = upper quartile = cuts off highest 25% of data, or lowest 75% = 75th percentile
- The difference between the upper and lower quartiles is called the interquartile range.

MEASURES OF CENTRAL DISPERSION/VARIATION

STANDARD DEVIATION:
It can be interpreted as the average distance of the individual observations from the mean. Standard deviation of the population is represented as "σ". Standard deviation of the sample is represented as "s".

$$S_x = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \overline{x}\right)^2}{n-1}}$$

Standard Deviation Formula

In the above formula,
Sx stands for standard deviation of the sample.
xi is the value of each variable in the data set.
x bar represents the mean.
n is the total sample size.
And Σ stands for summation i.e. it says that we need to take the sum of "xi – x bar" for all values of x.

VARIANCE:
Variance is defined as the square of standard deviation. Variance of the population is represented as σ times σ. Variance for the sample is represented as "s times s".

$$S_x^2 = \frac{\sum_{i=1}^{n}\left(x_i - \overline{x}\right)^2}{n-1}$$

Variance Formula

In the above formula,
Sx stands for standard deviation of the sample.
xi is the value of each variable in the data set.
x bar represents the mean.
n is the total sample size.
And Σ stands for summation i.e. it says that we need to take the sum of "xi – x bar" for all values of x.

RANGE:
Range is defined as the difference between largest value in a data set and the smallest value in a data set.

$$Range = Value_{Max} - Value_{Min}$$

Range Formula

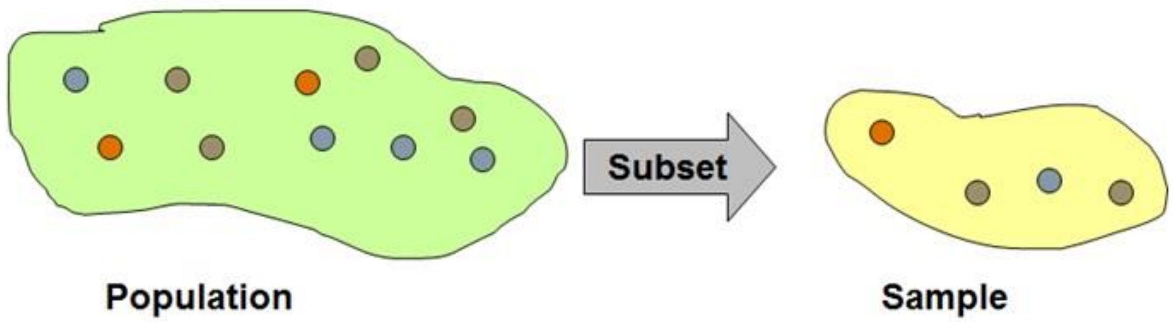
ValueMax stands for the highest (maximum) value in the data set and ValueMin stands for the lowest (minimum) value in the data set.

In a given data-set like 12, 13, 11, 12, 12
Range: 13 – 11 = 2
Mean: (12+13+11+12+12) / 5 = 12
Variance: Sum of [(X – mean) times (X – mean)] / (n – 1) = [0+1+1+0+0] / (5 – 1) = 2 / 4 = 0.50
Standard Deviation: Square Root of 0.50 = 0.7071

WHAT IS INFERENTIAL STATISTICS?

Inferential statistics is also a set of methods used to draw conclusions or inferences about characteristics of populations based on data from a sample.

μ – The mean calculated for a population
σ – The standard deviation calculated for a population



Inferential Statistics

Population : A complete set of data "N"
Samples : A subset of data representing the population "n"

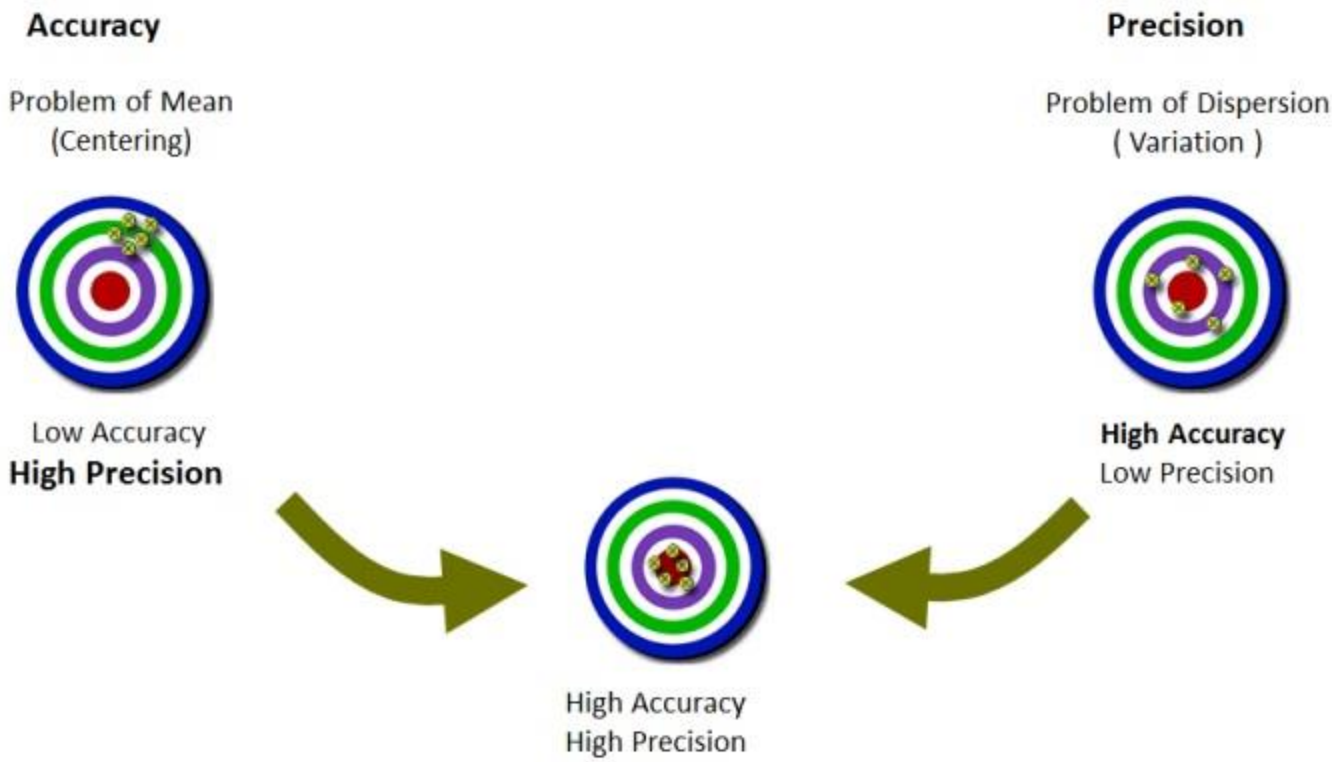
We do Sampling all the time. Whenever we execute a project, it has to be managed under many constraints such as time, cost, resources, among others. Thus, it may not be always feasible for the project to study 100% of the population to derive its inferences. For example, if we are improving the quality of ammunition manufactured in an ammunition factory, we may not be able to do quality test of 100% of the products. This is mainly because the product will get destroyed after testing. Thus, sampling is used in these cases where only a sample of products is taken in for quality testing and inferences are made for the population basis the result of this sampling.

Some other examples of sampling include manufacturing of cars in specific lots i.e. a car manufacturing company manufactures its cars in lots. If it is a lot of 400 cars, they will only test 10 – 15 cars and make an inference of whether to accept the lot or reject it.

Sampling helps in managing the project by utilizing lesser resources and is still effective in getting results. Sampling by and large is done by all of the organizations and thus, it is an important topic for our discussion.

ACCURACY VS PRECISION

Processes may have a problem of Low Accuracy and/or Low Precision. The processes and their associated measurements need to have High Precision and High Accuracy in order produce the expected business outcomes.



Accuracy vs Precision

As we see in the above picture on the top-left corner, all the darts are concentrated in one corner of the board instead of being concentrated at the center of the dart board. This is an example of High Precision and Low Accuracy. Processes which have high precision and low accuracy need to work towards improving their accuracy so that they start achieving the target.

Similarly, the picture on the top-right corner indicates that all the darts are around the internal blue line of the dart-board but are not exactly on target. This is an example of a situation with High Accuracy and Low Precision. Processes with High Accuracy and Low Precision need to focus on improving their precision so that they start achieving the target.

SIX SIGMA DMAIC PROCESS - INTRODUCTION TO "DEFINE" PHASE

Define Phase of Six Sigma DMAIC Process consists of following activities:

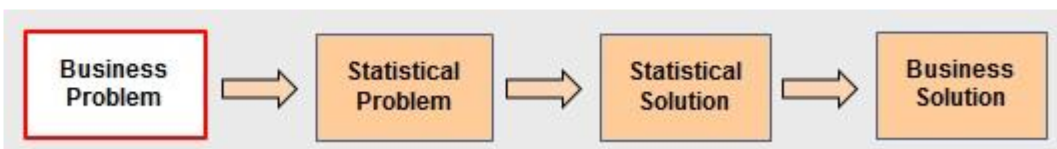
Step 1: Validating Business Opportunity and Project CTQ (Critical To Quality) Identification.

- Capturing Voice of Customer (VOC).
- Translating VOC into Y's.
- Selecting key Y(s) for the project.
- Initiate Project Charter for each "Y".

Step 2: Project Storyboarding and Team Charting.

- Create a business case.
- Problem and Goal Statement.
- Scoping the Project.
- Project Milestone.
- Resource Plan – Roles and Responsibility.

Step 3: SIPOC and As-Is Process Mapping.



Six Sigma DMAIC Process - Define Phase

SIX SIGMA DMAIC PROCESS - INTRODUCTION TO "MEASURE" PHASE

Measure Phase of Six Sigma DMAIC Process consists of following activities:

Step 4: Identify Possible Project Y's and Data Collection Strategy.

- Collect data on performance of y.
- Collect data on y for stability.

Step 5: Validate Measurement System.

- Study the Measurement System of y.
- Review R&R (Repeatability & Reproducibility) to validate the Measurement system.
- Improve R&R if variation is high.

Step 6: Determine Process Capability.

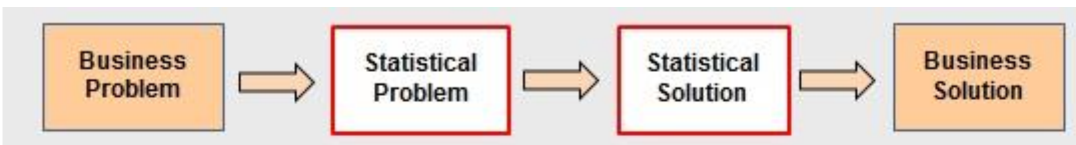
- Evaluate the capability of y (Calculate present Z value for y).
- Review Baseline Performance with set target and revise Targets if required.
- Update project charter and obtain Management approval.

SIX SIGMA DMAIC PROCESS - INTRODUCTION TO "ANALYZE" PHASE

Analyze Phase of Six Sigma DMAIC Process consists of following activities:

Step 7: Identify Vital Project X's and statistically validate them.

- Develop a Detailed business process map.
- Analyze the process map to identify variation sources.
- Determine the x's (the potential causes).
- Prioritize and collect data on x's.
- Quantify the relationship [Y = f(x)].
- Identify the vital x's from the potential x's.
- Validate the vital x's.



Six Sigma DMAIC Process - Analyze Phase

SIX SIGMA DMAIC PROCESS - INTRODUCTION TO "IMPROVE" PHASE

Improve Phase of Six Sigma DMAIC Process consists of following activities:

Step 8: Generate Potential Solution and Assess their Failure Mode.

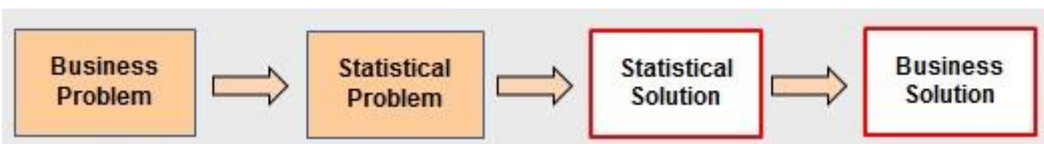
- Develop "Feasible solutions' to improve y.
- Determine operating limits of X's.
- Analyze cost-benefits aspects of the feasible solutions.

Step 9: Validate Pilot Solution(s).

- Develop a pilot plan to validate selected solution.
- Conduct pilot run to confirm the performance results of y with set targets [New Z value].
- Study the influence of solution on the other measures (y's) and on overall measure (Y).
- Evaluate financial gains.
- Finalize the modified process flow.

Step 10: Process Control and Risk Analysis.

- Develop risk mitigation plan and Process Control Systems.
- Develop roll out plan and Implement solution.



Six Sigma DMAIC Process - Improve Phase

Develop feasibility solutions to improve performance of Y and implement selected solutions are two key actionables of Improve Phase.

SIX SIGMA DMAIC PROCESS - INTRODUCTION TO "CONTROL" PHASE

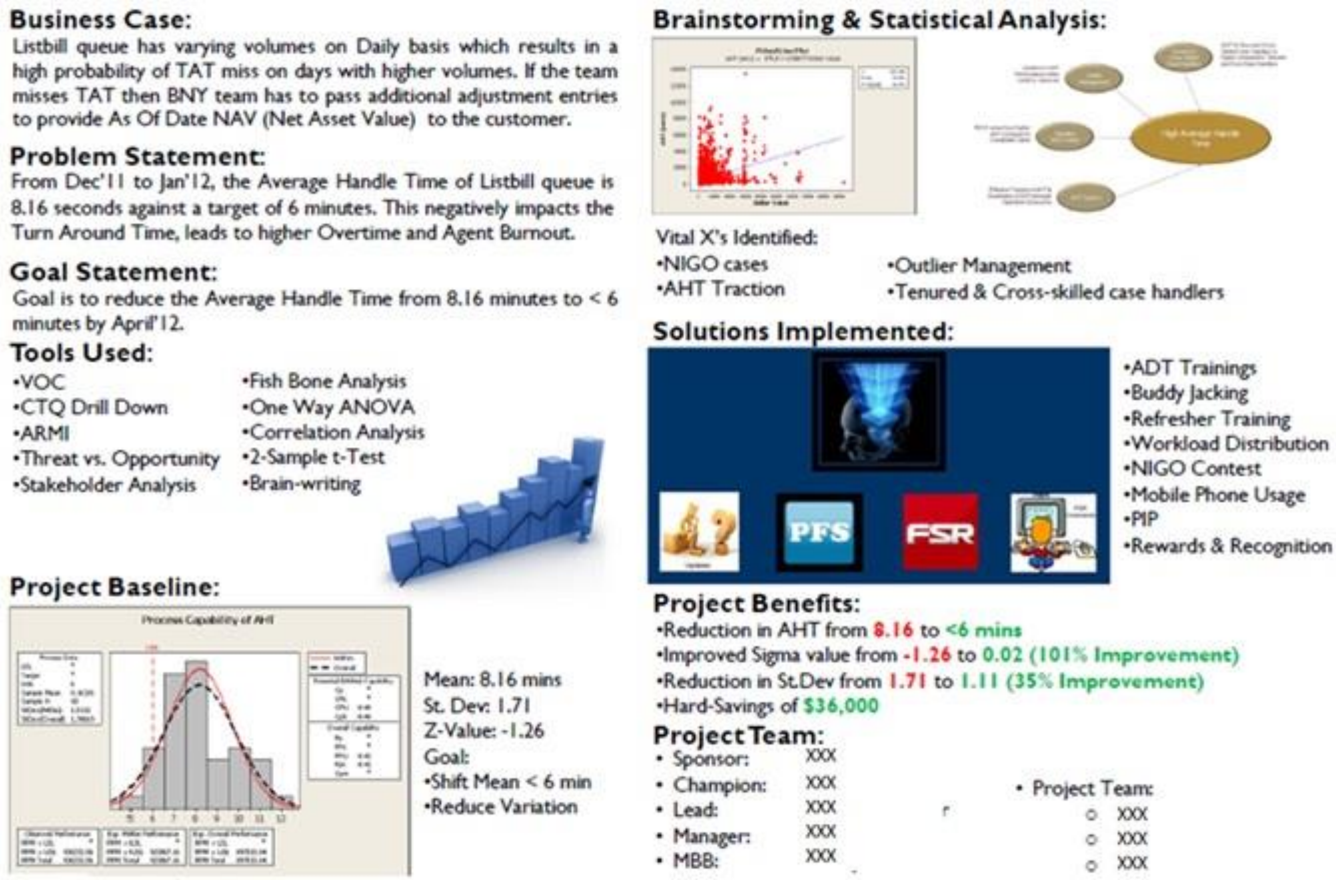
Control Phase of Six Sigma DMAIC Process consists of following activities:

Step 11: Execute control Plan and Finalize Documentation.

- Monitor post implementation process performance to ensure expected improvement in project y has occurred.
- Ensure ongoing process monitoring system is in place.

Step 12: Communicate to Business Results and sign off to close the Six Sigma Project.

SIX SIGMA DMAIC PROCESS - A REAL WORLD EXAMPLE



Six Sigma DMAIC Process - A Real World Example

SIX SIGMA DMAIC PROCESS - DEFINE PHASE - CAPTURING VOICE OF CUSTOMER (VOC)

What is Voice of Customer?
Voice of Customer is the customer's voice, expectations, preferences, comments, of a product or service in discussion. It is the statement made by the customer on a particular product or service.

Customer Identification:
Customer is the one who buys or uses your products/services and he/she is the one who receives the process output. We broadly classify customers into two categories:

- **Internal Customers:** Internal Customers are the ones who are internal to the organization. They are Management, Employee(s) or Any Functional Department in your organization.
- **External Customers:** External Customers are not a part of the organization. They are either the ones who use our product(s) or service(s) or have vested interest in the organization. For e.g. Clients, End-Customers, Shareholders, among others.

Customer Needs and Requirements:
Need is a desire or an expectation of a customer from a given product or service. Customers may have many stated needs which are often vague and generally are "wants" from a product/service.

For example Customer requires an Air-Conditioner for its use in his/her bed-room. The real need of the customer is cool temperature in the bedroom. Similarly, the real want from the Air-Conditioner is it has to be quite, cost-effective and maintenance free. When the customer states his/her requirements, we will often get to hear that the need is "Cool Temperature, Less Noise (quite), Cost Effective and Free of Maintenance". However, "Cool Temperature" is the need and the rest are just wants. It is important for the project team to understand the stated needs of the customer and separate them from wants.

The main reason that we separate needs and wants are: Needs are important critical features and Wants are expectations of the product or service over and beyond the needs. If the product/service is not able to fulfill "Wants" of the customer, the customer may only be highly displeased / dissatisfied. However, if the product/service is not able to fulfill "Needs" of the customer, he/she will not use the product/service and there is a high likelihood that he/she will switch to competitors product/service. Organizations reputation may also be at stake if "Needs" are not met.

Requirement is an attribute of the product or service which fulfils the needs of a customer. Customer defines these requirements and are the "musts" of a product or service.

For example in the above example of an air-conditioner, customer's requirement is "Cool Temperature" and the rest are "Good to Have" features. Customer will not buy the Air-Conditioner if all of "Good to Have" features are present but the "Requirement(s)" are not fulfilled. However, customer may buy the product/service if the "Requirement" is fulfilled and "Good to Have" features are present or not present.

Translating Voices to Needs:
Voice of Customer (VOC) methodology can be used to capture the customer needs – both current (stated needs) and latent (unstated needs). VOC methodology helps capture the needs of customer through stated verbatim comments (customer voices). It helps translate verbatim comments (customer voices) into customer needs to product/service output characteristics (customer requirements).

Distinct Categories of VOC:
At an organization level we broadly classify VOC into four distinct categories (AICP):

- **Voice of Associate:** The feedback that we get from our Employees
- **Voice of Investor:** The feedback that we get from our Management and Shareholders
- **Voice of Customer:** The feedback that we get from our Clients and End-customers
- **Voice of Process:** The feedback that we get from measuring our CTPs (Critical To Process) and CTQs (Critical To Quality)

Six Sigma - Voice of AICP (Associate, Customer, Investor and Process)

Voice of Customer (VOC) Methods:

- **Surveys:** Surveys are a designed set of questionnaire which is sent out to potential or existing customers. Surveys are cost effective, however, have very low response rate.
- **Interviews:** Interviews are individual meetings with potential or existing customers where a set of questions are asked and answers are discussed to understand customer voices. Interviews can tackle Complex Issues, however, requires Trained Resources.
- **Focus Group:** A group of people are called together in one conference room and a discussion is held on specific topics that need to be addressed. These focus groups are excellent for identifying the CTQ (Critical to Quality), however, are difficult to generalize.

- **Suggestions:** Client/Customer/Employee feedback is received and treated as suggestion to improve product or service. Suggestions provide good improvement opportunities, however, does not look at overall process.
- **Observations:** During the course of the process, individuals can have observations and can provide feedback to the process which does act as a Voice of Customer.

Below is a sample of Voice of Customer that is translated into a Requirement:

Verbatim	Need	Requirement
"I want the pizza that I ordered"	Right pizza to right person	Accuracy
"I want my pizza when you said it would be here"	Pizza delivered on time as promised to customer	Timeliness
"I want my delivery person to be friendly"	Pizza delivery person is polite	Complaints
"I'm not going to pay a lot for this pizza"	Price is equal to or less than all other pizza providers	Price

Six Sigma - Translating Voice of Customer into Requirements

SIX SIGMA DMAIC PROCESS - DEFINE PHASE - KANO ANALYSIS

KANO Analysis is about prioritizing customer requirements once they are established. Requirements are prioritized as:

- Basic Requirements
- Performance Requirements
- Delighter Requirements
- Indifferent Requirements
- Reverse Requirements

Six Sigma - KANO Analysis

Let's look at each of these Requirements in detail:

Basic Requirements:
Basic Requirements are "must-be's". They are the most important needs of customers. They are required and expected to be there. These are the needs the customer assumes will be met. When these requirements are unfulfilled, the customer is greatly dissatisfied and when fulfilled, the customer is neutral (i.e., they do not produce additional satisfaction).

Performance Requirements:
A direct positive correlation exists between satisfaction levels and the degree of presence of these performance requirements. The more performance requirement elements needs are met, the better

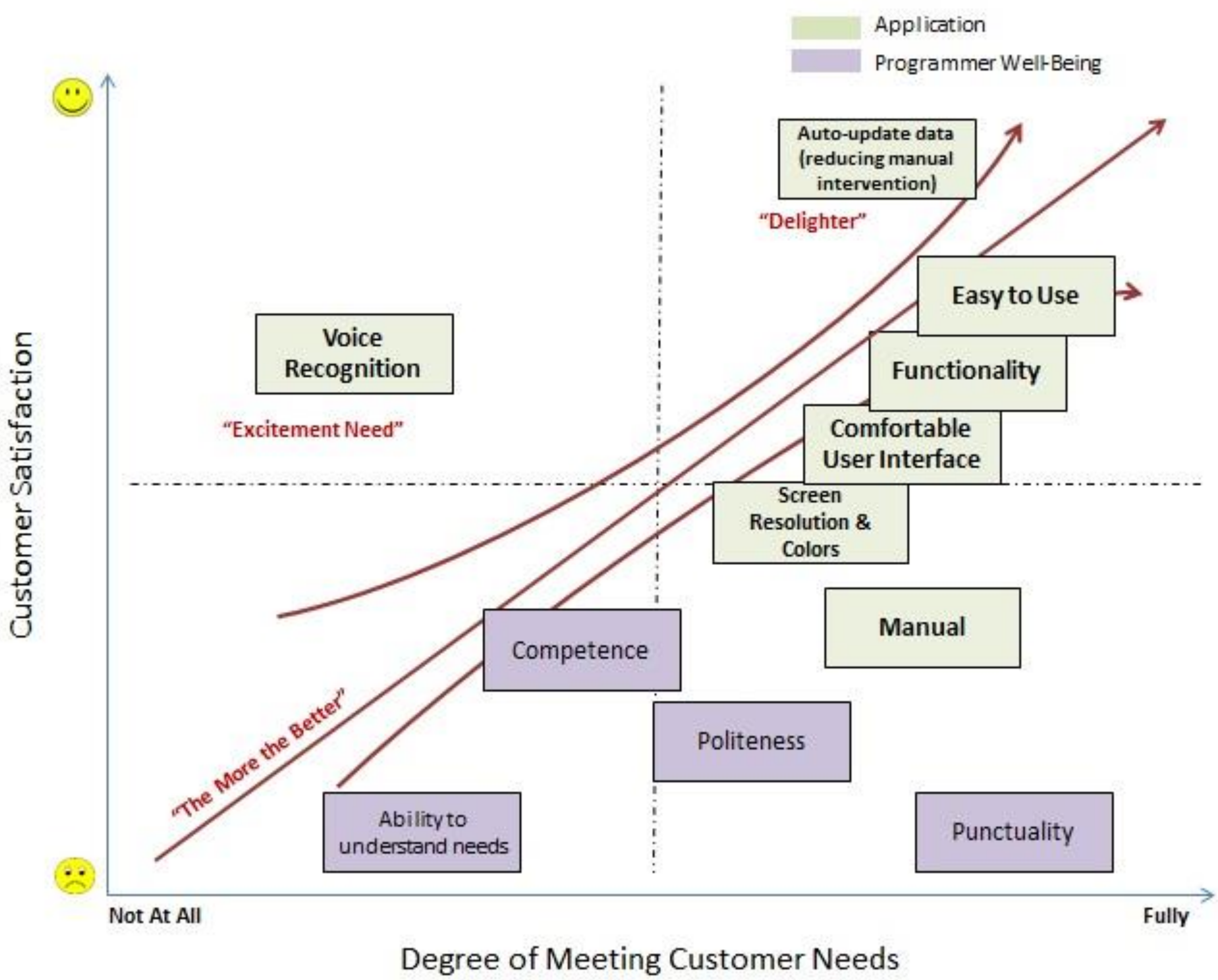
it is for the product or service.

Indifferent Requirements:
Indifferent elements are needs that result in neither satisfaction nor dissatisfaction whether they are present / met or not.

Reverse Requirements:
Reverse elements are needs that result in: 1) Dissatisfaction when they are fulfilled and Satisfaction even when they are not fulfilled. They may indicate that the perception of that question in the marketplace is the opposite of the perception of the survey's creator.

Delighter Requirements:
Delighter Requirements are “attracters”. Their presence in a product/process is unexpected and fulfill the latent needs of a customer. They lead to great satisfaction if found present. When delighters are absent, the customer still is neutral (& not dissatisfied).

Below is an example of a KANO Analysis for a Software Application.

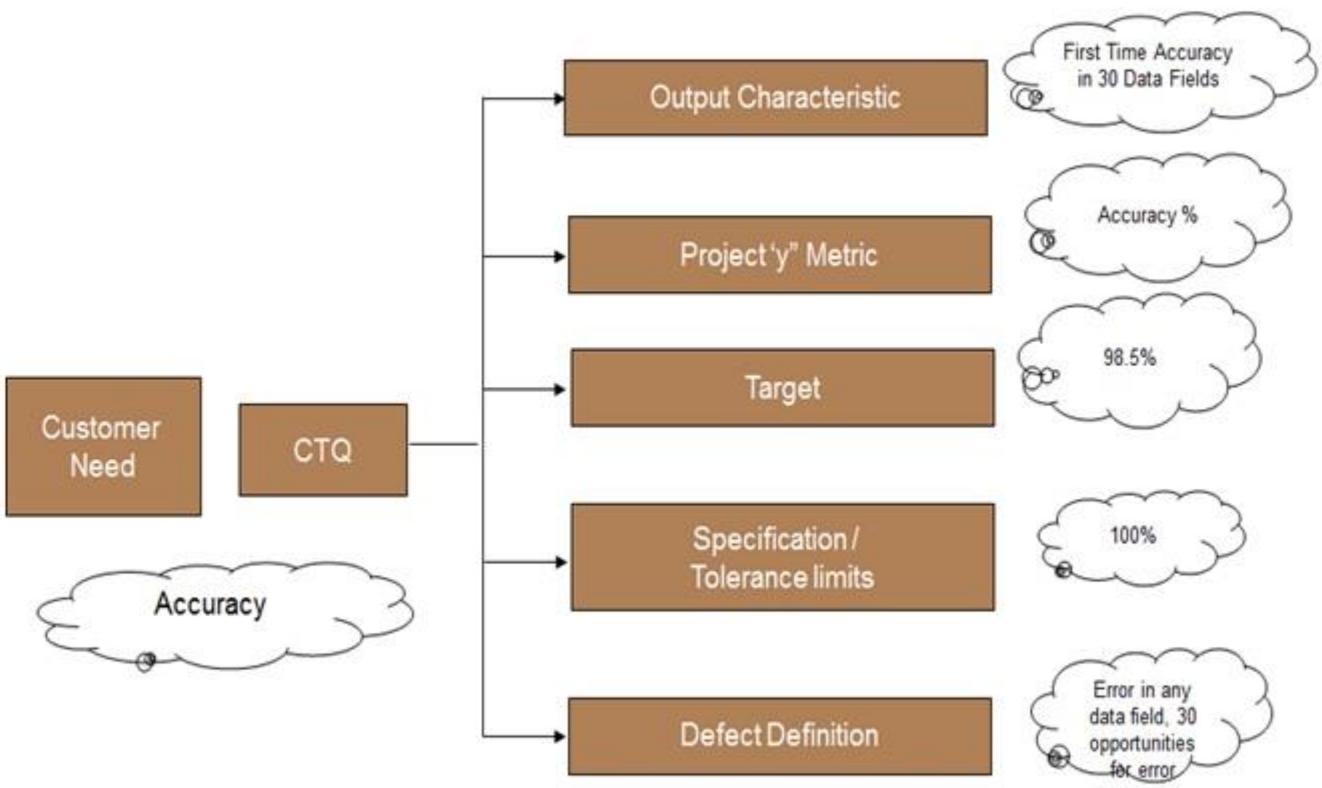


Six Sigma - KANO Analysis Example for a Software Application

SIX SIGMA DMAIC PROCESS - DEFINE PHASE - CTQ (CRITICAL TO QUALITY) DRILLDOWN TREE

CTQ (Critical to Quality) drilldown tree is a tool that can be used to effectively convert customer's needs and requirements to measurable product/service characteristics, to establish linkage between Project "Y" & Business "Y" and to bound the project or to make the project manageable.

Below is an example of CTQ Drilldown Tree and their associated measurements for two different processes:



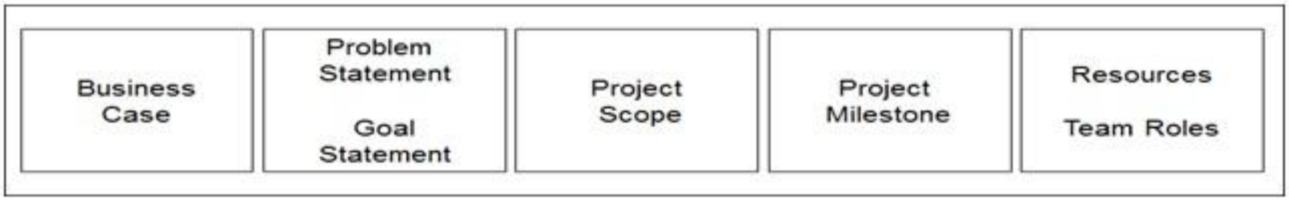
Six Sigma - CTQ (Critical to Quality) Drilldown Tree for Data Entry Application

Customer CTQs	Customer Needs	Output Measurements	Process Measurements	Input Measurements
Accuracy	Right pizza to right person	Y1: % of wrong pizzas delivered	X1.1: % orders matched (post oven)	
Politeness	Pizza delivery person is polite	Y2: % of complaints		
Timeliness	Pizza delivered on time promised to customer	Y3: # minutes taken (customer order time to pizza delivery time)	X3.1: Cook time X3.2: Oven temperature X3.3: Delivery time	X3.4: Order volume

Six Sigma - CTQ (Critical to Quality) Drilldown Tree for Pizza Delivery Process

SIX SIGMA DMAIC PROCESS - DEFINE PHASE - SIX SIGMA PROJECT CHARTER

Project Charter is a document that provides a framework and objective for a Six Sigma Process Improvement and/or Problem-solving Project.



Six Sigma Project Charter

Business Case:
Business case helps to understand how the project is linked with the overall business objectives. Business case explains why there is a need for the organization to undertake the project and how it will support organizational objectives.

The business case should be able to answer the following questions:

- Why is the project **worth doing?** Justify the resources necessary to engage in the project.
- Why is it **important to customers?**
- Why is it important to the **business?**
- Why is it important to **employees?**
- Why is it important to **do it now?**
- What are the **consequences of not doing** the project now?
- How does it **fit with the operational initiatives and targets?**

Business Case Example:
"By reducing the average transaction length, the queue would be able to enhance the Speed of Resolution and assist the end-users in fastest possible manner. This will not only help in achieving client targets but also increase end-user satisfaction score by offering lesser turn-around time."

Problem Statement:
Problem statement should quantitatively describe the pain in the current process

- What is the pain ?
- Where is it hurting?
- When – is it current? How long it has been?
- What is the extent of the pain?

What a Problem Statement should not do is Assign a Cause or Blame and Include a Solution.

Problem Statement Example:
"In the last 3 months **(when)**, 12% of our customers are late, by over 45 days in paying their bills **(what)** . This represents 20% **(magnitude)** of our outstanding receivables & negatively affects our operating cash flow **(consequence)** ."

Goal Statement:
Defines the improvement the team is seeking to accomplish. It starts with a verb. It Should not presume a cause or include a solution. It has a deadline. It is actionable and sets the focus. It should be SMART (Specific, Measurable, Attainable, Relevant and Time Bound).

Goal Statement Example: To reduce the percentage of late payments to 15% in next 3 months, and give tangible savings of 500KUSD/ year.

Project Scope:
Project Scope helps us to understand the start and end point for the process and also gives an insight on project constraints and dimensions. It's an attempt to define what will be covered in the project deliverables. Scoping sharpens the focus of the project team & sets the expectations right. There are two types of scoping:

- Longitudinal Scoping
- Lateral Scoping

Absence of proper scoping may result in the team **losing interest** in the project. Project becomes **difficult to implement**. Even after implementation, the **desired benefits are not seen.** Team focuses on trivial pain areas, and **missing out the real ones.** Process selected is **too broad to handle.**

Longitudinal Scoping: Longitudinal scoping is done on the length of the process
e.g. – From the receipt of PO till the delivery at the distributor's go-down
e.g. – From the time of customer reporting the complaint till final satisfaction confirmation
Mostly the 'start' & 'end' points are fixed. A macro as-is process map must be prepared to facilitate longitudinal scoping.

Lateral Scoping is done on the breadth of the process
e.g. – All despatches from North & South regions
e.g. – Calls received during general shift

By using Longitudinal and Lateral Scoping methods, we know what all kinds of units the process will cover, in what situations the process is valid, what are the qualifiers for the transactions, what functional domains does the process cover and in what geographical areas the process is valid.

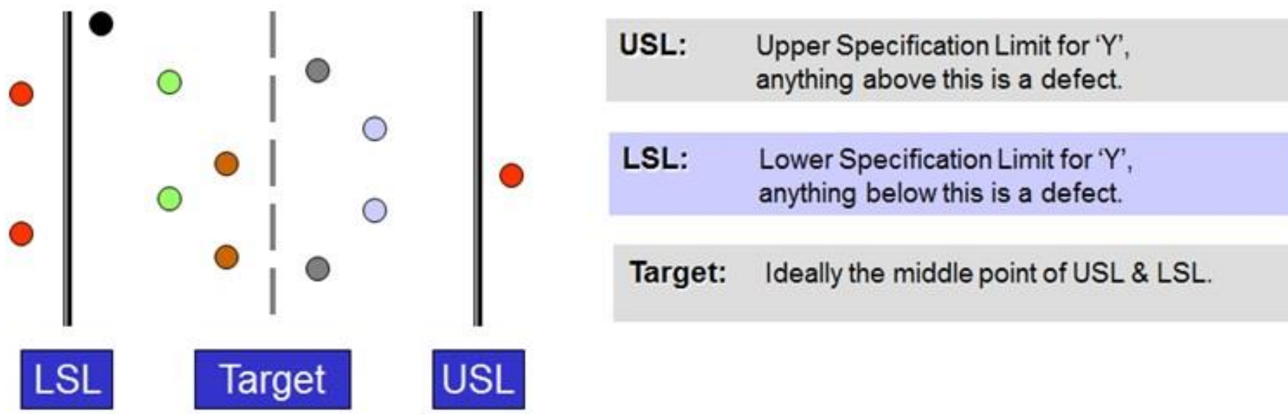
Scoping Example:

Longitudinal Scope: The time when the Sourcing team receives the resume of a referral or the time when a candidate walks in to organization premises for an interview and joins the organization.

Lateral Scope: Candidates interviewed till Senior Manager level across the organization, all locations.

Project Milestones:
Project milestone in a charter specifies timelines for completion of each phases with signed tollgates. It is a preliminary, high level project plan with dates, which is tied to phases of DMAIC process. It should be aggressive (don't miss "Window of Opportunity") yet should be realistic (don't force yourselves into "Band-aid" solution). The project milestones to further include a detailed project plan (Gantt chart) along with a documented communication plan.

Specification Limits:
A specification is a customer-defined tolerance for the output unit characteristics. There may be two-sided specifications – Upper Specification Limit (USL) and Lower Specification Limit (LSL). Any data point above the USL and below LSL is termed as defect. Specifications form the basis of any defect measurement exercise on continuous data.



Six Sigma Process Specification Limits

Specification limits should follow the RUMBA acronym. RUMBA stands for Reasonable, Understandable, Measurable, Believable and Attainable.

Reasonable: The specification based on a realistic assessment of customer's actual needs. We need to check if the specification relate directly to the performance of the characteristic.
Understandable: The specification is clearly stated and defined so that no one can misinterpret it.
Measurable: We should be able to measure the characteristic's performance against the

specification. If not, a lot of debate will ensue between you and your customer as to whether the specification has been met.

Believable: We should have bought into the specification setting. That is, we and our teams should strive to meet the specification.

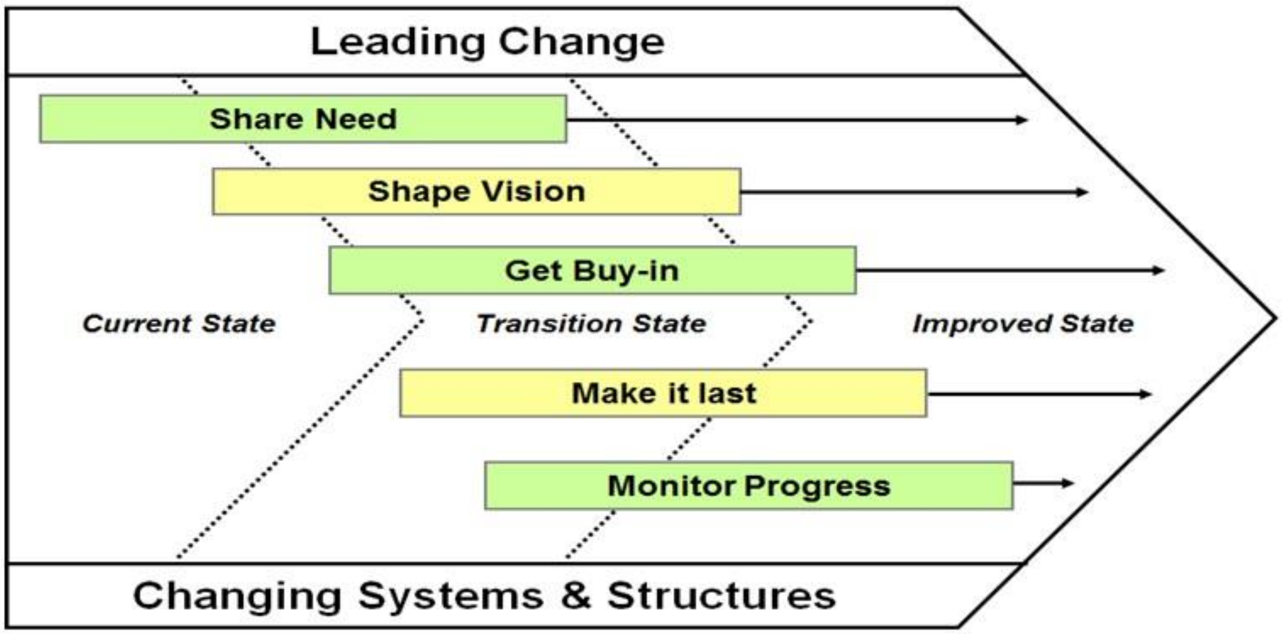
Attainable or Achievable: We should be able to reach the level and range of the specification.

Resources and Team Roles:

Ultimately executive leadership team together with Six Sigma Deployment Leader and Six Sigma Champion need to ensure that a trained Six Sigma Team and associated hardware and software resources are in place to successfully implement the Six Sigma project and deliver great results and customer value!

SIX SIGMA DMAIC PROCESS - DEFINE PHASE - CHANGE ACCELERATION PROCESS (CAP)

Change Acceleration Process (CAP) is the process of moving the Current State of the Process/Service/Product to an Improved State by catalyzing (speeding up) the Transition State.



Six Sigma Change Acceleration Process (CAP)

CAP depends on Leading Change, Creating a Shared Need, Shaping a Vision, Mobilizing Commitment (Getting buy-in from Stakeholders), Making the Change Last and Monitoring Progress. All implementation projects require a Champion who sponsors the change if they are to be successful (Leading Change). The reason to change, whether driven by threat or opportunity, is instilled within the organization and widely shared through data, demonstration, demand, or diagnosis. The need for change must exceed the resistance to change (Creating a Shared Need). The desired outcome of change is clear, legitimate, widely understood, and shared (Shaping a Vision). There is a strong commitment from key constituents to invest in the change, make it work, and demand and receive management attention (Mobilizing Commitment). Once change is started, it endures and flourishes and learnings are transferred throughout the organization (Making the Change Last). Progress is real; benchmarks are set and realized; indicators are established to guarantee accountability (Monitoring Progress). Management practices are used to complement and reinforce change (Changing Systems and Structures).

ARMI (Approver, Resource, Member, Interested Party):

ARMI model is a CAP tool used to assess each person's role in the project during various phases of the project. ARMI is an acronym of

- **A** - Approval of team decisions
- **R** - Resource of the team, one whose expertise/ skills may be needed
- **M** - Member of team, with the authorities and boundaries of the charter
- **I** - Interested Party, one who will need to keep informed on direction and findings

ARMI helps in defining the role of each individual within the project team. It helps in clarifying any ambiguity related to the roles and responsibilities of these individuals. Let's look at an example of ARMI:

Members	Role	Define	Measure	Analyze	Improve	Control
Name 1	Six Sigma Champion	A	A	A	A	A
Name 2	Six Sigma Champion	A	A	A	A	A
Name 3	Six Sigma Deployment Leader	A	A	A	A	A
Name 4	Master Black Belt	A	A	A	A	A
Name 5	Process Manager	A	I	I	A	A
Name 6	Black Belt	R	R	R	R	R
Name 7	Deployment Leader	R	R	R	R	R
Name 8	Subject Matter Expert	M	M	R	R	R
Name 9	Trainer	M	M	R	M	R
Name 10	Trainer	M	M	R	M	R

Six Sigma ARMI (Approver, Resource, Member, Interested Party) Example

Project Acceptability:
Project Acceptability is based on the below equation:
Effectiveness of a solution = **Quality** of a solution * **Acceptability** of the solution.

$$E = Q^*A$$

$$100\%[E] = 20\%[Q] * 80\%[A]$$

Six Sigma Effectiveness Equation

The above equation states that in order to achieve 100% Effectiveness, our Quality and Acceptability of the Solution contribute to the tune of 20% and 80% respectively.

Improvements bring about change and it is a commonly known fact that change is always resisted. It is important to for all of us to realize that just finding a solution to the problem is not good enough. The identified solution should be understood and implemented.

It is important to create a “shared-need” as early as possible in your project journey as it helps in. Then, it is important to continue building the momentum for the change initiative. Finally, it’s important to prepare your people/organization for the change by answering the most critical human need – “WIIFM!” (What’s In It For Me).

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.

Three commonly used CAP tools to help create a shared need are:

- Critical Success Factors
- Stakeholder Analysis

Critical Success Factors:
These are factors that are critical for the success of the project and needs to be considered and tracked. Some of these factors are Appropriate Metric, Data Availability, Resource Availability, Proximity to Champion/Stakeholders, Degree of Difficulty, Scalability, Benefits. All of the Critical Success Factors need to be articulated well to ensure stakeholder buy-in.

Stakeholder Analysis:
This tool helps the team answer questions like:

- Who are the key stakeholders?
- Where do they currently stand on the issues associated with this change initiative?
- Where do we need them to be in terms of their level of support?

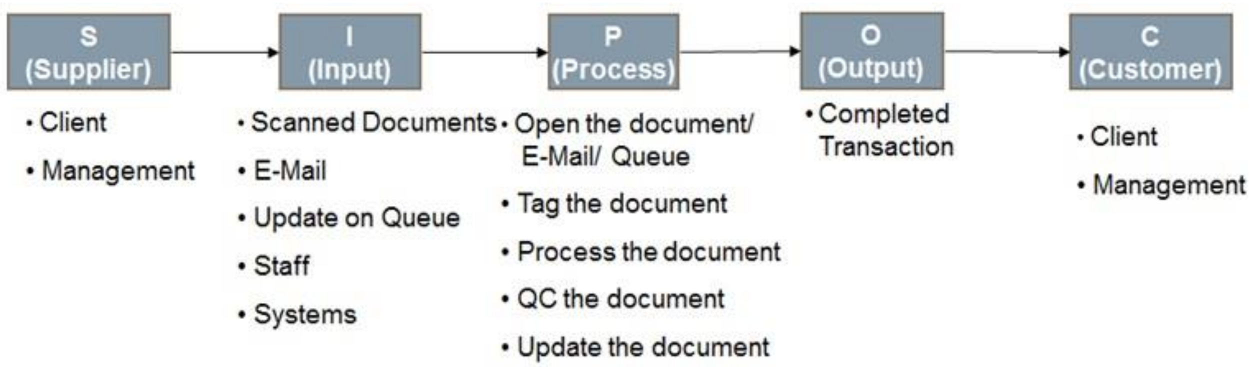
Stakeholder Name	Strongly Against	Moderately Against	Neutral	Moderately Supportive	Strongly Supportive
Director					√
Sr. Manager				√	
Master Black Belt					√
Black Belt					√
Team Member 1				√	
Team Member 2			√		
Team Member 3					√

Six Sigma Stakeholder Analysis Example

SIX SIGMA DMAIC PROCESS - DEFINE PHASE - PROCESS MAPPING / SIPOC

SIPOC is an acronym of Suppliers, Inputs, Processes, Outputs and Customer. SIPOC as a tool displays a cross-functional set of activities in a single and simple diagram which helps us identify process inputs (Xs) and outputs (Ys), identify process owner, customers & suppliers and identify & establish boundaries for the process. The five key elements of SIPOC are:

- **Supplier** – Whoever provides the input to your process
- **Input** – The product or data that a process does something to or with to deliver the required output
- **Process** – The activities you must perform to satisfy your customer's requirements and deliver the output
- **Output** – The product or data that results from the successful operation of a process
- **Customer** – Whoever receives the output of your process



Six Sigma SIPOC (Supplier, Input, Process, Output and Customer) Example

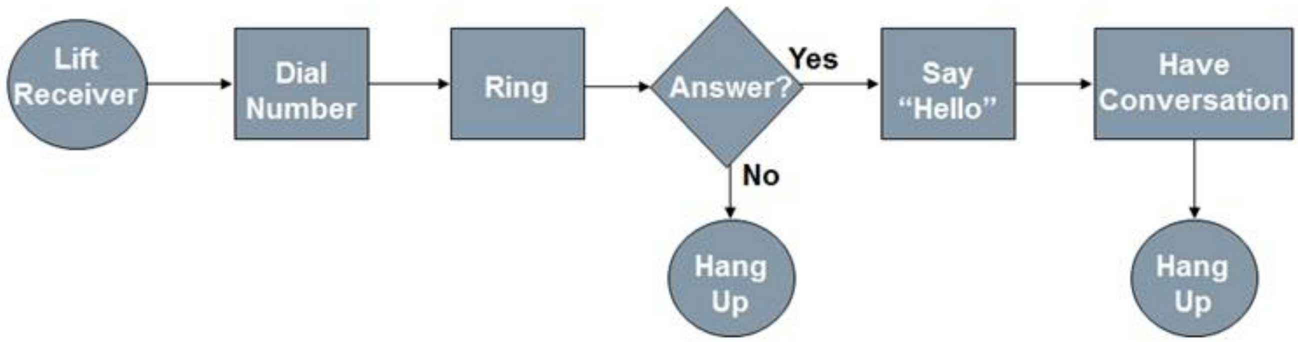
SIX SIGMA DMAIC PROCESS - DEFINE PHASE - PROCESS MAPPING / FLOW CHARTING

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

Process maps help characterize the functional relationships between various inputs and outputs. Three commonly used process mapping tools to create detailed process maps are:

- Process Flowchart
- Deployment Flowchart
- Alternate Path Flowchart

Process Flowchart:
Process Flowchart is a simple step by step process of activities carried out in the process.

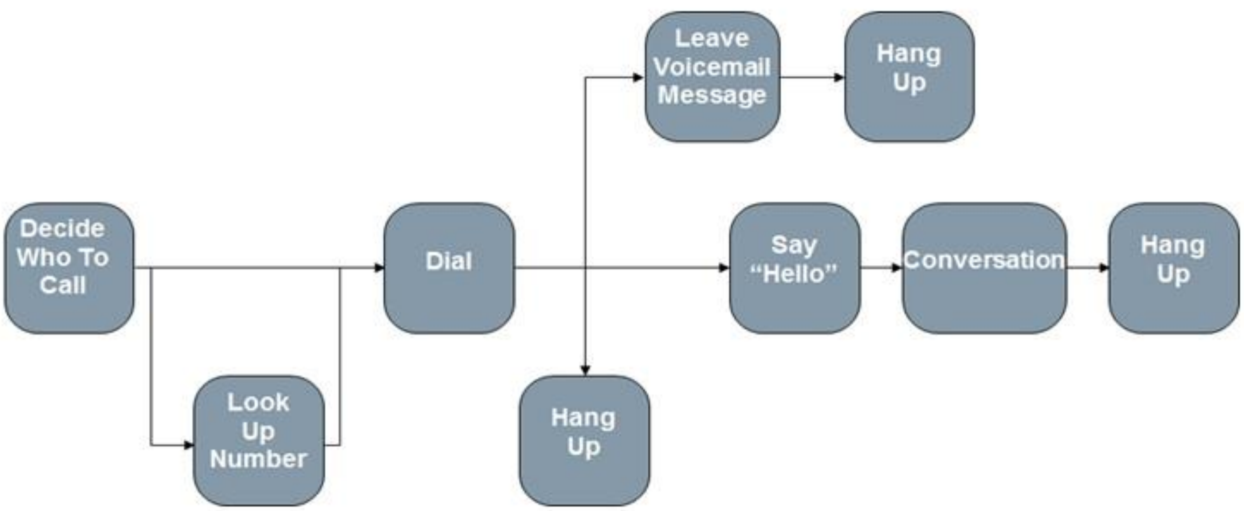


Six Sigma Process Flowchart

Deployment Flowchart:
A deployment flowchart is also referred to as Swimlane flow chart or cross-functional flowchart describing the roles of different departments/stakeholders involved in the process.

Six Sigma Deployment Flowchart

Alternate Path Flowchart:
Alternate Path Flowchart is a step-by-step flowchart which provides alternate paths for most of its steps. This is unlike the swimlane (deployment) or regular flow-charts.



Six Sigma Alternate Path Flowchart

SIX SIGMA DMAIC PROCESS - MEASURE PHASE - IDENTIFY POSSIBLE PROJECT Y's

Measurement Types to identify possible project Y's:

- **Effective measures:** Effective measures is how well a process meets the requirements. For example: Did I give the correct answer to an incoming call?
- **Efficiency measures:** Efficiency measures is how well resources are allocated to execute the process. For example: Cost per transaction.

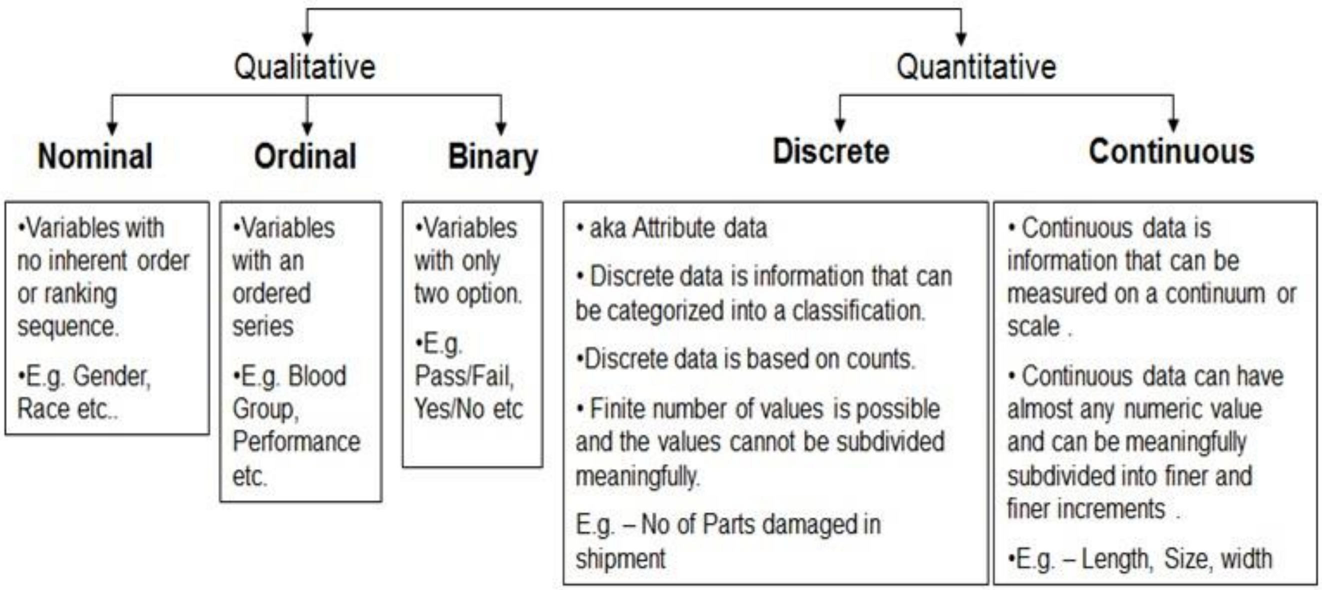
Consideration during evaluating measurements for Y's:

Measures always have the customer perspective and are linked to the business goal. Measurement system is understood in terms of its accuracy, repeatability, reproducibility. Benefits of capturing the measure outweigh the cost. Measure is relevant to the process. It has the process been mapped, identifying the key measurable outputs and inputs per step. And the measure is not ambiguous.

SIX SIGMA DMAIC PROCESS - MEASURE PHASE - TYPES OF DATA

There are two types of Data – Qualitative and Quantitative.

Qualitative data is subjective in nature and cannot be measured objectively. It can be ranked or ordered. Quantitative data is objective in nature and can be measured. Qualitative data is further bifurcated as Nominal, Ordinal and Binary whereas Quantitative data is either Discrete or Continuous. Example are described in the below diagram.



Six Sigma - Data Types

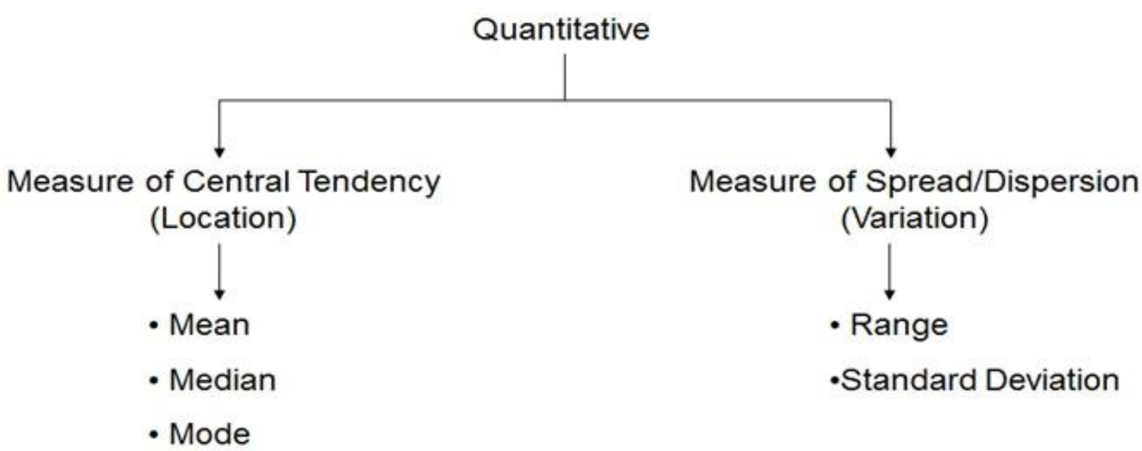
SIX SIGMA DMAIC PROCESS - MEASURE PHASE - VARIATION / DISCRETE VS CONTINUOUS THINKING

Discrete Thinking – For instance; Payment posted on time? (Yes/No) Is the Payment amount correct? (Yes/No).
Continuous Thinking – For instance; When was payment posted? (number of hours); How much payment was applied? (value of transaction).

Some example of Discrete and Continuous data are as follows:

- Response Time for an Email: Continuous
- Customer Satisfaction Score: Discrete (as it falls on an ordered scale)
- Talk Time: Continuous
- Fatal Accuracy: Continuous
- Survey Rating: Discrete
- Number of Calls: Discrete
- Number of Agents: Discrete

Characteristics of Data:
Quantitative data can be measured using Central Tendency and Spread/Variation.



Quantitative Data Characteristics

SIX SIGMA DMAIC PROCESS - MEASURE PHASE - DATA COLLECTION STRATEGY - SAMPLING

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

- We sample when the process involves destructive testing, e.g. taste tests, car crash tests, etc.
- We sample when there are constraints of time and costs
- We sample when the populations cannot be easily captured

Sampling is NOT done in situations like:

- We cannot sample when the events and products are unique and cannot be replicable

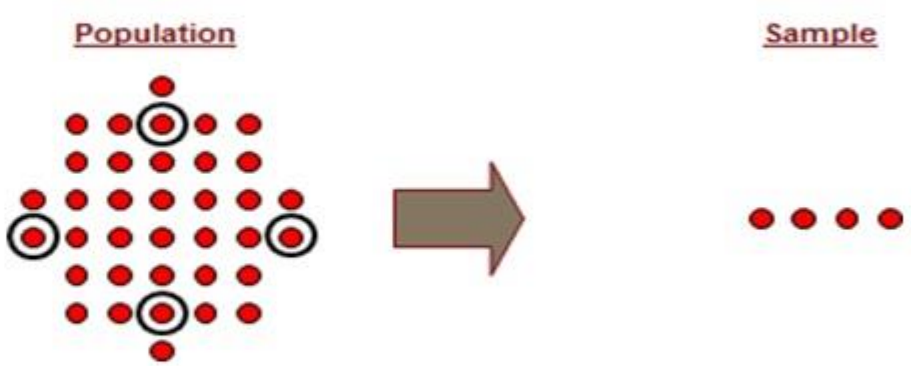
Sampling can be done by following methods:
Probability Sampling:

- Simple Random Sampling
- Stratified Random Sampling
- Systematic Sampling
- Cluster Sampling

Non Probability Sampling:

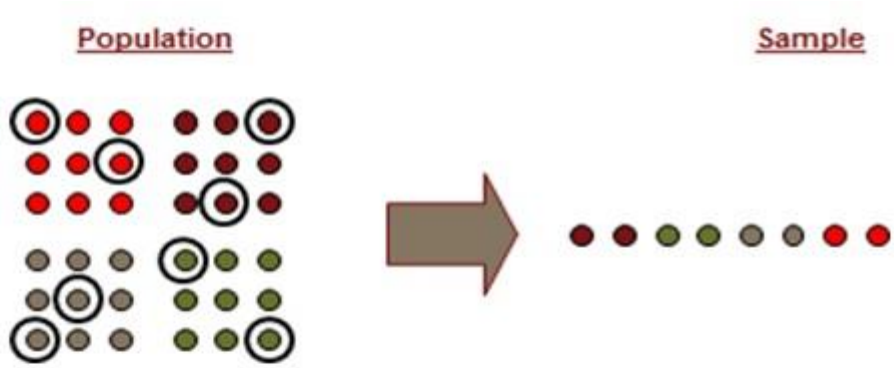
- Convenience Sampling
- Judgment Sampling
- Quota Sampling
- Snowball Sampling

Simple Random Sampling:
Simple random sampling is a method of sampling in which every unit has equal chance of being selected.



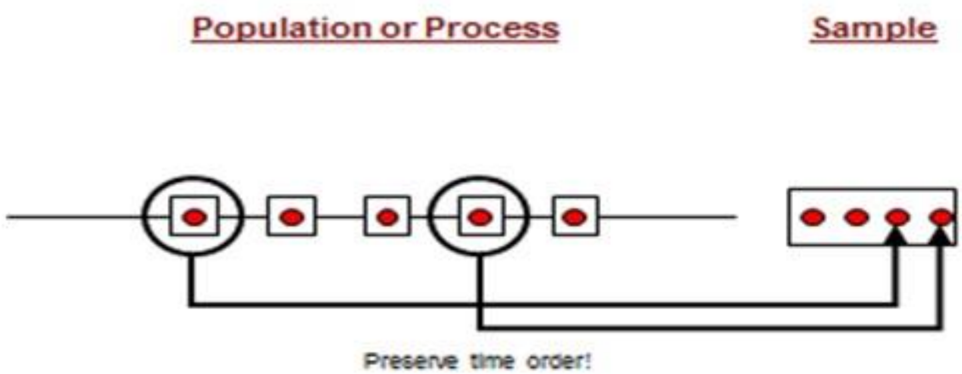
Six Sigma Simple Random Sampling

Stratified Random Sampling:
Stratified random sampling is a method of sampling in which stratum/groups are created and then units are picked randomly.



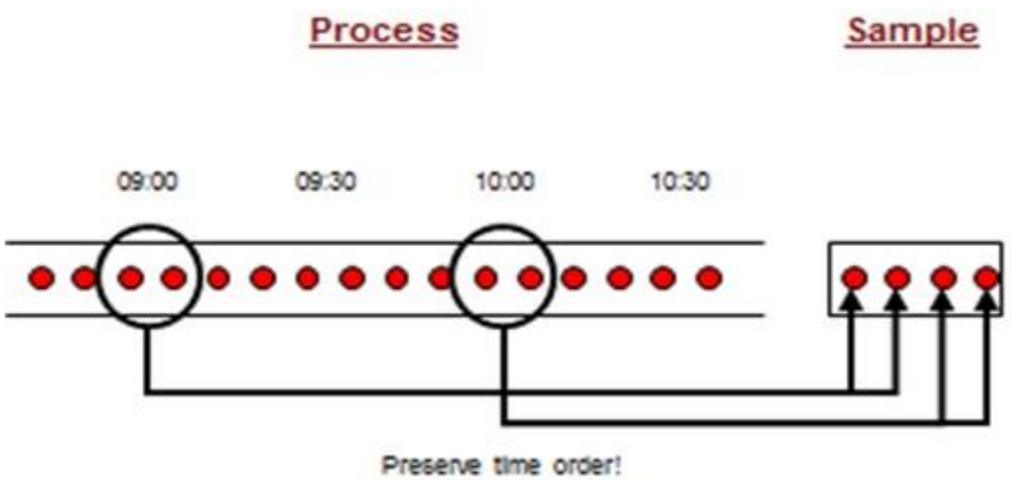
Six Sigma Stratified Random Sampling

Systematic Sampling:
Systematic sampling is a method of sampling in which every nth unit is selected from the population.



Six Sigma Systematic Sampling

Cluster Sampling:
Cluster sampling is a method of sampling in which clusters are sampled every Tth time.



Six Sigma Cluster Sampling

Non-Probability Sampling:
Convenience sampling relies upon convenience and access.
Judgment sampling relies upon belief that participants fit characteristics.
Quota sampling emphasizes representation of specific characteristics.
Snowball sampling relies upon respondent referrals of others with like characteristics.

Sampling Bias:
Bias occurs when systematic differences are introduced into the sample as a result of the selection process. A sample that is biased will not be representative of the population. A sample that is

biased will lead to incorrect conclusions about the population. The types of sampling bias are as follows:

- **Convenience sampling selection bias:** Occurs when the sample is drawn only from the part of the population that is easily accessible
- **Systematic sampling selection bias:** Can introduce a bias if the procedure matches an underlying structure
- **Environmental bias:** Introduced when environmental conditions have changes from the time the sample was drawn to the time the sample is used to draw conclusions about the population
- **Non-response bias:** Initiated by respondents. Only a subset of the population responds to the survey

Sample Size Formula:
In order to determine the sample size, we need to identify if the data type is continuous or discrete, whether we have standard deviation or proportion defectives and the confidence level.

$$n = \left(\frac{1.96\sigma}{\Delta}\right)^2$$

Six Sigma Sample Size Formula – Continuous Data

Here, n = Sample Size, σ = is the estimated standard deviation of our population and
Δ – is the precision or the level of uncertainty in your estimate that you are willing to accept (expressed in %).

$$n = \left(\frac{1.96}{\Delta}\right)^2 P(1-P)$$

Six Sigma Sample Size Formula – Discrete Data

Where, P – is the proportion defective that we are estimating (expressed in %) and
Δ – is the precision or the level of uncertainty in your estimate that you are willing to accept (expressed in %).

Let us solve a few questions to understand the formula better.
Given a sample size of 100, how precisely can we estimate a proportion defective estimated as P = 20%?

Here, P = 20% and n = 100, we need to find Δ.
Using the formula for Sample Size – Discrete Data,
Δ2 = (n)/ (1.96)2 * P(1 – P)
Δ2 = 100 / (3.8416) * 0.16
Δ2 = 162.681
Δ = 12.75

Given an estimated proportion defective guessed to be somewhere in the range of 5% to 15%, how many observations should we take to estimate the proportion defective within 2%?
Here, P = (15% - 5%) = 10% = 0.10, Δ = 0.02
Using the formula for Sample Size – Discrete Data,
n = (1.96/0.02)2 * (0.10)*(1-0.10)
n = 9604 * 0.09
n = 864.36

We want to estimate the average cycle time within 2 days. A preliminary estimate of the population standard deviation is 8 days. How many observations should we take?
Here, Δ = 2 and σ = 8 days
Using the formula for Sample Size – Continuous Data,
n = (1.96*8/2)2
n = 61.47

SIX SIGMA DMAIC PROCESS - MEASURE PHASE - MEASUREMENT SYSTEM

The Objective of this section is to identify and understand the components of variation arising out of the measurement system and to be able to use the appropriate tool for analysis depending on the data type.

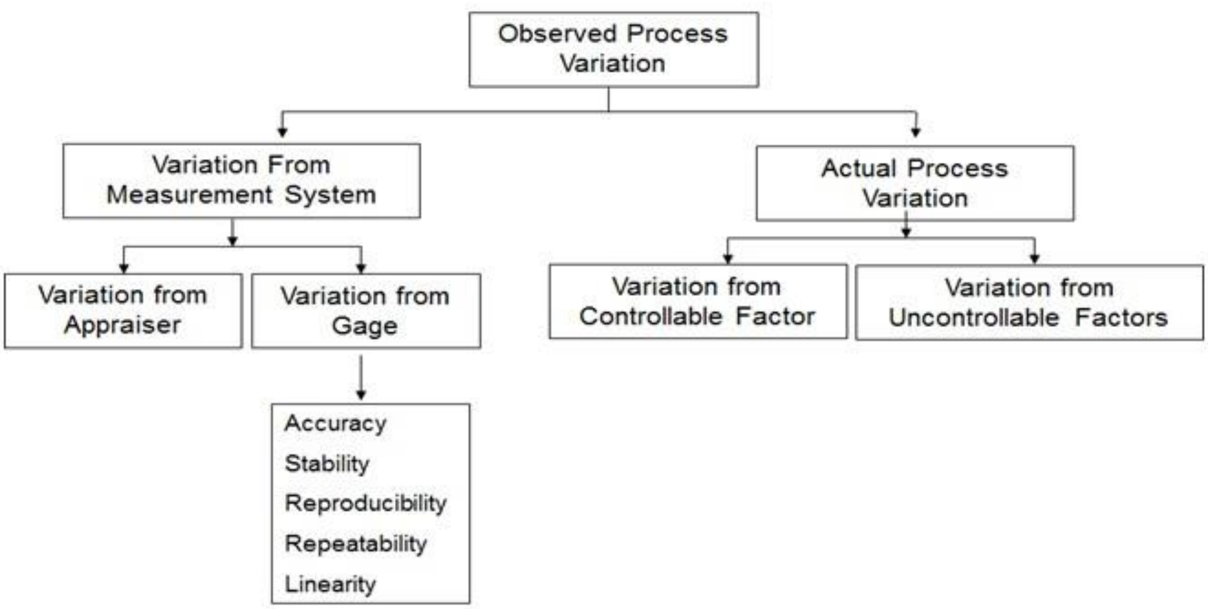
Measurement System Analysis (MSA) for Data Types: For continuous data type the Gage Repeatability and Reproducibility (R&R) studies are done and we check for

- % Tolerance
- % Contribution
- Number of Distinct Categories

For discrete data the Discrete Data Analysis (DDA) is done

- Accuracy
- Repeatability
- Reproducibility

All of the above values are derived out of any statistical software. We will see a few thumb of rules after understanding the Measurement System in more detail.



Six Sigma Components of Variation

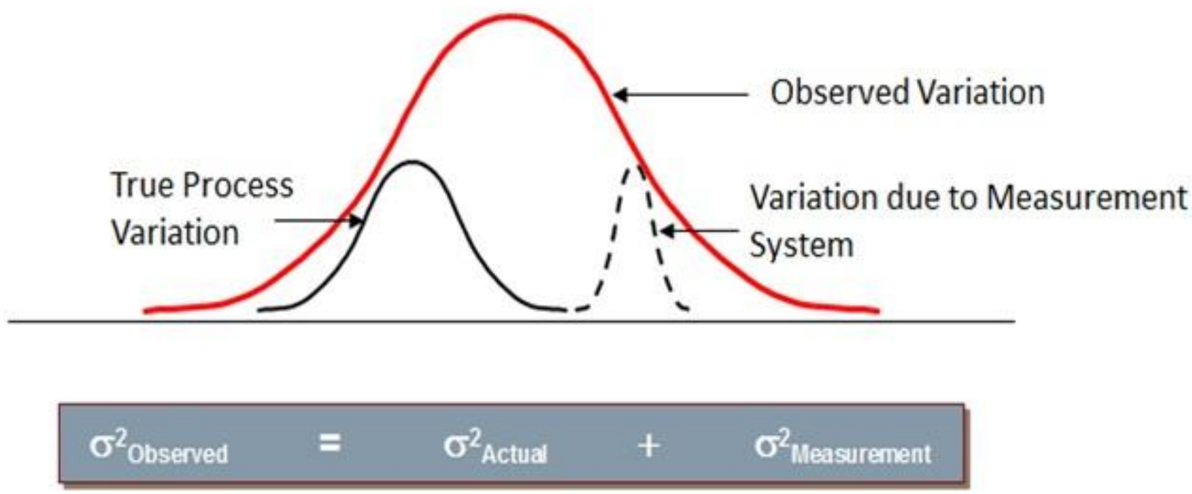
The variation in process can result due to the Actual Process Variation and the Variation from

Measurement System. The Actual Process Variation is resulted because of Controllable Factors and/or Uncontrollable Factors.

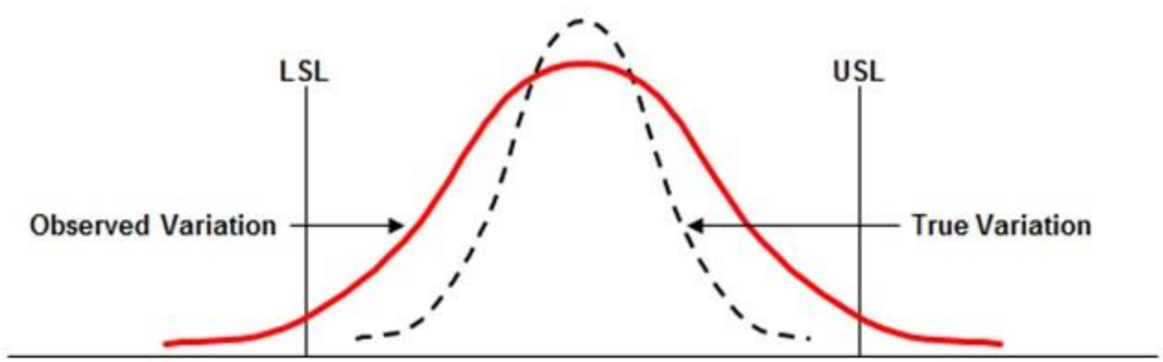
Variation from Measurement System is not advisable. This variation is due to Variation from Appraiser (due to the operator – individual who operates the tool/instrument/gate) and Variation from Gage i.e. Variation due to the instrument itself. Variation from gage can be further classified into Accuracy, Stability, Repeatability, Reproducibility and Linearity.

Variation (observed) = Variation (Actual) + Variation (Measurement)

The above equation indicates that the Observed Variation in a process is due to Actual Variation and the variation due to the Measurement System.



Six Sigma Process Variation



Six Sigma Observed Variation vs True Variation

In the above example, LSL – Lower Specification Limit and USL – Upper Specification Limit.

Measurement System Analysis:
Measurement system errors can be due to

- **Accuracy** – The difference between the average of observed values and the standard
- **Repeatability** – Variation in measurement when a person measures the same unit repeatedly with the same measuring gage (or tool)
- **Reproducibility** - Variation in measurement when two or more persons measure the same unit using the same measuring gage (or tool)
- **Stability -** Variation in measurement when the same person measures the same unit using the same measuring gage (or tool) over an extended period of time.
- **Linearity** – The consistency of the measurement across the entire range of the measuring gage.

Acceptable Level of Measurement System Variation (Thumb of rules):

Decision Criteria	Percentage Tolerance	Percentage Contribution	# of Distinct Categories
Acceptable	R&R < 8%	R&R < 2%	> 10
Evaluate Risk	8% >R&R < 30%	2% <>R&R < 7.7%	4 – 10
Unacceptable	R&R > 30%	R&R > 7.7%	< 4

Six Sigma Gage R&R Thumb Rule – Continuous Data

Decision Criteria	Accuracy	Repeatability	Reproducibility
Acceptable	> 90%	> 90%	> 90%
Unacceptable	< 90%	< 90%	< 90%

Six Sigma Attribute R&R Thumb Rule – Discrete Data

Process Variation:
Process Variation is generally due to two causes: Common Causes and Special Causes. Common cause is also called as Noise. Variation is inherent in the system. It results in a stable – IN CONTROL – process because the variation is predictable and it is evident in the system. Whereas Special causes are also called as Signals. They are unexpected occurrences due to unforeseen circumstances. It results in an unstable – OUT OF CONTROL – process because the variation is not predictable.

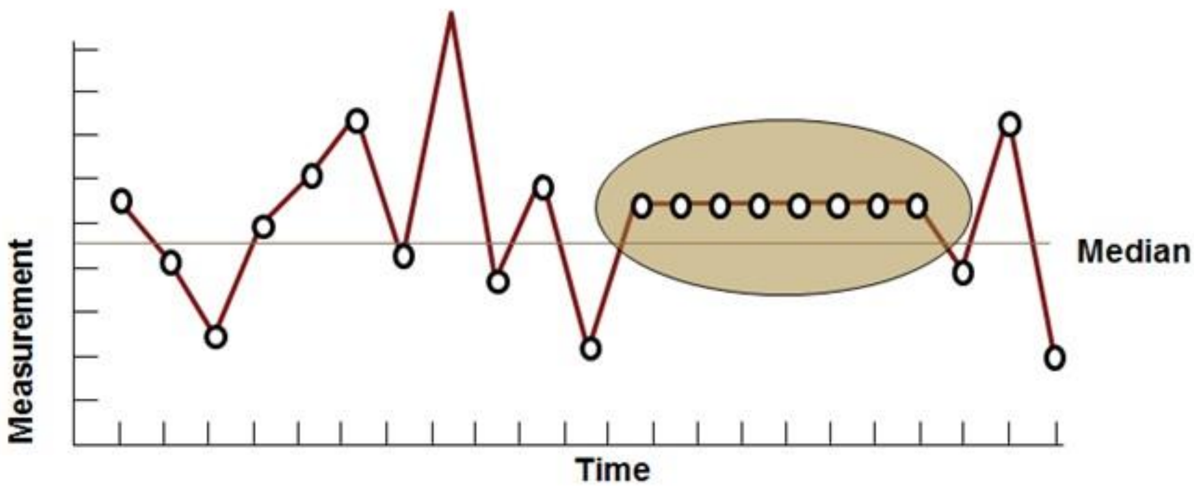
Data Interpretation:

Data is interpreted using factors such as **Stability, Normality, Shape, Spread and Centering.**

Let's take a look at the first factor – Stability. Run chart is an important tool for understanding data stability. Run charts are simple time ordered plots of process data. On run chart plots one can perform tests for certain patterns in the data to understand data stability and presence of these patterns indicate special causes of variation.

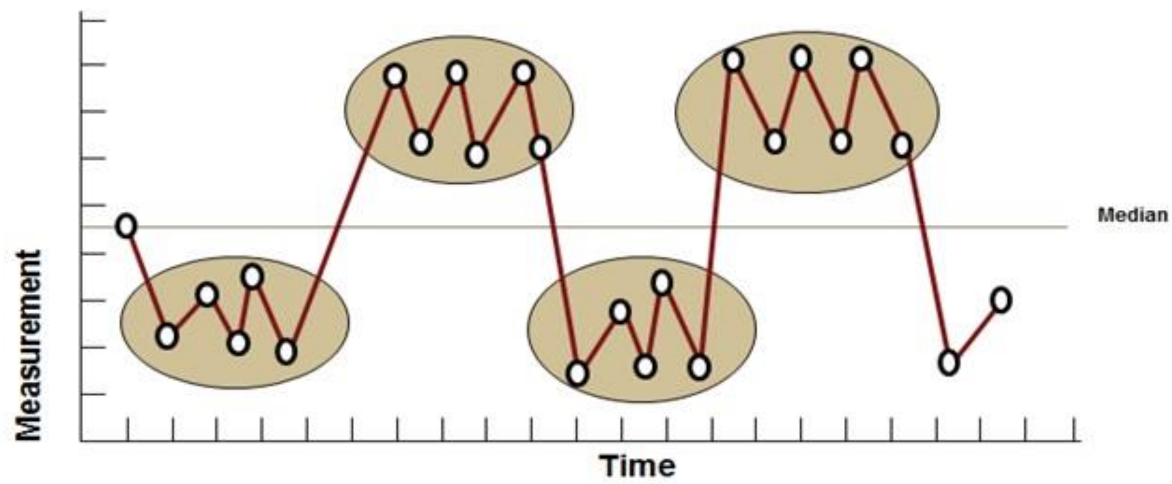
Special cause variation in a run chart can be understood by the following patterns: Same Value Plot, Clustering or Too Few Runs Plot, Mixtures or Too Many Runs Plot, Oscillations Plot, Trends Plot, Shifts Plot.

Run Chart – Same Value Plot:
A run chart having seven or more points with same value in a sequence indicates bias in the process.



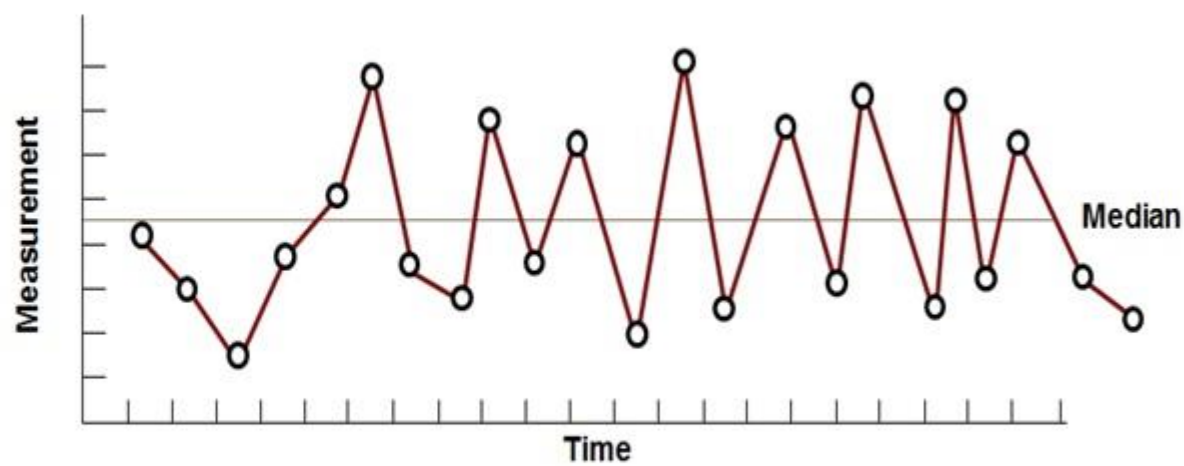
Six Sigma Run Chart – Same Value Plot

Run Chart – Clustering Plot:
Such a plot has lot of data points next to each other on one side of the median and the same way on the side of the median over time and indicates a periodic shift in process average due to lot-to-lot or setup variability; Also known as too few runs plot.



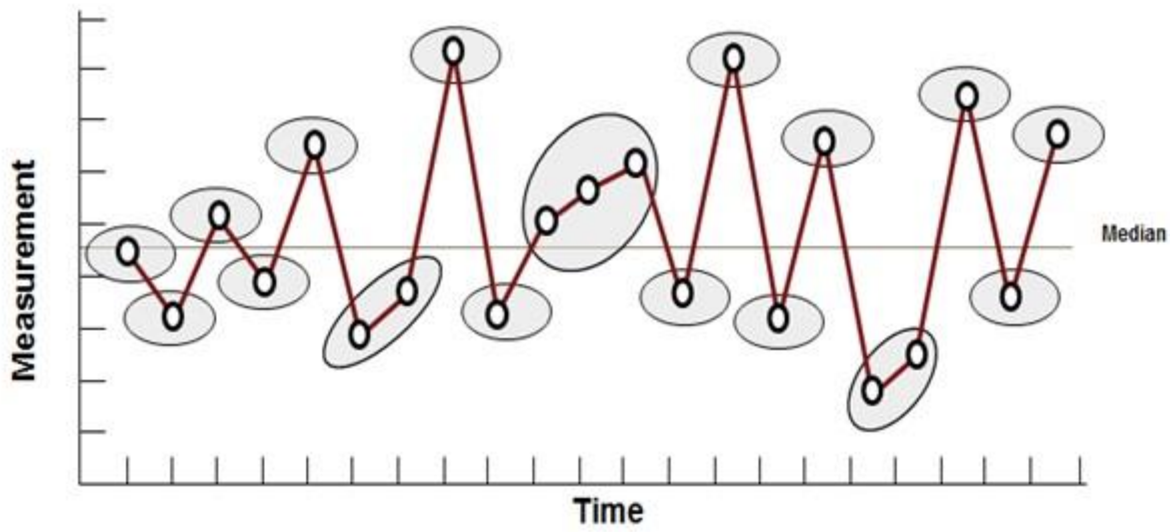
Six Sigma Run Chart – Clustering Plot

Run Chart – Mixtures Plot:
Such a plot has and absence of points near the center line with a sequence of fourteen or more points in a row alternating up and down; indicates a bias or systematic sampling from different sources or processes; Also known as cycle or too many runs plot.



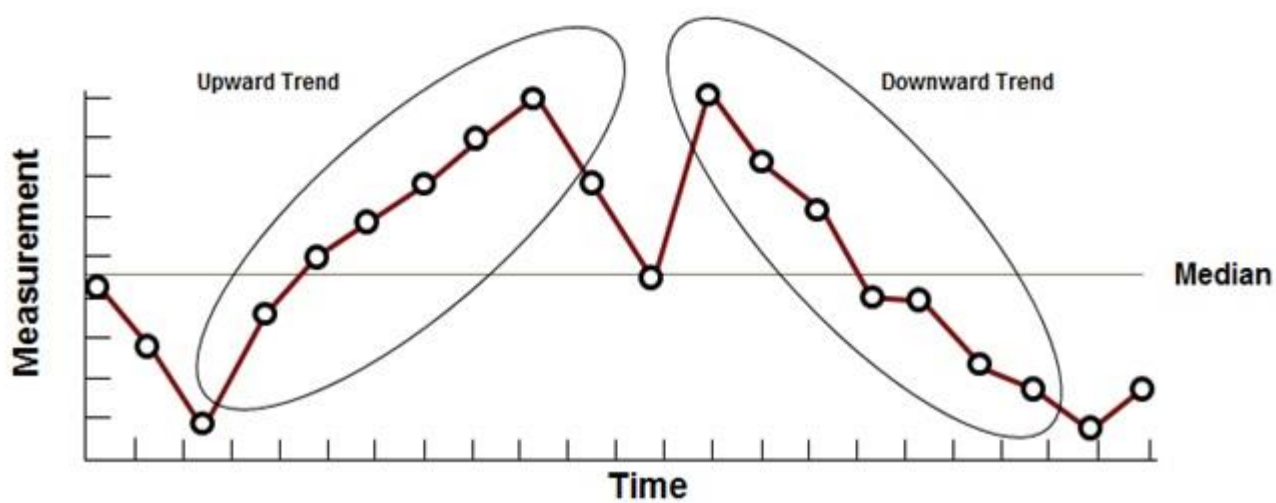
Six Sigma Run Chart – Mixtures Plot

Run Chart – Oscillation Plot:
Such a plot, has data points constantly fluctuating up and down rapidly around the median and indicates that the process is not steady or stable.



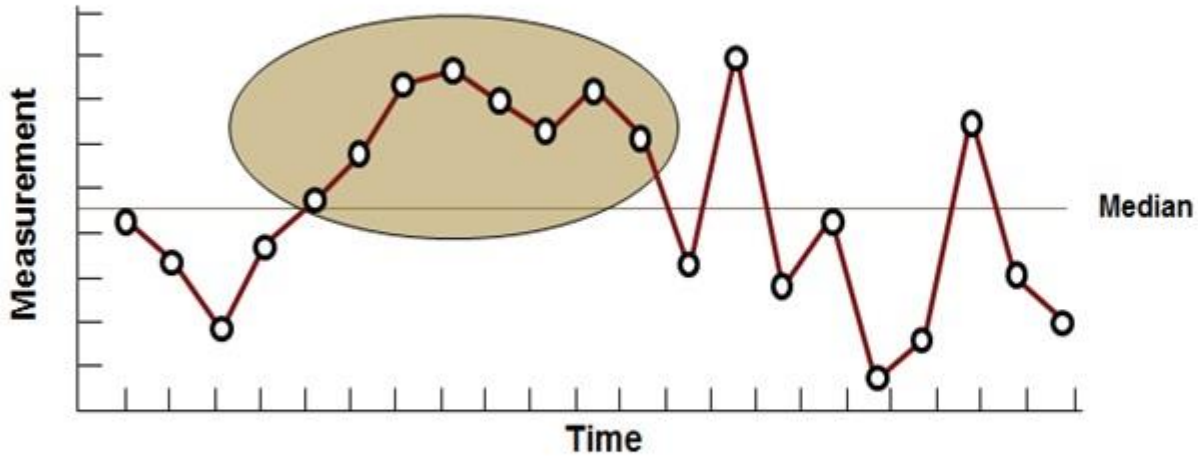
Six Sigma Run Chart – Oscillation Plot

Run Chart – Trend Plot:
Such a plot has a sequence of seven or more data points continuously increasing or decreasing and indicates a gradual increase or decrease trend in the data measurement methods.



Six Sigma Run Chart – Trend Plot

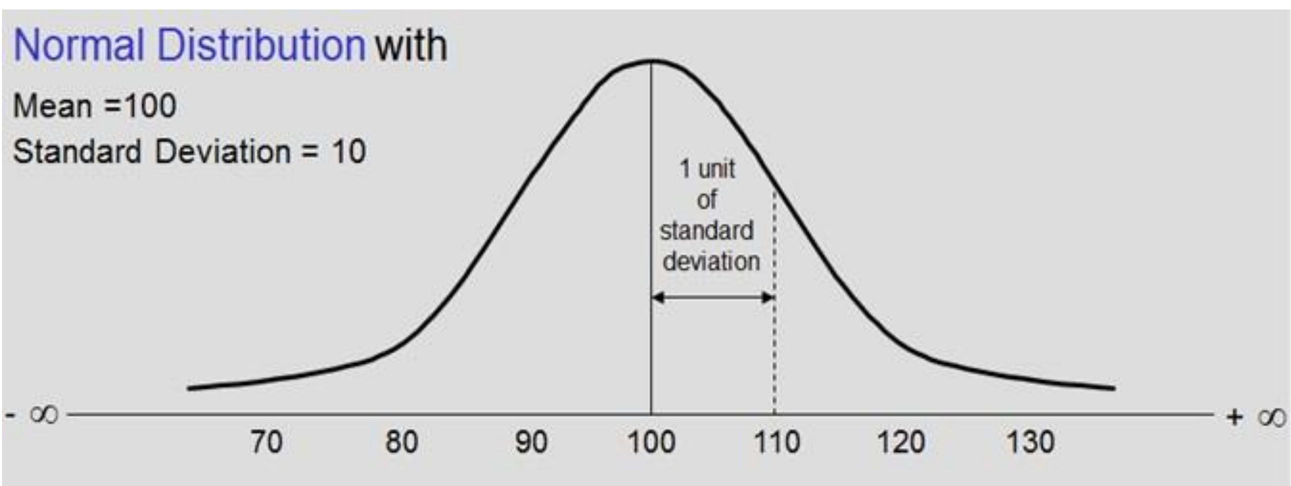
Run Chart – Shift Plot:
Such a plot has a sequence of eight or more points on the same side of the median and indicates a gradual shift in the process.



Six Sigma Run Chart – Shift Plot

Introduction to Normal Distribution:
Normal Distribution was developed by astronomer Karl Gauss. It is a most prominently used distribution in statistics. Its applicability is to many situations where given the population knowledge, we need to predict the sample behavior. It comes close to fitting the actual frequency distribution of many phenomena such as:

- Human characteristics such as weights, heights & IQ's
- Physical process outputs such as yields

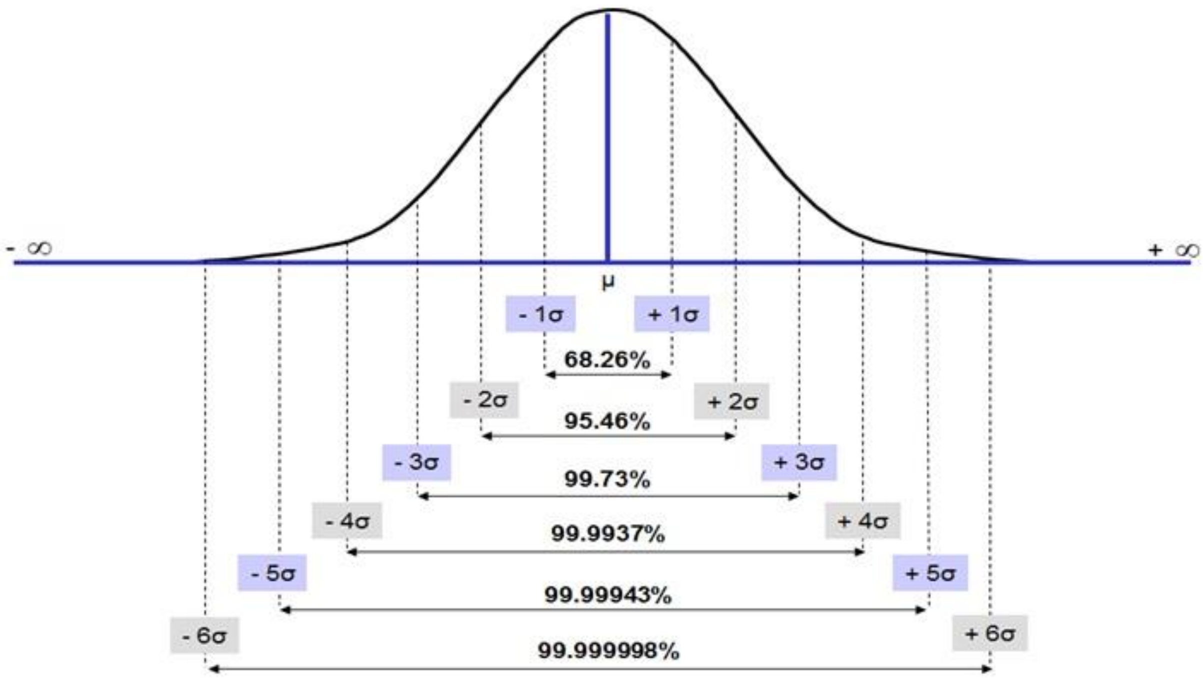


Six Sigma Normal Distribution - 1

It's a Probability Distribution, illustrated as N (μ, σ) i.e. it is characterized by Mean and

Standard Deviation. Simply put, a probability distribution is a theoretical frequency distribution. It has higher frequency of values around the mean & lesser & lesser at values away from mean. It is Continuous & Symmetrical. Its tails are asymptotic to X-axis i.e. the tails will never touch the X-axis. It is Bell shaped and the Total area under the Normal curve = 1.

For the data that does not follow normal distribution, the data will not be bell shaped as above. It could be stretched to the left or right or it can also have multiple peaks or it may show some other pattern. We term such data as non-normal data.

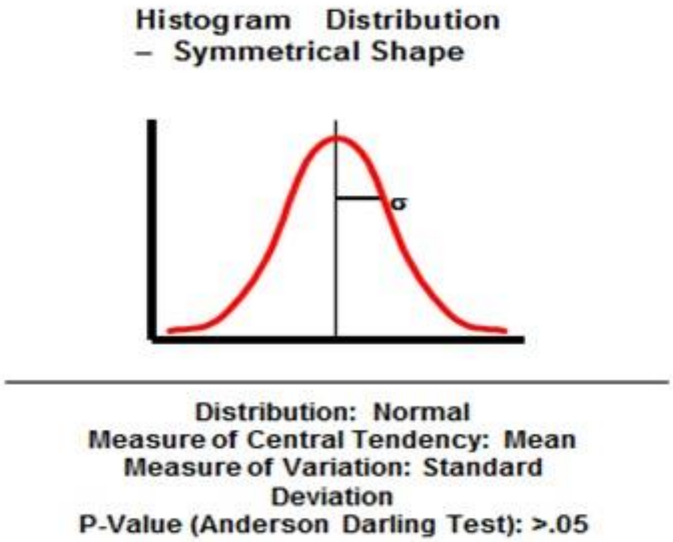


Six Sigma Normal Distribution - 2

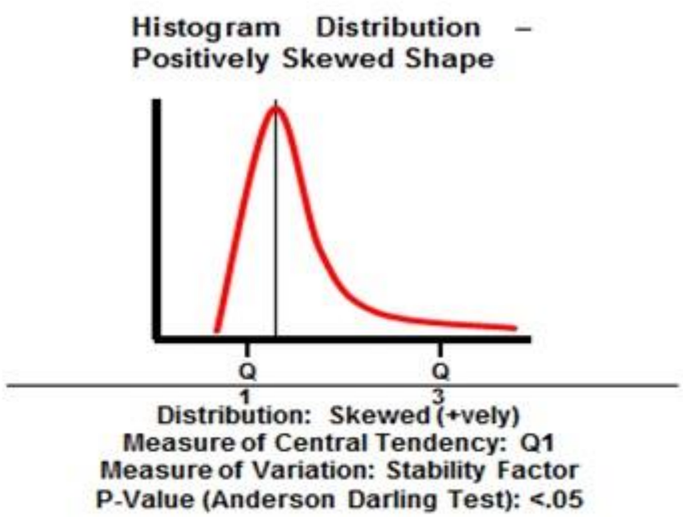
As you will observe in the above diagram, a process with 1σ (one sigma), the performance of the process is at 68.26%. As the Sigma value increases (2 σ, 3 σ, 4 σ, etc), the performance of the process also increases (95.46%, 99.73%, 99.9937%, etc). When the process achieves 6 σ level, the performance of the process is as high as 99.999998%.

Now let us look at how we can determine Normality of the data set. Anderson-Darling normality test is performed on the data to understand its normality characteristics. A data is considered to be normal if the P-value is greater than .05, and the hypothesis test states:

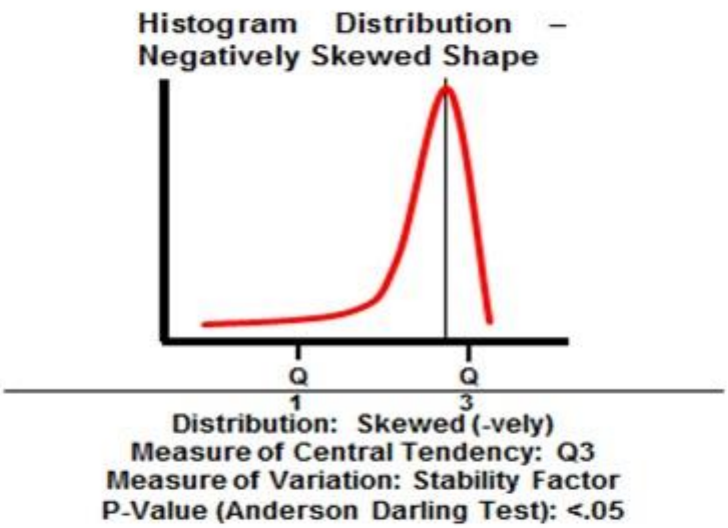
- H0 – Data is normal
- Ha – Data is not normal



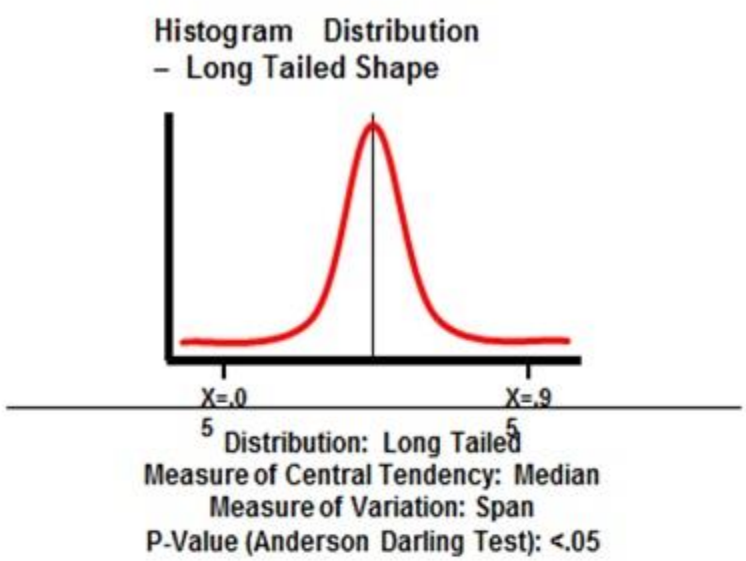
Six Sigma Histogram Distribution Symmetrical Shape



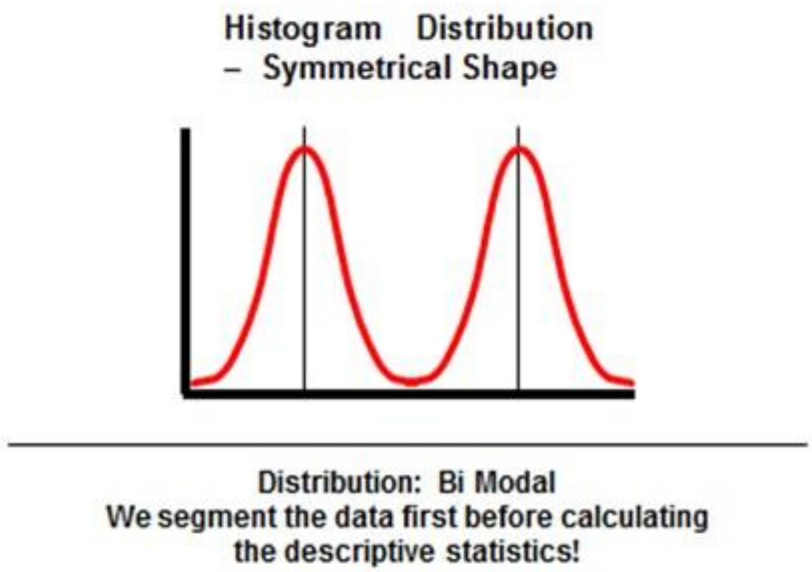
Six Sigma Histogram Distribution Positively Skewed Shape



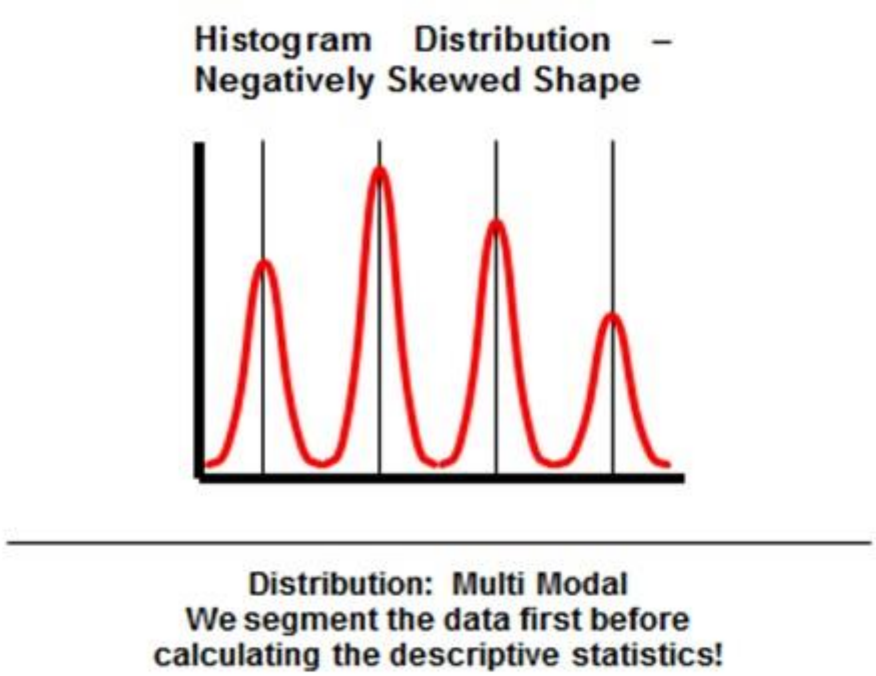
Six Sigma Histogram Distribution Negatively Skewed Shape



Six Sigma Histogram Distribution Long Tailed Shape



Six Sigma Histogram Distribution Bi-Modal Symmetrical Shape



Six Sigma Histogram Distribution Multi-Modal Negatively Skewed Shape

What do I do when data is Non Normal?

When the data is non-normal, we transform the data from non–normal to normal. We can transform the data with the following possibilities:

- Take the Log (any Base) of your raw measurement.
- Raise your individual measurements to a power.
- Use the reciprocal (1/y) of your individual measurements.

When we transform data, we should take following caution:

- When you transform your data, you must also transform your specification limits.
- You will use the transformed data throughout the analysis of your data.
- Use transformation of data the last resort after checking all other alternatives such as more data collection, validating data consistency.

SIX SIGMA DMAIC PROCESS - MEASURE PHASE - PROCESS CAPABILITY

The capability of a process is defined as the inherent variability of a process in the absence of any undesirable special causes and the variability is due to common causes.

Process capability can be categorized under two categories:

Short Term Capability:
Potential performance of a process, under control at a point in time. Calculated from data taken over a short period of time such that there is no external influence on the process (i.e. temperature change, shift change, operator change etc.). Short term capability represents the true process capability. Short term capability indicates the technology of the process.

Long Term Capability:
The actual performance of a process over a period of time. Calculated from data taken over a period of time long enough such that external factors can influence the process. Long term capability represents both the Technological capability combined with the controls that you exercise.

What is Process Sigma?
It is a measurement yardstick to evaluate the output of a process against the set performance standard. Higher the process sigma, better the process capability. Sigma measure gives us a common platform to compare different process that is otherwise being measured differently.

Process Sigma Calculation – Discrete Data:

- **What is a Unit** – An Item being processed
- **What is a Defect** – Failure to meet a customer Requirement or a Performance standard
- **What is an Opportunity** – Any product / service characteristics which is measured to a standard
- **What is Defective** – A unit that has s defect
- **Defects Per Million Opportunity** – Number of defects that would arise given a million opportunity

DPMO Calculation:
Defects Per Opportunity
DPO = D / (O*U)
D = Total No of defects
O = Opportunity for defects per unit
U = Total No of Units

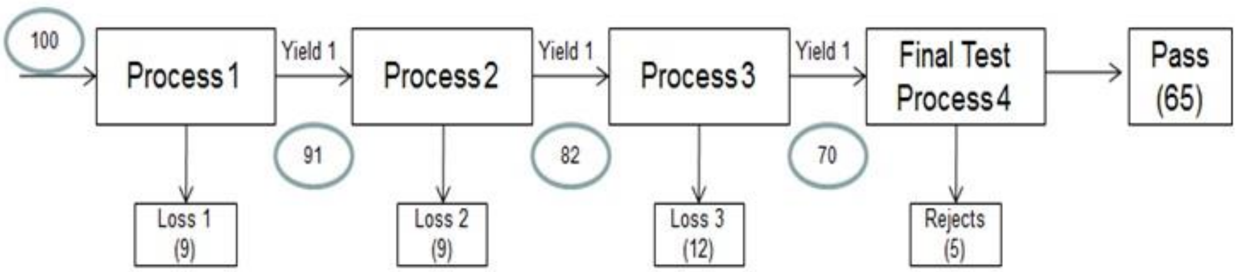
DPMO (Defects Per Million Opportunity)
DPMO = 1,000,000 * DPO = 1,000,000 * D/(O*U)

For any Six Sigma process, the calculation will always result the process to have only 3.4 per million opportunities (DPMO). For example, if a process had only 2 Defects, 18 Opportunity for

Defects per Unit and Total number of units to be 32500, the DPMO calculation will be as follows:

DPO = 2 / (18*32500) = 0.0000034188
DPMO = DPO * 1000000 = 3.4

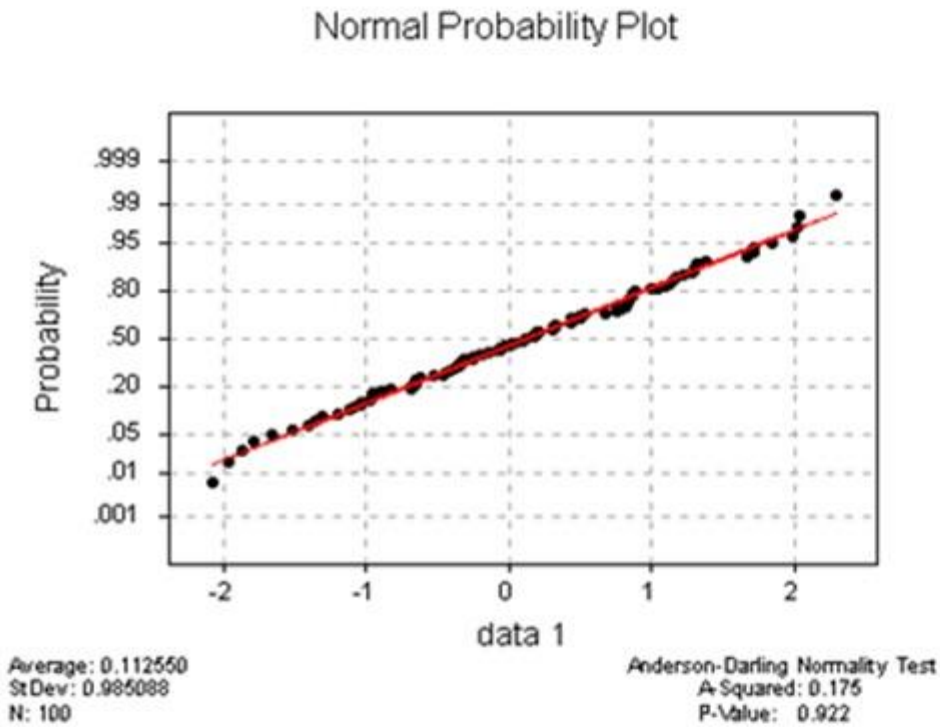
Yield:
Different types of fulfillment can impact the quality level we measure in our processes. Yield can be understood as Classical Yield, First Pass Yield and Rolled Throughput Yield.



Six Sigma Yield Definition and Example

Classic Yield (YC) – Units Passed / Final Units Tested = 65/70 = 0.93
First Time Yield (Yft) - Units Passed / Units input for First time = 65/100 = 0.65
Rolled Throughput Yield (Ytp) – Yield 1* Yield 2* Yield 3* Yield 4 = (91/100)*(82/91)*(70/82)*(65/70) = 0.65

Process Sigma Calculation – Continuous Data:
Check if the data is Normally distributed. The Larger the sample size, the higher the probability of having normal data. In normality plot the Y axis represents the cumulative percentage if the data points that fall below the corresponding data value on the X axis.



Six Sigma Normal Probability Plot

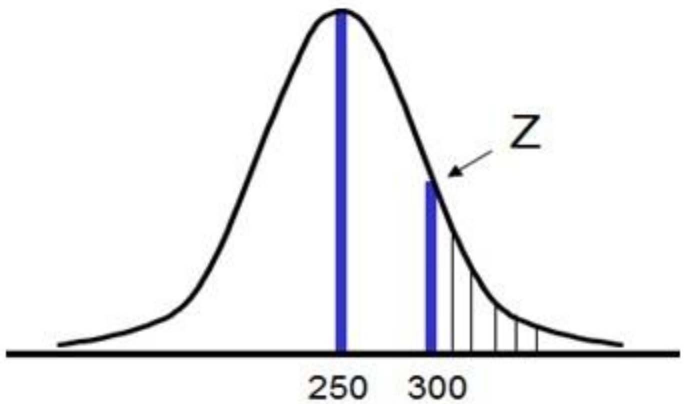
Calculation of Z value:
Z is the unit of measure that is equivalent to the number of Standard Deviation a value is away from the mean value.

$$Z = \frac{Y - \mu}{\sigma}$$

Calculation of Six Sigma Z Value

Y = Value of the data point we are concerned with
μ = Mean of the data points
σ = Standard Deviation of the data points
Z = Number of standard deviations between Y & the mean (μ)

Let’s look at some examples:
It’s found that runs scored by England cricket team while setting a score in one day internationals follow a normal distribution with mean of 250 & standard deviation of 23. What is the probability that team will score more than 300 runs in its next match?



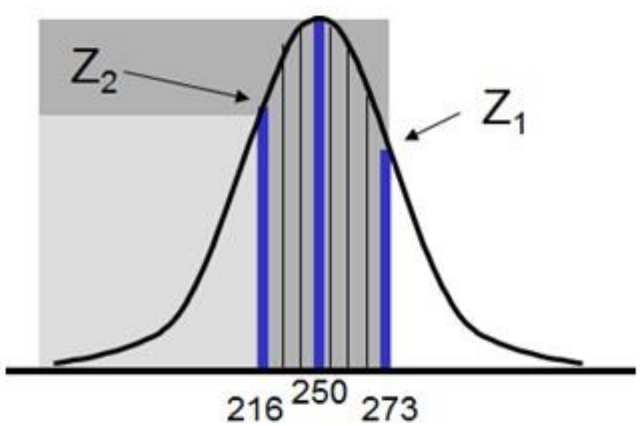
Normal Distribution Example

$$Z = \frac{300 - 250}{23} = 2.17$$

Z Calculation Example

Looking up Appendix below for Normal Distribution Table, we find that Z value of 2.17 covers an area of 0.98499 under itself. Thus, the probability that the team may score between 0 & 300 is 98.5% & <u>thus, chance of team scoring more than 300 runs is 1.5%.</u>

For the same data, what is the probability that team will score between 216 & 273?



Normal Distribution Example

$$Z_1 = \frac{273 - 250}{23} = 1 \qquad Z_2 = \frac{216 - 250}{23} = -1.47$$

Z Calculation Example

From Appendix:
Total area covered by Z1 = 0.841344740
Total area covered by Z2 = 1 - 0.929219087 = 0.0707
Intercepted area between Z1 & Z2 = 0.7705
<u>Thus, probability that the team may score between 216 & 273 runs in the next match is 77.05%.</u>

Appendix - Normal Distribution Tables

Z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0.500000000	0.503989379	0.507978354	0.511966527	0.515953499	0.519938873	0.523922253	0.527903240	0.531881440	0.535856456
0.1	0.539827896	0.543795364	0.547758470	0.551716823	0.555670033	0.559617712	0.563559473	0.567494933	0.571423709	0.575345420
0.2	0.579259687	0.583166134	0.587064387	0.590954073	0.594834824	0.598706274	0.602568057	0.606419814	0.610261186	0.614091818
0.3	0.617911357	0.621719457	0.625515770	0.629299955	0.633071673	0.636830590	0.640576374	0.644308699	0.648027240	0.651731677
0.4	0.655421697	0.659096986	0.662757237	0.666402148	0.670031420	0.673644759	0.677241874	0.680822481	0.684386299	0.687933051
0.5	0.691462467	0.694974281	0.698468229	0.701944056	0.705401511	0.708840345	0.712260318	0.715661192	0.719042736	0.722404724
0.6	0.725746935	0.729069152	0.732371166	0.735652770	0.738913765	0.742153956	0.745373154	0.748571176	0.751747842	0.754902979
0.7	0.758036422	0.761148006	0.764237576	0.767304982	0.770350076	0.773372720	0.776372779	0.779350124	0.782304631	0.785236183
0.8	0.788144666	0.791029974	0.793892006	0.796730665	0.799545861	0.802337508	0.805105527	0.807849842	0.810570386	0.813267094
0.9	0.815939908	0.818588775	0.821213646	0.823814480	0.826391238	0.828943888	0.831472403	0.833976760	0.836456943	0.838912939
1	0.841344740	0.843752345	0.846135756	0.848494980	0.850830029	0.853140919	0.855427672	0.857690314	0.859928875	0.862143390
1.1	0.864333898	0.866500443	0.868643073	0.870761839	0.872856799	0.874928011	0.876975542	0.878999459	0.880999834	0.882976744
1.2	0.884930268	0.886860491	0.888767499	0.890651383	0.892512238	0.894350161	0.896165253	0.897957619	0.899727366	0.901474606
1.3	0.903199451	0.904902018	0.906582427	0.908240802	0.909877266	0.911491948	0.913084979	0.914656492	0.916206622	0.917735507
1.4	0.919243289	0.920730109	0.922196112	0.923641445	0.925066257	0.926470700	0.927854925	0.929219087	0.930563344	0.931887852
1.5	0.933192771	0.934478263	0.935744490	0.936991617	0.938219807	0.939429229	0.940620050	0.941792438	0.942946563	0.944082597
1.6	0.945200711	0.946301077	0.947383870	0.948449263	0.949497431	0.950528549	0.951542794	0.952540341	0.953521368	0.954486051
1.7	0.955434568	0.956367097	0.957283815	0.958184901	0.959070532	0.959940886	0.960796142	0.961636477	0.962462069	0.963273096
1.8	0.964069734	0.964852162	0.965620555	0.966375089	0.967115942	0.967843287	0.968557300	0.969258155	0.969946026	0.970621086
1.9	0.971283507	0.971933461	0.972571119	0.973196650	0.973810224	0.974412010	0.975002175	0.975580885	0.976148306	0.976704602
2	0.977249938	0.977784475	0.978308376	0.978821799	0.979324905	0.979817852	0.980300797	0.980773894	0.981237299	0.981691164
2.1	0.982135643	0.982570884	0.982997038	0.983414253	0.983822675	0.984222449	0.984613720	0.984996631	0.985371321	0.985737932
2.2	0.986096601	0.986447466	0.986790661	0.987126322	0.987454580	0.987775567	0.988089412	0.988396244	0.988696189	0.988989373
2.3	0.989275919	0.989555950	0.989829586	0.990096947	0.990358150	0.990613313	0.990862548	0.991105971	0.991343692	0.991575823
2.4	0.991802471	0.992023745	0.992239749	0.992450589	0.992656367	0.992857185	0.993053143	0.993244339	0.993430871	0.993612833
2.5	0.993790320	0.993963425	0.994132240	0.994296853	0.994457354	0.994613830	0.994766365	0.994915046	0.995059954	0.995201171
2.6	0.995338778	0.995472853	0.995603474	0.995730718	0.995854658	0.995975369	0.996092924	0.996207393	0.996318845	0.996427351
2.7	0.996532977	0.996635789	0.996735852	0.996833231	0.996927987	0.997020181	0.997109875	0.997197128	0.997281997	0.997364539
2.8	0.997444809	0.997522864	0.997598756	0.997672537	0.997744260	0.997813974	0.997881730	0.997947576	0.998011558	0.998073724
2.9	0.998134120	0.998192789	0.998249775	0.998305122	0.998358871	0.998411062	0.998461736	0.998510932	0.998558689	0.998605044
3	0.998650033	0.998693692	0.998736057	0.998777162	0.998817040	0.998855724	0.998893246	0.998929637	0.998964929	0.998999149

Six Sigma Normal Distribution Table 1

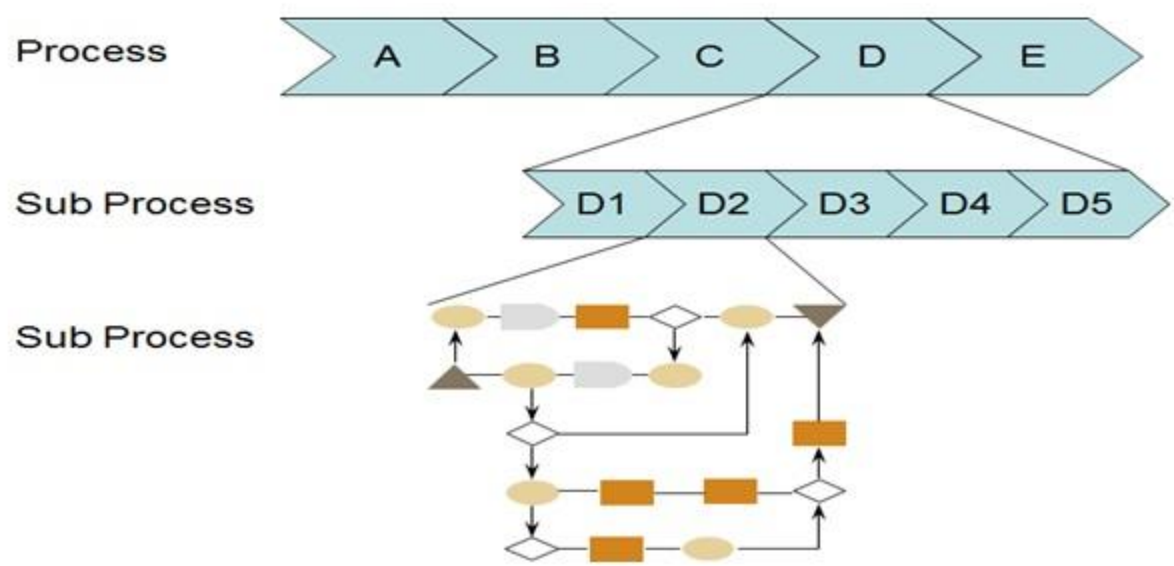
Z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
3.1	0.999032329	0.999064496	0.999095677	0.999125901	0.999155194	0.999183581	0.999211088	0.999237740	0.999263560	0.999288571
3.2	0.999312798	0.999336262	0.999358984	0.999380986	0.999402289	0.999422914	0.999442878	0.999462202	0.999480905	0.999499004
3.3	0.999516517	0.999533462	0.999549856	0.999565714	0.999581052	0.999595887	0.999610233	0.999624105	0.999637518	0.999650485
3.4	0.999663019	0.999675135	0.999686844	0.999698160	0.999709094	0.999719659	0.999729865	0.999739724	0.999749247	0.999758445
3.5	0.999767327	0.999775903	0.999784184	0.999792178	0.999799895	0.999807344	0.999814533	0.999821470	0.999828164	0.999834623
3.6	0.999840854	0.999846865	0.999852663	0.999858254	0.999863647	0.999868846	0.999873859	0.999878692	0.999883351	0.999887842
3.7	0.999892170	0.999896341	0.999900359	0.999904232	0.999907962	0.999911555	0.999915017	0.999918350	0.999921560	0.999924651
3.8	0.999927628	0.999930493	0.999933251	0.999935906	0.999938461	0.999940919	0.999943285	0.999945562	0.999947752	0.999949858
3.9	0.999951884	0.999953833	0.999955707	0.999957509	0.999959242	0.999960908	0.999962509	0.999964048	0.999965527	0.999966948
4	0.999968314	0.999969626	0.999970887	0.999972098	0.999973261	0.999974378	0.999975451	0.999976481	0.999977470	0.999978420
4.1	0.999979331	0.999980206	0.999981046	0.999981852	0.999982625	0.999983367	0.999984078	0.999984761	0.999985416	0.999986044
4.2	0.999986646	0.999987223	0.999987777	0.999988308	0.999988817	0.999989304	0.999989772	0.999990220	0.999990649	0.999991060
4.3	0.999991454	0.999991831	0.999992193	0.999992539	0.999992870	0.999993188	0.999993492	0.999993783	0.999994061	0.999994328
4.4	0.999994583	0.999994827	0.999995061	0.999995284	0.999995498	0.999995703	0.999995898	0.999996086	0.999996264	0.999996436
4.5	0.999996599	0.999996756	0.999996905	0.999997048	0.999997185	0.999997315	0.999997440	0.999997559	0.999997673	0.999997782
4.6	0.999997885	0.999997985	0.999998079	0.999998170	0.999998256	0.999998339	0.999998417	0.999998492	0.999998564	0.999998632
4.7	0.999998698	0.999998760	0.999998819	0.999998876	0.999998930	0.999998982	0.999999031	0.999999078	0.999999122	0.999999165
4.8	0.999999206	0.999999244	0.999999281	0.999999316	0.999999350	0.999999382	0.999999412	0.999999441	0.999999469	0.999999495
4.9	0.999999520	0.999999544	0.999999567	0.999999588	0.999999609	0.999999628	0.999999647	0.999999665	0.999999682	0.999999698
5	0.999999713	0.999999727	0.999999741	0.999999754	0.999999767	0.999999779	0.999999790	0.999999801	0.999999811	0.999999821
5.1	0.999999830	0.999999839	0.999999847	0.999999855	0.999999862	0.999999870	0.999999876	0.999999883	0.999999889	0.999999895
5.2	0.999999900	0.999999905	0.999999910	0.999999915	0.999999920	0.999999924	0.999999928	0.999999932	0.999999935	0.999999939
5.3	0.999999942	0.999999945	0.999999948	0.999999951	0.999999953	0.999999956	0.999999958	0.999999961	0.999999963	0.999999965
5.4	0.999999967	0.999999968	0.999999970	0.999999972	0.999999973	0.999999975	0.999999976	0.999999977	0.999999979	0.999999980
5.5	0.999999981	0.999999982	0.999999983	0.999999984	0.999999985	0.999999986	0.999999986	0.999999987	0.999999988	0.999999989
5.6	0.999999989	0.999999990	0.999999990	0.999999991	0.999999991	0.999999992	0.999999992	0.999999993	0.999999993	0.999999994
5.7	0.999999994	0.999999994	0.999999995	0.999999995	0.999999995	0.999999996	0.999999996	0.999999996	0.999999996	0.999999996
5.8	0.999999997	0.999999997	0.999999997	0.999999997	0.999999997	0.999999998	0.999999998	0.999999998	0.999999998	0.999999998
5.9	0.999999998	0.999999998	0.999999998	0.999999998	0.999999999	0.999999999	0.999999999	0.999999999	0.999999999	0.999999999
6	0.999999999	0.999999999	0.999999999	0.999999999	0.999999999	0.999999999	0.999999999	0.999999999	0.999999999	0.999999999
6.1	0.999999999	0.999999999	1.000000000	1.000000000	1.000000000	1.000000000	1.000000000	1.000000000	1.000000000	1.000000000
6.2	1.000000000	1.000000000	1.000000000	1.000000000	1.000000000	1.000000000	1.000000000	1.000000000	1.000000000	1.000000000

Six Sigma Normal Distribution Table 2

SIX SIGMA DMAIC PROCESS - ANALYZE PHASE - AS IS PROCESS MAP

As Is Process Map/Process Mapping is a graphical representation of all the activities carried out to deliver output for a process. It tells us all the activities being carried out to obtain the output. It also discusses on what all are the inputs going to deliver the output. It suggests which inputs are controllable and which are not in our control. It gives a list of critical inputs. It shares which of these activities are value added and which are non value added, the various handoffs and the opportunities to eliminate steps. It helps to determine the bottlenecks. It provides data collection points existing against those required. It also helps in identifying the efficiency of the process, as we capture the processing time for each activity.

Example of Mapping the AS IS processes to the micro level:



Six Sigma As Is Process Mapping

SIX SIGMA DMAIC PROCESS - ANALYZE PHASE - DATA DOOR ANALYSIS

Let us learn about a few Representation Tools that help us in analyzing the data and also representing them appropriately.

Process variation can be classified as Variation for a period of Time and Variation Over Time. Variation for a period of time can be defined for discrete and continuous data types as below:

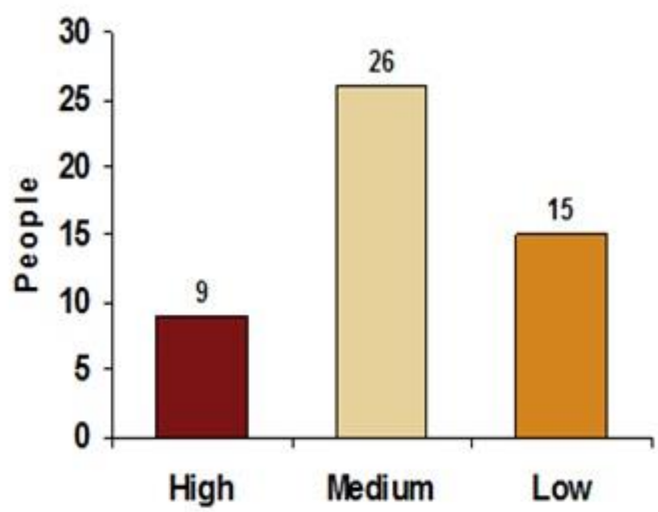
- Discrete Data: Bar Diagram, Pie Chart, Pareto Chart
- Continuous Data: Histogram, Box Plot

Variation Over Time can be defined for discrete and continuous data types as:

- Discrete Data: Run Charts, Control Chart
- Continuous Data: Run Chart, Control Chart

Bar Diagram:
A bar diagram is a graphical representation of attribute data. It is constructed by placing the attribute values on the horizontal axis of a graph and the counts on the vertical axis.

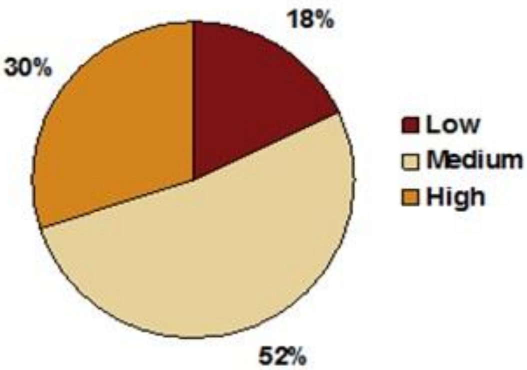
Social Status	No. of People
High	9
Medium	26
Low	15



Six Sigma Bar Diagram

Pie Chart:
A pie chart is a graphical representation of attribute data. The “pieces” represent proportions of count categories in the overall situation. Pie charts show the relationship among quantities by dividing the whole pie (100%) into wedges or smaller percentages.

Social Status	No. of People
High	9
Medium	26
Low	15

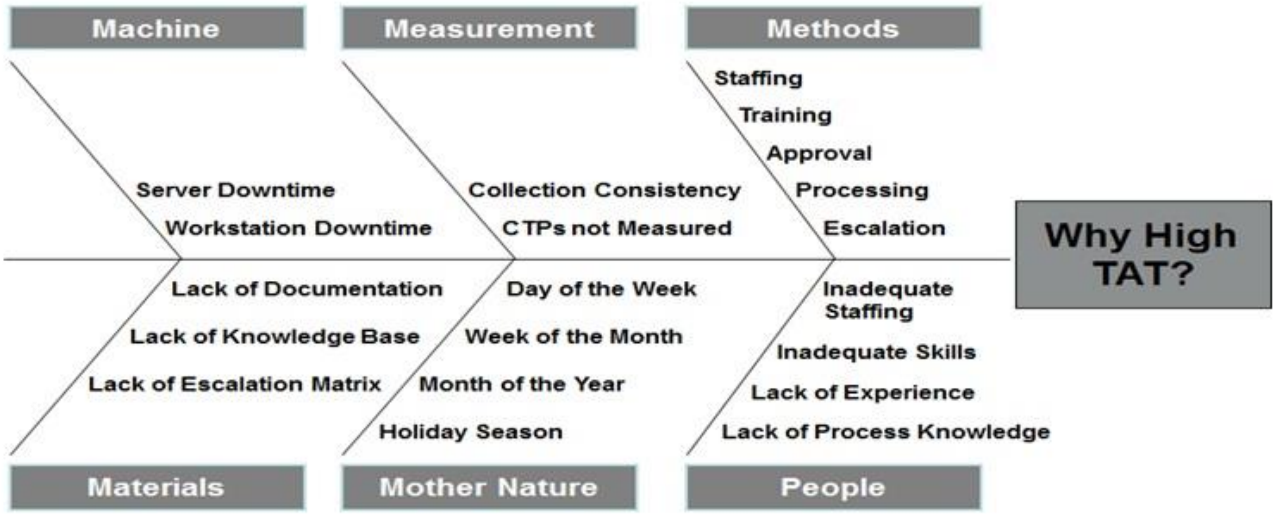


Six Sigma Pie Chart

Cause and Effect Diagram / Fish Bone Diagram / Ishikawa Diagram:
This is a visual tool used to brainstorm the probable causes for a particular effect to occur. Effect or the problem is analogously captured as the head of the fish and thus the name. The causes for this effect or problem is generated through team brainstorming and are captured along the bones of the fish. The causes generated in the brainstorming exercises by the team will depend on how closely the team is related to the problem. Typically the causes are captured under predetermined categories such as 6M's or 5M's and a P as given below:

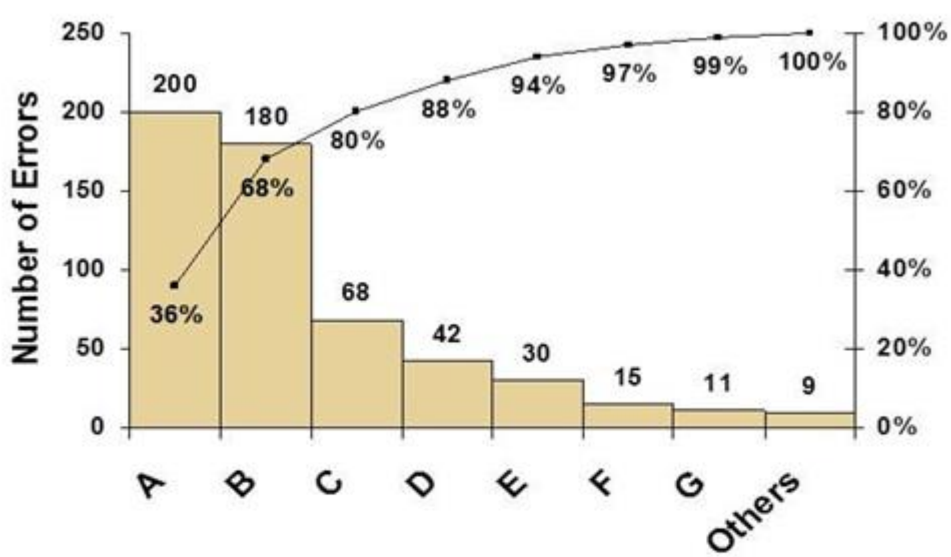
- **Machine:** This category groups root causes related to tools used to execute the process.
- **Material:** This category groups root causes related to information and forms needed to execute the process.
- **Nature:** This category groups root causes related to our work environment, market conditions, and regulatory issues.
- **Measure:** This category groups root causes related to the process measurement.
- **Method:** This category groups root causes related to procedures, hand-offs, input-output issues.
- **People:** This category groups root causes related people and organizations.

Below is an example of a fishbone diagram created for capturing the root causes of High Turn Around Time (TAT).



Six Sigma Cause and Effect Diagram / Fish Bone Diagram / Ishikawa Diagram

Pareto Chart:
A data display tool for numerical data that breaks down discrete observations into separate categories for the purpose of identifying the "vital few".

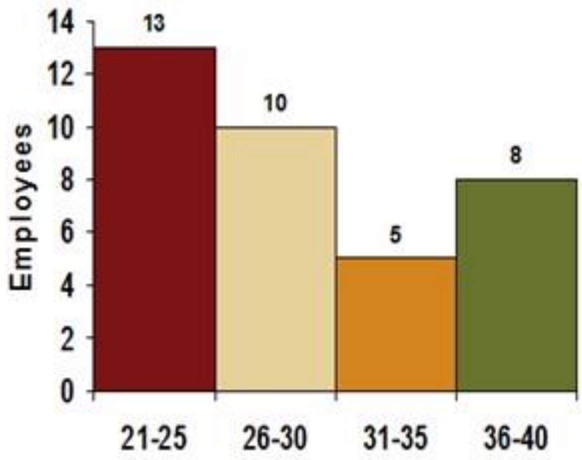


Six Sigma Pareto Chart

Histogram:

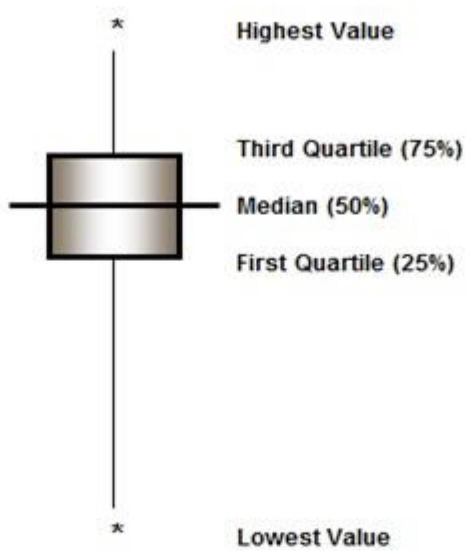
A histogram is a graphical representation of numerical data. It is constructed by placing the class intervals on the horizontal axis of a graph and the frequencies on the vertical axis.

Age Interval	Frequency
21-25	13
26-30	10
31-35	5
36-40	8



Six Sigma Histogram

Box Plot:
A box plot summarizes information about the shape, dispersion, center of process data and also helps spot outliers in the data.

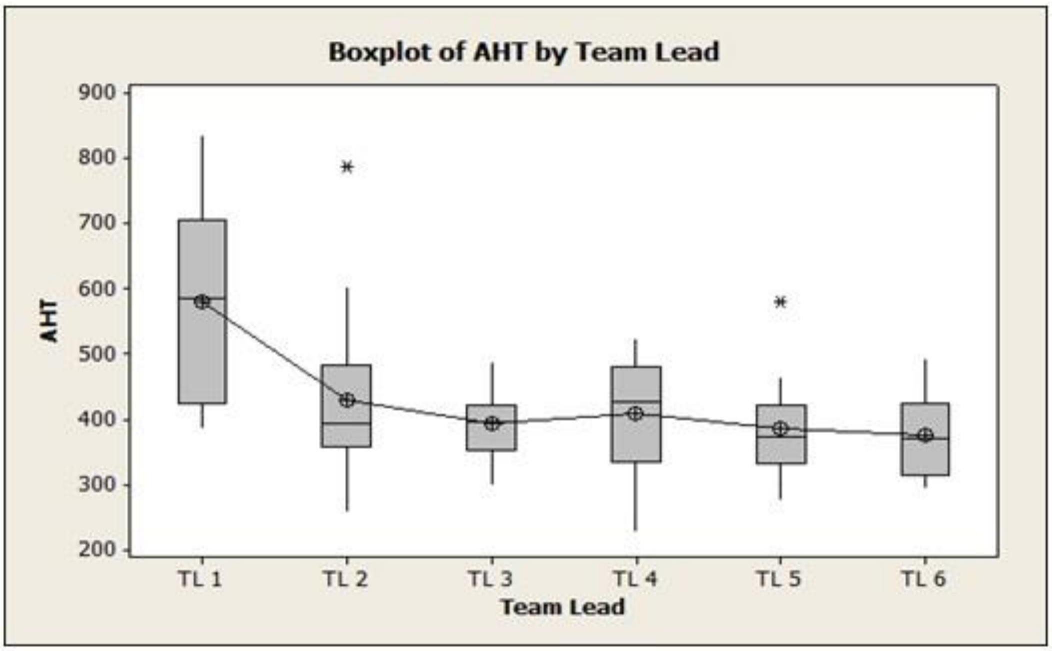


Six Sigma Box Plot

The box plot can be interpreted as follows:

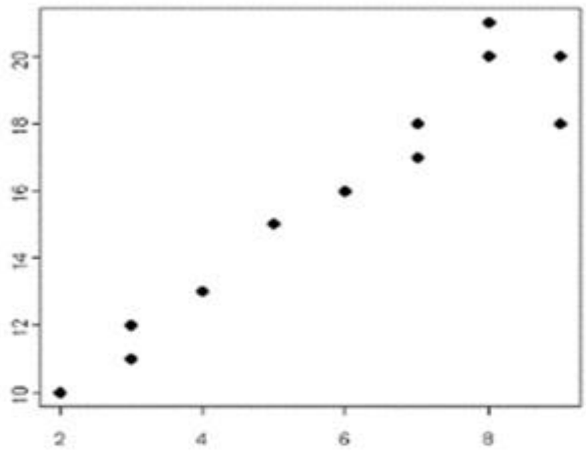
- Box – represents the middle 50% values of the process data.
- Median – represents the point for which 50% of the data points are above and 50% are below the line.
- Q1, Q3 – Q1 represents the point for which 25% of the data points are above and 75% are below the line; While, Q3 represents the point for which 75% of the data are above and 25% are below in the line.
- Aestrix – represents an outlier and is a point which is more than 1.5 times the inter-quartile range (Q3-Q1) in the data.
- Lines – These vertical lines represent a whisker which joins Q1 or Q3 with the farthest data-point but other than an outlier.

Example: Below is an example of a call center process where Average Handle Time (AHT) of the calls is compared between Team Leads of the process.



Six Sigma Box Plot Example

You will observe that the variation is highest for TL1 and for the rest it is much smaller. This indicates that the associates working under TL1 need training or some other help which will reduce the variation and bring the overall AHT under control. **Scatter Plot:**
A scatter plot is often employed to identify potential associations between two variables, where one may be considered to be an explanatory variable (such as years of education) and another may be considered a response variable (such as annual income).



Six Sigma Scatter Plot

Scatter plots are similar to line graphs in that they use horizontal and vertical axes to plot, large body of, data points. And, they have a very specific purpose too:

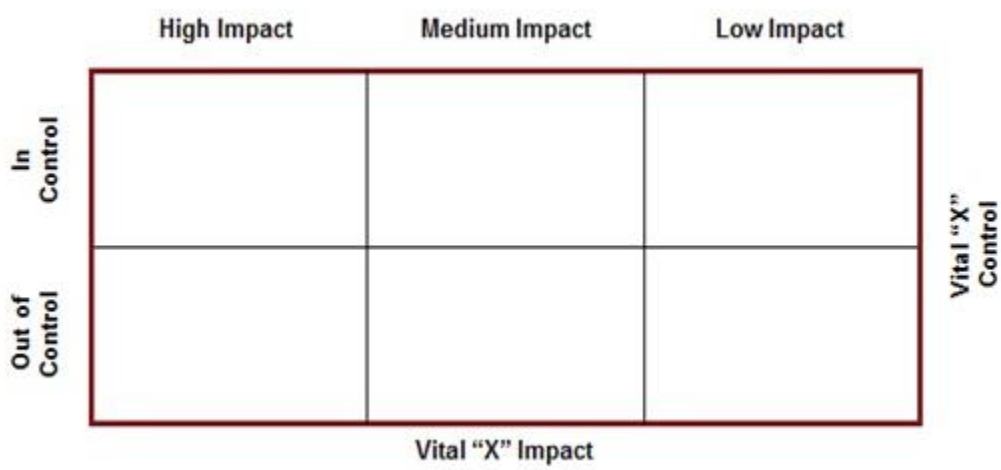
- They show how much one variable is affected by another variable and this relationship is called as their correlation.
- The closer the data points come when plotted to making a straight line, higher is the correlation between variables.
- If the data points make a straight line going from the origin out to high x- and y-values, then the variables are said to have a +ve correlation.
- If the line goes from a high-value on y-axis down to a high-value on x-axis, the variables have –ve correlation.

Once after identifying the factors we need to

- What is the extent of impact of the factors?
- Which one do you control?

SIX SIGMA DMAIC PROCESS - ANALYZE PHASE - CONTROL IMPACT MATRIX

This is a prioritization tool that is used in conjunction with the C&E tool typically after the causes have been captured using C&E. Prioritization is done based on factors (causes) that are in your control and the impact (extent) of the factor on the problem or the effect.



Six Sigma Control Impact Matrix

We generate the factors/causes using the C&E (Cause and Effect) matrix. Followed by verification of this qualitative assessment of the factors/causes by seeking data, which can then be prioritized using the control impact matrix or Pareto analysis. But are these the root causes? Or do we need to drill down further?

How do we do it?
Ask Why five times OR Ask why till a time when you do not have an answer to the Why OR The final answer that you may get could be a root cause.

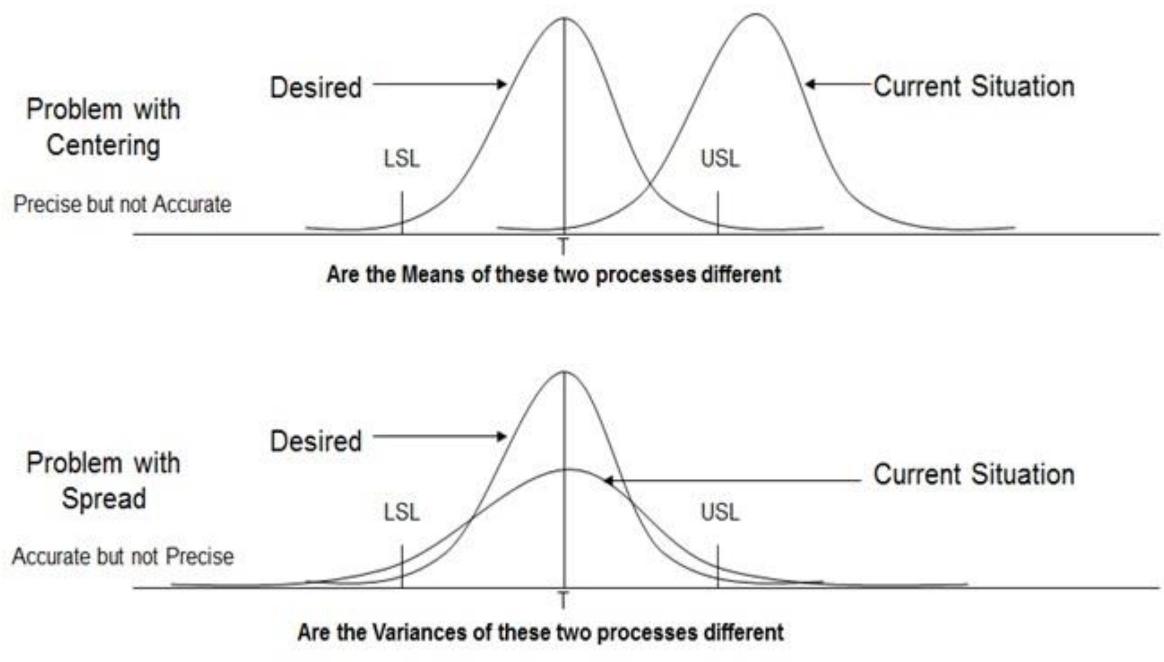
SIX SIGMA DMAIC PROCESS - ANALYZE PHASE - WHY ANALYSIS

Why Analysis is explained through the below example:

- Why does the Home finance loan application process take more than 10 working days to arrive at the decision of “Credit Worthy”? Because many application received especially by Post have fields that are either not clear or left blank.
- Why do we have applications that have blank fields? Because the customer did not fill out the details.
- Why did the customer not fill the details? Because they were not clear.
- Why were they not clear? Because the direction was not clear.
- Why were the direction not clear? Because many of the customers never read them.
- Why did they not read them? Because the print was too small.

SIX SIGMA DMAIC PROCESS - ANALYZE PHASE - HYPOTHESIS TESTING

In a process, we may face Problem with Centering and/or Problem with Spread. Below diagram will allow us to understand these two problems in detail:



Practical Six Sigma Problems that require Hypothesis Testing

Hypothesis testing tells us whether there exists statistically significant difference between the data sets for us to consider that they represent different distributions.

What is the difference that can be detected using Hypothesis Testing?
For Continuous data, hypothesis testing can detect Difference in Average and Difference in Variance. For Discrete data, hypothesis testing can detect Difference in Proportion Defective.

Steps in Hypothesis Testing:

- **Step 1:** Determine appropriate Hypothesis test
- **Step 2:** State the Null Hypothesis Ho and Alternate Hypothesis Ha
- **Step 3:** Calculate Test Statistics / P-value against table value of test statistic
- **Step 4:** Interpret results – Accept or reject Ho

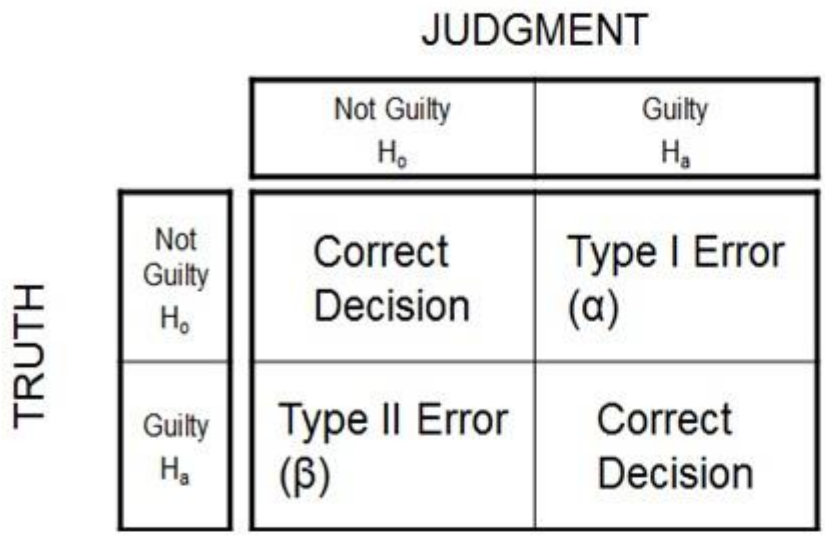
Mechanism:

- **Ho = Null Hypothesis** – There is No statistically significant difference between the two groups

- **Ha = Alternate Hypothesis** – There is statistically significant difference between the two groups

Hypothesis Testing Errors:
Type I Error – P (Reject Ho when Ho is true) = α
In type I Error, we reject the Null Hypothesis when it is true. It is also called as Alpha error or Producer's Risk.

Type II Error - P (Accept Ho when Ho is false) = β
Similarly, in type II Error, we accept Null Hypothesis when it is false. It is also called as Beta error or Consumer's Risk.



Six Sigma Hypothesis Testing Errors

P Value – Also known as Probability value, it is a statistical measure which indicates the probability of making an α error. The value ranges between 0 and 1. We normally work with 5% alpha risk, a p value lower than 0.05 means that we reject the Null hypothesis and accept alternate hypothesis.

Types of Hypothesis Testing:
We use the following grid to select the appropriate hypothesis test depending on the data types:

Select the appropriate Test		Output (Dependant Variable) Y	
		Continuous	Discrete
Input (Independent Variable) X's	Continuous	Simple Linear Regression Correlation	Logistic Regression
	Discrete	Normal Data T Test (1,2 Sample & Paired) ANOVA, F test , HOV Non-Normal Data Moods Median , HOV	Chi Square

Types of Six Sigma Hypothesis Testing

Situation	Statistical Test
Comparing a population mean against a given standard For example: Is the mean TAT of thread ≤15 minutes.	**1-sample t-Test**
Comparing means of two different populations For example: Is the mean of morning shift = mean of night shift.	**2-sample t-Test**
Comparing the means of more than two populations For example: Is the mean of staff A = mean of staff B = mean of staff C.	**ANOVA**
Comparing the variance of two or more than two populations For example: Is the variation of staff A = variation of staff B = variation of staff C.	**Homogeneity Of Variance**

Normal Continuous Y and Discrete X

Situation	Statistical Test
Comparing the variance of two or more than two populations For example: Is the variation of staff A = variation of staff B = variation of staff C.	**Homogeneity Of Variance**
Comparing the medians of two or more than two populations For example: Is the median of staff A = median of staff B = median of staff C.	**Mood's Median Test**

Non-Normal Continuous Y and Discrete X

Situation	Statistical Test
To see how output (Y) changes as the input (X) changes For example: If we need to find out how staff A's accuracy is related to his number of years spent in the process.	**Simple Linear Regression**

Continuous Y and Continuous X

Situation	Statistical Test
To see how output counts (Y) from two or more sub-groups (X) differ For example: If we want to find out whether defects from morning shift are significantly different from defects in the evening shift.	**Chi-square Test of Independence**

Discrete Y and Discrete X

Test	Null	Alternate
Normality	Data is Normal	Data is not Normal
Run Tests	No Special Causes	Special Causes Exist
t-test (1-sample)	μ = constant or T	$\mu \neq$ constant or T
t-test (2-sample, 2-tailed)	$\mu_1 = \mu_2$	$\mu_1 \neq \mu_2$
t-test (2-sample, 1-tailed)	$\mu_1 \leq \mu_2$	$\mu_1 > \mu_2$
Chi-square	$\chi^2 = 0$	$\chi^2 \neq 0$
HOV (3-sample)	$\sigma^2_1 = \sigma^2_2 = \sigma^2_3 = \ldots = \sigma^2_n$	$\sigma^2_1 \neq \sigma^2_2 \neq \sigma^2_3 \neq \ldots \neq \sigma^2_n$
ANOVA (3-sample)	$\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_n$	Atleast one is different
Mood's Median (3-sample)	$\text{Median}_1 = \text{Median}_2 = \ldots = \text{Median}_n$	$\text{Median}_1 \neq \text{Median}_2 \neq \ldots \neq \text{Median}_n$

Six Sigma Hypothesis Test – Null and Alternate Summary

SIX SIGMA DMAIC PROCESS - ANALYZE PHASE - ANALYSIS EXAMPLES

1-sample t-Test Example:
Definition: A hypothesis test for comparing a population mean against a given standard for any significant differences.
Situation: You have 50 data points on the TAT for your process and you want to check if the mean of your TAT is worse than your competitors TAT of 4.5 minutes.

Null: Mean TAT <= 4.5 minutes
Alternate: Mean TAT > 4.5 minutes

TAT (in Mins)				
4.82	4.41	4.60	4.68	4.80
4.76	4.62	4.83	4.49	4.67
4.52	5.04	5.09	4.48	4.91
4.71	4.62	5.46	5.01	4.44
5.09	4.68	4.67	4.63	4.58
5.03	4.77	4.55	4.20	4.97
4.86	5.16	4.87	4.94	4.44
4.68	4.98	5.04	4.62	4.47
4.71	4.58	4.91	4.55	4.84
4.49	4.93	4.74	5.50	4.94

Turn Around Time (in Mins)

One-Sample T: TAT (in Mins)

```
Test of mu = 4.5 vs > 4.5


                                                      95%
                                                     Lower
Variable        N     Mean     StDev  SE Mean      Bound     T      P
TAT (in Mins)  50  4.76805  0.25899  0.03663    4.70664  7.32  0.000
```

Analysis Result

Result: A One-Sample t-test helps us compare the mean of the sample to that of one value. In our example, we wanted to identify if our TAT is better or worse than 4.5. Using the results of the session window described above, we observe that the P-value is less than 0.05 which indicates that we reject the null hypothesis. Thus, our performance is worse than our competitors performance.

2-sample t-Test Example:
Definition: A hypothesis test for comparing means of two different populations for any

significant differences.
Situation: You have two shifts in your process, morning shift & evening shift and you want to find out if there is a significant difference in the average in TAT of morning shift and night shift.

Null: Mean of (Morning shift = Evening shift)
Alternate: Mean of (Morning shift != Evening shift)

Morning Shift					Night Shift			
13.79	15.58	16.70	13.92	14.00	15.56	16.37	21.67	13.37
15.29	14.68	18.71	14.11	9.14	11.28	17.62	20.78	20.95
13.40	12.37	20.12	8.83	18.97	15.04	23.15	18.33	18.02
12.10	12.76	12.99	17.04	16.53	22.29	14.92	19.14	12.11
16.00	17.41	18.67	12.38	10.02	16.78	20.96	17.75	17.34
12.53	17.03	18.68	15.25	12.64	20.12	20.83	14.67	16.65
14.75	18.77	11.83	15.49	13.58	19.27	18.23	19.39	9.89
21.10	15.56	10.69	11.51	15.89	16.65	16.84	16.76	17.81
14.18	13.79	17.26	14.84	15.56	14.97	18.19	13.65	15.07
12.06	15.53	11.85	10.70	9.81	16.38	19.30	19.90	16.72
15.25	15.74	17.77	11.44	14.92	15.81	13.09	15.54	18.46
13.46	12.85	14.83	14.33	17.45	19.96	15.97	15.17	21.92
12.06	15.41	20.58	19.73	18.34	17.31	16.90	19.45	15.23
14.86	12.16	13.06	11.67	14.02	16.66	22.23	10.25	19.07
14.25	16.78	12.68	15.05	19.83	14.35	21.28	16.63	14.65
13.97	8.36	9.85	17.59	21.92	18.58	21.77	19.34	
14.76	14.65	11.58	17.41	11.80	17.06	16.92	17.37	
13.83	18.58	20.19	15.82	11.21	14.18	14.40	17.38	
15.63	12.42	12.09	18.24	10.97	16.45	14.91	20.09	
15.34	16.46	15.91	16.19	15.46	13.59	13.69	22.73	

Morning Shift and Night Shift Data

```
Two-sample T for Morning Shift vs Night Shift

                N   Mean  StDev  SE Mean
Morning Shift  100  14.75   2.90     0.29
Night Shift     75  17.24   2.93     0.34


Difference = mu (Morning Shift) - mu (Night Shift)
Estimate for difference:  -2.49007
95% CI for difference:  (-3.36925, -1.61088)
T-Test of difference = 0 (vs not =): T-Value = -5.59  P-Value = 0.000  DF = 173
Both use Pooled StDev = 2.9161
```

Analysis Result

Result: A Two-Sample t-test helps us compare the mean of two samples. In our example, we wanted to identify if morning shift performance is equal to evening shift performance. Using the results of the session window described above, we observe that the P-value is less than 0.05 which indicates that we reject the null hypothesis. Thus, performance of morning shift is not equal to evening shift.

One-Way ANOVA Example:
Definition: A hypothesis test for comparing the means of more than two populations for any significant differences.
Situation: You want to see if there is a significant difference in the average TAT of your staff A, B, C, D.

Null: Mean of (Staff A = Staff B = Staff C = Staff D)
Alternate: Mean of (Staff A != Staff B != Staff C != Staff D)

Staff1	Staff1	Staff2	Staff2	Staff3	Staff3	Staff4	Staff4
20.56	13.43	18.18	16.17	13.55	8.93	19.43	21.40
13.84	14.43	16.86	14.61	6.55	9.82	19.15	14.67
14.30	12.51	15.27	20.12	15.84	11.88	15.55	17.75
15.66	12.49	18.80	19.62	15.83	13.16	17.18	14.29
15.26	18.64	15.44	14.15	14.07	14.20	18.84	19.72
12.77	13.80	15.19	13.72	13.08	12.82	18.03	18.98
8.38	14.08	16.81	15.71	15.94	15.84	19.08	22.14
14.01	16.49	16.21	18.98	8.55	11.83	19.35	15.58
13.34	15.25	19.54	14.40	14.00	12.82	16.10	16.30
13.28	14.02	16.01	18.63	9.92	17.53	18.59	15.17
14.95	13.12	19.18	18.34	15.63	11.96	19.05	15.48
18.64	10.43	16.86	15.29	16.04	12.08	21.64	17.42
14.22	12.08	14.87	14.17	14.20	14.13	20.26	16.74
15.30	13.33	17.34	17.53	13.24	13.61	20.94	17.82
15.77	10.63	16.98	16.06	16.26	19.32	20.29	11.04
17.27		16.84		15.59		14.12	
19.22		20.73		11.76		19.52	
17.25		18.77		11.01		14.36	
12.90		17.28		12.40		19.40	
15.80		16.98		10.17		19.85	

Staff 1, Staff 2, Staff 3 and Staff 4 Data

One-way ANOVA: Staff1, Staff2, Staff3, Staff4

```
Source   DF       SS      MS      F      P
Factor    3   475.48  158.49  26.93  0.000
Error   136   800.29    5.88
Total   139  1275.77

S = 2.426   R-Sq = 37.27%   R-Sq(adj) = 35.89%


                             Individual 95% CIs For Mean Based on
                             Pooled StDev
Level    N    Mean  StDev  --+---------+---------+---------+-------
Staff1  35  14.498  2.524          (----*----)
Staff2  35  16.904  1.866                        (----*----)
Staff3  35  13.245  2.700   (----*----)
Staff4  35  17.864  2.529                               (----*----)
                           --+---------+---------+---------+-------
                           12.8      14.4      16.0      17.6

Pooled StDev = 2.426
```

Analysis Result

Result: A One-Way ANOVA helps us compare the mean of more than two samples. In our example, we wanted to check if the performance of the four staff is same or different. Using the results of the session window described above, we observe that the P-value is less than 0.05 which indicates that we reject the null hypothesis. Thus, performance of Staff 1 != Staff 2 != Staff 3 != Staff 4.

Mood's Median Test Example:
Definition: A hypothesis test for comparing the medians of two or more than two populations for any significant differences.
Situation: You want to see if there is a significant difference in the TAT of your staff A, B, C, D.

Null: Median of (Staff A = Staff B = Staff C = Staff D)
Alternate: Median of (Staff A != Staff B != Staff C != Staff D)

Staff1	Staff1	Staff2	Staff2	Staff3	Staff3	Staff4	Staff4
20.56	13.43	18.18	16.17	13.55	8.93	19.43	21.40
13.84	14.43	16.86	14.61	6.55	9.82	19.15	14.67
14.30	12.51	15.27	20.12	15.84	11.88	15.55	17.75
15.66	12.49	18.80	19.62	15.83	13.16	17.18	14.29
15.26	18.64	15.44	14.15	14.07	14.20	18.84	19.72
12.77	13.80	15.19	13.72	13.08	12.82	18.03	18.98
8.38	14.08	16.81	15.71	15.94	15.84	19.08	22.14
14.01	16.49	16.21	18.98	8.55	11.83	19.35	15.58
13.34	15.25	19.54	14.40	14.00	12.82	16.10	16.30
13.28	14.02	16.01	18.63	9.92	17.53	18.59	15.17
14.95	13.12	19.18	18.34	15.63	11.96	19.05	15.48
18.64	10.43	16.86	15.29	16.04	12.08	21.64	17.42
14.22	12.08	14.87	14.17	14.20	14.13	20.26	16.74
15.30	13.33	17.34	17.53	13.24	13.61	20.94	17.82
15.77	10.63	16.98	16.06	16.26	19.32	20.29	11.04
17.27		16.84		15.59		14.12	
19.22		20.73		11.76		19.52	
17.25		18.77		11.01		14.36	
12.90		17.28		12.40		19.40	
15.80		16.98		10.17		19.85	

Staff 1, Staff 2, Staff 3 and Staff 4 Data

```
Mood median test for TAT
Chi-Square = 8.80    DF = 3    P = 0.032

                                 Individual 95.0% CIs
Staff   N<=  N>  Median  Q3-Q1  -------+---------+---------+---------
Staff1   13   7     6.5   16.9   (-*-----------)
Staff2   13   7     6.0   14.2  (--*-----)
Staff3    5  15    17.0   29.7         (------*------------------)
Staff4    9  11    11.8   20.4    (------*----------)
                                -------+---------+---------+---------
                                      10        20        30

Overall median = 8.9
```

Analysis Result

Result: A Mood’s Median Test helps us compare the medians of more than two samples. In our example, we wanted to check if the median performance of the four staff is same or different. Using the results of the session window described above, we observe that the P-value is less than 0.05 which indicates that we reject the null hypothesis. Thus, median performance of Staff 1 != Staff 2 != Staff 3 != Staff 4.

Chi-SquareTest Example:
Definition: A hypothesis test for comparing output counts from two or more sub-groups for any significant differences.
Situation: You want to see if one set of defectives data is significantly different from another set of defectives data.

Null: No difference in the two sub-groups
Alternate: Difference exists in the two sub-groups

	Men	Women
Agree	15	20
Disagree	30	35

Data for Chi-Square Test

Chi-Square Test: Men, Women

```
Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

          Men  Women  Total
    1      15     20     35
        15.75  19.25
        0.036  0.029

    2      30     35     65
        29.25  35.75
        0.019  0.016

Total      45     55    100

Chi-Sq = 0.100, DF = 1, P-Value = 0.752
```

Analysis Result

Result: A Chi-Square Test helps us compare the count data. In our example, we wanted to check if one set of defectives data is significantly different from another set of defectives data. Using the results of the session window described above, we observe that the P-value is greater than 0.05 which indicates that we fail to reject the null hypothesis. Thus, No difference in the two sub-groups.

SIX SIGMA DMAIC PROCESS - IMPROVE PHASE - SOLUTION PARAMETER

To define and come up with solution parameters for statistically validated X's we need to:

- Develop Decision Statement
- Develop Solution Criteria
- Classify Solution Criteria
- Refine Solution Criteria

Develop Decision Statement:
Solutions should be generated to clarify the purpose of the decision to be made. Parameters to be considered while drafting a decision statement are:

1. How will you manage expectations of customer?
2. How will you establish boundaries on alternatives to be considered to resolve the problem?
3. How will you reflect on prior decisions taken – "Level of Decision"?

The next thing to do is to Develop a Decision Statement and generate a list of six to twelve criteria to solve the problem. Consider desired results, restrictions being faced and availability of resources. **Classify Solution Criteria:**
Once criteria have been listed, we have a clearer statement of the objectives against which to judge the various alternatives. In most situations, criteria vary in their degree of importance. We need to classify these criteria to reflect their relative influence on the solution choice. We divide criteria into two basic categories:

1. Absolute Requirements or "Musts" – Mandatory, realistic and measurable requirements which help the project team to screen out unacceptable alternatives.
2. Comparison Criteria or "Wants" – Desirable characteristics which provide a basis for comparison for criteria.

Refine Solution Criteria
We need to refine the wants and musts criteria before generating possible solutions. The solution criteria can be refined by:
Clarifying Everyone's Understanding - Clarify everyone's understanding about each criteria by discussing and restating each criteria. Make use of the SCAMPER tool to refine or synthesize the solution criteria.

SCAMPER is a checklist of idea-spurring questions and stands for:

- S – Substitute
- C – Combine
- A – Adapt
- M – Modify Or Magnify
- P – Put to other Uses
- E – Eliminate Or Minify

- R – Reverse Or Rearrange

Weighing the "Wants" – Weigh the 'wants' to reflect upon the relative importance of each want criteria by using a Likert scale of 1-10.

SIX SIGMA DMAIC PROCESS - IMPROVE PHASE - GENERATE POSSIBLE SOLUTION

Involve those who will be Affected: We need to make sure we solicit the upfront involvement of People affected by the problem or its solution and People with expertise in the subject matter. We should then **Focus on the Root Causes** i.e. Make the affected parties revisit the significant root causes to get to a solution. Then, pick on **Idea Generation Technique.**

Five key techniques used for idea generation and synthesis are:

1. Brain-writing
2. Benchmarking
3. Assumption Busting
4. Creative Brainstorming
5. Modified Brainstorming

Idea Generation Technique - Brain-writing
Brain-writing is a technique used to generate many ideas in a short period of time. Two key modified brainstorming techniques used are Brain-writing 6-3-5 and Constrained Brain-writing.

Brain –writing 6-3-5 - The name brain-writing 6-3-5 comes from the process of having 6 people write 3 ideas in 5 minutes on a pre-defined parameter.

Constrained Brain-writing: The name constrained brain-writing comes the fact that on certain occasions the team may want to have a set of constrained ideas around a pre-determined focus, rather than ranging freely.

Idea Generation Technique - Benchmarking
Process benchmarking is a technique of continually searching for the best methods, practices and processes, and either adopting or adapting their good features and implementing them to become the "best of the best".

Idea Generation Techniques – Assumption Busting
Assumption busting as a technique is used to trace back from the current performance problems to identify rules and then surface underlying assumptions.
The key steps involved in assumption busting are:

- Revisit the current problem at hand.
- Identify the rule(s) responsible for the problem.
- Trace the rule(s) back to an assumption in the process.
- Test to break the assumption – Is it wrong from the start? Or, Can it be made untrue?

For example: In a personal loan approval process the problem is lengthy cycle time for approvals which is leading to dissatisfaction. Investigation of the process reveals that there is a rule existing in the process which makes every vital task in processing the loan pass through a specialist (legal expert, financial expert, credit expert) after it has been processed by an agent. The reason for rule existing in the process is an assumption which says that all loan deals are complex. On investigation and data-collection it is found that only 5% of deals are complex and thus the process assumption is wrong.

Idea Generation Technique – Creative Brainstorming

Nominal Group Technique: The nominal group technique is a structured method to narrow down & prioritize on a list of choices. It is called "nominal" because during the session the group doesn't engage in the usual amount of interaction typical of a team. Because of this relatively low level of interaction, nominal group technique is an effective tool when some group members are new to each other, relatively low level of interaction is required, issues are of highly controversial nature and a team is stuck in disagreement.

Idea Generation Technique – Modified Brainstorming

Modified brainstorming technique makes some basic and/or simple amendments to the "regular" creative brainstorming in order to help expand the number and quality of ideas. Three key modified brainstorming techniques used are: Analogy Technique, Channeling Technique and Anti-Solution Technique.

Analogy Technique - The ideas generated on the "analogy" then get translated to the real situation (the problem at hand). Channeling Technique - We begin by listing "categories" of ideas for the issue at hand. Then, as the team brainstorms, over a period of time it can "change channels" when new ideas slow down. The objective is to capture a broad range of ideas (several channels), as well as of quantity (as many ideas as possible in each channel).

Anti-Solution Technique - We begin by brainstorming around the opposite of the issue at hand. This is probably the easiest of modified brainstorming methods. For example, rather than brainstorming on ways to ensure complete information on a personal loan form we brainstorm on how to ensure we get no/incomplete information on the personal loan form.

SIX SIGMA DMAIC PROCESS - IMPROVE PHASE - SCREEN AGAINST MUSTS AND WANTS

Once possible solutions are listed, we can begin the process of seeing how they perform against the solution criteria. We base our assessment on the best available information about each alternative. In addition to known facts, this information may take the form of our best projections or the opinion of experts. The criteria serve as the guide for our data gathering. For each criteria we must have complete information about all of the alternatives, so that we can make a reasonable judgment.

SIX SIGMA DMAIC PROCESS - IMPROVE PHASE - CONDUCT COST-BENEFIT ANALYSIS

Cost-benefit analysis weighs the real costs of a potential solution under consideration against the potential benefits of the solution. Consider all costs associated with getting the proposed solution up and running. Cost examples would be: Capital investment needed, Implementation costs (time of project team, process improvement costs, etc), Start-up costs (training, lost production during switch from the old to new process), Operation costs (additional cost of running new process compared to old process).

The steps involved in doing a cost-benefit analysis for possible solutions are:

- Consider all costs associated with getting solution up and running
- Quantify benefits of a fully implemented solution
- Compare the real costs of solution against potential benefits

Does the identified solution have any risk?
Risk can be mitigated for the proposed solution by Identifying potential problem if any with the solution, Ensuring that the solution attempts to reduce the opportunity for error if not eliminated, Is it an “All terrain” or a" Feather bed” solution – How robust is the solution and Understanding the Failure Modes and Effect Analysis.

SIX SIGMA DMAIC PROCESS - IMPROVE PHASE - 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).

RPN = S*O*D

Based on the above suitable action plans can be created to contain the risk. It is used as a living document and could be a good foundation for building robustness.

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 failure mode (1-likely to detect; 10-not likely to detect)
- RPN is an acronym for Risk Priority Number. It is calculated by multiplying the Severity, Occurrence and Detectability.

Ranking	Severity	Occurrence	Detectability
1	No effect	Remote: Failure is unlikely <1 in 15,00,000	Design control will detect potential cause or the mechanism and subsequent failure mode
2	System operable with minimal interference	Low: Relatively few failures <1 in 150,000	Very high chance the design control will detect potential cause/mechanism and subsequent failure mode
3	System operable with some degradation of performance	Low: Relatively few failures <1 in 15000	High chance the design control will detect potential cause/mechanism and subsequent failure mode
4	System operable with significant degradation of performance	Moderate: Occasional failures <1 in 2000	Low chance the design control will detect potential cause/mechanism and subsequent failure mode
5	System inoperable with no damage	Moderate: Occasional failures <1 in 400	Moderate chance the design control will detect potential cause/mechanism and subsequent failure mode

Failure Mode Effect Analysis (FMEA) - 1

Ranking	Severity	Occurrence	Detectability
6	System inoperable with minor damage	Moderate: Occasional failures <1 in 80	Low chance the design control will detect potential cause/mechanism and subsequent failure mode
7	System inoperable with equipment damage	High: Repeated failures <1 in 20	Very low chance the design control will detect potential cause/mechanism and subsequent failure mode
8	System inoperable with destructive failure without compromising safety	High: Repeated failures <1 in 8	Remote chance the design control will detect potential cause/mechanism and subsequent failure mode
9	Very high severity ranking when a potential failure mode affects safe system operation with warning	Very High: Failure is almost inevitable <1 in 3	Very remote chance the design control will detect potential cause/mechanism and subsequent failure mode
10	Very high severity ranking when a potential failure mode affects operation without warning	Very High: Failure is almost inevitable <1 in 2	Design control cannot detect potential cause/mechanism and subsequent failure mode

Failure Mode Effect Analysis (FMEA) - 2

SIX SIGMA DMAIC PROCESS - IMPROVE PHASE - PILOT SOLUTION IMPLEMENTATION

In general, there is a way to pilot all or some part of every solution that you will want to implement. It is almost always worth the extra effort to pilot. You certainly need to pilot when the scope of the change is large, the change could cause far-reaching unintended consequences, implementing the change will be a costly process and the change implemented would be difficult to reverse.

The key steps involved in conducting a pilot are strong leadership from top management, select a steering committee/pilot team, conduct briefings with the pilot team, pilot planning for issueless execution, sell to employees affected under pilot, employee training for pilot execution, pilot implementation on the shop-floor, debriefing after pilot implementation and extend to a second area, if required.

SIX SIGMA DMAIC PROCESS - IMPROVE PHASE - VALIDATE MEASUREMENT SYSTEM

For continuous data we use Gage R&R and we check for % Tolerance, % Contribution and # of Distinct Categories and for discrete data we use Attribute R&R and we check for Accuracy, Repeatability and Reproducibility.

SIX SIGMA DMAIC PROCESS - IMPROVE PHASE - NEW PROCESS CAPABILITY / MAPPING

New Process Capability can be calculated using DPMO Method or Z value method as discussed in the Measure phase.

New Team Targets: With the desired results coming from the pilot, the current process baselining needs to be revisited. The new process capability achieved should be made the basis of re-baselining exercise and we need to set new internal team targets accordingly for the staff.

With the desired results coming from the pilot, the new improved process "should-be" needs to be mapped. While mapping the new process, we should consider the following workflow instructions:

- Establish a product orientation or customer orientation
- Establish one-at-a-time processing
- Balance flow through bottleneck
- Drive parallel processing
- Reduce handoffs

SIX SIGMA DMAIC PROCESS - CONTROL PHASE - STATISTICAL PROCESS CONTROL

SPC was developed by Walter Shewhart in 1924. Traditionally SPC has been used to monitor and control the output parameters of the process (Y's).

SPC is used to analyze and control process performance, proactively control processes, distinguish between natural and assignable variation, identify and prevent process from Special causes and involves the use of Control Charts to determine if a process is operating "in control".

SIX SIGMA DMAIC PROCESS - CONTROL PHASE - WHAT IS A PROCESS CONTROL?

A control mechanism that ensures that the process performance be maintained are at level that satisfies the customer's need and drive the ongoing improvement of process performance. The key elements that constitute a process control system are

- Documentation of the process
- Develop process metrics
- Monitor the process based on the defined metrics

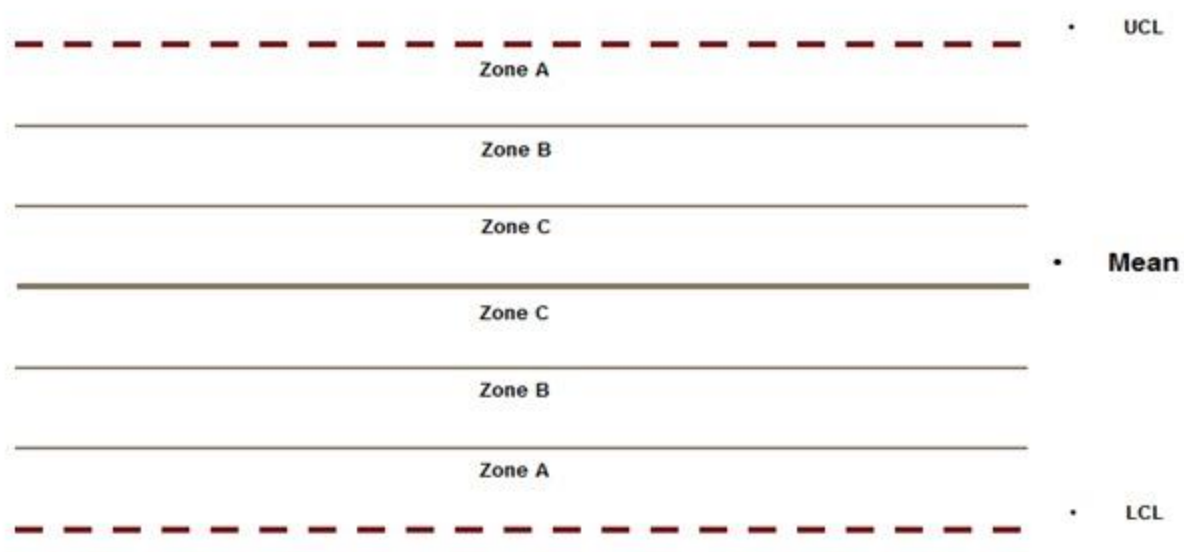
When we talk of a process is operating "In-Control" it translates to a situation that only common cause variation is present, process is predictable and process is stable.

Control limit Vs Specification limit
Control Limits: It is defined based on process performance. It help determine if the process is "in control". It is plotted on control charts and it changes when there is a verified, significant change to the process.

Specification Limits: It is provided by the customer part of SLA. It help determine if the process is producing defects. It is not plotted on control charts and it changes when requirement comes from the customer.

SIX SIGMA DMAIC PROCESS - CONTROL PHASE - WHAT ARE CONTROL CHARTS?

Control Chart is a graphical tool that helps determine if a process is “in control or not”. A control chart has three zones and is graphically represented as:



Six Sigma Control Chart Zones

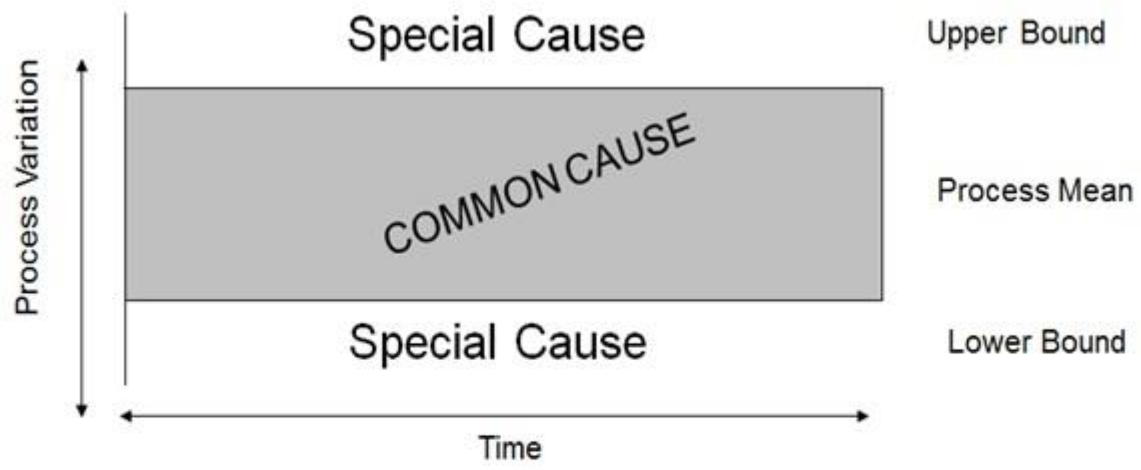
Common Causes and Special Causes which result with Variations

Characteristics of Common Causes:

- Present all the time
- Have a small effect individually
- Result in random variation
- Effect can be tolerated

Characteristics of Special Causes:

- Not always present
- Come from outside influences
- Typically have bigger influence than common causes
- Effect we want to hear about

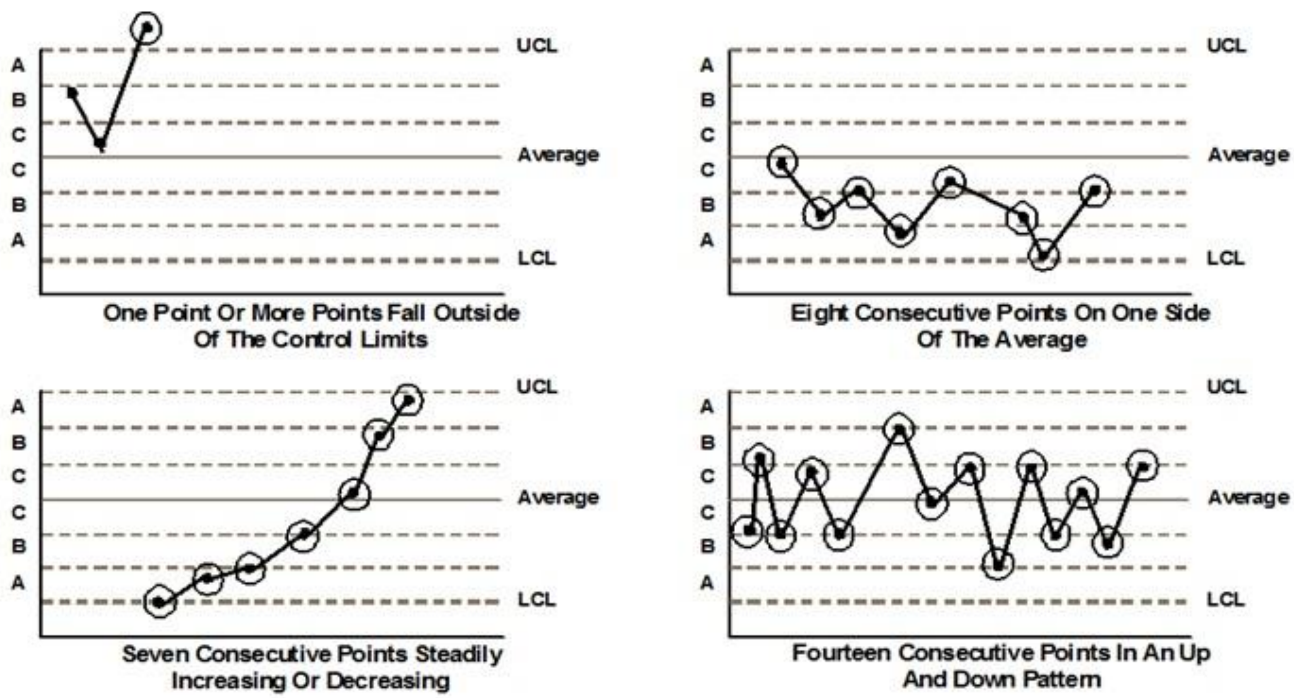


Six Sigma Common Causes and Special Causes

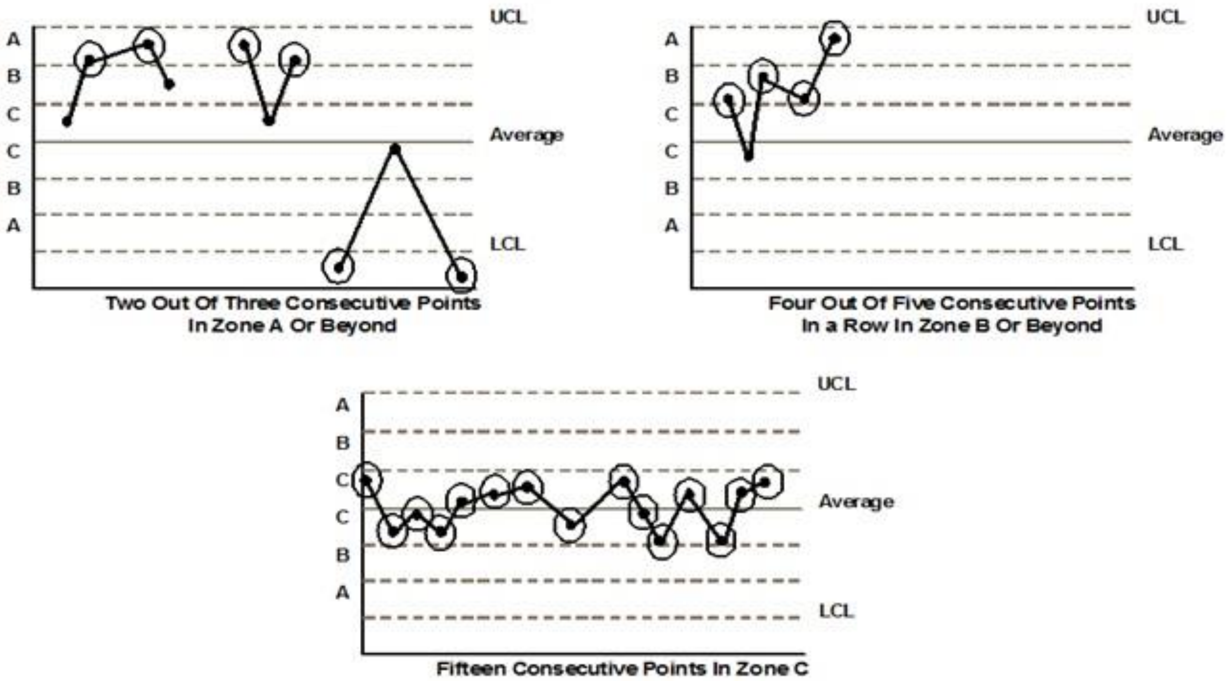
SIX SIGMA DMAIC PROCESS - CONTROL PHASE - SPC - OUT OF CONTROL

A process is said to be out of control if:

- One or more data points fall outside the control limits
- Seven consecutive data points increasing or decreasing
- Eight consecutive data points are on one side of average
- Fourteen consecutive data points alternating up & down
- Two data points, out of three consecutive data points, are on the same side of the average in zone A or beyond
- Four data points, out of five consecutive data points, are on the same side of the average in zone B or beyond
- Fifteen consecutive data points are within zone C (above and below the average)



Six Sigma Out of Control Charts-1



Six Sigma Out of Control Charts-2

SIX SIGMA DMAIC PROCESS - CONTROL PHASE - LEADING INDICATOR VS LAGGING INDICATOR

While interpreting control charts we also talk of two indicators:

Leading indicator:
A leading indicator shows the trend before the defect occurs. For example, you may be able to see a trend of six downward points. This is a leading indicator that the process will produce a defect outside the lower control limit.

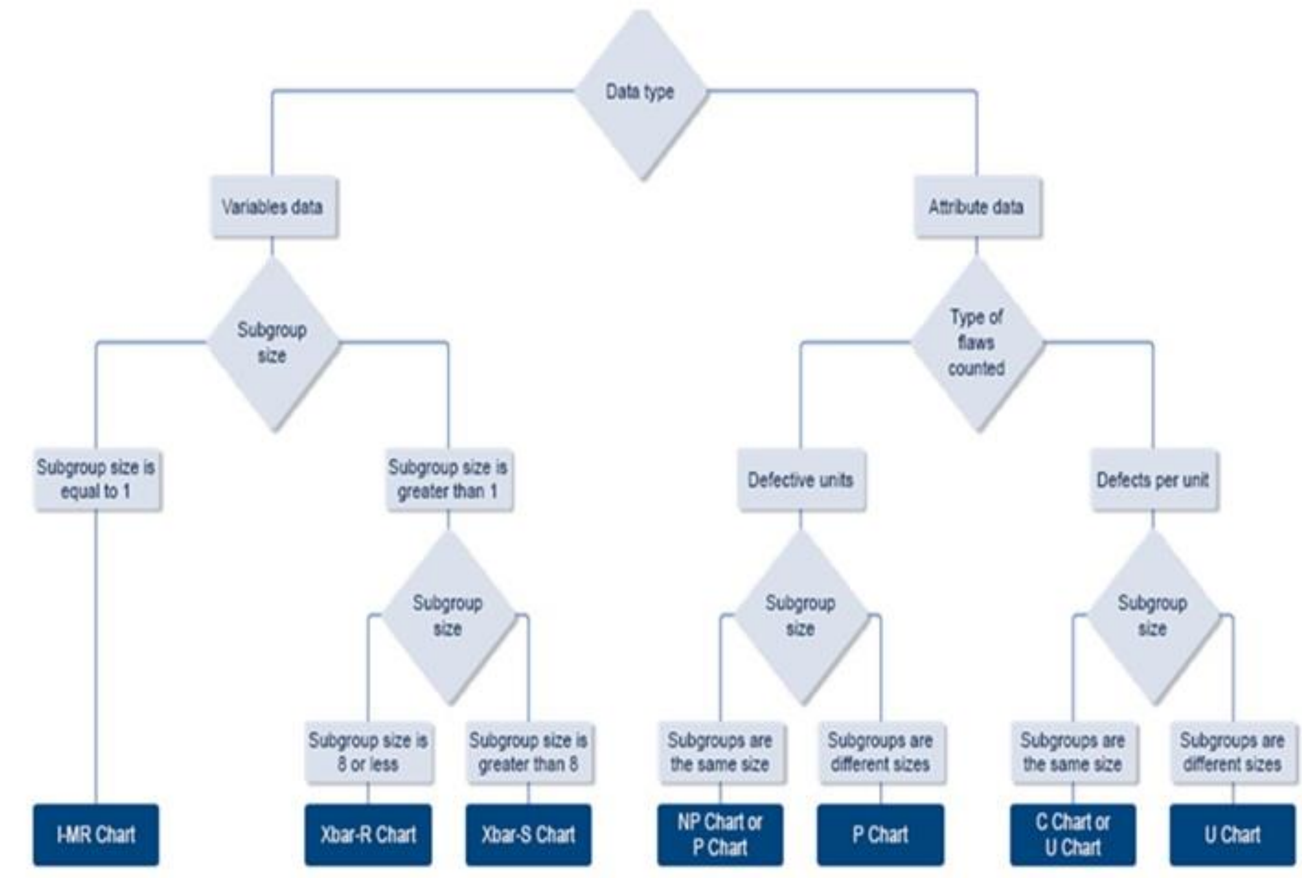
Lagging indicator:
A lagging indicator is an outlier that is already outside the upper or lower control limit. This is a lagging indicator that the defect has already occurred in the process.

SIX SIGMA DMAIC PROCESS - CONTROL PHASE - CONTROL CHART SELECTION

Points to keep in mind while selecting a control charts:

Continuous Data: For continuous data we can measure the average and the variation, thus X bar &R (Range) or X bar and S (Standard deviation) can be used.

Attribute Data: For Attribute data we first have to determine what are we measuring – Defects or Defectives. In case we are capturing defective data then determine if we are sampling for subgroup of equal sample size or not. In case if we are capturing data for defects then determine if the opportunity for the defects are the same for each subgroup or not. Based on the above we need to select the appropriate chart.



Six Sigma Control Chart Selection Guidelines

Situation	Statistical Test
Continuous data, one figure at a time For example: A team is tracking the length of time, measured in days, it takes to process claims. They are randomly selecting one completed claim each day and plotting the time it took to complete that one claim.	**Individuals and Moving Range** **I & MR Chart**
Continuous data, averages with small sub-group sizes For example: A team is tracking cycle time, measured in days, for claims processing. They are randomly selecting five completed claims each day and plotting the average cycle time.	**Average and Range** **X bar & R Chart**
Continuous data, averages with large sub-group sizes For example: A process owner is monitoring call length, measured in minutes and seconds. Each day, the average length for all calls received is plotted. The call center receives over 100 calls per day.	**Average and Standard Deviation** **X bar & S Chart**

Six Sigma Control Chart Selection – Continuous Y

Situation	Statistical Test
Discrete data, measuring defects with a constant sample size For example: A team is tracking the number of incomplete fields on applications. Each day, they pull a random sample of fifty applications and review them for completeness. They plot the total number of fields that are incomplete.	**Number of Defects** **(c Chart)**
Discrete data, measuring defects with a variable sample size For example: Another process owner is tracking the number of fields that are incomplete on applications. Each day her team reviews all incoming applications for completeness and plots the number of incomplete fields per number of applications.	**Number of Defects per Unit** **(u Chart)**
Discrete data, measuring defective units with a constant sample size For example: A team is tracking the number of applications that come in with incomplete information. Each day, they pull a random sample of fifty applications and review them for completeness. They plot the number that are incomplete.	**Number Defective** **(np Chart)**
Discrete data, measuring defective units with a variable sample size For example: A team is tracking the number of applications that come in with incomplete information. Each day, they review all applications for completeness and plot the percent that are incomplete.	**Fraction Defective** **(p Chart)**

Six Sigma Control Chart Selection – Discrete Y

SIX SIGMA DMAIC PROCESS - CONTROL PHASE - RISK ASSESSMENT AND MISTAKE PROOFING - POKA YOKE

Risk needs to be assessed on the “should-be” process to make the implemented solution more robust. Risk assessment of the new improved process makes sure that any potential effects of the possible failure modes do not result in loss of “holding of gains” over a period of time. Two key techniques to assess risk and make sure that no possible failures occur post control phase are:

- Failure Modes and Effects Analysis
- Mistake Proofing (or Poke Yoke)

Mistake Proofing – Poke Yoke:
Mistake proofing or poke yoke (derived from two Japanese words **poka** – inadvertent errors and **yokeru** – to avoid) helps de-link the Y’s from the X’s. Mistake proofing eliminates the potential for a problem to happen.

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

The three methods for prediction and detection approach are:

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

SIX SIGMA DMAIC PROCESS - CONTROL PHASE - CONTROL AND IMPLEMENTATION PLANS

The four techniques used for process control plans are:

- Standardization
- Documentation
- Monitoring Plan
- Response Plan

Standardization:
Standardization of the "should-be" process steps is required to ensure all responsible for execution have the same understanding. Standardizing the should-be process helps answer queries like:

- What are the steps in the process?
- Who does these steps in the process and when?
- Where more detailed work instructions can be found?

Documentation:
Documentation is a necessary step to insure that the learning gained via improvement is institutionalized and shared across the team by having it documented with proper work procedures. Often the live processes have a tendency to evolve in an ad-hoc manner. How to accomplish each process activity is usually left up to the individuals and thus, much of the organizational knowledge resides only in the minds of all those responsible for execution.
Procedure: A procedure is the documented sequence of steps & other instructions necessary to carry out an activity for a process.

Monitoring Plan:
Monitoring: It helps detect changes as and when they occur in the process and assure that improvements continue to hold for us to be able to meet customer requirements over a period of time. While observing a process a monitoring plan helps define:

- Key process and output measures for ongoing measurement of the improved process
- When data is to be collected and at how often
- Define the method for gathering, recording, and reporting data on the measures

Response Plan:
Response plan helps identify the next steps on what needs to be done if one detects a change in the process while monitoring. For each of the measure in the monitoring plan, the response plan helps define:

- What actions will be taken for an out-of-control event occurrence with a timeframe for the action
- Who takes action based on the monitoring data
- Where to find trouble-shooting procedures to fix problem

The key elements of a full scale implementation plan are:

- Clear Objectives
- Pilot Learning's Incorporated
- Implementation Milestones
- Resource Needs
- Influence Strategy
- Implementation Budget
- Process Control Plan
- Process Documentation

SIX SIGMA DMAIC PROCESS - CONTROL PHASE - REVIEW AND SIGN-OFF

The project gets closed when defect reduction is demonstrated over a significant period of time. Black belt and master black belt agrees on time period needed to collect and analyze data. If improvement is not confirmed, project will be reopened. The problem is “turned off” with confirmation run (and “turned on” when old process is used again).

The idea of “on-off” is key. We don’t want shift and drift caused by other variables to lead to a wrong decision. Project financial scorecard signed by six sigma champion, black belt, deployment leader, finance manager, process manager, and functional head. The leadership team agrees with the stated benefits.

THANK YOU!

Six Sigma is a complex, and yet an interesting subject. One of the biggest challenges with learning Six Sigma was to find useful training material which can really teach you Six Sigma.

And this was the main reason and motivation why International Six Sigma Institute ™ wrote this book for you. We hope that you enjoyed reading this book as much as we had enjoyed while we were writing it and you managed to build a strong Six Sigma foundation for yourself!

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