benchmark six sigma
Inspiring Minds, Facilitating Excellence

Volume

1

BENCHMARK SIX SIGMA

Lean Six Sigma

Green Belt Preparatory Module V12

BENCHMARK SIX SIGMA

Lean Six Sigma Green Belt Preparatory Module

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Preface

Lean Six Sigma Green Belt preparatory module introduces basic tools and techniques that are most important for Green Belts. The objective of this book is to familiarize readers with Lean Six Sigma tools, application of the tools and techniques in business scenarios and also enable them to absorb more during the classroom. In this preparatory module, learners are introduced to

- Elementary Statistics
- Basics of Six Sigma Project Management
- DMAIC Roadmap, tools and techniques
- Six Sigma Glossary
- Practice data files
- Reference Study links

Green Belt workshop primarily focuses on application of Six Sigma tools and techniques in different business situations. During the workshop, we will explore multiple case studies across industries, and also complete a practice project. Therefore, it is imperative for Green Belt participants to thoroughly study the preparatory module before attending the workshop. You may list down your questions and share it with the facilitator on the 1st day.

Benchmark Six Sigma has invested over 3000 hours of research in developing Lean Six Sigma Green Belt Workshop and continues to invest 480-640 hours/ year of content research and development exclusively for Green Belt workshop. We encourage you to participate in this activity.

If you spot an error or would like to suggest changes, or want to share specific case studies, articles, please e-mail us at sk@benchmarksixsigma.org

Chapter

1

What is Six Sigma?

History and Evolution of Lean Six Sigma

Defining Six Sigma

Six Sigma has been labelled as a metric, methodology, a management and now a philosophy. Green Belts, Black Belts, Master Black Belts, Champions and Sponsors have been trained on Six Sigma as a metric and methodology, however very few have experienced or been exposed to Six Sigma as an overall management system and a way of life. Reviewing the metric and the methodology will help create a context for beginning to understand Six Sigma as a management system.

Six Sigma is a **vehicle for strategic change** ... an organizational approach to performance excellence. It is important for business operations because it can be used both to increase top-line growth and also reduce bottom line costs. Six Sigma can be used to enable:

- **Transformational change** by applying it across the board for large-scale fundamental changes throughout the organization to change processes, cultures, and achieve breakthrough results.
- **Transactional change** by applying tools and methodologies to reduce variation and defects and dramatically improve business results.

When people refer to Six Sigma, they refer to several things:

Table 1

It is a philosophy	It is based on facts & data
It is a statistical approach to problem solving	It is a structured approach to solve problems or reduce variation
It refers to 3.4 defects per million opportunities	It is a relentless focus on customer satisfaction
Strong tie-in with bottom line benefits	Metric, Methodology, Management System

Six Sigma as a methodology provides businesses with the tools to improve the capability of their business processes. For Six Sigma, a process is the basic unit for improvement. A process could be a product or a service process that a company provides to outside customers, or it could be an internal process within the company, such as a billing or production process. In Six Sigma, the purpose of process improvement is to increase performance and decrease performance variation. This increase in performance and decrease in performance variation will lead to defect reduction and improvement in profits, to employee morale, Quality of product, and eventually to business excellence

The name "Six Sigma" derives from statistical terminology; Sigma(s) means Standard Deviation. In a production process, the "Six Sigma standard" means that the defective rate of the process will be 3.4 defects per million units. Clearly Six Sigma indicates a degree of extremely high consistency and extremely low variability. In statistical terms, the purpose of Six Sigma is to reduce variation to achieve very small standard deviations.

When compared with other Quality initiatives, the key difference of Six Sigma is that it applies not only to product Quality but also to all aspects of business operation by improving key processes. For example, Six Sigma may help create well-designed, highly reliable, and consistent customer billing systems; cost control systems; and project management systems.

History of Six Sigma

In the late 1970's, Dr. Mikel Harry, a senior staff engineer at Motorola's Government Electronics Group (GEG), experimented with problem solving through statistical analysis. Using this approach, GEG's products were being designed and produced at a faster rate and at a lower cost. Subsequently, Dr. Harry began to formulate a method for applying Six Sigma throughout Motorola. In 1987, when Bob Galvin was the Chairman, Six Sigma was started as a methodology in Motorola. Bill Smith, an engineer, and Dr. Mikel Harry together devised a 6 step methodology with the focus on defect reduction and improvement in yield through statistics. Bill Smith is credited as the father of Six Sigma. Subsequently, Allied Signal began implementing Six Sigma under the leadership of Larry Bossidy. In 1995, General Electric, under the leadership of Jack Welch began the most widespread implementation of Six Sigma.

Dr.Mikel Harry Bill Smith Larry Bossidy Jack Welch

General Electric: "It is not a secret society, a slogan or a cliché. Six Sigma is a highly disciplined process that helps focus on developing and delivering near-perfect products and services. Six Sigma has changed our DNA – it is now the way we work."

Honeywell: "Six Sigma refers to our overall strategy to improve growth and productivity as well as a Quality measure. As a strategy, Six Sigma is a way for us to achieve performance breakthroughs. It applies to every function in our company and not just to the factory floor."

The tools used in Six Sigma are not new. Six Sigma is based on tools that have been around for centuries. For example, Six Sigma relies a lot on the normal curve which was introduced by Abraham de Moivre in 1736 and later popularized by Carl Friedrich Gauss in 1818.

Six Sigma and Balanced Scorecard

The Balanced Scorecard was first developed in the early 1990s by two guys at the Harvard Business School: Robert Kaplan and David Norton. The key problem that Kaplan and Norton identified in today's business was that many companies had the tendency to manage their businesses based solely upon financial measures that may have worked well in the past; the pace of business in today's world requires better and more comprehensive measures. Though financial measures are necessary, they can only report what has happened in the past, where your business has been and they are not able to report where it is headed.

Balanced Scorecard is a *management system,* not a *measurement system*. Yes, measurement is a key aspect of the Balanced Scorecard, but it is much more than just measurement: it is a means of setting and achieving the strategic goals and objectives for your organisation. Balanced Scorecard is a management system that enables your organisation to set, track and achieve its key business strategies and objectives. Once the business strategies are developed, they are deployed and tracked through what we call the Four Legs of the Balanced Scorecard. These four legs are made up of four distinct business perspectives: Customer Leg, Financial Leg, Internal Business Process Leg, Knowledge, Education, and Growth Leg.

- **Customer scorecard:** Measures your customers' satisfaction and their performance requirements — for your organisation and what it delivers, whether it is products or services.
- **Financial scorecard:** Tracks your financial requirements and performance.
- **Internal Business Process scorecard**: Measures your critical to customer process requirements and measures.
- **Knowledge, Education, and Growth scorecard**: Focuses on how you train and educate your employees, gain and capture your knowledge, and how Green Belt/Black Belt use it to maintain a competitive edge within your markets

Six Sigma projects should positively impact these Key Performance Indicators; therefore Balanced Scorecard is closely monitored. Six Sigma is Management System for executing business strategy. Six Sigma is a solution to help organizations to:

- Align their business strategy to critical improvement efforts
- Mobilize teams to attack high impact projects
- Accelerate improved business results
- Govern efforts to ensure improvements are sustained

Chapter
2

Understanding Lean

Why do we want to lose excess Fat?

Defining Lean

Lean operation principles are derived from the Lean manufacturing practices. Lean manufacturing is a very effective strategy first developed by Toyota. The key focus of Lean is to identify and eliminate wasteful actions that do not add value to customers in the manufacturing process. Because Lean deals with production system from a pure process point of view, and not a hardware point of view, it has been found that the principles of Lean can be readily adopted in other types of processes, such as office process and product development process. Therefore, Lean operation principles can be used greatly to improve the efficiency and speed of all processes.

The strategy part of Lean looks at balancing multiple value streams (i.e., typically, a family of products or services) and integrating the work done in operations and in the rest of the organisation (be it a factory, a hospital, a software development company) with the customer in mind. The concept is simple. "Lean" describes any process developed to a goal of near 100% value added with very few waste steps or interruptions to the workflow. That includes physical things like products and less tangible information like orders, request for information, quotes, etc.

Lean is typically driven by a need for quicker customer response times, the proliferation of product and service offerings, a need for faster cycle times, and a need to eliminate waste in all its forms. The Lean approach challenges everything and accepts nothing as unchangeable. It strives continuously to eliminate waste from all processes, a fundamental principle totally in alignment with the goals of the Six Sigma Management System. These methods are especially effective in overcoming cultural barriers where the impossible is often merely the untried.

Lean, like any other major business strategy, is best if driven from the top, linked into the organisation's performance measurement systems, and used as a competitive differentiator. This is what we would like to do however sometimes reality differs. In most instances, the Champions driving this approach should look for pilot areas in the organisation to test the concept and see if a business case for Lean can be built over time. One cannot just flip a switch and get the whole organisation doing this anyway, so starting small and building from there can be a valuable approach.

Lean in the Office

Lean in an assembly manufacturing plant tends to focus on one-piece flow. In a process or job shop, it tends to focus on eliminating wait time. The idea of eliminating wait time and defining "standard work" also applies to the office and administrative environments. Most overhead departments and activities do not have effective metrics. Standard work does not exist for most tasks. Most overhead departments would score poorly in a 5S assessment (Sort, Set-order, Shine, Standardize, and Sustain). Many administrative or transaction type systems are typically designed to handle the most complex transactions. These problems can cause excessive rework, delays in processing, and confusion. A few examples:

- An account closing process typically takes a long time to do because a flood of transactions take place at the end of the period: journal entries, special analysis, allocations, report preparation, etc. The excessive transactions cause accounting departments to be somewhat chaotic places at the end of the period. Adopting Lean in this world is different from a factory, but the goal is still stable amounts of work, flexible operations (within defined parameters), and pull from the customers of the process.
- Imagine a purchase order going through a process. Ninety-nine percent of its processing life is going to be "wait" time. It may also have re-work problems as people try to get the information right, and in terms of workload balance, some purchase orders are more difficult to do than others. This is not so different from what goes on in the factory. Many of these problems can be individually addressed using Kaizen and Lean Teams.
- Multiple re-inputs of information into Excel spread sheets, Access data bases, requirements generators, etc. Or the different languages used inside a business for the same physical product. Purchasing has a different numbering scheme than engineering, which has a different numbering scheme than accounting. And someone is supposed to keep a matrix up-to-date that maps these relationships now there's a value adding activity from a customer perspective!

Simple Lean tools with extraordinary benefits

What is 5S?

5S is a process and method for creating and maintaining an organised, clean, and high performance workplace. 5S enables anyone to distinguish between normal and abnormal conditions at a glance. 5S is the foundation for continuous improvement, zero defects, cost reduction, and a safe work area. 5S is a systematic way to improve the workplace, our processes and our products through production line employee involvement. 5S can be used in Six Sigma for quick wins as well as control. 5S should be one of the Lean tools that should be implemented first. If a process is in total disarray, it does not make sense to work on improvements. The process needs to be first organised (stabilized) and then improved.

The 5 S’s are:

- **Sort** – Clearly distinguish needed items from unneeded items and eliminate the latter.
- **Straighten /Stabilize/ Set in Order** – Keep needed items in the correct place to allow for easy and immediate retrieval.
- **Shine** – Keep the work area clean.
- **Standardize** – Develop standardized work processes to support the first three steps.
- **Sustain** – Put processes in place to ensure that the first four steps are rigorously followed.

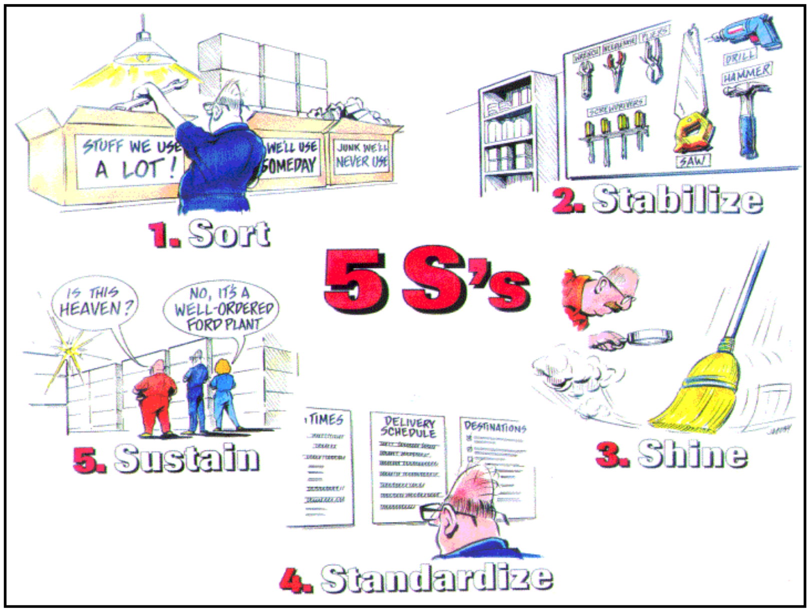


Figure 1: 5S Image from www.tpfeurope.com

What is Kaizen?

Kaizen is a Japanese word that means to break apart to change or modify (Kai) to make things better (Zen). Kaizen is used to make small continuous improvements in the workplace to reduce cost, improve quality and delivery. It is particularly suitable when the solution is simple and can be obtained using a team based approach. Kaizen assembles small cross-functional teams aimed at improving a process or problem in a specific area. It is usually a focused 3-5 day event that relies on implementing "quick" and "do-it-now" type solutions. Kaizen focuses on eliminating the wastes in a process so that processes only add value to the customer. Some of the 7 wastes targeted by Kaizen teams are:

- Waiting/Idle Time/Search time (look for items, wait for elements or instructions to be delivered)
- Correction (defects/re-work & scrap - doing the same job more than once)
- Transportation (excess movement of material or information)
- Overproduction (building more than required)
- Over-processing (processing more than what is required or sufficient)
- Excess Motion (excess human movements at workplace)
- Storage/warehousing (excess inventory)

The benefits of doing Kaizen are less direct or indirect labour requirements, less space requirements, increased flexibility, increased quality, increased responsiveness, and increased employee enthusiasm. Figure 2 shows a Kaizen team in action discussing improvements.

Figure 2: A Kaizen Team at Boeing in Action

Poka-Yoke

Poka-Yoke is a structured methodology for mistake-proofing operations. It is any device or mechanism that either prevents a mistake from being made or ensures that the mistakes don't get translated into errors that the customers see or experience. The goal of Poka-Yoke is both prevention and detection: "errors will not turn into defects if feedback and action take place at the error stage." (Shigeo Shingo, industrial engineer at Toyota. He is credited with starting "Zero Quality Control"). The best operation is one that both produces and inspects at the same time.

There are three approaches to Poka-Yoke:

- Warning (let the user know that there is a potential problem – like door ajar warning in a car)
- Auto-correction (automatically change the process if there is a problem – like turn on windshield wipers in case of rain in some advanced cars)
- Shutdown (close down the process so it does not cause damage – like deny access to ATM machines if password entered is wrong 3 times in a row)

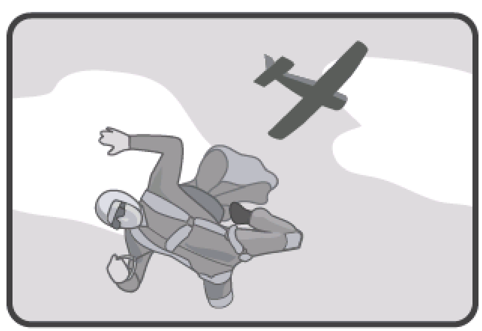


Figure 3: Poka-Yoke Example – Possibility of Parachute failing to open should not exist

7 Wastes in Lean

The 7 Wastes (also referred to as Muda) in Lean are:

Table 2: 7 Waste in lean

W	O	R	M	P	I	T
Waiting	**Over-Production**	**Rework**	**Motion**	**Over-processing**	**Inventory**	**Transportation**

The underutilization of talent and skills is sometimes called the **8th waste in Lean.**

Waiting is non- productive time due to lack of material, people, or equipment. This can be due to slow or broken machines, material not arriving on time, etc. Waste of Waiting is the cost of an idle resource. Examples are:

- Processing once each month instead of as the work comes in
- Waiting on part of customer or employee for a service input
- Delayed work due to lack of communication from another internal group.

Over-Production refers to producing more than the next step needs or more than the customer buys. Waste of Over-production relates to the excessive accumulation of work-in-process (WIP) or finished goods inventory. It may be the worst form of waste because it contributes to all the others. Examples are:

- Preparing extra reports
- Reports not acted upon or even read
- Multiple copies in data storage
- Over-ordering materials

Rework or Correction or defects are as obvious as they sound. Waste of Correction includes the waste of handling and fixing mistakes. This is common in both manufacturing and transactional settings. Examples are:

- Incorrect data entry
- Paying the wrong vendor
- Misspelled words in communications
- Making bad product or materials or labour discarded during production

Motion is the unnecessary movement of people and equipment. This includes looking for things like documents or parts as well as movement that is straining. Waste of Motion examines how people move to ensure that value is added. Examples are:

- Extra steps
- Extra data entry
- Having to search for something for approval

Over-Processing refers to tasks, activities and materials that don't add value. Can be caused by poor product or process design as well as from not understanding what the customer wants. Waste of Over-processing relates to over-processing anything that may not be adding value in the eyes of the customer. Examples are:

- Sign-offs
- Reports that contain more information than the customer wants or needs
- Communications, reports, emails, contracts, etc that contain more than the necessary points (concise is better)
- Voice mails that are too long
- Duplication of effort/reports

Inventory is the liability of materials that are bought, invested in and not immediately sold or used. Waste of Inventory is identical to over-production except that it refers to the waste of acquiring raw material before the exact moment that it is needed. Examples are:

- Transactions not processed
- Bigger "in box" than "out box"
- Over-stocking raw materials

Transportation is the unnecessary movement of material and information. Steps in a process should be located close to each other so movement is minimized. Examples are:

- Extra steps in the process
- Moving paper from place to place

Forwarding emails to one another

Chapter

3

Statistics for Lean Six Sigma

Elementary Statistics for Business

The field of statistics deals with the collection, presentation, analysis, and use of data to make decisions, solve problems, and design products and processes. Statistical techniques can be a powerful aid in designing new products and systems, improving existing designs, and designing, developing, and improving processes

Statistical methods are used to help us describe and understand variability. By variability, we mean that successive observations of a system or phenomenon do not produce exactly the same result. We all encounter variability in our everyday lives, and statistical thinking can give us a useful way to incorporate this variability into our decision-making processes. For example, consider the gasoline mileage performance of your car. Do you always get exactly the same mileage performance on every tank of fuel? Of course not—in fact, sometimes the mileage performance varies considerably. This observed variability in gasoline mileage depends on many factors, such as the type of driving that has occurred most recently (city versus highway), the changes in condition of the vehicle over time (which could include factors such as tire inflation, engine compression, or valve wear), the brand and/or octane number of the gasoline used, or possibly even the weather conditions that have been recently experienced. These factors represent potential sources of variability in the system. Statistics gives us a framework for describing this variability and for learning about which potential sources of variability are the most important or which have the greatest impact on the gasoline mileage performance.

Descriptive statistics focus on the collection, analysis, presentation, and description of a set of data. For example, the United States Census Bureau collects data every 10 years (and has done so since 1790) concerning many characteristics of residents of the United States. Another example of descriptive statistics is the employee benefits used by the employees of an organisation in fiscal year 2005.These benefits might include healthcare costs, dental costs, sick leave, and the specific healthcare provider chosen by the employee.

Inferential statistics focus on making decisions about a large set of data, called the population, from a subset of the data, called the sample. The invention of the computer eased the computational burden of statistical methods and opened up access to these methods to a wide audience. Today, the preferred approach is to use statistical software such as Minitab to perform the computations involved in using various statistical methods.

Basic terms and Sampling Methods

Now, in order to become familiar with sampling, you need to become familiar with some terms.

- A **population**, also called a *universe*, is the entire group of units, items, services, people, etc., under investigation for a fixed period of time and a fixed location.

- A **frame** is a physical list of the units in the population.

- The **gap** is the difference between the units in the population and the units in the frame.

If the units in the gap are distributed like the units in the frame, no problems should occur due to the gap. However, if the units in the gap are not distributed like the units in the frame, a systematic bias could result from the analysis of the frame. For example, if the frame of New York City residents over 18 years of age is the voter registration list, then a statistical analysis of the people on the list may contain bias if the distribution of people 18 and older is different for people on the list (frame) and people not on the list (gap). An example of where this difference might have an impact is if a survey was conducted to determine attitudes toward immigration because the voter registration list would not include residents who were not citizens.

A **sample** is the portion of a population that is selected to gather information to provide a basis for action on the population. Rather than taking a complete census of the whole population, statistical sampling procedures focus on collecting a small portion of the larger population. For example, 50 accounts receivable drawn from a list, or frame, of 10,000 accounts receivable constitute a sample. The resulting sample provides information that can be used to estimate characteristics of the entire frame.

There are four main reasons for drawing a sample.

- A sample is less time-consuming than a census.
- A sample is less costly to administer than a census.
- A sample is less cumbersome and more practical to administer than a census.
- A sample provides higher-quality data than a census.

There are two kinds of samples: non-probability samples and probability samples.

In a **non-probability sample**, items or individuals are chosen without the benefit of a frame. Because non-probability samples choose units without the benefit of a frame, there is an unknown probability of selection (and in some cases, participants have self-selected). For a non-probability sample, the theory of statistical inference should not be applied to the sample data. For example, many companies conduct surveys by giving visitors to their web site the opportunity to complete survey forms and submit them electronically. The response to these surveys can provide large amounts of data, but because the sample consists of self-selected web users, there is no frame. Non-probability samples are selected for convenience (**convenience sample**) based on the opinion of an expert (**judgment sample**) or on a desired proportional representation of certain classes of items, units, or people in the sample (**quota sample**). Non-probability samples are all subject to an unknown degree of bias. Bias is caused by the absence of a frame and the ensuing classes of items or people that may be systematically denied representation in the sample (the gap).

Non-probability samples have the potential advantages of convenience, speed, and lower cost. However, they have two major disadvantages: potential selection bias and the ensuing lack of generalized ability of the results. These disadvantages offset advantages of non - probability samples. Therefore, you should only use non-probability sampling methods when you want to develop rough approximations at low cost or when small-scale initial or pilot studies will be followed by more rigorous investigations.

You should use probability sampling whenever possible, because valid statistical inferences can be made from a probability sample. In a **probability sample**, the items or individuals are chosen from a frame, and hence, the individual units in the population have a known probability of selection from the frame.

The four types of probability samples most commonly used are simple random, stratified, systematic, and cluster. These sampling methods vary from one another in their cost, accuracy, and complexity.

- ✓ **Simple Random Sample**

In a **simple random sample**, every sample of a fixed size has the same chance of selection as every other sample of that size. Simple random sampling is the most elementary random sampling technique. It forms the basis for the other random sampling techniques. With simple random sampling, *n* represents the sample size, and *N* represents the frame size, not the population size. Every item or person in the frame is numbered from 1 to *N.* The chance of selecting any particular member of the frame on the first draw is 1/*N.* You use random numbers to select items from the frame to eliminate bias and hold uncertainty within known limits.

Two important points to remember are that different samples of size *n* will yield different sample statistics, and different methods of measurement will yield different sample statistics. Random samples, however, do not have bias on average, and the sampling error can be held to known limits by increasing the sample size. These are the advantages of probability sampling over non-probability sampling.

- ✓ **Stratified Sample**

In a **stratified sample**, the *N* items in the frame are divided into sub populations or strata, according to some common characteristic. A simple random sample is selected within each of the strata, and you combine results from separate simple random samples. Stratified sampling can decrease the overall sample size, and, consequently, lower the cost of a sample. A stratified sample will have a smaller sample size than a simple random sample if the items are similar within a stratum (called *homogeneity*) and the strata are different from each other (called *heterogeneity*). As an example of stratified sampling, suppose that a company has workers located at several facilities in a geographical area. The workers within each location are similar to each other with respect to the characteristic being studied, but the workers at the different locations are different from each other with respect to the characteristic being studied. Rather than take a simple random sample of all workers, it is cost efficient to sample workers by location, and then combine the results into a single estimate of a characteristic being studied.

- ✓ **Systematic Sample**

In a **systematic sample**, the *N* individuals or items in the frame are placed into *k* groups by dividing the size of the frame *N* by the desired sample size *n*. To select a systematic sample, you choose the first individual or item at random from the *k* individuals or items in the first group in the frame. You select the rest of the sample by taking every *k*th individual or item thereafter from the entire frame.

If the frame consists of a listing of pre-numbered checks, sales receipts, or invoices, or a preset number of consecutive items coming off an assembly line, a systematic sample is faster and easier to select than a simple random sample. This method is often used in industry, where an item is selected for testing from a production line (say, every fifteen minutes) to ensure that machines and equipment are working to specification. This technique could also be used when questioning people in a sample survey. A market researcher might select every 10th person who enters a particular store, after selecting a person at random as a starting point; or interview occupants of every 5th house in a street, after selecting a house at random as a starting point.

A shortcoming of a systematic sample occurs if the frame has a pattern. For example, if homes are being assessed, and every fifth home is a corner house, and the random number selected is 5, then the entire sample will consist of corner houses. Corner houses are known to have higher assessed values than other houses. Consequently, the average assessed value of the homes in the sample will be inflated due to the corner house phenomenon.

- ✓ **Cluster Sample**

In a **cluster sample**, you divide the *N* individuals or items in the frame into many *clusters.* Clusters are naturally occurring subdivisions of a frame, such as counties, election districts, city blocks, apartment buildings, factories, or families. You take a random sampling of clusters and study all individuals or items in each selected cluster. This is called single-stage cluster sampling.

Cluster sampling methods are more cost effective than simple random sampling methods if the population is spread over a wide geographic region. Cluster samples are very useful in reducing travel time. However, cluster sampling methods tend to be less efficient than either simple random sampling methods or stratified sampling methods. In addition, cluster sampling methods are useful in cutting cost of developing a frame because first, a frame is made of the clusters, and second, a frame is made only of the individual units in the selected clusters. Cluster sampling often requires a larger overall sample size to produce results as precise as those from more efficient procedures.

Types of Variables

Variable: In statistics, a **variable** has two defining characteristics:

- A variable is an attribute that describes a person, place, thing, or idea.
- The value of the variable can "vary" from one entity to another.

For example, a person's *hair colour* is a potential variable, which could have the value of "blonde" for one person and "brunette" for another.

Data could be classified into two types: **attribute data** and **measurement data.**

Attribute Data

- **Attribute data** (also referred to as *categorical* or *count data*) occurs when a variable is either classified into categories or used to count occurrences of a phenomenon.
- Attribute data places an item or person into one of two or more categories. For example, gender has only two categories.
- In other cases, there are many possible categories into which a variable can be classified. For example, there could be many reasons for a defective product or service.
- Regardless of the number of categories, the data consists of the number or frequency of items in a particular category, whether it is number of voters in a sample who prefer a particular candidate in an election or the number of occurrences of each reason for a defective product or service.
- Count data consists of the number of occurrences of a phenomenon in an item or person. Examples of count data are the number of blemishes in a yard of fabric or number of cars entering a highway at a certain location during a specific time period.
- The colour of a ball (e.g., red, Green, blue) or the breed of a dog (e.g., collie, shepherd, terrier) would be examples of qualitative or categorical variables.

- Examples of discrete data in non-manufacturing processes include:
  - Number of damaged containers
  - Customer satisfaction: fully satisfied vs. neutral vs. unsatisfied
  - Error-free orders vs. orders requiring rework

Measurement Data

- **Measurement data** (also referred to as *continuous* or *variables data*) results from a measurement taken on an item or person. Any value can theoretically occur, limited only by the precision of the measuring process.
- For example, height, weight, temperature, and cycle time are examples of measurement data.
- E.g. suppose the fire department mandates that all fire fighters must weigh between 150 and 250 pounds. The weight of a fire fighter would be an example of a continuous variable; since a fire fighter's weight could take on any value between 150 and 250 pounds.
- Examples of continuous data in nonmanufacturing processes include:
  - Cycle time needed to complete a task
  - Revenue per square foot of retail floor space
  - Costs per transaction

From a process point of view, continuous data are always preferred over discrete data, because they are more efficient (fewer data points are needed to make statistically valid decisions) and they allow degree of variability in the output to be quantified. For example, it is much more valuable to know how long it actually took to resolve a customer complaint than simply noting whether it was late or not.

Variables can also be described according to the level of measurement scale.

There are four scales of measurement: nominal, ordinal, interval, and ratio. Attribute data classified into categories is **nominal scale** data—for example, conforming versus nonconforming, on versus off, male versus female. No ranking of the data is implied. Nominal scale data is the weakest form of measurement. An **ordinal scale** is used for data that can be ranked, but cannot be measured—for example, ranking attitudes on a 1 to 5 scale, where 1 = very dissatisfied, 2 = dissatisfied, 3 = neutral, 4 = satisfied, and 5 = very satisfied. Ordinal scale data involves a stronger form of measurement than attribute data. However, differences between categories cannot be measured.

Measurement data can be classified into interval- and ratio-scaled data. In an **interval scale**, differences between measurements are a meaningful amount, but there is no true zero point. In a **ratio scale**, not only are differences between measurements a meaningful amount, but there is a true zero point. Temperature in degrees Fahrenheit or Celsius is interval scaled because the difference between 30 and 32 degrees is the same as the difference between 38 and 40 degrees, but there is no true zero point (0° F is not the same as 0° C).Weight and time are ratio-scaled variables that have a true zero point; zero pounds are the same as zero grams, which are the same as zero stones. Twenty minutes is twice as long as ten minutes, and ten minutes is twice as long as five minutes.

Summary Measures

- **Population:** A population consists of a set of all measurements for which the investigator is interested.
- **Sample:** A sample is a subset of the measurements selected from the population.
- **Census:** A census is a complete enumeration of every item in a population.

We use measures of central tendency (Mean, Median) to determine the location and measures of dispersion (Standard Deviation) to determine the spread. When we compute these measures from a sample, they are **statistics** and if we compute these measures from a population, they are **parameters**. (To distinguish sample statistics and population parameters, Roman letters are used for sample statistics, and Greek letters are used for population parameters.)

✓ **Central Tendency:** The tendency of data to cluster around some value. Central tendency is usually expressed by a measure of location such as the mean, median, or mode.

Measures of Central Tendency

✓ **Mean (Arithmetic Mean**)

The mean of a sample of numerical observations is the sum of the observations divided by the number of observations. It is the simple arithmetic average of the numbers in the sample. If the sample members are denoted by $x_1, x_2, \ldots, x_n$ where n is the number of observations in the sample or the sample size, then the sample mean is usually denoted by$\bar{x}$and pronounced "x-bar". The population mean is denoted by μ

The arithmetic mean (also called the *mean* or *average*) is the most commonly used measure of central tendency. You calculate the arithmetic mean by summing the numerical values of the variable, and then you divide this sum by the number of values.

For a sample containing a set of *n* values, *X*1, *X*2. . .*Xn*, the arithmetic mean of a sample (given by the symbol *X* called *X-bar*) is written as:

$$\bar{x} = \frac{\textit{Sum of the Values}}{\textit{Number of the Values}}$$

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n}$$

To illustrate the computation of the sample mean, consider the following example related to your Personal life: the time it takes to get ready to go to work in the morning. Many people wonder why it seems to take longer than they anticipate getting ready to leave for work, but very few people have actually measured the time it takes them to get ready in the morning. Suppose you operationally define the time to get ready as the time in minutes (rounded to the nearest minute) from when you get out of bed to when you leave your home. You decide to measure these data for a period of 10 consecutive working days, with the following results:

Table 3

Day Time	1	2	3	4	5	6	7	8	9	10
Minutes	39	29	43	52	39	44	40	31	44	35

To compute the mean (average) time, first compute the sum of all the data values, 39 + 29 + 43 + 52 + 39 + 44 + 40 + 31 + 44 + 35, which are 396. Then, take this sum of 396 and divide by 10, the number of data values. The result, 39.6, is the mean time to get ready. Although the mean time to get ready is 39.6 minutes, not one individual day in the sample actually had that value. In addition, the calculation of the mean is based on all the values in the set of data. No other commonly used measure of central tendency possesses this characteristic.

CAUTION: WHEN TO USE THE ARITHMETIC MEAN

Because its computation is based on every value, the mean is greatly affected by any extreme value or values. When there are extreme values, the mean presents a distorted representation of the data. Thus, the mean is not the best measure of central tendency to use for describing or summarizing a set of data that has extreme values.

- ✓ **Median**

It is the point in the middle of the ordered sample. Half the sample values exceed it and half do not. It is used, not surprisingly, to measure where the center of the sample lies, and hence where the center of the population from which the sample was drawn might lie. The median of a set of data is that value that divides the data into two equal halves. When the number of observations is even, say 2*n*, it is customary to define the median as the average of the *n*th and (*n*+ 1) st rank ordered values.

The **median** is the value that splits a ranked set of data into two equal parts. If there are no ties, half the values will be smaller than the median, and half will be larger. The median is not affected by any extreme values in a set of data. Whenever an extreme value is present, the median is preferred instead of the mean in describing the central tendency of a set of data.

To calculate the median from a set of data, you must first rank the data values from smallest to largest. Then, the median is computed, as described next.

We can use Equation to compute the median by following one of two rules:

Rule 1: If there are an odd number of values in the data set, the median is the middle ranked value.

Rule 2: If there is an even number of values in the data set, then the median is the average of the two values in the middle of the data set.

$$\boldsymbol{Median = \frac{n+1}{2} ranked\ value}$$

Where *n* = the number of values

To compute the median for the sample of 10 times to get ready in the morning, you place the raw data in order as follows:

Table 4

29	**31**	**35**	**39**	**39**	**40**	**43**	**44**	**44**	**52**
RANKS									
1	2	3	4	5	6	7	8	9	10

Median=39.5

Using rule 2 for the even-sized sample of 10 days, the median corresponds to the (10 + 1)/2 = 5.5 ranked value, halfway between the fifth-ranked value and the sixth ranked value. Because the fifth-ranked value is 39 and the sixth ranked value is 40, the median is the average of 39 and 40, or 39.5. The median of 39.5 means that for half of the days, the time to get ready is less than or equal to 39.5 minutes, and for half of the days, the time to get ready is greater than or equal to 39.5 minutes.

- ✓ **Mode**

The mode of a sample is that observed value that occurs most frequently.

Measures of Dispersion (Spread)

A second important property that describes a set of numerical data is variation. **Variation** is the amount of **dispersion**, or spread, in a set of data, be it a sample or a population. Three frequently used measures of variation are the range, the variance, and the standard deviation

- ✓ **Range**

The range is the simplest measure of variation in a set of data. The **range** is equal to the largest value minus the smallest value. The smallest sample value is called the minimum of the sample, and the largest sample value is called the maximum. The distance between the sample minimum and maximum is called the range of the sample.The range clearly is a measure of the spread of sample values. As such it is a fairly blunt instrument, for it takes no cognizance of where or how the values between the minimum and maximum might be located.

Range = largest value – smallest value

Using the data pertaining to the time to get ready in the morning

Range = largest value – smallest value

Range = 52 – 29 = 23 minutes

This means that the largest difference between any two days in the time to get ready in the morning is 23 minutes.

- ✓ **Inter-quartile Range**

Difference between third and first quartile **(Q_3 - Q_1)**

Quartiles divide the sample into four equal parts. The lower quartile has 25% of the sample values below it and 75% above. The upper quartile has 25% of the sample values above it and 75% below. The middle quartile is, of course, the median. The middle half of the sample lies between the upper and lower quartile. The distance between the upper and lower quartile is called the inter-quartile range. Like the range, the inter-quartile range is a measure of the spread of the sample. It measures variability or dispersion.

The Variance and the Standard Deviation

Although the range is a measure of the total spread, it does not consider *how* the values distribute around the mean. Two commonly used measures of variation that take into account how all the values in the data are distributed around the mean are the variance and the standard deviation. These statistics measure how the values fluctuate around the mean.

A simple measure around the mean might just take the difference between each value and the mean, and then sum these differences. However, if you did that, you would find that because the mean is the balance point in a set of data, for every set of data, these differences would sum to zero. One measure of variation that would differ from data set to data set would square the difference between each value and the mean and then sum these squared differences. In statistics, this quantity is called a **sum of squares** (or ***SS***).This sum of squares is then divided by the number of values minus 1 (for sample data) to get the sample **variance**. The square root of the sample variance (s^2) is the sample **standard deviation** (s). This statistic is the most widely used measure of variation.

Sample Variance and Sample Standard Deviation:

The standard deviation of a sample of numerical observations is a measure of the spread or range of the sample values. It is derived from the distance of each point in the sample from the sample mean (positive distance to the right, negative to the left). These distances are the *deviations* of the title - they are deviations from the sample mean. If you sum the squared deviations, and then divide by one less than the sample size, you get what is known as the sample *variance*. Typically this is denoted by 's^2'. The sample variance is a useful measure in itself of the variability in the sample values, but its units of measurement are the square of those of the sample values themselves. The standard deviation of a sample is the (positive) square root of the sample variance, and is usually denoted by '**s**'. It is a measurement on the same scale as that of the original sample values.

The standard deviation cannot be less than zero. If the standard deviation of a sample is zero, then all sample values are the same. If the sample values are not all the same then they must exhibit some form of variability. How much variability the sample values exhibit is encapsulated by the standard deviation. If the standard deviation is small, then the sample values cluster close to the sample mean. If the standard deviation is large then the sample values are widely dispersed.

The steps for computing the variance and the standard deviation of a sample of data are

COMPUTING s^2 AND s

To compute s^2, the sample variance, do the following:

1. Compute the difference between each value and the mean.

2. Square each difference.
3. Add the squared differences.
4. Divide this total by *n*– 1.

To compute *s*, the sample standard deviation, take the square root of the variance.

Table 5 illustrates the computation of the variance and standard deviation using the steps for the time to get ready in the morning data. You can see that the sum of the differences between the individual values and the mean is equal to zero.

Table 5

Time (X)	Difference Between the X and the Mean	Squared Difference Around the Mean
39	- 0.6	0.36
29	- 10.6	112.36
43	3.4	11.56
52	12.4	153.76
39	- 0.6	0.36
44	4.4	19.36
40	0.4	0.16
31	- 8.6	73.96
44	4.4	19.36
35	- 4.6	21.16
Mean = 39.6	**Sum of Differences = 0**	**Sum of Squared Differences = 412.4**

You calculate the sample variance S^2 by dividing the sum of the squared differences computed in step 3 (412.4) by the sample size (10) minus 1:

$$\textbf{Sample Variance } (s^2) = {}^{412.4}/_{9} = 45.82$$

Because the variance is in squared units (in squared minutes for these data), to compute the standard deviation, you take the squared root of the variance. Thus:

$$\textbf{Sample standard deviation } (s) = \sqrt{45.82} = 6.77$$

As summarized, we can make the following statements about the range, variance, and standard deviation.

Characteristics of Range, Variance and Standard Deviation

- The more spread out or dispersed the data is, the larger will be the range, the variance, and the standard deviation.

- The more concentrated or homogeneous the data is the smaller will be the range, the variance, and the standard deviation.
- If the values are all the same (so that there is no variation in the data), the range, variance, and standard deviation will all be zero.
- The range, variance, or standard deviation will always be greater than or equal to zero.

EQUATIONS FOR THE VARIANCE AND STANDARD DEVIATION

$$s^2 = \frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1}$$

$$s = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1}}$$

Where

$\bar{X}$ = Sample Mean
n = Sample Size
X_i =i^{th} Value of the Variable X

$\sum_{i=1}^{n}(X_i - \bar{X})^2$ = summation of all the squared differences between the *X* values and $\bar{X}$

$$s^2 = \frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1}$$

$$s^2 = \frac{412.4}{10-1} = 45.82$$

$$s = \sqrt{45.82} = 6.77$$

GRAPHICAL PLOT

✓ Histogram:

A histogram (from the Greek *histos* meaning mast of the ship – vertical bars of the histogram) of a sample of numerical values is a plot which involves rectangles which represent frequency of occurrence in a specific interval. A Histogram can be used to assess the shape and spread of continuous sample data.

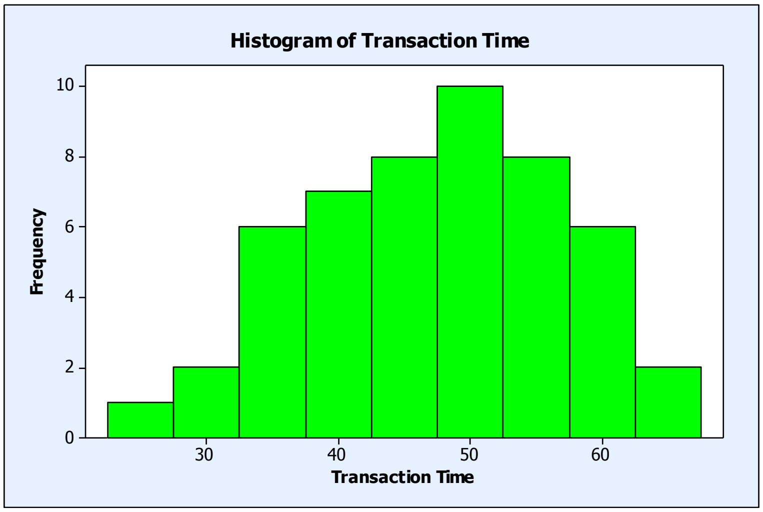


Figure 4

Worksheet: Transaction.mtw

✓ Box Plot

Box Plot can be used to show the shape of the distribution, its central value, and variability.

The median for each dataset is indicated by the black center line, and the first and third quartiles are the edges of the Green area, which is known as the inter-quartile range (IQR). The extreme values (within 1.5 times the inter-quartile range from the upper or lower quartile) are the ends of the lines extending from the IQR. We may identify outliers on boxplots by labeling observations that are at least 1.5 times the interquartile range (Q3 – Q1) from the edge of the box and highlighting the data point as an asterisk. . These points represent potential outlier.

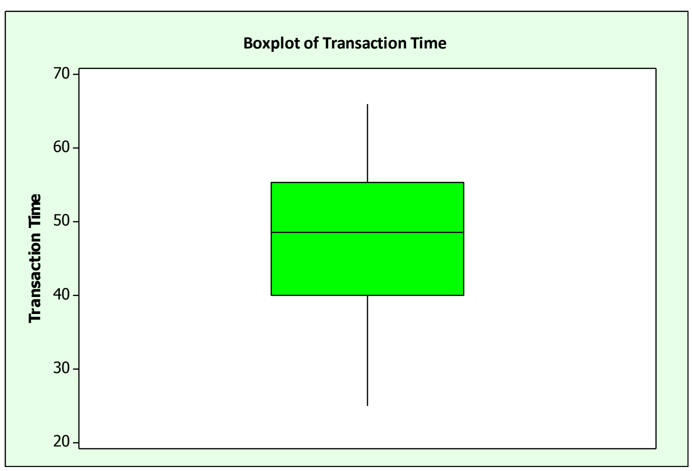


Figure 5

Worksheet: Transaction.mtw

✓ Scatter Plot

A graph of a set of data pairs (x, y) used to determine whether there is a statistical relationship between the variables x and y. In this scatter plot, we explore the correlation between Weight Gained (Y) and Calories Consumed (X)

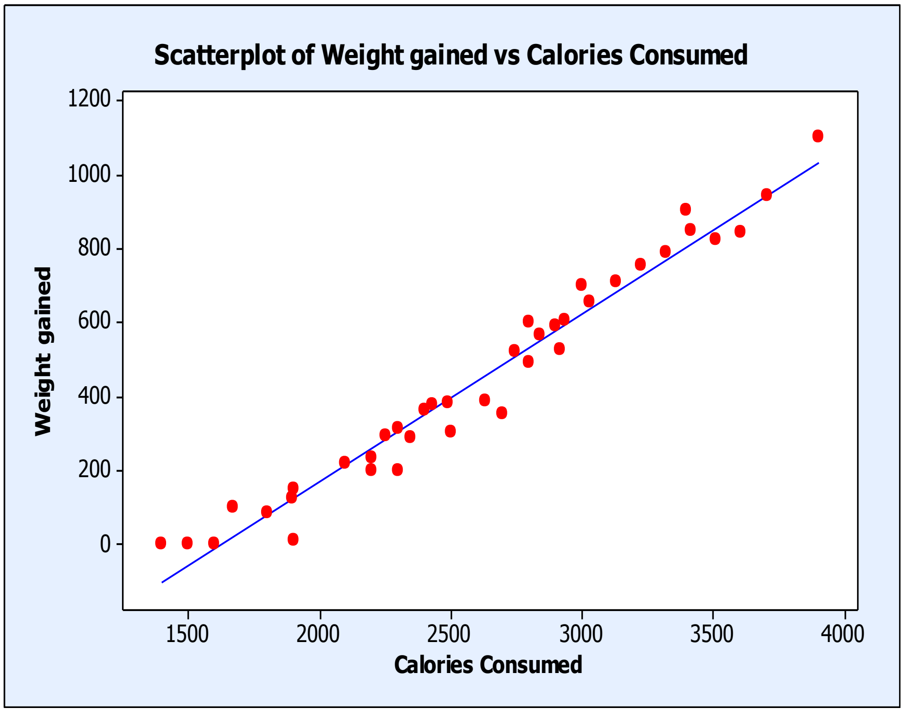


Figure 6

Worksheet: Calories Consumed.mtw

Random Variable and Probability Distributions

- A **random variable** is a variable whose value is determined by the outcome of a random experiment.
- A **discrete random variable** is one whose set of assumed values is **countable** (arises from **counting**). The probability distribution of a discrete random variable is a discrete distribution. E.g. Binomial, Poisson
- A **continuous random variable** is one whose set of assumed values is uncountable (arises from **measurement.**). The probability of a continuous random variable is a continuous distribution. E.g. Normal

✓ **Binomial distribution**

Binomial distribution describes the possible number of times that a particular event will occur in a sequence of observations. The event is coded binary; it may or may not occur. The binomial distribution is used when a researcher is interested in the occurrence of an event, not in its magnitude. For instance, in a clinical trial, a patient may survive or die. The researcher studies the number of survivors, and not how long the patient survives after treatment. The binomial distribution is specified by the number of observations, n, and the probability of occurrence, which is denoted by p.

Other situations in which binomial distributions arise are quality control, public opinion surveys, medical research, and insurance problems

The following conditions have to be met for using a binomial distribution:

- The number of trials is fixed
- Each trial is independent
- Each trial has one of two outcomes: event or non-event
- The probability of an event is the same for each trial

Suppose a process produces 2% defective items. You are interested in knowing how likely is it to get 3 or more defective items in a random sample of 25 items selected from the process. The number of defective items (X) follows a binomial distribution with n = 25 and p = 0.02.

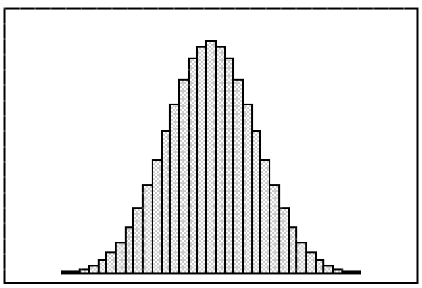


Figure 7

One of the properties of a binomial distribution is that when n is large and p is close to 0.5, the binomial distribution can be approximated by the standard normal distribution. For this graph, n = 100 and p = 0.5.

✓ **Poisson distribution**

The Poisson Distribution was developed by the French mathematician Simeon Denis Poisson in 1837.The Poisson distribution is used to model the number of events occurring within a given time interval. The Poisson distribution arises when you count a number of events across time or over an area. You should think about the Poisson distribution for any situation that involves counting events. Some examples are:

- the number of Emergency Department visits by an infant during the first year of life,
- The number of white blood cells found in a cubic centimetre of blood.

Sometimes, you will see the count represented as a rate, such as the number of deaths per year due to horse kicks, or the number of defects per square yard.

✓ **Four Assumptions**

Information about how the data was generated can help Green Belt/Black Belt decide whether the Poisson distribution fits. The Poisson distribution is based on four assumptions. We will use the term "interval" to refer to either a time interval or an area, depending on the context of the problem.

- The probability of observing a single event over a small interval is approximately proportional to the size of that interval.
- The probability of two events occurring in the same narrow interval is negligible.
- The probability of an event within a certain interval does not change over different intervals.
- The probability of an event in one interval is independent of the probability of an event in any other non-overlapping interval.

The Poisson distribution is similar to the binomial distribution because they both model counts of events. However, the Poisson distribution models a finite observation space with any integer number of events greater than or equal to zero. The binomial distribution models a fixed number of discrete trials from 0 to n events.

- ✓ **Normal Distribution**

The most widely used model for the distribution of a random variable is a normal distribution. Whenever a random experiment is replicated, the random variable that equals the average (or total) result over the replicates tends to have a normal distribution as the number of replicates becomes large. De Moivre presented this fundamental result, known as the central limit theorem, in 1733. Unfortunately, his work was lost for some time, and Gauss independently developed a normal distribution nearly 100 years later. Although De Moivre was later credited with the derivation, a normal distribution is also referred to as a Gaussian distribution.

A Normal distribution is an important statistical data distribution pattern occurring in many natural phenomena, such as height, blood pressure, lengths of objects produced by machines, etc. Certain data, when graphed as a histogram (data on the horizontal axis, amount of data on the vertical axis), creates a bell-shaped curve known as a normal curve, or normal distribution.

Normal distribution is symmetrical with a single central peak at the mean (average) of the data. The shape of the curve is described as bell-shaped with the graph falling off evenly on either side of the mean. Fifty percent of the distribution lies to the left of the mean and fifty percent lies to the right of the mean. The spread of a normal distribution is controlled by the standard deviation. The smaller the standard deviation, more concentrated the data. The mean and the median are the same in a normal distribution. In a normal standard distribution, mean is 0 and standard deviation is 1

For example, the heights of all adult males residing in the state of Punjab are approximately normally distributed. Therefore, the heights of most men will be close to the mean height of 69 inches. A similar number of men will be just taller and just shorter than 69 inches. Only a few will be much taller or much shorter.

The mean (μ) and the standard deviation (σ) are the two parameters that define the normal distribution. The mean is the peak or center of the bell-shaped curve. The standard deviation determines the spread in the data. Approximately, 68.27% of observations are within +/- 1 standard deviation of the mean; 95.46% are within +/- 2 standards deviations of the mean; and 99.73% are within +/- 3 standard deviations of the mean.

For the height of men in Punjab, the mean height is 69 inches and the standard deviation is 2.5 inches. For a continuous distribution, like to normal curve, the area under the probability density function (PDF) gives the probability of occurrence of an event.

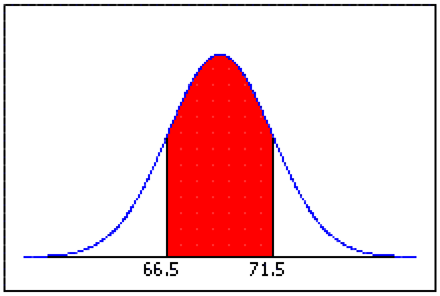


Figure 8

Approximately 68.27% of men in Punjab are between 66.5 (m - 1s) and 71.5 (m + 1s) inches tall.

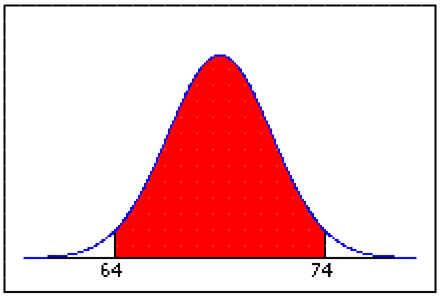


Figure 9

Approximately 95.46% of men in Punjab are between 64 (m - 2s) and 74 (m + 2s) inches tall.

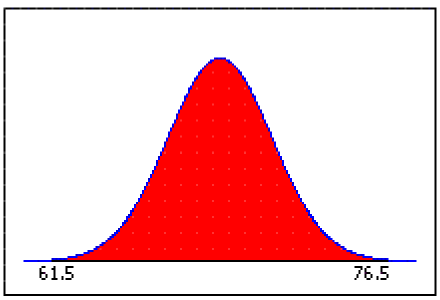


Figure 10

Approximately 99.73% of men in Punjab are between 61.5 (m - 3s) and 76.5 (m + 3s) inches tall.

A useful link for calculating probabilities: http://www.graphpad.com/quickcalcs/probability1.cfm

Chapter

4

Managing Six Sigma Projects

Managing Projects

Six Sigma is different from other quality or process improvement methodologies- 'IT DEMANDS RESULTS'. These results are delivered by PROJECTS that are tightly linked to customer demands and enterprise strategy.The efficacy of Six Sigma projects is greatly improved by combining project management and business process improvement practices.

What is a Project?

A project is a temporary endeavor undertaken to create a unique product, service, or result. The temporary nature of project indicates a definite beginning and end. The end is reached when the project's objectives have been achieved or when the project is terminated because its objectives will not or cannot be met, or when the need for the project no longer exists. Temporary doesn't necessarily mean short in duration. Temporary doesn't generally apply to the product, service, or result created by the project; most projects are undertaken to create a lasting outcome.

The logical process flow

A logical process flow as explained by Thomas Pyzdek is as follows:

1. Define the project's goals and deliverables.
    a. If these are not related to the organisation's strategic goals and objectives, stop. The project is not a Six Sigma project. This does not necessarily mean that it isn't a "good" project or that the project shouldn't be done. There are many worthwhile and important projects that are not Six Sigma projects.
2. Define the current process.
3. Analyze the measurement systems.
4. Measure the current process and analyze the data using exploratory and descriptive statistical methods.
    a. If the current process meets the goals of the project, establish control systems and stop, else …
5. Audit the current process and correct any deficiencies found.
    a. If the corrected process meets the goals of the project, establish control systems and stop, else …
6. Perform a process capability study using SPC.
7. Identify and correct special causes of variation.
    a. If the controlled process meets the goals of the project, establish control systems and stop, else …
8. Optimize the current process by applying statistically designed experiments.
    a. If the optimized process meets the goals of the project, establish control systems and stop, else …

9. Employ breakthrough strategy to develop and implement an entirely new process that meets the project's goals.
10. Establish control and continuous improvement systems and stop.

Project Plan

✓ **Develop the Project Charter**

Project charters (sometimes called project scope statements) should be prepared for each project and subproject. The Project Charter includes the project justification, the major deliverables, and the project objectives. It forms the basis of future project decisions, including the decision of when the project or subproject is complete. The Project Charter is used to communicate with stakeholders and to allow scope management as the project moves forward. The Project Charter is a written document issued by the Project Sponsor. The Project Charter gives the project team authority to use organisational resources for project activities.

✓ **Conduct a Feasibility Analysis- Is This a Valid Project?**

Before launching a significant effort to solve a business problem, be sure that it is the correct problem and not just a symptom. Is the "defect" Green Belt/Black Belt are trying to eliminate something the customer cares about or even notices? Is the design requirement really essential, or can engineering relax the requirement? Is the performance metric really a key business driver, or is it arbitrary? Conduct a project validation analysis and discuss it with the stakeholders

✓ **Project Metrics**

At this point Green Belt/Black Belt know who the project's customers are and what they expect in the way of project deliverables. Now Green Belt/Black Belt must determine precisely how Green Belt/Black Belt will measure progress toward achieving the project's goals.

✓ **What Is the Total Budget for This Project?**

Projects consume resources, therefore to accurately measure project success, it is necessary to keep track of how these resources are used. The total project budget sets an upper limit on the resources this project will be allowed to consume. Knowing this value, at least approximately, is vital for resource planning.

✓ **How Will I Measure Project Success?**

Green Belt/Black Belt should have one or more metrics for each project deliverable.

- Metrics should be selected to keep the project focused on its goals and objectives.
- Metrics should detect project slippage soon enough to allow corrective action to avert damage.
- Metrics should be based on customer or Sponsor requirements.

✓ **Financial Benefits**

Preliminary estimates of benefits were made previously during the initial planning. However, the data obtained by the team will allow the initial estimates to be made more precisely at this time. Whenever possible, "characteristics" should be expressed in the language of management: dollars. One needn't strive for to-the-penny accuracy; a rough figure is usually sufficient. It is recommended that the finance and accounting department develop dollar estimates; however, in any case it is important that the estimates at least be accepted (in writing) by the accounting and finance department as reasonable. This number can be used to compute a return on investment (ROI) for the project.

✓ **How Will I Monitor Satisfaction with Project Progress?**

Six Sigma projects have a significant impact on people while they are being conducted. It is important that the perspectives of all interested parties be periodically monitored to ensure that the project is meeting their expectations and not becoming too disruptive. The Green Belt/Black Belt should develop a means for obtaining this information, analyzing it, and taking action when the results indicate a need. Data collection should be formal and documented. Relying on "gut feeling" is not enough.

Means of monitoring includes but not limited to Personal interviews, Focus groups, Surveys, Meetings, Comment cards. Green Belt/Black Belt may also choose to use Stakeholder analysis and Force Field analysis to proactively assess change management challenges that lie ahead.

✓ **Work Breakdown Structures (WBS):**

The creation of work breakdown structures involves a process for defining the final and intermediate products of a project and their interrelationships. Defining project activities is complex. It is accomplished by performing a series of decompositions, followed by a series of aggregations. For example, a software project to develop an SPC software application would disaggregate the customer requirements into very specific engineering requirements. The customer requirement that the product create $\overline{x}$ charts would be decomposed into engineering requirements such as subroutines for computing subgroup means and ranges, plotting data points, drawing lines, etc. Re-aggregation would involve, for example, linking the various modules to produce an xbar chart and display it on the screen.

✓ **Creating the WBS**

The project deliverables expected by the project's sponsors were initially defined in the Project Charter. For most Six Sigma projects, major project deliverables are so complex as to be unmanageable. Unless they are broken into components, it isn't possible to obtain accurate cost and duration estimates for each deliverable. WBS creation is the process of identifying manageable components or sub-products for each major deliverable.

✓ **Project Schedule Development**

Project schedules are developed to ensure that all activities are completed, reintegrated, and tested on or before the project due date. The output of the scheduling activity is a time chart (schedule) showing the start and finish times for each activity as well as its relationship to other activities in the project and responsibility for completing the activity. The schedule must identify activities that are critical in the sense that they must be completed on time to keep the project on schedule.

The information obtained in preparing the schedule can be used to improve it. Activities that the analysis indicates to be critical are prime candidates for improvement. Pareto analysis can be used to identify those critical elements that are most likely to lead to significant improvement in overall project completion time. Cost data can be used to supplement the time data and the combined time/cost information can be analysed using Pareto analysis

✓ **Project Deadline**

- What is the latest completion date that allows the project to meet its objective?

- What are the penalties for missing this date? Things to consider are lost market share, contract penalties, fines, lost revenues, etc.

✓ **Activity Definition**

Once the WBS is complete, it can be used to prepare a list of the activities (tasks) necessary to complete the project. Activities don't simply complete themselves. The resources, time, and personnel necessary to complete the activities must be determined. A common problem to guard against is *scope creep*. As activities are developed, be certain that they do not go beyond the project's original scope. Equally common is the problem of *scope drift*. In these cases, the project focus gradually moves away from its original Charter. Since the activities are the project, this is a good place to carefully review the scope statement in the Project Charter to ensure that the project remains focused on its goals and objectives.

✓ **Activity Dependencies**

Some project activities depend on others: sometimes a given activity may not begin until another activity is complete. To sequence activities so they happen at the right time, Green Belt/Black Belt must link dependent activities and specify the type of dependency. The linkage is determined by the nature of the dependency. Activities are linked by defining the dependency between their finish and start dates

✓ **Estimating Activity Duration**

In addition to knowing the dependencies, to schedule the project Green Belt/Black Belt also need estimates of how long each activity might take. This information will be used by senior management to schedule projects for the enterprise and by the project manager to assign resources, to determine when intervention is required, and for various other purposes.

✓ **Identify Human Resources and other resources**

Needed to complete the Project - All resources should be identified, approved, and procured. Green Belt/Black Belt should know who is to be on your team and what equipment and materials Green Belt/Black Belt are acquiring to achieve project goals. In today's business climate, it's rare for people to be assigned to one project from start to finish with no additional responsibilities outside the scope of a single project. Sharing resources with other areas of the organisation or among several projects requires careful resource management to ensure that the resource will be available to your project when it is needed.

✓ **Visualize Project plan using Gantt Charts**

A Gantt chart shows the relationships among the project tasks, along with time estimates. The horizontal axis of a Gantt chart shows units of time (days, weeks, months, etc.). The vertical axis shows the activities to be completed. Bars show the estimated start time and duration of the various activities.

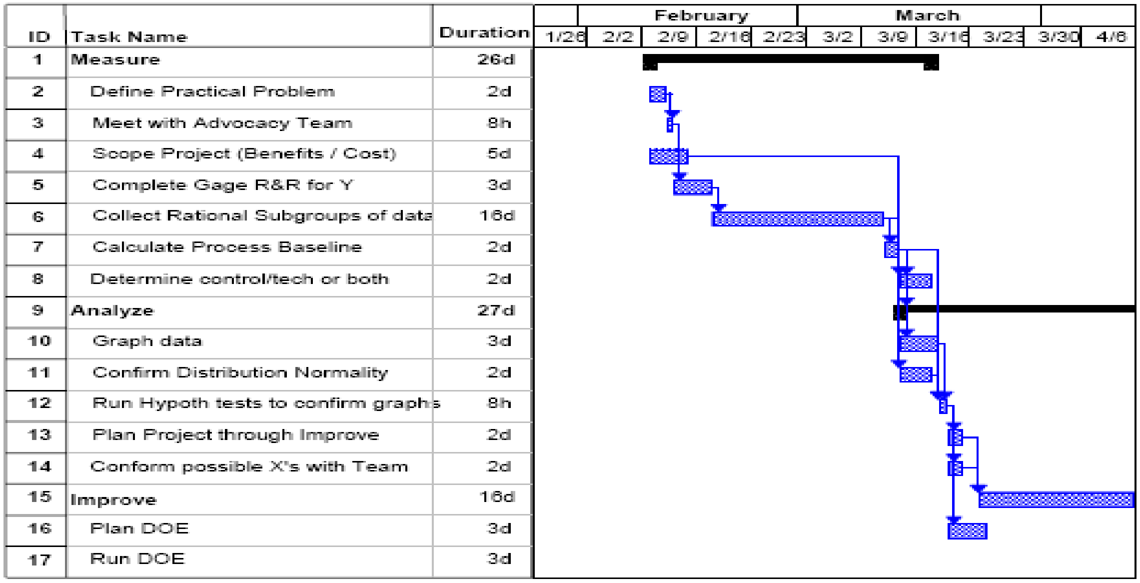


Figure 11: Visualization of Project plan using Gantt chart

✓ **Analyse Network Diagrams**

A project network diagram shows both the project logic and the project's critical path activities, i.e., those activities that, if not completed on schedule, will cause the project to miss its due date. Although useful, Gantt charts and their derivatives provide limited project schedule analysis capabilities. The successful management of large-scale projects requires more rigorous planning, scheduling, and coordinating of numerous, interrelated activities. To aid in these tasks, formal procedures based on the use of networks and network techniques were developed beginning in the late 1950s. The most prominent of these procedures have been PERT (Program Evaluation and Review Technique) and CPM (Critical Path Method).

Critical Path Method systems are used to:

- Aid in planning and controlling projects
- Determine the feasibility of meeting specified deadlines
- Identify the most likely bottlenecks in a project
- Evaluate the effects of changes in the project requirements or schedule
- Evaluate the effects of deviating from schedule
- Evaluate the effect of diverting resources from the project or redirecting additional resources to the project.

Project scheduling by CPM consists of four basic phases: planning, scheduling, improvement, and controlling.

The planning phase involves breaking the project into distinct activities. The time estimates for these activities are then determined and a network (or arrow) diagram is constructed, with each activity being represented by an arrow.

The ultimate objective of the scheduling phase is to construct a time chart showing the start and finish times for each activity as well as its relationship to other activities in the project. The schedule must identify activities that are critical in the sense that they *must* be completed on time to keep the project on schedule.

It is vital not to merely accept the schedule as given. The information obtained in preparing the schedule can be used to improve it. Activities that the analysis indicates to be critical are candidates for improvement. Pareto analysis can be used to identify those critical elements that are most likely to lead to significant improvement in overall project completion time. Cost data can be used to supplement the time data. The combined time/cost information can be analyzed using Pareto analysis.

The final phase in CPM project management is project control. This includes the use of the network diagram and time chart for making periodic progress assessments. CPM network diagrams can be created by a computer program or constructed manually.

The Critical Path Method (CPM) calculates the **longest path in a project** so that the project manager can focus on the activities that are on the critical path and get them completed on time.

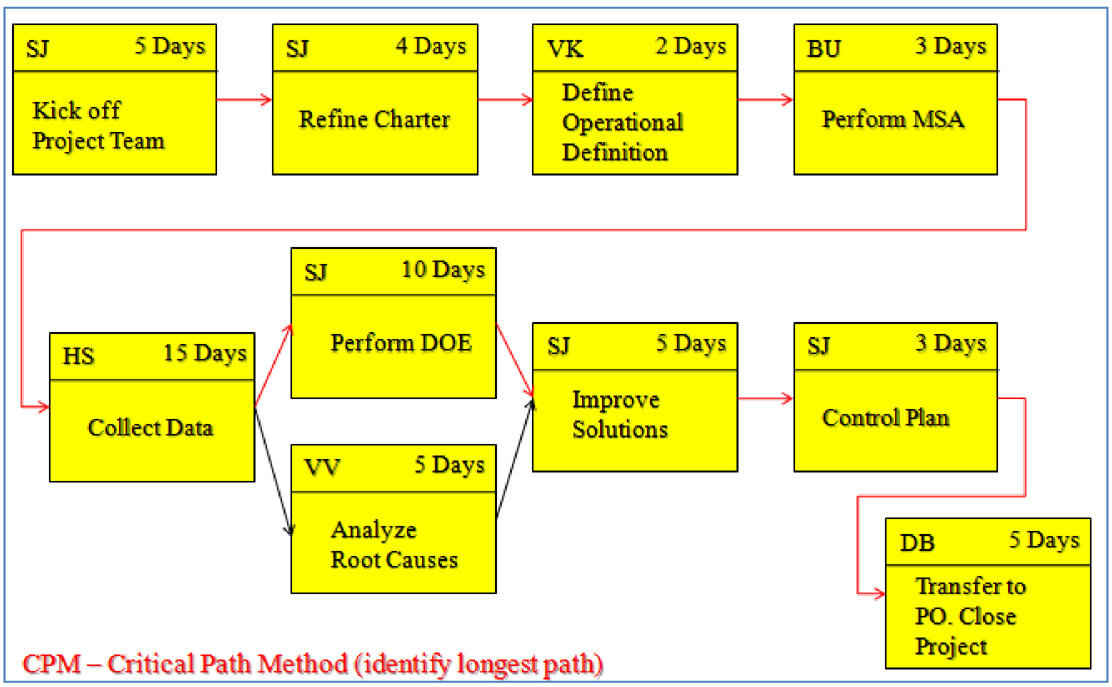


Figure 12: Example Critical Path Method (CPM)

Managing Teams

Stages of a Team - The four stages that all teams go through are shown below. In each phase, the project leader has to use different techniques to push the team along.

Form
- Identifying and informing members
- Everyone is excited at the new responsibilities
- Use Project Charter to establish a common set of expectations for all team members

Storm
- Teams start to become disillusioned. Why are we here, is the goal achievable?
- Identifying resistors, counselling to reduce resistance.
- Help people with the new roles & responsibilities
- Have a different person take meeting minutes, lead team meetings etc

Norm
- Communication of norms (rules), building up of relationships amongst members.
- Productivity of team is increasing
- Help team push to the next stage

Perform
- Contribution from the members- Ideas, innovation, creation.
- All members contribute to the fullest.
- Teams should reach this stage quickest for the best results.
- Motivate team members by recognition, financial rewards, quick-win opportunities.

Some of the problems with teams are:

- Groupthink – which is the unquestioned acceptance of teams' decisions
- Feuding – fighting between different team members
- Floundering – teams that take forever to reach a decision
- Rushing – teams that want to skip all steps and finish the project soon

Managing Change

We will discuss three change management tools: Force Field analysis, Stakeholder analysis, and Resistance analysis.

Force Field Analysis

Force Field Analysis is a useful technique for looking at all the forces for and against a decision. It helps in identifying the restrainers and drivers to change. In effect, it is a specialized method of weighing pros and cons. By carrying out the analysis Green Belt/Black Belt can plan to strengthen the forces supporting a decision, and reduce the impact of opposition to it. Figure 13 shows an example of Force Field analysis. In this example, there are 4 forces for the change and 2 forces against the change. This indicates that there are more forces for the change. Can Green Belt/Black Belt think of deploying some action items to further increase the forces for change?

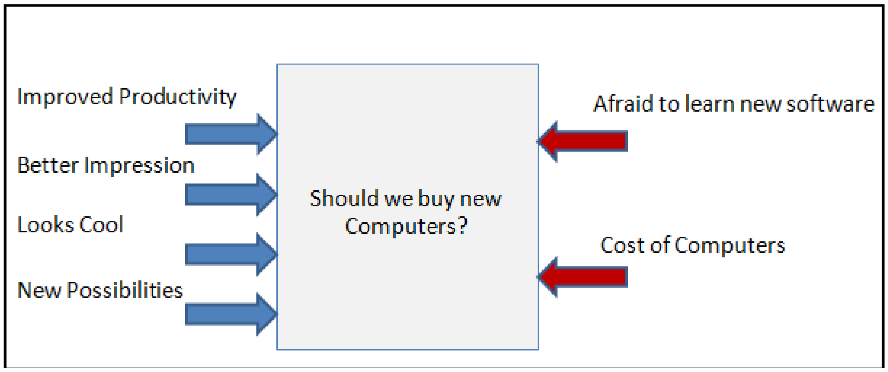


Figure 13: Sample Force Field Analysis

Stakeholder Analysis

Stakeholder Analysis is a technique that identifies individuals or groups affected by and capable of influencing the change process. Assessment of stakeholders and Stakeholder issues and viewpoints are necessary to identify the range of interests that need to be taken into consideration in planning change and to develop the vision and change process in a way that generates the greatest support. The following parameters are used to develop the segmentation of the stakeholders:

- Levels of Influence: *High, Medium, Low*
- Level of Impact: *High, Medium, Low*
- Minimum Support Required: *Champion, Supporter, Neutral*
- Current Position: *Champion, Supporter, Neutral, Concerned, Critic, Unknown*

✓ **Stakeholder Action Plan**

- The plan should outline the perceptions and positions of each Stakeholder group, including means of involving them in the change process and securing their commitment
- Define how Green Belt/Black Belt intend to leverage the positive attitudes of enthusiastic stakeholders and those who "own" resources supportive of change
- State how Green Belt/Black Belt plan to minimize risks, including the negative impact of those who will oppose the change
- Clearly communicate change actions, their benefits and desired Stakeholder roles during the change process
- This plan should be updated regularly and should continue throughout the life of the project.

Resistance Analysis

- **Technical Resistance:**

Stakeholders believe Six Sigma produces feelings of inadequacy or stupidity on statistical and process knowledge

- **Political Resistance:**

Stakeholders see 6 Sigma as a loss of power and control

- **Organisational Resistance:**

Stakeholders experience issues of pride, ego and loss of ownership of change initiatives

- **Individual Resistance:**

Stakeholders experience fear and emotional paralysis as a result of high stress

✓ **Strategies to Overcome Resistance**

- **Technical Resistance:**

Focus on high level concepts to build competencies. Then add more statistical theorems as knowledge base broadens

- **Political Resistance:**

Address issues of "perceived loss" straight on. Look for Champions to build consensus for 6 Sigma and its impact on change

- **Organisational Resistance:**

Look for ways to reduce Resistance.

- **Individual Resistance:**

Decrease the fear by increased involvement, information and education

John Kotter's 8 Step Change Management Plan

John Kotter considers 'lack of communication' as one of the most common reasons for project failure. According to John Kotter, the following eight steps can be followed to enable change within an organisation.

- Step 1: Increase Urgency
- Step 2: Build a Guiding Team
- Step 3: Get the Vision Right
- Step 4: Communicate for Buy-In
- Step 5: Empower Action
- Step 6: Create Short-Term Wins
- Step 7: Don't Let Up
- Step 8: Make Change Stick

Chapter 5

Define

Define Overview

A Lean Six Sigma project starts out as a practical problem that is adversely impacting the business and ultimately ends up as a practical solution that improves business performance. Projects state performance in quantifiable terms that define expectations related to desired levels of performance and timeline.

The primary purpose of the define phase is to ensure the team is focusing on the right thing. The Define phase seeks to answer the question, "What is important?" That is, what is important for the business? The team should work on something that will impact the Big Y's - the key metrics of the business. And if Six Sigma is not driven from the top, a Green/Black Belt may not see the big picture and the selection of a project may not address something of criticality to the organisation.

The Key Performance Indicators (KPIs) that are tracked by businesses to measure its progress towards strategic objectives are usually displayed together on a scorecard. This scorecard is reviewed by management on at least a monthly basis to identify problem areas and take corrective actions as needed. There are four primary areas within a scorecard: Financial, Customer, Internal Business Processes, and Learning & Growth. Some indicators are lagging indicators in the sense that they talk about what has already occurred. An example of a lagging indicator is revenue in the last quarter. It can be an important indicator for the business to know about but it does not tell the full story of what is going to happen in the future. Hence, scorecards must also contain indicators that predict future performance. These indicators are called leading indicators. For example, if we know that all employees are trained 20 hours this year, this could be a leading indicator of future employee performance. Following are some traditional KPIs that businesses track within their scorecard:

Table 6

Financial Indicators	Customer Indicators
• Revenue (amount of money collected by selling products or services) • Cost of Goods Sold (amount of money expended to produce products or services) • Gross Income (difference between Revenue & Cost of Goods Sold) • Net Income (profitability of the company after subtracting all expenses) • Percentage of Industry Sales (PINS – indicator of market share)	• Customer Returns (Amount of $$ returned by customers – an indicator of how satisfied customers are with products/services) • Warranty (More the money spent on warranty, less satisfied are the customers) • Net Promoter Score (NPS – will our customers recommend us to others based on survey results) • On time delivery (% of products/services

• Earnings per Share • Cash Flow (Amount of money earned vs. spent during the indicated period)	delivered on time) • Number of Complaints Received • Customer Churn
Internal Business Process	**Learning & Growth**
• Efficiency (Productivity indicator for key resources) • New Product Introduction Time (Time taken for development of new products) • Net Revenue by Product (Indicator of which products contribute to revenue • Material or Production Costs • Quality Indicators (Re-work) • Production Cycle Time	• Training duration per Employee • Labour Productivity • Staff Turnover • Pace of Promotion • Six Sigma or Lean Benefits

The objective is to identify and/or validate the improvement opportunity, develop the business processes, define Critical Customer Requirements, and prepare an effective project team. The deliverables from the Define phase include:

- Identification of CTQ (Critical to Quality)/Output Measure
- Project Charter
- High Level Process Map

The three steps that enable us to do so are:

Step 1
- Generate Project Ideas

Step 2
- Select Project

Step 3
- Finalize Project Charter and High level process map

Step 1- Generate Project Ideas

Project ideas may be generated from (a) Voice of Customer, (b) Voice of Business and (c) Cost of Poor Quality. The common sources of such Project ideas are

Table 7

Customer Dashboards	Surveys and Scorecards
Internal/External Audits	Financial Analysis of Business Units/ Center
Benchmarking Data	Focus Groups

VOC, VOB and COPQ data help us develop project themes which can help us understand the Big Y (output)

Some common Project themes are

Table 8

Product returns or High Warranty Cost	Customer Complaints
Accounts receivables or Invoicing issues	Cycle time, Lead time
Defective Services or Products	Yield Improvement, Re-work or Scrap Reduction
Capacity Constraints, Inventory	Resource Utilisation

Post the team that has the pertinent VOC, VOB and COPQ data, they then need to translate this information into Critical Customer Requirements (CCR's). A CCR is a specific characteristic of the product or service desired by and important to the customer. The CCR should be measurable with a target and an allowable range. The team would take all the data, identify the key common customer issues, and then define the associated CCR's. The Critical Customer Requirements (CCR's) often are at too high a level to be directly useful to the team. So the next step is to take the applicable CCR's and translate them into Critical to Quality (CTQ) measures. A CTQ is a measure on the output of the process. It is a measure that is important to meeting the defined CCR's.

Table 9

Big Y	**Reduce Operational Expenditure**
Voice of Business	Collection of accounts receivable is taking too long
CCR	Accounts Receivable to be closed within 60 days
CTQ	Time to receive payments

Of course there are multiple alternative methods to drill down to an appropriate CTQ. Project team may also choose to drill down to the Project CTQ from the Big Y.

Step 2- Select Project

A good Six Sigma project should:

- Impact a key business goal
- Require analysis to uncover the root cause of the problem. The cause and solution of the problem should be unknown or not clearly understood.

- Address a source of customer pain or dissatisfaction
- Focus on improving a key business process
- Produce quantifiable results (e.g. financial savings, customer satisfaction)
- Be able to be completed in time to make a difference to the business goal
- Be scoped so that results can be achieved in reasonable timeframe, possible 2-3 months for Green Belt projects, and 4-6 months for Black Belt.

Ideally, Green Belts and Black Belts are expected to work on projects and are not directly responsible for generation or selection of Six Sigma projects. Six Sigma projects are selected by senior management on certain criteria. These criteria include linkage between the proposed project and company strategy, expected timeline for project completion, expected revenue from the projects, whether data exists to work on the problem, whether the root cause or solution is already known. Table 10 shows a typical project selection template used by management to pick projects. The projects that have the highest net score are the ones that get picked for execution.

Table 10: Example Project Selection Template

Number	Sponsor	Project Description	Costs	Benefits	Timeline	Strategy	Risk	Score
1	Job Smith	Reduce Inventory levels for 123 series product	0	1,00,000	6 months	High	Low	4.4
2	Bob Bright	Improve efficiency for machine 456 - 2333	5000	2,00,000	6 months	Medium	Low	5.0
3	John Travolta	Improve employee retention by 5%	0	40,000	3 months	High	Medium	4.0
4	Peter Hunt	Reduce cycle time for making products	1000	1,00,000	1 year	Medium	Low	**3.4**
5	Bill Richards	Improve customer satisfaction scores	0	0	1 year	High	Low	**2.8**

Some basic guidelines that can be considered for selecting a project are:

✓ **Result**

- Does it have significant impact on customer satisfaction? Customer First (Customers are known to be the lifeblood of every business and to support these vital resources, businesses spend a significant amount of time and effort maintaining customer satisfaction)
- Does the project strongly relate to business goals? (Revenue Growth, Cost Reduction, Capital Reduction, Key Business Objectives, On Time Delivery, Lead Time, Quality, Customer Satisfaction)

✓ **Effort**

- Can the project be completed in 3 to 6 months? ---A Good Project Must Be Manageable. Prolonged projects risk loss of interest and start building frustrations within the team and all the way around. The team also runs the risk of disintegrating

✓ **What not to Select?**

- It should neither be a “bean-sized” project so that the improvements are too small to be appreciated, nor a “world-hunger” project wherein implementing the solutions is beyond the control of the stakeholders.

✓ **What Problem to Select?**

- The cause of this problem should be unknown or not clearly understood .There shouldn’t be any predetermined or apparent optimal solution. If Green Belt/Black Belt already knows the answer, then just go fix it!

Step3- Finalize Project Charter and High Level Map

Project Charter

The Project Charter is used to establish a clear understanding of the project amongst the team, the Project leader, Champion, Sponsor and stakeholders. It is a written document and works as an agreement between management and the team about what is expected. It includes a documented business case, opportunity for improvement, goals, scope, timeline and members of the project team. The Project Charter is the key document that defines the scope and purpose of any project. The Charter functions as the communication vehicle for the team, the Sponsor, Process Owner and Champion, the team leader, and all other team members involved. It is used to assure that the team sees the vision of leadership, and understands what the project opportunity and performance improvement goals are, what is expected of the team and keeps the team focused and aligned on the organisational priorities. It transfers the project from the champion to the project team.

One common **misconception** is that the Project Charter is written and then not touched again. The team should refer to the Charter often to ensure that the project is staying on track. In addition, it should be considered a living document that may be revised as the team learns more in the Define and the Measure phase.

Elements of a Project Charter

Table 11

Opportunity Statement	Pain or Problems
Business Case	Financial Benefits
Goal Statement	Success Criteria, usually a 'SMART' statement
Project Scope	Boundaries of the project, In and out scope list
Team Members	Who and What
Project Plan	Activities, Timelines, Critical Path, Review Schedule

✓ **Opportunity Statement**

The opportunity statement describes the "why" of undertaking the improvement initiative. The problem statement should address the following questions:

- What is wrong or not working?
- When and where do the problems occur?
- How extensive is the problem?

What is the impact "pain" on our customers / business / employees?

✓ **Business Case**

The business case describes the benefit for undertaking a project. The business case addresses the following questions:

- What is the focus for the project team?
- Does it make strategic sense to do this project?
- Does this project align with other business initiatives (Critical Success Factors)?
- What benefits will be derived from this project?
- What impacts will this project have on other business units and employees?

✓ **Goal Statement**

The goal statement should be most closely linked with the Opportunity statement. The goal statement defines the objective of the project to address the specific pain area, and is SMART (Specific, Measurable, Achievable, Relevant and Time-bound). The goal statement addresses:

- What is the improvement team seeking to accomplish?
- How will the improvement team's success be measured?
- What specific parameters will be measured? These must be related to the Critical to Cost, Quality, and/or Delivery (Collectively called the CTQ's).
- What are the tangible results deliverables (e.g., reduce cost, cycle time, etc.)?
- What is the timetable for delivery of results?

✓ **Project Scope**

The project scope defines the boundaries of the business opportunity. One of the Six Sigma tools that can be used to identify/control project scope is called the In-Scope/Out-of Scope Tool. Project Scope defines:

- What are the boundaries, the starting and ending steps of a process, of the initiative?
- What parts of the business are included?
- What parts of the business are not included?
- What, if anything, is outside the team's boundaries?
- Where should the team's work begin and end?

✓ **Team Roles & Responsibilities**

Yellow Belt

- Provide support to Black Belts and Green Belts as needed
- May be team members on DMAIC teams
- Supporting projects with process knowledge and data collection

Green Belt

- Is the Team Leader for a Project within own functional area
- Selects other members of his project team
- Defines the goal of project with Champion & team members
- Defines the roles and responsibilities for each team member
- Identifies training requirements for team along with Black Belt
- Helps make the Financial Score Card along with his CFO

Black Belt

- Leads project that are cross-functional in nature (across functional areas)
- Ends role as project leader at the close of the turnover meeting
- Trains others in Six Sigma methodologies & concepts

- Sits along with the Business Unit Head and helps project selection
- Provides application assistance & facilitates team discussions
- Helps review projects with Business Unit Head
- Informs Business Unit Head of project status for corrective action

Master Black Belt:

- Participates in the Reviews and ensures proper direction.
- Trains and coaches Process Owners on Process Management principles

Team Member:

- A Team Member is chosen for a special skill or competence
- Team Members help design the new process
- Team Members drive the project to completion

Subject Matter Expert (SME):

- Is an expert in a specific functional area
- May be invited to specific team meetings but not necessarily all of them
- Provides guidance needed to project teams on as needed basis

Project Sponsor:

- Acts as surrogate Process Owner (PO) until an owner is named
- Becomes PO at Improve/Develop if PO is not named
- Updates Tracker with relevant documents and pertinent project data
- Part of senior management responsible for selection / approval of projects

Process Owner:

- Takes over the project after completion
- Manages the control system after turnover
- Turns over PO accountability to the new Process Owner if the process is reassigned to another area or another individual

Deployment Champion:

- Responsible for the overall Six Sigma program within the company
- Reviews projects periodically
- Adds value in project reviews since he is hands-on in the business
- Clears road blocks for the team
- Has the overall responsibility for the project closure

✓ **Project Plan**

The project plan shows the timeline for the various activities required for the project. Some of the tools that can be used to create the project timeline are the Network diagram or the GANTT chart. We may also like to identify the activities on critical path, milestones for tollgate reviews to ensure that timely completion of the project.*Please refer to Chapter 4 to learn more about Project Management practices*

Project Charter sections are largely interrelated: as the scope increases, the timetable and the deliverables also expand. Whether initiated by management or proposed by operational personnel, many projects initially have too broad a scope. As the project cycle time increases, the tangible cost of the project deployment, such as cost due to labour and material usage, will increase. The intangible costs of the project will also increase: frustration due to lack of progress, diversion of manpower away from other activities, and delay in realization of project benefits, to name just a few. When the project cycle time exceeds 6 months or so, these intangible costs may result in the loss of critical team members, causing additional delays in the project completion. These "world peace" projects, with laudable but unrealistic goals, generally serve to frustrate teams and undermine the credibility of the Six Sigma program.

High Level Process Map

Process maps are graphical representations of a process flow identifying the steps of the process, the inputs and outputs of the process, and opportunities for improvement. Process maps can cross functional boundaries if the start points and stop points are located in different departments or if several persons from different departments are responsible for satisfying specific customer need. Process maps are applicable to any type of process: manufacturing, design, service, or administrative. Process maps are used to document the actual process and helps locate value and Non-Value added steps. These maps can be an excellent way to communicate information to others and train employees.

It can be very useful to start with a high level process map of five to ten steps representing the sub-processes. This helps to establish the scope of the process, identify significant issues and frame the more detailed map later.

SIPOC is an acronym for Suppliers – Inputs – Process – Outputs – Customers. It is a high level process map that describes the boundaries of the process, major tasks and activities, Key Process Input and Output Variables, Suppliers & Customers. When we refer to customers, we usually talk about both internal and external customers. It can be used to identify the key stakeholders and describe the process visually to team members and other stakeholders. A Stakeholder is anyone who is either impacted by the project or could impact the outcome of the project. Not everyone is a stakeholder but a project may have several stakeholders including employees, Suppliers, customers, shareholders etc.

Suppliers: Provide inputs

Inputs: Data / unit required to execute the process

Process Boundary: Identified by the hand-off at the input (the start point of process) and the output (the end point of the process)

Outputs: Output of a process creating a product or service that meets a customer need

Customers: Users of the output

Table12: Shows a filled out SIPOC matrix

Suppliers	Inputs	Process	Output	Customer
Employees	Employee Setup Data	Set Up Resources	Active Employee Record	Project Manager and Team
Contractors	Contractor Setup Data		Active Contractor Record	Project Manager and Team
Employees & Contractors	Planning Meeting	Assign Activities to Resources	Project Schedule	Project Manager and Team
Contracting Officer	Statement of Work		Project Schedule	Project Manager and Team
Payroll Department	Employee Pay Rates	Assign Rates to Resources	Rate Table	System Administrator
Contractors	Contractor Pay Rates		Rate Table	System Administrator
Employees	Timesheets	Enter Time Sheets	Labour Cost Report	Project Manager and Team
Contractors (Time & Materials)	Timesheets		Labour Cost Report	Project Manager and Team
Contractors (Fixed Priced)	Invoices	Enter Vendor Invoices	Contractor Cost Report	Project Manager and Team
Project Management System	Timesheet & Invoices	Summarize and Report Costs	Monthly Performance Reports	CIO, Program Managers, VP Finance

Define Phase Tollgate checklist

- ✓ Has the project been chosen because of its alignment with Organisation goals and the strategic direction of the 'business'?
- ✓ What is the problem statement – detailing (what) is the problem, (when) was the problem first seen, (where) was it seen, and what is the (magnitude or extent) of the problem. Is the problem measured in terms of Quality, Cycle Time, Cost Efficiency, net expected financial benefits? Ensure there is no mention or assumptions about causes and solutions.
- ✓ Does a goal statement exist that defines the results expected to be achieved by the process, with reasonable and measurable targets? Is the goal developed for the "what" in the problem statement, thus measured in terms of Quality, Cycle Time or Cost Efficiency?
- ✓ Does a financial business case exist, explaining the potential impact (i.e. measured in dollars) of the project on the organisation budgets, Net Operating Results, etc.?
- ✓ Is the project scope reasonable? Have constraints and key assumptions been identified?
- ✓ Who is on the team? Are they the right resources and has their required time commitment to the project been confirmed by your Sponsor and team?
- ✓ What is the high level Project plan? What are the key milestones (i.e. dates of tollgate reviews for DMAIC projects)?
- ✓ Who are the customers for this process? What are their requirements? Are they measurable? How were the requirements determined?
- ✓ Who are the key stakeholders? How will they be involved in the project? How will progress be communicated to them? Do they agree to the project?
- ✓ What kinds of barriers/obstacles will need assistance to be removed? Has the risk mitigation plan to deal with the identified risks been developed?

In the Green Belt Workshop, we will discuss

- ✎ **Translation of VOC,VOB, COPQ to measurable Output Parameters**
- ✎ **Selection of Project Primary CTQ**
- ✎ **Project Charter Key sections**
- ✎ **High Level Process Map and Project Scope**

Participants will work on Define phase of practice project 1&2

Chapter 6

Measure

Measure Phase Overview

The primary purpose of the Measure phase is to answer the question, "How are we doing?" In other words, the team must baseline the current state of each CTQ or CTP. Many times in a project, the critical measure identified by the team is not an already reported measure. Although the team may not think the measure is meeting the goal, they need to collect data to verify the current performance level.

The deliverables from the Measure phase include:

- Operational definition
- Measurement system analysis
- Data collection plan
- Baseline Performance

The objective is to identify and/or validate the improvement opportunity, develop the business processes, define critical customer requirements, and prepare an effective project team. The three steps that enable us to do so are:

Step 4	• Finalize Project Y, Performance Standards for Y
Step 5	• Validate Measurement System for Y
Step 6	• Measure Current Performance and Gap

Step 4-Finalize Project Y, Performance Standards for Y

Data collection can be difficult. To help, the team should use operational definitions and data collection plans. Operational definition has been constant source of worry for Measurement system reliability.

- ✓ **Operational Definition**

An Operational Definition is a precise definition of the specific Y to be measured. The data collected using this definition will be used to baseline the performance. The purpose of the definition is to provide a single, agreed upon meaning for each specific Y. This helps in ensuring reliability and consistency during the measurement process although the concept is simple, the task of creating a definition should not be underestimated. A clear concise operational definition will ensure reliable data collection and reduction in measurement error.

Table 13

CTQ Performance Characteristics					
CTQ Measure	Data Type	Operational definition	LSL	USL	Target
A	B	c	d1	d2	d3

- **a**: CTQ Measure is a measurable characteristic of output
- **b**: Data type, whether it is continuous or discrete
- **c**: A clear, concise detailed definition of a measure. Operational definitions should be very precise and be written to avoid possible variation in interpretations.
- **d**: Specification limits are usually derived from customer needs or stated by the customer
    - USL- Upper Specification limit
    - LSL- Lower Specification limit

Step 5- Validate measurement system for Y

Measurement System Analysis

One important step in the Measure phase, sometimes skipped by inexperienced Six Sigma teams, is conducting a Measurement System Analysis (MSA). MSA is carried out to verify that the measurement system produces valid data, before the team makes data-based decisions.
A measurement system is defined as the collection of operations, procedures, gauges and other equipment, software, materials, facilities, and personnel used to assign a number to the characteristic being measured. Measurement System Analysis is a critical part of any Six Sigma Project, regardless of the environment (e.g. transactional, service, etc.). The philosophy behind this kind of study is applicable to all project types. Depending on the type of data, the statistical analysis will be different. For a continuous measurement, there are a variety of statistical properties that can be determined: stability, bias, precision (which can be broken down into repeatability and reproducibility), linearity, and discrimination.
For a discrete measurement, estimates of the error rates can be determined from within appraiser, each appraiser versus standard, between appraisers, and all appraisers versus standard. The properties related to both continuous and discrete measures are discussed below.

Properties of Discrete Measurements

For discrete measurements, a blind study may also be done. An expert would usually determine whether the product is good or bad. Then, a variety of good and bad units is given to two or three appraisers. The appraisers each then determine if they think the product is good or bad.
They are asked to look at the same unit more than once, without knowing that they had evaluated the unit previously. This is called the "within appraiser" error rate. It can then be determined how well all the appraisers are able to get the same result on the same product, the "between appraiser" error rate. In addition, it can be determined how well the appraisers agree with the expert, known as the "appraiser versus standard" error rate.

Attribute Repeatability& Reproducibility (AR&R)

Attribute gauge studies are typically used when the measurement result is binary, such as defect/no defect or successful/unsuccessful, although rating scales can also be validated with this method. Multiple measurement system operators are chosen to measure a sample set two or more times. In this way, both repeatability (variation within the operator) and reproducibility (variation between the operators) can be quantified. In an attribute study, a standard can be used for comparison with the results from the measurement system operators. The standard is the 'truth' and any discrepancy from truth due to the measurement system is considered as an error (or defect).
AR&R studies can be done using statistical software packages which provide graphical output and other summary information; however, they are often done by hand due to the straightforward nature of the calculations.

We use Attribute Agreement Analysis to answer:

- Does the appraiser agree with himself on all trials?
- Does the appraiser agree with the known standard on all trials?
- Do all appraisers agree with themselves and others on all trials? (within and between appraisers)
- Do all appraisers agree with themselves, others, and with the standard?

AR&R studies can be done using statistical software packages which provide graphical output and other summary information; however, they are often done by hand due to the straightforward nature of the calculations.

Step 6- Measure current performance and Gap

Data Collection Plan

Once Measurement system reliability has been established, team develops a data collection plan of Y measure. It is a plan defining the precise data that will be collected, the amount of data that will be collected, a description of the logistical issues - who, where, when data will be collected - and what will be done with data collected.

Table 14

Y Measure	Operational Definition	Data Source	Sample Size	Who will collect the data	When will the data be collected	How will data be collected	X data that can be collected at the same time
Cycle time	Difference between the barcode info on receipt and barcode on customer notification minus nonworking hours (holidays, weekends)	IT System	300	Process Representatives	First 21 days of the month	Data collection form, IT reports	Customer type; application method, day of the week; Representative initiating call; IT rep; wait time; rep sending notification, process sub-step cycle times

The figure above shows an example data collection plan for a project focused on reducing cycle time.

✓ **Collecting the Data**

One major determinant of the duration of a Six Sigma project is the time required to collect the data. The time required is dependent on how frequently the data are available in the process and the ease of collection. The team needs to be involved in the data collection to make sure it is done right and that any anomalies or problems are recorded and understood. This will make the analysis of the data in the Analyse phase easier.

Baseline Performance

Once the team collects the data, they must answer the question "How are we doing?" by base lining the Y data. This is the final step in the Measure phase. The process baseline provides a quantifiable measure of the process performance before any improvement efforts have been initiated. Process baselines are a critical part of any process improvement effort, as they provide the reference point for assertions of benefits attained.
There are a variety of metrics that can be used to baseline these Y's. These metrics include Sigma Level, Cp and Cpk, First time Yield and Rolled Throughput Yield. The team should select a metric that is appropriate for their business.

✓ **Sigma Level**

Sigma Level is a very commonly used Metric for evaluating performance of a process. Sigma level can be computed for continuous data, discrete data and yield; therefore can be computed for most Y measures. Sigma level corresponds to a certain Defects per million opportunities (DPMO). Higher the Sigma Level (Z), lower is the DPMO which simply means lower defect rate.

Table 15

Zlt(Sigma Level Long term)	Zst(Sigma Level Short term)	DPMO
1	2.5	158655.25
1.5	3	66807.20
2	3.5	22750.13
2.5	4	6209.67
3	4.5	1349.90
3.5	5	232.63
4	5.5	31.67
4.5	6	3.40

✓ **Capability Indices**

Process capability is the ability of the process to meet the requirements set for that process. One way to determine process capability is to calculate capability indices. Capability indices are used for continuous data and are unit less statistics or metrics.

- **Cp**

It is the potential capability indicating how well a process could be if it were centred on target. This is not necessarily its actual performance because it does not consider the location of the process, only the spread. It doesn't take into account the closeness of the estimated process mean to the specification limits.

- **Cpk**

It is the resultant process capability as it not only considers variation; it also takes into account the location of the data by considering the closeness of the mean to the specification limits.

✓ **Yield**

Yield can be defined in multiple ways; traditionally it has been defined as the ratio of the total units delivered defect-free to the customer over the total number of units that entered the system. However this definition can obscure the impact of inspection and rework. Process Improvement experts usually are more interested in evaluating yield without rework to understand the true capability of the process.

- **FTY** (First time Yield a.k.a. First Pass Yield): It is the ratio of the units of a product that pass completely through the process the first time without rework over the number of units entered into the process.
- **RTY** (Rolled Throughput Yield): The combined overall likelihood of an item passing through all steps successfully first time

Measure Phase Tollgate checklist

✓ Has a detailed Process Map been completed to better understand the process and problem, and show where in the process the root causes might reside?

✓ Has the team identified the specific input (x), process (x), and output (y) measures needing to be collected for both effectiveness and efficiency categories (I.e. Quality, Speed, and Cost Efficiency measures)?

✓ Has the team developed clear, unambiguous operational definitions for each measurement and tested them with others to ensure clarity and consistent interpretation?

✓ Has a clear, reasonable choice been made between gathering new data or taking advantage of existing data already collected by the organization?

✓ Has an appropriate sample size and sampling frequency been established to ensure valid representation of the process we are measuring?

✓ Has the measurement system been checked for repeatability and reproducibility, potentially including training of data collectors?

✓ Has the team developed and tested data collection forms or check sheets which are easy to use and provide consistent, complete data?

✓ Has baseline performance and process capability been established? How large is the gap between current performance and the customer (or project) requirements?

✓ Has the team been able to identify any 'Quick Wins'?

✓ Has the team completed the baseline savings documentation?

In the Green Belt workshop, we will discuss

- **Impact of operational definition on data collection**
- **Determination of performance standards**
- **Assessing reliability of the current measurement system.**
- **Evaluation of current performance using Sigma Level and Cp, Cpk**

Participants will work on Measure Phase of practice project 1&2. Participants will also work on multiple cross industry cases to assess measurement system and evaluate current performance. Participants will explore cases that include

- **Measurement system Analysis for**
    - **Bank Application form**
    - **Quality Checklist**
    - **Patient Registration forms**
- **Sigma level computation for**
    - **Neck, Chest Measurement of a shirt**
    - **Average Handling Time**
    - **Re-imbursement cycle time**
    - **Laboratory test result turn-around time**
    - **Circumference of a cricket ball**
    - **Defects in garments**
    - **Defects in Circuit Board**
    - **Call Calibration Checklist**
    - **Defective Petri-dishes**
- **Cp, Cpk computation for**
    - **Voltage**
    - **Average talk time**
    - **Diameter of extrusion die**

Chapter
7

Analyze

Analyze Phase Overview

In the Analyze phase, the question to be answered is "What is wrong?" In other words, in this phase the team determines the root causes of the problems of the process. The team identified the problems of the process in the Define and Measure phases of the project. The key deliverable from this phase is validated root causes. The team will use a variety of tools and statistical techniques to find these root causes. The team must choose the right tools to identify these root causes as if there is no fixed set of tools for a certain situation. The tools chosen are based on the type of data that were collected and what the team is trying to determine from the data. The team usually would use a combination of graphical and numerical tools. The graphical tools are important to understand the data characteristics and to ensure that the statistical analyses are meaningful (e.g., not influenced by outliers). The numerical (or statistical) analyses ensure that any differences identified in the graphs are truly significant and not just a function of natural variation.

The team should have already identified the process outputs - CTQ's and CTP's, or the little Y's - in the Define phase. The X's are process and input variables that affect the CTQ's and CTP's. The first consideration in the Measure phase is to identify the x data to collect while base lining these y variables. The y data are needed to establish a baseline of the performance of the process. The x data are collected concurrently with the Y's in this phase so that the relationships between the X's and Y's can be studied in the Analyse phase will impact the Big Y's - the key metrics of the business. And if Six Sigma is not driven from the top, a Green/Black Belt may not see the big picture and the selection of a project may not address something of criticality to the organization.
The objective is to identify and/or validate the improvement opportunity, develop the business processes, define critical customer requirements, and prepare an effective project team. The three steps that enable us to do so are:

Step 7	• List All Probable X's
Step 8	• Identify Critical X's
Step 9	• Verify Sufficiency of Critical X's for the project

Step 7- List all Probable X's

Most project executions require a cross-functional team effort because different creative ideas at different levels of management are needed in the definition and the shaping of a project. These ideas are better generated through brainstorming sessions.

Qualitative Analysis

- ✓ **Brainstorming**

Brainstorming is used at the initial steps and during the Analyze phase of a Project to identify potential factors that affect the output. It is a group discussion session that consists of encouraging a voluntary generation of a large volume of creative, new, and not necessarily traditional ideas by all the participants. It is very beneficial because it helps prevent narrowing the scope of the issue being addressed to the limited vision of a small dominant group of managers. Since the participants come from different disciplines, the ideas that they bring forth are very unlikely to be uniform in structure. They can be organized for the purpose of finding root causes of a problem and suggest palliatives. If the brainstorming session is unstructured, the participants can give any idea that comes to their minds, but this might lead the session to stray from its objectives.

- ✓ **Five Why's Analysis**

Asking "Why?" may be a favourite technique of your three year old child in driving you crazy, but it could teach you a valuable Six Sigma quality lesson. The 5 Whys is a technique used in the Analyze phase of the Six Sigma DMAIC methodology. By repeatedly asking the question "Why" (five is a good rule of thumb),Green Belt/Black Belt can peel away the layers of symptoms **which can lead to the root cause of a problem**. Although this technique is called "5 Whys," you may find that you will need to ask the question fewer or more times than five before you find the issue related to a problem. The benefits of 5 Why's is that it is a simple tool that can be completed without statistical analysis. Table 16 shows an illustration of the 5 Why's analysis. Based on this analysis, we may decide to take out the non-value added signature for the director.

Table 16: 5 Why's Example

	Customers are unhappy because they are being shipped products that don't meet their specifications.
Why	Because manufacturing built the products to a specification that is different from what the customer and the sales person agreed to.
Why	Because the sales person expedites work on the shop floor by calling the head of manufacturing directly to begin work. An error happened when the specifications were being communicated or written down.
Why	Because the "start-work" form requires the sales director's approval before work can begin and slows the manufacturing process (or stops it when the director is out of the office).
Why	Because the sales director needs to be continually updated on sales for discussions with the CEO.

✓ **Affinity Diagram**

If the ideas generated by the participants to the brainstorming session are few (less than 15), it is easy to clarify, combine them, determine the most important suggestions, and make a decision. However, when the suggestions are too many it becomes difficult to even establish a relationship between them. An affinity diagram or KJ method (named after its author, Kawakita Jiro) is used to diffuse confusion after a brainstorming session by organizing the multiple ideas generated during the session. It is a simple and cost-effective method that consists of categorizing a large amount of ideas, data, or suggestions into logical groupings according to their natural relatedness. When a group of knowledgeable people discuss a subject with which they are all familiar, the ideas they generate should necessarily have affinities. To organize the ideas, perform the following:

a. The first step in building the diagram is to sort the suggestions into groups based on their relatedness and a consensus from the members.
b. Determine an appropriate header for the listings of the different categories.
c. An affinity must exist between the items on the same list and if some ideas need to be on several lists, let them be.
d. After all the ideas have been organized; several lists that contain closely related ideas should appear. Listing the ideas according to their affinities makes it much easier to assign deliverables to members of the project team according to their abilities.

✓ **Cause-and-Effect Analysis**

The cause-and-effect (C&E) diagram—also known as a fishbone (because of its shape) or Ishikawa diagram (named after Kaoru Ishikawa, its creator)—is used to visualize the relationship between an outcome and its different causes. There is very often more than one cause to an effect in business; the C&E diagram is an analytical tool that provides a visual and systematic way of linking different causes (input) to an effect (output). It shows the relationship between an effect and its first, second and third order causes.
It can be used to identify the root causes of a problem. The building of the diagram is based on the sequence of events. "Sub-causes" are classified according to how they generate "sub-effects," and those "sub-effects" become the causes of the outcome being addressed.

- The first step in constructing a fishbone diagram is to define clearly the effect being analyzed.
- The second step consists of gathering all the data about the key process input variables (KPIV), the potential causes (in the case of a problem), or requirements (in the case of the design of a production process) that can affect the outcome.
- The third step consists of categorizing the causes or requirements according to their level of importance or areas of pertinence. The most frequently used categories are:
    - Manpower, machine, method, measurement, mother-nature, and materials for manufacturing
    - Equipment, policy, procedure, plant, and people for services

Subcategories are also classified accordingly; for instance, different types of machines and computers can be classified as subcategories of equipment.

- The last step is the actual drawing of the diagram. The diagram is immensely helpful to draw a mind map of the cause and effect relationship

The fishbone diagram does help visually identify the potential root causes of an outcome. Further statistical analysis is needed to determine which factors contribute the most to creating the effect.

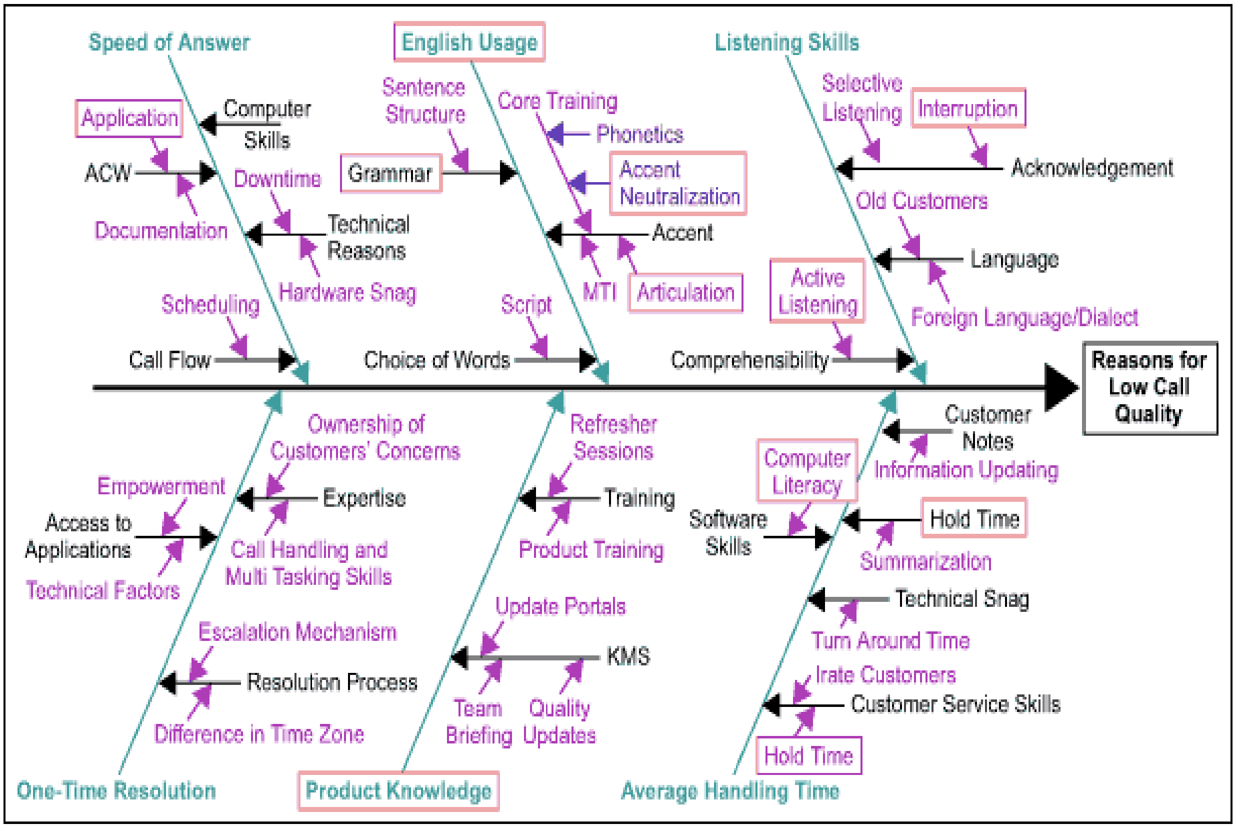


Figure 14: Fishbone Diagram

Process Mapping

Many business processes are poorly defined or totally lacking in description. Many procedures are simply described by word of mouth or may reside in documents that are obsolete. In process management, often by simply trying to define and map the process, we provide a means for both understanding and communicating operational details to those involved in the process.

- It also provides a baseline, or standard, for evaluating the improvement. In many cases, merely defining and charting the process as it can reveal many deficiencies such as redundant and needless steps and other non-value-added activities.
- Process mapping allows the team to represent the process associated with their problem in a way that others find easy to understand, making the job of defining the current process easier.
- It also allows people to easily understand where waste exists in the process and where the process has been poorly defined

The first step in analyzing process map is developing detailed process maps. The initial AS-IS process maps should always be created by cross functional team members and must reflect the actual process rather than an ideal or desired state.

- Start with a high level map: It can be very useful to start with a high level process map of say five to ten steps. Six Sigma team would have developed a High Level process map (SIPOC) in Define Phase. This helps to establish the scope of the process, identify significant issues and frame the more detailed map.

- Six Sigma team may choose a **Top-Down Flow Chart** describes the activities of the process in a hierarchical order or **Functional Deployment Flow Chart** that shows the different functions that are responsible for each step in the process flow chart.
- Map the process like a flowchart detailing each activity, arrow and decision. For each arrow, boxes, and diamond, list its function and the time spent (in minutes, hours, days).

	Start & End Points	Identify the boundaries of the process.
	Activity	What is being done. Indicates necessary and unnecessary activities performed in the process.
	Decision	Illustrates decision points and where loops occur in the process. Also used to accept, reject, approve, etc.
	Arrow	Represents a process path/flow.
	Input or Output	Shows important inputs or outputs without describing in detail.
	Process Connectors	Connect flow to another page or process.
A#	**Activity Number**	Shows the activity in the sequence performed.
D#	**Decision Number**	Shows the decision points in the sequence performed.

Table 15: Typical Symbols used in Process Maps

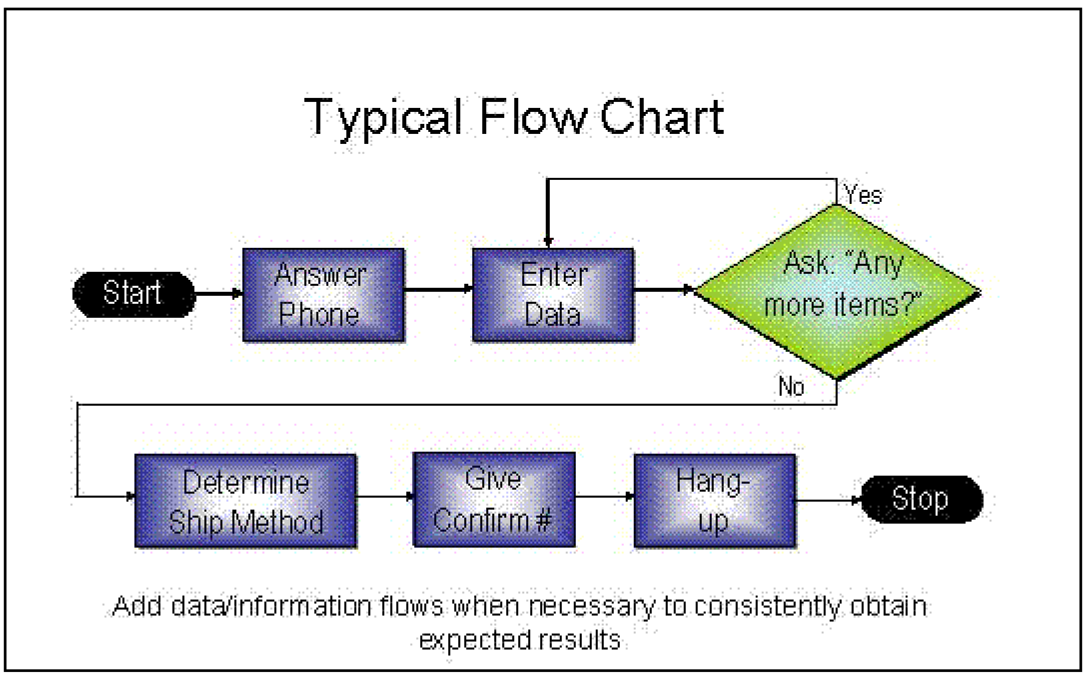


Figure 16: Typical Flow Chart

Functional Deployment Flow Chart: A functional deployment flow chart shows the different functions that are responsible for each step in the process flow chart. An example is shown below:

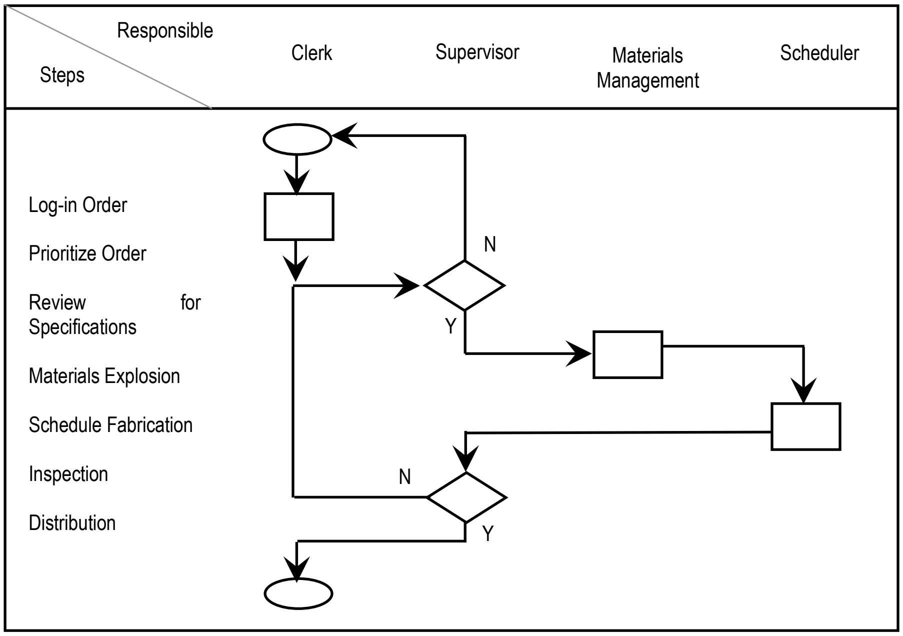


Figure 17: Example Process Maps with Functions Shown

The second step is analysing the process map for:

Time: One of the most effective lean tools used in understanding waste in a process map is **Value add/ Non-Value add analysis**. It assists in analysing

- Time-per-event (reducing cycle time)
- Process repeats (preventing rework)
- Duplication of effort (identifying and eliminating duplicated tasks)
- Unnecessary tasks (eliminating tasks that are in the process for no apparent reason)
- Identifying and segregating Value-added and non-value-added tasks

Risks: Process Maps can be analysed to determine prevalent risks in the current process. Failure Mode and Effects Analysis is a structured and systematic process to identify potential design and process failures before they have a chance to occur with the ultimate objective of eliminating these failures or at least minimizing their occurrence or severity. **FMEA** (Failure Modes and Effects Analysis) can help us determine potential failure modes, potential failure effects, severity rank of the failure effect, potential causes of failure, occurrence rank of the failure, current process controls and the effectiveness of the control measures.

- Identifying the areas and ways in which a process or system can fail (failure mode)
- Estimating risk associated with specific causes
- Identifying and prioritizing the actions that should be taken to reduce those risks
- Evaluating and documenting proposed process plans or current control plans

Graphical Tools

Data displayed graphically helps us develop hypothesis and determine further analysis plans. We can use

- Box Plot
- Histogram
- Pareto Plots

Pareto Plots

The Pareto chart is based on the Pareto principle. Vilfredo Pareto was an economist in the early 1900's who discovered that 80% of all the wealth was held by 20% of all the people. This became known as the 80/20 rule and it was found to be applicable to more than the economy. Eighty percent of the warehouse space is taken up by 20% of the part numbers. Eighty percent of the defects are caused by 20% of the defect types. The Pareto chart is a bar chart. The height of the bars indicates the count, or frequency, of occurrence. The bars represent one grouping of the data, such as defect type. The idea motivating this chart is that 80% of the count will be due to 20% of the categories. The bars are arranged in descending order, therefore the dominant group can be determined and it will be the first bar on the left. This chart can be used in a variety of places in a Six Sigma project.

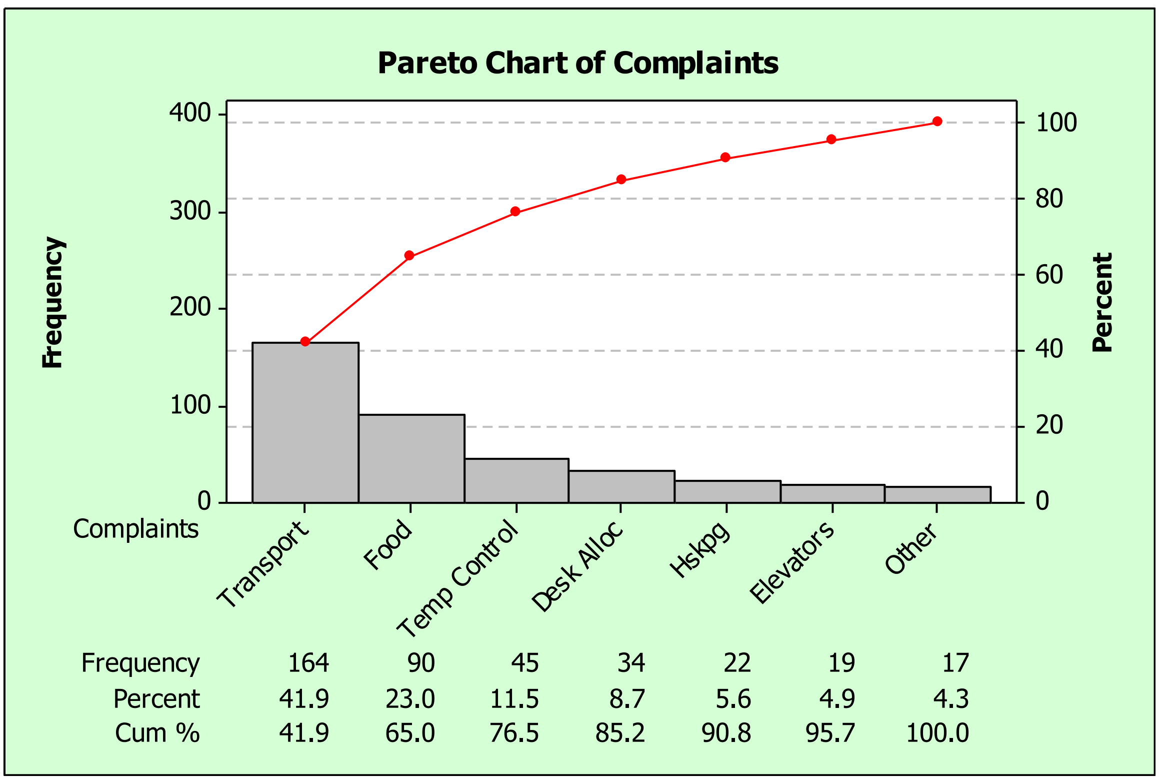


Figure 18

Worksheets: Complaints.mtw

Step 8- Identify Critical Xs

Hypothesis Testing

Hypothesis testing is a statistical analysis where a hypothesis is stated, sample data are collected, and a decision is made based on the sample data and related probability value. This testing can be used to detect differences such as differences between a process mean and the target for the process, differences between two suppliers, or differences between multiple employees.

To conduct a hypothesis test, the first step is to state the business question involving a comparison. For instance, the team may wonder if there is a difference in variability seen in thickness due to two different material types. Once the business question is posed, the next step is to convert the business language or question into statistical language or hypothesis statements. Two hypothesis statements are written.
The first statement is the null hypothesis, H_0. This is a statement of what is to be disproved.

The second statement is the alternative hypothesis, H_a. This is a statement of what is to be proved. Between the two statements, 100% of all possibilities are covered. The hypothesis will be focused on a parameter of the population such as the mean, standard deviation, variance, proportion, or median.

The type of hypothesis test that could be conducted is based on the data type (discrete or continuous) of the y data. For instance, if the data are continuous, the analysts may want to conduct tests on the mean, median, or variance. If the data are discrete, the analysts may want to conduct a test on proportions.

Hypothesis Testing

A **statistical hypothesis** is an assumption about a population parameter. This assumption may or may not be true. The best way to determine whether a statistical hypothesis is true would be to examine the entire population. Since that is often impractical, researchers typically examine a random sample from the population. If sample data are not consistent with the statistical hypothesis, the hypothesis is rejected.

Hypothesis Tests

Statisticians follow a formal process to determine whether to reject a null hypothesis, based on sample data. This process, called **hypothesis testing**, consists of four steps.

- State the hypotheses: This involves stating the null and alternative hypotheses. The hypotheses are stated in such a way that they are mutually exclusive. That is, if one is true, the other must be false.
- Formulate an analysis plan: The analysis plan describes how to use sample data to evaluate the null hypothesis. The evaluation often focuses around a single test statistic.
- Analyze sample data: Find the value of the test statistic (mean score, proportion, t-score, z-score, etc.) described in the analysis plan.
- Interpret results: Apply the decision rule described in the analysis plan. If the value of the test statistic is unlikely, based on the null hypothesis, reject the null hypothesis.

Null Hypothesis (H_o): It is a hypothesis which states that there is no difference between the procedures and is denoted by H_o

Alternative Hypothesis (H_a): It is a hypothesis which states that there is a difference and is denoted by H_a

- **The Language of Hypothesis**

The Null Hypothesis (H_0)

- A statement of 'No difference'
- It is a statement you are testing in order to determine whether or not that statement is true
- In other words, observations are the result purely of chance
- An example expression is H_0: $\mu_A = \mu_B$

Alternative Hypothesis (H_a)

- A statement of 'difference'
- It is that there is a real effect and the observations are affected by the effect and some pure chance variation
- It depends on the direction of the effect we are looking for. For example,
- For Example: H_a: $\mu_A \neq \mu_B$ or H_a: $\mu_A > \mu_B$ or H_a: $\mu_A < \mu_B$

- **Decision Errors**

There is always possibility of errors in the decisions we make. Two types of errors can result from a hypothesis test. They are:

- **Type I error**. A Type I error occurs when the researcher rejects a null hypothesis when it is true. The probability of committing a Type I error is called the **significance level**. This probability is also called **alpha**, and is often denoted by α.
- **Type II error**. A Type II error occurs when the researcher fails to reject a null hypothesis that is false. The probability of committing a Type II error is called **Beta**, and is often denoted by β. The probability of not committing a Type II error is called the **Power of the test**.

Steps of Hypothesis testing using the p-value approach

- State the null hypothesis H_0, and the alternative hypothesis H_a.
- Choose the level of significance (α) and the sample size, n.
- Determine the appropriate test statistic and sampling distribution.
- Collect the data and compute the sample value of the appropriate test statistic.
- Calculate the p-value based on the test statistic and compare the p-value to α.
- Make the statistical decision. If the p-value is greater than or equal to α, we fail to reject the null hypothesis. If the p-value is less than α, we reject the null hypothesis.
- Express the statistical decision in the context of the problem.

Correlation and Regression

Let's take a look a few scenarios.

- Administrative – A financial analyst wants to predict the cash needed to support growth and increases in capacity.
- Market/Customer Research – The marketing department wants to determine how to predict a customer's buying decision from demographics and product characteristics.
- Hospitality – Food and Beverage manager wants to see if there is a relationship between room service delays and order size.
- Customer Service - GB is trying to reduce call length for potential clients calling for a good faith estimate on a mortgage loan. GB thinks that there is a relationship between broker experience and call length.
- Hospitality - The Green Belt suspects that the customers have to wait too long on days when there are many deliveries to make at Six Sigma Pizza.

In the scenarios mentioned here, there is something common, i.e. we want to explore the relationship between Output and Input, or between two variables. Correlation and Regression helps us explore statistical relationship between two continuous variables.

✓ **Correlation**

Correlation is a measure of the relation between two or more continuous variables. The Pearson correlation coefficient is a statistic that measures the linear relationship between the x and y. The symbol used is r. The correlation value ranges from -1 to 1. The closer the value is to 1 in magnitude, the stronger the relationship between the two.

- A value of zero, or close to zero, indicates no linear relationship between the x and y.
- A positive value indicates that as x increases, y increases.
- A negative value indicates that as x increases, y decreases.

The Pearson correlation is a measure of a linear relationship, so scatter plots are used to depict the relationship visually. The scatter plot may show other relationships.
The figure 19 below shows a scatter plot with correlation coefficient r=0.982.

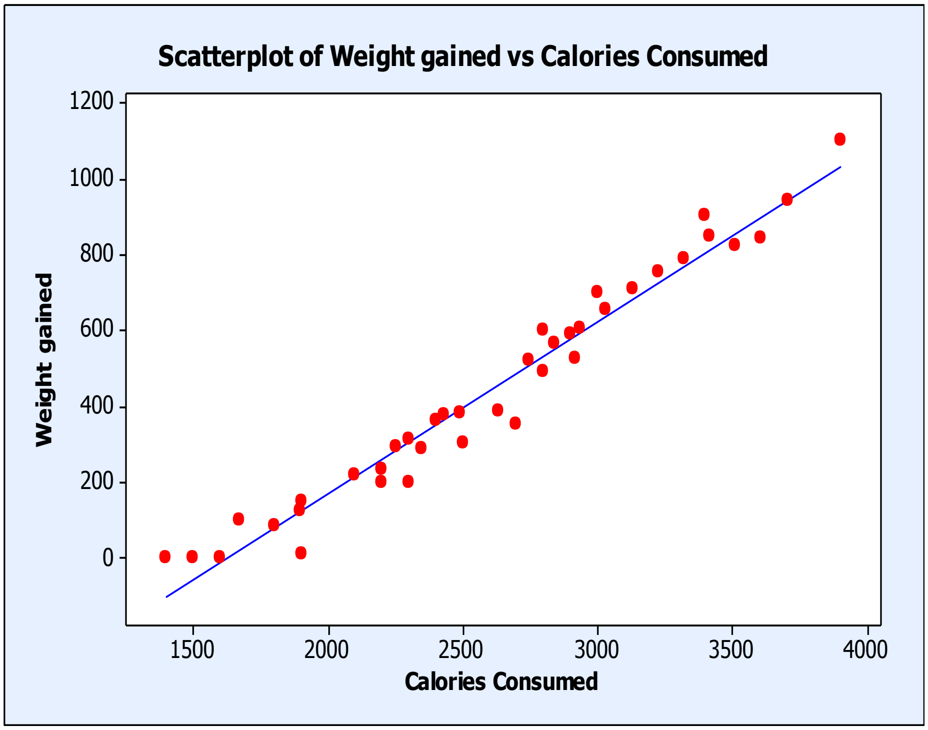


Figure 19

Worksheet: Calories Consumed.mtw

- ✓ **Regression**

A natural extension of correlation is regression. Regression is the technique of determining a mathematical equation that relates the x's to the y. Regression analysis is also used with historical data - data where the business already collects the y and associated x's. The regression equation can be used as a prediction model for making process improvements.

- ✓ **Simple Linear Regression**

Simple linear regression is a statistical method used to fit a line for one x and one y. The formula of the line is where b_0 is the intercept term and b_1 is the slope associated with x. These beta terms are called the coefficients of the model. The regression model describes a response variable y as a function of an input factor x. The larger the b_1 term, the more change in y given a change in x.

In Simple Linear Regression, a single variable "X" is used to define/predict "Y"

- e.g.; Wait Time = b_0 + (b_1) x (Deliveries) + E (error)
- Simple Regression Equation: Y = b_0 + (b_1) * (X) + E (error)
- Y=mx+c+e
    - m= slope, c= constant/intercept, e= error

Regression terms

Types of Variables

- Input Variable (X's): These are also called predictor variables or independent variables. It is best if the variables are continuous
- Output Variable (Y's): These are also called response variables or dependent variables (what we're trying to predict). It is best if the variables are continuous.

R-squared-also known as Coefficient of determination- The **coefficient of determination** (**r^2**) is the ratio of the regression sum of squares (SSR) to the total sum of squares (SST). It represents the % variation in output (dependent variable) explained by input variables/s or Percentage of response variable variation that is explained by its relationship with one or more predictor variables.

Prediction and Confidence Interval: These are types of confidence intervals used for predictions in regression and other linear models.

- **Prediction Interval:** It represents a range that a single new observation is likely to fall given specified settings of the predictors.
- **Confidence interval of the prediction:** It represents a range that the mean response is likely to fall given specified settings of the predictors.

The prediction interval is always wider than the corresponding confidence interval because of the added uncertainty involved in predicting a single response versus the mean response.

Step 9- Verify Sufficiency of Critical X's for project

Although a statistical analysis may show that there is a statistically significant difference, there may not be a practical difference. In other words, the difference may not be big enough to be of importance to the business. The bigger the sample size used in an analysis, the smaller the deviation from the null hypothesis that may be detected. Always remember to check for outliers that may be influencing results. And finally, ask whether this difference means anything practically.

Analyze phase Tollgate checklist

- ✓ Has the team conducted a value-added and cycle time analysis, identifying areas where time and resources are devoted to tasks not critical to the customer?
- ✓ Has the team examined the process and identified potential bottlenecks, disconnects, and redundancies that could contribute to the problem statement?
- ✓ Has the team analyzed data about the process and its performance to help stratify the problem, understand reasons for variation in the process, and generate hypothesis as to the root causes of the current process performance?
- ✓ Has an evaluation been done to determine whether the problem can be solved without a fundamental 'white paper' recreation of the process? Has the decision been confirmed with the Project Sponsor?
- ✓ Has the team investigated and validated (or revalidated) the root cause hypothesis generated earlier, to gain confidence that the "vital few" root causes have been uncovered?
- ✓ Does the team understand why the problem (the Quality, Cycle Time, or Cost Efficiency issue identified in the Problem Statement) is being seen?
- ✓ Has the team been able to identify any additional 'Quick Wins'?
- ✓ Have 'learning's' to-date required modification of the Project Charter? If so, have these changes been approved by the Project Sponsor and the Key Stakeholders?
- ✓ Have any new risks to project success been identified, added to the Risk Mitigation Plan, and a mitigation strategy put in place?

In the Green Belt workshop, we will discuss

- Identification of potential inputs using qualitative tools which include brainstorming,5 Whys, Affinity Diagram, Ishikawa Diagram
- Analysing Process cycle time and identify Value add and Non-valued added tasks
- Analysing Process Risks using Failure Modes and Effects Analysis
- Validation of potential inputs using quantitative tools like Hypothesis tests, Correlation and Regression
- Establishing Practical Significance versus Statistical Significance

Participants will work on Analyze Phase of practice project 1&2.

Participants will explore Process mapping analytic cases that include:

- ✓ Value Add/Non-Value Add classification of a Fast Food restaurant
- ✓ Risk Analysis of Tele-booking process
- ✓ Risk Analysis of Baggage Handling process for an airline
- ✓ Risk Analysis of Invoice generation process

Participant will explore application of Hypothesis testing in business situations and how we can draw inferences for a population using a relatively small sample. We will explore cases which include

- ✓ Comparison of Defectives% by Region, Unit
- ✓ Comparison of Transaction Processing time by Vendors, Shift
- ✓ Comparison of Purchase per customer by type of promotion
- ✓ Effect on Cutlet Diameter by Unit, Supplier
- ✓ Effect on Reports Turn Around Time by laboratory, equipment
- ✓ Bugs per function points by Developer Experience categories

Participants will explore application of Scatter Plot, Correlation and Regression in business situations and how we can arrive at reliable estimates using these tools. We will explore cases which include

- ✓ Effect of Calories Consumed on Weight Gained
- ✓ Effect of Advertisement expenditure on Sales Revenue
- ✓ Effect of washing time on reduction of Environment Colony forming units
- ✓ Effort hours versus Function points, KLoC
- ✓ Labour hours versus Cubic feet movement of material
- ✓ Used car price versus age of the car, Miles run

Chapter

8

Improve

Improve Phase Overview

In the Improve phase, the team has validated the causes of the problems in the process and is ready to generate a list of solutions for consideration. They will answer the question "What needs to be done?" As the team moves into this phase, the emphasis goes from analytical to creative. To create a major difference in the outputs, a new way to handle the inputs must be considered. When the team has decided on a solution to present to management, the team must also consider the cost/benefit analysis of the solutions as well as the best way to sell their ideas to others in the business. The deliverables from the Improve phase are:

- Proposed solution(s)
- Cost/benefit analysis
- Presentation to management
- Pilot plan

Step 10	• Generate and Evaluate Alternative Solutions
Step 11	• Select and Optimize best solution
Step 12	• Pilot, Implement and Validate the Solution

Step 10- Generate and evaluate Alternative Solutions

The first task in the Improve phase is to develop ideas for improving the process. The traditional method for developing improvement ideas is to use conventional brainstorming however Green Belt/Black Belt may also choose alternative ways to generate creative ideas in a team. Let's explore few of those techniques in the following section.

Ideation Techniques

✓ **Brainstorming (Round-Robin)**

Most project executions require a cross-functional team effort because different creative ideas at different levels of management are needed in the definition and the shaping of a project. These ideas are better generated through brainstorming sessions. Brainstorming is a tool used at the initial steps or during the Analyze phase of a project. It is a group discussion session that consists of encouraging a voluntary generation of a large volume of creative, new, and not necessarily traditional ideas by all the participants. It is very beneficial because it helps prevent narrowing the scope of the issue being addressed to the limited vision of a small dominant group of managers. Since the participants come from different disciplines, the ideas that they bring forth are very unlikely to be uniform in structure. They can be organized for the purpose of finding root causes of a problem and suggest palliatives.

✓ **Brainstorming using De-Bono Six Thinking Hats**

Dr. Edward de Bono developed a technique for helping teams stay focused on creative problem solving by avoiding negativity and group arguments. Dr. Bono introduced Six Thinking Hats which will represent different thought processes of team members, and also discussed how we can harness these thoughts to generate creative ideas. These hats are:

- The **White Hat** thinking requires team members to consider only the **data and information** at hand. With white hat thinking, participants put aside proposals, arguments and individual opinions and review only what information is available or required.
- The **Red Hat** gives team members the opportunity to present their **feelings or intuition** about the subject without explanation or need for justification. The red hat helps teams to surface conflict and air feelings openly without fear of retribution. Use of this hat encourages risk-taking and right-brain thinking.
- The **Black Hat** thinking calls for **caution and critical judgment**. Using this hat helps teams avoid "groupthink" and proposing unrealistic solutions. This hat should be used with caution so that creativity is not stifled.
- The **Blue Hat** is used for **control** of the **brainstorming process**. The blue hat helps teams evaluate the thinking style and determine if it is appropriate. This hat allows members to ask for summaries and helps the team progress when it appears to be off track. It is useful for "thinking about thinking."
- The **Green Hat** makes time and space available for **creative thinking**. When in use, the team is encouraged to use divergent thinking and explore alternative ideas or options.
- The **Yellow Hat** is for **optimism** and a positive view of things. When this hat is in use, teams look at the logical benefits of the proposal. Every green hat idea deserves some yellow hat attention.

This technique is called the Six Thinking Hats. It can be used to enhance team creativity and evaluate ideas. This technique can be applied during solution or idea generation and also can assist in building consensus. This technique has been used world-wide, in a variety of corporations. During the Green Belt training, we will discuss how we can utilize this concept to generate creative ideas and also to build consensus on generated ideas.

✓ **Creative Thinking using Probing Methods**

Structured Probing methods are extremely helpful in lateral thinking and problem solving approaches. Process Improvement experts also consider challenging an idea, or disproving an idea to be an initiation point for creative ideas. Most scientists, innovators will like to probe to understand the existence, validity and feasibility of an idea and this helps in improving and optimizing the idea, and may also trigger a new idea.

Benchmarking

Benchmarking is a popular method for developing requirements and setting goals. In more conventional terms, benchmarking can be defined as measuring your performance against that of best-in-class companies, determining how the best-in-class achieve those performance levels, and using the information as the basis for your own company's targets, strategies, and implementation.
Benchmarking involves research into the best practices at the industry, firm, or process level. Benchmarking goes beyond a determination of the "industry standard" it breaks the firm's activities down to process operations and looks for the best-in-class for a particular operation. For example, to achieve improvement in their parts distribution process Xerox Corporation studied the retailer L.L. Bean.

Benchmarking must have a structured methodology to ensure successful completion of thorough and accurate investigations. However, it must be flexible to incorporate new and innovative ways of assembling difficult-to-obtain information. It is a discovery process and a learning experience. It forces the organization to take an external view, to look beyond itself. The essence of benchmarking is the acquisition of information.

- The process begins with the identification of the process that is to be benchmarked. The process chosen should be one that will have a major impact on the success of the business.
- Once the process has been identified, contact a business library and request a search for the information relating to your area of interest. The library will identify material from a variety of external sources, such as magazines, journals, special reports, etc. Internet, organization's internal resources, Subject Matter experts in key department and of course network of contacts is immensely helpful in this research.
- Look for the best of the best, not the average firm. One approach is to build a compendium of business awards and citations of merit that organizations have received in business process improvement. Sources to consider are Industry Week's Best Plant's Award, National Institute of Standards and Technology's Malcolm Baldrige Award, USA Today and Rochester Institute of Technology's Quality Cup Award, European Foundation for Quality Management Award, Occupational Safety and Health Administration (OSHA), Federal Quality Institute, Deming Prize, Competitiveness Forum, Fortune magazine, United States Navy's Best Manufacturing Practices, to name just a few.
- Green Belt/Black Belt may wish to subscribe to an "exchange service" that collects benchmarking information and makes it available for a fee. Once enrolled, Green Belt/Black Belt will have access to the names of other subscribers—a great source for contacts. Don't overlook your own suppliers as a source for information. If your company has a program for recognizing top suppliers, contact these suppliers and see if they are willing to share their "secrets" with you. Suppliers are predisposed to cooperate with their customers; it's an automatic door-opener. Also contact your customers. Customers have a vested interest in helping you do a better job. If your quality, cost, and delivery performance improve, your customers will

benefit. Customers may be willing to share some of their insights as to how their other suppliers compare with you. Again, it isn't necessary that you get information about direct competitors. Which of your customer's suppliers are best at billing? Order fulfilment? Customer service?

- Another source for detailed information on companies is academic research. Companies often allow universities access to detailed information for research purposes. While the published research usually omits reference to the specific companies involved, it often provides comparisons and detailed analysis of what separates the best from the others. Such information, provided by experts whose work is subject to rigorous peer review, will often save Green Belt/Black Belt thousands of hours of work.
- After a list of potential candidates is compiled, the next step is to choose the best three to five targets. As the benchmarking process evolves, the characteristics of the most desirable candidates will be continually refined. This occurs as a result of a clearer understanding of your organization's key quality characteristics and critical success factors and an improved Knowledge of the marketplace and other players. This knowledge and the resulting actions tremendously strengthen an organization.

Benchmarking is based on learning from others, rather than developing new and improved approaches. Since the process being studied is there for all to see, benchmarking cannot give a firm a sustained competitive advantage. Although helpful, benchmarking should never be the primary strategy for improvement. Competitive analysis is an approach to goal setting used by many firms. This approach is essentially benchmarking confined to one's own industry. Although common, competitive analysis virtually guarantees second-rate quality because the firm will always be following their competition. If the entire industry employs the approach hit will lead to stagnation for the entire industry, setting them up for eventual replacement by outside innovators.

Pugh Matrix

Pugh Matrix was introduced by Stuart Pugh. Pugh Matrix Concept Selection is a quantitative technique used to rank the multi-dimensional options of an option set. It is frequently used in engineering for making design decisions but can also be used to rank investment options, vendor options, product options or any other set of multidimensional entities.

Pugh Matrix refers to a matrix that helps determine a solution from a list of potential solutions. It is a scoring matrix used for concept selection, in which options are assigned scores relative to some pre-defined criteria. The selection is made based on the consolidated score. The Pugh matrix is a tool to facilitate a methodical team based approach for the selection of the best solution. It combines the strengths of different solutions and eliminates the weaknesses. This solution then becomes the datum of the base solution against which other solutions are compared. The process is iterated until the best solution or concept emerges.

The basic steps of the Pugh Concept Selection Process are

- Develop a list of the selection criteria. For evaluating product designs, list VOC requirements; for evaluating improvement proposals, list customer requirements or organizational improvement goals.
- Develop a list of all potential improvement solutions or all product designs to be rated.
- Select one potential improvement or product design as the baseline - all other proposals are compared to the baseline.
    - For product designs, the baseline is usually either the current design or a preferred new design.
    - For improvement proposals, the baseline is usually the improvement suggested by the team or an improvement that has strong management support.

- The current solution in place may also be used as a baseline
- Enter the baseline proposal in the space provided.
- Enter the selection criteria along the left side of the matrix and the alternative product or improvement proposals across the top of the matrix.
- Apply a weighting factor to all the selection criteria. These weights might not be the same for all projects, as they can reflect localized improvement needs or changes in customer requirements. A 1-to-9 scale or 1-to-5 scale can be used for weighting the importance of the selection criteria, using 1 for the least important criteria and 5 or 9 for the most important criteria.
- Based on team input, score how well the baseline proposal matches each of the selection criteria. Use a 1-to-9 or 1-to-5 scale for scoring the baseline, using 5 or 9 for very strong matches to the criteria, and 1 for very poor matches to the criteria. We may also use 1 for strong match. The moderator may define the scale.
- For each alternative proposal, the team should determine whether the alternative is Better, the Same, or Worse than the baseline, relative to each of the selection criteria:
    - Better results in a +1 score
    - Same results in a 0 score
    - Worse results in a -1 score.
- Multiply the scores by the criteria weights and add them together to obtain the weighted score.

Table 17: Example Pugh Matrix

Evaluation Criteria	Imp	Datum	B	C	D
Ease of guests finding the lobby for check - in	3	S	S	S	-
Minimum weight times for check in the process	5	S	-	-	+
Minimum errors in the room assignment	5	S	-	S	S
Appearance of the lobby area cleanliness	4	S	-	-	-
Sum of Same		4	1	2	1
Sum of Positives		0	0	0	1
Sum of Negatives		0	3	2	2
Weighted Sum of Positives		0	0	0	5
Weighted Sum of Negatives		0	14	9	7

- ✓ **Scoring the Proposed Solutions**

Each Proposed Solution is rated on how well it addresses a selection criterion compared with the Baseline Solution. For each Proposed Solution, select whether it is Better than the Baseline Solution, the Same as the Baseline Solution (default), or Worse than the Baseline Solution.

- ✓ **Solution Scores**

Based on your choice of Better, Same or Worse for each Proposed Solution (relative to the Baseline Solution), three scores are calculated:

- Weighted Score: Each Better rating receives a raw score of 1, each same rating receives a raw score of 0, and each Worse rating receives a raw score of -1. The raw scores are multiplied by the Importance of Selection Criteria, and the sum of the raw scores times the Importance is the Weighted Score. A higher Weighted Score is better.
- Worse/ Weighted Negative Score: Tracks the number of times that a Proposed Solution is rated worse than the Baseline Solution. The lower the Worse Score, the better a proposed solution is relative to the Baseline Solution.
- Better/Weighted Positive Score: Tracks the number of times that a Proposed Solution is rated better than the Baseline Solution. The higher the Better Score, the better a Proposed Solution is relative to the Baseline Solution.

Risk Analysis

Project leader may choose to carry out FMEA to analyze risks and solution. Solutions are not devoid of risks, and therefore analyzing the potential impact of the solution on the risk parameter is important.

Consensus Building tools

Multi- voting

By design, brainstorming generates a long list of ideas. However, also by design, many are not realistic or feasible. The Multi-voting activity allows a group to narrow their list or options into a manageable size for sincere consideration or study. It may not help the group make a single decision but can help the group narrow a long list of ideas into a manageable number that can be discussed and explored. It allows all members of the group to be involved in the process and ultimately saves the group a lot of time by allowing them to focus energy on the ideas with the greatest potential.

- ✓ **When to use Multi-voting**

When the group has a long list of possibilities and wants to narrow it down to a few for analysis and discussion and or when a selection process needs to be made after brainstorming.

Guidelines for Conducting the Multi-voting Activity:

- **Brainstorm a list of options**: Conduct the brainstorming activity to generate a list of ideas or options.
- **Review the list from the Brainstorming activity:** Once Green Belt/Black Belt have completed the list, clarify ideas, merge similar ideas, and make sure everyone understands the options. **Note:** at this time the

group is not to discuss the merits of any idea, just clarify and make sure everyone understands the meaning of each option.

- **Participants vote for the ideas that are worthy of further discussion**: Each participant may vote for as many ideas as they wish. Voting may be by show of hands or physically going to the list and marking their choices or placing a dot by their choices. If they so desire, participants may vote for every item.
- **Identify items for next round of voting**: Count the votes for each item. Any item receiving votes from half the people voting is identified for the next round of voting. For example, if there are 12 people voting, any item receiving at least six votes is included in the next round. Signify the items for the next vote by circling or marking them with a symbol, i.e., all items with a star by the number will be voted on the next round.
- **Vote again.** Participants vote again, however this time they may only cast votes for half the items remaining on the list. In other words, if there are 20 items from the last round that are being voted on, a participant may only vote for ten items.
- **Repeat steps 4 and 5.** Participants continuing voting and narrowing the options as outlined in steps 4 and 5 until there is an appropriate number of ideas for the group to analyze as a part of the decision-making or problem solving process. Generally groups need to have three to five options for further analysis.
- **Discuss remaining ideas**. At this time the group engages in discussing the pros and cons of the remaining ideas. This may be done in small groups or the group as a whole.
- **Proceed with appropriate actions.** At this point the group goes to the next steps. This might be making a choice of the best option or identifying the top priorities.

Item	Number of Votes
1. Have a meeting agenda	● ● ● ● ●
~~**2. Inform participants why they have to attend meeting**~~	● ●
~~**3. Have someone take notes at the meeting**~~	●
~~**4. Have a clear meeting objective**~~	● ● ●
~~**5. Reduce the number of topics to be discussed at each meeting**~~	●
6. Start and end meetings on time	● ● ● ● ● ●

Figure 20: Multiple Voting Activity

Nominal Group Technique

A technique that Supplements Brainstorming. Structured approaches to generate additional ideas, surveys the opinions of a small group, and prioritize brainstormed ideas. Nominal (meaning in name only) group technique (NGT) is a structured variation of a small-group discussion to reach consensus. NGT gathers information by asking individuals to respond to questions posed by a moderator, and then asking participants to prioritize the ideas or suggestions of all group members. The process prevents the domination of the discussion by a single person, encourages all group members to participate, and results in a set of prioritized solutions or recommendations that represent the group's preferences. The nominal group technique is a decision making method used among groups who want to make their decision quickly, as by a vote, but want everyone's opinions taken into account. First, every member of the group gives their view of the solution, with a short explanation. Then, duplicate solutions are eliminated from the list of all solutions, and the members proceed to rank the solutions, 1st, 2nd, 3rd, 4th, and so on. The numbers each solution receives are totalled, and the solution with the lowest (i.e. most favoured) total ranking is selected as the final decision. Figure 21 shows results of the nominal group technique. Each idea was ranked by several team members. The idea with the lowest total score is selected as the winner. In this example (Idea N).

- Structured to focus on problems, not people. To open lines of communication, tolerate conflicting ideas.
- Builds consensus and commitment to the final result. Especially good for highly controversial issues
- Nominal Group Technique is most often used after a brainstorming session to help organize and prioritize ideas

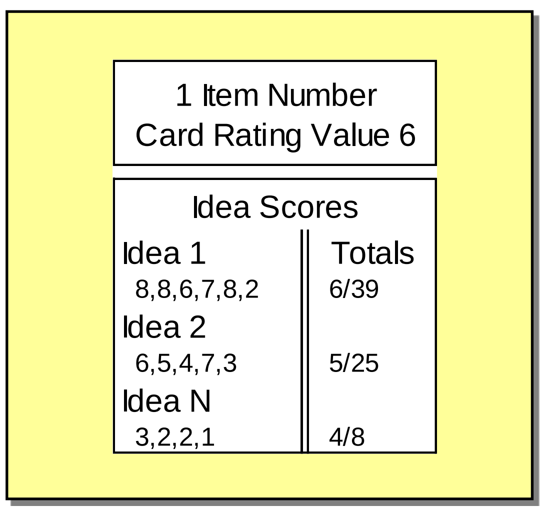


Figure 21: Example of Nominal Group Technique with ideas rated

The Four Step Process to Conduct Nominal Group Technique:

- **Generating Ideas:** The moderator presents the question or problem to the group in written form and reads the question to the group. The moderator directs everyone to write ideas in brief phrases or statements and to work silently and independently. Each person silently generates ideas and writes them down.
- **Recording Ideas:** Group members engage in a round-robin feedback session to concisely record each idea (without debate at this point). The moderator writes an idea from a group member on a flip chart that is visible to the entire group, and proceeds to ask for another idea from the next group member, and so on. There is no need to repeat ideas; however, if group members believe that an idea provides a different emphasis or variation, feel free to include it. Do not Proceed until all members' ideas have been documented.
- **Discussing Ideas:** Each recorded idea is then discussed to determine clarity and importance. For each idea, the moderator asks, "Are there any questions or comments group members would like to make about the

item?" This step provides an opportunity for members to express their understanding of the logic and the relative importance of the item. The creator of the idea need not feel obliged to clarify or explain the item; any member of the group can play that role.

- **Voting on Ideas:** Individuals vote privately to prioritize the ideas. The votes are tallied to identify the ideas that are rated highest by the group as a whole. The moderator establishes what criteria are used to prioritize the ideas. To start, each group member selects the five most important items from the group list and writes one idea on each index card. Next, each member ranks the five ideas selected, with the most important receiving a rank of 5, and the least important receiving a rank of 1 (Green Belt/Black Belt may change the rank i.e. rank 1 can be the best and rank 5 can be the worst).

  After members rank their responses in order of priority, the moderator creates a tally sheet on the flip chart with numbers down the left-hand side of the chart, which correspond to the ideas from the round-robin. The moderator collects all the cards from the participants and asks one group member to read the idea number and number of points allocated to each one, while the moderator records and then adds the scores on the tally sheet. The ideas that are the most highly rated by the group are the most favoured group actions or ideas in response to the question posed by the moderator.

✓ **When to Use NGT**

NGT is a good method to use to gain group consensus, for example, when various people (program staff, stakeholders, community residents, etc.) are involved in constructing a logic model and the list of outputs for a specific component is too long and therefore has to be prioritized. In this case, the questions to consider would be: "Which of the outputs listed are most important for achieving our goal and are easier to measure? Which of our outputs are less important for achieving our goal and are more difficult for us to measure?"

✓ **Disadvantages of NGT**

- Requires preparation.
- Is regimented and lends itself only to a single-purpose, single-topic meeting.
- Minimizes discussion, and thus does not allow for the full development of ideas, and therefore can be a less stimulating group process than other techniques.

✓ **Advantages of NGT**

- Generates a greater number of ideas than traditional group discussions.
- Balances the influence of individuals by limiting the power of opinion makers (particularly advantageous for use with teenagers, where peer leaders may have an exaggerated effect over group decisions or in meetings where established leaders tend to dominate the discussion).
- Diminishes competition and pressure to conform, based on status within the group.
- Encourages participants to confront issues through constructive problem solving.
- Allows the group to prioritize ideas democratically.
- Typically provides a greater sense of closure than can be obtained through group discussion.

Delphi Technique

Delphi Technique is a method of relying on a panel of experts to anonymously select their responses using a secret ballot process. After each round, a facilitator provides the summary of the experts' opinions along with the reasons for their decisions. Participants are encouraged to revise their answers in light of replies from other experts. The process is stopped after pre-defined criteria such as number of rounds. The advantage of this technique is that if there are team members who are boisterous or overbearing, they will not have much of an impact on swaying the decisions of other team members.

The Delphi technique, mainly developed by Dalkey and Helmer (1963) at the Rand Corporation in the 1950s, is a widely used and accepted method for achieving convergence of opinion concerning real-world knowledge solicited from experts within certain topic areas.

The Delphi technique is a widely used and accepted method for gathering data from respondents within their domain of expertise. The technique is designed as a group communication process which aims to achieve a convergence of opinion on a specific real-world issue. The Delphi process has been used in various fields of study such as program planning, needs assessment, policy determination, and resource utilization to develop a full range of alternatives, explore or expose underlying assumptions, as well as correlate judgments on a topic spanning a wide range of disciplines. The Delphi technique is well suited as a method for consensus-building by using a series of questionnaires delivered using multiple iterations to collect data from a panel of selected subjects. Subject selection, time frames for conducting and completing a study, the possibility of low response rates, and unintentionally guiding feedback from the respondent group are areas which should be considered when designing and implementing a Delphi study.

Delphi technique's application is observed in program planning, needs assessment, policy determination, resource utilization, marketing & sales and multiple other business decision areas.

Fowles (1978) describes ten steps for the Delphi method:

- Formation of a Delphi team to undertake a Delphi on a subject.
- Selection of expert panel(s).
- Development of the first round questionnaire
- Testing the questionnaire for proper wording.
- Transmission to the panel lists.
- Analysis of 1st responses
- Preparation of 2nd round.
- Transmission of 2nd round questionnaires to the panel lists
- Analysis of the 2nd round responses (7 to 9 may be repeated to get consensus)
- Preparation and presentation of report

Organizations do customize these steps to meet their requirements, as they may have time constraints and large number of iterations may not be possible.

Step 11-Select and optimize best solution

Experiments

Designed experiments play an important role in quality improvement. While the confidence intervals and hypothesis tests previously discussed are limited to rather simple comparisons between one sample and requirements or between two samples, the designed experiments will use ANOVA (analysis of variance) techniques to partition the variation in a response amongst the potential sources of variation.
The traditional approach, which most of us learned in high school science class, is to hold all factors constant except one. When this approach is used we can be sure that the variation is due to a cause and effect relationship or so we are told. However, this approach suffers from a number of problems:

- It usually isn't possible to hold all other variables constant.
- There is no way to account for the effect of joint variation of independent variables, such as interaction.
- There is no way to account for experimental error, including measurement variation.

The statistically designed experiment usually involves varying two or more variables simultaneously and obtaining multiple measurements under the same experimental conditions. The advantage of the statistical approach is threefold:

- Interactions can be detected and measured. Failure to detect interactions is a major flaw in the OFAT approach.
- Each value does the work of several values. A properly designed experiment allows Green Belt/Black Belt to use the same observation to estimate several different effects. This translates directly to cost savings when using the statistical approach.
- Experimental error is quantified and used to determine the confidence the experimenter has in his conclusions.

Much of the early work on the design of experiments involved agricultural studies. The language of experimental design still reflects these origins. The experimental area was literally a piece of ground. A block was a smaller piece of ground with fairly uniform properties. A plot was smaller still and it served as the basic unit of the design. As the plot was planted, fertilized and harvested, it could be split simply by drawing a line. A treatment was actually a treatment, such as the application of fertilizer. Unfortunately for the Six Sigma analyst, these terms are still part of the language of experiments.

Experimental area can be thought of as the scope of the planned experiment. For us, a block can be a group of results from a particular operator, or from a particular machine, or on a particular day—any planned natural grouping which should serve to make results from one block more alike than results from different blocks. For us, a treatment is the factor being investigated (material, environmental condition, etc.) in a single factor experiment. In factorial experiments (where several variables are being investigated at the same time) we speak of a treatment combination and we mean the prescribed levels of the factors to be applied to an experimental unit. For us, a yield is a measured result and, happily enough, in chemistry it will sometimes be a yield.

- ✓ **Definitions**

A designed experiment is an experiment where one or more factors, called independent variables, believed to have an effect on the experimental outcome are identified and manipulated according to a predetermined plan. Data collected from a designed experiment can be analysed statistically to determine the effect of the independent variables, or combinations of more than one independent variable. An experimental plan must also include provisions for dealing with extraneous variables, that is, variables not explicitly identified as independent variables.

- Response variable—the variable being investigated, also called the *dependent variable*, sometimes called simply *response*.
- Primary variables—The controllable variables believed most likely to have an effect. These may be quantitative, such as temperature, pressure, or speed, or they may be qualitative such as vendor, production method, and operator.
- Background variables—Variables, identified by the designers of the experiment, which may have an effect but either cannot or should not be deliberately manipulated

The objective is to determine the optimum combination of inputs for desired output considering constraints.

Simulation

Simulation is a means of experimenting with a detailed model of a real system to determine how the system will respond to changes in its structure, environment, or underlying assumptions. A system is defined as a combination of elements that interact to accomplish a specific objective. A group of machines performing related manufacturing operations would constitute a system. These machines may be considered, as a group, an element in a larger production system. The production system may be an element in a larger system involving design, delivery, etc.

Simulations allow the system or process designer to solve problems. To the extent that the computer model behaves as the real world system it models, the simulation can help answer important questions. Care should be taken to prevent the model from becoming the focus of attention. If important questions can be answered more easily without the model, then the model should not be used. The modeller must specify the scope of the model and the level of detail to include in the model. Only those factors which have a significant impact on the model's ability to serve its stated purpose should be included. The level of detail must be consistent with the purpose. The idea is to create, as economically as possible, a replica of the real world system that can provide answers to important questions. This is usually possible at a reasonable level of detail. Well-designed simulations provide data on a wide variety of systems metrics, such as throughput, resource utilization, queue times, and production requirements.

While useful in modelling and understanding existing systems, they are even better suited to evaluate proposed process *changes*. In essence, simulation is a tool for rapidly generating and evaluating ideas for process improvement. By applying this technology to the creativity process, Six Sigma improvements can be greatly accelerated.

✓ **Predicting CTQ Performance**

A key consideration for any design concept is the CTQ that would result from deploying the design. It is often very difficult to determine the overall result of a series of process steps, but relatively easy to study each step individually. Software can then be used to simulate the process a number of times and calculate the performance of CTQ at the end of the series.

Step 12- Pilot, Implement and Validate solution

Pilot

A pilot is a test of a proposed solution. This type of test has the following properties:

- Performed on a small scale, usually on a subset of the target population
- Used to evaluate both the solution and the implementation of the solution
- Purpose is to make the full scale implementation more effective
- Provides data about expected results and exposes issues/ challenges in the implementation plan

Pilot Study helps to

- Identify previously unknown performance problems, improve the solution and understand risks of the solution
- Validate expected results and facilitate buy-in from stakeholders, cross-functional team.
- Smooth implementation with limited or no teething issues

Full Scale Implementation

The team first develops a plan to implement the one or more solutions selected in the Improve phase.
It is important to create a solution implementation plan based on the results from the pilot plan and pilot implementation. A big piece of the solution implementation plan is to leave tools to help the owner manage the process after the team has gone on to other projects. A large-scale project may require dealing with multiple processes and sub-processes, multiple implementation locations, a large number of implementation teams and several different disciplines and methodologies.

Full Scale Implementation should be treated as a project in itself, and project management practises should not be ignored.

What plan should include but not limited to:

- Potential Risk analysis – Failure Modes and Effect Analysis
- Solution Implementation Schedule
- Training Plan
- Communication Plan
- Cost and Benefit Analysis

Improvement Validation

Once full scale implementation has been successfully completed, Green Belt/Black Belt should

- Revalidate the measurement system to ensure that data collected post improvement is reliable
- Collect data for Output (Y) to evaluate performance post full scale implementation
    - Sigma level –Sigma level computed during the Measure phase acts as a baseline and can be compared with Sigma level computed in Improve phase
    - Cp, Cpk – Similarly process capability indices can also be compared post improvement versus baseline

- Hypothesis tests: If sample data are collected post improvement, Hypothesis test should be carried to ascertain whether the improvement is observed for the population process performance
- FMEA – Process FMEA may also be revised to cover the new changes in the process. It will help in ascertaining whether the solution and changes induced by solution have affected the risk parameters of the process.

The main deliverable of Improve phase is **Selected Solution**.

Improve Phase Tollgate Checklist

- ✓ What techniques were used to generate ideas for potential solutions?
- ✓ What narrowing and screening techniques were used to further develop and qualify potential solutions?
- ✓ What evaluation criteria were used to select a recommended solution?
- ✓ Do the proposed solutions address all of the identified root causes, or at least the most critical?
- ✓ Were the solutions verified with the Project Sponsor and Stakeholders? Has an approval been received to implement?
- ✓ Was a pilot run to test the solution? What was learned? What modifications were made?
- ✓ Has the team seen evidence that the root causes of the initial problems have been addressed during the pilot? What are the expected benefits?
- ✓ Has the team considered potential problems and unintended consequences (FMEA) of the solution and developed preventive and contingency actions to address them?
- ✓ Has the proposed solution been documented, including process participants, job descriptions, and if applicable, their estimated time commitment to support the process?
- ✓ Has the team developed an implementation plan? What is the status?
- ✓ Have changes been communicated to all the appropriate people?
- ✓ Has the team been able to identify any additional ‘Quick Wins’?
- ✓ Have ‘learning’s’ to-date required modification of the Project Charter? If so, have these changes been approved by the Project Sponsor and the Key Stakeholders?
- ✓ Have any new risks to project success been identified and added to the Risk Mitigation Plan.

In the Green Belt workshop, we will discuss

- Generation of potential solutions using De Bono Six thinking Hats, Creative Thinking, Benchmarking
- Evaluation of alternative solutions using Pugh Matrix, FMEA, Nominal Group Technique, Multi-voting and Delphi Technique
- Pilot Study, Full Scale Implementation and Validation of Solution

Participants will work on Improve Phase of practice project 1&2. Participants will also explore cases that include:

- **Process Benchmarking in improving supply chain processes at US Army**
- **Pugh Matrix to evaluate Room lighting alternatives, Training pedagogy, Car Horn Design**
- **Pilot Study examples across industries**

Chapter 9

Control

Control Phase Overview

In the Control phase, the emphasis is on maintaining the gains achieved. The question the team is trying to answer is, "How can we guarantee performance?". In the Improve phase, the team had a successful pilot and also got an opportunity to tweak the solution. They used this information to plan the solution implementation and carried out full scale implementation. It is time now to ensure that, when they finish the project, the success that they have observed will be sustained. This involves transferring the responsibility to the process owner.

The deliverables in the Control phase are:

- Process Control Plan
- Solution documentation and Validation of Benefits
- Successful transfer to Process Owner

Step 13	• Implement Control System for Critical X's
Step 14	• Document Solution and Benefits
Step 15	• Transfer to Process Owner, Project Closure

Step 13- Implement Control System for Critical X's

Control System is the complete strategy for maintaining the improved process performance over time. It identifies the specific actions and tools required for sustaining the process improvements or gains.
The objective is

- To ensure sure that the process stays in control after the solution has been implemented.
- To quickly detect the out of control state and determine the associated special causes so that actions can be taken to correct the problem before non-conformances are produced.

Green Belt/Black Belt will develop a **control plan** which the process owner will use as a guideline for sustaining the gains. **Control plan** provides a written summary description of the systems used in minimizing process and service variation

- Control plans do not replace information contained in detailed instructions
- In a grand sense the control plan describes the actions that are required at each phase of the process including receiving, in-process, outgoing, and periodic requirements to assure that all process outputs will be in a state of control

Ultimately, the control plan is a living document reflecting current methods of control and measurement systems used

- What is the process that is being controlled?
- What measures (numbers) are we monitoring?
- For each measure, what are the "trigger point" values where action should be taken?
- What action should be taken when a "trigger point" is reached? Who is responsible for taking action?

A control plan includes but not limited to

Table 18

Control Plan	
Process Documentation	**Communication Plan**
Data Collection Plan	**Audit/Inspection Plan**
Mistake Proofing System	**Risk Mitigation System**
Response/Reaction Plan	**Statistical Process Control**

Mistake Proofing (Poka Yoke)

Mistake Proofing is a method for avoiding errors in a process. The simplest definition of "Mistake Proofing" is that it is a technique for eliminating errors by making it impossible to make mistakes in the process. It is often considered the best approach to process control.

A Poka-Yoke device is any mechanism that either prevents a mistake from being made or makes the mistake obvious at a glance. The ability to prevent mistakes is essential because the cause of defects lies in errors committed due to imperfect processes. Defects result from either being unaware of the errors or neglecting to do anything to correct them.

Inspection/Audits

Inspection isn't the most likely control method however they may be the only option left if we are unable to identify a suitable mistake proofing measure. We can classify inspection as

- **Source Inspection:** Inspection carried out at source or as close to the source of the defect as possible. Mistakes detected close to source can be reworked or corrected before it is passed.

- **Informative Inspection:** Inspection carried out to investigate the cause of any defect found, so action can be taken. It only provides information on defect after it has occurred.

- **Judgment Inspection:** Inspection carried out to separate good units from bad units once processing has occurred. It doesn't decrease the defect rate

Statistical Process/ Quality Control

Common Cause and Special Cause

Common Cause Variation

In any process, regardless of how well-designed or carefully maintained it is, a certain amount of inherent or natural variability will always exist. This natural variability or "background noise" is the cumulative effect of many small, essentially unavoidable causes. In the framework of statistical quality control, this natural variability is often called a "stable system of chance causes (common causes)." A process that is operating with only **chance causes** of variation present is said to be in statistical control. In other words, the chance causes (common causes) are an inherent part of the process.

Special Cause Variation

In a process, other kinds of variability may occasionally be present. This variability in key quality characteristics can arise from sources like improperly adjusted machines, operator errors, defective raw materials, untrained resources, system outage etc. Such variability is generally large when compared to the background noise, and usually stands out. We refer to these sources of variability that are not part of the chance cause pattern as **assignable causes or special causes.** A process that is operating in the presence of assignable causes is said to be out of control. Production processes will often operate in the in-control state, producing acceptable product for relatively long periods of time. Occasionally, however, assignable causes will occur, seemingly at random, resulting in a "shift" to an out-of-control state where a large proportion of the process output does not conform to requirements. A major objective of statistical process control is to quickly detect the occurrence of assignable causes or process shifts so that investigation of the process and corrective action may be undertaken before many nonconforming units are manufactured. The control chart is an online process-monitoring technique widely used for this purpose.

Types of Control Charts

Control charts may be classified into two general types.

- **Attribute Control Charts**
  Many characteristics are not measured on a continuous scale or even a quantitative scale. In these cases, we may judge each unit of product as either conforming or nonconforming on the basis of whether or not it possesses certain attributes, or we may count the number of nonconformities (defects) appearing on a unit of product. Control charts for such quality characteristics are called **attributes control charts. We will explore the following charts**
    - Area of opportunity charts for count data:
        - Number of defects charts for constant areas of opportunity – c chart
        - Number of defects per unit charts for variable areas of opportunity – u chart
    - Proportion nonconforming charts (*p*-charts) for classification data:

- Proportion of nonconformities for constant subgroup size- np chart
- Proportion of nonconformities for variable subgroup size – p chart

- **Variable Control Charts**:
  Many characteristics can be measured and expressed as numbers on some continuous scale of measurement. In such cases, it is convenient to describe the quality characteristic with a measure of central tendency and a measure of variability. Control charts for central tendency and variability are collectively called **variables control charts.** The chart is the most widely used chart for monitoring central tendency, whereas charts based on either the sample range or the sample standard deviation are used to control process variability.
  - Charts based on individual measurements for subgroups of $n = 1$ – Individual and moving range chart
  - Charts based on subgroups of $n>=2$:
    - Subgroups of $2 \leq n \leq 10$: Mean and range chart
    - Subgroups of $n > 10$: Mean and standard deviation chart

COMPUTING CONTROL LIMITS

- Process mean of the statistic ± 3 standard deviations of the statistic so that
  - ✓ Upper control limit (*UCL*) = process mean of the statistic + 3 standard deviations of the statistic
  - ✓ Lower control limit (*LCL*) = process mean of the statistic – 3 standard deviations of the statistic

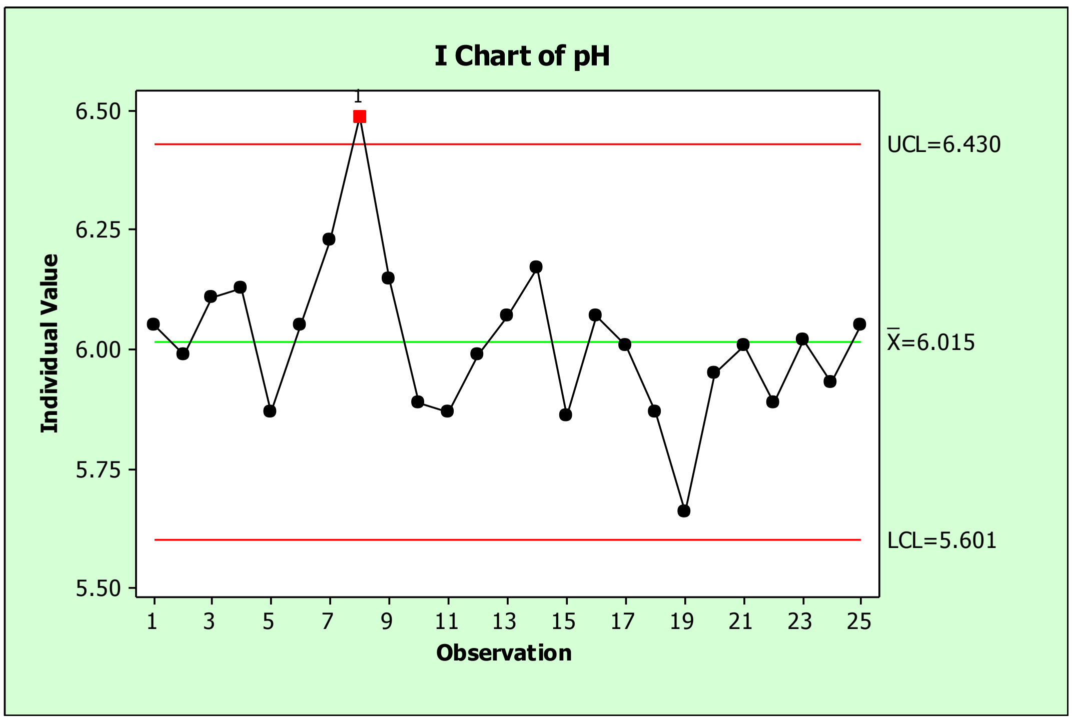


Figure 22

Worksheet: Detergent.mtw

A typical control chart is shown in Figure 22, which is a graphical display of a quality characteristic that has been measured or computed from a sample versus the sample number or time. Often, the samples are selected at periodic intervals such as every hour. The chart contains a center-line (CL) that represents the average value of the quality characteristic corresponding to the in-control state. (That is, only chance causes are present.) Two other horizontal lines, called the upper control limit (UCL) and the lower control limit (LCL) are also shown on the chart.

There is a close connection between control charts and hypothesis testing. Essentially, the control chart is a test of the hypothesis that the process is in a state of statistical control. A point plotting within the control limits is equivalent to failing to reject the hypothesis of statistical control, and a point plotting outside the control limits is equivalent to rejecting the hypothesis of statistical control.

The most important use of a control chart is to *improve* the process. We have found that, generally

- Most processes do not operate in a state of statistical control.
- Consequently, the routine and attentive use of control charts will identify assignable causes. If these causes can be eliminated from the process, variability will be reduced and the process will be improved.
- The control chart will only *detect* assignable causes. Management, operator, and engineering *action* will usually be necessary to eliminate the assignable cause. An action plan for responding to control chart signals is vital.

In identifying and eliminating assignable causes, it is important to find the underlying **root cause** of the problem and to attack it. A cosmetic solution will not result in any real, long-term process improvement. Developing an effective system for corrective action is an essential component of an effective SPC implementation.

Step 14- Document Solution and Benefits

Solutions should be documented for review and replication in other processes in the organization. It also acts a lessons learnt document for other Green Belts and Black Belts.

✓ **Standardization and Solution Replication**

One of the powerful aspects of Six Sigma is to take successful implementations and expand them across the organization. This is accomplished with replication and standardization.

- Replication is taking the solution from the team and applying it to the same type or a similar type of process.
- Standardization is taking the lessons/solutions from the team and applying those good ideas to processes that may be dissimilar to the original process improved.

The team should consider standardization and replication opportunities to significantly increase the impact on the sigma performance of processes to far exceed the anticipated results by the pilot and solution implementation.
As the implementation expands to other areas, four implementation approaches can be combined or used independently. The appropriate approach will depend on the resources available, the culture of the organization and the requirements for a fast implementation. The four approaches are:

- A sequenced approach is when a solution is fully implemented in one process or location; implementation begins at a second location.
- A parallel approach is when the solution is implemented at two or more locations or processes simultaneously.
- A phased approach is when a pre-determined milestone is achieved at one location; the implementation at a second location begins.

- A flat approach is when implementation is done at all target locations, companywide.

✓ **Project Benefits**

The results of the improvement and financial benefits need to be monitored (generally) for one year.

The project leader should prepare a Project Closure Document. A Project Closure document displays the results of the project, control activities, status of incomplete tasks, approval of key stakeholders (for example, the process owner, finance, quality systems, and environmental) to confirm that the project is complete. This document is often used as the formal hand-off of the project to the process owner. It provides a formal place to record final project results, document key stakeholder approvals and a record of the status of the improved process at the completion of the project. This record may be the basis for ongoing auditing.

A Project Closure document should examine the following:

- Record all pertinent performance and financial data.
- Reference controls (or the control plan).
- Review and resolve any incomplete tasks.
- Obtain signatures (varies by project and organization).
- Finance – Are financial benefits valid?
- Process owners – Do they accept the controls and do they agree the project is complete?
- Environmental, health, and safety – Do they agree that all procedures and policies have been followed?
- Quality systems – Have sufficient verifiable controls been instituted to ensure project success? Have all procedures and policies been followed?
- Project technical support (for example, Master Black Belt) – Does the project meet the requirements of the process improvement model that is used?
- Management (for example, Champion) – Does management agree that the project is completed?
- Green Belt/Black Belt should first obtain the signature of an independent quality group to confirm that controls are: (1) in place, (2) verifiable, and (3) sufficient to ensure the project benefits will continue to accrue. Without such controls, the project should not be approved for closure.
- Financial benefits may be soft, which can be difficult to measure (for example, improved product lets us keep a key customer, reduced order to delivery time, reduced environmental emissions, improved ergonomics, and standardization of product/process).

Step 15-Transfer to Process Owner, Project Closure

In the Control phase, the team needs to ensure that when they finish the project, the success that they have seen in implementation will continue. This involves transferring the responsibility to the process owner. This may require:

- Process control plan
- Review meetings to communicate the state of the process.
- Updated flowcharts, procedures and statement of work
- Statistical Process/Quality Control measures including control plan

- Out-of-Control Action Plans, Response Plans to define how irregularities in the process are handled

As the project wraps up, a couple of additional activities may be appropriate:

- The team might consider evaluating how the team worked together
- Management may devise rewards to recognize the work and success of the team

Recognition and celebration of a successful Six Sigma drives process excellence philosophy within the organization and managing change becomes simpler

A Six Sigma project does not really "end" at the conclusion of the Control phase. There should be opportunities to extend the success of this project team in other areas. The team and champion may share the knowledge gained with others, replicate the solution in other processes, and develop standards for other processes based on what they learned from their solution implementation. The team may continue to examine the process to look for opportunities for continuous process improvement.

Control Phase Tollgate Checklist

- ✓ Has the team prepared all the essential documentation for the improved process, including revised/new Standard Operating Procedures (SOP's), a training plan, and a process control system?
- ✓ Has the necessary training for process owners/operators been performed?
- ✓ Have the right measures been selected, and documented as part of the Process Control System, to monitor performance of the process and the continued effectiveness of the solution? Has the metrics briefing plan/schedule been documented? Who owns the measures? Has the Process Owner's job description been updated to reflect the new responsibilities? What happens if minimum performance is not achieved?
- ✓ Has the solution been effectively implemented? Has the team compiled results data confirming that the solution has achieved the goals defined in the Project Charter?
- ✓ Has the Financial Benefit Summary been completed? Has the Resource Manager reviewed it?
- ✓ Has the process been transitioned to the Process Owner, to take over responsibility for managing continuing operations? Do they concur with the control plan?
- ✓ Has a final Storyboard documenting the project work been developed?
- ✓ Has the team forwarded other issues/opportunities, which were not able to be addressed, to senior management?
- ✓ Have “lessons learned” been captured?
- ✓ Have replication opportunities been identified and communicated?
- ✓ Has the hard work and successful efforts of our team been celebrated?

In the Green Belt workshop, we will discuss

- Development of Process Control Plan
- Selection of appropriate control charts for service and manufacturing cases
- Distinguishing common and special cause variation using rules and tests
- Determining whether the process is stable
- Solution Documentation and Replication
- Handover to Process Owner

Participants will work on Control Phase of practice project 1&2. Participants will explore Control chart identification cases that include

- Purchase forms
- Fill Height of Wine Bottle
- Call Quality Checklist
- Claims processing time
- Shampoo pH balance
- Defective toy car remotes

Appendix

- ✓ Acronyms
- ✓ Important Links for Online Learning and Discussions
- ✓ References

Acronyms

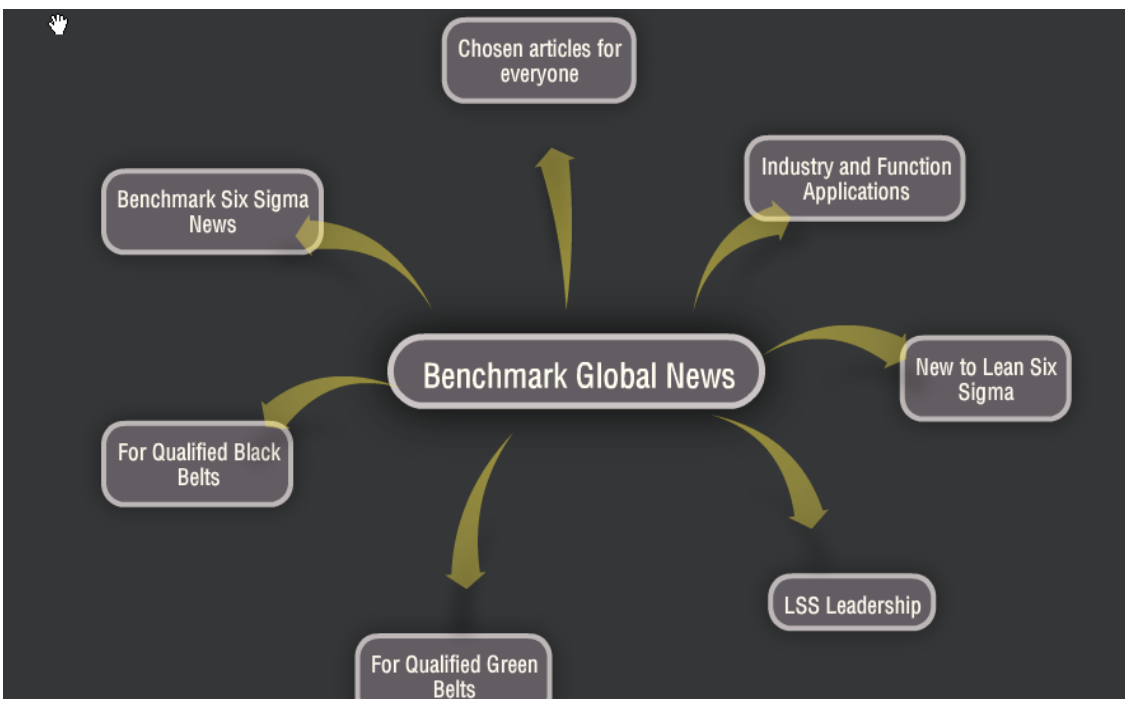
AAA	Attribute Agreement Analysis
AIAG	Automotive Industry Action Group
ANOVA	Analysis of Variance
CCR	Critical Customer Requirement
cdf	Cumulative distribution function
COPQ	Cost of Poor Quality
C_P, C_{Pk}	Process Capability Indices (Short Term)
CTQ	Critical to Quality
DFSS	Design for Six Sigma
DMADV	Define, Measure, Analyze, Design, Validate/Verify
DMAIC	Define, Measure, Analyze, Improve, Control
DOE	Design of Experiments
DPMO	Defects per Million Opportunities
DPU	Defects per Unit
FMEA	Failure Modes & Effects Analysis
HACCP	Hazard Analysis and Critical control points
IDOV	Identify, Design, Optimize, Validate/Verify
Kaizen	Continuous Improvement
KPI	Key Performance Indicator
LCL	Lower Control Limit
μ	Population Arithmetic Mean
MSA	Measurement Systems Analysis
Muda	Waste
PDCA	Plan Do Check Act
pdf	Probability density function
pmf	Probability mass function
P_P, P_{PK}	Process Capability Indices (Long Term)
s	Sample Standard Deviation

σ	Population standard deviation
SMED	Single minute exchange of die
UCL	Upper Control Limit
USL	Upper Specification Limit
VOB	Voice of Business
VOC	Voice of Customer
$\overline{X}$	Sample Arithmetic Mean
Zlt	Sigma level long term
Zst	Sigma Level short term

Important Links for online Learning and Discussion

For answers to these questions, please use the following link
http://globalnews.benchmarksixsigma.com/

1. How does Six Sigma apply in various Industries and Functional Areas?
2. What is the role of Lean Six Sigma in business or career growth?
3. What are the useful globally available insights for Six Sigma Green Belts? Are there any example Green Belt projects that I can refer?
4. What are the success stories of people who have benefited a lot from Six Sigma?
5. How can I network with professionals who have been trained at Benchmark Six Sigma?
6. What is the post training support provided by Benchmark Six Sigma?



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- ✓ Berenson, M. L.,D. M. Levine, and T.C. Krehbiel. Basic Business Statistics: Concepts and Applications,
- ✓ Issa Bass, Barbara Lawton, Ph.D Lean Six Sigma Using SigmaXL and Minitab
- ✓ Theodore T. Allen, Introduction to Engineering, Statistics and Lean Sigma
- ✓ Kai Yang, Basem S. El-Haik, Design for Six Sigma, A Roadmap for Product Development
- ✓ Thomas Pyzdek, Paul A. KellerThe Six Sigma Handbook
- ✓ Thomas Pyzdek, The Six Sigma Project Planner