LEAN SIX SIGMA: TOOLS TO USE

(What, When, Why!!)

This short book is an attempt to summarize Lean Six Sigma Tools usage: What, When and Why?

Dr. Tansen D Chaudhari,
Head of Process Asia, Xchanging Bangalore 560066
9/18/2009

Lean Six Sigma Tools

1-Sample T-test
1-Sample T-test compares process mean to target. This is useful in identifying a significant difference between a sample mean and a specified value which could be target or expected outcome. Best to compare data gathered before process improvements and after and is a way to prove that the mean has actually shifted. The 1-Sample t-test is used with continuous data.

1-way ANOVA
ANOVA tests to see if there are differences between the means of a single factor. One-way ANOVA is useful for identifying a statistically significant difference between means of three or more levels of a factor for e.g. when we need to compare three or more means.

2-Sample T-test
A statistical test used to detect differences between means of two populations. The 2- Sample t-test is useful when we have two samples of continuous data, and we need to know if they both come from the same population or if they represent two different populations

5S tools
Mainly useful for establishing standards to detect an abnormality, create and maintain an organized, clean and safe work area, conditioning discipline for Action Workout. Below are definitions of 5S:
Sort (*Seiri*)- Separate what is needed now from what is not needed now. Simplify / Set in Order (*Seiton*)- Organize and arrange what we need. Sweep / Shine (*Seiso*)- Keep the area clean, Standardize (*Seiketsu*)- Standardize workstations and processes to remove variation and maintain safety and quality. Sustain / Self Discipline (*Shitsuke*)- Sustain 5S through individual leadership.

Action work out (AWO)
A 3 to 5 day, team-based activity focused on improving processes by observing what is actually happening and quickly making changes to get results. Action Work Outs focus on: waste elimination, cycle time reduction, action and results. AWOs Priorities are: safety, quality, delivery, cost.
In short, People getting together to Make Improvements is AWO.
Prior to AWO it is suggested to do the following: identify projects, show relationship to Big Y & benefits, develop clear concise focused objectives, complete target sheets, meet stake holder. Pre work is dependent on AWO topic. Also try to understand the Critical X's.
For best possible results, include all functional representatives of the team involved in AWO.

ANOVA GLM
ANOVA General Linear Model (GLM) is a statistical tool used for testing differences in means. ANOVA GLM tests to see if there are differences between the means for levels of single factors (called main effects) and combinations of factors (called interactions). The General Linear Model allows learning one form of ANOVA that can be used for all tests of mean differences involving two or more factors or levels. Because ANOVA GLM is useful for identifying the effect of two or more factors (independent variables) on a dependent variable, it is also extremely useful for identifying important Xs for a project Y.
Use ANOVA GLM when there is a need to identify a statistically significant difference in the mean of the dependent variable due to two or more factors with multiple levels, alone and in combination. Uses of ANOVA GLM can be - to identify significant Xs for improving either centering or spread, -also can be used

to quantify the amount of variation in the response that can be attributed to a specific factor in a designed experiment.

Benchmarking
Benchmarking is an improvement tool whereby an organization measures its performance or process against other organizations best in class practices, Determines how those organizations have achieved their performance levels, Uses the information to improve its own performance.
Benchmarking is an important tool because- it allows us to compare our relative position for a product or service against industry leaders or other organizations outside our industry who perform similar functions, -it helps identify potential Xs by comparing process to the benchmarked process, - it may encourage innovative or direct applications of solutions from other businesses to our product or process. Also, benchmarking can help to build acceptance for project results in comparison to benchmark data obtained from industry leaders. Benchmarking can be done at any point in the Six Sigma process when we need to develop a new process or improve an existing one.

Binary Logistic Regression
Binary logistic regression is useful in modeling the relationship between a binary Y and continuous Xs.
The predicted values will be probabilities of an event such as success or failure. The predicted values will be bounded between zero and one.

Box Plot
A box plot is a graphics tool that displays the centering, spread, and distribution of a continuous data set. It is made up of a box and whiskers (and outliers) that correspond to each quartile of the data set. The box represents the first and third quartiles of data. The line that bisects the box is the median of the entire data set-50% of the data points fall below this line and 50% fall above it. It is especially useful to view more than one box plot simultaneously to compare the performance of several processes. A box plot can be used throughout an improvement project, although it is most useful in the Analyze phase. In the Measure phase one can use a box plot to begin to understand the nature of a problem.

Box-Cox Transformation
Used to find the mathematical function needed to translate a continuous but non-normal distribution into a normal distribution. This is a tool for finding a transformation that will make a data set closer to a normal distribution. The Box-Cox transformation can be useful for correcting non-normality in process data, and for correcting problems due to unstable process variation. Under most conditions, it is not necessary to correct for non-normality unless the data is highly skewed.

Brainstorming
Brainstorming is a tool that allows for open and creative thinking. It encourages all team members to participate and to build on each other's creativity. Brainstorming can be used at any time when team needs to creatively generate numerous ideas on any topic. This can be done using few other tools such as QFD, tree diagrams, FMEA, etc.

C chart
A graphical tool that allows to view the actual number of defects in each subgroup. Being a discrete data control chart it can monitor many product quality characteristics simultaneously. The c chart is a tool that will help determine if process is in control or out of control due to special causes. The c chart monitors the number of defects per sample taken from a process when data size is small and sample size is constant.

CAP

CAP-Change acceleration process is change management tool. Used to establish scope and facilitate discussion. Effort focuses on delineating project boundaries. Encourages group participation. increases individual involvement and understanding of team efforts. Prevents errant team efforts in later project stages (waste). Helps to orient new team members. Few of the typical CAP tools used are: Stakeholder analysis-ARMI (Approver, Resource, Member, Interested party), Team work- GRPI(Goals, Roles, Processes, Interpersonal), Project Scoping- In/Out matrix, Threat/Opportunity matrix.

Capability Analysis

Capability analysis is a Minitab tool that visually compares actual process performance to the performance standards. The capability analysis output includes an illustration of the data and several performance statistics. The plot is a histogram with the performance standards for the process expressed as upper and lower specification limits (USL and LSL). A normal distribution curve is calculated from the process mean and standard deviation; this curve is overlaid on the histogram. Also includes a table listing several key process parameters such as mean, standard deviation, capability indexes, and parts per million (ppm) above and below the specification limits.

When describing a process, it is important to identify sources of variation as well as process segments that do not meet performance standards. Capability analysis is a useful tool because it illustrates the centering and spread of our data in relation to the performance standards and provides a statistical summary of process performance. Capability analysis is used with continuous data whenever we need to compare actual process performance to the performance standards. We can use this tool in the Measure phase to describe process performance in statistical terms. In the Improve phase, we can use capability analysis when we optimize and confirm our proposed solution. In the Control phase, capability analysis will help us compare the actual improvement of our process to the performance standards.

Cause and Effect Diagram

A cause and effect diagram is a visual tool that logically organizes possible causes for a specific problem or effect by graphically displaying them in increasing detail. It is sometimes called a fishbone diagram because of its fishbone shape. This shape allows the team to see how each cause relates to the effect. It then allows us to determine a classification related to the impact and ease of addressing each cause. A cause and effect diagram allows our team to explore, identify, and display all of the possible causes related to a specific problem. The diagram can increase in detail as necessary to identify the true root cause of the problem. Proper use of the tool helps the team organize thinking so that all the possible causes of the problem are captured. Therefore, the cause and effect diagram reflects the perspective of the team as a whole and helps foster consensus in the results because each team member can view all the inputs. We can use the cause and effect diagram whenever we need to break an effect down into its root causes. It is especially useful in the Measure, Analyze, and Improve phases of the DMAIC process

Chi-square goodness of fit

The chi square goodness of fit test compares the observed frequencies to expected frequencies assuming a particular distribution. The null hypothesis is that the data fit the assumed distribution; the alternative hypothesis is that it does not. This test checks whether an assumed distribution is reasonable. We can use this test against an assumed distribution, e.g., normality, or to generate other types of tests, e.g., whether a particular value is a median or quartile.

Chi-square-test of independence

The chi square-test of independence is a test of association (non-independence) between discrete variables. It is also referred to as the test of association. It is based on a mathematical comparison of the number of observed counts against the expected number of counts to determine if there is a difference in output counts based on the input category. The chi square-test of independence is useful for identifying a significant difference between count data for two or more levels of a discrete variable. Many statistical problem statements and performance improvement goals are written in terms of reducing DPMO/DPU. The chi square-test of independence applied to before and after data is a way to prove that the DPMO/DPU have actually been reduced.

Control Charts

Control charts are time-ordered graphical displays of data that plot process variation over time. Control charts are the major tools used to monitor processes to ensure they remain stable. Control charts are characterized by - A centerline which represents the process average, or the middle point about which plotted measures are expected to vary randomly, - Upper and lower control limits which define the area three standard deviations on either side of the centerline. Control limits reflect the expected range of variation for that process. Control charts determine whether a process is in control or out of control. A process is said to be in control when only common causes of variation are present. This is represented on the control chart by data points fluctuating randomly within the control limits. Data points outside the control limits and those displaying nonrandom patterns indicate special cause variation. When special cause variation is present, the process is said to be out of control. Control charts identify when special cause is acting on the process but do not identify what the special cause is.

There are two categories of control charts, characterized by type of data we are working with: continuous data control charts and discrete data control charts.

Control charts serve as a tool for the ongoing control of a process and provide a common language for discussing process performance. They help us understand variation and use that knowledge to control and improve our process. In addition, control charts function as a monitoring system that alerts us to the need to respond to special cause variation so we can put in place an immediate remedy to contain any damage.

In the Measure phase, use control charts to understand the performance of our process as it exists before process improvements. In the Analyze phase, control charts serve as a troubleshooting guide that can help us identify sources of variation (Xs). In the Control phase, use control charts to:

1. Make sure the vital few Xs remain in control to sustain the solution. 2. Show process performance after full-scale implementation of the solution. Compare compare the control chart created in the Control phase with that from the Measure phase to show process improvement. 3. Verify that the process remains in control after the sources of special cause variation have been removed.

Design of Experiment

Design of experiment (DOE) is a tool that allows us to obtain information about how factors (Xs), alone and in combination, affect a process and its output (Y). Usual approach is to generate data by changing one factor at a time. This approach often requires too many runs and cannot capture the effect of combined factors on the output. By allowing us to test more than one factor at a time-as well as different settings for each factor-DOE is able to identify all factors and combinations of factors that affect the process Y. In general, use DOE when we want to: Identify and quantify the impact of the vital few Xs on our process output, describe the relationship between Xs and a Y with a mathematical model, determine the best configuration

<u>Orthogonality:</u> Since our goal in experimentation is to determine the effect each factor's response, independent of the effects of other factors, experiments must be designed so as to be horizontally and vertically balanced. An experimental array is vertically balanced if there are an equal number of high and low values in each column. The array is horizontally balanced if for each level within each factor we are testing an equal number of high and low values from each of the other factors. If we have a balanced design in this manner, it is Orthogonal. Standard generated designs are orthogonal. When modifying or fractionating standard designs be alert to assure maintenance of orthogonality.

Repetition Completing a run more than once without resetting the independent variables is called repetition. It is commonly used to minimize the effect of measurement and to analyze factors affecting short-term variation in the response.
Replication Duplicate experimental runs more than once after resetting the independent variables is called replication. It is commonly used to assure generalization of results over longer term conditions.
Randomization Running experimental trials in a random sequence is a common, recommended practice that assures that variables that change over time have an equal opportunity to affect all the runs. Whenever possible, randomizing should be used for designed experimental plans.
Blocking A block is a group of homogeneous units. It may be a group of units made at the same time, such as a block by shift or lot, or it may be a group of units made from the same material. When blocking an experiment, we are adding a factor to the design.

Dot plot
Dot plot is a quick graphical comparison of two or more processes' variation or spread.

Failure Mode Effect Analysis
A means / method to Identify ways a process can/may fail, estimate the risks of those failures, evaluate a control plan, prioritize actions related to the process. Best suggested for Complex or new processes. Cross-functional team needs to be involved during FMEA. This has basically before and after scenarios. We rate each identified failure mode by Severity, Occurrence, Detection and combined product is represented by Risk Priority Number (RPN).

Gage R&R-ANOVA method
Gage R&R-ANOVA method is a tool used to assess the variation in a measurement system due to reproducibility and/or repeatability. An advantage of this tool is that it can separate the individual effects of repeatability and reproducibility and then break down reproducibility into the components "operator" and "operator by part." This tool applies to continuous data only. In Measure phase -Use Gage R&R-ANOVA method after the project data collection plan is formulated or modified and before the project data collection plan is finalized and data is collected.

Gage R&R-short Method
Gage R&R-Short Method is a tool used to assess the variation in a measurement system due to the combined effect of reproducibility and repeatability. An advantage of this tool is that it requires only two operators and five samples to complete the analysis. A disadvantage of this tool is that the individual effects of repeatability and reproducibility cannot be separated. This tool applies to continuous data only.
Gage R&R-Short Method is an important tool because it provides a quick method of assessing the most common types of measurement variation using only five parts and two operators. Choose the Gage R&R-Short Method when we have continuous data and you believe the total measurement variation due to repeatability and reproducibility is an acceptably small portion of the total observed variation, but we need to confirm this belief. Gage R&R-Short Method can also be used in cases where sample size is limited.

GRPI
GRPI is an excellent Change management tool for organizing newly formed teams. It is valuable in helping a group of individuals work as an effective team-one of the key ingredients to success in a DMAIC project. GRPI is an excellent team-building tool and, as such, should be initiated at one of the first team meetings. In the DMAIC process, this generally finds best use in the Define phase, where we create our charter and form the team. It is best to continue to update the GRPI checklist throughout the DMAIC process as the project unfolds and as the team develops

Histogram
A histogram is a basic graphing tool that displays the relative frequency or occurrence of data values-or which data values occur most and least frequently. A histogram illustrates the shape, centering, and spread of data distribution and indicates whether there are any outliers. The frequency of occurrence is displayed on the y-axis, where the height of each bar indicates the number of occurrences for that interval (or class) of data. Classes of data are displayed on the x-axis. The grouping of data into classes is the distinguishing feature of a histogram. In real life it is important to identify and control all sources of variation. Histograms allow us to visualize large quantities of data that would otherwise be difficult to interpret. They give us a way to quickly assess the distribution of our data and the variation that exists in our process. The shape of a histogram offers clues that can lead us to possible Xs. Histograms can be used throughout an improvement project. In the Measure phase, we can use histograms to begin to understand the statistical nature of the problem. In the Analyze phase, histograms can help us identify potential Xs that should be investigated further. They can also help eliminate potential Xs. In the Improve phase, one can use histograms to characterize and confirm the solution. In the Control phase, histograms give a visual reference to help track and maintain improvements.

Homogeneity of Variance
Homogeneity of variance is a test used to determine if the variances of two or more samples are different, or not homogeneous. While large differences in variance between a small number of samples are detectable with graphical tools, the homogeneity of variance test is a quick way to reliably detect small differences in variance between large numbers of samples. The main reason for using the homogeneity of variance test is: in 2-sample-t-test, basic assumption is that the variances of the different samples are equal. So, to gain additional test power, please verify if the variances of the two samples can be considered equal,

Hypothesis Testing
Since most of the data are variable, an observed change could be due to chance and may not be repeatable. Hypothesis testing determines if the change could be due to chance alone, or if there is strong evidence that the change is real and repeatable. First assume there is no change (Null Hypothesis, H_O). If the observed change is larger than the change expected by chance, then the data are inconsistent with the null hypothesis of no change. We then “reject” the null hypothesis of no change and accept the alternative hypothesis, H_A. If the means are equal and our decision is that they are equal, then we made the correct decision. If the means are not equal and our decision is that they are not equal, then we made the right decision. If the means are equal but our decision is that they are not equal, then we made a type 1 error. The probability of this error is alpha. If the means are not equal but our decision is that they are equal, then we made a Type 2 error. The probability of this error is beta.

I-MR chart
The I-MR chart helps determine if process is in control by seeing if special causes are present. Eliminating the influence of these factors will improve the performance of our process and bring process into control. The Measure phase focuses to separate common causes of variation from special causes. The Analyze and Improve phases ensure process stability before completing a hypothesis test. The Control phase can verify that the process remains in control after the sources of special cause variation have been removed

Kano Analysis
Kano analysis is a customer research method for classifying customer needs into four categories; it relies on a questionnaire filled out by or with the customer. It helps us understand the relationship between the fulfillment or non-fulfillment of a need and the satisfaction or dissatisfaction experienced by the customer.

The four categories are 1. Delighters, 2. Must Be, 3. One – dimensional's, & 4.Indifferent elements. There are two additional categories into which customer responses to the Kano survey can fall: they are reverse elements and questionable result. The categories in Kano analysis represent a point in time, and needs are constantly evolving. Often what is a delighter today can become simply a must-be over time. Kano analysis provides a systematic, data-based method for gaining deeper understanding of customer needs by classifying them. Use Kano analysis after a list of potential needs that have to be satisfied is generated. Kano analysis is useful when we need to collect data on customer needs and prioritize them to focus our efforts.

Kaizen

Kaizen is a customer-focused improvement strategy. In order to survive in the market and generate profits in the long run, an enterprise has to align itself to meet the customer needs. A continuous focus on the customer requirements will result in quality improvements, delivery reliability and cost reductions. Kaizen workshop bring outs: Voice of Business, Root Cause Analysis, Root Cause Evaluation, Development of Solutions, Definition of Actions and Responsibilities. The Kaizen One Pager is a vital tool within the programme. Kaizen is a continuous focused activity which guides quick solution implementation than a data analysis.

Matrix Plot

Tool used for high-level look at relationships between several parameters. Matrix plots are often a first step at determining which X's contribute most to our Y. Matrix plots can save time by allowing us to drill-down into data and determine which parameters best relate to our Y. We should use matrix plots early in our analyze phase.

Mistake Proofing

Mistake-proofing devices prevent defects by preventing errors or by predicting when errors could occur.

Mistake proofing is an important tool because it allows us to take a proactive approach to eliminating errors at their source before they become defects.

You should use mistake proofing in the Measure phase when we are developing our data collection plan, in the Improve phase when we are developing our proposed solution, and in the Control phase when developing the control plan. Mistake proofing is appropriate when there are :1. Process steps where human intervention is required2. Repetitive tasks where physical manipulation of objects is required 3. Steps where errors are known to occur 4. Opportunities for predictable errors to occur

Mote Carlo Analysis

Monte Carlo analysis is a decision-making and problem-solving tool used to evaluate a large number of possible scenarios of a process. Each scenario represents one possible set of values for each of the variables of the process and the calculation of those variables using the transfer function to produce an outcome Y. By repeating this method many times, we can develop a distribution for the overall process performance. Monte Carlo can be used in areas such as finance, commercial quality, engineering design, manufacturing, and process design and improvement. Monte Carlo can be used with any type of distribution; its value comes from the increased knowledge we gain in terms of variation of the output. Performing a Monte Carlo analysis is one way to understand the variation that naturally exists in our process. One of the ways to reduce defects is to decrease the output variation. Monte Carlo focuses on understanding what variations exist in the input Xs in order to reduce the variation in output Y.

Multiple Regression

This method enables to determine the relationship between a continuous process output (Y) and several factors (Xs). Understanding this relationship allows to: 1. Identify important Xs 2. Identify the amount of variation explained by the model 3. Reduce the number of Xs prior to design of experiment (DOE) 4.Predict Y based on combinations of X values 5.Identify possible nonlinear relationships such as a quadratic (X_1^2) or an interaction (X_1X_2). The output of a multiple regression analysis may demonstrate the need for designed experiments that establish a cause and effect relationship or identify ways to further improve the process. We can use multiple regression during the Analyze phase to help identify important Xs and during the Improve phase to define the optimized solution. Multiple regression can be used with both continuous and discrete Xs. If we have only discrete Xs, ANOVA-GLM is best. Typically you would use multiple regressions on existing data. If we need to collect new data, it may be more efficient to use a DOE.

Multi-vari chart

A multi-vari chart is a tool that graphically displays patterns of variation. It is used to identify possible Xs or families of variation, such as variation within a subgroup, between subgroups, or over time. A multi-vari chart enables us to see the effect multiple variables on a Y. It also helps us see variation within subgroups, between subgroups, and over time. By looking at the patterns of variation, we can identify or eliminate possible Xs

Normality Test

A normality test is a statistical process used to determine if a sample, or any group of data, fits a standard normal distribution. A normality test can be done mathematically or graphically. Many statistical tests (tests of means and tests of variances) assume that the data being tested is normally distributed. A normality test is used to determine if that assumption is valid. Check normality when the test we use requires or assumes normality, e.g., Process Report, Z calculations, t-test and ANOVA, etc.

Np chart

This chart allows us to view the actual number of defectives and detect the presence of special causes. The np chart is a tool that will help us determine if your process is in control by seeing if special causes are present. Use an np chart in the Control phase to verify that the process remains in control after the sources of special cause variation have been removed. The np chart is used for processes that generate discrete data. The np chart is used to graph the actual number of defectives in a sample. The sample size for the np chart is constant.

p chart

This graphical tool allows viewing the proportion of defectives and detects the presence of special causes. The p chart is used to understand the ratio of nonconforming units to the total number of units in a sample. The p chart is a tool that will help you determine if your process is in control by determining whether special causes are present. Usually p chart is used in the Control phase to verify that the process remains in control after the sources of special cause variation have been removed. The p chart is used for processes that generate discrete data.

Pareto Chart

A Pareto chart is a graphing tool that prioritizes a list of variables or factors based on impact or frequency of occurrence. This chart is based on the Pareto principle, which states that typically 80% of the defects in a process or product are caused by only 20% of the possible causes. It is easy to interpret, which makes it a convenient communication tool for use by individuals not familiar with the project. The Pareto chart will not detect small differences between categories; more advanced statistical tools are required in such cases.

Process Mapping

Process mapping is a tool that provides structure for defining a process in a simplified, visual manner by displaying the steps, events, and operations (in chronological order) that make up a process. As we examine our process in greater detail, our map will evolve from the process we "think" exists to what "actually" exists. Our process map will evolve again to reflect what "should" exist-the process after improvements are made. In the Define phase, we create a high-level process map to get an overview of the steps, events, and operations that make up the process. This will help us understand the process and verify the scope we defined in our charter. It is particularly important that our high-level map reflects the process as it actually is, since it serves as the basis for more detailed maps. In the Measure and Analyze phases, we create a detailed process map to help us identify problems in the process. In the Improve phase, we can use process mapping to develop solutions by creating maps of how the process "should be."

Pugh Matrix

This tool is used to facilitate a disciplined, team-based process for concept selection and generation. Several concepts are evaluated according to their strengths and weaknesses against a reference concept called the benchmark/datum. The datum is the best current concept at each iteration of the matrix. The Pugh matrix encourages comparison of several different concepts against a base concept, creating stronger concepts and eliminating weaker ones until an optimal concept finally is reached. It provides an objective process for reviewing, assessing, and enhancing design concepts the team has generated with reference to the project's CTQs. Because it employs agreed-upon criteria for assessing each concept, it becomes difficult for one team member to promote his or her own concept for irrational reasons. The Pugh matrix is the recommended method for selecting the most promising concepts in the Analyze phase of the DMADV process. It is used when the team already has developed several alternative concepts that potentially can meet the CTQs developed during the Measure phase and must choose the one or two concepts that will best meet the performance requirements for further development in the Design phase

Quality Function Deployment

QFD is a methodology that provides a flow-down process for CTQs from the highest to the lowest level i.e. measureable. The flow-down process begins with the results of the customer needs mapping (VOC) as input. From that point we cascade through a series of four Houses of Quality to arrive at the internal controllable factors. QFD is a prioritization tool used to show the relative importance of factors rather than as a transfer function. QFD drives a cross-functional discussion to define what is important. It provides a vehicle for asking how products/services will be measured and what the critical variables to control process are. The QFD process highlights trade-offs between conflicting properties and forces the team to consider each trade off in light of the customer's requirements for the product/service. Also, it points out areas for improvement by giving special attention to the most important customer wants and to have systematic flow down through the QFD process.

Risk Assessment

The risk-management process is a methodology used to identify risks, analyze risks, plan, communicate, and implement abatement actions, and track resolution of abatement actions. Any time we make a change in a process, there is potential for unforeseen failure or unintended consequences. Performing a risk assessment allows us to identify potential risks associated with planned process changes and develop abatement actions to minimize the probability of their occurrence. The risk-assessment process also determines the ownership and completion date for each abatement action.

Run chart
A run chart is a graphical tool that allows us to view the variation of our process over time. The patterns in the run chart can help identify the presence of special cause variation. The patterns in the run chart allow us to see if special causes are influencing the process. This will help us to identify Xs affecting the process run chart. This is used in many phases of the DMAIC process.

Scatter Plot
A basic graphic tool that illustrates the relationship between two variables. The variables may be a process output (Y) and a factor affecting it (X), two factors affecting a Y (two Xs), or two related process outputs (two Ys). This is useful in determining if trends exist between two or more sets of data. Scatter plots are used with continuous data and are especially useful in the Measure, Analyze, and Improve phases of DMAIC projects.

Simple Linear Regression
Simple linear regression is a method that enables us to determine the relationship between a continuous process output (Y) and one factor (X). The relationship is typically expressed in terms of a mathematical equation, such as Y = mX + c, where Y is the process output, c is a constant, m is a coefficient, and X is the process input or factor. We can use simple linear regression during the Analyze phase to help identify important Xs and during the Improve phase to define the settings needed to achieve the desired output.

Six Sigma Process Report
Calculates Z values for the specifications Z_{bench} ST and LT, Z_{shift}. When data are normally distributed, the LT numbers are valid; when the S chart is in control, the ST numbers are valid and so is the shift. It helps us compare the performance of our process or product to the performance standard and determine if technology or control is the problem, assuming that centering is not a problem.

Six Sigma Product Report
Calculates DPMO and short term process capability. It helps us compare the performance of our process or product to the performance standard and determine if technology or control is the problem, used with discrete data, helps us determine process capability for our project Y.

Standard Worksheet
This tool is used to show the sequence of operations the operator performs including auto and travel time. This tools is most typically used in Manufacturing Lean events

Takt Time Bar Chart
By measuring the Processing Time (Touch Time & Automatic time) for various Process Steps and comparing it to the Takt Time (Takt Time is the frequency at which each unit should be completed at each process step in order to meet customer demand), we can determine whether our process is capable of meeting customer demand. Processing Time is the total manual working time for one cycle of the process (Touch Time) plus Automatic run time. First, we typically compare the average Processing Times for various steps in the processes to the Takt Time in a Takt Time bar chart.

Testing Equality of Variances
The “F” test is used to compare the variances of two distributions. It tests the hypothesis, Ho, that the variances of two distributions are equal. It is performed by forming a ratio of two variances from two

samples and comparing the ratio with a value in the “F” distribution table. The “F” test can be used to demonstrate that the variance has been increased or decreased after a process change. Since “t” tests and “ANOVA” need to know if population variance is the same or different, this test is also a prerequisite for doing other types of hypothesis testing. In Minitab, this test is done as “Homogeneity of Variance”. The “F” test is also used during the ANOVA process to confirm or reject hypotheses about the equality of averages of several populations.

Tree Diagram

A tree diagram is a tool that is- used to break any concept (such as a goal, idea, objective, issue, or CTQ) into subcomponents, or lower levels of detail, -Useful in organizing information into logical categories. A tree diagram is helpful in 1.Relating a CTQ to sub process elements, 2.Determining the project Y 3.Selecting the appropriate Xs. 4.Determining task-level detail for a solution to be implemented.

u chart

An u chart, or proportional count chart, is a graphical tool that allows viewing the variation in process over time. A u chart lets you perform statistical tests that signal when a process may be going out of control. A process that is out of control has been affected by special causes as well as common causes. The chart can also show you where to look for sources of special cause variation. u is the number of defects divided by the number of units in subgroups distributed over time.

The u chart is used for processes that generate discrete data. The u chart monitors the number of defects per unit taken from a process.

Value Stream Map

All the actions, both value added and non value added, currently required to bring a product from raw materials to the customer. VSM gives Picture of material and information flow. It measures time and waste in a process, starts with the customer and works backwards, is a real-time snap shot of the process, it is a working document - Identifies opportunities for improvement and measures production lead time and processing time.

It focuses on- Material: Raw, WIP/Sub Assembly, Finished Goods; Information: What info is required to move material, What is the timing, Are the relationships 1:1; People: Standard Work, Takt Time; Equipment; Engineering: Quality, Tooling, Cutting tools, Programs; Value Added Activity: Any activity that changes the form, fit, or function of a product/transaction. All other actions and unwanted features are by definition—WASTE i.e. Over-production, Excess Inventory, Unnecessary Processing, Unnecessary Motion, Defects, Waiting, and Transportation & Conveyance

Voice of Customer

The following tools are commonly used to collect VOC data: Dashboard, Focus group, Interview, Scorecard, and Survey. These are tools used to develop specific CTQs and associated priorities.

Each VOC tool provides the team with an organized method for gathering information from customers. Without the use of structured tools, the data collected may be incomplete or biased. Key groups may be inadvertently omitted from the process, information may not be gathered to the required level of detail, or the VOC data collection effort may be biased because of your viewpoint. VOC tools can also be used whenever you need additional customer input such as ideas and suggestions for improvement or feedback on new solutions

Xbar-R chart

An Xbar-R chart, or mean and standard deviation chart, is a graphical tool that allows you to view the variation in your process over time. A process that is out of control has been affected by special causes as well as common causes. The X portion of the chart contains the mean of the subgroups distributed over time. The R portion of the chart represents the range of data points in a subgroup. Xbar-R charts can be used in many phases of the DMAIC process when you have continuous data broken into subgroups. Consider using an Xbar-R chart· in the Measure phase to separate common causes of variation from special causes,· in the Analyze and Improve phases to ensure process stability before completing a hypothesis test, or in the Control phase to verify that the process remains in control after the sources of special cause variation have been removed.

Xbar-S chart

An Xbar-S chart, or mean and standard deviation chart, is a graphical tool that allows viewing the variation in process over time. A process that is out of control has been affected by special causes as well as common causes. The X portion of the chart contains the mean of the subgroups distributed over time. The S portion of the chart represents the standard deviation of data points in a subgroup.

The Xbar-S chart is a tool to help determine if process is in control by seeing if special causes are present. An Xbar-S chart can be used in many phases of the DMAIC process when you have continuous data. Use the Xbar-R chart if the sample size is small.