Introduction to Six Sigma

Note: This report is a general introduction to Six Sigma intended for guidance purposes only.

1. What is Six Sigma?

1.1 Definition

Six Sigma is a statistically-based process improvement methodology that aims to reduce defects to a rate of 3.4 defects per million defect opportunities by identifying and eliminating causes of variation in business processes. In defining defects, Six Sigma focuses on developing a very clear understanding of customer requirements and is therefore very customer focused.

The Six Sigma methodology is based on a concept called DMAIC: Define, Measure, Analyze, Improve, and Control. For more on this, please see section 3 of this report on DMAIC. Six Sigma is not a quality management system, such as ISO-9001, or a quality certification system.

Instead it is a methodology for reducing defects based on process improvement. For many Vietnamese companies this means that instead of focusing quality initiatives primarily on checking products for defects, the focus is shifted towards improving the production process so that defects don't occur.

1.2 Key themes in Six Sigma

Some of the key themes of Six Sigma can be summarized as follows:

- Continuous focus on the customer's requirements;
- Using measurements and statistics to identify and measure variation in the production process;
- Identifying the root causes of problems;
- Emphasis on process improvement to remove variation from the production process and therefore lower defects;
- Pro-active management focusing on problem prevention, continuous improvement and constant striving for perfection;
- Cross-functional collaboration within the organization; and
- Setting very high targets.

1.3 Six Sigma levels

"Sigma" means standard deviation and therefore Six Sigma means six standard deviations.

Sigma Level	Defects per Million	Defects as Percent
One Sigma	690,000.0	69.0000%

Two Sigma	308,000.0	30.8000%
Three Sigma	66,800.0	6.6800%
Four Sigma	6,210.0	0.6210%
Five Sigma	230.0	0.0230%
Six Sigma	3.4	0.0003%

The objective of Six Sigma is only 3.4 defects (or errors) out of every million defect opportunities. This translates into 99.99966% perfection.

Since most private manufacturing companies in Vietnam are currently around Three Sigma, a process improvement project using Six Sigma principles may initially aim at Four Sigma or Five Sigma, which would nonetheless result in significant defect reduction.

An important clarification is that Six Sigma measures defect opportunities and not defective products.

The more complex a product, the more defect opportunities it has. For example, there are more defect opportunities in an automobile compared to a paper clip.

1.4 Focus on Causes of Variation

From the Six Sigma view, a business process is normally represented in terms of Y=f(X's), in which the

Outputs (Y) are determined by some Input variables (X's). If we suspect that there is a relationship between an outcome (Y) and potential causes (X's), we must collect and analyze data to prove our hypothesis. If we want to change the outcome, we need to focus on identifying and controlling the causes rather than checking the outcomes. When we know enough and have good control of the X's we can accurately predict Y. Otherwise, we have to focus our effort on Non Value-Added Activities like inspection, testing and reworking.

1.5 Measurements and Statistics

Building new measurement systems (metrics) and then asking new questions is an integral part of Six Sigma methodology. To improve results, a company needs to identify ways to measure variation in business processes, generate statistics based on those measurements and then use those statistics to ask new questions about the sources of quality problems relating to its products, services, and processes.

1.6 Six Sigma is not just about manufacturing

Although Six Sigma is most commonly used to reduce defects in the manufacturing process, the same methodology can be used to improve other business process. For example, it can be used to

- identify ways to increase production capacities of equipment;
- improve on-time-delivery;
- reduce cycle time for hiring and training new employees;
- improve sales forecasting ability;

- reduce quality or delivery problems with suppliers;
- improve logistics;
- improve quality of customer service; etc.

1.7 Worldwide use of Six Sigma

Six Sigma invented by Motorola in the 1986 and popularized by General Electric (GE) in the 1990's. Organizations including Honeywell, Citigroup, Motorola, Starwood Hotels, DuPont, Dow Chemical, American Standard, Kodak, Sony, IBM, Ford have implemented Six Sigma programs across diverse business operations ranging from highly industrial or high-tech manufacturing to service and financial operations. Although not yet widespread in Vietnam, several foreign invested companies such as American Standard and Samsung in Vietnam have introduced Six Sigma programs.

2. Benefits of Six Sigma

2.1 Reduced production costs

By significantly lowering defect rates, the company can eliminate wastage of materials and inefficient use of labour which is associated with defects. This will reduce the cost of goods sold for each unit of output and therefore add significantly to the company's gross margin or allow the company to sell its products at a lower price in order to generate higher revenues.

2.2 Reduced overhead costs

By significantly lowering defect rates, the company can reduce the amount of time that senior management and middle management spends resolving problems associated with high levels of defects. This also frees up management to focus on more value-added activities.

2.3 Improved Customer Satisfaction

Many private companies in Vietnam have had recurring problems associated with shipping products to customers which didn't meet customer specifications and therefore caused the customer to be unhappy and sometimes even cancel orders. By significantly lowering defect rates, the company will be able to consistently ship products to customers which strictly meet the customer's specifications and therefore increase customer satisfaction.

Increased customer satisfaction reduces the likelihood of losing orders from customers while increasing the likelihood that the customer will place larger orders with the company. This can mean significantly higher revenues for the company.

Furthermore, the cost of acquiring new customers is high so companies that have lower customer turnover will have lower sales and marketing expenses as a percent of total revenue.

2.4 Reduced Cycle Times

The longer it takes for inventory to move through the production process, the higher the production costs since slow moving inventory must be moved, stored, counted, retrieved and faces greater risk of becoming damaged or not meeting specifications. However, with Six Sigma, fewer problems arise during a manufacturing process, which means that the process can consistently be completed more quickly and therefore production costs, especially labour costs per unit produced, are lower. In addition to reducing production costs, quicker turnaround times are often a selling point for many customers who want the product delivered as soon as possible.

2.5 On-Time-Delivery

A common problem for many private Vietnamese manufacturing companies is a high rate of delayed shipments or deliveries to customers. The variations which can be eliminated in a Six Sigma project can include variations in delivery time. Therefore, Six Sigma can be used to help ensure consistent on-time-delivery.

2.6 Greater ease of expansion

A company with a significant emphasis on process improvement and elimination of the sources of defects will have a deep understanding of the potential causes of problems in expansion projects, as well as systems in place for measuring and identifying the sources of those problems. Therefore problems are less likely to occur as the company expands its production, and if they do occur, they are likely to be resolved more quickly.

2.7 Higher expectations

By aiming for 3.4 defects per million defect opportunities, it allows the company to set high expectations. Higher expectations themselves can lead to higher performance since they reduce the risk of complacency. Furthermore, Six Sigma programs introduce many new measurements which help to discover and monitor recurring problems and therefore create more of a sense of urgency to get those problems resolved.

2.8 Positive Changes to Corporate Culture

Six Sigma is as much about people excellence as it is about technical excellence. Employees often wonder how they are going to solve a difficult problem, but when they are given the tools to ask the right questions, measure the right things, correlate a problem with a solution and plan a course of action, they can find solutions to the problem more easily. Therefore, with Six Sigma, the company's corporate culture shifts to one that includes a methodical approach to problem solving and a pro-active attitude among employees. Successful Six Sigma programs also contribute to the overall sense of pride of the company's employees. Six Sigma transforms the way a company thinks and works on major business issues:

- **Process desig**n: Designing production processes to have the best and most consistent outcomes from the beginning.
- **Variable investigatio**n: conducting studies to identify what the variables cause variation and how they interact with each other.
- **Analysis and reasonin**g: using facts and data to find the root causes of variations, instead of educated guesses or intuition.
- **Focus on process improvemen**t: focusing on process improvement as key to excellence in quality.
- **Pro-activenes**s: Encouraging people to be pro-active about preventing potential problems instead of waiting for problems to occur.
- **Broad participation in problem solvin**g: getting more people involved in finding causes and

solutions for problems.

- **Knowledge sharing**: learning and sharing new knowledge in terms of best practices to speed up overall improvement.
- **Goal setting**: aiming at stretch goals, instead of “good enough” targets, so that the company is constantly striving for improvement.
- **Suppliers**: cost is not the only criteria for vendor evaluation, but relative capability to consistently provide quality materials with the shortest lead time.

3. DMAIC Roadmap

The DMAIC methodology is central to Six Sigma process improvement projects. The following phases provide a problem-solving process in which specific tools are employed to turn a practical problem into a statistical problem, generate a statistical solution and then convert that back into a practical solution.

3.1 Define (D)

The purpose of the Define phase is to clearly identify the problem, the requirements of the project and the objectives of the project. The objectives of the project should focus on critical issues which are aligned with the company’s business strategy and the customer’s requirements. The Define phase includes:

- define customer requirements as they relate to this project. Explicit customer requirements are called Critical-to-Quality (CTQ) characteristics;
- develop defect definitions as precisely as possible;
- perform a baseline study (a general measure of the level of performance before the improvement project commences);
- create a team charter and Champion;
- estimate the financial impact of the problem; and
- obtain senior management approval of the project

The applicable tools at this phase are the Project Charter, Trend Chart, Pareto Chart, and Process Flow Chart.

3.2 Measure (M)

The purpose of the Measure phase is to fully understand the current performance by identifying how to best measure current performance and to start measuring it. The measurements used should be useful and relevant to identifying and measuring the source of variation. This phase includes:

- identify the specific performance requirements of relevant Critical-to-Quality (CTQ) characteristics;
- map relevant processes with identified Inputs and Outputs so that at each process step, the relevant Outputs and all the potential Inputs (X) that might impact each Output are connected to each other;
- generate list of potential measurements
- analyze measurement system capability and establish process capability baseline;

- identify where errors in measurements can occur;
- start measuring the inputs, processes and outputs and collecting the data;
- validate that the problem exists based on the measurements;
- refine the problem or objective (from the Analysis phase)

The applicable tools at this phase include the Fishbone Diagram, Process Mapping, Cause & Effect Matrix, preliminary Failure Mode & Effect Analysis (FMEA), Gauge Repeatability & Reproducibility (GR&R), Statistical Process Control, and others.

3.3 Analyze (A)

In the Analyze phase, the measurements collected in the Measure phase are analyzed so that hypotheses about the root causes of variations in the measurements can be generated and the hypothesis subsequently validated. It is at this stage that practical business problems are turned into statistical problems and analyzed as statistical problems. This includes:

- generate hypotheses about possible root causes of variation and potential critical Inputs (X's);
- identify the vital few root causes and critical inputs that have the most significant impact; and
- validate these hypotheses by performing Multivariate analysis.

The Analyze phase offers specific statistical method and tools to isolate the key factors that are critical to explaining the number of defective products which include Five Why's, Tests for normality

(Descriptive Statistics, Histograms), Correlation/Regression Analysis, Main Effect Plot, Regression Plot, Analysis of Variances (ANOVA), and complete FMEA.

3.4 Improve (I)

The Improve phase focuses on developing ideas to remove root causes of variation, testing and standardizing those solutions. This involves:

- identify ways to remove causes of variation;
- verify critical Inputs;
- discover relationships between variables;
- establish operating tolerances which are the upper and lower specification limits (the engineering or customer requirement) of a process for judging acceptability of a particular characteristic, and if strictly followed will result in defect-free products or services;
- optimize critical Inputs or reconfigure the relevant process.

Applicable tools at this phase are Hypothesis testing (T-test, F-test), Process Capability Analysis (CPK), DOE (Design of Experiment), DFSS (Design for Six Sigma) and others.

3.5 Control (C)

The Control phase aims to establish standard measures to maintain performance and to correct problems as needed, including problems with the measurement system. This includes:

- validate measurement systems;
- verify process long-term capability;
- implement process control with control plan to ensure that the same problems don't reoccur by continually monitoring the processes that create the products or services.

Tools at the Control phase include: Control Plan Summary, Operating Flow Chart(s) with Control Points, SPC charts, Time Series Plots, Check Sheets and others.

4. Six Sigma vs. Other Quality Systems

Six Sigma builds upon many of the successful elements of the previous quality improvement strategies and incorporates unique methods of its own. Compared to other quality management and improvement systems, Six Sigma stands out as a methodology for identifying the causes of specific quality problems and solving those problems. Six Sigma can often be used to complement other quality management or improvement systems.

4.1 ISO 9001

4.1.1 ISO 9001 objectives

ISO 9001 is a Quality Management System, which includes specialized quality management standards for specific industries. A Quality Management System is a system of clearly defined organizational structures, processes, responsibilities and resources used to assure minimum standards of quality and can be used to evaluate an organizations overall quality management efforts. An ISO 9001 certification assures a company's customers that minimum acceptable systems and procedures are in place in the company to guarantee that minimum quality standards can be met.

4.1.2 Comparison with Six Sigma

ISO 9001 and Six Sigma serve two different purposes. ISO 9001 is a quality management system while Six Sigma is a strategy and methodology for business performance improvement.

ISO 9001, with guidelines for problem solving and decision making, requires a continuous improvement process in place but does not indicate what the process should look like while Six Sigma can provide the needed improvement process. Meanwhile, Six Sigma does not provide a template for evaluating an organization's overall quality management efforts whereas ISO9001 does.

4.1.3 Combining Six Sigma with ISO

Six Sigma provides a methodology for delivering certain objectives set by ISO such as:

- prevention of defects at all stages from design through servicing;
- statistical techniques required for establishing, controlling and verifying process capability and product characterization;
- investigation of the cause of defects relating to product, process and quality system;
- continuous improvement of the quality of products and services.

Six Sigma supports ISO and helps an organization satisfying the ISO requirements. Further, ISO is an excellent vehicle for documenting and maintaining the process management system involving Six Sigma. Besides, extensive training is required by both systems for successful deployment.

4.2 Total Quality Management (TQM)

4.2.1 TQM objectives

Total Quality Management (TQM) is a structured system for satisfying internal and external customers and suppliers by integrating the business environment, continuous improvement, and breakthroughs with development, improvement, and maintenance cycles while changing organizational culture. TQM aims for quality principles to be applied broadly throughout an organization or set of business processes.

4.2.2 Comparison with Six Sigma

TQM and Six Sigma have a number of similarities including the following:

- A customer orientation and focus
- A process view of work
- A continuous improvement mindset
- A goal of improving all aspects and functions of the organizations
- Data-based decision making
- Benefits depend highly on effective implementation

A key difference between TQM and Six Sigma is that Six Sigma focuses on prioritizing and solving specific problems which are selected based on the strategic priorities of the company and the problems which are causing the most defects whereas TQM employs a more broad based application of quality measures to all of the company's business processes.

Another difference is that TQM tends to apply quality initiatives within specific departments whereas Six Sigma is cross functional meaning that in penetrates every department which is involved in a particular business process that is subject to a Six Sigma project.

Another difference TQM provides less methodology in terms of the deployment process whereas Six Sigma's DMAIC framework provides a stronger platform for deployment and execution. For example, Six Sigma has a much stronger focus on measurement and statistics which helps the company define and achieve specific objectives.

4.2.3 Combining TQM with Six Sigma

Six Sigma is complementary to TQM because it can help to prioritize issues within a broader TQM program and provides the DMAIC framework which can be used to meet TQM objectives.

4.3 Six Sigma and Lean Manufacturing

4.3.1 Lean Manufacturing objectives

Lean Manufacturing aims to reduce the time from customer order to manufacturing and delivering products by eliminating non-value added activities and waste in the production stream. The ideal of a lean system is a one-piece flow which is driven by customer demand and a lean manufacturer is continuously improving in the direction of that ideal.

4.3.2 Comparison with Six Sigma

Both Six Sigma and Lean Manufacturing have unique strengths and they integrate well because they're both focus on improving results by improving processes.

A key focus of Lean is the elimination of waste of all types: excess floor space, inventories, raw materials, scrap, rework, cycle time, wasted capital, labor and time which are also often the subject of Six Sigma projects. Also, some of the Lean tools are used in Six Sigma projects when needed.

Lean tools are not statistical in nature and as a result not very effective in dealing with variation, but variation exists in all processes and must be addressed if the process is to be improved. Secondly, Lean methodology are mostly useful in manufacturing environments only while Six Sigma is a much more effective for creating a common languages and methodology usable across the whole organization.

4.3.3 Combining Lean Manufacturing with Six Sigma

It is quite common for companies to combine Lean Manufacturing with Six Sigma in what is sometimes called Lean Six Sigma.

Six Sigma provides a richer infrastructure and toolset for problem solving especially with unknown solutions. When the objective is process design, factory layout, waste reduction and the way to accomplish the objectives is known, Lean tools and approaches are recommended. Conversely, to improve problems with unknown solutions, Six Sigma is should be used. Since the overall improvement system will include both solution-known and solution-unknown projects, there is room for both Six Sigma and Lean in the system.

5. Six Sigma Implementation

5.1 Steps for building Six Sigma capacity within the organization

Discover: recognize the need for Six Sigma and explore its potential impact on the company.

Decide: senior management approves the Six Sigma initiative, and then defines the purpose and scope of Six Sigma.

Organize: establish financial targets; set time lines; train senior executive team and Deployment Champions who are responsible for planning and mechanism building.

Initialize: create detailed deployment plans including the numbers of Six Sigma Black Belts and other human resources needed per business unit, training requirements, proposals for Six Sigma project opportunities with estimated cost savings, project review agendas and formats, instructions and systems for individual project benefit tracking and overall expected Six Sigma financial impact versus the current situation.

Deploy: train project Champions and Black Belts. Meanwhile, select and execute improvement projects.

Sustain: train Six Sigma Green Belts and Process-Improvement Team Leaders to speed up improvements and maintain achievements.

5.2 Critical Success Factors

5.2.1 Senior Management Commitment

Implementation of Six Sigma represents a long term commitment. The success of Six Sigma projects depends substantially on the level of commitment by the senior management. General Electric's success with Six Sigma is due in large part to the role that Jack Welch (former CEO) played in relentlessly advocating Six Sigma and integrating it into the core of the company's strategy.

5.2.2 Initial Questions to ask before Adopting Six Sigma

- Does the company's leadership understand and completely behind implementing Six Sigma?
- Is the company open and ready to change?
- Is the company hungry to learn?
- Is the company willing to commit resources, including people and money, to implement this initiative?

5.2.3 Selecting and Training The Right People

It is necessary to attract the best people to be involved in the company's Six Sigma initiative and motivate them by compensation, rewards, recognition and promotion which are linked to performance.

Training programs should focus on statistical, analytical, problem-solving skills and leadership skills that help to remove barriers and create initial momentum.

Furthermore, getting people excited and motivated about the Six Sigma initiative should be done through training and communication. Everyone in the company should understand how Six Sigma will benefit themselves as well as the company.

5.2.4 Selecting Six Sigma projects

Primarily, Six Sigma projects should focus on key problem areas with strategic alignment in terms of high customer satisfaction impact and critical to business impact in terms of faster or larger financial return (higher revenues, lower cost, etc.).

5.2.5 Managing Six Sigma projects

During project execution, it is important to

- lead a focus effort in which the project Champion is responsible for conducting a project review, uses his authority to solve cross-functional problems and allocate needed resources.
- check for real financial impact (please refer to 5.2.6);
- continuously communicate progress to executive leadership and those involved in the projects.
- implement effective control plans including such documents as Process Maps, C&E Matrix, FMEA, Control Plan Summary and approved procedure changes to ensure that improvements are maintained.
- review the project's effectiveness at regularly scheduled intervals;
- roles and responsibilities of relevant parties should be clearly defined;
- conduct regular Six Sigma training to reinforce the initiative throughout the company.

5.2.6 Finance Department involvement

The finance department needs to be involved from the beginning of each project to ensure that cost savings are being tracked for each Six Sigma project and actually being reflected in the bottom line. Project baseline and claimed improvements must be strictly verified by finance team. Improvements are converted into dollar amount savings whenever possible and deducted if any cost arises due to the project.

5.3 Costs of Six Sigma Projects

Although Six Sigma projects can have many benefits and help the company to save money over the long run, there are also costs associated with Six Sigma projects. They typically include the following:

- **Direct Payroll** - Payroll expenses for individuals dedicated to the Six Sigma project on a full time basis.
- **Indirect Payroll** – The cost of time devoted by senior executives, team members, process owners and others in the implementation of the Six Sigma project.
- **Training and Consulting** – The cost of teaching people Six Sigma skills
- **Improvement Implementation Costs** – The costs of improving the production process to eliminate the sources of variation identified in the Six Sigma project. This might involve new equipment, new software, additional personnel costs for newly formed positions, etc.
- **Software** – Some software such as Minitab Inc.'s Minitab statistical software or Microsoft's Visio, for generating flow-charts, may also be required. More advanced software tools sometimes include Popkin's System Architect, Proforma's Provision or Corel's iGrafx Process 2003 for Six Sigma.

6. Definition of Terms

Analysis of Variances (ANOVA): A statistical test that allows for comparisons of multiple sources of variation, or effects, to determine if any of these sources significantly affect the variability of the outcome being studied.

Black Belt (BB): expert in leading project execution with relevant experience in one or more specific fields; extensive training and strong background in statistics and analysis. A BB will be certified after meeting qualifications specified by the company in term of significant cost savings achievement; effective application of tool and philosophy, analytical skills, project management and team building skills. BB is also responsible for training and coaching Green Belts.

Cause & Effect Matrix: A prioritization matrix or diagram that enables selection of those process input variables (X's) that have the greatest effect on the process output variables (Y's). The tool is also used to emphasize the importance of understanding the customer requirements.

Champion(s): selected senior executives and managers familiar with basic and advanced statistical tools, who allocate resources and remove barriers for Six Sigma projects; create the vision of Six Sigma for the company; develop training plan; select high impact projects; select potential people; construct and improve deployment mechanism; monitor SS project review; recognize people for their efforts and contribution.

Check Sheets: Forms or worksheets facilitating data collection and compilation. These are generally used to count different types of defects.

Control Plan Summary: a process control document that logically describes the system for controlling processes and maintaining improvements in order to ensure that the company consistently operates its processes such that products meet customer requirements all the times.

Correlation Analysis: A statistical method to identify if a relationship exists between the two variables by plotting paired values. To quantify the relationship, a regression line, which is characterized by its slope and intercept, can be drawn through the scatter-plot of the paired data points. The tighter the paired data points fit the line, the stronger the relationship.

Critical to Quality (CTQ): Explicit customer requirements (specifications) which if not met are considered defects.

Critical Inputs: The vital few factors proven to be primarily responsible for a specified outcome (Y).

Defect: Any failure of products or services to meet one of the acceptance criteria of the company's customers (internal or external). A defective unit may have one or more defects.

Defect Opportunity: Any situation in a process which presents a reasonable possibility of causing a defect on a unit of output which is important to the customer. A complex product such as a car has

many more defect opportunities than a simple product such as a paperclip.

Design for Six Sigma (DFSS): Describes the application of Six Sigma tools to product development and Process Design efforts with the goal of "designing in" Six Sigma performance capability. This can also apply to process redesign efforts at the Improve phase of a Six Sigma project.

Design of Experiment (DOE): An efficient method of experimentation which identifies, with minimum testing, those factors and their optimum settings that affect the mean and variation of the outputs.

DMAIC: Acronym for a Process Improvement/Management System which stands for Define, Measure, Analyze, Improve and Control.

Failure Mode & Effect Analysis (FMEA): A structured approach for preventing defects by documenting failure events, the way in which a process can fail, estimating the risk associated with specific causes, and prioritizing potential problems and their resolution.

Fishbone Diagram (cause & effect diagram): Also known as a "Fishbone" or "Ishikawa Diagram", a channeled brainstorming tool used for determining root-causes (the bones of the fish) for a specific effect, or problem.

Five Why's: A method used to move past symptoms and understand the true root cause of a problem. It is said that only by asking "Why?" five times, successively, you can delve into a problem deeply enough to understand the ultimate root cause.

Gauge Repeatability & Reproducibility (GR&R): A statistical tool that measures the amount of variation or error in the measurement system arising from the measurement device and the people taking the measurement.

Green Belt (GB): who current positions are associated with the problem to be solved while performing their regular duties, familiar with basic statistical tools and less intensive in training.

Hypothesis testing (T-test, F-test): The process of using a variety of statistical tools to analyze data and, ultimately, to accept or reject the null hypothesis. From a practical point of view, finding statistical evidence that the null hypothesis is false allows you to reject the null hypothesis and accept the alternate hypothesis. A null hypothesis (H0) is a stated assumption that there is no difference in parameters (mean, variance, defects per million defect opportunities) for two or more populations. The alternate hypothesis (Ha) is a statement that the observed difference or relationship between two populations is real and not the result of chance or an error in sampling.

ISO-9000: Standard and guideline used to certify organizations as competent in defining and adhering to documented processes. It is mostly associated with quality management systems, rather than quality improvement efforts.

Lean Manufacturing: A system of tools for reducing the time from customer order to manufacturing and delivering products by eliminating non-value added activities and waste in the production stream.

Lean Six Sigma: The combination of Lean Manufacturing with Six Sigma.

Main Effect Plot: A statistical study that samples the process as it operates, and through statistical and graphical analysis, identifies the important variables.

Mean: The average data point value within a data set. To calculate the mean, add all of the individual data points then divide that figure by the total number of data points.

Non-Value Added Activities: Steps/tasks in a process that do not add value to the external customer such as rework, handoffs, inspection/control, wait/delays, etc.

Non-Value Added Waste: By-products of the production process which are non-value added.

Operating Flow Chart(s) with Control Points: Similar to process flow chart but also highlighting critical areas where control measures are applied. This is a frequently updated document useful as a process control guideline.

Pareto Chart: A tool for establishing priorities based on the Pareto principle, also know as the 80/20 rule, which is that 20% of the causes result in 80% of the impact. For example, 20% of the causes of defect opportunities tend to cause 80% of the defect opportunities. The Pareto chart uses attribute data with columns arranged in descending order, with highest occurrences (highest bar) shown first. It uses a cumulative line to track percentages of each category/bar, which distinguishes the 20 percent of items causing 80 percent of the problem. The purpose of this is to prioritize which problems should be solved.

Process: A series of activities or steps that create a product or services.

Process capability: Ability of a process to produce a defect-free product or service in a controlled manner of production or service environment.

Process Capability Analysis: Analysis of the degree to which a process is or is not meeting customer requirements.

Process Flow Chart: Graphical display of the process flow that shows all activities, decision points, rework loops, and handoffs. This is different from Process Mapping.

Process improvement: Improvement approach focused on incremental changes/solutions to eliminate or reduce defects, costs or cycle time. It leaves basic design and assumptions of a process intact.

Process Mapping: A step-by-step pictorial sequence of a process showing various process inputs, process outputs and process steps which is a first step toward understanding how those inputs affect the output. This is different from a Process Flow Chart.

Project Description: Broad statement defining area of concern or opportunity including impact/benefit of potential improvements, or risk of not improving a process. It includes links to business strategies, the customer, and/or company values. It is provided by senior management to an improvement team and used to develop problem statement and Project Charter.

Project Charter: A document that clearly addresses a Six Sigma project scope, target(s), projected financial savings, project Champion, team involved and project timeline, etc.

Process redesign: method of restructuring process flow elements eliminating handoffs, rework loops, inspection points, and other non-value-added activities.

Quality management system (QMS): A system of clearly defined organizational structures, processes, responsibilities and resources used to assure minimum standards of quality. ISO9000 is a quality management system.

Regression Analysis: A statistical technique for estimating a model for the relationship among several variables. It gives us an equation that uses one or more variables to help explain the variation in another variable.

Regression Plot: A graphical display used to evaluate the relationship between two or more variables by determining an equation to estimate the interested outcome from knowledge of the input variables.

Sigma (□): The Greek letter used to represent standard deviation in statistics.

Six Sigma Level: The performance level with only 3.4 defects per million defect opportunities.

Six Sigma: A statistically-based process improvement methodology that aims to reduce defects to a rate of 3.4

defects per million defect opportunities by identifying and eliminating causes of variation in business processes.

Statistical Process Control (SPC): Use of data gathering and statistical analysis to monitor processes, identify performance issues, measure variation and capability, and distinguish between common and special cause. This serves as a basis for data-based decision-making for product or service quality maintenance or improvement.

Statistical Quality Control (SQC): See Statistical Process Control.

SPC charts: Charts which track Statistical Process Control data.

Tests for normality (Descriptive Statistics, Histograms): A statistical process used to determine if a sample or any group of data fits a standard normal distribution. Descriptive statistics and histogram tools graphically show the shape of a set of data - where it centres, and how far it spreads out on either side.

Time Series Plots: A graphical display often used in process variation studies in which observations (data points) are plotted to show the trend over time. The upper and lower control limits are also included to evaluate the process stability.

Total Quality Management (TQM): A structured system for satisfying internal and external customers and suppliers by integrating the business environment, continuous improvement, and breakthroughs with development, improvement, and maintenance cycles while changing organizational culture.

Trend Chart: A graphical display used to show trends in data over time. All processes vary, so single point measurements can be misleading. Displaying data over time increases understanding of the real performance of a process, particularly with regard to an established target or goal.

Variables: refers the input factors (X's) that causes variation of process output.

Variation: Change or fluctuation of a specific characteristic, which determines how stable or predictable the process may be; affected by environment, people, machinery/equipment, methods/procedures, measurements, and materials; Process Improvement aims to reduce or eliminate variation.