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IACPE No 19, Jalan Bilal Mahmood 80100 Johor Bahru Malaysia	**STATISTICAL PROCESS CONTROL** **CPE LEVEL II** **TRAINING MODULE**	

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3. **Encourage practicing engineers and management professionals to participate in a continuing program of personal and professional development**

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INTRODUCTION

Scope

This training module covers the basic elements of statistical process control and quality management in sufficient detail to allow an engineer to develop and implement a total quality management system.

The objective of quality engineering is to include quality in the design of products and processes and to identify potential quality problems prior to production. Quality control consists of making a series of inspections and measurements to determine whether quality standards are being met. If quality standards are not being met, corrective and/or preventive action can be taken to achieve and maintain conformance.

Statistical quality control (SQC) is the term used to describe the set of statistical tools used by quality professionals. The original techniques of statistical quality control (SQC) have been available for over three-quarters of a century; Shewhart's first book on control charts was written in 1924. There is now a vast academic literature on SPC and related subjects such as six-sigma.

Six-sigma is a disciplined approach for improving performance by focusing on producing better products and services faster and cheaper. Six-sigma delivers cost savings whilst retaining or even improving value to the customers. While statistic process control (SPC) is basically the use of statistical techniques to measure and analyze the variation in processes, and improve the quality of the process through variance reduction. Successful implementation of SPC depends on the approach to the work being structured. This applies to all organizations, whatever their size, technology or product/service range.

SPC tools and procedures are discussed in this guideline. In this section, there are tables that assist in making these SPC tools from the vary reference sources. All the important parameters use in the guideline are explained in the definition section which help the reader more understand the meaning of the parameters or the term used.

The theory section explained about SPC tools and procedures, quality management and acceptance samples procedure. The examples of application will make the engineer easier to study.

General Design Consideration

Six sigma was developed at Motorola in the 1980s as a method to measure and improve high-volume production processes. Its overall goal was to measure and eliminate waste by attempting to achieve near perfect results. The term *six sigma* refers to a statistical measure with no more than 3.4 defects per million. Numerous companies, including General Electric, Ford, and Chrysler, have credited six sigma with saving them billions of dollars.

Six-sigma is a disciplined approach for improving performance by focusing on producing better products and services faster and cheaper. The emphasis is on improving the capability of processes through rigorous data gathering, analysis and action, and:

- Enhancing value for the customer;
- Eliminating costs which add no value (waste).

Unlike simple cost-cutting programs six-sigma delivers cost savings whilst retaining or even improving value to the customers. Like all 'new management fads' six sigma has been hailed as the savior to generate real business performance improvement. It adds value to the good basic approaches to quality management by providing focus on business benefits and, as such, now deserves separate and special treatment in this guideline.

Proven quality principles and techniques.

Incorporating elements from the work of many quality pioneers, Six Sigma aims for virtually error free business performance. Sigma, s, is a letter in the Greek alphabet used by statisticians to measure the variability in any process. A company's performance is measured by the sigma level of their business processes. Traditionally companies accepted three or four sigma performance levels as the norm, despite the fact that these processes created between 6,200 and 67,000 problems per million opportunities.

The Six Sigma standard of 3.4 problems per million opportunities is a response to the increasing expectations of customers and the increased complexity of modern products and processes.

Six Sigma takes a handful of proven methods and trains a small cadre of in-house technical leaders, known as Six Sigma Black Belts, to a high level of proficiency in the application of these techniques. To be sure, some of the methods Black Belts use are highly advanced, including up-to-date computer technology. But the tools are applied within a simple performance improvement model known as Define-Measure-Analyze-Improve-Control, or DMAIC

D Define the scope and goals of the improvement project in terms of customer requirements and the process that delivers these requirements – inputs, outputs, controls and resources.

M Measure the current process performance – input, output and process – and calculate the short and longer-term process capability – the sigma value.

A Analyze the gap between the current and desired performance, prioritize problems and identify root causes of problems. Benchmarking the process outputs, products or services, against recognized benchmark standards of performance may also be carried out

I Generate the improvement solutions to fix the problems and prevent them from reoccurring so that the required financial and other performance goals are met

C This phase involves implementing the improved process in a way that 'holds the gains'. Standards of operation will be documented in systems such as ISO9000 and standards of performance will be established using techniques such as statistical process control (SPC).

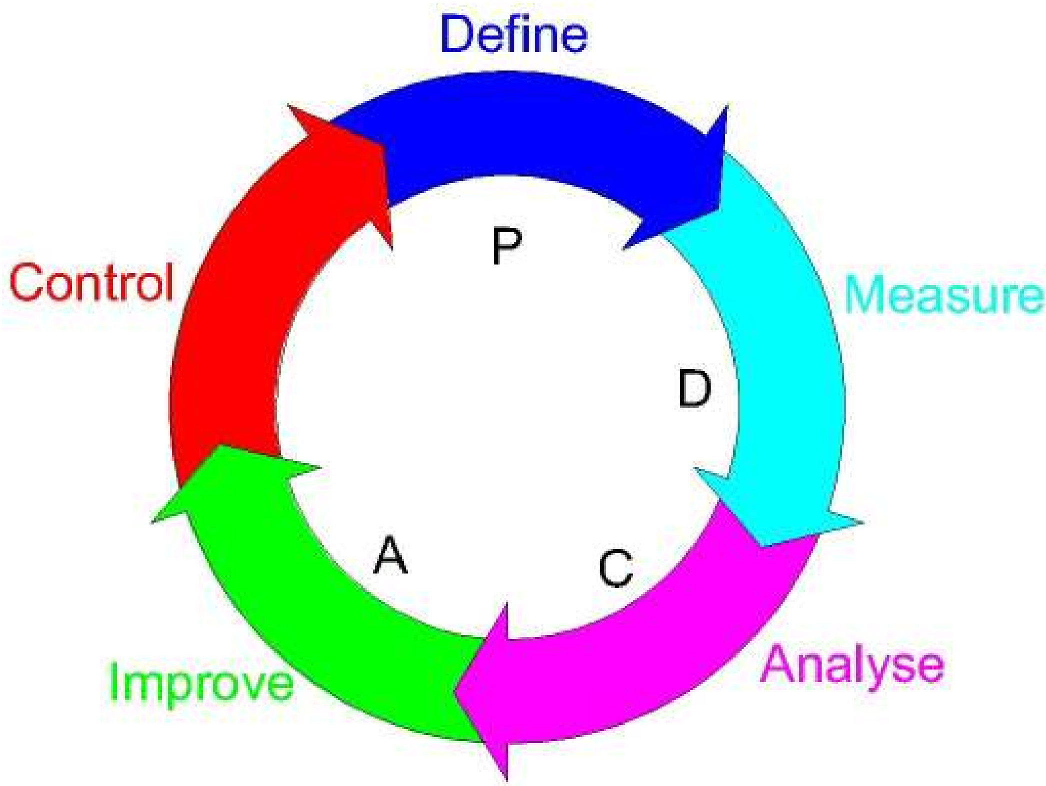


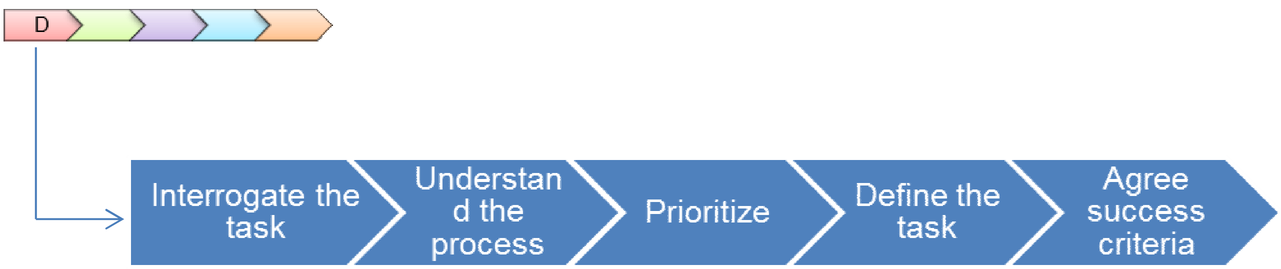
Figure 1: The six-sigma improvement model – DMAIC

The following is a brief description of the steps involved in the six sigma process:

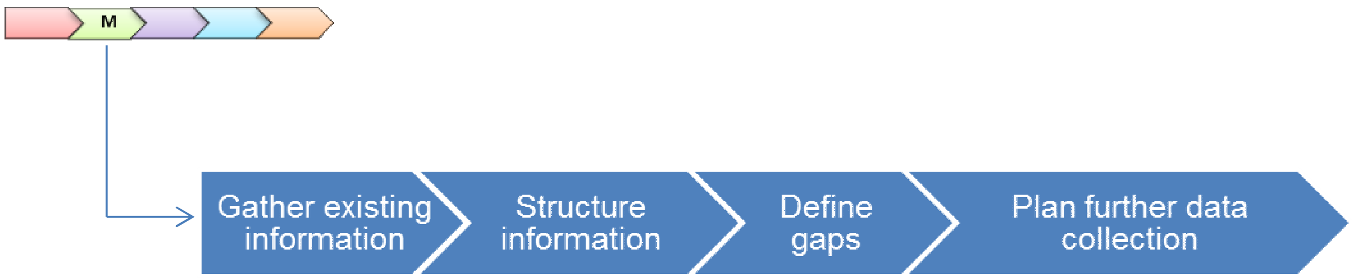
1. Break down business process flow into individual steps
2. Define what defects there are
3. Measure the number of defects
4. Probe for the root cause
5. Implement changes to improve
6. Re-measure
7. Take a long-term view of goals

Six Sigma is the application of the scientific method to the design and operation of management systems and business processes which enable employees to deliver the greatest value to customers and owners. The scientific method works as follows:

1. Observe some important aspect of the marketplace or your business.
2. Develop a tentative explanation, or hypothesis, consistent with your observations.
3. Based on your hypothesis, make predictions.
4. Test your predictions by conducting experiments or making further careful observations. Record your observations. Modify your hypothesis based on the new facts. If variation exists, use statistical tools to help you separate signal from noise.
5. Repeat steps 3 and 4 until there are no discrepancies between the hypothesis and the results from experiments or observations.



Interrogate the task	Understand the process	Prioritize	Define the task	Agree success criteria
What is the brief? Is it understood? Is there agreement with it? Is it sufficiently explicit? Is it achievable?	Which processes contain the problem? What is wrong at present? Brainstorm problem ideas Perhaps draw a rough flowchart to focus thinking	Set boundaries to the investigation Make use of ranking, Pareto, matrix analysis, etc., as appropriate Review and gain agreement in the team of what is do-able	Produce a written description of the process or problem area that can be confirmed with the team's main sponsor Confirm agreement in the team May generate clarification questions by the sponsor of the process.	List possible success criteria. How will the team know when it has been successful? Choose and agree success criteria in the team Agree timescales for the project Agree with sponsor Document the task definition, success criteria and time scale for the complete project



Locate sources
_ Verbal
_ Existing files
_ Charts
_ Records
_ Etc.

Go and collect, ask, investigate

Structure information – it may be available but not in the right format

Define gaps

Is enough information available?

What further information is needed?

What is affected?

Is it from one particular area?

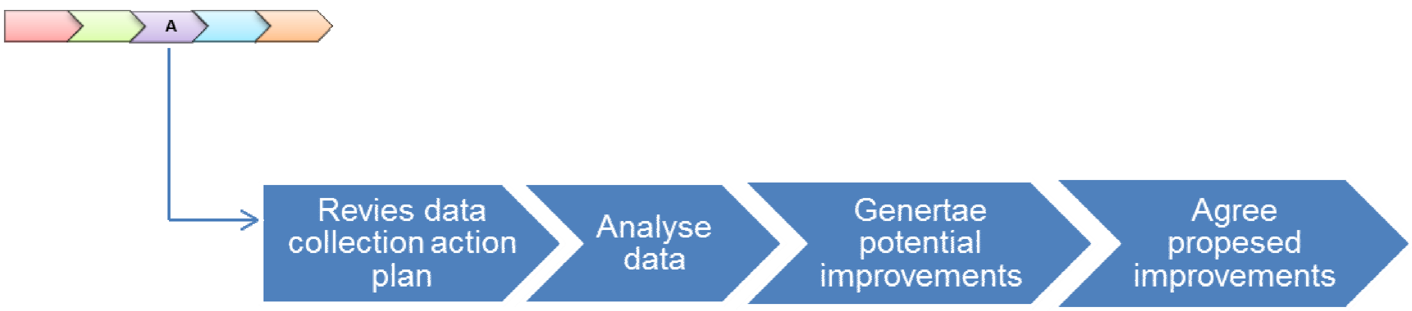
How is the service at fault?

If the answer to any of these questions is 'do not know' then:

Plan for further data collection

- Use data already being collected
- Draw up check sheet(s)
- Agree data collection tasks in the team – *who, what, how, when*
- Seek to involve others where appropriate
  Who actually has the information?
  Who really understands the process?

- NB this is a good opportunity to start to extend the team and involve others in preparation for the *execute* stage later on



Revies data collection action plan

Check at an early stage that the plan is satisfying the requirements

Analyse data

What picture is the data painting?

What conclusions can be drawn?

Use all appropriate problem solving tools to give a clearer picture of the process

Genertae potential improvements

Brainstorm improvements

Discuss all possible solutions

Write down all suggestions (have there been any from outside the team?)

Agree propesed improvements

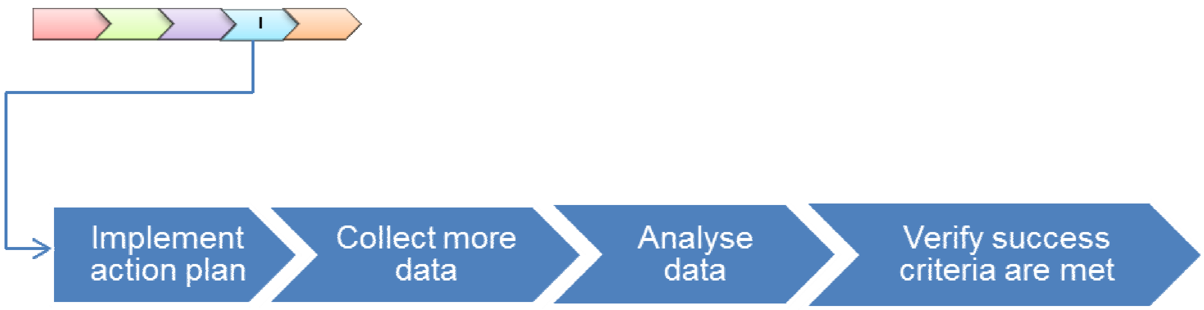
Prioritize possible improvements

Decide what is achievable in what timescales

Work out how to test proposed solution(s) or improvements

Design check sheets to collect all necessary data

Build a verification plan of action



Carry out the agreed tests on the proposals

Consider the use of questionnaires if appropriate

Make sure the check sheets are accumulating the data properly

Analyze using a mixture of tools, teamwork and professional judgement.

Focus on the facts, not opinion

Compare performance of new or changed process with success criteria from define stage

If not met, return to appropriate stage in DMAIC model

Continue until the success criteria are met. For difficult problems it may be necessary to go a number of times around this loop

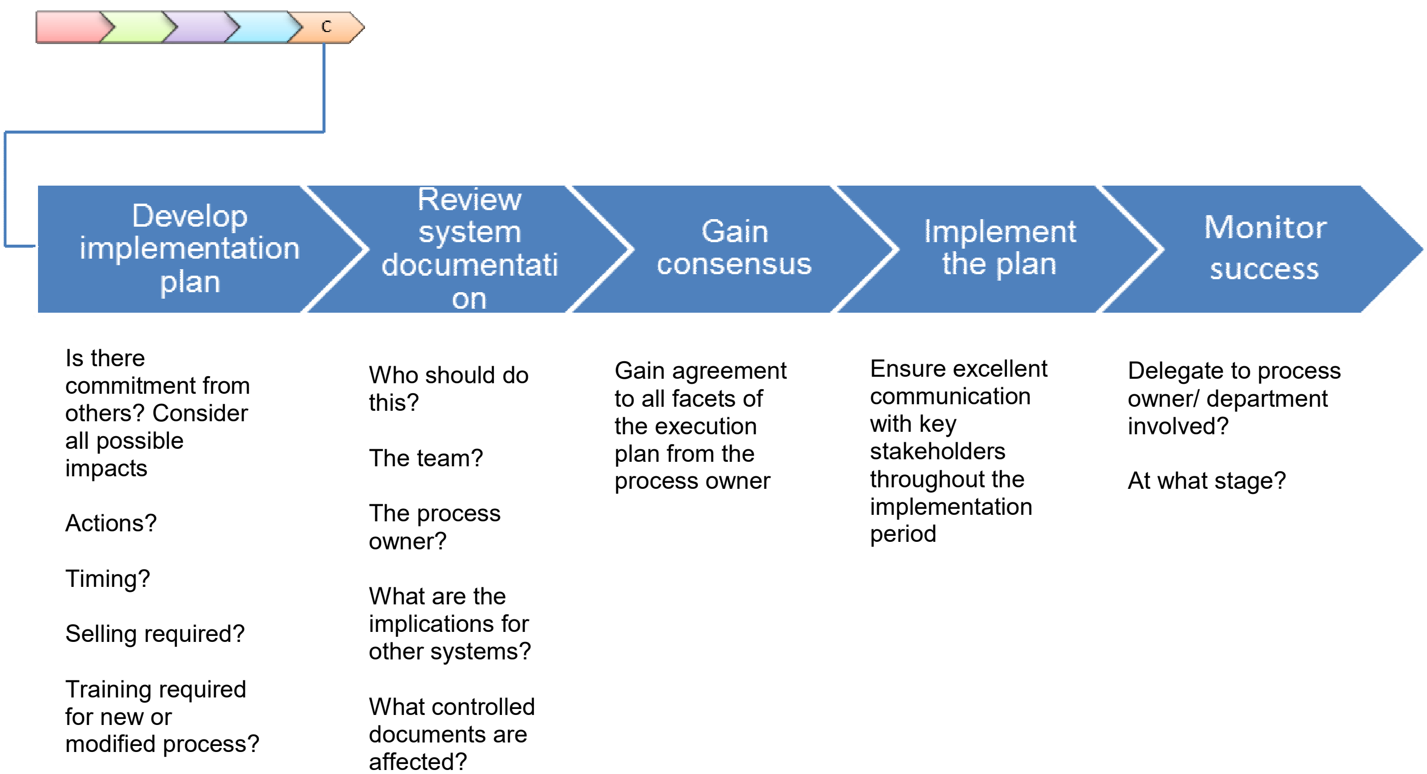


Figure 2: Explanation in DMAIC

Six-sigma approaches question many aspects of business, including its organization and the cultures created. Six-sigma organizations focus on:

- understanding their customers' requirements;
- identifying and focusing on core/critical processes that add value to customers;
- driving continuous improvement by involving all employees;
- being very responsive to change;
- basing management on factual data and appropriate metrics;
- obtaining outstanding results, both internally and externally.

The key is to identify and eliminate variation in processes. Every process can be viewed as a chain of independent events and, with each event subject to variation, variation accumulates in the finished product or service. Properly implemented six-sigma strategies involve:

- leadership involvement and sponsorship;
- whole organization training;
- project selection tools and analysis;
- improvement methods and tools for implementation;
- measurement of financial benefits;
- communication;
- control and sustained improvement.

One highly publicized aspect of the six-sigma movement is the establishment of process improvement experts, known variously as 'Master Black Belts', 'Black Belts' and 'Green Belts'. In addition to these martial arts related characters, who perform the training, lead teams and do the improvements, are other roles which the organization may consider, depending on the seriousness with which they adopt the six-sigma discipline.

These include the:

- Leadership Group or Council/Steering Committee
- Sponsors and/or Champions/Process Owners
- Implementation Leaders or Directors – often Master Black Belts
- Six-sigma Coaches – Master Black Belts or Black Belts
- Team Leaders or Project Leaders – Black Belts or Green Belts
- Team Members – usually Green Belts

The 'Black Belts' reflect the finely honed skill and discipline associated with the six-sigma approaches and techniques. The different levels of Green, Black and Master Black Belts recognize the depth of training and expertise.

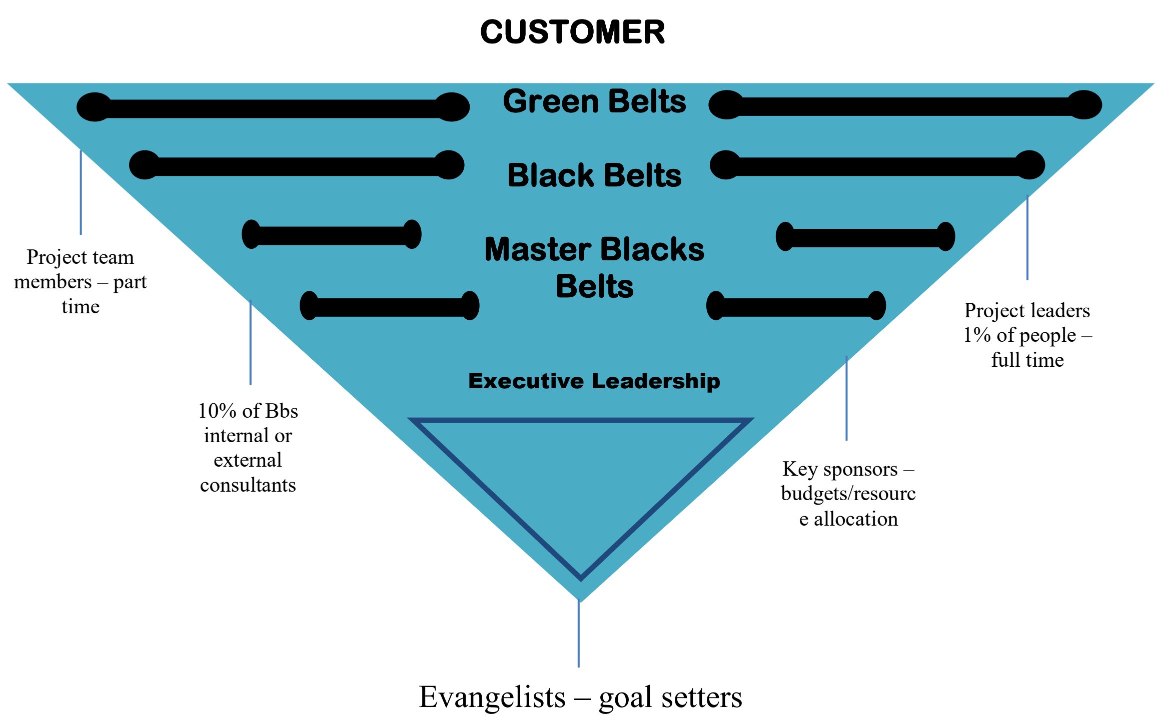


Figure 3: A six-sigma company

Leadership

Six Sigma involves changing major business value streams that cut across organizational barriers. It provides the means by which the organization's strategic goals are to be achieved. This effort cannot be lead by anyone other than the CEO, who is responsible for the performance of the organization as a whole. Six Sigma must be implemented from the top down. Six Sigma has zero chance of success when implemented without leadership from the top. This is because of the Six Sigma focus on cross-functional, even enterprise-wide processes. Six Sigma is not about local improvements, which are the only improvements possible when top-level support is lacking.

Champions and Sponsor

Six Sigma champions are high-level individuals who understand Six Sigma and are committed to its success. In larger organizations Six Sigma will be lead by a full-time, high-level champion, such as an Executive Vice President. In all organizations, champions also include informal leaders who use Six Sigma in their day-to-day work and communicate the Six Sigma message at every opportunity. Sponsors are owners of processes and systems who help initiate and coordinate Six Sigma improvement activities in their areas of responsibilities.

Black Belt

Candidates for Black Belt status are technically oriented individuals held in high regard by their peers. They should be actively involved in the process of organizational change and development. Candidates may come from a wide range of disciplines and need not be formally trained statisticians or analysts. However, because they are expected to master a wide variety of technical tools in a relatively short period of time, Black Belt candidates will probably possess a background in college-level mathematics, the basic tool of quantitative analysis. Successful candidates will be comfortable with computers.

At a minimum, they should be proficient with one or more operating systems, spreadsheets, database managers, presentation programs, and word processors. As part of their training they will also be required to become proficient in the use of one or more advanced statistical analysis software packages and probably simulation software. The important to the success of a Black Belt are the weights. Figure 4 show the success factors of Black Belt

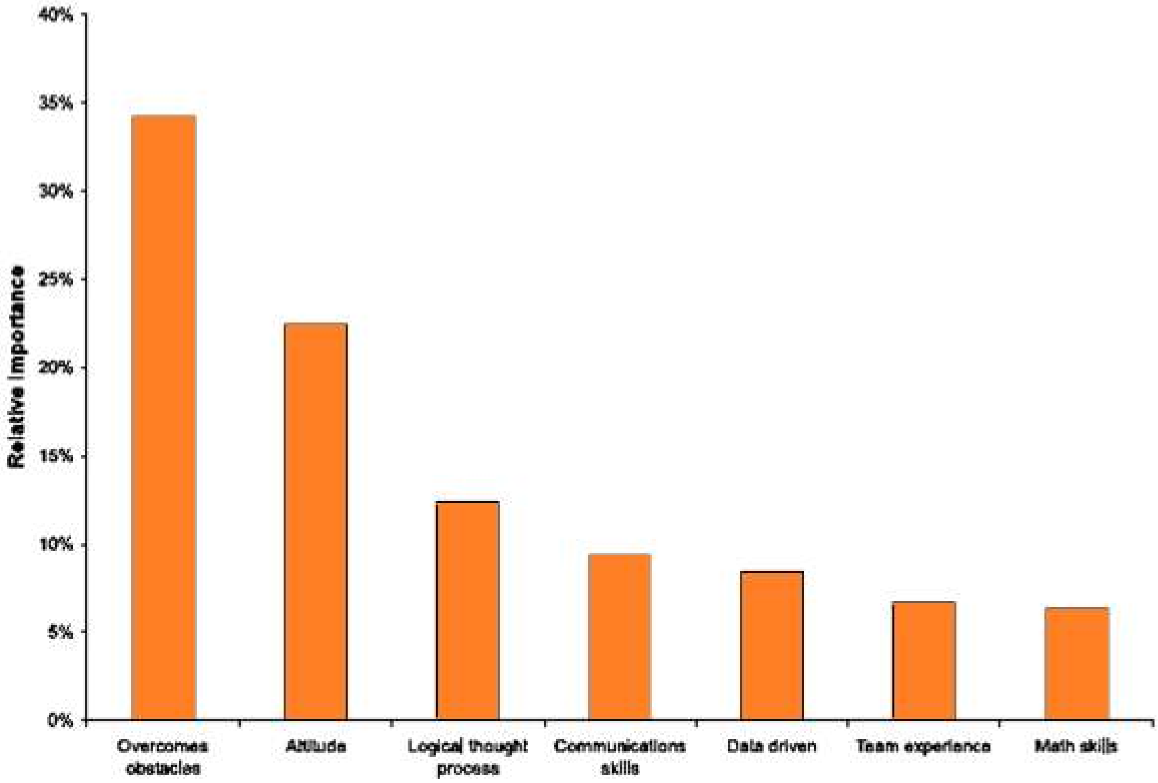


Figure 4: Black Belt success factors and importance weights

Black Belts will receive 200 hours of training, much of it focused on the practical application of statistical techniques using computer software. Software automates the analysis, making math skills less necessary. Black Belt will often have to rely on their own abilities to deal with the obstacles to change they will inevitably encounter. Failure to overcome the obstacle will often spell failure of the entire project.

Minimum criteria for Black Belt

Education : Bachelors Degree, minimum.

Work Experience : At least 3years of business, technical, or managerial experience plus technical application of education and experience as a member or leader of functional and cross-functional project teams.

Technical Capability: Project management experience is highly desired. Understanding of basic principles of process management. Basic college algebra proficiency as demonstrated by exam.

Computer Proficiency: MS Office Software Suite.

Communication : Demonstrate excellent oral and written communication skills.

Team Skills : Ability to conduct meetings, facilitate small groups and successfully resolve conflicts. Ability to mentor and motivate people.

Green Belt

Green Belts are change agents who work part time on process improvement. The bulk of the Green Belt's time is spent performing their normal work duties. A Green Belt will usually complete one or two major projects per year. Green Belts are Six Sigma project leaders capable of forming and facilitating Six Sigma teams and managing Six Sigma projects from concept to completion Green Belt training consists of five days of classroom training and is conducted in conjunction with Six Sigma projects. Training covers project management, quality management tools, quality control tools, problem solving, and descriptive data analysis. Six Sigma champions should attend Green Belt training. Usually, Six Sigma Black Belts help Green Belts define their projects prior to the training, attend training with their Green Belts, and assist them with their projects after the training.

Minimum criteria for Green Belt

Education : High school or equivalent.

Work Experience : At least 3years of business, technical, or managerial experience.

Technical Capability: High school algebra proficiency as demonstrated by a passing grade in an algebra course.

Computer Proficiency: Word processing, presentation and spreadsheet software.

Team Skills : Willingness to lead meetings, facilitate small groups and successfully resolve conflicts. Ability to mentor and motivate people.

Master Black Belt

This is the highest level of technical and organizational proficiency. Master Black Belts are recruited from the ranks of Black Belts. Master Black Belts provide technical leadership of the Six Sigma program. Thus, they must know everything the Black Belts knows, as well as additional skills vital to the success of the Six Sigma program. The additional skill might be deep understanding of the mathematical theory on which the statistical methods are based. Master Black Belts must be able to assist Black Belts in applying the methods correctly in unusual situations, especially advanced statistical methods. Whenever possible, statistical training should be conducted only by qualified Master Black Belts or equivalently skilled consultants. Because of the nature of the Master's duties, all Master Black Belts must possess excellent communication and teaching skills. Master Black Belt candidates usually make their interest known to Six Sigma leadership. Master Black Belts often have advanced technical degrees and extensive Black Belt experience.

Table 1: The list of roles and responsibilities for each belt

Responsible Entity	Roles	Responsibilities
Master Black Belt	Enterprise Six Sigma expert Permanent full-time change agent Certified Black Belt with additional specialized skills or experience especially useful in deployment of Six Sigma across the enterprise	• Highly proficient in using Six Sigma methodology to achieve tangible business results • Technical expert beyond Black Belt level on one or more aspects of process improvement (e.g., advanced statistical analysis, project management, communications, program administration, teaching, project coaching) • Identifies high-leverage opportunities for applying the Six Sigma approach across the enterprise • Basic Black Belt training • Green Belt training • Coach/Mentor Black Belts • Participates on Six Sigma Certification Board to certify Black Belts and Green Belts
Black Belt	Six Sigma technical expert Temporary, full-time change agent (will return to other duties after completing a two to three year tour of duty as a Black Belt)	• Leads business process improvement projects where Six Sigma approach is indicated • Successfully completes high-impact projects that result in tangible benefits to the enterprise • Demonstrated mastery of Black Belt body of knowledge • Demonstrated proficiency at achieving results through the application of the Six Sigma approach • Internal Process Improvement Consultant for functional areas • Coach/Mentor Green Belts • Recommends Green Belts for Certification

Responsible Entity	Roles	Responsibilities
Green Belt	Six Sigma project originator Six Sigma project leader Part-time Six Sigma change agent. Continues to perform normal duties while participating on Six Sigma project teams Six Sigma champion in local area	• Demonstrated mastery of Green Belt body of knowledge • Demonstrated proficiency at achieving results through the application of the Six Sigma approach • Recommends Six Sigma projects • Participates on Six Sigma project teams • Leads Six Sigma teams in local improvement projects • Works closely with other continuous improvement leaders to apply formal data analysis approaches to projects • Teaches local teams, shares knowledge of Six Sigma • Successful completion of at least one Six Sigma project every 12 months to maintain their Green Belt certification
Leaders	Champions for Six Sigma	• Ensures flow-down and follow-through • on goals and strategies within their organizations • Plans improvement projects • Charters or champions chartering process • Identifies teams or individuals required to facilitate Six Sigma deployment • Integrates Six Sigma with performance appraisal process by identifying measurable Six Sigma goals/objectives/results • Identifies, sponsors and directs Six Sigma projects • Holds regular project reviews in accordance with project charters • Includes Six Sigma requirements in expense and capital budgets • Identifies and removes organizational and

Responsible Entity	Roles	Responsibilities
		cultural barriers to Six Sigma success • Rewards and recognizes team and • individual accomplishments (formally • and informally) • Communicates leadership vision • Monitors and reports Six Sigma progress • Validates Six Sigma project results • Nominates highly qualified Black Belt and/or Green Belt candidates
Sponsor	Charter and support Six Sigma project teams	• Sponsor is ultimately responsible for the success of sponsored projects • Actively participates in projects • Assures adequate resources are provided for project • Personal review of progress • Identifies and overcomes barriers and issues • Evaluates and accepts deliverable

Statistical Process / Quality Control (SPC) / (SQC)

Statistical quality control (SQC) is the term used to describe the set of statistical tools used by quality professionals. The original techniques of statistical quality control (SQC) have been available for over three-quarters of a century; Shewhart's first book on control charts was written in 1924. There is now a vast academic literature on SPC and related subjects such as six-sigma.

Where Statistical process control (SPC) is properly in use it has been shown that quality-related costs are usually known and low, and that often the use of SPC was specified by a customer, at least initially. Companies using the techniques frequently require their suppliers to use them and generally find SPC to be of considerable benefit.

Where there is low usage of Statistical process control (SPC) the major reason found is lack of knowledge of variation and its importance, particularly amongst senior managers. Although they sometimes recognize quality as being an important part of corporate strategy, they do not appear to know what effective steps to take in order to carry out the strategy. Even now in some organizations, quality is seen as an abstract property and not as a measurable and controllable parameter.

Statistical quality control can be divided into three broad categories:

1. Descriptive statistics are used to describe quality characteristics and relationships. Included are statistics such as the mean, standard deviation, the range, and a measure of the distribution of data.
2. Statistical process control (SPC) involves inspecting a random sample of the output from a process and deciding whether the process is producing products with characteristics that fall within a predetermined range. SPC answers the question of whether the process is functioning properly or not.
3. Acceptance sampling is the process of randomly inspecting a sample of goods and deciding whether to accept the entire lot based on the results. Acceptance sampling determines whether a batch of goods should be accepted or rejected

The tools in each of these categories provide different types of information for use in analyzing quality. All three of these statistical quality control categories are helpful in measuring and evaluating the quality of products or services. However, statistical process control (SPC) tools are used most frequently because they identify quality problems during the production process

In-depth work in organizations which use SPC successfully has given clear evidence that customer-driven management systems push suppliers towards the use of process capability assessments and process control charts. The most commonly occurring influence contributing to the use of SPC was exerted by an enthusiastic member of the management team. Other themes which recur in successful user organizations are:

- Top management understood variation and the importance of SPC techniques to successful performance improvement.
- All the people involved in the use of the techniques understood what they were being asked to do and why it should help them.
- Training, followed by clear and written instructions on the agreed procedures, was systematically introduced and followed up.

In 1974 Dr. Kaoru Ishikawa brought together a collection of process improvement tools in his text *Guide to Quality Control*. Known around the world as the seven quality control (7–QC) tools, they are:

- Cause–and–effect analysis
- Check sheets/tally sheets
- Control charts
- Graphs
- Histograms
- Pareto analysis
- Scatter analysis

In addition to the basic 7–QC tools, there are also some additional tools known as the seven supplemental (7–SUPP) tools:

- Data stratification
- Defect maps
- Events logs
- Process flowcharts/maps
- Progress centers
- Randomization
- Sample size determination

Statistical quality control (SQC) is the application of the 14 statistical and analytical tools (7–QC and 7–SUPP) to monitor process *outputs* (dependent variables). Statistical process control (SPC) is the application of the same 14 tools to control process *inputs* (independent variables). The figure below portrays these relationships (ReVelle, 2004)

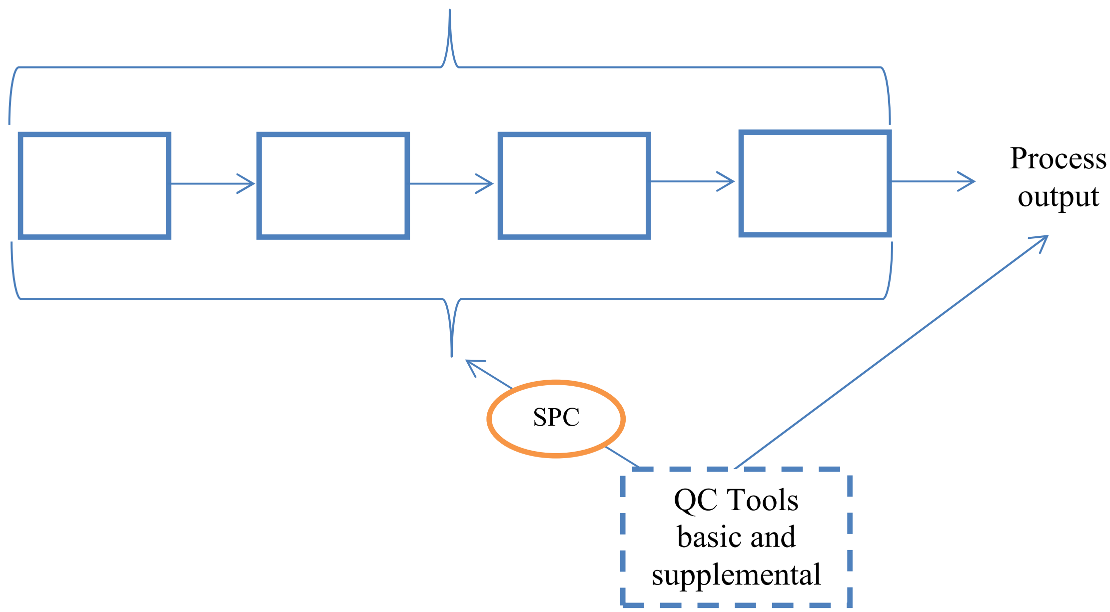


Figure 5: SQC versus SPC

Successful implementation of SPC depends on the approach to the work being structured. This applies to all organizations, whatever their size, technology or product/service range. Unsuccessful SPC implementation programs usually show weaknesses within either the structure of the project or commitment to it.

What purpose does a quality management system serve?

- Establishes a vision for the employees
- Sets standards for employees
- Build motivation within the company
- Sets goals for employees
- Helps fight the resistance to change within organizations
- Helps direct the corporate culture

Why is quality important, because business success may simply be the extent to which your organization can produce a higher-quality product or service than your competitors are able to do at a competitive price? When quality is the key to a company's success, quality management systems allow organizations to keep up with and meet current quality levels, meet the consumer's requirement for quality, retain employees through competitive compensation programs, and keep up with the latest technology.

Elements of a quality system

There are several elements to a quality system, and each organization is going to have a unique system. The most important elements of a quality system include participative management, quality system design, customers, purchasing, education and training, statistics, auditing, and technology.

- Participative Management
  The entire quality process, once started, will be an ongoing dynamic part of the organization, just like any other department such as marketing or accounting. It will also need the continuous focus of management of a successful quality system involves many different aspects that must be addressed on a continuous basis.

- Vision and Values
  The starting point for the management and leadership process is the formation of a well-defined vision and value statement. This statement will be used to establish the importance of the quality system and build motivation for the changes that need to take place, whether the organization plans to exceed customer expectations, commit to a defined level of customer satisfaction, or commit to zero defects.

- Developing the Plan

  The plan for the quality system is going to be different for every organization, but there are similar characteristics:
  - There should be clear and measurable goals
  - There are financial resources available for quality
  - The quality plan is consistent with the organization's vision and values.

DEFINITIONS

Accuracy - Accuracy of measurements refers to the closeness of agreement between observed values and a known reference standard. Any offset from the known standard is called bias.

Attribute data - Qualitative data that can be counted for recording and analysis. Examples include: number of defects, number of errors in a document; number of rejected items in a sample, presence of paint flaws. Attributes data are analyzed using the p-, np-, c- and u-charts.

Plot - A graphical display of data that shows the median and upper and lower quartiles, along with extreme points and any outliers.

Capability - The amount of variation inherent in a stable process. Capability can be determined using data from control charts and histograms and is often quantified using the Cp and Cpk indices.

Cause-and-Effect Diagram - A quality control tool used to analyze potential causes of problems in a product or process. It is also called a fishbone diagram or an Ishikawa diagram after its developer.

Center Line (CL) - The line on the control chart that represents the long-run expected or average value of the quality characteristic that corresponds to the in-control state which occurs when only chance causes are present.

Common Causes - Problems with the system itself that are always present, influencing all of the production until found and removed. These are “common” to all manufacturing or production output. Also called chance causes, system causes or chronic problems. Common causes contrast to **special causes**.

Continuous Improvement - The ongoing improvement of products, services, or processes through incremental and breakthrough improvements.

Control Chart - A graphical mechanism for deciding whether the underlying process has changed based on sample data from the process. Control charts help determine which causes are “special” and thus should be investigated for possible correction. Control charts contain the plotted values of some statistical measure for a series of samples or subgroups, along with the upper and lower control limits for the process.

Control Limits - Statistically calculated control chart lines which indicate how the process is behaving and whether the process is in control. There is typically an upper control limit (UCL) and a lower control limit (LCL). If the process is in control and only common causes are present, nearly all of the sample
points fall within the control limits. Sometimes called the Natural Process Limits for the sample size.

CUSUM - A control chart designed to detect small process shifts by looking at the Cumulative SUMs of the deviations of successive samples from a target value.

Design of Experiments - A branch of applied statistics dealing with planning, conducting, analyzing, and interpreting controlled tests which are used to identify and evaluate the factors that control a value of a parameter of interest.

Histogram - A graph of the observed frequencies versus each value or range of values for a set of data. A histogram provides a graphical summary of the variation in the data.

In-Control Process - A process in which the quality characteristic being evaluated is in a state of statistical control. This means that the variation among the observed samples can all be attributed to common causes, and that no special causes are influencing the process.

Over control - An element often introduced into a process by a well-meaning operator or controller who considers any appreciable deviation from the target value as a special cause. In this case, the operator is wrongly viewing common cause variation as a fault in the process. Over control of a process can actually increase the variability of the process and is viewed as a form of tampering.

Pareto Chart - A problem-solving tool that involves ranking all potential problem areas or sources of variation according to their contribution to cost or total variation. Typically, 80% of the effects come from 20% of the possible causes, so efforts are best spent on these “vital few” causes, temporarily ignoring the “trivial many” causes.

Process Capability - A measure of the ability of a process to produce output that meets the process specifications

Runs Chart - A simple graphic representation of a characteristic of a process which shows plotted values of some statistic gathered from the process. The graphic can be analyzed for trends or other unusual patterns.

Scatter Plots - A graphical technique used to visually analyze the relationship between two variables. Two sets of data are plotted on a graph, with the y-axis being used for the variable to be predicted and the x-axis being used for the variable to make the prediction.

Six Sigma - A high-performance, data-driven approach to analyzing the root causes of business problems and solving them. Six-sigma techniques were championed by Motorola.

Special Causes - Causes of variation which arise periodically in a somewhat unpredictable fashion. Also called assignable causes, local faults, or sporadic problems. Contrast to common causes. The presence of special causes indicates an out-of-control process

Standard Deviation - A measure of the spread of a set of data from its mean, abbreviated: σ for a population
s for a sample The standard deviation is the square root of the variance

Statistic - A value calculated from or based on sample data which is used to make inferences about the population from which the sample came. Sample mean, median, range, variance and standard deviation are commonly calculated statistics.

Statistical Control - The condition describing a process from which all special causes of variation have been removed and only common causes remain.

Statistical Process Control (SPC) - A collection of problem solving tools useful in achieving process stability and improving capability through the reduction of variability. SPC includes using control charts to analyze a process to identify appropriate actions that can be taken to achieve and maintain a state of statistical control and to improve the capability of the process.

Statistical Quality Control (SQC) - Another name commonly used to describe statistical process control techniques.

Stratified Sampling - Stratification arises in practice when samples are collected by drawing from each of several processes, for example machines, filling heads or spindles. Stratified sampling can increase the variability of the sample data and make the resulting control chart less sensitive to changes in the process.

Variables Data - Data values which are measurements of some quality or characteristic of the process. The data values are used to construct the control charts. This qualitative data is used for the x-bar, R-, s- and individuals charts, as well as the CUSUM and moving range charts.

NOMENCLATURE

A_2	factor obtained from Table…
$\overline{R}$	average range of the samples
$\overline{x}$	the mean
xi	observation i, i _ 1, . . . , n
$\overline{\overline{x}}$	the average of the sample means
n	number of observations
z	standard normal variable

Greek Letters

σ	standard deviation of a sample
$\sigma_{\overline{x}}$	standard deviation of the distribution of sample means
σ	population (process) standard deviation

Superscript

LCL	Lower Control Limit
UCL	Upper Control Limit
CL	Center line