Chapter – 1

Introduction
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1.1 Introduction

Statistics and statisticians can throw more light on an issue than a committee of experts for making decisions on real life problems.

Professor C. Radhakrishna Rao comments that whenever statistical methods are used in designing a product, production has increased usually in the range of 10 percent to 100 percent without further investments.

Statistical quality control is a technological invention, which so wide in application, yet so simple in theory, which is effective in its results, yet so easy to adopt and requires less investment.

It has played a major role in an era where the world is rapidly getting integrated and issues of a global nature are becoming increasingly more important.

Now a days, the statistical quality control system has generated data which are necessary to undertake analysis and facilitate policy decisions in a multilateral frame work.
In statistical quality control, six sigma is a business philosophy and initiative to achieve world class quality in every aspect of business. The principle is to effect continuous improvements to achieve highest level of customer satisfaction.

Total quality management impresses the management by fact, attempts people based management and aims at continuous improvement.

Quality is a combination of various factors reliability, durability, serviceability, aesthetics, features and conformance to standards and specification.

When a production process is executed repeatedly, its output is seldom identical. For example when a gun is successively fired at a target, all bullets will not pass through the same hole. The lack of uniformity of repeatability is caused by the variation or variability in the process. If those causes are understood, then this can lead to the development of solutions to reduce the variation in the process. This will facilitate more consistent products which require less inspection, less testing, less rejection and failure, less cost to build and have more satisfied customers. Statistical process of the technological control chart is a powerful collection of problem solving tools useful in achieving
process stability and improving capability through the reduction of variability. The major technological tools are:

- Histogram
- Check Sheet
- Pareto chart
- Cause and effect diagram
- Defect concentration diagram
- Scatter diagram
- Control chart

Of these seven tools, the control chart is the most vibrant and technically sophisticated tool. It has been developed by Dr Walter A. Shewhart (1926) of Bell Telephone Laboratories.

1.2 Origin of statistical quality control

Quality assurance and quality improvement have always an integral part all products and services. In terms of manufacturing and cost principles, a major area of concern for any product is related to quality and quality enhancement. Control charts, which are effective tools to monitor finished product and process quality characteristics, were initially developed by Shewhart. Since then, several types of control charts have been developed for different applications.
1.3 Statistical process control

Statistical process control is the application of statistical techniques to determine, if the outputs of a process conform to target product or service models. Concept of control charts demonstrates how to analyze control chart data so that quality technicians and other professionals can judge whether a process has changed, and by how much. They will also be able to associate patterns on a chart with specific influences that are affecting a process to decide whether they want to address those influences.

A statistical tool used to distinguish between process variation resulting from common causes and variation resulting from special cause

Statistical process control (SPC) is the collection of method that uses statistical techniques to measure, interpret and ultimately control product quality. SPC is directed towards the recognizing special causes and bringing a process into a state of control and reducing variation about a target value. Hence the control charts enhance both quality and productivity in a production process. Many approaches have been suggested to improve the performance of the control charts proposed by Shewhart, Cumulative Sum (CUSUM) charts, Exponentially Weighted Moving Average (EWMA) charts, Adaptive control charts and Fuzzy control charts etc.
SPC applications involve three major tasks in sequence:

- Monitoring the process
- Diagnosing the deviated process
- Taking corrective action

1.4 Quality control charts

One of the most important actions that can help to maintain the quality of any goods or service is to collect relevant data consistently over a period of time, plot it, and examine the plots carefully. All statistical process control charts plot data (or statistical measured calculated from data) verses times, with control limits designed to alert the analyst to events beyond normal sampling variability.

1.5 Characteristics of control charts

Shewhart has defined chance and assignable causes as the two sources of quality variation. A process that is operating with only chance cause of variation is said to be in statistical control. A process that is operating with assignable cause of variation is said to be out of control. The underlying concept of Shewhart chart is to construct its limits based on variation allowable as it is in – control state and monitor the quality of the product produced. If variation attributable to assignable causes occur, product quality quickly exceed the control limits and assignable causes can be investigated and corrective action be undertaken. The Average
Run Length (ARL) of the Shewhart chart when the process is in control is

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ARL = \frac{1}{\alpha} = \frac{1}{0.0027} = 370
\]

where \( \alpha = P[|X - \mu| > 3\sigma] = 0.0027 \), is the probability that a single point falls outside the limits when the process is in control.

When the quality related characteristics, such as appearance, softness, colour, etc., cannot be represented in numerical values. Product units are classified as either conforming or nonconforming; depending upon whether or not they meet specification. The number of nonconformities can be counted. The control charts constructed for attribute data are called attribute control charts.

If a single quality characteristic has been measured or computed from a sample, the control chart shows the value of the quality characteristic verses the sample number or verses time. In general, the chart contains a centre line that represents the mean value for the in control process. Two other horizontal lines, called the Upper Control Limit (UCL) and the Lower Control Limit (LCL) are also shown on the chart. Those control limits are chosen so that almost all of the data points will fall within these limits as long as the process remains in control.
A stable process is one that is consistent over time with respect to the centre and the spread of the data. Control charts help to monitor the behaviour of the process to determine whether it is stable. Like run charts, the display data in the time sequence in which they occurred. However control charts are assessing and achieving process stability.

1.6 Quality control chart applications

Quality control charts can be applied to almost any area within a company or organization, including manufacturing, process development, engineering design, finance and accounting, marketing, software engineering, Computer intrusion detection technique and data mining. Shewhart $\bar{X}$ and $R$ control charts are extensively used to monitor continuous process variables.

In addition to the continuous type of quality characteristics mentioned, there is another data type of quality characteristic referred to as attribute data. Control charts constructed for discrete data are called attribute control charts. Their applications also include in the number of defectives in the integrated circuit board fabrication and health care.
The Technological Uses of the Control Charts are:

- Monitor process variation overtime
- Identify special cause of variation
- Assess the effectiveness of changes to improve a process
- Communicate how a process performed during a specific period.

1.7 Demonstration of the techniques of the control limits

Technology of the control chart limit is given below which shows the theoretical basis for a control charts:

The control limits as pictured in the graph might be 0.001 probability limits. If so, and if chance causes alone were present, the probability of a point falling either above the upper limit or below the lower limit would be one out of a thousand. One would be searching for
an assignable cause, if a point would fall outside those limits, where those limits will determine the risk of undertaking when, in reality, there is no assignable cause for variation.

Since two out of a thousand is a very small risk, the 0.001 limits may be said to give practical assurances that, if a point falls outside those limits, the variation was caused by an assignable cause. It must be noted that two out of one thousand is a purely arbitrary number. There is no reason why it could have been set to one out of a hundred or even larger. The decision would depend on the amount of risk the management of the Quality control program is willing to take. In general, it is customary to use limits that approximate the 0.002 standard.

Let $x$ be the value of a process characteristic. If the system of chance causes generates a variation in $x$ that follows the normal distribution, the 0.001 probability limits will be very close to the $3\sigma$ limits. From normal tables, the $3\sigma$ in one direction is 0.00135, or in both directions is 0.0027. For normal distributions, the $3\sigma$ limits are the practical equivalent of 0.001 probability limits.
1.8 Three sigma limits

In the literature, whether \( x \) is normally distributed or not, it is all acceptable practice to have the control limits upon a multiple of the standard deviation. Usually this multiple is 3 and thus the limits are called 3\( \sigma \) limits. This term is used whether the standard deviation is the universe or population parameter or some estimate thereof, or simply a standard value for control chart purposes. It should be inferred from the context what standard deviation is involved.

If the underlying distribution is skewed, say in the positive direction the 3\( \sigma \) limit will fall short of the upper 0.001 limit, while the lower 3\( \sigma \) limit will fall below the 0.001 limit. This situation means that the risk of looking for assignable causes of positive variation, when none exists, will be greater than one out of a thousand. But the risk of searching for an assignable cause of negative variation, when none exists, will be reduced. The net result, however, will be an increase in the risk of a chance variation beyond the control limits. How much this risk will be increased will depend on the degree of skewness.

If variation in quality follows a Poisson distribution with mean 0.8. For example, the risk of exceeding the upper limit by chance would be raised by the use of 3\( \sigma \) limits from 0.001 to 0.009 and the lower limit
reduces from 0.001 to 0. Since the mean and variance of Poisson distribution are both equal to np. The upper $3\sigma$ limit is $0.8 + 3 \sqrt{0.8} = 3.48$ and the lower limit = 0. For np= 0.8, the probability of getting more than 3 successes = 0.009.

1.9 Strategies for control limits

If a data point falls outside the control limits, one assumes that the process is out of control and that an investigation is warranted to find and eliminate the cause or causes. When all points fall within the limits, the process is in control, if the plot looks non-random, that is, if the points exhibit some form of systematic behaviour, there is still something wrong. For example, if the first 25 of 30 points fall above the centre line and the last 5 fall below the centre line, one should wish to know why this is so. Statistical methods to detect sequences or non-random patterns can be applied to the interpretation of control charts. To be sure ‘in control’ that all points fall between the control limits and they form a random pattern.
1.10 Multivariate control charts

There are many situations in which the simultaneous control of two or more related quality characteristics is necessary. Controlling several quality characteristics independently can be misleading. Quality control problem in which several related variables sometimes called multivariate quality control charts are of interest. Hotelling (1947) has proposed the multivariate control chart during II World war. Many authors have motivated to study several related variables as multivariate quality control charts. Prominent among are Hicks (1955), Jockson (1956), Montgomery and Jackson (1972) etc.

1.11 Markov dependent sample scheme

The Shewhart (1926) control charts detect moderates – to – large shift in the process average and the process standard deviation. For the above charts, small subgroups of size $n = 4, 5$ or $6$ are needed to construct $\bar{X}$ and $S$ charts. If one tries to detect small process shifts, then larger sample sizes are needed. In small subgroup sizes, there is less risk of any process shift occurring while the samples are being taken. On the other hand, when larger samples are used, there is a greater ability of the control chart to detect small process shift.
Sivasamy, Santhakumaran and Subramanian (2000) have proposed a control chart for Markov dependent sampling method. This control chart is designed to detect all the types of process shift (small, moderate and large) by taking both small and large samples under the switching rule of Markov dependent sampling. The proportions of the time using the types of sample means are varied based on random experiments in the constructions of the control chart. In this study, the researcher proposes to account the dependence of the random start of the diagonal systematic sampling method of selecting the sampling units and there by using the types of sample means. They are defined by considering the stationary probabilities of the Markov dependence. The construction of the control chart performs well to detect assignable causes, if there is trend or other systematic behaviours.

1.12 Selection of sub groups through Markovian switching rules

A Markov Chain (MC) describe a process, which moves between possible states such that the probability of moving to one of the next states only depends on the current state and does not depend on any prior state. Recent research is focused on the applications of Markov dependent sampling schemes in the selection of subgroups for the construction of control charts. In such a situation, the sample size (and any interval) may
be selected according to a Markov Chain switching rules. Sawalapurkar et al. (1990) and Costa (1997) have studied the performance of $\bar{X}$ chart using MC rule and Sivasamy et al. (2000) have generalized the construction of $\bar{X}$ chart for Markov dependent sample size. They have showed that the charts under Markovian switch rule are quicker, sensitive and more economical in detecting shifts in the production process than under classical control charts.

1.13 Objectives of the study

From the year 1926 to till date a very few works have been found on the literature for dependent technological process control charts. Recently the dependence technology has been attracted by many researchers. Only a few contributions appeared in the literature for Markov dependent sample sizes. This has motivated the researcher to study the problem of Markov dependent sample sizes to detect the assignable causes in production processes.

The objectives of the statistical control charts are:

- To improve the quality of a product in the modern business environment
- To make link between quality improvement and productivity
- To detect the assignable causes through on line
To detect occurrence of assignable causes or process shifts or process trends or systematic behaviours or cyclical variations by considering appropriate pattern of the statistical data

To develop valid control charts for independent and dependent data

To achieve the standard of quality through modern techniques

To adopt the applications of statistical quality control to industries

1.14 Chapter organization

Chapter I: deals with the basic concepts of the Statistical process control in production processes and objectives of the study.

Chapter II: deals with some of the research contributions on the SPC in production process.

Chapter III: focuses control chart which detects whenever trends or systematic behaviours present in the production processes. The trends or other systematic behaviours are present; the variable sample size control chart with Markov dependence and diagonal systematic sampling method of selecting the sampling units performs well to detect the assignable causes.
Chapter IV: studies the ARL for control chart for Markov dependent sample size. The ARL for this control chart converges rapidly to one as the sample sizes are steadily increasing as compared with the ARL for variable sample size.

Chapter V: gives a modified multivariate exponentially weighted moving average control chart. The MEWMA control chart can be modified in the following ways.

- How many past and current observations can be viewed as the weighted moving averages of a production process?
- The weights of the moving averages are not a choice
- The moving averages and their weights depend on the nature of the changing direction of a production process