CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The term quality in manufacturing refers to a measure of excellence or a state of being free from defects, deficiencies and significant variations. It is brought about by strict and consistent commitment to certain standards that achieve uniformity of a product in order to satisfy specific customer or user requirements. ISO 8402-1986 standard defines quality as "the totality of features and characteristics of a product or service that bears its ability to satisfy stated or implied needs." Quality is of paramount importance to any organization. If an automobile company finds a defect in one of their cars and makes a product recall, customer reliability and therefore production will decrease because trust will be lost in the car's quality. Quality in business, engineering and manufacturing has a pragmatic interpretation as the non-inferiority or superiority of something; it is also defined as fitness for purpose. Quality is a perceptual, conditional and somewhat subjective attribute and may be understood differently by different people. Consumers may focus on the specification quality of a product/service, or how it compares to competitors in the marketplace. Producers might measure the conformance quality, or degree to which the product/service was produced correctly. Support personnel may measure quality in the degree that a product is reliable, maintainable, or sustainable. Simply put, a quality item has the ability to perform satisfactorily in service and is suitable for its intended
purpose. There are five aspects of quality in a business context: Producing - providing something. Checking - confirming that something has been done correctly. Quality Control - controlling a process to ensure that the outcomes are predictable. Quality Management – directing an organization so that it optimizes its performance through analysis and improvement. Quality Assurance – obtaining confidence that a product or service will be satisfactory.

Quality can be defined in many ways. The common understanding of many about quality is one or more characteristics that a product should possess. Quality is an important factor considered for selection of a product among many competing products.

1.1.1 Dimensions of Quality

The quality of product can be evaluated in different dimensions (Garvin 1998), viz., Performance, Reliability, Durability, Serviceability, Aesthetics, Features, Perceived Quality, Conformance to Standards, etc. The long-established definition for quality is fitness or in good condition for use.

**Performance** is the characteristics of seeing whether the product will do the intended job.

**Reliability** greatly deals with how often the product fails; the longer time it takes to fail better will be the quality of the product.

**Durability** deals with the effective service life of the product; the product should work satisfactorily over a long period of time.

**Serviceability** refers to repair the product easily when it goes out of service.
Aesthetics refers to the visual appeal of the product like colour, style, shape, etc.

Features refer to the additional functions that the product can do apart from the basic performance.

Perceived Quality relates to the reputation of the company.

Conformance to Standards refers to whether the product is made exactly as per the requirements or specifications of the user.

The modern definition relates quality to variability, i.e., quality is inversely proportional to variability. Excessive variability in process performance often results in waste. Therefore, an alternate and highly useful definition is that quality improvement is the reduction of waste.

1.1.2 Evolution of Quality Control and Improvement

It is not always easy for the companies in manufacturing or service industries to produce high quality products. It is very difficult for many organizations to provide the customer with the products that have high quality characteristics and identical from unit to unit. The major reason for the organizations unable to provide the identical units is the term called variability as naturally there exists a certain amount of variability in every product and the organizations are always trying to reduce this variability present in their products, though it cannot be eliminated fully. This variability can be best described in statistical terms and statistical methods play a significant role in quality improvement efforts.

Quality has been an integral part of virtually all products and services. However, the awareness of its importance and the introduction of
formal methods for quality control and improvement have been an evolutionary development.

Table 1.1 presents a timeline of some of the important milestones in this evolutionary process (Douglas C Montgomery 2003).

<table>
<thead>
<tr>
<th>Period</th>
<th>Developments</th>
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<tbody>
<tr>
<td>1700–1900</td>
<td>Quality is largely determined by the efforts of an individual craftsman. Eli Whitney introduces standardized, interchangeable parts to simplify assembly.</td>
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<td>1875</td>
<td>Frederick W. Taylor introduces “Scientific Management” principles to divide work into smaller, more easily accomplished units – the first approach to dealing with more complex products and process. The focus was on productivity. Later contributors were Gilbreth and Gantt.</td>
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<tr>
<td>1900 – 1930</td>
<td>Henry Ford – the assembly line – further refinement of work methods to improve productivity and quality; Ford developed mistake-proof assembly concepts, self-checking, and in process inspection.</td>
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<td>1901</td>
<td>First standards laboratories established in Great Britain.</td>
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<td>1907 – 1908</td>
<td>AT&amp;T begins systematic inspection and testing of products and materials.</td>
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<tr>
<td>1915 – 1919</td>
<td>WWI – British government begins a supplier certification programme.</td>
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<tr>
<td>1920s</td>
<td>AT&amp;T Bell Laboratories forms a quality department – emphasizing quality, inspection and test, and product reliability.</td>
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<tr>
<td>1922 – 1923</td>
<td>R.A. Fisher publishes series of fundamental papers on designed experiments and their application to the agricultural sciences.</td>
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<tr>
<td>1924</td>
<td>W.A. Shewhart introduces the control chart concept in a Bell Laboratories technical memorandum.</td>
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<tr>
<td>1928</td>
<td>Acceptance sampling methodology is developed and refined by H.F. Dodge and H.G. Roming at Bell Labs.</td>
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Table 1.1 (Continued)

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<th>Period</th>
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<tr>
<td>1931</td>
<td>W.A. Shewhart publishes <em>Economic Control of Quality of Manufactured Product</em>—outlining statistical methods for use in production and control chart methods.</td>
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<tr>
<td>1932</td>
<td>W.A. Shewhart gives lectures on statistical methods in production and control charts at the University of London.</td>
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<tr>
<td>1932–1933</td>
<td>British textile and wooden industry and German chemical industry begin use of designed experiments for product/process development.</td>
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<td>1933</td>
<td>The Royal Statistical Society forms and Industrial and Agricultural Research Section.</td>
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<tr>
<td>1938</td>
<td>W.E. Deming invites Shewhart to present seminars on control charts at the U.S. Department of Agriculture Graduate School.</td>
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<tr>
<td>1940</td>
<td>The U.S. War Department publishes a guide for using control charts to analyse process data.</td>
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<td>1940–1943</td>
<td>Bell Labs develop the forerunners of the military standard sampling plans for the U.S. Army.</td>
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<td>1942</td>
<td>In Great Britain, the Ministry of Supply Advising Service on Statistical Methods and Quality Control is formed.</td>
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<tr>
<td>1942–1946</td>
<td>Training courses on statistical quality control are given to industry; more than 15 quality societies are formed in North America.</td>
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<tr>
<td>1944</td>
<td><em>Industrial Quality Control</em> begins publication.</td>
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<tr>
<td>1946</td>
<td>The American Society for Quality Control (ASQC) is formed as the merger of various quality societies. Deming is invited to Japan by the Economic and Scientific Services Section of the U.S. War Department to help occupation forces in rebuilding Japanese industry. The Japanese Union of Scientists and Engineers (JUSE) is formed.</td>
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<tr>
<td>1946–1949</td>
<td>Deming is invited to give statistical quality control seminars to Japanese industry.</td>
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<tr>
<td>1948</td>
<td>Professor G. Taguchi begins study and application of experimental design.</td>
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<tr>
<td>1950</td>
<td>Deming begins education of Japanese industrial managers; statistical quality control methods begin to be widely taught in Japan. Professor K. Ishikawa introduces the cause-and-effect method.</td>
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diagram.
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<tr>
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<tr>
<td>1951</td>
<td>G.E.P. Box and K.B. Wilson publish fundamental work on using designed experiments and response surface methodology for process optimization; focus is on chemical industry. Applications of designed experiments in the chemical industry grow steadily after this.</td>
</tr>
<tr>
<td>1954</td>
<td>Dr. Joseph M. Juran is invited by Japanese to give some lectures on quality management and improvement. British statistician E.S. Page introduces the CUSUM control chart.</td>
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<tr>
<td>1957</td>
<td>J.M. Juran and F.M. Gryna’s <em>Quality Control Handbook</em> is first published.</td>
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<tr>
<td>1960</td>
<td>G.E.P. Box and J.S. Hunter write fundamental papers on $2^{k-p}$ factorial design. The quality control circle concept is introduced in Japan by K. Ishikawa.</td>
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<tr>
<td>1960s</td>
<td>Courses in statistical quality control become widespread in Industrial Engineering academic programs. Zero defects (ZD) programs are introduced in certain U.S. industries.</td>
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<tr>
<td>1969</td>
<td><em>Industrial Quality Control</em> ceases publication, replaced by <em>Quality Progress</em> and the Journal of <em>Quality Technology</em> (Dr. Lloyd S. Nelson is the founding editor of <em>JQT</em>).</td>
</tr>
<tr>
<td>1970s</td>
<td><em>Industrial Quality Control</em> ceases publication, replaced by <em>Quality Progress</em> and the British Quality Association.</td>
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<tr>
<td>1975 – 1978</td>
<td>Books on designed experiments oriented toward engineers and scientists begin to appear. Interest in quality circles begins in North America – this grows into the total quality management (TQM) movement.</td>
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### Table 1.1 (Continued)

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<th>Period</th>
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<tr>
<td>1980s</td>
<td>Experimental design methods are introduced to and adopted by a wider group of organizations, including electronics, aerospace, semiconductor, and the automotive industries. The works of Professor G. Taguchi on designed experiments appear in the United States for the first time.</td>
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<tr>
<td>1984</td>
<td>The American Statistical Association (ASA) establishes the Ad Hoc Committee on quality productivity; this later becomes a full Section of the ASA.</td>
</tr>
<tr>
<td>1986</td>
<td>Box and others visit Japan, noting the extensive use of designed experiments and other statistical methods.</td>
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<tr>
<td>1988</td>
<td>The Malcolm Baldrige National Quality Award is established by the U.S. Congress.</td>
</tr>
<tr>
<td>1989</td>
<td>The journal <em>Quality Engineering</em> appears. Motorola’s six-sigma initiative begins.</td>
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<tr>
<td>1995</td>
<td>Many undergraduate engineering programs require formal courses in statistical techniques, focusing on basic methods for process characterization and improvement.</td>
</tr>
<tr>
<td>1997</td>
<td>Motorola’s six-sigma approach spreads to other industries.</td>
</tr>
<tr>
<td>1998</td>
<td>The American Society for Quality Control becomes the American Society for Quality, attempting to indicate the broader aspects of the quality improvement field.</td>
</tr>
</tbody>
</table>

Source: Douglas C Montgomery, 2003

### 1.2 STATISTICAL METHODS FOR QUALITY CONTROL

Statistical methods and their application in quality improvement have had a long history. In 1924, Walter A. Shewhart of the Bell Telephone Laboratories developed the statistical control-chart concept, which is considered as the beginning of statistical quality control. By the end of the 1920, Dodge and Romig, of Bell Telephone Laboratories, developed statistically based acceptance sampling as an alternative to 100% inspection. Statistical quality control methods were in wide use by the middle of the
1930s, at Western Electric, the manufacturing arm of the Bell System. However, the value of statistical quality control was not widely recognized by industry.

World War II saw a greatly expanded use and acceptance of statistical quality-control concepts in manufacturing industries. The experience had during wartime proved that statistical techniques were necessary to control and improve product quality. The American Society for Quality Control was formed in 1946. This organization promotes the use of quality improvement techniques for all types of products and services. It offers a number of conferences, technical publications, and training programs in quality assurance. The 1950s and 1960s saw the emergence of reliability engineering, the introduction of several important textbooks on statistical quality control, and the viewpoint that quality is a way of managing for organization.

In the 1950s, designed experiments for product and process improvement were first introduced in the United States. The initial applications were in the chemical industry. These methods were widely exploited in the chemical industry, and they are often cited as one of the primary reasons that the U.S. chemical industry is one of the most competitive in the world and has lost little business to foreign companies. The spread of these methods outside the chemical industry was relatively slow until the late 1970s or early 1980s, when many Western companies discovered that their Japanese competitors had been systematically using designed experiments since the 1960s for process troubleshooting, new process development, evaluation of new product designs, improvement of reliability and field performance of products, and many other aspects of product design, including selection of component and system tolerances. This discovery sparked further interest in statistically designed experiments and resulted in extensive efforts...
to introduce the methodology in engineering and development organizations in industry, as well as in academic engineering curricula.

There has been a profound growth in the use of statistical methods since 1980s for quality improvement in the United States. This has been motivated by the widespread loss of business and markets suffered by many domestic companies that began during the 1970s. For example, the U.S. automobile industry was nearly destroyed by foreign competition during this period. One domestic automobile company estimated its operating losses at nearly $1 million per hour in 1980. The adoption and use of statistical methods have played a central role in the re-emergence of U.S. industry. Various management structures have also emerged as frameworks in which to implement quality improvement.

In fact, some of the cheapest items in everyday life can have very high quality. For an instance if anyone sees the case of the paper used in a copying machine, for little over a rupee a page, they can buy smooth white paper, less than one hundredth of an inch thick and of uniform size. The consumers have come to expect such high quality in copier paper that they do not examine individual pages before loading it into a copier. One would not think of measuring the thickness of each page to make sure that it was thin enough not to jam the copier, but thick enough so that you could print on both sides and not have the two images interfere with each other.

The copy paper example is a hint to a working definition of quality. Things that are of high quality are those that work in the way we expect them to. As quality expert Joseph M. Juran has put it, quality implies fitness for use. In this sense, quality means conformance to requirements. This is not quite the same as conformance to specifications. Copy paper that is cut to size for
American copy machines will not fit Indian machines that demand the slightly narrower A4 metric format.

The idea of “things that work in the way we expect them to” points out that quality is defined by customers as well as by producers. Meeting the needs of customers is central to Total Quality Management. Working definitions of quality vary in different contexts, especially when we contrast goods and services. But in keeping with the notion of conformance to requirements, most working definitions of quality will include the concepts of consistency, reliability, and lack of errors and defects.

### 1.3 STATISTICAL QUALITY CONTROL

Many of the techniques developed by mathematical statisticians for the analysis of data may be used in the control of product quality. The expression statistical quality control may be used to cover all uses of statistical techniques for this purpose. However, it often relates particularly to four separate but related techniques that constitute the most common working statistical tools in quality control. All manufactured products must meet certain requirements, either express or implied. Many of these requirements may be stated as variables. Examples are dimensions, hardness, bulk density, operating temperatures in degrees Fahrenheit or Celsius, tensile strength in pounds per square inch, per cent of a particular impurity in a chemical compound, weight in pounds of the contents of any container, time in seconds of the blow of a fuse, etc. Most specifications of variables give both upper and lower limits for the measured value. Some, such as the per cent of a particular impurity in a chemical compound may have an upper limit only, whereas others, such as strength, may have a lower limit only. Variables are dealt with in the Shewhart control chart for $\bar{X}$ and $R$ and for $\bar{X}$ and $S$. 
These tools are:

1. The Shewhart control charts for measurable quality characteristics. In the technical language of the subject, these are described as charts for variables, or as chart for $\overline{X}$ and $R$ (average and range) and charts for $\overline{X}$ and $S$(average and standard deviation).

2. The Moving Range chart. It assesses whether the between-subgroup variation is in control.

3. The Cumulative Sum control chart. In the technical language of the subject, this is described as CUSUM Chart. It displays the cumulative sums of the deviations of the sample values from the target. In other words, CUSUM is a sum of the differences between sample values and the target. CUSUM charts are used for in-control processes to detect small shifts away from the target. CUSUM charts are suitable for processes in which it takes some time to produce a single item.

4. The Multivariate chart. It is used to determine whether or not the process mean vector and joint process variability for two or more variables are in control.

1.4 STATISTICAL PROCESS CONTROL

In this era of strains on the resources and rising costs of manufacturing, it becomes increasingly apparent that decisions must be made on facts, not just opinions. Consequently, data must be gathered and analyzed. This is where statistical process control (SPC) comes in. For over 70 years, the manufacturing arena has benefited from the tools of SPC that
have helped guide the decision-making process. In particular, the control chart has helped determine whether special-cause variation is present implying that action needs to be taken to either eliminate that cause if it has a detrimental effect on the process or to make it standard operating procedure if that cause has a beneficial effect on the process. If no special-cause variation is found to be present, SPC helps define the capability of the stable process to judge whether it is operating at an acceptable level. Statistical Process Control is an analytical decision making tool which allows the researcher to see when a process is working correctly and when it is not. The strength of SPC is its simplicity; and with the use of statistical software like Minitab and SPSS to make the calculations and to plot the charts, the simplicity becomes complete.

Statistical Process Control (SPC) is a group of tools and techniques used to determine the stability and predictability of a process. The concepts of Statistical Process Control (SPC) were initially developed by Dr. Walter Shewhart of Bell Laboratories in the 1920's, and were expanded upon by Dr. W. Edwards Deming, who introduced SPC to Japanese industry after World War II. Graphical depictions of process output are plotted on Control Charts. The first Control Charts were developed by Walter Shewhart at Bell Labs in the 1920's. At this time, telephone technology was in its infancy with poor reliability. Shewhart used SPC to study variation and reduce special causes of failure. Quality and reliability in phone service increased dramatically as a result of SPC. W. Edwards Deming is credited for introducing SPC to the Japanese after World War II. The resulting rise in Japanese quality and reliability is well documented. After early successful adoption by Japanese firms, Statistical Process Control has now been incorporated by organizations around the world as a primary tool to improve product quality by reducing process variation.
Dr. Shewhart identified two sources of process variation: Chance variation that is inherent in process, and stable over time, and Assignable, or Uncontrolled variation, which is unstable over time - the result of specific events outside the system. Dr. Deming relabeled chance variation as Common Cause variation, and assignable variation as Special Cause variation.

Based on experience with many types of process data, and supported by the laws of statistics and probability, Dr. Shewhart devised control charts used to plot data over time and identify both Common Cause variation and Special Cause variation.

If a product is to meet customer requirements, generally it should be produced by a process that is stable or repeatable. More precisely, the process must be capable of operating with little variability around the target or nominal dimensions of the product’s quality characteristics. Statistical Process Control (SPC) is a powerful collection of problem solving tools useful in achieving process stability and improving capability through the reduction of variability. The central idea of SPC is to control variation so as to avoid product defects.

There are two kinds of variation in any process: common causes and special causes. Common causes refer to occurrences that contribute to the natural variation in any process. Special causes are unusual occurrences that are not normally (or intentionally) part of the process. While some degree of common cause variation will naturally occur in any process, it's important to identify and attempt to eliminate special causes of variation.

SPC can be applied to any process. Its seven major tools are:

1. **Histogram or stem-and-leaf display**—A histogram is the graphical display of the frequency distribution;
A stem-and-leaf plot displays each data value as a "stem" and a "leaf." This examines the shape and spread of data by arranging the raw data values from smallest to largest.

2. **Check sheet** – consisting of the historical operating data about the process under investigation. It is a time oriented summary of defects and useful in looking for trends or other meaningful patterns.

3. **Pareto chart** – A Pareto chart ranks the defects from the largest to the smallest contributor, which can help to separate the "vital few" problems from the "trivial many."
4. **Cause-and-effect diagram** – is used to facilitate quality and process improvement and quality planning. In situations where causes are not obvious, the cause-and-effect diagram is a formal tool frequently useful in analyzing potential causes.

5. **Defect concentration diagram** – is a picture of the unit, showing all relevant views. Then various types of defects are drawn on the picture, and the diagram is analyzed to determine whether the location of the defects on the unit conveys any useful information about the potential causes of the defects.

6. **Scatter diagram** – useful for identifying a potential relationship between two variables.
7. Control chart - Although these tools, often called “the magnificent seven,” are an important part of SPC, they comprise only its technical aspects. SPC builds an environment in which all individuals in an organization desire continuous improvement in quality and productivity.

In this research work, the researcher concentrated only on control charts to find if the manufacturing process of paper is in control.

1.4.1 Implementing Statistical Process Control

Deploying Statistical Process Control is a process in itself, requiring organizational commitment across functional boundaries. The major components of an effective SPC effort are listed below.

1. Determine Measurement Method

Statistical Process Control is based on the analysis of data, so the first step is to decide what data to collect. There are two categories of control chart distinguished by the type of data used: Variable or Attribute.

Variable data comes from measurements on a continuous scale, such as: temperature, time, distance, weight. Attribute data is based on upon discrete distinctions such as good/bad, percentage defective, or number defective per hundred.
2. Qualify the Measurement System

A critical but often overlooked step in the process is to qualify the measurement system. No measurement system is without measurement error. If that error exceeds an acceptable level, the data cannot be acted upon reliably.

3. Initiate Data Collection and SPC Charting

Develop a sampling plan to collect data (subgroups) in a random fashion at a determined frequency. Train the data collectors in proper measurement and charting techniques. Establish subgroups following a rational subgrouping strategy so that process variation is captured BETWEEN subgroups rather than WITHIN subgroups. If process variation (e.g. from two different shifts) is captured within one subgroup, the resulting control limits will be wider, and the chart will be insensitive to process shifts.

4. Develop and Document Reaction Plan

Each process charted should have a defined reaction plan to guide the actions to those using the chart in the event of an out-of-control or out-of-specification condition. One simple way to express the reaction plan is to create a flow chart with a reference number, and reference the flow chart on the SPC chart. Many reaction plans will be similar, or even identical for various processes.

5. Calculate Control Limits

Shewhart found that control limits placed at three standard deviations from the mean in either direction provide an economical tradeoff between the risk of reacting to a false signal and the risk of not reacting to a true signal - regardless the shape of the underlying process distribution.
If the process has a normal distribution, 99.73% of the population is captured by the curve at three standard deviations from the mean. Stated another way, there is only a $1 - 99.73\%$, or $0.27\%$ chance of finding a value beyond three standard deviations. Therefore, a measurement value beyond three standard deviations indicates that the process has either shifted or become unstable (more variability).

6. **Assess Control**

After establishing control limits, the next step is to assess whether or not the process is in control (statistically stable over time). This determination is made by observing the plot point patterns and applying six simple rules to identify an out-of-control condition.

**Out of Control Conditions:**

1. If one or more points falls outside of the upper control limit (UCL), or lower control limit (LCL). The UCL and LCL are three standard deviations on either side of the mean.
2. If two out of three successive points fall in the area that is beyond two standard deviations from the mean, either above or.
3. If four out of five successive points fall in the area that is beyond one standard deviation from the mean, either above or below.
4. If there is a run of six or more points that are all either successively higher or successively lower.
5. If eight or more points fall on either side of the mean.
6. If 15 points in a row fall within the area on either side of the mean that is one standard deviation from the mean.
1.5 ABOUT THE ORGANIZATIONS

The primary data have been collected from two of the leading industries in paper manufacturing, one from Private sector and the other from the government sector. M/s. Seshasayee Paper and Boards Limited (SPB) is the private sector organization and M/s. TamilNadu Newsprint and Papers Limited (TNPL) is the Tamil Nadu government-owned organization.

1.5.1 Seshasayee Paper and Boards Limited

Seshasayee Paper and Boards Limited (SPB), the flagship company belonging to 'ESVIN GROUP', operates an integrated pulp, paper and paper board Mill at Pallipalayam, Erode-638 007, District Namakkal, Tamilnadu, India.

SPB, incorporated in June 1960, was promoted by Seshasayee Brothers (Pvt) Limited in association with a foreign collaborator M/s Parsons and Whittemore, South East Asia Inc., USA. After commencement of commercial production, having fulfilled their performance guarantee obligations, the foreign collaborators withdrew in 1969. Main promoters of the Company as on date are a group of companies belonging to the ESVIN group headed by Mr. N Gopalaratnam.

SPB commenced commercial production in December 1962, on commissioning a 20000 tpa integrated facility, comprising a Pulp Mill and two Paper Machines (PM-1 and PM-2), capable of producing, writing, printing, kraft and poster varieties of paper.

The Plant capacity was expanded to 35000 tpa in 1967-68, by modification of PM-2 and addition of a third Paper Machine (PM-3). The cost
of the expansion scheme, at Rs 34 Millions, was part financed by All India Financial Institutions (Rs 31 Millions).

In the second stage of expansion, undertaken in 1976, capacity was enhanced to 55000 tpa, through addition of a 60 tpd new Paper Machine (PM-4). Cost of the project, including cost of a Chemical Recovery Boiler and other facilities for enhanced requirement of utilities, was estimated at Rs. 176 Millions. The same was part financed by term loans from Institutions and Banks to the extent of Rs. 145 Millions and the balance out of internal generation.

SPB undertook various equipment balancing and modernisation programmes, since then, for improving its operating efficiency, captive power generation capacity, etc., upto 1992-93.

**Expansion / Modernisation Project**

The Company embarked on an Expansion / Modernisation Project to enhance its production capacity from 60000 tonnes per annum, to 1,15,000 tonnes per annum and to upgrade some of the existing facilities, at an estimated cost of Rs 1890 millions.

The said Expansion / Modernisation Project was completed in December 2000. After successful trials, the Commercial Production out of the new Paper Machine commenced on July 1, 2000. The current installed capacity of the Company stands at 1,15,000 tonnes per annum.

**Raw Materials**

The Company's paper plant was originally designed for using bagasse, as the primary raw material mixed with 20% bamboo fibre. Bagasse
was being obtained from nearby sugar mill on substitution basis using oil fired boilers.

With sharp increase in oil prices in 1970-71, the Company shifted over to the use of hardwood, at the time of its expansion undertaken in 1978. Raw material mix underwent a substantial change, with bamboo and hardwood forming 60% and 40%, respectively, of its raw material consumption.

Soon Company started apprehending difficulties in procurement of bamboo. In 1981, it added one more digester, to increase the share of the hardwood in the furnish mix to 80% and restricting bamboo use to only 20%.

With the commissioning of more wood based industries in Tamil Nadu, there was again an apprehension about availability of hardwood.

As a long term strategy, the Company at this time decided on restructuring use of bagasse which was seen to be the most reliable source of fibre for the entire Industry.

In 1984, the Company promoted Ponni Sugars and Chemicals Limited, as the captive source for bagasse supply. It added bagasse handling systems and modernised PM-1 and PM-2, to shift over to the use of bagasse.

The furnish mix for the existing Paper Machines of the Company is 55% bagasse and 45% hardwood. The Company has vast experience in handling bagasse and is expected to be one of the major strong points vis-à-vis its competitors in India, as the Indian Paper Industry will continue to be bogged down by the problem of raw material availability.
For the new Paper Machine, the furnish is imported waste paper and imported pulp which are sourced from Far East countries, Europe and USA. A small quantity is supplemented out of captive pulp production.

**Exports performance**

SPB's exports are nearly 20% of its production and is a significant exporter in the Indian Paper Industry. Due to its excellent export performance, SPB has been awarded 'Golden Export House' status.

**Awards**

SPB is in receipt of various Awards awarded by Government of India, Government of Tamilnadu, Industry Associations, etc. Some of the Awards received by SPB in the past include:

- Capacity Utilisation Award
- Energy Conservation Award
- Environmental Protection Award
- Safety Award

**Export Performance Award**

- Good Industrial Relations Award
- TERI - Corporate Environmental Award

**Environmental Protection**
The Company attaches paramount importance to the conservation and improvement of the environment. In its efforts to improve the environmental protection measures, the Company has installed:

- Two Electro Static Precipitators for its Boilers to control dust emissions
- An Anaerobic lagoon for high BOD liquid effluents
- A Secondary Treatment System for liquid effluents and
- An Electro Static Precipitator and Cascade Evaporator to the Recovery Boiler.

These facilities will ensure sustained compliance by the Company of the pollution control norms prescribed by the Pollution Control Authorities.

**ISO 9001/ ISO 14001 Accreditation**

The Company's quality systems continue to be covered by the "ISO 9001" accreditation awarded by Det Norske Veritas, The Netherlands.

The Company has also been accredited with "ISO 14001" certification by Det Norske Veritas, The Netherlands, for its Environmental Quality Systems.

**Board of Directors**

The Company's Board is broad based comprising 10 Directors:

Sri N Gopalaratnam, Chairman
Sri R V Gupta, I.A.S., (Retd.)
Dr S Narayan, I.A.S., (Retd.)
Sri V Sridar
Sri S K Prabakar, I.A.S (Nominee of TIIC)
Sri Hans Raj Verma, I.A.S (Nominee of Govt. of Tamilnadu)
Sri A L Somayaji
Dr Nanditha Krishna
Sri K S Kasi Viswanathan, Managing Director
Sri V Pichai, Deputy Managing Director & Secretary

**Organisation**

The day to day affairs of the Company are looked after by the Chairman and supported by:

Sri K S Kasi Viswanathan, Managing Director and
Sri V Pichai, Deputy Managing Director & Company Secretary.

They are ably assisted by a team of qualified and experienced professionals in operations, personnel, finance and marketing disciplines.

**1.5.2 Tamil Nadu Newsprints and Papers Limited**

Tamil Nadu Newsprint and Papers Limited (TNPL) was established by the Government of Tamil Nadu during early eighties to produce Newsprint and Printing & Writing Paper using bagasse, a sugarcane residue, as primary raw material. The Company commenced production in the year 1984 with an initial capacity of 90,000 tonnes per annum (tpa). Over the years, the production capacity has been increased to 2,45,000 tpa and the Company has emerged as the largest bagasse based Paper Mill in the world consuming about one million tonnes of bagasse every year. The Company completed a Mill Expansion Plan during December 2010 to increase the mill capacity to 4,00,000 tpa.
TNPL exports about 1/5th of its production to more than 50 countries. Manufacturing of quality paper for the past two and half decades from bagasse is an index of the company’s technological competence. A strong record in adopting minimum impact best process technology, responsible waste management, reduced pollution load and commitment to the corporate social responsibility make the company one of the most environmentally compliant paper mills in the world.

Products of TNPL

TNPL offers high-quality surface sized and non-surface sized paper to suit the needs of modern high speed printing machines. TNPL’s cutting edge technology backed by experienced professionals ensures quality products to customers. TNPL’s manufacturing processes are equipped with state-of-the-art control systems to maintain critical quality parameters on line. The paper produced by TNPL is eco-friendly as the pulp is manufactured out of renewable raw material and is subjected to Elemental Chlorine Free (ECF) bleaching. As the paper is acid free, it has a longer colour stability and enhanced permanency in terms of strength characteristics.

TNPL caters to the requirements of multifunctional printing processes like sheet-fed, web offset, and digital printers. The paper reels have uniform profile with strength properties to cope even with high speed machines. TNPL manufactures Printing and Writing Papers in substances ranging from 50 GSM to 110 GSM.

The quality policy is TNPL is committed to design, manufacture and supply eco-friendly papers to customers’s satisfaction with emphasis on
continual improvement in its process, technology and quality management system to ensure consistent quality.

**Research & Development and Quality Control**

TNPL’s contemporary cutting edge technology processes and equipments along with a team of dedicated trained professionals ensure that customers always get consistent quality products. State of the art ‘Online Process Control Systems’ installed at various stages of manufacturing processes continuously measure and control critical parameters. R&D and QC activities are aimed towards achieving company’s corporate goals.

- Sustained R&D efforts to support process for improvements in quality and trouble shooting.
- Customized support to customers and provide workable solutions for specific problems.
- Right quality and quantity of raw materials usage ensured through structured sampling and testing.
- Effective pollution abatement measures to meet all statutory and mandatory norms which also fetch Carbon Credit benefits.
- Set product norms/specifications to meet customer requirements based on national/ international standards applicable.
- Appraise conformance by inspection and testing of periodic samples in one of the best equipped laboratories in the country.
- Take corrective action, if necessary and sustain the standards achieved.
R&D and QC department plays a pro active roll in meeting the company’s environmental and quality policy.

**Board of Directors**

Thiru. C.V.Sankar, I.A.S., Chairman & Managing Director
Thiru. A. Velliangiri, Deputy Managing Director
Thiru. V. Narayanan, Director
Thiru. N. Kumaravelu, Director
Thiru. Mahesan Kasirajan, I.A.S., Director
Thiru. R. Mani, Director (Operations)
Thiru. V. Nagappan, Director
Thiru. M.R. Kumar, Director
Tmt. Sarada Jagan, Director

1.6 **STRUCTURAL CHARACTERISTICS OF PAPER**

- **Grammage (Substance)**
- **Caliper**
- **Bulk Density**

**Grammage**: Mass of paper per unit area Grams per square meter (g/m²)

- Measure area, A
- Measure mass (weight), M
- Grammage = M/A

**Basis Weight**

Historically paper was sold in reams, usually packs of 500 sheets or a specified length and width (not universal)
Paper Grade  Ream Size
Writing and Printing  17 inches X 22 inches
Newsprint  24 inches x 36 inches
Paperboard  1000 feet²

Basis Weight, ream weight, and substance are all names for mass or weight of one ream of paper (lb)

Example of Basis Weight Label

| 8 1/2 x 11 | Metric: 216x279 mm |
| SUBSTANCE 20 | 75 g/m² |
| White--Long | 500 sheets |

Example

| Copy paper | Liner Board |
| Grammage = | 75 gr/m² | 205 gr/m² |
| Ream = | 120.6 m² | 92.9 m² |
| Basis weight = | 20 lb | 42 lb |

Caliper

- Caliper is the thickness of the sheet
- Usually measured in microns (10-6 meters) or mils (0.001 inches)
- Often caliper is given as number of points; 1 point = 0.001 inch
Because of surface irregularity and compressibility of paper, the caliper depends on the method of measurement.

**Caliper Measurement**

![Caliper Measurement Diagram]

**Examples**

Copy paper: 0.004 inches
4 mils or points
102 µm
42 lb linerboard: 0.012 inches
12 mils or points 293 µm

**Bulk Density**

Bulk density of paper equals the inverse of basis weight (substance) divided by the caliper (thickness)

\[
\text{Bulk Density} = \frac{\text{Caliper}}{\text{Substance}} \text{ m}^3/\text{kg}
\]

**1.7 STATEMENT OF THE PROBLEM**

Statistical quality control techniques had been extensively deployed in several industries like heavy engineering industry (Jagadeesh 1994),
service industry (Farhat Ali Burney 1998, Irena Ograjenšek 2002), IT industry (Fugee Sang 2000), aerospace industry (Mark Goh 1996), food industry (Grigg 1998), HR management (Chen 1998), facility management (Kincaid 1994), Wood industry (Dramm 2000), paper industry (Cheek 1990), telecommunications industry (Yan Xu 2001), finance (Cox 2009), hospital (Cem Canal 2010), etc. But, however, very few works have been developed to control quality of paper in the paper industry in India.

The benefits which statistical process control (SPC) can accrue to manufacturing processes have long been recognized in the engineering-related industries, particularly in high-volume manufacturing situations, and in those where product quality is synonymous with safety or reliability (Grigg 1997). Such benefits include predictable levels of process control, timely detection of process drift or “special causes” of variation, quantifiable customer quality assurance and effective recording of quality related data (e.g. Cheng 1994; Chiu & Huang, 1996; Gaafar & Keats 1992; Gelinas 1994; Sulek et al 1995; Wu 1994; Xie & Goh 1993).

The paper manufacturing industry is also involved in high-volume production, and is one in which product quality control is paramount, owing to the delicate nature of the product and the potentially severe consequences of a lapse in process control. It might reasonably be expected that SPC is equally widely used in this industry. However, most of the paper companies do make use of SPC; however, and some consider it unnecessary, or else find it so difficult to understand and implement that they are unable to do so effectively, if at all.

This study examines where and how SPC can be of benefit to paper manufacturing industry within the operational frameworks of the relevant consumer protection legislation. The study looks at the nature and extent of current usage of SPC in the paper industry, in order to ascertain whether more
can or indeed should be done to promote or encourage its use within the sector.

In the paper industry taken for study, i.e., the quality department in organizations from which data had been gathered, are currently using only basic statistical techniques like histogram to monitor quality of their process. As the extensive use of statistical techniques to control quality in other industries proved to be efficient in improving their quality, the researcher felt these statistical techniques through statistical process control could be of utmost help to paper industry to monitor quality. The main characteristics like substance (grammage), caliper and bulk density of paper had been considered to see the feasibility of deployment of statistical techniques like control charts. This research is focused on the feasibility of adopting statistical quality control techniques in paper mill and find out the manufacturing process for different brands of paper is in control.

1.8 SCOPE OF THE STUDY

The present study deals with the application of statistical methods in the control of quality in the paper industry. The various statistical tools used in this study are various types of control charts like X-Bar / R Chart, X-Bar/S Chart, Moving Range Chart, EWMA Chart, Cusum Chart, Multivariate Chart. These control charts are used to determine as to whether the manufacturing process of paper in under statistical control. The techniques discussed in this study are widely applicable for the paper industry, as these techniques have been implemented in other fields of industry. The paper industry will be benefitted by effective application of the techniques discussed in this study to control the quality of the paper manufactured by them at the time of production itself. These statistical
methods can also be applied in all other industries to control the quality at the time of production.

1.9 PERIOD OF STUDY

The study was conducted from the period 2010 to 2015.

1.10 OBJECTIVES OF THE STUDY

Primary objective:

To study the effectiveness of Statistical Quality Control techniques and its impact in production process of paper machine.

- To assess whether the quality of the product produced at paper mill conforms to specifications.
- To assess whether the manufacturing process is in control.
- To assess the process capability index. $C_p = \frac{Tolerance}{6\sigma}$

Secondary objectives:

- Establishment of effective process control techniques.
- To provide tools that make process inspection more effective.
- To forecast the possible deviations in process in future.
- To analyze reasons for out-of-control process.
1.11 SIGNIFICANCE OF THE STUDY

Measured quality of manufactured product is always subject to a certain amount of variation as a result of chance. Some stable “system of chance causes” is inherent in any particular scheme of production and inspection. Variation within this stable pattern is inevitable. When the output of some process is found to be reliable, not always confirming to requirements, we must carefully examine and the reasons for variation outside this stable pattern may be discovered and corrected. Application of statistical techniques to control quality of products through control charts often brings substantial improvement in product quality and reduction of spoilage and rework. Moreover, by identifying certain of the quality variations as inevitable chance variations, the control chart tells when to leave a process alone and thus prevents unnecessarily frequent adjustments that tend to increase the variability of the process rather than to decrease it.

1.12 LIMITATIONS OF STUDY

The accuracy of the findings depends on the accuracy of the data provided by the technicians. Performance of human operators are inconsistent; human fatigue and tediousness may perhaps be the reason for variations in operation. The data were collected at several continuous processes, thus the operating parameters of the machine may slightly vary from process to process.

1.13 ORGANIZATION SCHEME
The framework of this research work has been structured to gain insights into the above purpose and thus includes five chapters. A brief outline of each of them is given below:

**Chapter 1:** The introductory chapter deals with introduction, significance of the study, statement of the problem, scope of the study, objectives, limitations and organization of chapters.

**Chapter 2:** The second chapter focuses on the reviews from the relevant literature in this field carried out by various researchers.

**Chapter 3:** The third chapter provides a conceptual framework and the theoretical model that will be empirically tested to look into the possibility of applying statistical techniques in paper machine.

**Chapter 4:** The chapter four provides a neat outlook on research design and methodology adopted by the researcher in the conduct of the study.

**Chapter 5:** The fifth chapter reveals the analysis and interpretation of the observations which were gathered during experimentation procedure. A wide range of sub-topics under this theme has been discussed elaborately.

**Chapter 6:** The sixth chapter summarizes the findings, research contributions and conclusion of the study.